City of Chattanooga
Rainwater Management Guide

It Takes All Of Us. . .

RMG Table of Contents

The chapters in this manual have been organized to lead the user through a logical sequence of site selection, assessment, design, review, and approval. The chapters are as follows:

City of Chattanooga

Rainwater Management Guide (RMG) – Addendum # 1

Effective Date – 11/29/2017

This Addendum shall be used in conjunction with the December 1, 2014 edition of the City of Chattanooga's *Rainwater Management Guide* (RMG) to regulate stormwater control measure design, operation, and maintenance. The latest edition of the *Rainwater Management Guide* can be downloaded at the following web address: http://chattanooga.gov/public-works/water-quality-program/resource-rain. The addenda noted below are the City of Chattanooga's additions, clarifications, and exceptions based on the revised City Stormwater Ordinance, approved by Chattanooga City Council on November 21 and 28, 2017, and became effective upon signature by the Mayor and City Council Chairperson, as well as knowledge gained over the past three years of Stormwater Control Measures implementation.

This document shall have an effective date of November 29, 2017.

11-29-17

William C. Payne, PE — Date
City Engineer – Engineering Department
Public Works – City of Chattanooga

11-29-17

John T. Kinder, PE — Date
Site Development Manager – Land Development Office
Economic and Community Development - City of Chattanooga

General Comments (Apply to the Entire RMG):

Overview

Below are some clarifications and changes to the Stay-On Volume (SOV) calculation method:

1. SOV is required when there is 1 acre or more of disturbed area.
2. Calculations for SOV may be based on impervious area only (not disturbed area, as before).
3. As before, SOV will be below perforated outlet pipes or Internal Water Storage (IWS). TSS only above these areas.
4. The entire City of Chattanooga will use 1.0" of rainfall for SOV. The South Chickamauga watershed no longer requires 1.6" for rainfall.
5. SOV may still be used to adjust Curve Numbers. However, only SOV may be used for this CN adjustment.
6. Impervious area disconnection may only be used for SOV calculations. All other stormwater calculations are not allowed to use disconnection.

Concept, preliminary, and final meetings/submittals are no longer required. One may voluntarily schedule any of the above with the City of Chattanooga as needed.

Disturbed/undisturbed areas are to be clearly delineated on the design documents. Drawings and calculations without undisturbed areas clearly labeled will be assumed to have disturbance for the entire property area. Measures describing how the undisturbed areas will be protected in the field must also be specified and installed prior to clearing, grading, or land disturbance.

A properly completed LDP checklist (in Excel) is required at the time of each LDP submittal and/or resubmittal.

Calculation Methodology

One may use the *Runoff Reduction Analysis Tool* (RRAT) and Tennessee *Permanent Stormwater Management and Design Guidance Manual* by TDEC, if desired (see: http://tnpermanentstormwater.org/index.asp?vp=1), instead of the City of Chattanooga's LID Calc Tool spreadsheet and *Rainwater Management Guide* or *WinSLAMM*. However, only one may be used for a project, and not a combination. When using RRAT or WinSLAMM, one is required to perform flood control calculations as there are currently no Curve Number adjustments in those tools (see Chattanooga Ordinance 31-313.7).

Worksheet 1 of the Chattanooga LID Calc Tool spreadsheet must be completed for all projects disturbing one acre or more and are located outside of the Chattanooga combined sewer area, including those using green infrastructure, modified green infrastructure, proprietary, man-made devices, or extended detention.

Site Infeasibilities and Procedures

Unless a site or portion of a site is documented and approved as "infeasible," Stay-On Volume (SOV) is still required. That portion of the site that is not approved as "infeasible" will still be required to use SOV. Documentation shall include, but not be limited to, the City of Chattanooga's *Stay-On Volume Infeasibility Application*.

Sites previously approved by the City of Chattanooga's Land Development Office under the RMG will be deemed as being "feasible" and will not be changed to being "infeasible" unless new, documented field evidence indicates the previously approved plan is not able to be constructed as previously designed and approved. Any false information submitted to the City of Chattanooga may be referred to the appropriate Tennessee State Board for disciplinary action.

