IOWA STORMWATER MANAGEMENT MANUAL

7.04 STORMWATER PLANTERS AND TREE TRENCHES

IOWA Department of Natural Resources

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Refer to the glossary for words in **bold black text.**
Some items of emphasis are in **bold blue text.**

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7.04-1 DESIGN

A. SUMMARY

Tree and planter stormwater **best management practices (BMPs)** are typically located in a more intensely developed urban environment, where greenspace is scarce. They are most often appropriate for linear arrangements within street rights-of-ways and in parking lots. They feature subsurface soil elements that support the growth of healthy trees and plants. They can also be configured to meet stormwater management requirements, particularly those for smaller storm events. While this section of ISWMM is focused on the design of these systems to manage stormwater, some design components (such as providing adequate soil volume for tree growth) can be adapted to promote healthy tree growth in non-stormwater management applications. These systems can be used alone or paired with other stormwater BMPs installed in series to collectively meet treatment requirements.

DESIGN PROCESS OVERVIEW

1. Complete Site Evaluation and Planning
2. Develop Site Into Watershed Subareas and Evaluate Preliminary Sizing
3. Size Water Entry and Subsurface Storage Elements
4. Prepare Planting Plan / Select Appropriate Tree Species
5. Develop Maintenance Plan
6. Integrate into Stormwater Plan

MAINTENANCE REQUIREMENTS

1. Designate Responsible Parties for Maintenance
2. Complete Construction Sequencing
3. Remove Accumulated Sediment and Debris Frequently from Pretreatment Area
4. Perform Regularly Occurring Maintenance on Pavement Surfaces, Inlets and Plant Materials

NOTE

See Section 7-04-2 for details on the design process and Section 7.04-4 for more detail on maintenance requirements.

Stormwater planter boxes in La Crosse, Wisconsin.

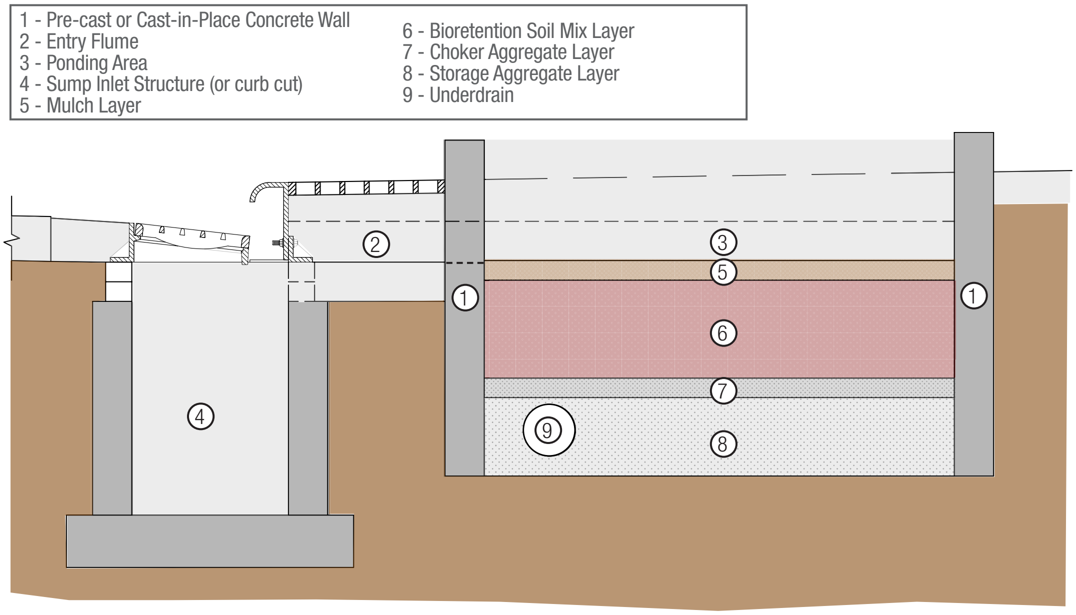
B. APPLICATIONS

There are different types of tree and planter stormwater BMPs. Where there are some similarities in their arrangement and function, there are some key differences between the practice types. These types of practices are usually used to address either the **Recharge Volume (Rev)** or **Water Quality volume (WQv)** elements of the **Unified Sizing Criteria**. They typically have insufficient capacity to fully address the requirements for larger storm events. However, their presence may reduce the rate of runoff being directed to downstream stormwater management practices used to address those larger events.

Within this section, these practices are described as stormwater planters and tree trenches. Stormwater planters have already been used in multiple projects across the state at the time of publication of this section. Tree trenches are newer to Iowa but have been adopted for use in other states and municipalities across the United States, Canada and Europe. **The designer should understand how these practices are similar and how they differ when deciding to include these types of practices for stormwater management.**

STORMWATER PLANTERS

Stormwater planters typically include a concrete "planting box" area that is often surrounded by paved surfaces and other urban landscapes. These structures can be pre-cast concrete boxes or cast in place structures. Runoff is typically introduced into the planter box at the surface of the planter where it may pond temporarily before it is infiltrated through layers of soil and **aggregate media**. The materials placed within planter boxes are often constructed similar to bioretention cells, planted with native plans which would be appropriate for a bioretention cell.



Cross section of a planter box.

NOTE

See the Bioretention Systems section of ISWMM for more information about the design and construction of bioretention cells.

NOTE

See photo examples on pages 16, 19, 23, 57, 59 and 61.

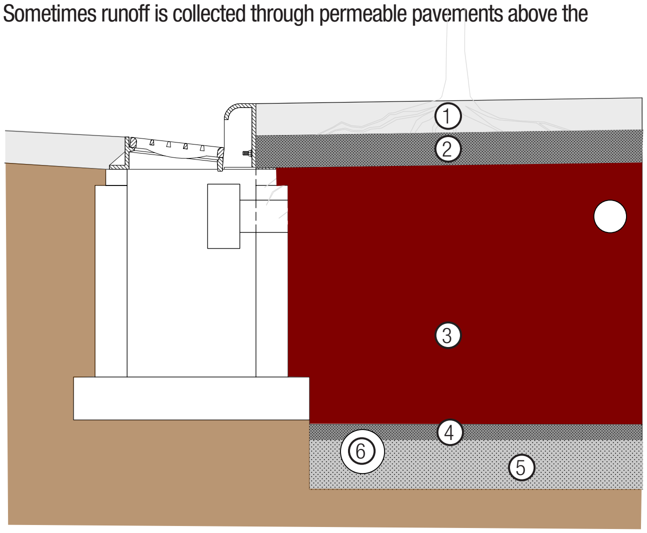
TREE TRENCHES

Tree trenches can be used to meet water quality treatment goals while also supporting the healthy growth of trees. By adding uncompacted root zone space, these systems can include individual trees or multiple trees that are connected by trenches. **These are filled with soil and interlocking aggregate or manufactured open structure systems below the surface that can support a structural load from the surface without causing soil compaction.** The trenches can be installed in linear strips or scattered across a small area.

When the root growth zone extends below adjacent paved areas, structural cell or structural soils are used to provide the required volume of soil while providing structural strength to support the pavement surface.

Runoff to be treated is typically captured in an inlet and then routed into the soil materials through a perforated drain that is elevated at a shallow depth within the soil material. Sometimes runoff is collected through permeable pavements above the structure cell or soil material.

1 - Concrete or Paver Surface
2 - Subbase Aggregate
3 - Structural Soils or Cells
4 - Choker Aggregate Layer
5 - Storage Aggregate Layer
6 - Underdrain



Example of a tree trench cross-section.

COMPARING STORMWATER PLANTERS AND TREE TRENCHES

While there are some similarities between tree trenches and stormwater planters, they are separate types of stormwater BMPs. Stormwater planters may require a smaller footprint area than a tree trench, when treating a similar volume of runoff. Since water ponds at the surface, most maintenance needs and sediment removal will be visible at the surface. Stormwater planters offer the flexibility of plant materials which includes both trees and native grasses and wildflowers.

Tree trenches do not require the construction of a planter box. Since there is no surface ponding, the ground surface around the tree can be more similar to the surrounding paved areas, which may provide greater pedestrian safety in some areas. The use of the elevated drain may allow fewer storm inlets to be used as collection points to deliver flow to multiple trees along the tree trench installation.

Tree trench installed under permeable pavers..

PROPRIETARY “GREEN INLETS”

Some companies market proprietary systems that are advertised to include pretreatment and soil media to promote tree growth while improving water quality. These systems typically only have enough soil capacity to sustain plants up to the size of large shrubs and should not be used to attempt to grow trees of any size.

During the development of this section, concerns were expressed with past project performance and promises of high infiltration rates. For this reason, these systems are not covered within this section. **It is recommended that local jurisdictions should evaluate manufacturers’ design materials, specifications and testing results prior to including such products as a water quality practice.** (1)

Examples of green inlets installed in Cedar Falls.

Sources:
(1) Minnesota Stormwater Manual, Types of Tree BMPs

STRUCTURAL CELL AND SOIL MATERIALS

Structural cells

Soil volume for tree root growth and stormwater management can be provided within a tree trench or expanded beyond the open surface footprint of the stormwater planter by using structural cells to support paved surfaces. These cells are typically proprietary products that are used to support finished surfaces above the soil media installed within the grid of the structural cells.

These cells are often modular in design, which allows for the footprint of the rooting and bioretention zone to be shaped for specific sites. They can be used to support soils around utilities, but it requires some planning to position the cells to provide adequate structural support to the surface while working around potential utility conflicts. (2)

1 - Concrete or Paver Surface
2 - Subbase Aggregate
3 - 8" Ponding Depth (Void Space)
4 - Soil Cell Units
5 - Elevated Perforated Drain
6 - 31" Planting Soil Depth
7 - 3" Choker Aggregate Layer
8 - 9" Storage Aggregate Layer
9 - Underdrain Set at Least 3" Above Bottom of Storage Aggregate Layer

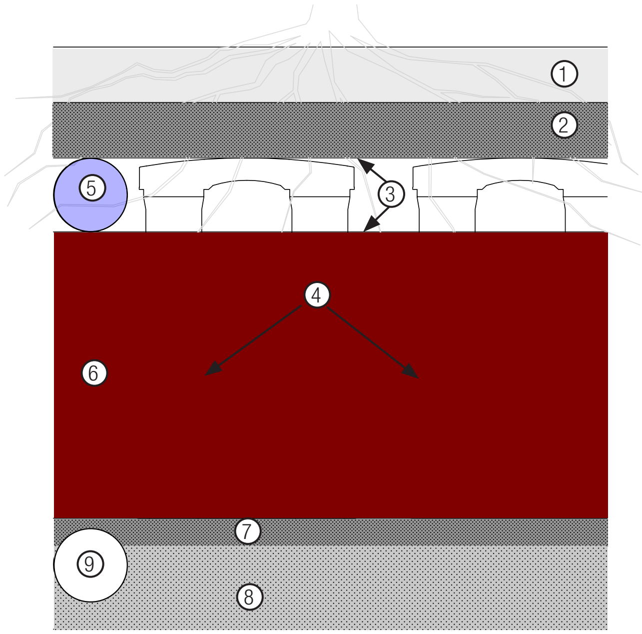


Illustration of structural cells.

NOTE

See photographs on page 21.

Sources:
(2) Minnesota Stormwater Manual, Types of Tree BMPs.

STRUCTURAL SOILS

Structural soils are soil media designed to be compacted to provide structural support to adjacent paved surfaces while still permitting tree root growth through the media. It may be used below paved areas adjacent to stormwater planters and tree trenches to allow tree roots to expand outward from the surface footprint of a planter or trench. (3)

1 - Concrete or Paver Surface
2 - Subbase Aggregate
3 - Structural Soils or Cells
4 - Elevated Perforated Drain (if used for water entry)
5 - 3" Choker Aggregate Layer
6 - 9" (min) Storage Aggregate Layer
7 - Underdrain Set at Least 3" Above Bottom of Storage Aggregate Layer

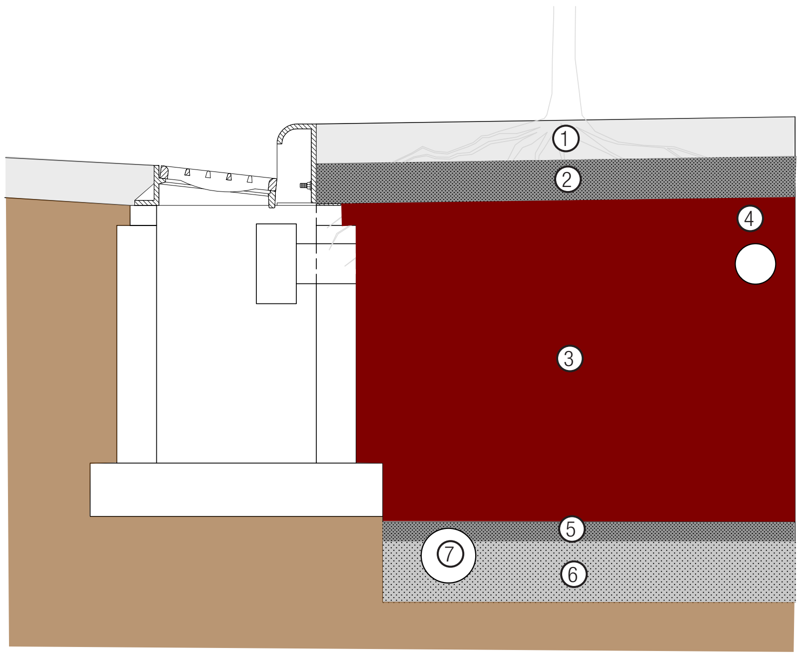


Illustration of a tree trench.

NOTE

See photographs on page 21.

Sources:

(3) Stormwater Tree Trench. Toronto and Region Conservation Authority.

C. SITE FEASIBILITY

SOILS

Stormwater planters and tree trenches can be placed within any type of soils. However, if the existing soils have limited ability for infiltration or percolation, subdrain systems are needed to collect excess water after it has filtered through the system. Most tree species will not tolerate having saturated roots for lengthy periods of time. Tree trenches and planters must drain properly in order to provide healthy soil for tree growth.

Subdrainage systems should be provided in most cases unless it can be demonstrated that subsoil percolation rates after construction are expected to be high enough that the system can be fully drained within 24 hours. ESSENTIAL

REQUIRED SPACE

The planter box portion of a stormwater planter will typically need be about 5% of the impervious area expected to be treated by the practice. The area required for tree trenches depends on the area and depth required to provide the required soil volume to support tree growth. The footprint area will frequently range between 5-10% of the impervious area to be treated, but detailed design calculations will need to be completed to determine the actual required footprint.

TOPOGRAPHY

It is more challenging, but not impossible to install stormwater planters and tree trenches on steeper grades. The surface within a planter box needs to be level, so consideration needs to be given on how to address the difference between the surface elevation within the planter and the proposed surfaces around the perimeter. In some cases, multiple planters or trenches or stepped cells may be needed to provide for a level surface ponding area within a planter box in areas with greater slope. The slope of the adjacent gutter may also make it more difficult to intercept runoff at the throat of a curb cut or intake structure.

In tree trenches, steeper surface slopes may mean that less of the soil and aggregate layers may be available for water storage, since the volume used for storage can only extend up to the overflow elevation at the lowest point in the system. When working on slopes, a curb bump out may be needed at the lowest inlet to ensure the desired flow is captured. CAUTION

Tree trench on a steep slope in Ames, Iowa.

OUTFALL ELEVATION

There needs to be adequate depth in the nearby storm sewer network to allow connection from the subdrainage system. In some cases, a **surface inlet** may be placed in the planter boxes for large storm overflow. The **local jurisdiction** may require additional elevation drop between the subdrain and the downstream pipe network to make sure that high flows don't surcharge back into the system subdrain.

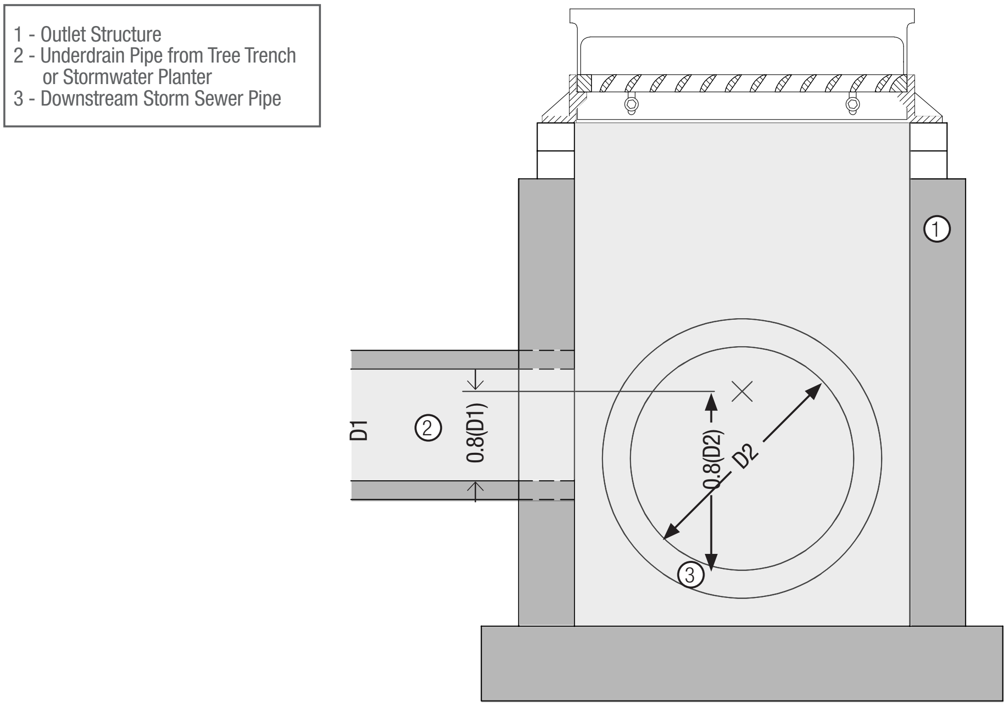


Illustration of an outfall elevation.

UTILITIES

Existing or proposed utilities can create challenges with installation of system structural elements and plantings. **It is critically important to locate all utilities prior to design.** If utilities need to be relocated, that work should be completed prior to construction of the stormwater practice. In some cases, these elements can be designed to bridge over existing utilities as long as the utility is installed at a depth where it will not be impacted by tree installation. In any case, all existing utilities should be located and surveyed prior to design or early in the design phase. The designer should coordinate with the local utility early in the planning process to reduce potential conflicts, understand future maintenance needs and discuss required horizontal and vertical clearances. ESSENTIAL

WATER TABLE

A minimum separation of two (2) feet should be provided between the bottom of the planter or trench and the seasonally high-water table. Where this separation can't be provided, a low permeability geotextile should be provided along the sides and bottom of the planter or trench at least up to the point where that level of separation is provided. (4) ESSENTIAL

SURROUNDING BUILDINGS

When the footprint of the planter or trench is within ten (10) feet of a building foundation with a basement or other occupied space below grade, an impermeable geotextile should be provided along the sides and bottom of the planter or trench at least to the point where that level of separation is provided. In any case, geotechnical or structural engineers may recommend additional protections or setback requirements. ESSENTIAL

Sources:
(4) Stormwater Tree Trench. Toronto and Region Conservation Authority.

ADDITIONAL SETBACKS

Trees should be setback from buildings a sufficient distance to accommodate the expected growth of the tree canopy. Tree species should be selected based on the available space for canopy growth.

Check with local jurisdictions if there are restrictions on infiltration-based practices within **wellhead protection areas.** ESSENTIAL

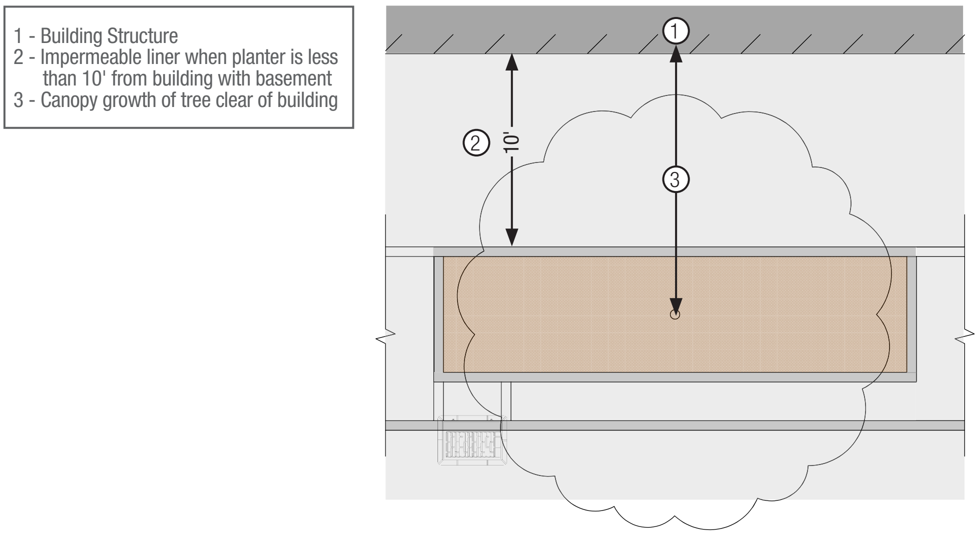


Illustration of a building setback.

SALT APPLICATIONS

Some types of vegetation are particularly sensitive to runoff and snowmelt containing salt and other ice melt compounds. Refer to the ISWMM Native Landscaping section (Section 11) for guidance on plant selection where heavy use of ice melt compounds is expected. TARGET

Salt applications should be limited on permeable pavement areas that may be installed close to trenches or planters. However, some studies have shown that high salt concentrations are flushed through a tree trench system with early spring rains (5).

Sources:
(5) Application of Stormwater Tree Trenches in the City of Vancouver. 2018.

PEDESTRIAN SAFETY

In some applications, ponding depths and surrounding slopes may result in 12 to 24 inches of elevation difference between the soil surface within the planter and surrounding paved surfaces. Small railings or fences may be used to prevent pedestrians from stepping or falling into the planter or trench surface area. When located along parking stalls, the planter box should be set back far enough to allow car doors to open and allow passengers to exit the vehicle. Planter boxes should be set at least 24 inches behind the back of curb when placed along streets where parallel parking is allowed. TARGET

Railing along sidewalk in Coralville, Iowa.

Safety features along sidewalk and boardwalk in Des Moines, Iowa.

LOCAL REQUIREMENTS

Each local jurisdiction may have requirements that may be applicable such as (but not limited to) sight vision clearance, plant material restrictions and utility protections. The designer should consult the local review authority early in the planning process to determine if there are any local requirements that could influence the proposed design or determine if these types of practices are suitable at a given location. ESSENTIAL

D. DESIGN ELEMENTS AND CRITERIA

WATER ENTRY METHODS

There are several methods that can be used to allow runoff to enter the stormwater planter or tree trench for treatment. Whatever method is chosen, it needs the capacity to allow the expected peak flow rate for the desired storm event to enter the BMP and pass into the subsurface storage elements. Most typically, the storm event to be intercepted and treated will be the Water Quality event (WQv – 1.25” rainfall). ESSENTIAL

Curb Cuts

A cut opening the curb may be used to allow runoff from the gutter of an adjacent street or parking lot area into the planter box. This option may be best applied where the opening is located at a low point of the pavement so all runoff is easily funneled into the practice. Some flow might bypass the curb cut if it is used along a gutter that has slope running past the opening. The opening into the planter should be set at least one (1) inch below the adjacent gutter elevation to make sure there is positive slope from the gutter into the practice. TARGET

Curb cut entry from street into stormwater planter in Coralville, Iowa.

Small curb openings allow water to enter from sidewalk areas in Coralville, Iowa.

NOTE

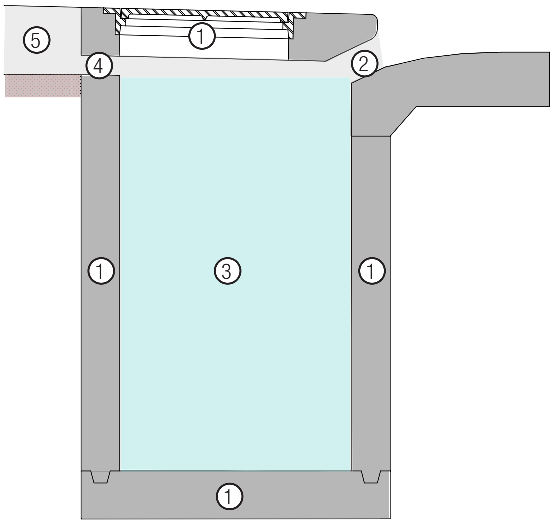
See Part 7.04-2 of this section for additional information on checking for flow bypass at curb cuts and inlets.

Inlet Sump Structure

An inlet structure may be used to intercept flow running along the edge of the practice. This inlet will not be connected to the conventional storm drain network. allowing the bottom of the structure to act as a pretreatment collection sump. Water will build up to a point where it reaches a pipe, cut opening or flume that allows water to enter the planter box. For tree trenches, water typically will build up until it can flow into the elevated perforated drain.

Installing an inlet sump structure is more expensive than a curb cut, but keeps the planter looking cleaner with much less maintenance. Direct curb cuts the planter will allow more sediment and debris into the planter, requiring additional maintenance and repairs within the planter box itself.

1 - Modified SW-507 Curb Intake
2 - Inlet from Gutter
3 - Pretreatment Sump Storage Depth
4 - Opening to Planter Box
5 - Planter Box Ponding Area (or Flume to Ponding Area)

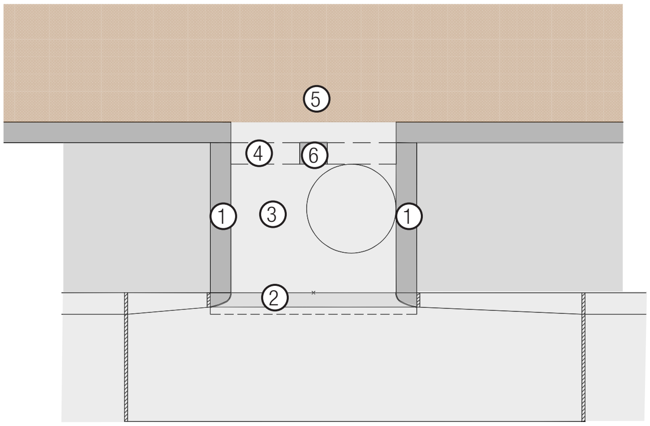


This sump inlet is a modified SUDAS Type SW-507 structure.

NOTE

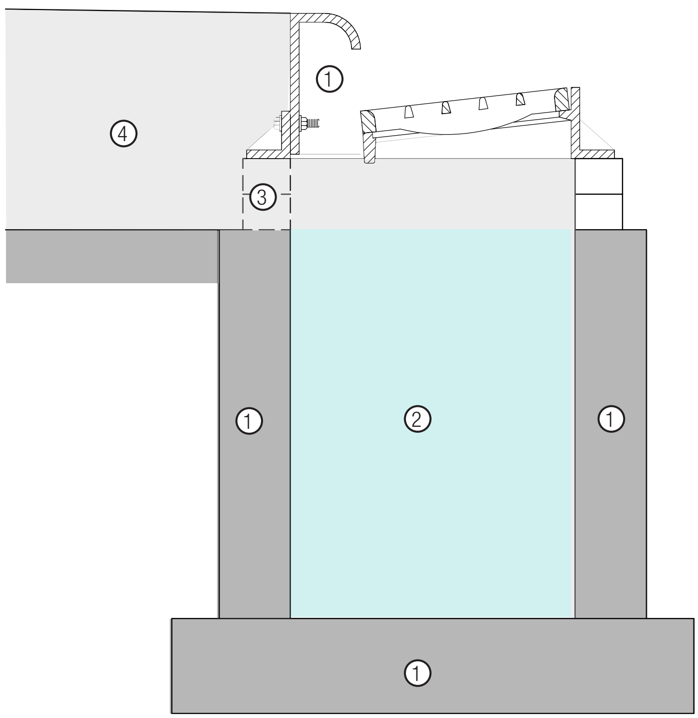
See photo examples on pages 16, 19, 23, 57, 59 and 61.

1 - Modified SW-507 Curb Intake
2 - Inlet from Gutter
3 - Pretreatment Sump Storage Depth
4 - Opening to Planter Box
5 - Planter Box Ponding Area (or Flume to Ponding Area)
6 - Optional Center Pier to Divide Opening to Planter Box



This is a top view of the sump inlet which is a modified SW-507 structure.

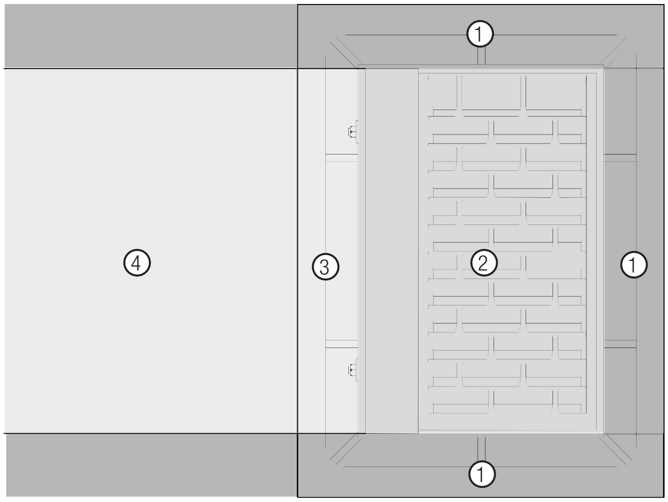
1 - Modified SW-501 Curb Intake
2 - Pretreatment Sump Storage Depth
3 - Opening to Planter Box
4 - Flume to Ponding Area
(may be covered with grate)



This sump inlet is a modified SW-501 structure.

NOTE

See photo examples on pages 16, 19, 23, 57, 59 and 61.



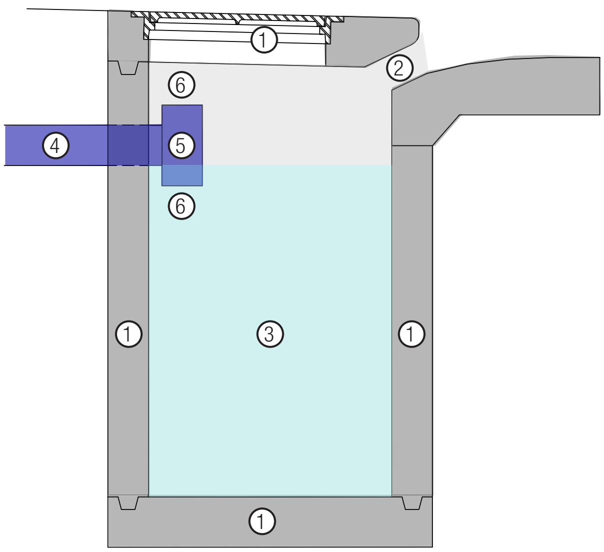
1 - Modified SW-501 Curb Intake
2 - Pretreatment Sump Storage Depth
3 - Opening to Planter Box
4 - Flume to Ponding Area
(may be covered with grate)

This is a top view of the sump inlet which is a modified SW-501 structure.

Elevated Perforated Drain

An elevated perforated drain can be used to collect runoff from inlet structures or roof drains and direct it to the soil layers within the tree trench (or stormwater planter). The elevated drain should have at least six (6) inches of soil cover above the pipe and be located below any subbase or compacted subgrade materials under the adjacent paved surfaces. It should be located as high as possible so that runoff has to percolate through as much soil as possible before reaching the underdrain outlet. The inlet side of the elevated drain should be protected by a removable grate rodent guard (similar to as detailed in SUDAS Figure 4040.233). A cleanout should be provided at the endpoints of the perforated drain line, allowing for inspection and cleaning of the perforated drain. TARGET

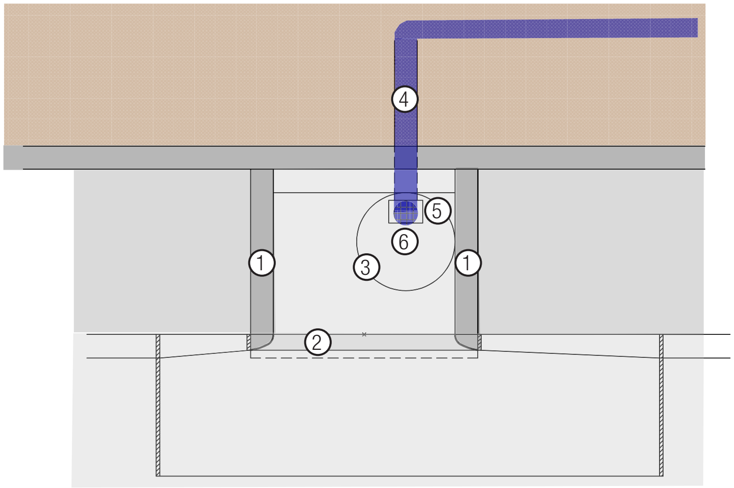
When it is desired to direct roof water to the perforated drain, there needs to be a method to allow flow from larger storm events to bypass the subdrain so that there isn't a risk of surcharging flow into the downspout or roof drain system.



1 - Modified SW-507 Curb Intake (or SW-501)
2 - Inlet from Gutter
3 - Pretreatment Sump Storage Depth
4 - Elevated Perforated Drain
5 - Tee
6 - Removable Subdrain Grate

Illustration of an elevated drain.

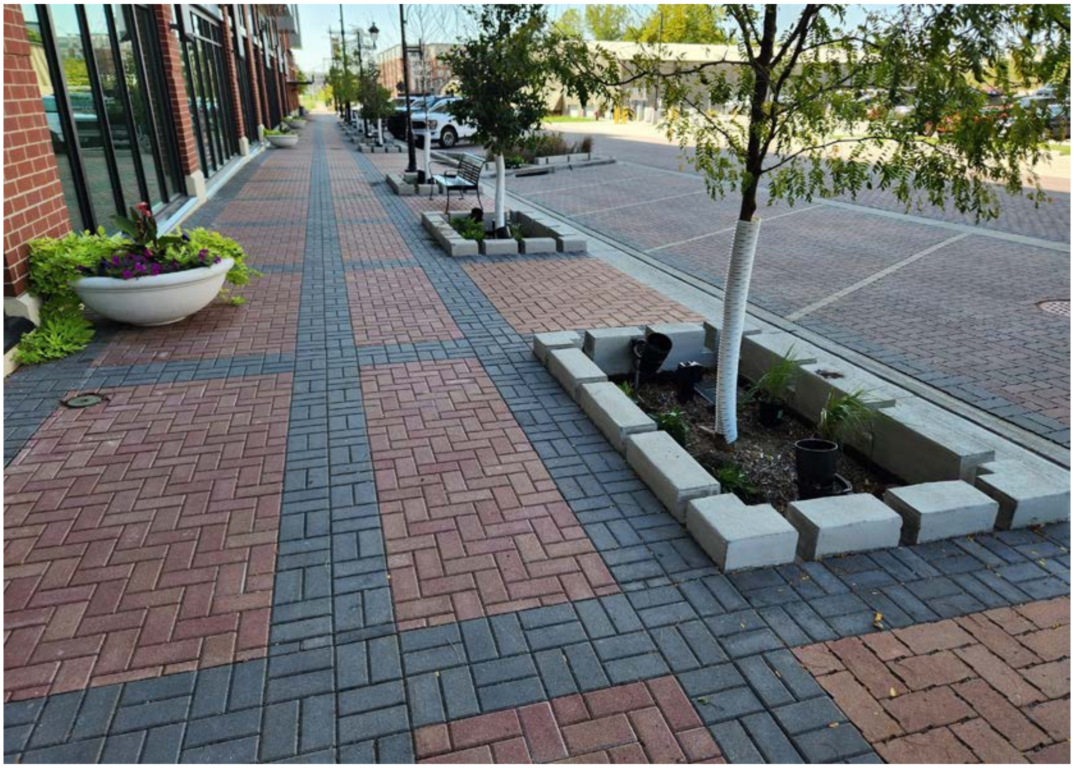
1 - Modified SW-507 Curb Intake (or SW-501)
2 - Inlet from Gutter
3 - Pretreatment Sump Storage Depth
4 - Elevated Perforated Drain
5 - Tee
6 - Removable Subdrain Grate



This is a top view of the elevated drain illustration.

Permeable Pavements Systems or Infiltration Trenches

Permeable pavement systems can be used to intercept runoff flowing across areas above or adjacent to the footprint of the planter or trench. The paver area should be positioned over the structural cell or soil elements, or otherwise hydraulically connected so flow may pass through the aggregate layers beneath the pavers and enter the subsurface elements of the planter or trench. ESSENTIAL A rock infiltration trench can also be used to capture flows and route them to the surface of the planter box, or the elevated drain of the tree trench.



Permeable pavers between each planter box and within the adjacent parking stalls are used to direct runoff into the subsurface storage layers surrounding this planter box in Coralville, Iowa.

PRE-TREATMENT

Pre-treatment measures are used to capture the heaviest sediments and debris and allow them to settle out of flow before they are conveyed into the planter or trench. This will reduce the potential for sediments or other debris from clogging and reducing the infiltration potential of the installed soils. The method used for pretreatment will vary depending on the method used to introduce runoff into the BMP. Without effective pretreatment, practices are more likely to be corrupted by debris and sediments, reducing their ability to infiltrate and treat stormwater. ESSENTIAL

For stormwater planters and tree trenches, the target should be to provide a pretreatment practice that has the ability to store at least 5% of the target WQv volume. TARGET

However, there is often limited space available with these types of practices to meet that requirement. **If the provided pre-treatment storage is less than optimal, it should be expected that the pre-treatment area will need to be inspected and cleaned out more frequently.** CAUTION

NOTE

See Section 7.04-4 for maintenance recommendations for pretreatment structures.

NOTE

See Section 5.06 for more information about the planning, design and maintenance of inlet sump structures.

Inlet Sump Structures

Inlet structures can be used as a pretreatment device, as noted previously. The inlet can be constructed to have an invert that is two (2) to four (4) feet below the point where flow will be directed into the practice. As noted previously, a pipe or structure overflow opening can be used on the side opposite the gutter to allow runoff to enter the BMP.

If a pipe is used, it will often be set so it connects to an elevated perforated drain. If a surface overflow opening is used, it will often be set close to the elevation of the surface storage or ponding area that is located downstream. In either case, the first flush of runoff will enter the structure allowing sediments and heavier debris to settle into the bottom of the intake where they can be removed.

A trash screen can be used to prevent floatable debris from being washed into the practice. If a trash screen is used over a surface overflow opening into a planter box, the clear spacing between any bars should not be less than two (2) inches. TARGET Alternatively, screens may be omitted, and any **floatable debris** would be removed from the surface of the planter box if it was washed into the practice.

SUDAS Type SW-507 inlet modified to include a sump, with two small openings that overflow into the planter box in Coralville, Iowa.

A small concrete sump is located under the small grate at the curb cut in this photo in Coralville, Iowa.

Edger with Openings

Within the footprint of the planter or tree trench, create an edger or short curb section to act as a flow stop which will slow the velocity of flow where runoff enters the practice. The curb or wall should have smaller vertical cuts or openings to allow flow to slowly enter the surface storage or ponding area within the BMP. The top elevation of the curb or wall should be set at least one (1) inch below the elevation of the curb cut. Between the flow stop and the curb cut, use pavers, **articulated blocks,** articulated mat sections or another solid surface. This is where heavier sediments and debris will most typically collect. Sediment and other debris can be removed from the surface of the pretreatment area with a scoop or shovel. These "micro-forebays" will typically have less storage capacity, so a target pretreatment volume of 2.5% of the WQv is recommended. Because of their limited capacity, these applications will need to be inspected and cleaned frequently. TARGET

A cast in place concrete curb box is located downstream of the curb cut at the entry point to this planter box in Coralville.

A metal edger is used as a pretreatment area at a curb cut at this location in Des Moines.

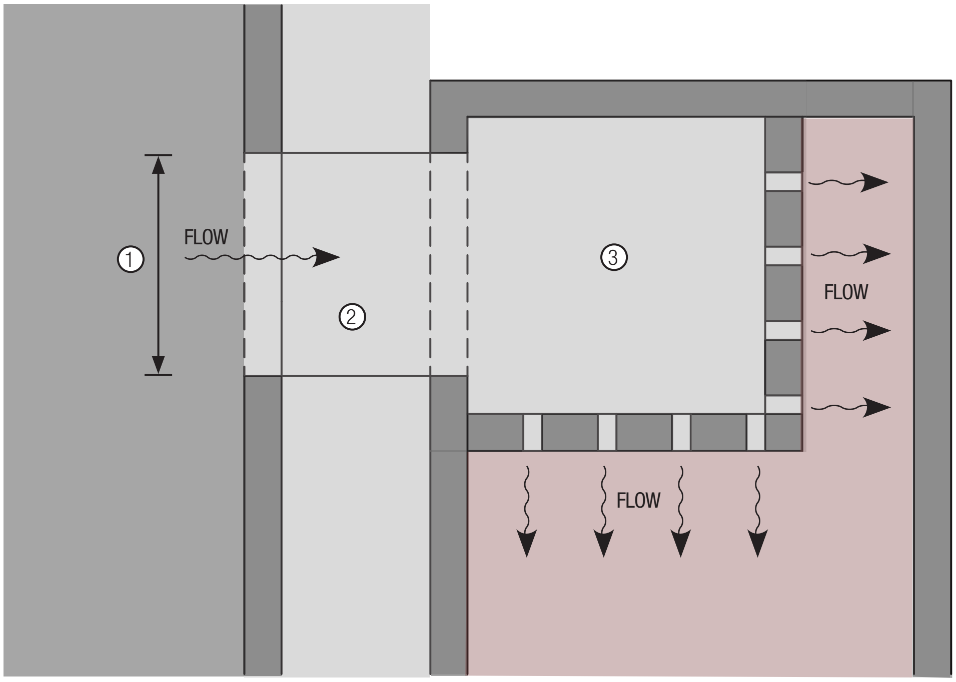


Illustration of a possible configuration of a micro-forebay at the entry point to a planter box.

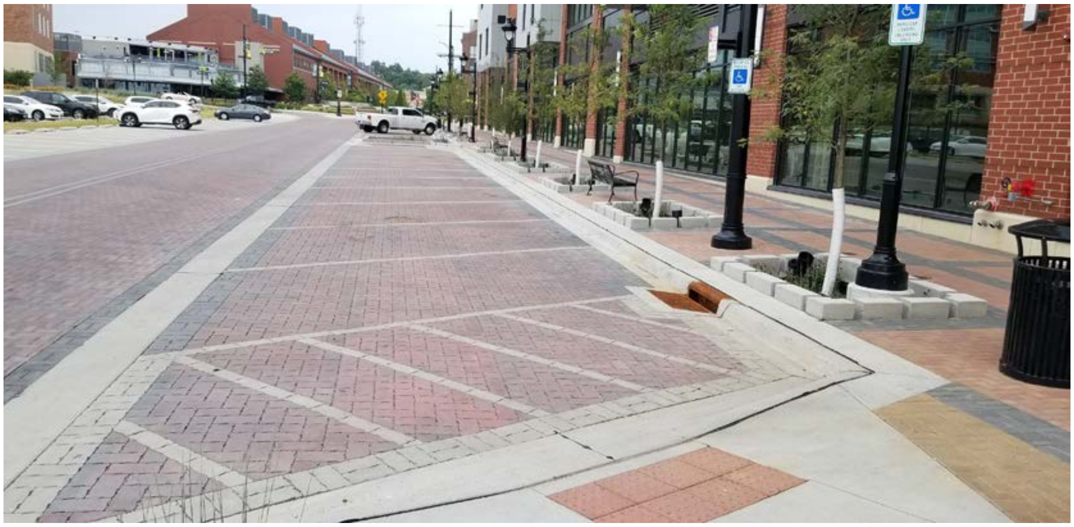
1 - Curb Opening	3 - Stabilized Forebay Area
2 - Stabilized Water Entry Into Planter Box	4 - Edger with Small Openings

NOTE

See Section 5.04 for more information about the planning, design and maintenance of micro-forebay pretreatment structures.

Permeable Pavements

The surface of the permeable pavements system essentially acts as a pretreatment device. **Scheduled cleaning of the surface of the pavement to remove collected sediment particles and replacement of rock chips between pavers is needed to allow it to continue to function at the desired infiltration capacity.**



The surface of the permeable pavers at this location acts as a pretreatment measure for the subsurface elements surrounding these planter boxes. The pavers and planter boxes work as a series of practices to collectively manage for water quality from Coralville.

SURFACE STORAGE OR PONDING AREA

When water is introduced into the planter box at the surface, a ponding area is required to allow the water to collect until it can infiltrate into the subsurface storage elements. This is similar to the ponding area used within bioretention cells. The surface of the ponding area should be level at one **elevation from end to end and side to side.** The surface of the ponding area should be set so that when water rises to the expected ponding depth, the water level will be at or below the adjacent gutter elevation or surface water entry point. **This ponding depth will typically range between three (3) to nine (9) inches.** Planter boxes often have smaller ponding depths to allow for an overall shallower dispersion and to reduce the difference in elevation between the ponding surface and the surrounding paved areas. TARGET

The level surface area within the planter box below the elevation of the adjacent street gutter is the ponding area at this location in Coralville.

NOTE

Note that the recommended minimum ponding depth of three inches is less than required for typical bioretention cells. This allowance is to reduce the elevation difference between the ponding surface and the expected finished grades around the perimeter of the planter.