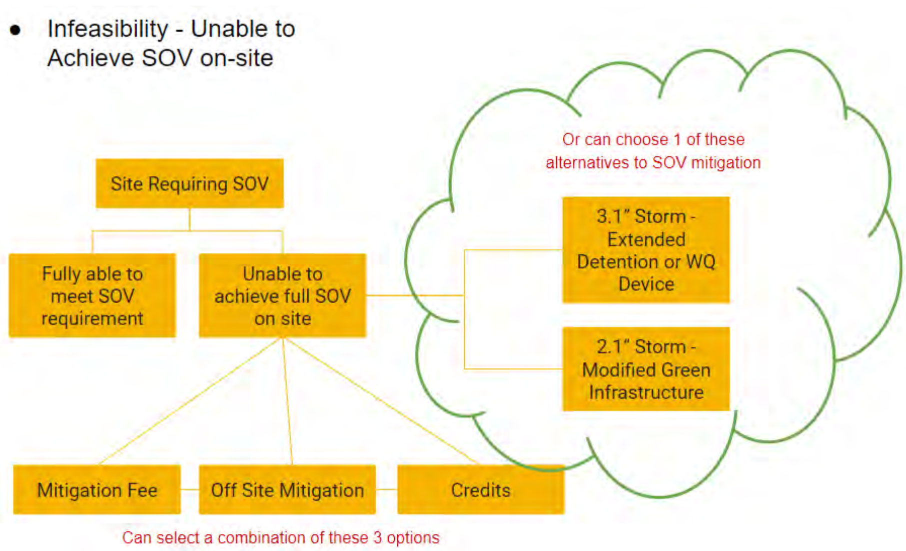
"Infeasibility Criteria" means documenting that a site or portion of a site is ineligible to implement some combination of Stay-On Volume (SOV) measures. Limitations to the installation of runoff reduction measures include, but are not limited to, physical site infeasibilities such as:

1. Groundwater pollution potential (hotspots)
2. Soil contamination (brownfields certified by TDEC)
3. Karst geology/sinkholes
4. Limited infiltration capacity (< 0.5 in./hr.)
5. High permanent groundwater table (< 2 feet to water table from bottom of proposed SCM)

On projects where conventional, onsite SCM's are infeasible for SOV, offsite mitigation and/or use of coupons are still allowed. However, in-lieu of offsite mitigation or using coupons, one or a combination of the following methods may be used to remove a minimum of 80% TSS from the stormwater when "infeasibility criteria" has been met:

1. modified green infrastructure using 2.1" storm, and/or
2. extended detention pond using 3.1" storm, and/or
3. proprietary, man-made devices meeting NJCAT verification (www.njcat.org) and using 3.1" storm.

The following diagram below illustrates this process:



Modified green infrastructure is defined as green infrastructure SCM's that are unable to provide adequate SOV through infiltration, evapotranspiration, or rainwater harvesting, but having amended soil, stone, perforated pipe, orifice to reduce flows, and other features to allow a slow release of filtered stormwater.

Both green infrastructure and modified green infrastructure are required to have loading ratios at or below the target loading ratio shown on the Chattanooga LID Calc spreadsheet.

Extended detention ponds are defined as detention ponds that provide for the temporary storage of stormwater runoff for some minimum time (e.g., 24 to 72 hours) to allow suspended sediments and other associated pollutants to settle to the pond bottom, and therefore, not discharge to downstream channels. Extended detention ponds shall be designed in accord with the TDEC/UTK manual, *Tennessee Permanent Stormwater Management and Design Guidance Manual*. When using this method, TDEC/UTK's Treatment Volume (Tv) = Chattanooga's Stay-On Volume (SOV) using 3.1" of rainfall (or, SOV = 3.1" X R_v X A (in ft.^{2}) X (1 ft./12 in.)). Peak flow attenuation for the 2-year, 5-year, 10-year, and 25-year storm events are still required, and check for the 100-year storm event. A forebay must be located at each major inlet to the pond. Low-flow orifices 3" or less shall have perforated pipes in stone with geo-wrap, or other acceptable means to prevent clogging. Low-flow orifices shall be sized using the following equation:

$$a = \frac{2A(H-H_o)^{0.5}}{3600CT(2g)^{0.5}}$$

Where:

a	=	Area of orifice (ft^2)
A	=	Average surface area of pond (ft^2)
C	=	Orifice coefficient, 0.66 for thin, 0.80 for materials thicker then the orifice dia.
T	=	Drawdown time of pond (hrs.), must be greater than 24 hours
g	=	Gravity (32.2 ft./sec.^{2})
H	=	Elevation when pond is full to storage height (ft.)
H_o	=	Final elevation when pond is empty (ft.)

"Grandfathering" Procedures

For sites seeking "grandfathering," written evidence must be provided that prior LDP approval from the City of Chattanooga was actually obtained before December 1, 2014, along with copies of all approved construction plans (i.e., drawings, hydrology report, etc…). Projects submitted without approved construction plans will be reviewed as if "grandfathering" was not requested, or, not accepted for review until said documentation is provided. "Grandfathered" sites will be considered exempted from certain permanent stormwater treatment requirements, such as SOV, but will not be exempted from other requirements of the City of Chattanooga that may currently be required (such as zoning, landscaping, detention, ADA, etc…). For subdivisions with a Preliminary Plat and approved construction documents before December 1, 2014, a new Preliminary Plat and new Land Disturbance Permit will still be required (since Preliminary Plat approval expires in two years).

Landscaping Criteria

For a listing of suggested bioretention and wetland plants, please refer to the *Tennessee Permanent Stormwater Management and Design Guidance Manual – Appendix D,* or Nashville's *Metro Stormwater Management Manual – Vol. 5 – Low Impact Development – Bioretention – GIP – 01 –* pages 22-28, unless said plants are restricted by City of Chattanooga tree or landscaping ordinances. Additionally, bioretention and rain gardens plant placement may be in accord with templates found at: *Rain Gardens for Nashville: A Resource Guide for Planning, Designing, and Maintaining a Beautiful Rain Garden*. A Tennessee Professional Landscape Architect may also recommend other plants not on these lists.