STRUCTURAL DESIGN OF PLANTER BOX

Frequently, there will be a structural edge creating a planter box around the planter to separate it from surrounding sidewalk, roadway or parking areas. It is typically a raised curb that extends around any surface ponding area. In some cases, the curb may be constructed as a hardscape edge that is flush with the surface around the planter or trench area.

In other cases, the curb may be constructed as walls that extend down to the bottom of the subsurface storage elements. These walls may include openings to allow for water movement and root growth into structural cells or soils that are located immediately adjacent to the perimeter of the planter box. These curbs or walls can be cast-in-place or constructed out of precast concrete panels.

If trees are planned to be installed within the planter box, the walls of the planter box should include openings that are tall and wide enough to allow for free growth of the tree's root structure into soils, structural cells or structural soils that are installed in sufficient volume around the planter box to support the desired tree.

The width and depth of the openings will vary depending on the root growth pattern of the selected tree(s).

Cast in place planter box during construction in Coralville.

NOTE

See Section 7-04-3 for details on about planter box construction options.

NOTE

See page 32 for more information about soil volume required to support tree growth.

NOTE

Choker aggregate layer should be one of the following:

1/2" aggregate complying with Iowa DOT Spec Section 4125, Gradation No. 20 (AASHTO M43 / ASTM D448, Size 7)

3/8" aggregate complying with Iowa DOT Spec Section 4125, Gradation No. 21 (AASHTO M43 / ASTM D448, Size 8)

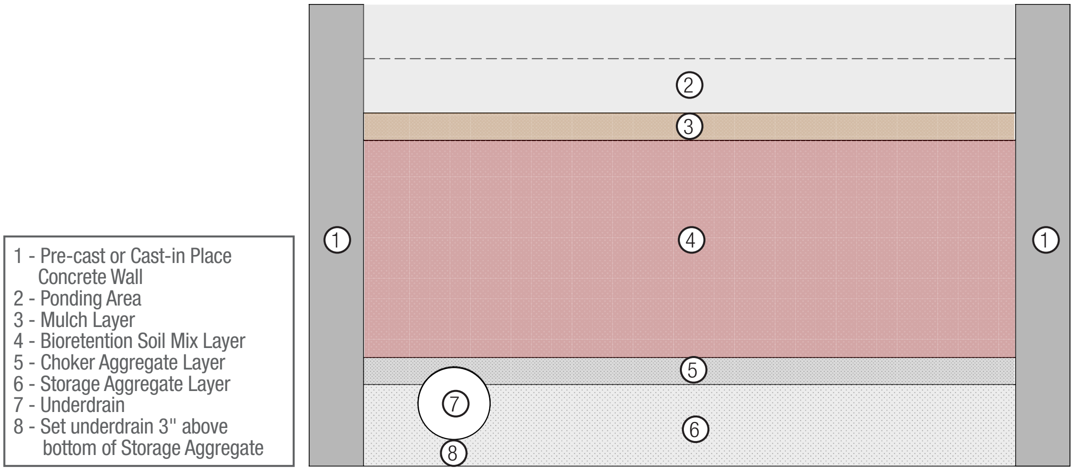
Storage aggregate layer should be Iowa DOT Section 4115, Gradation No. 3, Class 2 durability crushed stone (AASHTO M43 / ASTM D448, Size 57)

Underdrain materials should be perforated pipe (solid pipe should be used for riser or cleanout sections and sections extending beyond the aggregate layers) complying with with Iowa SUDAS Specification Section 4040.

SUBSURFACE STORAGE ELEMENTS

Soil matrix

Within the planter box, bioretention planters use a cross-section like what was described in the Bioretention Systems section of ISWMM. The typical cross-section includes layers of hardwood mulch, modified soil, and aggregate. The specific makeup of the engineered soil medium will vary depending if the BMP is intended to support trees or shrubs. The required ponding depth in that section may be reduced to three (3) inches to reduce the elevation difference between the surface of the ponding area and the surrounding finished surfaces outside of the planter box. Refer to ISWMM Section 7.06 (currently Chapter 5, Section 4) for detailed information.



Cross section of a planter box.

Table 7.04-1-1

PLANTER BOX MODIFIED SOIL LAYER		
	Application	
	No Trees or Shrubs	With Trees or Shrubs
Sand	75 - 90%	45 - 55%
Topsoil	0 - 25%	35 - 45%
Compost	0 - 10%	0 - 10%
Depth of Modified Soil Layer	18 - 30 inches	36 - 60 inches

Source: ISWMM Bioretention Systems section, Table C5-S4-7

Structural Cells

The subsurface storage elements within structural soil cells should be based on the recommendations of the manufacturer of the proprietary system. **ESSENTIAL** They are most typically constructed of modular elements used to provide structural support which are filled with soil and aggregate materials. The structural cells can have a higher cost for the product but also have a higher volume of soil used per unit of overall system volume.This manual does not endorse specific manufacturers for use. The designer should evaluate potential options and review those with the local jurisdiction to determine if a specific system is acceptable for use, based on site conditions. (6) However, a few examples are:

- Silva Cells: from Deeproot Green Infrastructure
- RootSpace: by GreenBlue Urban
- Stratavault: by CityGreen

Structural cells under construction.

The following information could be integrated into product selection criteria or project specifications (7):

- The structure should be designed to support AASHTO H-20 loads and any local jurisdictional requirements.
- The cells should be designed and tested for the purpose of growing tree roots, rainwater filtering, detention and/or retention.
- Each soil cell or stack should be structurally independent of all adjacent **soil stack** so that a single stack or group of stacks can be removed later to facilitate future utility installation or repairs.
- The design of each cell should facilitate the movement of roots and water between each cell, the edges of the cell system and surrounding soils. **ESSENTIAL**

Structural Soils – Rock Based

Rock based structural soils use washed rock (stones without fine materials on them) to provide load bearing capacity. The rock materials are mixed with soil to protect soil within the void spaces from compaction. The general parameters for these types of systems are:

- Stones are uniformly graded and crushed or angular for maximum porosity, compaction, and structural interface.
- Mean pore space needs to be large enough to accommodate root growth.
- Significant crushing of stone should not occur during compaction.

Soils need to have sufficient nutrient and water holding capacity to support tree growth. A **tackifier** can be used to keep the soil uniformly distributed within the void spaces within the aggregate layers (8).

Permeable geotextiles are frequently used to prevent the migration of fine particles from the road or sidewalk base materials into the structural soils. However, for installations below permeable pavers, the **choker aggregate** course may be used for that function. Compaction to 95% Standard Proctor Density is achieved by planning the materials in lifts and providing geotechnical compaction testing. (9)

Example of a structural soil mix.

Sources:
(6) Minnesota Stormwater Manual, Types of Tree BMPs.
(7) Specification for Tree Planting Solutions in Hard Boulevard Areas, City of Toronto
(8) Minnesota Stormwater Manual, Types of Tree BMPs.
(9) Stormwater Tree Trenches, Sustainable Technologies Evaluation Program.

NOTE

Choker aggregate layer should be one of the following:

1/2" aggregate complying with Iowa DOT Spec Section 4125, Gradation No. 20 (AASHTO M43 / ASTM D448, Size 7)

3/8" aggregate complying with Iowa DOT Spec Section 4125, Gradation No. 21 (AASHTO M43 / ASTM D448, Size 8)

Storage aggregate layer should be Iowa DOT Section 4115, Gradation No. 3, Class 2 durability crushed stone (AASHTO M43 / ASTM D448, Size 57)

Underdrain materials should be perforated pipe (solid pipe should be used for riser or cleanout sections and sections extending beyond the aggregate layers) complying with comply with Iowa SUDAS Specification Section 4040.

Table 7.04-1-2

SPECIFICATIONS FOR STORMWATER TREE TRENCHES USING STRUCTURAL SOILS				
Structural Soil Type	**Median Stone Size (range)**	**Soil Texture**	**Tackifying Agent**	**Approximate Porosity**
CU[1] (Cornell University) - Soil™	1 inch (0.5 - 1.5 inches) *30 mm* *(20 - 40 mm)**	Gravel: <5% Sand: 20-45% Silt: 20-50% Clay: 20-40% Cation Exchange Capacity (CEC) >10 pH: 5.5 - 6.5 Organic Content: 2-5% by dry weight	Hydrogel (coated potassium propenoate-propenamide copolymer)	0.26
B.C. Soil[10]	75 mm / 60 - 80 mm	Sand: 45-55% Silt: 25-35% Clay: 0-10% Silt + Clay: 25-45% pH: 6.0-7.0 Organic Content: 15-20%**	Stabilizer	0.33
Stockholm Soil Method[11]	4 to 6 inches (100 to 150 mm)	Nutrient retaining soil		0.30

Note:

* Larger or smaller stone sizes are accepted as long as they do not comprise more than 10% above or 10% below the indicated range.

** Soil texture is the City of Vancouver, British Columbia specification for structural soils

Source: (10) Stormwater Tree Trenches. LID SWM Planning and Design Guide. (11) Planting Beds in the City of Stockholm. 2009.

COMPARING STRUCTURAL CELLS AND SOILS

Soil cells that use a weight bearing support structure typically allow for greater volumes of soil in the same space compared to sand or aggregate based structural soils (about 70% of the volume within structural soils is occupied in the sand or aggregate elements). So structural soils will typically require a larger area to provide soil support for tree growth. However, structural soils do not require the purchase and installation of the weight bearing support cells.

Structural soils may allow the system to not need to be disturbed when nearby utility work is performed. The soils can dug be up and replaced with little material loss. Soil cells are likely to be damaged or destroyed and would likely need replaced for similar utility work.

UNDERDRAINS

Underdrains will typically be required to allow excess water to be drained after it has been treated by flowing through the system. The only exception will be locations with high permeability subsoils (as noted previously). The underdrains should be at least four (4) inches in diameter and constructed from perforated pipe materials as allowed within Iowa Statewide Urban Design and Specifications (SUDAS) Section 4040. If it is desired to accommodate larger cleaning and camera inspection equipment, a minimum of eight (8)-inch diameter pipe material should be used. TARGET

The underdrains should be set at least three (3) inches above the bottom of the subsurface storage elements, to ensure that water can freely enter the perforated underdrain. A cleanout structure (compliant with SUDAS Section 4040) should be provided at the upstream end of each underdrain. If bends in the underdrain are necessary, provide a curved radius of at least 5 feet and/or place a cleanout near the bend allowing access to the portion of the underdrain downstream of the bend. TARGET

The type of cleanout may vary depending if the cleanout lid is to be positioned within the planter box or within adjacent surfaces. If located within the planter box, it is recommended to set the lid of the cleanout one (1) to three (3) inches above the surface of the ponding area, so that it can be easily located when needed. TARGET

Photograph of a subdrain being installed in Coralville.

OUTLETS AND OVERFLOWS

If surface runoff enters the planter box or elevated drain through a curb cut or inlet sump structure, those features will typically act as the system overflow point. When the volume available above the ponding surface within the planter or trench is full, no additional water will be able to flow into the system. Any additional runoff will bypass the practice and flow down the gutter to the next practice, storm sewer inlet or surface overflow point.

The exception to this may be if the entry point to the planter or trench is located near a low point in the street profile or parking area. In those locations there may need to be another inlet or surface overflow route within or near the BMP that would allow runoff from larger storm events to leave the practice. In such a case, any overflow inlet and/or surface overflow path should be designed to meet local storm sewer capacity and flood protection requirements. ESSENTIAL

The underdrain system typically will connect to a downstream storm sewer inlet. The underdrain may need a cap with an orifice opening to ensure the desired **hydraulic retention time** in the system is provided. TARGET

An overflow inlet shown during construction in a planter box in Coralville. The small holes in the side of the box allow for subsurface water movement into adjacent subsurface rock chambers.

In this location, the inlet itself acts as an overflow. Once the planter box is full of water to the gutter elevation, water will continue downstream to the next storm inlet (in La Crosse, WI).

NOTE

See an illustration of a cap with orifice on page 33.

NOTE

See Section 7-04-2 for details on the design process for sizing outlet conditions for underdrains.

LANDSCAPING / VEGETATION

Stormwater planters are typically designed with high-permeability soil media. For this reason, plants should be selected that would be expected to be compatible with bioretention systems. **Any tree species planned for tree trenches or stormwater planters should be selected that are suitable for the soils, groundwater levels and planned inundation of the system.** The use of subdrains typically would mean that tree species selected should be tolerant of well drained soils. Additionally, sun exposure, air pollution, and traffic are all factors to consider when selecting tree species. Overstory trees should be typically spaced no closer than 30 feet from center to center. Smaller trees may be more closely spaced. The appendix of this section has a list of recommended trees, although landscape architects, foresters or other experts may be consulted to select tree species, based on the considerations noted in this section.

Stormwater planters in La Crosse, WI include native perennials and trees.

NOTE

See Section 7.04-4 for more detail on maintenance requirements.

MAINTENANCE ACCESS

Adjacent streets, sidewalks or parking lots typically can be used to provide an access path where a small truck or other maintenance vehicles could be positioned near the practice. **The clear path for maintenance vehicles and equipment to the planter or trench should be identified with the party responsible for maintenance during the design process.** ESSENTIAL

IRRIGATION

The type of vegetation selected may influence if permanent irrigation is needed. Use of permanent irrigation could keep the soils within the planter or trench frequently saturated, limiting its capacity to treat stormwater runoff. **It is advised to avoid selecting plant materials that will require permanent irrigation if the vegetation is part of a system designed to infiltrate and treat stormwater runoff.** In many cases, temporary irrigation may be needed to help establish and sustain desired trees and vegetation. Irrigation may also be useful in the case of phased projects where roof drains or other paved surfaces in the future may supply stormwater planters and tree trenches built in advance with water, but in the interim the water needs of plant material are not being met from storm events.

ELECTRICAL AND LIGHTING ACCOMODATIONS

Lighting and electric outlets can be included in the design of stormwater planters and tree trenches. **However, for planter boxes, the design of these systems needs to consider the effects of ponding water that may be present for a few hours after a storm event.** The lighting design also needs to consider the effects lighting elements may have on the growth of desired vegetation.

The following is a list of a few key things to consider when incorporating lighting into stormwater planters and tree trenches. **More extensive guidance is included in the Appendix of this section.** In all these applications, the design team should include or consult with lighting designers and/or electrical engineers to evaluate these considerations and develop the appropriate construction details and specifications for a given project. TARGET

- Within stormwater planters where water is expected to pond, place fixtures and electrical outlets above the expected ponding depth. Select fixtures with proper protection from solids and water entry.
- Lighting systems should include time-clock lighting controls to turn off up-lighting of trees after a set period.
- Consider the wavelength of light for proper tree growth and health.
- **Remote drivers** should be placed outside of areas where water can accumulate. Select a location for drivers to serve multiple planters or trenches while reducing the overall distances to fixtures.
- Consider the effects of other lighting, including pole mounted and bench mounted lights.
- Placing fixtures above the expected depth of water ponding may widen the selection.

This planter box in Coralville includes lighting and an electrical outlet.

E. SPECIAL CASE ADAPTATIONS

ADJACENT PERMEABLE PAVEMENT SYSTEMS

Permeable pavement systems are not required to be installed near stormwater planters or tree trenches. However, they can be used as one way to increase treatment capacity beyond what the surface area of the planter or trench can handle.

HYBRID SYSTEMS

Several different elements, such as tree trenches, permeable pavers, box planters, underground infiltration facilities, native landscaping, and other elements can be combined in creative ways to form hybrid systems. These hybrid solutions can better fit a site situation, provide added amenities, and give greater performance. The challenge becomes integrating the various recommendations and guidelines for design when various elements are combined. This will require the designer understand the intent and underlying purpose of the various elements so they can be combined effectively. **In some cases, multiple practices can be combined to access and share underground storage and treatment facilities and capacity for a more efficient and cost-effective design.**

PRACTICES IN SERIES

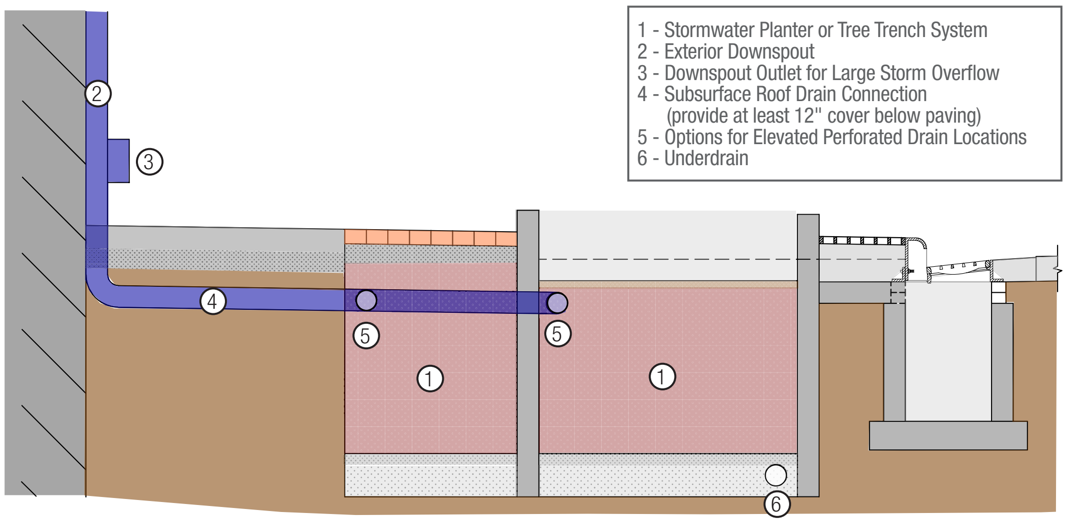
Stormwater planters and tree trenches are typically small in surface area and therefore each practice has a limited ability to manage stormwater. Multiple practices may be necessary to completely meet the treatment goals for a given area. **If an individual BMP isn't sized to completely meet the desired WQv treatment volume, the excess volume above its capacity can be assumed to be routed to the next available practice downstream.** In some cases, practices could be installed upstream of a planter or trench to reduce the amount of WQv volume the planter or trench is expected to treat.

NOTE

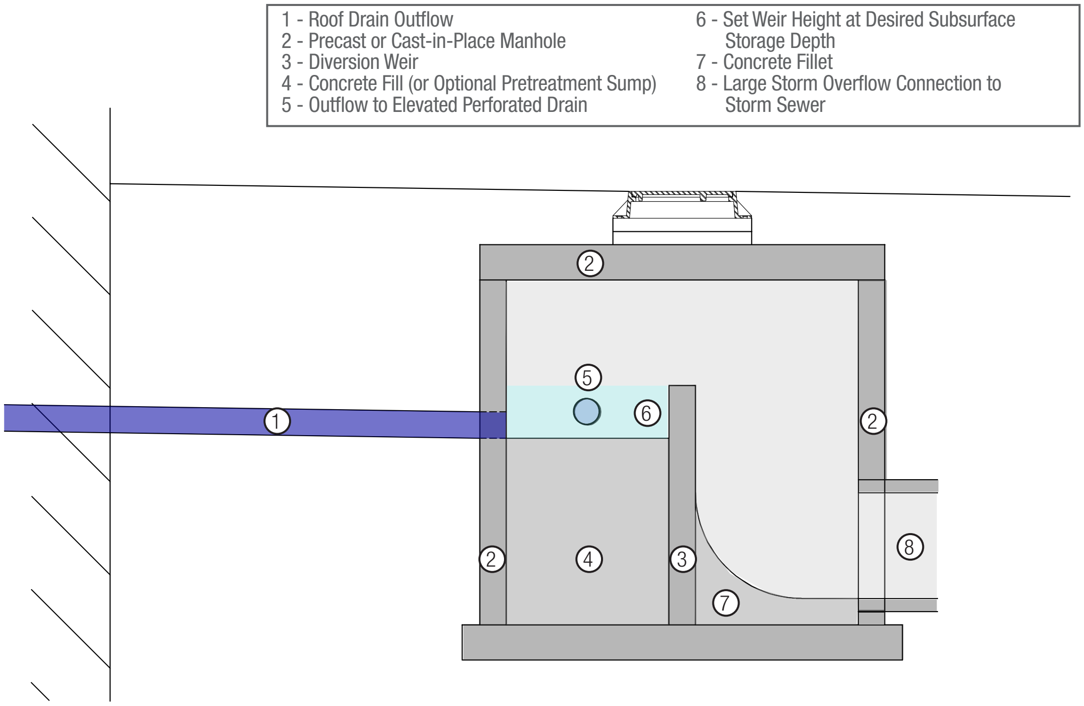
See Section 3.01 (Unified Sizing Criteria) and 9.12 (Stormwater Detention Combinations and Retrofits) for more information and limitations for using stormwater BMPs in series to meet management goals.

ROOF DRAIN CONNECTIONS

Drainage from adjacent roofs can either be introduced to the surface of the planter box or can be routed directly into the subsurface storage elements by using an elevated subsurface drainage pipe. If it is introduced below the surface, the designer needs to make sure the target flowrate to be treated can escape the elevated surface drainpipe quickly enough to enter the storage elements of the planter. **The system should also be designed so flows from larger events (that aren't expected to be treated by the BMP) can bypass the system.** ESSENTIAL



Roof downspout connection elements.



Underground roof drain connection.

SECTION 7.04-2 SIZING CALCULATIONS

A. CALCULATION PROCEDURES

The basic concept of sizing stormwater planters and tree trenches is to verify that:

1) There is adequate capacity for the flow to be treated to enter the practice.

2) There is adequate capacity within the practice to store the volume to be treated.

This part of this section of ISWMM will describe how to evaluate these sizing criteria for various elements of stormwater planters and tree trenches.

NOTE

As per ISWMM Section 9.12, each BMP must be sized to treat at least 30% of the WQV volume allowed to enter the practice to qualify as treating any portion of the WQv requirements.

WATER ENTRY METHOD SIZING

To be credited as managing all or a certain portion of the WQv requirements, the practices must be designed to be able to capture the peak rate of flow from that storm event and route it to the subsurface storage elements. If it is desired to use these practices to manage runoff from a larger storm event, the same principle would apply. ESSENTIAL

Curb cut or Inlet Sump Structure

Calculate the peak flow rate to the inlet. This should be completed using software running the NRCS TR-55 computational method using the appropriate Curve Number (CN) for the design event. For the WQv, the CN is typically adjusted as described in the ISWMM Small Storm Hydrology section (Section 3.02 – currently titled Chapter 3, Section 6).

Evaluate the capacity to capture the peak flow for the design event based on methods described in Iowa SUDAS Design Section 2C. Section 2C-3 specifically includes the calculations used to size inlets and determine what portion of flow is intercepted and what share will bypass the inlet and continue flowing downstream over the surface.

It may also be necessary to **perform orifice or weir flow calculations to check the capacity of the opening from an inlet sump structure leading to a planter or trench** when that type of configuration is used.

For calculating WQv treatment requirements, only the portion of flow calculated as captured can be assumed to enter the planter or trench for treatment. For example, if calculations show that at a given inlet can capture 80% of the peak flow expected to be directed to it during the WQv event, the adjacent planter or trench can at most be expected to treat that portion of the WQv from that area. Any remaining volume should be assumed to be directed to the next available treatment practice downstream.

ELEVATED PERFORATED DRAINS

Calculations are required to select the appropriate size and length of pipe when an elevated drain is used to allow runoff from an inlet sump structure or roof drain to percolate directly into the subsurface storage elements of the planter or trench. When calculating WQv treatment requirements, if the capacity of the elevated perforated drain is less than the WQv peak flow collected by the inlet sump structure or roof drain, the flow portion assumed to be entering the practice should match the capacity of the elevated perforated drain. Any excess flow beyond the capacity of the elevated drain should be assumed to be directed to the next available treatment practice downstream. ESSENTIAL

The length of pipe required can be found from the following equation:

Equation 7.04-2-1

$$L=Q/(B^* \, Cd^* \, Ao^* \, \sqrt{2gh})$$

Where:

L = Length of perforated pipe required (feet)

Q = Design flow rate for the WQv treatment volume (cfs)

B = Clogging factor (portion of openings blocked by soil materials = 0.25)

Cd = Orifice coefficient (0.6)

Ao = Perforation open area per unit length of pipe (square feet per foot)

g = gravitational constant (32.2 ft/s2)

H = head (use 3/4 of pipe diameter to represent the elevation difference at the top of the pipe to the centroid of perforations) in feet

Source: (12) Flow through Perforated Pipe. LID SWM Planning and Design Guide.

PERMEABLE PAVERS

Calculate the peak flow rate expected during the design event (typically WQv event) to the permeable paver area. Use the NRCS TR-55 computational method as described above. The surface area of the paver installation should be sufficiently sized to be able to capture the peak flow rate expected to be generated during the event to be treated.

For calculating WQv treatment requirements, if the paver area is sized to capture only a portion of the peak flow rate, only the captured portion can be assumed to enter the subsurface elements around the planter or trench for treatment. Any remaining volume should be assumed to be directed to the next available treatment practice downstream. ESSENTIAL

Equation 7.04-2-2

$$App = \frac{\left(Q^*3600\,\frac{sec}{hr}\;\;x\;12\,\frac{inch}{foot}\right)}{10\ inch/hour}$$

Where:

App = Minimum area of permeable pavement required (in square feet)

Q = peak flow rate of runoff to the paver area during the WQv storm event (in cubic feet per second, cfs)

NOTE

Refer to ISWMM Section 8 for additional information on the design and sizing of permeable paver installations.

SUBSURFACE STORAGE ELEMENT SIZING

Surface Storage or Ponding Area

The ponding area used when water is introduced into the planter box at the surface should be sized using the calculation method for bioretention cells, as described in more detail in the Bioretention Systems section of ISWMM. The WQv volume to be treated is used to calculate the required ponding area, based on the percolation rate of the subsurface elements, the ponding depth of the surface and the desired system drawdown time.

Equation 7.04-2-3

$$A_f = \frac{WQv \times d_f}{\left[k\left(h_f + d_f\right)t_f\right]}$$

Af = Required area to treat WQv volume (square feet, SF)

WQv = Water Quality volume to be treated (cubic feet, CF)

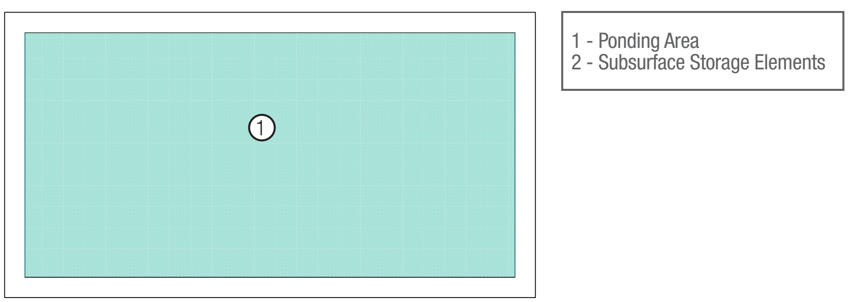
df = depth of filter bed material (feet – typically measured from surface to flowline of underdrain)

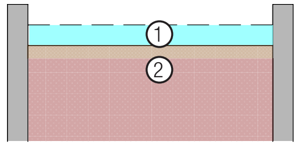
k = coefficient of permeability (2 foot / day)

hf = average ponding depth (in feet – take maximum ponding depth [in inches] and divide by 2) in feet

tf = time to drain modified soil layer (1 day)

The WQv treated by the ponding area will be credited to the volume of subsurface storage elements located directly below the footprint of the ponding area.





This illustration shows the vailable surface storage and ponding areas in planter boxes.

NOTE

Porosity values for common structural soils are listed in Table 7.04-1-2 (page 22).

SOIL STRUCTURAL CELLS OR STRUCTURAL SOIL

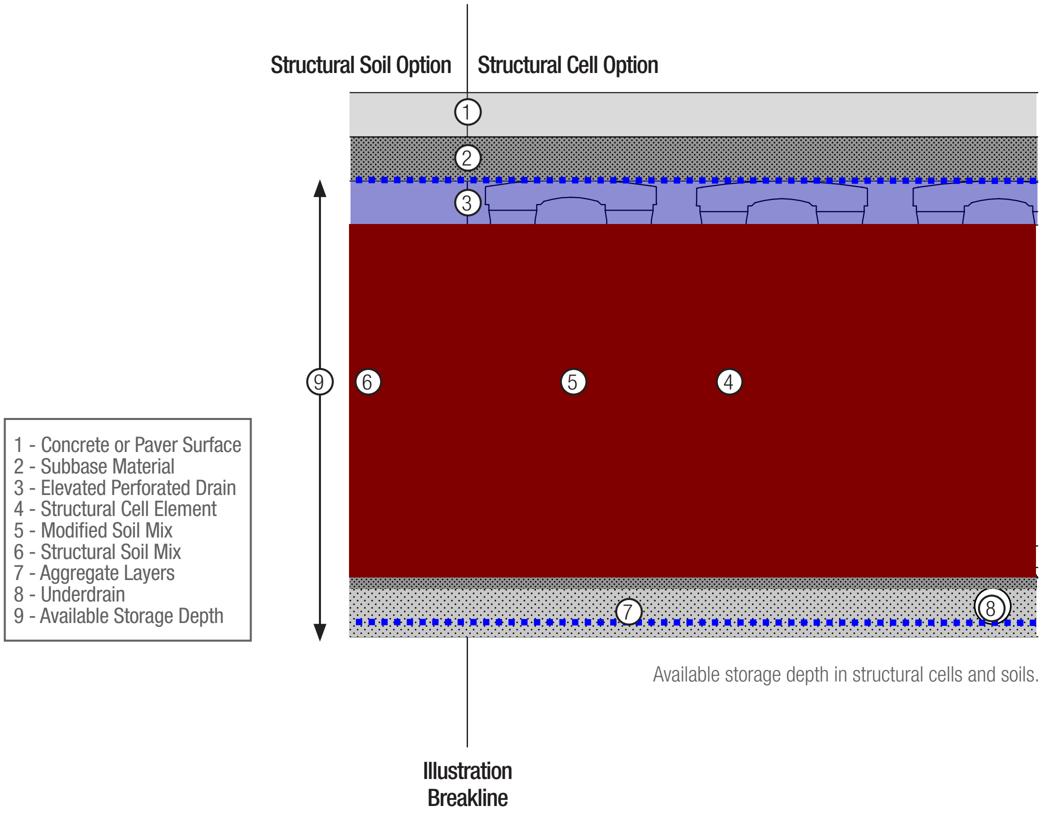
The storage volume within soil structural cells, structural soils and aggregate materials may be used to meet the WQv treatment volume as follows:

Equation 7.04-2-4

Available WQv treatment volume (cubic feet) = Total Volume of Structural Cells or Soils (cubic feet) x porosity

Equation 7.04-2-4 is applicable as long as the following conditions are met:

- There should be an appropriately sized water entry method that allows stormwater runoff to enter those features. For example, permeable pavers or elevated perforated drains that are properly sized could be used to introduce runoff into these subsurface storage elements.
- The design of the adjacent structural cells or soils should not rely on water movement through the surface storage or ponding areas within the planter box that have been sized based on the equations used for bioretention cells.
  - Those calculations assume that the subsurface elements below the bioretention cell are close to the same size as the surface ponding area.
  - The surface ponding area within the planter box will be the limiting factor which would not be sized large enough to convey the desired flowrate to an expanded subsurface footprint.
- Only the volume of the cells or soils above the underdrain should be counted for use in Equation 7.04-2.4 unless:
  - The percolation rate for subsoils below the installation has been determined through approved testing methods.
  - Calculations show that the volume stored below the underdrains can be percolated into subsoil layers within 24 hours.
  - These requirements would apply to any planter or trench systems that are installed without underdrains. ESSENTIAL



Available storage depth in structural cells and soils.

NOTE

The illustration shows the available storage depth for structural soil and structural cell options.

Left of the breakline shows the structural soil option.

Right of the breakline shows the structural cell option.

RECOMMENDED SOIL VOLUMES REQUIRED TO SUSTAIN TREES

Adequate rootable soil volume is vital to growing and sustaining healthy trees. The following table lists the volume of soil that is recommended based on tree sizes (see the appendix for a list of tree species and relative size). Typically, this soil volume should extend to a minimum depth three (3) to five (5) feet below the finished surface elevation. IDEAL

Trees need sufficient soil to thrive, even if they are not part of a stormwater management practice. The guidelines in this section aren't intended to require certain soil volumes for each tree (or to reduce the number of trees to fit within an available volume). **The goal is for designers to consider these guidelines as a potential goal for adequate soil support for trees.** IDEAL

NOTE

See page 42 for more information on calculating soil volume available in structural soils.

NOTE

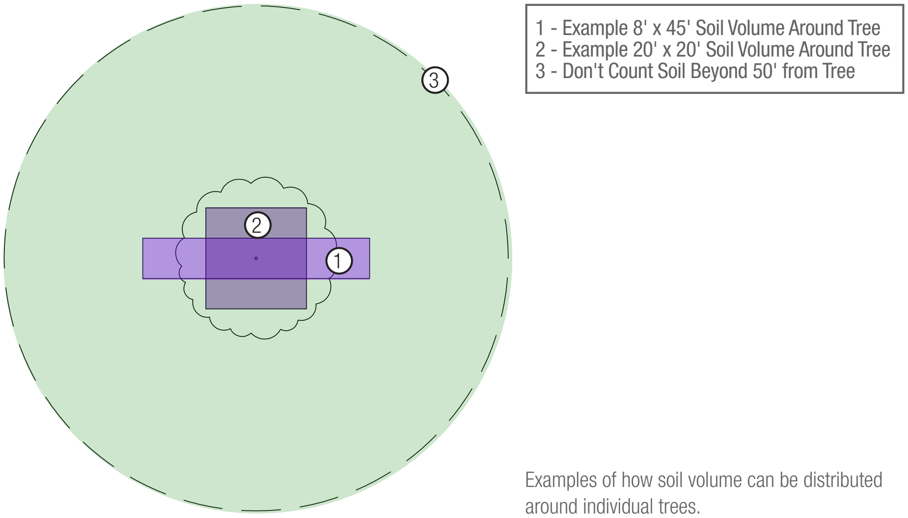
See the appendix for a complete list of recommended tree species.

Table 7.04-2-1

TARGET SOIL VOLUME BY TREE TYPE		
Relative Tree Size	Recommended Tree Soil Volume with Individual Tree (CF)	Recommended Tree Soil Volume Per Tree When Soil Volume is Shared by Multiple Trees (CF)
Small	640	430
Medium	980	660
Medium-Large	1,200	800
Large	1,420	950

Source: (13) Report for Design/Schematic Level Specifications for Soils and Tree Planting. Minnesota Department of Transportation. 2013.

Reference to tree sizes by species: Minnesota Stormwater Manual.
https://stormwater.pca.state.mn.us/index.php?title=Tree_species_list_-_morphology



Examples of how soil volume can be distributed around individual trees.

OUTLET UNDERDRAIN FLOW CONTROL

To prevent the planter or trench system from draining too quickly, a cap with an **orifice opening** should be installed on the end of any subdrain that is larger than four (4) inches in diameter. Since most installations have fairly small watershed areas, the typical minimum orifice diameter of three (3) inches will often be applicable. TARGET

However, designers can use the methods listed in the ISWMM Small Storm Hydrology section to calculate the allowable release rate to provide a twenty-four (24) hour drawdown period from the system during the design storm event (typically the WQv event). Once the allowable release rate is known, the orifice can be sized by solving the equation below:

Equation 7.04-2-5

$$A = Qa / [C \times (2gh)^{1/2}]$$

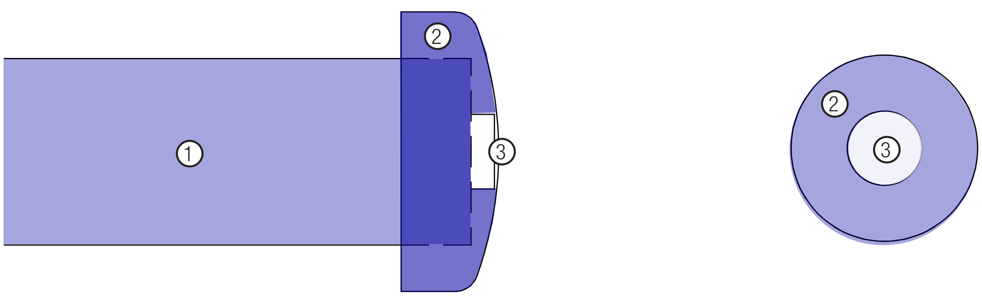
A = Target orifice cross-sectional area (square feet, SF)

Qa = Peak allowable release rate to provide extended detention (cubic feet per second, cfs)

g = Gravitational constant (32.2 ft/sec^2)

h = Elevation head: difference in elevation between centroid of orifice and top of subsurface storage elements (feet)

C = Coefficient for orifices (typically = 0.6)



Example of orifice control on underdrain outlet.

1 - Underdrain PVC Pipe
2 - Threaded PVC Cap
3 - Drilled or Cut Orifice Opening (Size Determined by Designer)

NOTE

A minimum orifice size of 1 inch may be used on underdrains if they do not intercept any direct surface flow.

B. DESIGN EXAMPLES

Design examples included are as follows:

1) Accounting for curb cut or sump inlet interception rate

2) Sizing the surface ponding area within a stormwater planter

3) Sizing treatment volume provided by structural cells

4) Sizing treatment volume provided by structural soils

5) Recommended tree soil volume calculations

6) Recommended tree soil volume calculations for linear tree trenches

7) Using linear tree trench applications to meet WQv requirements

8) Adjacent permeable paver installation calculations

9) Overflow from inlet structure into planter box

10) Sizing elevated perforated drains

11) Sizing overflow subdrain

Note that each application will be unique and not all of the above calculations will be required for each project.

INLET CAPACITY CALCULATION

Example #1 - Accounting for curb cut or sump inlet interception rate

For this example, assume that interception and bypass calculations have been completed based on the procedures and equations listed in SUDAS Section 2C-3.

Step 1 – Calculate peak rate of flow to inlet expected during WQv event:

A storm inlet is planned to be used to intercept runoff and divert it to a stormwater planter. A subarea draining to an inlet has 3,000 square feet (0.0689 acres) of area draining to it (100% impervious). Calculations were performed using TR-55 methods following the Small Storm Hydrology section of ISWMM. The adjusted Curve Number (CN) using Equation C3-S6-3 was determined to be 99.

Using the following assumptions:

- Time of concentration (Tc) = 5 minutes
- Type II rainfall distribution
- 1.25” rainfall, 24-hour storm duration
- 1-minute calculation increments

Using Hydraflow Hydrographs software to complete the TR-55 calculations, the peak flowrate from this area was found to be 0.126 cubic feet per second (cfs). (If there was any bypass flow from upstream areas, that would need to be added to this value.)

Step 2 – Calculate the WQv volume from the area draining to the inlet:

The Water Quality Volume to be treated is calculated based on Equations C3-S6-1 and C3-S6-2 in the Small Storm Hydrology section of ISWMM.

NOTE

If there is any bypass flow from upstream areas the expected rate and volume of bypass flow should be added to these calculations.

Step 2a – Calculate WQv runoff coefficient (Rv):

Rv = 0.05 + 0.009 (I)

Where Rv = runoff coefficient and I = impervious cover (%)

Rv = 0.05 + 0.009 (100) = 0.95

Step 2b – Calculate WQv treatment volume (WQv):

WQv = Rv x P x A / 12

Where:

WQv = water quality volume (acre-feet)

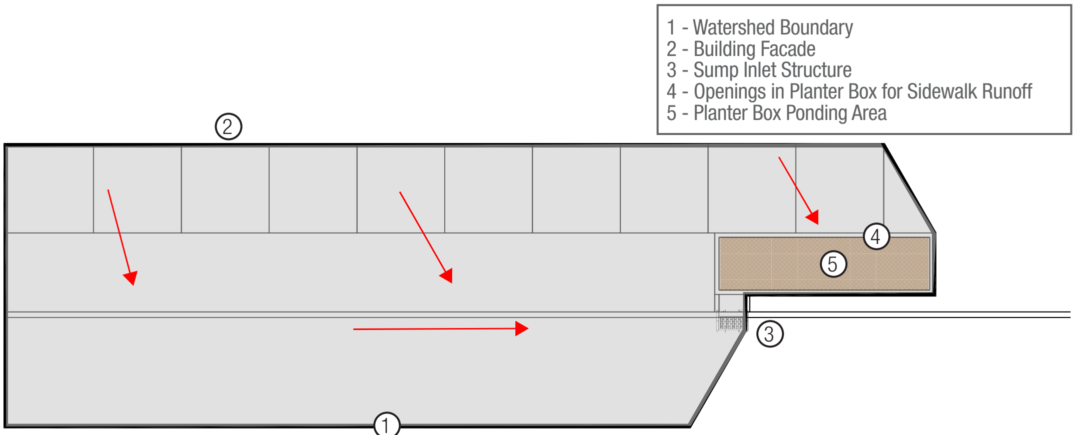
A = drainage area (acres)

P = Water Quality event rainfall = 1.25 inches

WQv = 0.95 x 1.25 x 0.0689 acres / 12 = 0.00682 acre-feet

Multiplying by 43,560 square feet / acre results in:

WQv = 0.00682 acre-feet x 43,560 square feet / acre = 297 cubic feet (CF).



Watershed illustration for Example #1.

Step 3 – Determine the portion of flow intercepted by the inlet.

Multiply the WQv peak flow rate and treatment volume by the interception rate calculated for the storm inlet (or curb cut) to determine how much flow is diverted to the BMP and the remaining flow that will bypass.

If the inlet interception calculations were solved and found that 85% of this flow was expected to be intercepted and diverted to the stormwater planter:

- Flow to the planter would be:
  - 85% x WQv peak flow = 85% x 0.126 cfs = 0.107 cfs
- Flow bypassing the planter would then be 0.019 cfs. This flow would need to be assigned to the next practice or storm collection point downstream.
- The WQv treatment volume to be directed to the planter would be;
  - 85% x WQv volume = 85% x 297 CF = 252 CF
- The WQv treatment volume bypassing the inlet would be 45 CF. This WQv volume would need to be assigned to the next practice downstream.

NOTE

The result of the inlet interception calculations is given for this example. In practice, the procedures listed in SUDAS Section 2C-3 would be used to determine the interception ratio for the design storm event (WQv in this example).

NOTE

If some of the flow from this area were bypassing the bioretention cell, the WQv used for design could be reduced.

For instance, in Example #1, because 15% of the flow was bypassing the inlet leading to the stormwater planter, the WQv routed into the planter was only 252 CF.

In such a case, the remaining 45 CF should be directed to another water quality practice downstream.

SIZING STORMWATER PLANTERS AND TREE TRENCHES

Example #2 – Sizing the surface ponding area within a stormwater planter

For this example, a stormwater planter is proposed to be located along a street in a downtown shopping district between the sidewalk and the back of curb of the street. Building facades are directly adjacent to the sidewalk. The plan view of the watershed to the stormwater planter is similar to that shown for Example #1.

The area draining to the practice is 3,000 square feet (0.0689 acres), with 100% impervious cover. The watershed subarea properties used in Example #2 are the same as used in Example #1.

The surface ponding area is sized using Equation 7-04-2-3:

$$A_f = \frac{WQv \times d_f}{[k(h_f + d_f)t_f]}$$

Af = Required area to treat WQv volume (square feet, SF)

WQv = 297 CF (solved in Example #1)

k = 2 foot / day

tf = 1 day

For this example, the designer has chosen to use this cross-section for the subsurface elements within the planter:

- 3-inch surface ponding depth
- Filter bed materials
  - 3-inch wood mulch layer
  - 18-inch modified soil layer
  - 3-inch choker aggregate layer
  - 9-inch storage aggregate layer (portion above flowline of subdrain)

In this case:

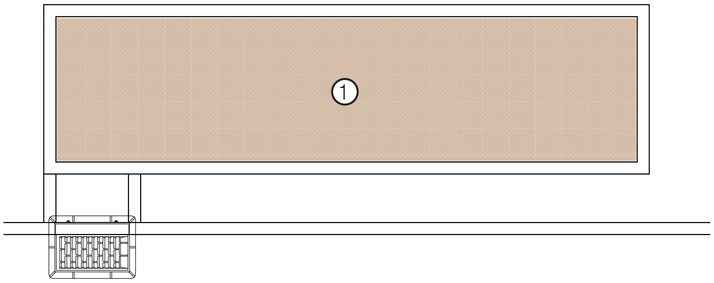
hf = average ponding depth = 3 inches / 2 = 1.5 inches = 0.125 feet

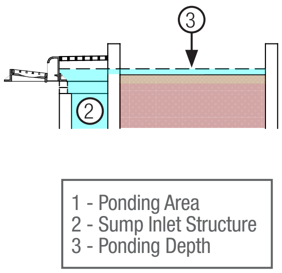
df = depth of filter bed material = 3+18+3+9 = 33 inches = 2.75 feet

$$Af = \frac{297\ CF * 2.75\ feet}{2\frac{feet}{day} * (0.125\ feet + 2.75\ feet) * 1\ day}$$

Af = 142 square feet

The stormwater planter could have an interior dimension where ponding could occur of 6 feet x 24 feet (144 square feet) and meet this requirement.





Ponding area for Example #2.

Example #3 – Sizing treatment volume provided by structural cells

The watershed for this example is the same as the setting used for Example #2, but a tree trench is proposed to be used. The planter box used to create a ponding area within the tree trench is reduced in size to 6 feet x 12 feet (72 square feet). Structural cells are planned around the planter box to allow for tree root growth and to provide storage for any remaining treatment volume above the capacity of the area within the planter box.

To determine the capacity of the planter box, Equation 7.04-2-3 can be re-arranged as follows:

$$WQv = Af * \frac{[k\ (hf + df)]}{df}$$

WQv = treatment volume capacity (CF)

Af = 72 square feet

k = 2 foot / day

tf = 1 day

hf = (same as Example #2) = 0.125 feet

For this example, the designer has chosen to use this cross-section for the subsurface elements within the planter:

- 3-inch wood mulch layer
- 48-inch modified soil layer (to support tree growth)
- 3-inch choker aggregate layer
- 9-inch storage aggregate layer (portion above flowline of subdrain)
- df = 3+48+3+9 = 63 inches = 5.25 feet

$$WQv = 72\ SF * \frac{\left[2\frac{feet}{day} * (0.125\ feet + 5.25\ feet)\right]}{5.25\ feet}$$

WQv = 147 cubic feet

As solved in Example #2, the total WQv to be treated is 297 CF, so the remaining 150 CF (51% of the WQv to be treated) needs to be stored in the surrounding structural cells.

Note that since the planter box is at capacity, the remaining flow will need to be introduced into the structural cells by another entry method, such as permeable pavers or an elevated perforated drain. See Example #10 for more information. For this example, the elevated drain would need to have capacity for 51% (150 CF / 297 CF = 51%) of the peak flow expected from the WQv event.

This example will use Silva Cells to provide the additional storage volume adjacent to the planter box. Other manufactured systems can be sized in a similar manner. Silva cells will include layers for soil materials and aggregate. Sometimes, a "ponding layer" is provided at the top of the system which provides void space where water can be stored before it infiltrates into the soil layers.

The treatment volume capacity for each layer can be computed as:

Equation 7.04-2-6

$$V = A \times D \times \eta$$

- V = Volume Capacity (cubic feet)
- A = Footprint Area (square feet)
- D = Depth of Material (feet)
- η = porosity

NOTE

Solve for the volume in each zone and then add them together to find the total volume treated.

NOTE

Silva cell systems are currently provided in three heights: 1x, 2x and 3x.

NOTE

The porosity of the ponding depth was calculated based on information provided by the manufacturer. The ponding depth zone is primarily open space, except for the volume occupied by the structural cell materials that support the pavement layers above.

NOTE

The volume stored below the subdrain may be counted if it can be demonstrated though testing that subsoil layers have the capacity to drain the volume below the subdrain within 24 hours.

For this example, the following parameters will be used, based on Silva Cells (3x system):

- Ponding depth of 8" (0.667 feet), porosity = 0.92 (some space occupied by structural cell materials)
- Planting depth of 31" (2.583 feet), porosity = 0.25
- Aggregate depth of 9" (0.75 feet) above subdrain, porosity = 0.30

$$V = [A \times D_{pond} \times \eta_{pond}] + [A \times D_{soil} \times \eta_{soil}] + [A \times D_{agg} \times \eta_{agg}]$$

V = [A x (0.667 feet) x 0.92] + [A x (2.583 feet) x 0.25] + [A x (0.75 feet) x 0.30]

V = (1.484 feet) x A

To find the required footprint area to store the required treatment volume, the equation can be rearranged:

A = V / (1.484 feet)

A = 150 cubic feet / (1.484 feet) = 102 square feet

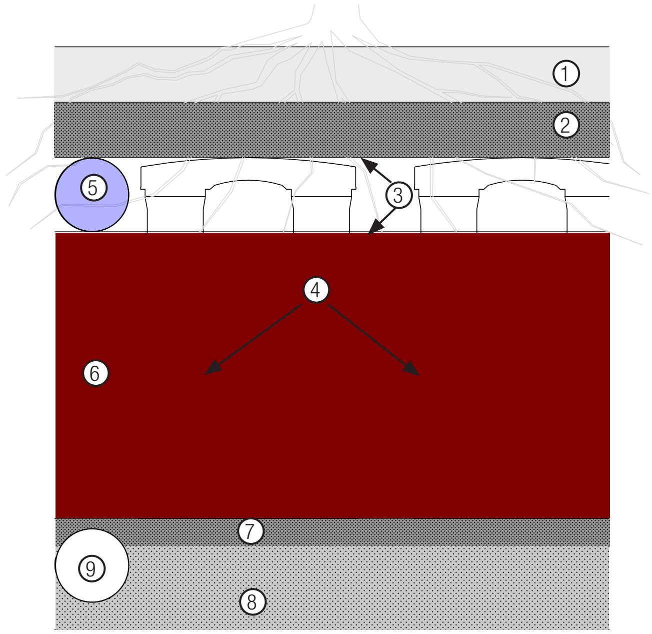
This could be provided by installing the structural cells in a zone within 3.5 feet around three sides of the 6' x 12' planter box.

A = 3.5 feet x 13 feet + 2 x 3.5 feet x 10.5 feet = 119 square feet.

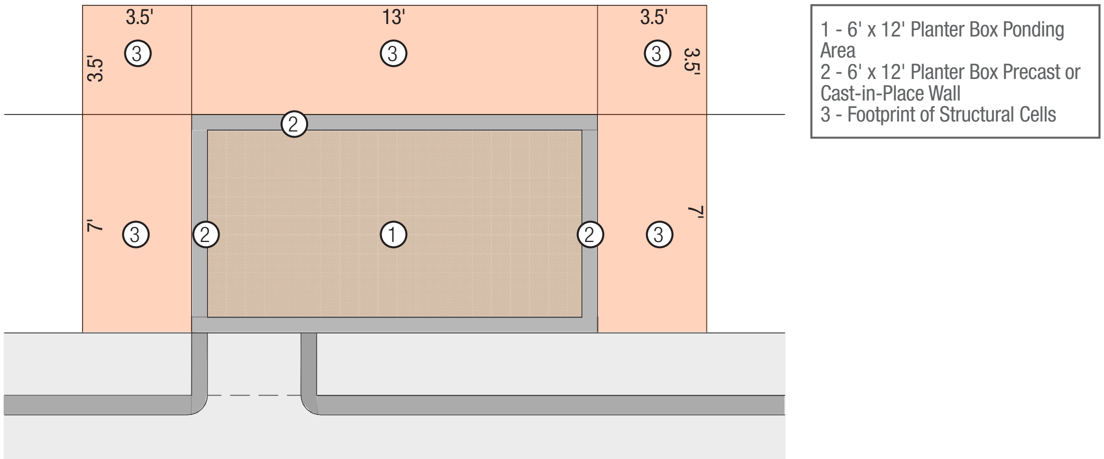
Rechecking for total capacity:

Volume available in ponding layer:	V = A x D x n = 119 SF x 0.667 feet x 0.92 =	73 CF	= 175 CF
Volume available in soil layer:	V = A x D x n = 119 SF x 2.583 feet x 0.25 =	76 CF	
Volume available in aggregate layers:	V = A x D x n = 119 SF x 0.75 feet x 0.30 =	26 CF	
Volume available in planter box:		147 CF	
Total WQv capacity:		322 CF	

1 - Concrete or Paver Surface
2 - Subbase Aggregate
3 - 8" Ponding Depth (Void Space)
4 - Soil Cell Units
5 - Elevated Perforated Drain
6 - 31" Planting Soil Depth
7 - 3" Choker Aggregate Layer
8 - 9" Storage Aggregate Layer
9 - Underdrain Set at Least 3" Above Bottom of Storage Aggregate Layer



Structural cell cross-section for Example #3.



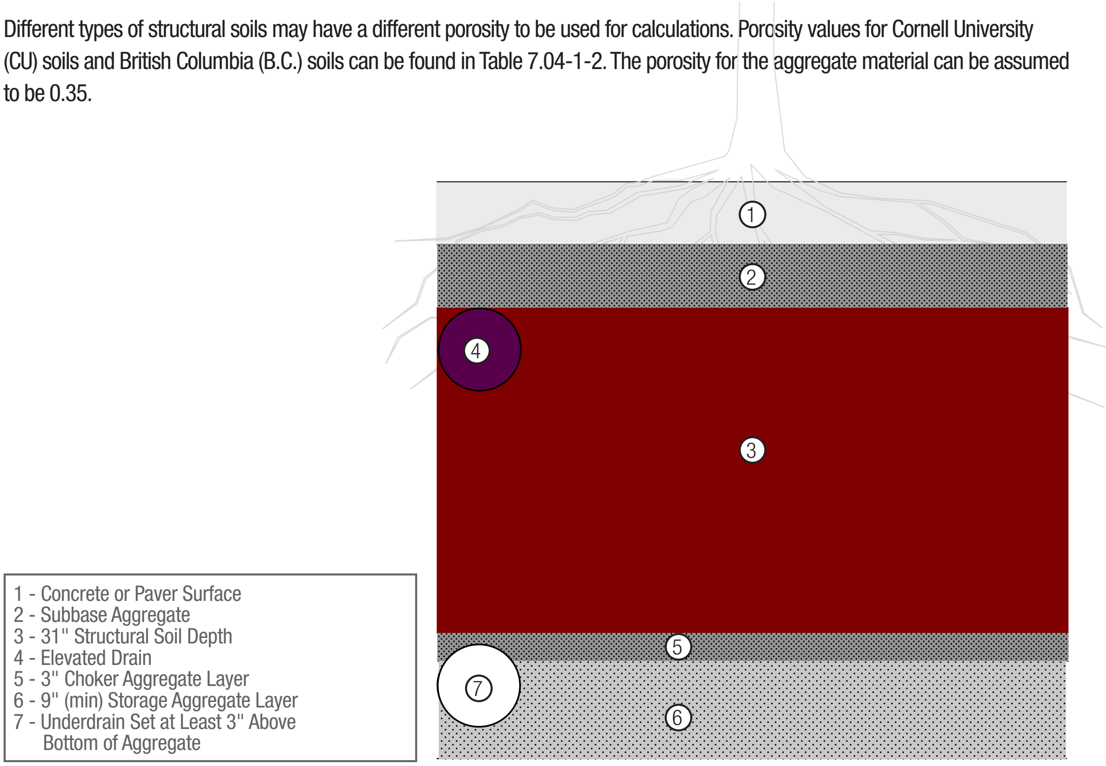
Footprint area of structural cells from Example #3.

Example #4 – Sizing treatment volume provided by structural soils

This example has similar parameters to Example #3, except structural soils are proposed to provide the additional required storage around the planter box.

Only the volume that is below the expected ponding depth and above the flowline of the subdrain should be counted towards treating the WQv volume. For this example, there is 43 inches (3.583 feet) of structural soil and 9 inches (0.75 feet) of aggregate materials located above the flowline of the subdrain.

Different types of structural soils may have a different porosity to be used for calculations. Porosity values for Cornell University (CU) soils and British Columbia (B.C.) soils can be found in Table 7.04-1-2. The porosity for the aggregate material can be assumed to be 0.35.



Structural soil cross-section for Example #4.

The treatment volume capacity for each layer can be computed as:

Equation 7.04-2-6

$$V = A \times D \times \eta$$

- V = Volume Capacity (cubic feet)
- A = Footprint Area (square feet)
- D = Depth of Material (feet)
- η = porosity

For this example, using CU soils and the cross-section previously described:

$$V = [A \times D_{soil} \times \eta_{soil} + A] \times [D_{agg} \times \eta_{agg}]$$

V = [A x (3.583 feet) x 0.26] + [A x (0.75 feet) x 0.35]

V = (1.194 feet) x A

To find the required footprint area to store the required treatment volume, the equation can be rearranged:

A = V / (1.194 feet)

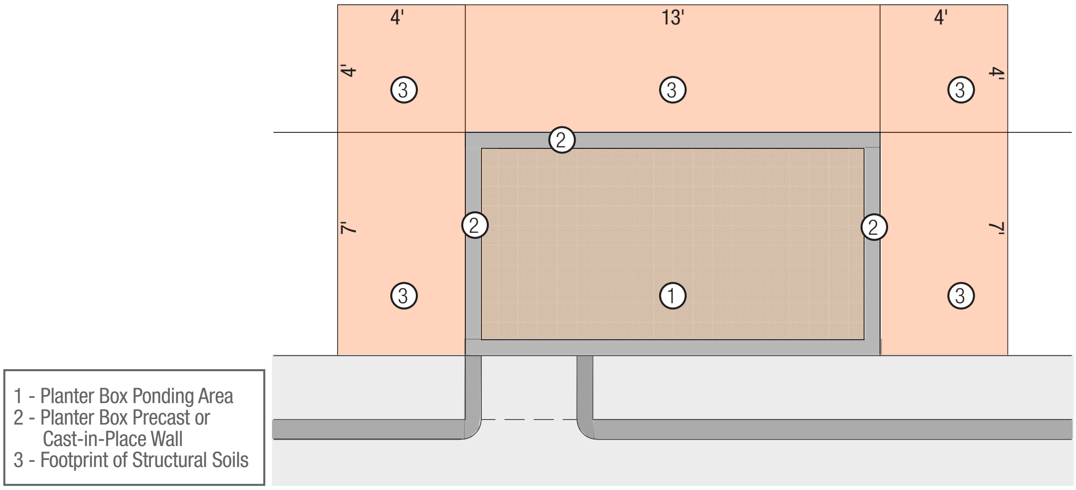
A = 150 cubic feet / (1.194 feet) = 126 square feet

This could be provided by installing the structural soil under 4 feet around three sides of the 6' x 12' planter box.

A = 4 feet x 13 feet + 2 x 4 feet x 11 feet = 140 square feet.

Rechecking for total capacity:

Volume available in structural soil:	V = A x D x n = 140 SF x 3.583 feet x 0.26 =	130 CF	= 166 CF
Volume available in aggregate layers:	V = A x D x n = 140 SF x 0.75 feet x 0.35 =	36 CF	
Volume available in planter box:		147 CF	
Total WQv capacity:		313 CF	



Footprint for CU soils from Example #4.

If BC soils were used for this same application:

$$V = [A \times D_{soil} \times \eta_{soil}] + [A \times D_{agg} \times \eta_{agg}]$$

$$V = [A \times (3.583 \text{ feet}) \times 0.33] + [A \times (0.75 \text{ feet}) \times 0.35]$$

$$V = (1.445 \text{ feet}) \times A$$

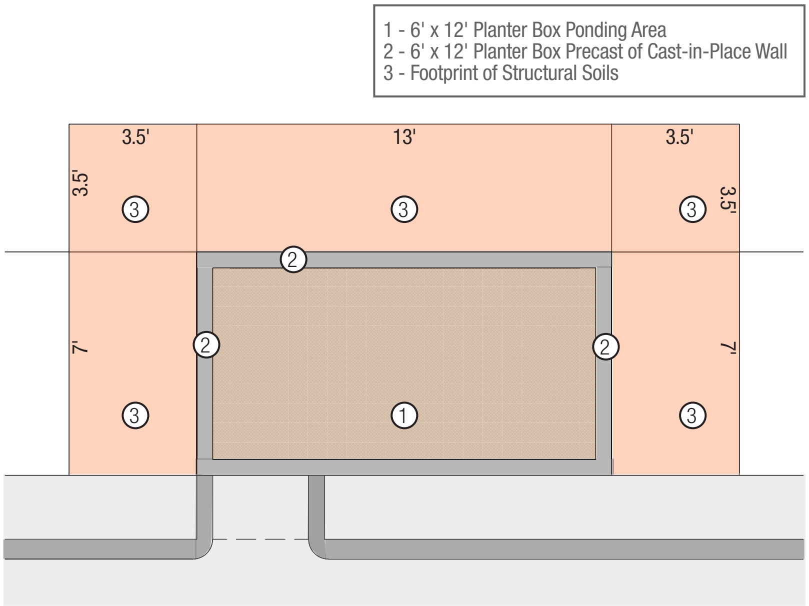
To find the required footprint area to store the required treatment volume, the equation can be rearranged:

$A = V / (1.445 \text{ feet})$

$A = 150 \text{ cubic feet} / (1.445 \text{ feet}) = 104 \text{ square feet}$

This could be provided by installing the structural soil for 3.5 feet around three sides of the planter box.

$A = 3.5 \text{ feet} \times 13 \text{ feet} + 2 \times 3.5 \text{ feet} \times 10.5 \text{ feet} = 119 \text{ square feet}.$



Footprint for BC soils from Example #4.

NOTE

The correction factor (%) will vary based on the selected structural soil type.

For structural cells, there is no aggregate material, so the correction factor is 1.0.

NOTE

See the appendix for a copy of the tree species list, to determine which tree size is applicable.

Example #5 – Recommended tree soil volume calculations

Once a tree trench has been sized to be able to provide the appropriate storage to manage the WQv treatment volume, the amount of soil provided to support the desired tree(s) can be checked.

Structural soils use high proportions of sand or aggregates which displace soil needed for nutrient and water holding capacity to sustain plants. Unless the volume of structural soil provided for the planting is increased proportionally, a tree will achieve a smaller stature when compared to a stormwater planter or tree trench using a majority soil growing media.

Therefore, it is recommended to look up the aggregate mixes of the selected structural soil and apply a scaling factor relative to the soil content of the mixes. For example, if a structural soil contained 30% soil and 70% aggregate, a total volume of 3.33 cubic feet (1 cubic foot / 0.30) would be needed to equal 1 cubic foot of actual soil material to support tree growth.

Using the information from Example #4, the planter box may only be large enough to support one tree. The total soil volume available to the tree would be:

Volume (planter box)	= 72 square feet area x 4 feet soil depth	= 288 cubic feet
Volume (structural soil, CU soil example)	= 119 square feet area x 3.583 feet soil depth x 30%	= 128 cubic feet
	Total soil volume	= 416 cubic feet

Table 7.04-2-2

TARGET SOIL VOLUME BY TREE TYPE		
Relative Tree Size	Minimum Tree Soil Volume with Individual Tree (CF)	Minimum Tree Soil Volume Per Tree When Soil Volume is Shared by Multiple Trees (CF)
Small	640	430
Medium	980	660
Medium-Large	1,200	800
Large	1,420	950

Copy of Table 7.04-2-1 for user convenience.

This volume is not sufficient to support a small tree.

The additional area required to support larger trees could be solved as:

Equation 7.04-2-7

Additional area (square feet) = Volume shortfall (cubic feet) / [Depth of soil media (feet) x correction factor (%)]

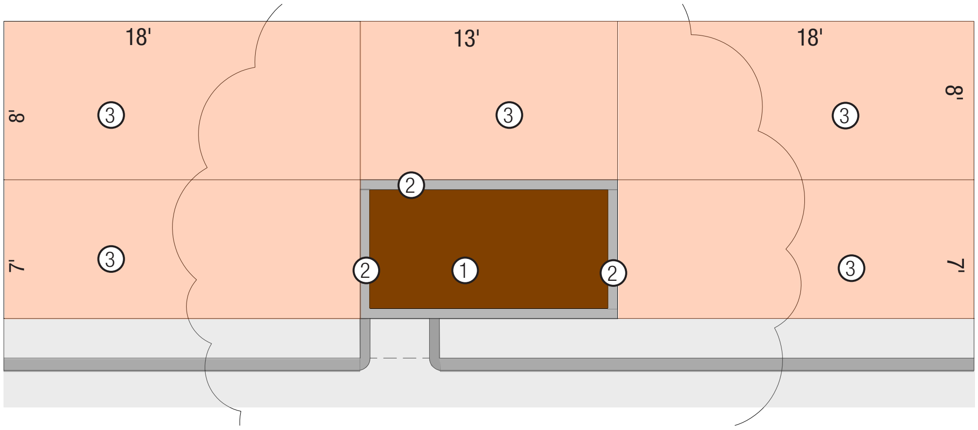
To support a medium size tree in this example:

Additional structural soil area (square feet) = (980 CF – 416 CF) / (3.583 feet x 30%) = 525 square feet

Therefore, the total structural soil area recommended would be 119 square feet (size at start of this example) + 525 square feet = 644 square feet.

Expanding the CU soil area on each side of the planter box as shown below would provide the additional recommended soil volume.

Volume (planter box)	= 72 square feet area x 4 feet soil depth	= 288 cubic feet
Volume (structural soil, CU soil example)	= 644 square feet area x 3.583 feet soil depth x 30%	= 692 cubic feet
	Total soil volume	= 980 cubic feet



Expanded structure soils to support trees from Example #5.

Repeating this calculation for larger trees using the parameters from this example, the recommended additional area would be as listed in Table 7.04-2-3.

Table 7.04-2-3

RECOMMENDED STRUCTURAL SOIL AREA TO SUPPORT A TREE FROM THIS EXAMPLE			
Relative Tree Size	Recommended Tree Soil Volume with Individual Tree (CF)	Shortfall in Soil Volume with Original Design (CF)	Recommended Additional Structural Soil Area (SF)
Medium	980	564	524
Medium-Large	1,200	784	730
Large	1,420	1,004	935

A similar procedure can be followed to evaluate the soil volume to support trees using the soil volume contained within structural cells. However, since the soil layers within the structural cells do not use aggregate materials to provide strength, the volume of the soil mix layers within the cell is almost completely usable to support plant growth. So the reduction factor noted for structural soils does not apply. This means the footprint of the soil support area for a tree may be significantly smaller when structural cells are used, compared to structural soils.

NOTE

The footprint area of structural soils could be increased to provide the recommended soil volume for the desired size of tree.

NOTE

The shortfall in soil volume in Table 7.04-2-3 is calculated for this example, based on the soil volume provided in Example #5 (416 CF) subtracted from the recommended soil volume.

The additional structural soil area outside the planter box is calculated using the methods listed in this example compared to the original footprint in Example #5 (119 SF).

Example #6 – Recommended tree soil volume calculations for linear tree trenches

When longer or larger tree trenches are created using a continuous subsurface installation of amended soils, structural soils and/or structural cells the calculation methods can be amended as follows:

- Only the soil material located within 50 feet of the center of any tree should be counted toward meeting the target soil volume for that tree
- Recommended soil volumes can be reduced when multiple trees are located within 50 feet (center to center)
- If the soil volume is shared between multiple trees and trees are located closer than 50 feet apart, don't double count the soil volume located between two trees.

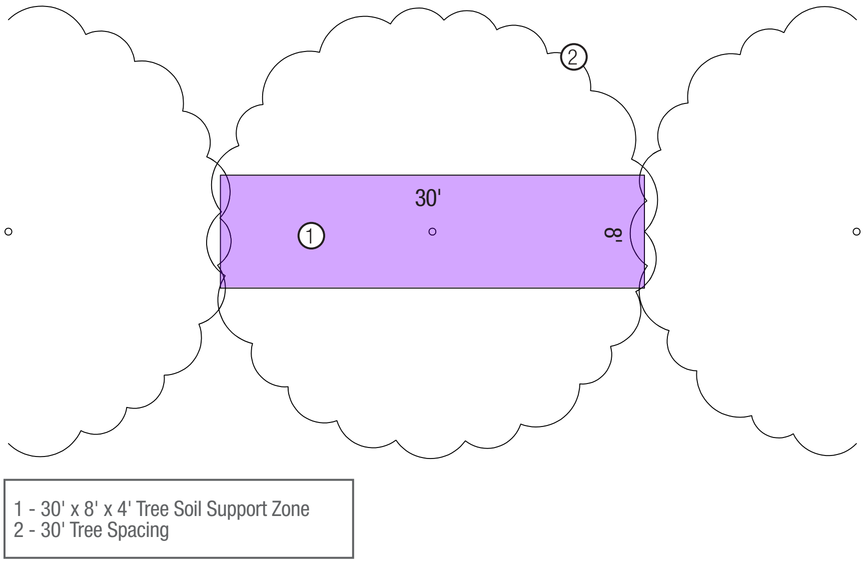
Consider an example, where the landscape area (verge) between a sidewalk and street is 8 feet wide. A modified soil depth of 4 feet is proposed. Trees are to be spaced 30 feet center to center.

The soil volume for each tree would be:

Volume (cubic feet) = Length (feet) x Width (feet) x Depth (feet)

Volume = 30 feet x 8 feet x 4 feet = 960 cubic feet

From the values listed in Table 7.04-2-1, it can be seen that this volume exceeds the 950 square feet required to support a large tree. If there had been a shortfall in soil volume, the width of the verge could have been widened, or structural soils (or structural cells) could be installed under adjacent paved areas to provide for the required root growth area.



Example of footprint of tree trench from Example #6.

Example #7 – Using linear tree trench applications to meet WQv requirements

If flow from the WQv event could be captured in a storm inlet and then distributed into a linear tree trench through an elevated perforated pipe, the available volume within the linear tree trench could be used to address the WQv treatment volume requirements.

Using the information in Example #6, the available storage volume within the soil provided around each tree can be found as:

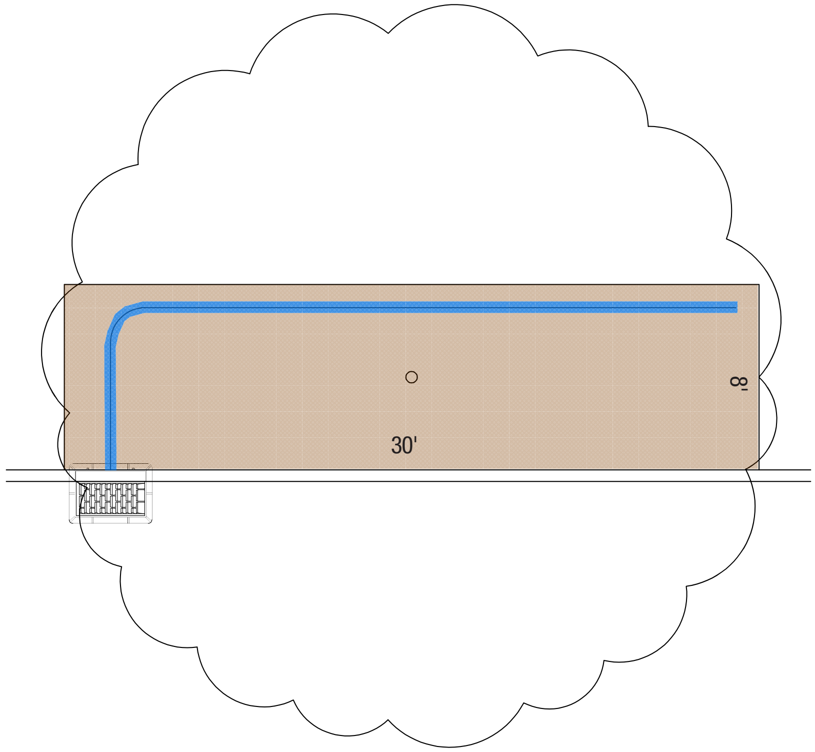
$$V = A \times D \times \eta$$

- V = Volume Capacity (cubic feet)
- A = Footprint Area (square feet) = (8 feet x 30 feet) = 240 square feet
- D = Depth of Material (feet) = 4 feet (BC soil) and 0.75 feet (9" of aggregate above subdrain)
- η = porosity = projected to be 0.30 (for a tree based bioretention soil mix) 0.33 (for BC soil layers) and 0.35 (for aggregate layers)

V = [A x Dsoil x nsoil] + [A x Dagg x nagg]

V = [(240 SF) x 4 feet x 0.33] + [(240 SF) x 0.75 x 0.35] = 379.8 cubic feet

In this example, if stormwater could be distributed along the trench using an elevated perforated subdrain, each tree (240 square feet of trench area in this example) has the capacity to treat 380 cubic feet of the WQv treatment volume.



Footprint area of tree trench footprint from Example #7.

NOTE

Equation C3-S6-3 can be found in the Small Storm Hydrology section of ISWMM.

SIZING WATER ENTRY METHODS

Example #8 – Adjacent permeable paver installation calculations

Permeable pavers can be used as one method to allow runoff to enter the subsurface elements of a stormwater planter or tree trench.

What if the parameters for the planter box designed in Example #2 were changed so that the 3,000 square feet of impervious area was just from within the street? An additional 1,824 square feet of area draining toward the street is to be intercepted by an 8-foot-wide strip of permeable pavers installed in the verge area between the sidewalk and street.

For the area draining to the paver installation, calculations were performed using TR-55 methods following the Small Storm Hydrology section of ISWMM. The adjusted Curve Number (CN) using Equation C3-S6-3 was determined to be 99.

Using the following assumptions:

- Time of concentration (Tc) = 5 minutes
- Type II rainfall distribution
- 1.25” rainfall, 24-hour storm duration
- 1-minute calculation increments

Using Hydraflow Hydrographs software to complete the TR-55 calculations, the peak flowrate from this area was found to be 0.076 cubic feet per second (cfs).

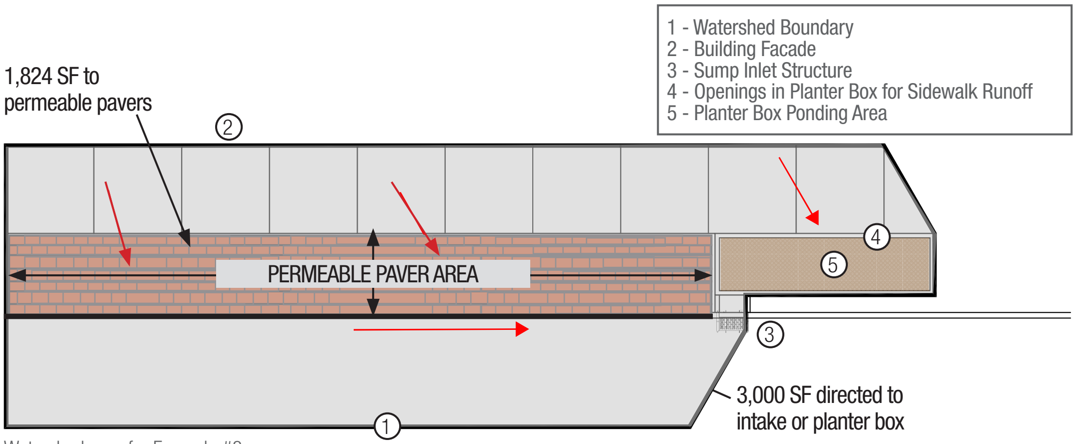
The area required to intercept this flow can be determined using Equation C8-S1-3 from the ISWMM Permeable Pavement Systems section.

$$App = \frac{\left(Q * 3600\frac{sec}{hr} * 12\frac{inch}{foot}\right)}{10\frac{inches}{hour}}$$

In this equation, App is the required area of permeable pavers (in square feet) and Q is the peak flow rate expected to be conveyed through the paver surface.

$$App = \frac{\left(0.076\,cfs * 3600\frac{sec}{hr} * 12\frac{inch}{foot}\right)}{10\frac{inches}{hour}}$$

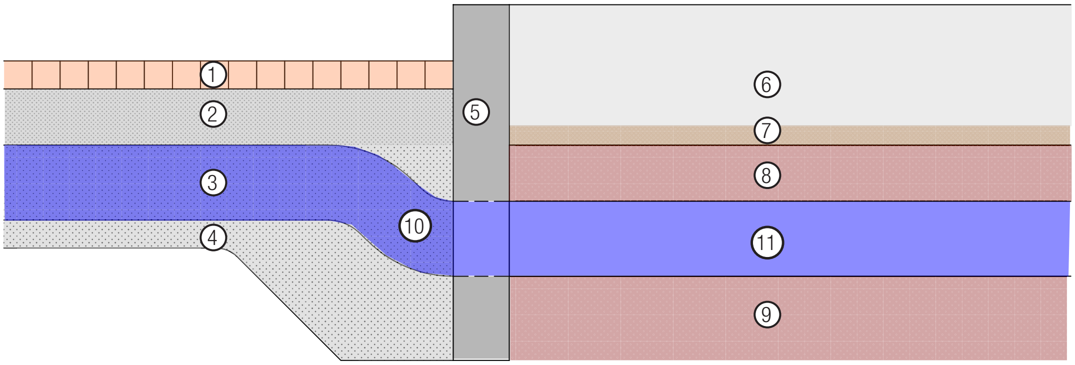
App = 328 square feet



Watershed area for Example #8.

In this example, the paver surface is expected to be 70 feet long x 8 feet wide = 560 square feet

- This exceeds the required area, so this design is sufficient to capture the WQv runoff from this area.
- The WQv treatment volume could be satisfied by storing this volume below the permeable paver installation. In this case, the methods listed in ISWMM Section 8 for designing the depth of storage and underdrains beneath the permeable pavers should be followed.
- In some cases, the paver system is simply used as a means to capture runoff and direct it to structural soils, structural cells or even the soil layers within a planter box.
  - In those cases, the structural soils or structural cells should be sized to contain the runoff volume directed to them.
  - The permeable pavers should be hydraulically connected to the structural soils or structural cells so that water may move freely between the rock and soil layers of each practice. This can be accomplished by having the aggregate and soil layers between each practice directly connect, or by providing a perforated subdrain installed below the pavers to the elevated perforated drain within the structural soils or structural cells.



Cross-section of method to connect subdrain from permeable paver installation to elevated perforated subdrain.

1 - Permeable Pavers
2 - Minimum 6" Aggregate Above Underdrain
3 - 8" Paver Underdrain
4 - Minimum 3" Aggregate Below Underdrain
5 - Planter Box Wall
6 - Ponding Depth
7 - 3" Mulch Layer
8 - 6" Bioretention Soil Mix Above Elevated Perforated Drain
9 - Bioretention Soil Mix Below Elevated Perforated Brain
10 - Connection from Paver Underdrain to Elevated Perforated Drain
11 - Elevated Perforated Drain

NOTE

A similar method could be used to connect permeable pavement subdrains to the elevated subdrains within structural cell or structural soil installations.

Example #9 – Overflow from inlet structure into planter box

The capacity of the opening from a curb cut or structure opening will typically be evaluated using equations for sizing flow through orifices or weirs. In some cases, it will be necessary to evaluate the opening as both an orifice and a weir, with the method resulting in the least capacity used for design.

Orifice equation: **Equation 7.04-2-8**

$$Qo = Co * A\sqrt{(2gH)}$$

Where:

Qo = flow through the orifice (cubic feet per second)

A = area of the orifice (square feet)

Co = orifice coefficient (typically, 0.6)

g = gravitational constant (32.2 ft/s^2)

H = head (elevation difference between water elevation upstream of orifice and centroid of orifice opening)

Weir equation: **Equation 7.04-2-9**

$$Qw = Cw * L * H^{1.5}$$

Where:

Qw = flow across weir opening (cubic foot per second)

Cw = weir coefficient (3.3 for sharp crested weirs, 2.6 for broad-crested weirs)

L = length of weir measured perpendicular to flow direction (feet)

H = head (elevation difference between water elevation upstream of weir and crest elevation of weir)

For this example, the parameters listed for Example #1 are to be used. An inlet sump structure is being used to capture flow and deliver it to a ponding area within the planter box. There will be a 3-foot wide by 3 inch tall opening provided in the back of the inlet, which allows water to flow from the inlet into the planter box. The bottom of this opening will be set 3 inches below the gutter elevation to ensure that water ponding in the planter box or in the inlet structure isn't backing up into the gutter during the WQv event.

The peak flowrate from the WQv storm event was computed as 0.126 cfs in Example #1.

Using the orifice equation, the capacity of this opening would be found to be:

$$Qo = 0.60 * (\sqrt{[2 * 32.2 \frac{ft}{sec^2} * \left(\frac{1.5\ inches}{12\ inch/foot}\right)]}$$

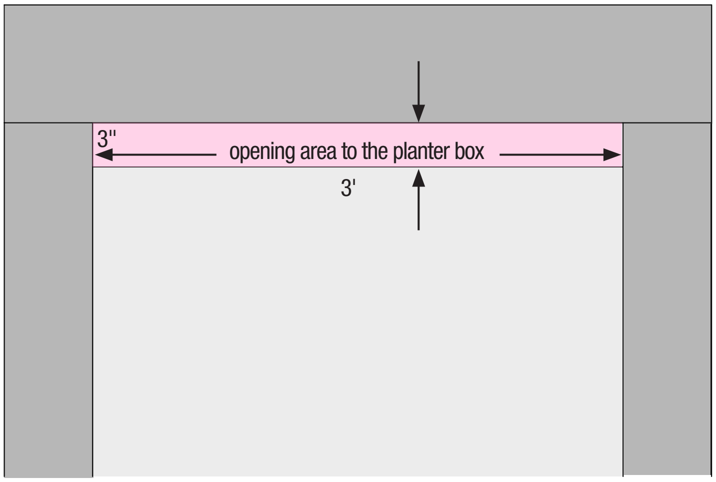
Qo = 1.70 cfs

Using the weir equation, the capacity of this opening would be found to be:

$$Qw = 3.3 * 3\ feet * \left(\frac{3\ inches}{12\ inches/foot}\right)^{1.5}$$

Qw = 1.23 cfs

In this case, the weir condition results in the lower capacity. It is well above the expected WQv peak flow rate of 0.126 cfs, so the opening is sufficiently sized to allow the peak flow from the WQv event to enter the planter box from the inlet structure.



Cross-Section of the opening area to the planter box described in Example #9.

NOTE

The head condition (h) in the orifice equation in this example is equal to half the height of the opening (3" / 2) - since it is measured to the centroid of the opening.

For the weir equation, the head condition is equal to the full height of the opening (3").

Example #10 – Sizing elevated perforated drains

When a perforated drain is used as the water entry method to distribute flow into the subsurface elements of a stormwater planter or tree trench, an adequate length of pipe needs to be provided so that the perforations have sufficient open area to allow the design flow to be distributed into the surrounding soils.

The length of pipe required can be found from the following equation:

Equation 7.04-2-10

$$L = Q/(B * Cd * Ao * \sqrt{2gh})$$

Where:

L = Length of perforated pipe required (feet)

Q = Design flow rate for the WQv treatment volume (cfs)

B = Clogging factor (portion of openings blocked by soil materials = 0.25)

Cd = Orifice coefficient (0.6)

Ao = Perforation open area per unit length of pipe (square feet per foot)

g = gravitational constant (32.2 ft/s2)

H = head (use 3/4 of pipe diameter to represent the elevation difference at the top of the pipe to the centroid of perforations) in feet

Pipe manufacturer data sheets can be used to identify the open area per unit length of pipe which will vary based on pipe material and diameter.

Using the parameters from Example #1 and the following information:

- If 6” N-12 HDPE pipe material is to be used, the open area is 1.0 square inches (1/144 square feet) per linear foot

$$L = 0.126\ cfs/(0.25 * 0.60 * (\frac{1}{144} SF) * \sqrt{2(32.2\frac{ft}{s^2})(0.75 * 6\ inches * \frac{1\ foot}{12\ inches})}$$

L = 25 feet

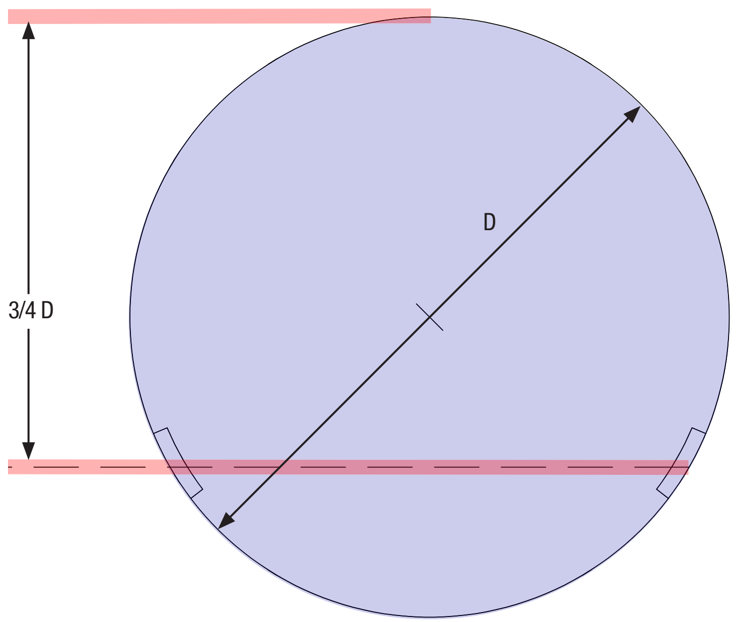
At least this length of elevated perforated drain would be needed to direct the design flow rate into the stormwater planter or tree trench.

If the perforated drain is only be used to route part of the design flow into the practice, it would only need to be sized for that portion of the design flow. For example, following what was described in Example #3 – 49% of the design flow volume was expected to be directed to the surface ponding in a planter box. That leaves 51% of the design volume that would need to be directed into the structural cells by a perforated subdrain.

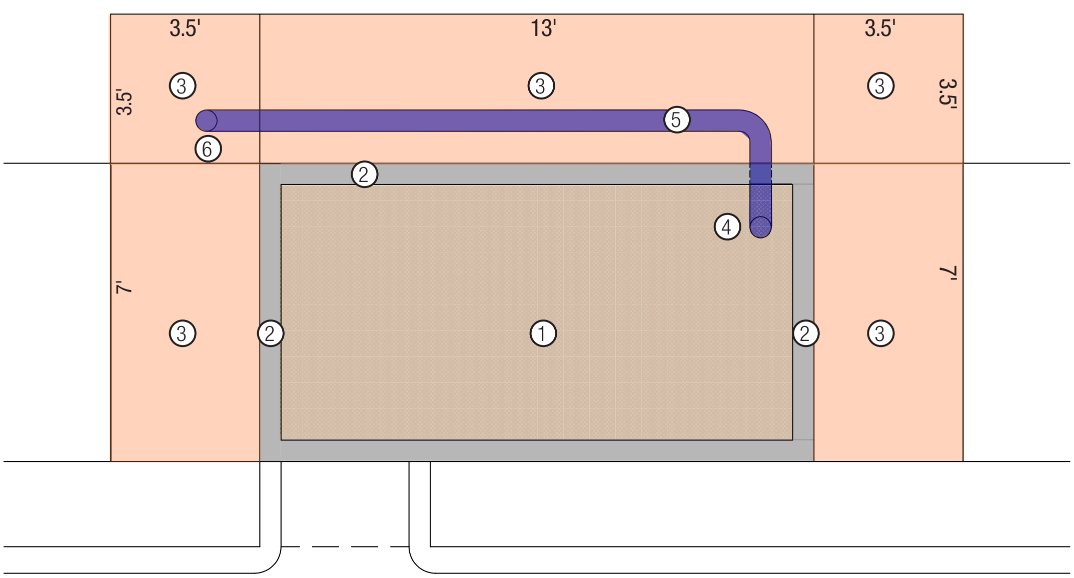
The design flowrate for the perforated drain would be 0.126 cfs x 51% = 0.064 cfs. In that situation:

$$L = 0.064\ cfs/(0.25 * 0.60 * (\frac{1}{144} SF/LF) * \sqrt{2(32.2\frac{ft}{s^2})(0.75 * 6\ inches * \frac{1\ foot}{12\ inches})}$$

L = 13 feet - this would need to be the length of pipe located within the structural cell (or soil) footprint



Elevation head as assumed for elevated perforated subdrains.



1 - 6' x 12' Planter Box Ponding Area
2 - 6" Planter Box Precast or Cast-in-Place Wall
3 - Footprint of Structural Cells
4 - Inlet to Elevated Perforated Drain
5 - Elevated Perforated Drain
6 - Cleanout

Plan view of elevated perforated drain from Example #10.

NOTE

The inlet into the elevated perforated drain could be an inlet set above the surface of the soil within the planter box, but below the ponding depth. The inlet would need to have capacity to convey the design flow into the elevated drain.

Another option would be to place the inlet within a catch basin designed to route flow into the BMP. See illustration on page 16.

SIZING OUTFLOW CONTROLS

Example #11 – Sizing outflow subdrain

The capacity of the outflow subdrain system will typically have ample capacity to allow flow to pass through the system. **For this reason, it may be necessary to place a cap with an orifice where the subdrain exits to the storm sewer system.**

The capacity of the subdrain system can be calculated as per Equation 7.04-2-11.

Equation 7.04-2-11

$$Q = L * B * \ Cd * \ Ao * \ \sqrt{2gh}$$

Where:

Q = Outflow capacity from the subdrain (cfs)

L = Length of perforated pipe required (feet)

B = Clogging factor (portion of openings blocked by soil materials = 0.25)

Cd = Orifice coefficient (0.6)

Ao = Perforation open area per unit length of pipe (square feet per foot)

g = gravitational constant (32.2 ft/s2)

H = head (difference between high water of ponding elevation of system and the invert of the subdrain pipe)

Using the parameters from Example #3, the head condition would be the sum of:

- Ponding depth = 3 inches
- Soil media depth = 48 inches
- Aggregate depth above flowline of subdrain = 9 inches
- Center orifice in subdrain – subtract pipe radius = - 4 inches
- Total elevation head = 56 inches (4.67 feet)

For this example, the length of the pipe could be the subdrain length measured horizontally along the planter box, which would be 24 feet.

$$Q = 24\ feet * 0.25 * \ 0.60 * \frac{1}{144}\left(\frac{SF}{LF}\right) * \ \sqrt{2 * 32.2\frac{ft}{s^2} * 4.67\ feet}$$

Q = 0.42 cfs

This capacity is 3.5 times the expected flowrate into the practice during the WQv event. So water will be free to move through the system as quickly as allowed by the soil media and aggregate layers.

For this reason, a cap with an orifice opening placed on the end of the subdrain pipe could be used to increase retention time within the system. However, to accomplish this, a small sized orifice opening may be required.

The orifice equation can be rearranged to solve for the required orifice area:

$$Qo = Co * A\sqrt{(2gH)}$$

$$A = \frac{Qo}{Co * \sqrt{2gH}}$$

Where:

Qo = flow through the orifice (cubic feet per second) – target 25% of WQv peak inflow rate to practice, 0.126 cfs (from information in previous examples) x 25%

A = area of the orifice (square feet)

Co = orifice coefficient (typically, 0.6)

g = gravitational constant (32.2 ft/s^2)

H = head (elevation difference between water elevation upstream of orifice and centroid of orifice opening), 4.67 feet from the previous information provided for this example

$$A = \frac{(0.126\ cfs * 0.25) * \sqrt{2 * 32.2\frac{ft}{s^2} * 5\ feet}}{0.60}$$

$$A = \frac{(0.126\ cfs * 0.25)}{0.60 * \sqrt{2 * 32.2\frac{ft}{s^2} * 4.67\ feet}}$$

A = 0.003 square feet

The diameter of a circular orifice can be solved by:

$$D = \sqrt{4A/\pi}$$

D = 0.062 feet = 0.74 inches

This is smaller than the minimum orifice size of 3 inches recommended in the Small Storm section of ISWMM. However, since there is no surface flow into the subdrain, the opportunity for clogging an orifice of this size should be minimal, so it could be used. The cap on the subdrain should be located inside of a storm inlet structure or manhole where it could be removed and replaced as needed to clear any obstruction.

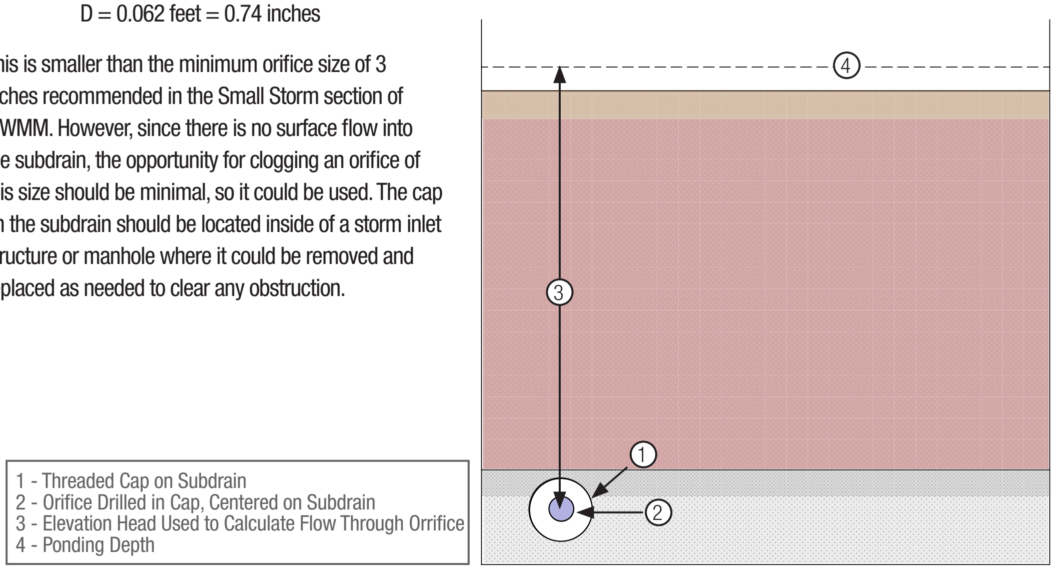


Illustration showing definition of head elevation for Example #11.

NOTE

A minimum orifice size of 1 inch may be used on underdrains if they do not intercept any direct surface flow.

SECTION 7.04-3 CONSTRUCTION

A. EROSION AND SEDIMENT CONTROLS

If the stormwater planter or tree trench is part of a project whose total disturbed area exceeds one acre (including all parts of a common plan of development) a stormwater pollution prevention plan (SWPPP) shall be prepared.

Prior to construction, coverage under the State of Iowa's NPDES General Permit No. 2 shall be obtained (or, if required, coverage through an individual permit).

The SWPPP document will meet state and local regulatory requirements and will detail the structural and non-structural pollution prevention best management practices (BMPs) that are to be employed at the site.

EXTERIOR PROTECTION

Around the perimeter of the overall construction site, all perimeter and site exit controls should be installed prior to any land-disturbing activities. Such controls may include (but are not limited to) site construction exits, perimeter sediment controls, construction perimeter fencing, waste collection, sanitary facilities, and concrete washout containment systems.

During construction and excavation, runoff should be diverted away from the planter or tree trench. If there are disturbed soils from active construction upstream of the practice, the water entry point to the practice should be blocked to prevent sediment laden runoff from entering the practice. If permeable pavers are being used in the area around the practice, it is particularly important to prevent construction runoff from being washed across those surfaces.

INTERIOR PROTECTION

There typically will not be sediment or erosion controls located within the planter or trench itself. **Keep in mind that pre-treatment measures are intended to capture the heaviest sediments and debris from post-construction runoff.** They are not sized to deal with heavier sediment loads expected during site construction. If there is active construction upstream of the practice, these features will need to be regularly inspected and accumulated sediment or debris removed.

B. CONSTRUCTION SEQUENCING

The exact construction sequencing of these types of practices may vary greatly depending on the nature of the project. Staging a project in a newly developing area or a large construction site may be very different than a retrofit within an existing right-of-way in a more densely developed urban area. **Generally, construction may follow these steps, but they will need to be adapted on a case-by-case basis.**

1. **Verify location of any utility conflict prior to starting major construction activities** (this should be done before the design phase, but it is wise to have contractor recheck just before construction). In some cases, it may be necessary to **pothole existing utilities** to verify their exact position and depth to see if any adjustments to the design are needed.
2. **Install other subsurface utilities prior to construction of the planter or trench.** Specifically, any storm sewer system which will be used to connect underdrains or system drain outlets should be completed.
    a. Extend any underdrain or storm sewer connections to the footprint of the planter or trench installation.
3. **Install any temporary flow diversions** to prevent stormwater flow from entering the footprint of the planter or trench installation.

4. **Excavate the area required for the structural planter box** or tree trench (including any subsurface storage elements as applicable). Throughout construction, avoid driving equipment on the footprint of the excavation area as much as possible.
5. **Install conduits or make provisions for electrical installations** (as applicable).
6. **Install any pre-treatment inlet sump structures** (as applicable).
7. **For installations with structural planter box elements that extend several feet into the ground, install these features.** (For installations with shallow curbs used to create the box, these might be delayed.)
    a. Boxes are typically constructed with either cast-in place or pre-cast concrete walls or curbs.
    b. Using pre-cast wall sections may reduce the time required to install each box.
    c. If pre-cast sections are used, it is advised to verify utility locations prior to the design of the sections, so any required openings or shape adjustments can be accommodated.
        i. The pre-cast sections can have openings to accommodate root growth to storage aggregate or structural cells or soil adjacent to the planter box.
        ii. If multiple planters or boxes are planned, it is advised to design the planters so that they can be assembled as few "typical" panel sections as possible. Having panels of similar dimensions that can be used at multiple locations will allow for more efficient production and delivery of the pre-cast sections, which can reduce cost.
    d. For deeper installations, delay installation of the subsurface storage elements that are within the planter box until Step 12, then proceed as noted.
8. **Install the adjacent storage aggregate, structural cell, or soils** (as applicable).
    a. Install the storage aggregate materials up to the elevation of the underdrain.
    b. Install the underdrain and make connections to underdrains from adjacent aggregate, structural cells, and soil installations.
        i. Connect underdrain to the downstream storm sewer system.
        ii. Install any overflow inlets within the planter box (as applicable).
    c. Install the remaining subsurface storage materials and soils (leave soil materials loosely compacted). If trees or shrubs are proposed, integrate installation of those at the correct depths as storage materials are installed.
    d. Install any pre-treatment areas proposed within the planter box.
    e. Install surface mulch and smaller plant materials (as applicable).

Precast planter boxes being installed in La Crosse, Wisconsin.

Permeable pavers being installed next to a planter box.

9. **Follow manufacturer's installation guidelines if proprietary systems are being used.**
10. **For installations with a shallow curb (either cast-in-place or precast) which is used to create the planter box, install the subsurface storage elements prior to installing the shallow curb.**
11. **Install adjacent pavement surfacing.** Protect any permeable pavement areas from any tracking or wash of sediment or debris. Do not allow storage of materials (including landscaping or mulch materials) on or near the permeable pavement installation.
12. **For deeper planter boxes with pre-cast or cast-in-place walls, install the subsurface storage materials within the planter box only after upstream areas have been fully stabilized.** Once construction proceeds follow steps listed in item 8.a through 8.e above.
13. **Install any remaining electrical items, plants, trees and mulch materials.**
14. **Remove any temporary flow diversions** to prevent stormwater flow from entering the footprint of the planter or trench installation.
15. **Install any railings or pedestrian safety items.**
16. **Complete any final installation items.** Perform cleanup and final inspection.
17. **Complete watering and other maintenance activities for planted vegetation** through any warranty or establishment and short-term maintenance period.

Planter box construction in Coralville.

Cast in place flume construction in La Crosse, Wisconsin.

Installing grates over flume constructed in La Crosse, Wisconsin

Precast mockup of planter boxes to test methods of assembly for those to be in stalled in La Crosse, Wisconsin.

Precast foundation units placed prior to installation of precast planter boxes to be installed in La Crosse, Wisconsin.

C. CONSTRUCTION OBSERVATION

A designated representative of the owner should observe construction operations on a frequent basis to confirm the following:

- Site area topsoil stripping, stockpiling and re-spread activities have been completed as specified (as applicable).
- At each stage of construction observe the excavation, aggregate installation, soil materials and mulch before the subsequent layers of material have been installed. Document these stages of construction with photos or video.
- Rough grading of surrounding areas generally conforms to plan elevations and test results have been provided that demonstrate that compaction requirements have been met. (Compaction tests are often performed by a geotechnical engineer and provided for owner review.)
- Storm sewer and pipe structures are installed to the dimension, location and elevations specified on the plans. Verify that proper installation techniques and trench compaction techniques have been followed. (Compaction tests performed by a geotechnical engineer and provided for owner review.)
- Proper compaction around all storm structures should be verified.
- Storm facilities should be kept free of sediment and debris during construction and inspected again at a final site walk-through.
- The excavation for the planter boxes and subsurface storage elements should match the depth, width and length as identified on the construction documents within specified tolerances. The correct ponding depth within the planter box should be verified.
- The installation of the planter boxes and subsurface storage elements should follow the sequences as identified in the contract documents.
- Site lighting or electrical equipment should be installed with the correct materials with proper seals and at appropriate elevations as per contract documents.
- Installation of adjacent permeable pavers or other paved surfaces is completed as per the requirements of the contract documents.
- Proposed trees, shrubs and other plants are installed properly within the planter or tree trench.
- The proper mulch materials are installed to the specified depth within the planter or trench.
- Complete a walk-through with the designer and contractor to identify any items which are not in compliance with project requirements. Document said issues in a punch list and confirm when all such items are installed.
- As needed by the local jurisdiction, author a letter of acceptance noting either conformance with construction documents, or any allowed deviation thereof.

If the project is required to be permitted under the State of Iowa's NPDES General Permit No. 2, qualified personnel shall be employed to complete the following until final establishment:

- Maintain and update the SWPPP document and retain records.
- Conduct site inspections as required by the general permit.
- Throughout construction, work with the erosion and sediment control contractor to coordinate proper installation of all BMPs.
- Verify that exterior sediment and erosion BMPs are in place prior to initiation of site disturbing activities.
- Observe that interior BMPs are implemented as site work progresses.
- Complete site inspection reports, make recommendations for additional BMPs as necessary.
- Upon final establishment of permanent vegetation (as defined by the permit), recommend to the owner that the site Notice of Discontinuation be completed and submitted to the Iowa Department of Natural Resources (DNR).

POST-CONSTRUCTION DOCUMENTATION

During construction, records should be kept by the contractor (and site observer) that will allow record drawings of constructed improvements to be provided to the owner. **To demonstrate that the project has complied with contract documents, these records should include, but not be limited to, the following:**

- The horizontal and vertical position of the extents of the subsurface storage elements.
- The position and elevation of underdrains at changes of horizontal or vertical alignment.
- All **rim, invert and flowline elevation** of inlet sump structures, storm structures and pipes, or any other utilities included as part of the project.
- The top elevation around the perimeter of the planter box.
- The surface elevation within the planter box.
- Confirmation that required trees, shrubs and other plants have been installed. Record their condition for documentation of condition at beginning and end of warranty period (recommended to use photos or video to record their condition) Warranty requirements should follow SUDAS requirements or otherwise as identified in project specifications.

A concrete flume below a metal gate connects two sump inlets to the stormwater planter box in La Crosse, Wisconsin. For record drawings, the information listed above would need to be surveyed.

SECTION 7.04-4 MAINTENANCE

A. SHORT-TERM MAINTENANCE

The contract documents should identify the warranty period or short-term maintenance activities that are needed to ensure that trees, shrubs or other proposed plants are properly established after initial installation.

At minimum, trees, shrubs and plants should be thoroughly watered during installation and regularly in the absence of rain through the first growing season.

B. ROUTINE OR LONG-TERM MAINTENANCE

During the design process, the entity responsible for routine and long-term maintenance should be established. These tasks are necessary to maintain the planter's or trench's ability to function and support the desired vegetation and stormwater function. The capacity of the system to infiltrate and filter runoff may be reduced or desired plants may not be maintained if these tasks are not completed. A maintenance plan should be provided to the responsible party for its execution. ESSENTIAL

Table 7.04-4-1

ACTIVITY	SCHEDULE
Inspect pre-treatment features for sediment deposition and debris. Remove collected sediment and debris. Check for erosion near inflow points to planter box (make repairs as needed).	After each rain event of 0.25 inch or larger for first year. Adjust frequency of maintenance based on observations after that.
Remove and replace annual vegetation. Inspect trees and shrubs for evidence of damage from insects or disease.	Seasonally, as applicable.
Clean the surfaces of any permeable pavement installations (refer to ISWMM Section 8 for list of required activities).	At least two (2) times annually.
Inspect storm inlets and outlets for sediment and debris. Remove sediment and debris as necessary.	At least three (3) times annually.
Inspect wood mulch. Replenish mulch materials and remove weeds as necessary.	At least one (1) time per month during growing season.
For installations with native forbs or wildflowers, cut vegetation down to three (3) inch height during dormant winter period. Remove cut vegetation.	Annually during dormant period.
Monitor vegetation and perform replacement planting as necessary.	Annually (after short-term maintenance period).

This photo was taken in La Crosse, Wisconsin in September, five years after installation.
Fall leaves have collected in the sump and need to be removed.

SECTION 7.04-5 SIGNAGE RECOMMENDATIONS

Signage may be provided as an educational tool to explain the purpose, function and benefits of the stormwater planter or tree trench to the general public. Signage may also be used to advise maintenance staff against discouraged practices, such as broad application of herbicides to native plantings.

An educational sign installed at Western Technical College in La Crosse, Wisconsin.

SECTION 7.04-6 GLOSSARY

Articulated blocks	Blocks that interlock together to cover an area with a solid surface.
Best management practice (BMPs)	A feature designed to meet stormwater water quality or quantity management goals.
Choker aggregate	Small stone material used to keep soil mix layers from migrating down into the storage aggregate layers.
Floatable debris	Debris and materials that are buoyant or typically float in stormwater runoff.
Flowline elevation	The elevation of the bottom of the inside of a storm sewer pipe.
Hydraulic retention time	The amount of time it takes for stormwater to completely drain out of the subsurface elements of a stormwater planter or tree trench.
Interception credit	Water quality treatment credit based on rainfall intercepted by the canopy of trees.
Invert elevation	Another name for flowline elevation. The invert is the lowest part of the inside of a pipe.
Local jurisdiction	Any state, county or other regulatory agency that administers stormwater requirements at a local level.
Orifice opening	A hole through a wall or plate which are often used to limit the rate of water flow out of a stormwater BMP.
Recharge volume (Rev)	One of the Unified Sizing Criteria intended to reduce overall surface runoff volumes. See also ISWMM Section 3.01 (Unified Sizing Criteria).
Remote drivers	Devices that regulate voltage and current to lighting sources.
Rim elevation	The elevation of a manhole lid or grate of an inlet structure.
Surface inlet	A structure designed to capture stormwater runoff and convey it to a stormwater BMP or storm sewer system.
Tackifier	Adhesive compounds that help bind structural soil materials together.
Underdrain	A perforated pipe used to capture subsurface water and direct it to a storm sewer system or surface outlet point.
Unified Sizing Criteria (USC)	The set of measurement standards used throughout the ISWMM documents to evaluate management of quality and quantity of stormwater runoff. See also ISWMM Section 3.01 (Unified Sizing Criteria).
Water Quality volume (WQv)	One of ISWMM's Unified Sizing Criteria, defined as the runoff generated by a 1.25-inch rainfall event. Over 90% of all rainfall events in Iowa are at or less than this amount of rain. See also ISWMM Section 3.01 (Unified Sizing Criteria).
Wellhead protection area	Areas around wells used as drinking water sources where infiltration of surface water may be discouraged.

SECTION 7.04-7 RESOURCES AND REFERENCES

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SECTION 7.04-8 APPENDIX

KEY DESIGN PARAMETER CHECKLIST

There are important aspects of this manual to consider when jurisdictions seek to create stormwater ordinances or policies that reference or adopt this manual. The Iowa Department of Natural Resources (IDNR) is responsible for the creation and maintenance of this manual, working with a technical committee of local volunteers. However, regulation and enforcement of post-construction stormwater management is primarily left to local jurisdictions.

Therefore, the IDNR does not enforce as requirements, the sizing and design criteria set for this document. For this reason, the language used within this manual has purposefully been written as a guideline, rather than a standard. This means certain language that conveys something is required (i.e. shall, must, etc.) is generally avoided. This has the potential to leave “gray areas” as to what may be interpreted to be required and what is recommended or optional, if this manual is adopted and referenced by local jurisdictions as a standard.

Throughout this section, different design parameters or considerations have been grouped into key categories:

ESSENTIAL

An element of the design of a BMP seen as critical to its proper performance, operation or aesthetics. **These aspects should be most important for inclusion and compliance and should rarely be deviated from.**

TARGET

An element of the design of a BMP seen as important to its proper performance, operation or aesthetics. **These aspects should be included in designs, if at all possible.** However, there is more flexibility to allow deviations if it can be demonstrated that it is infeasible to meet the requirement at a given location, or if a certain requirement is in conflict with other requirements. **Designers should explain any reason for deviation from targets, for the consideration of the jurisdiction as part of their review.**

IDEAL

An element of the design of a BMP seen as the recommended approach for its proper performance, operation or aesthetics. Designers are encouraged to include these in designs as best practice. However, these items are seen as less critical as those noted as essentials or targets.

CAUTION

These are notes or design guidance to highlight items for the designers’ careful consideration.

ADVISORY

These are practices, techniques or potential deviations from the design ethic that should be avoided in most circumstances.

ESSENTIAL

1. Subdrainage systems should be provided in most cases unless it can be demonstrated that subsoil percolation rates after construction are expected to be high enough that the system can be fully drained within 24 hours. (page 7)
2. The designer should coordinate with the local utility early in the planning process to reduce potential conflicts, understand future maintenance needs and discuss required horizontal and vertical clearances. (page 8)
3. A minimum separation of two (2) feet should be provided between the bottom of the planter or trench and the seasonally high-water table. Where this separation can't be provided, a low permeability geotextile should be provided along the sides and bottom of the planter or trench at least up to the point where that level of separation is provided. (page 8)
4. When the footprint of the planter or trench is within ten (10) feet of a building foundation with a basement or other occupied space below grade, an impermeable geotextile should be provided along the sides and bottom of the planter or trench at least to the point where that level of separation is provided. In any case, geotechnical or structural engineers may recommend additional protections or setback requirements. (page 8)
5. Trees should be setback from buildings a sufficient distance to accommodate the expected growth of the tree canopy. Tree species should be selected based on the available space for canopy growth. (page 9)
6. Check with local jurisdictions if there are restrictions on infiltration-based practices within wellhead protection areas. (page 9)
7. Each local jurisdiction may have requirements that may be applicable such as (but not limited to) sight vision clearance, plant material restrictions and utility protections. The designer should consult the local review authority early in the planning process to determine if there are any local requirements that could influence the proposed design or determine if these types of practices are suitable at a given location. (page 10)
8. The water entry point to the stormwater planter or tree trench needs the capacity to allow the expected peak flow rate for the desired storm event to enter the BMP and pass into the subsurface storage elements. (page 11)
9. When used, permeable paver areas should be positioned over the structural cell or soil elements, or otherwise hydraulically connected so flow may pass through the aggregate layers beneath the pavers and enter the subsurface elements of the planter or trench. (page 15)
10. Pre-treatment measures should be used to capture the heaviest sediments and debris and allow them to settle out of flow before they are conveyed into the planter or trench. (page 15)
11. The subsurface storage elements within structural soil cells should be based on the recommendations of the manufacturer of the proprietary system. (page 21)
12. The following information could be integrated into product selection criteria or project specifications (page 21):
    - The structure should be designed to support AASHTO H-20 loads and any local jurisdictional requirements.
    - The cells should be designed and tested for the purpose of growing tree roots, rainwater filtering, detention and/or retention.
    - Each soil cell or stack should be structurally independent of all adjacent soil stack so that a single stack or group of stacks can be removed later to facilitate future utility installation or repairs.
    - The design of each cell should facilitate the movement of roots and water between each cell, the edges of the cell system and surrounding soils.
13. Any overflow inlet and/or surface overflow path should be designed to meet local storm sewer capacity and flood protection requirements. (page 23)
14. The clear path for maintenance vehicles and equipment to the planter or trench should be identified with the party responsible for maintenance during the design process. (page 24)
15. When roof drains are directly connected to an elevated drain, they should also be designed so flows from larger events (that aren't expected to be treated by the BMP) can bypass the system. (page 27)
16. To be credited as managing all or a certain portion of the WQv requirements, the practices must be designed to be able to capture the peak rate of flow from that storm event and route it to the subsurface storage elements. (page 28)
17. When elevated drains are used to direct flow into the subsurface storage elements of the planter or trench, calculations are required to select the appropriate size and length of pipe. (page 29)
    a. When calculating WQv treatment requirements, if the capacity of the elevated perforated drain is less than the WQv peak flow collected by the inlet sump structure or roof drain, the flow portion assumed to be entering the

practice should match the capacity of the elevated perforated drain.

b. Any excess flow beyond the capacity of the elevated drain should be assumed to be directed to the next available treatment practice downstream.

18. When permeable pavers are used to convey flow into a stormwater planter or trench, if the paver area is sized to capture only a portion of the peak flow rate, only the captured portion can be assumed to enter the subsurface elements around the planter or trench for treatment. (page 29)

    a. Any remaining volume should be assumed to be directed to the next available treatment practice downstream.

19. To receive full credit for storage within structural soils and cells, the following conditions need to be met (page 31):

    a. There should be an appropriately sized water entry method that allows stormwater runoff to enter those features.

    b. The design of the adjacent structural cells or soils should not rely on water movement through the surface storage or ponding areas within the planter box that have been sized based on the equations used for bioretention cells.

        i. Those calculations assume that the subsurface elements below the bioretention cell are close to the same size as the surface ponding area.

        ii. The surface ponding area within the planter box will be the limiting factor which would not be sized large enough to convey the desired flowrate to an expanded subsurface footprint.

    c. Only the volume of the cells or soils above the underdrain should be counted for use in Equation 7.04-2.4 unless:

        i. The percolation rate for subsoils below the installation has been determined through approved testing methods.

        ii. Calculations show that the volume stored below the underdrains can be percolated into subsoil layers within 24 hours.

        iii. These requirements would apply to any planter or trench systems that are installed without underdrains.

20. During the design process, the entity responsible for routine and long-term maintenance should be established. A maintenance plan should be provided to the responsible party for its execution. (page 60)

TARGET

1. Consider potential for salt and other snow melt compound applications when selecting plant materials. (page 9)
2. Small railings or fences may be desired to prevent pedestrians from stepping or falling into the planter or trench surface area. (page 10)
3. When located along parking stalls, the planter box should be set back far enough to allow car doors to open and allow passengers to exit the vehicle. (page 10)
4. Planter boxes should be set at least 24 inches behind the back of curb when placed along streets where parallel parking is allowed. (page 10)
5. The curb opening into the planter should be set at least one (1) inch below the adjacent gutter elevation to make sure there is positive slope from the gutter into the practice. (page 11)
6. The elevated drain should have at least six (6) inches of soil cover above the pipe and be located below any subbase or compacted subgrade materials under the adjacent paved surfaces. (page 14)
7. The elevated drain should be located as high as possible so that runoff has to percolate through as much soil as possible before reaching the underdrain outlet. (page 14)
8. The inlet side of the elevated drain should be protected by a removable grate rodent guard (similar to as detailed in SUDAS Figure 4040.233). (page 14)
9. A cleanout should be provided at the endpoints of the perforated drain line, allowing for inspection and cleaning of the perforated drain. (page 14)
10. For stormwater planters and tree trenches, the target should be to provide a pretreatment practice that has the ability to store at least 5% of the target WQv volume. (page 15) When used, micro-forebays should have a pretreatment volume of 2.5% of the WQv. (page 17)

11. If a trash screen is used over a surface overflow opening into a planter box, the clear spacing between any bars should not be less than two (2) inches. (page 16)
12. The surface of the ponding area within a planter box should be level at one elevation from end to end and side to side. This ponding depth will typically range between three (3) to nine (9) inches. (page 19)
13. When used, underdrains should be at least four (4) inches in diameter and constructed from perforated pipe materials as allowed within Iowa Statewide Urban Design and Specifications (SUDAS) Section 4040. If it is desired to accommodate larger cleaning and camera inspection equipment, a minimum of eight (8)-inch diameter pipe material should be used. (page 23)
14. Underdrains should be set at least three (3) inches above the bottom of the subsurface storage elements, to ensure that water can freely enter the perforated underdrain. (page 23)
15. A cleanout structure (compliant with SUDAS Section 4040) should be provided at the upstream end of each underdrain. (page 23)
16. If bends in the underdrain are necessary, provide a curved radius of at least 5 feet and/or place a cleanout near the bend allowing access to the portion of the underdrain downstream of the bend. (page 23)
17. The type of cleanout may vary depending if the cleanout lid is to be positioned within the planter box or within adjacent surfaces. If located within the planter box, it is recommended to set the lid of the cleanout one (1) to three (3) inches above the surface of the ponding area, so that it can be easily located when needed. (page 23)
18. The underdrain may need a cap with an orifice opening to ensure the desired hydraulic retention time in the system is provided. When used, the orifice should be placed inside a storm structure or other location where it can be accessed for maintenance. (page 23)
19. The design team should include or consult with lighting designers and/or electrical engineers to evaluate these considerations and develop the appropriate construction details and specifications for a given project. (page 25)
20. To prevent the planter or trench system from draining too quickly, a cap with an orifice opening should be installed on the end of any subdrain that is larger than four (4) inches in diameter. In most installations the typical minimum orifice diameter of three (3) inches will often be applicable. A minimum orifice size of one (1) inch may be used on underdrains if they do not intercept any direct surface flow. (page 33)

IDEAL

1. The soil volume for trees should extend to a depth three (3) to five (5) feet below the finished surface elevation. (page 32)
2. Refer to Table 7.04-2-3 for guidance on soil volumes recommended to sustain trees. (page 32)

CAUTION

1. When on steeper slopes, a curb bump out may be needed at the lowest inlet to ensure the desired flow is captured. (page 7)
2. If the provided pre-treatment storage is less than optimal, it should be expected that the pre-treatment area will need to be inspected and cleaned out more frequently. (page 15)

A. TREE CANOPY INTERCEPTION CREDITS

Tree Canopy Interception

A WQv treatment credit may be applied to trees whose trunk center is located within 20 feet of an impervious surface area. To qualify for the interception credit, the tree must have an adequate adjacent soil volume to support the tree as described in the upcoming Surface Storage Element Sizing part of this section. The interception credits can be calculated as follows:

WQv interception credit volume (cubic feet, CF) = Ic (feet) x canopy protection area (square feet, SF) **(Equation 7.02-8-1)**

Where Ic = interception coefficient (capacity of tree canopy to intercept rainfall)

Table 7.02-8-1

CANOPY PROTECTION AREA BY TREE TYPE		
	Ic (inches)	Ic (inches)
All Trees	0.40	0.14

Table 7.02-8-2

CANOPY PROTECTION AREA BY TREE TYPE			
Relative Tree Size	Canopy Protection Area (SF)	Coniferous Tree WQv Interception Credit (CF)	Deciduous Tree WQv Interception Credit (CF)
Small	320	11	4
Medium	490	16	6
Medium-Large	600	20	7
Large	710	24	8

Table 7.08-2 works out the WQv credits using Equation 7.08-2-1 based on the type and size of each tree. Since the **interception credit** itself is small, designers may decide to skip completing these calculations. If the area beneath the tree drains to a downstream stormwater quality BMP, the credit volume may be deducted from the volume that would have otherwise been assigned to that practice. If the area beneath the tree does not drain to a water quality BMP, then the credit can be applied against the WQv requirements of that area that would have otherwise left the site study area without treatment.

Adapted from Source: Calculating credits for tree trenches and tree boxes - Minnesota Stormwater Manual (state.mn.us)

In the following table is a list of recommended trees for stormwater planters and tree trenches. The list identifies the relative tree size species for each tree species on that list.

Scientific Name	Common Name	Height at Maturity (ft)	Canopy Diameter at Maturity (ft)	Relative Tree Size[4]	Relative Growth Rate to Maturity (S = slow, M = moderate, R = rapid)
Acer rubrum [2]	Red maple	68	35	Large	R
Acer x freemanii [2]	Freeman maple	60	40	Large	R
Alnus incana ssp. rugosa [1,2]	Speckled alder	25	10	Small	R
Alnus maritimia	Seaside Alder	20	20	Small	M
Amelanchier spp. [2]	Juneberry/serviceberry	20	15	Small	M
Betula nigra 'Cully' & ' BNMFT' [1,2]	Heritage and Dura-Heat river birch	50	30	Large	R
Betula populifolia [2]	Gray birch	25	30	Small	R
Carpinus betulus [2]	European hornbeam	30	30	Medium	S
Carpinus caroliniana [2]	American hornbeam	30	20	Medium	S
Catalpa speciosa [2]	Narthern catalpa	60	25	Large	R
Celtis occidentalis [2]	Common hackberry	60	60	Large	R
Cercis canadensis [2]	Eastern redbud	30	25	Small	S
Cladrastis kentukea [2]	Yellowood, Kentucky yellowood	40	20	Large	M
Crataegus crus-galli var. inermis [2]	Thornless cockspur hawthorn	30	25	Small	M
Crataegus phaenopyrum [2]	Washington hawthorn	30	25	Small	M
Gingko biloba [2]	Gingko – male only	80	30	Large	S
Gleditsia tricanthos var. inermis [2]	Thornless common honeylocust	70	40	Medium	R
Gymnocladus dioicus [2]	Kentucky coffeetree	100	30	Large	S
Hamamelis virginiana	Common witchhazel	25	20	Small	M
Larix decidua [3]	European larch	99	30	Large	M
Larix laricina [1]	Tamarack	80	20	Large	R
Liquidambar styraciflua	Sweet gum	80	40	Large	R
Maackia amurensis [2]	Amur maackia	30	15	Small	
Malus spp. [2]	Crabapple spp.	30	20	Small	M
Nyssa sylvatica	Black tupelo	50	25	Medium	M
Ostrya virginiana [2]	American hophornbeam, ironwood	45	20	Medium	S
Phellodendron amurense [2]	Amur corktree	45	25	Medium	
Populus deltoides [1,2]	Eastern cottonwood	100	50	Large	R
Prunus sargentii [2]	Sargent cherry	40	25	Medium	R
Prunus virginiana [2]	Chokecherry	30	18	Small-medium	R
Pyrus fauriei 'Westwood' [2]	Korean SunTM pear	12	15	Small	M
Pyrus ussuriensis [2]	Ussurian pear, Chinese pear	25	15	Small	S
Quercus bicolor [2]	Swamp white oak	100	60	Large	R

Scientific Name	Common Name	Height at Maturity (ft)	Canopy Diameter at Maturity (ft)	Relative Tree Size[4]	Relative Growth Rate to Maturity (S = slow, M = moderate, R = rapid)
Quercus macropcarpa [2]	Bur oak	90	60	Large	S
Quercus rubra [2]	Red oak	81	40	Large	M
Salix babylonica	Weeping or Babylon willow	70	70	Medium	R
Salix nigra [1]	Black willow	100	35	Large	R
Sorbus alnifolia [2]	Korean mountainash	50	30	Medium	M
Sorbus americana [3]	American mountainash	40	15	Medium	M
Sorbus x hybrida, Sorbus x thuringiaca [2]	Oak-leaf mountainash	35	26	medium	
Syringa reticulata [2]	Japanese tree lilac	30	25	Medium	M
Taxodium distichum [2]	Common baldcypress	70	40	Large	M
Tilia americana [2]	Basswood	100	35	Large	M
Tilia cordata [2]	Littleleaf linden	100	35	Large	M
Tilia x euchlora [2]	Crimean linden, Caucasian lime	60	20	Large	M
Tilia tomentosa	Silver linden	70	40	Large	R
Ulmus x species [2]	Elm hybrids	70	40	Large	R

Adapted from Source: Tree species list - morphology - Minnesota Stormwater Manual (state.mn.us)

[1] Shaw, D. and R. Schmidt. 2003. Plants for Stormwater Design: Species Selection for the Upper Midwest. Minnesota Pollution Control Agency (MPCA).

[2] Bassuk, N. et al. 2009. Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance. Urban Horticulture Institute, Dept of Horticulture, Cornell University, Ithaca, NY.

[3] USDA NRCS Plants Database. www.usda.plants.gov

[4] Small = 15 to 30 feet, Medium = 30 to 50 feet, Large > 50 feet

The list has been adapted based on multiple sources as listed at the end of this table. When selecting plant species based on site specific conditions consider plant species suitability for the site in the near and long-term, availability in the nursery industry, and desirable species based on local tree canopy diversity.

Some notes about this list:

- Maple trees were removed from the selected list as Iowa has a high percentage of maple trees, which could be a liability if a pest or disease issue arose that affected those species. Therefore, the Iowa Department of Natural Resources suggests that maples be used in a more limited way in designed plantings. (If used, maple trees would fall into the "large" tree size category.)
- Ash trees were removed from the list, due to the presence of the Emerald ash borer in Iowa. Planting new ashes are not recommended.
- Aspen trees were removed from the list as climate change projections suggest that some tree species that were suitable in Iowa may not fare well under warmer conditions with changes to historical rainfall. (If used, aspen trees would fall into the "large" tree size category.)
- European alder was removed from the list as they are a species of concern for invasive potential.
- Shagbark hickory was removed from the list due to limited nursery sales, or discontinued for sale in states adjacent to Iowa. The status of this species in Iowa should be checked if being considered. (If used, shagbark hickory trees would fall into the "large" tree size category.)

Source materials:

Minnesota Stormwater Manual

https://stormwater.pca.state.mn.us/index.php?title=Tree_species_list_-_morphology

Missouri Botanical Gardens https://www.missouribotanicalgarden.org/PlantFinder/plantfindersearch.aspx

NC State Plant Database

https://plants.ces.ncsu.edu/

Cornell Woody Plant Database

https://woodyplants.cals.cornell.edu/home

Morton Arboretum Plant Database

https://mortonarb.org/plant-and-protect/trees-and-plants/

B. ELECTRICAL AND LIGHTING GUIDANCE

Lighting has been proven to have adverse effects on plant life. Lighting without proper shielding and lighting controls can disrupt the natural sleep and wake cycle of certain kinds of plants. The effects of this can result in reduced flowering and foliage, shortened life span, increased susceptibility to air pollution and water stress during growing season, and disruption of natural relationships with pollinators.

Lighting also effects the circadian rhythm of humans and plant life, as well as insects and other species of animals. Nocturnal mammals and insects rely on the natural day and night path of the sun to indicate sleep/wake cycles which allow for proper time for recouperation. Increased nighttime lighting has led to reduction in the restorative sleep cycle of certain insects which can affect reproduction resulting in smaller populations and decreased pollination of plants. By decreasing the number of pollinators and by making nighttime pollinators less effective, we risk the health and wellness of our plant life.

The following is a list of things to do and things to avoid when designing electrical systems in stormwater planters and tree trenches.

Up-lighting Trees

DO THE FOLLOWING:

- Consider the species of tree and how it will look during other times of year (i.e. Winter) – determine if controls are needed to turn off lighting when foliage is less desirable.
- Consider the root system and growth rate of the tree and allow flexibility for lighting to move as tree grows
    - Allow for adjustable aiming of the fixtures. Minimum 12” from tree base is a good starting point but should be evaluated based on tree species and coordinated with root structure.
- Select fixtures with proper ingress protection rating to allow placement in an outdoor environment (see exhibit 7.02-8-1).
- Consider vandalism on public facing applications. The fixture may need to be mounted differently or feature tamper resistant hardware.
- Design any lighting system with proper lighting controls featuring time-clock capabilities to turn lighting off after a reasonable curfew.
- Consider the wavelength of the light you want to use when designing for proper tree health/growth
    - Trees photosensitivity lies in the blue spectrum. This is observed in the reflection of the green coloring in foliage.
    - Lighting on trees should consider exposure both in spectrum (exhibit 7.02-8-2) and duration to ensure proper growth and encourage natural photosynthesis cycles.
- Properly design enclosures of remote drivers and consider maximum run distances to fixtures.
- Properly shield fixtures to ensure minimal glare and more focused lighting on the target.

DON’T DO THE FOLLOWING:

- Design outdoor lighting without proper lighting controls.
    - Tree lighting should be turned off at a reasonable curfew nightly.
    - Never leave on all night as this can damage the health of the tree.
- Place drivers within an area where water can accumulate – proper NEMA rated (exhibit 7.02-8-3) enclosures should be used for all electrical connections and components.
- Place drivers in sealed air-tight boxes when not properly rated for such enclosures.

- Utilize dry location drivers outdoors.
- Shine lighting straight upwards into the night sky.
  - Improper aiming and shielding of fixtures increases night sky brightness and results in light pollution and "sky glow" (reduced ability to see night sky/stars).

Pedestrian Light Poles

DO THE FOLLOWING:

- Space light poles evenly to ensure maximum uniformity and decreased shadowing from adjacent trees.
- Ensure proper optics and shielding to decrease light trespass on adjacent properties, walkways, or planting beds – be a good neighbor!
- Consider pole height with city recommendations and required output to meeting uniformity and minimum light level standards.
- Consider glare and upward light pollution to create a sustainable and comfortable design that promotes health of flora, fauna and humans.
- Decrease lighting during period of vacancy and after curfew hours.
- Select fixtures with proper ingress protection rating to allow placement in an outdoor environment.

DON'T DO THE FOLLOWING:

- Increase light output to increase lighting level and uniformity. Instead review the optics and efficacy of the fixture.
- Design outdoor lighting without proper lighting controls. Poles should dim when areas are unoccupied and should be time-clock controlled with curfew hours where appropriate.
- Design light pole locations without proper bases for mounting.
- Place light poles within planting boxes or tree trenches without proper bases. It is not recommended to place in these locations at all if possible.
  - Consider bases in submersed locations. Elevation of footing should be above the expected ponding depth to avoid water getting into pole base or conduit.
  - Structural engineer should be consulted based on soil conditions in the area.
- Design light poles with receptacles within areas where water accumulation is common/likely.

Exhibit 7.02-8-1:

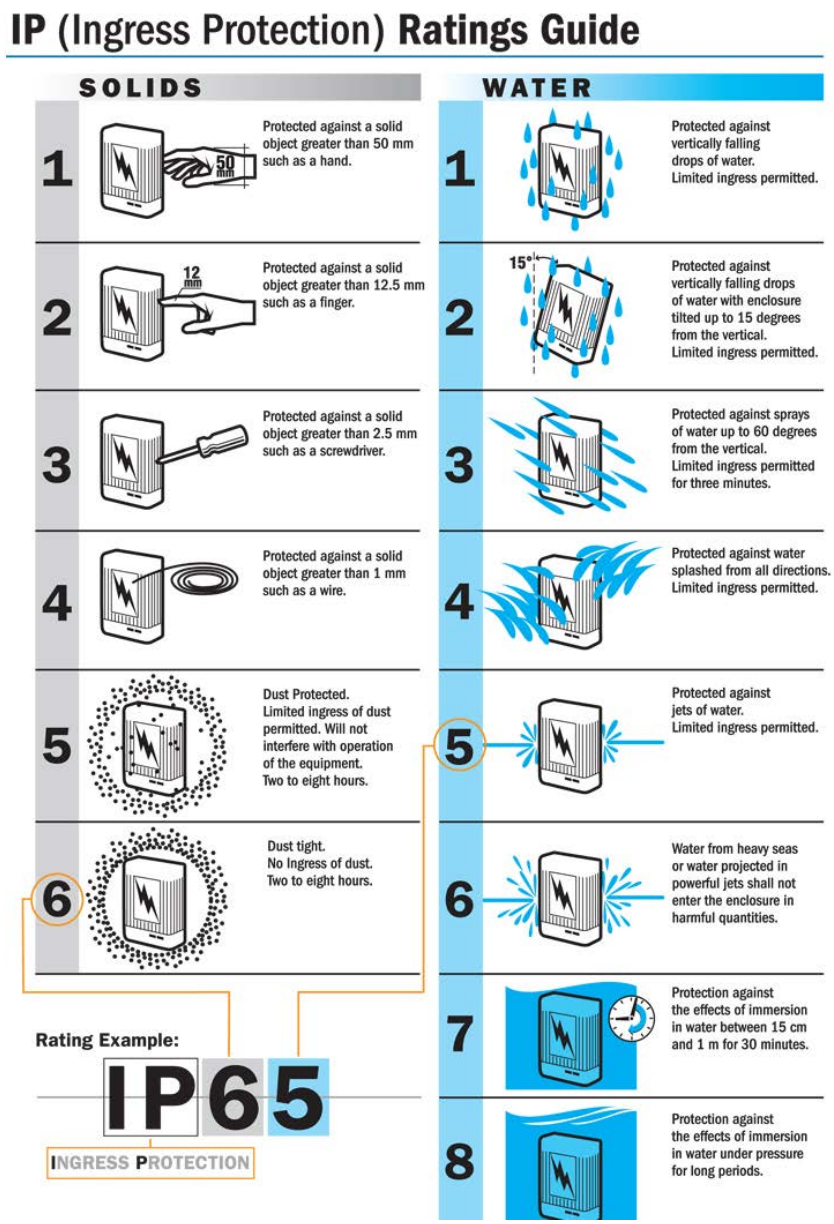

Exhibit 7.02-8-2:

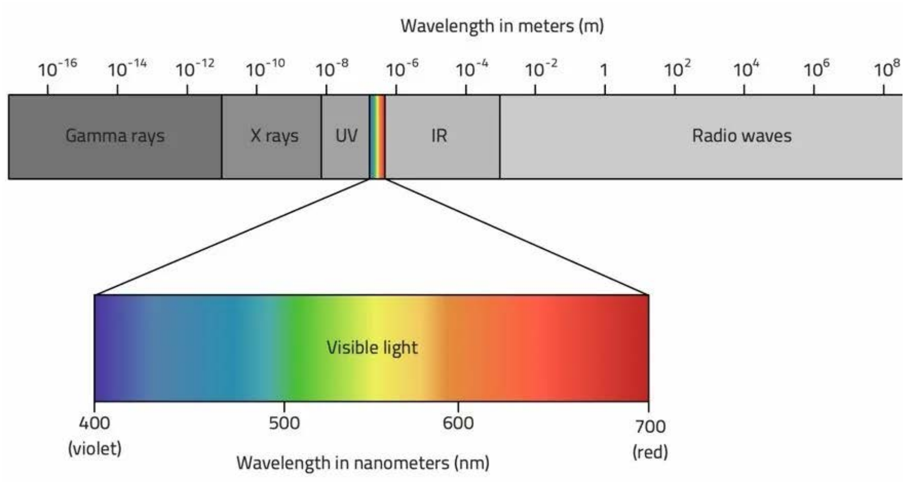

Exhibit 7.02-8-23

NEMA ENCLOSURE RATINGS

		INDOOR USE					OUTDOOR USE							
		Type 1	Type 2	Type 5	TypeS 12/12K	Type 13	Type 3	Type 3S	Type 3X	Type 3SX	Type 3R	TYPE 3RX	Type 4	Type 4X
SOLIDS	INCIDENTAL CONTACT	●	●	●	●	●	●	●	●	●	●	●	●	●
	FALLING DIRT	●	●		●	●	●	●	●	●	●	●	●	●
	CIRCULATING DUST				●	●							●	●
	SETTLING AIRBORNE DUST			●	●	●							●	●
	WINDBLOWN DUST						●	●	●	●			●	●
LIQUIDS	LIGHT SPLASH		●	●	●	●	●	●	●	●	●	●	●	●
	HOSEDOWN & SPLASH												●	●
	TEMPORARY SUBMERSION													
	PROLONGED SUBMERSION													
	RAIN, SNOW & SLEET						●	●	●	●	●	●	●	●
	ICE LADEN							●		●				
CHEMICALS	OIL & COOLANT SEEPAGE				●	●								
	OIL & COOLANT SPLASH					●								
	CORROSION								●	●		●		●
Comparable IP Rating		IP 20	IP 22	IP 53	IP 54		IP 55				IP 24		IP 66	

Resources (Lighting Impact Research):

https://www.extension.purdue.edu/extmedia/fnr/fnr-faq-17.pdf

https://www.bbc.com/future/article/20230308-how-light-pollution-disrupts-plants-senses

https://depts.washington.edu/hortlib/pal/night-light-and-plant-growth/

Additional Resources (Lighting Impact Research)

https://www.smithsonianmag.com/smart-news/light-pollution-contributes-insect-apocalypse-180973642/

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8386932/

https://www.darksky.org/3-insects-affected-by-light-pollution/