For landscaping associated with new or existing construction of buildings 5,000 sf or more or greater than two stories, the use of a Tennessee State Board of Architectural and Engineering registrant (architect, engineer, or landscape architect) is required. For non-building /landscape related projects where site improvements are 5,000 sf or more in area, a registrant is also required (see *The Tennessee Board of Architectural and Engineering Examiners Reference Manual for Building Officials and Design Professionals*, Question # 26, Page 11, dated December 2015). A Tennessee Professional Landscape Architect is required to certify/stamp planting plans for rain gardens, bioretention, and constructed wetland areas (see *City of Chattanooga Policy Statement – Water Quality/Landscape Architecture*, dated January 4, 2011).

For bioretention, rain gardens, and constructed wetland areas, native plant species are preferred over non-native species. Invasive or exotic species are not allowed (see: http://www.tnipc.org/invasive-plants/ for list of such plants in Tennessee). In general, the vegetative goal is to achieve surface area coverage of at least 75% in the first two years.

Construction Criteria

Observation wells/ports are required for each underground SCM. Observation wells/ports shall be tied into any T's or Y's in the underdrain system, or installed at one per 50 linear feet of practice. Also, a hook screw shall be installed a few inches from the top of the observation well/port to allow a data logger to measure the SCM drawdown rate. The drawdown rate should be measured at the observation well for three (3) days following a storm event in excess of 0.5 inches. If standing water is observed or measured after 72 hours, this will be considered a clear sign that the SCM is not functioning properly and will need to be repaired and/or replaced.

Chattanooga odor control structures (Chattanooga Standard # SD-310.01) are still required as needed on stormwater structures for combined sewer areas.

All Stormwater Control Measures (SCM's), including disconnection, require permanent stormwater easements and shall be recorded as part of the Inspection and Maintenance Agreement.

SCM's shall not be installed until the site is substantially stabilized. Exceptions may be made when other special construction measures are used to prevent sediment from damaging the SCM's during construction. Otherwise, damaged and/or SCM's not functioning as designed will need to be replaced before approval by the City of Chattanooga.

Individual Chapter Comments:

Chapter 1 – No changes.

Chapter 2 – No changes.

Chapter 3 –

p. 3-3 – Table 3-1 is no longer accurate. The Simple Method is not required and may be deleted. Additionally, sites between 5,000 sf and 1.0 acre are not required to use the Performance Method; therefore, SOV for sites less than one acre is not required.

p. 3-10 – As previously stated, the Simple Method is not required and may be deleted.

Chapter 4 –

pp. 4-1ff - As previously stated, Concept, Preliminary, and Final Meetings are no longer mandatory, but are voluntary only (though encouraged).

Chapter 5 –

p. 5-5 – Figure 5-1 should include a new reference to dry extended detention ponds, as referenced in the General Comments section of this Addendum.

p.5.3.4-18 – Perforated underdrains with Internal Water Storage (IWS) are required for all bioretention areas, as found in the *Tennessee Permanent Stormwater Management and Design Guidance Manual – Section 5.4.6 – Bioretention – pp. 149*.

p. 5.3.10-7 - For clarification, disconnection:

a. Must be sheetflow (depths of 0.1' or less). Shallow, concentrated flow is not allowed.
b. Pervious flow length must be at least twice as long as the impervious flow length.
c. Receiving pervious area must be at least twice as large as the contributing impervious area.
d. Permanent stormwater easements are required for the disconnection areas and shall be recorded as part of the Inspection and Maintenance Agreement.
e. Disconnection not meeting (b) and (c) above may be prorated if a minimum of 50% of the required lengths and areas are provided. Other criteria listed in the RMG still apply, including maximum allowable impervious area per disconnection.
f. Disconnection may only be used for SOV/green infrastructure calculations (not flood control calculations).

p. 5.3.12-1ff – As previously stated in the General Comments section of this Addendum, proprietary, man-made devices must have NJCAT verification (www.njcat.org) and use 3.1" of rainfall for design purposes. No SOV or detention allowances will be given for these devices. Proprietary, man-made SCM devices must be installed upstream (not downstream) of detention facilities. Inlet filter/bag systems are allowed for retrofit projects only and not for new construction projects.

Chapter 6 – No changes.

Chapter 7 –

p. 7-4 – Calculations may be made using either the Small Storm Hydrology Method (as per the Chattanooga LID Calc Tool spreadsheet), WinSLAMM, or TDEC Runoff Reduction Analysis Tool (RRAT). However, one may not use a combination of the above methodologies on any one project.

p. 7-4 – SOV calculations may be based on impervious areas only, not disturbed areas.

p. 7-17 – Update Table 7-2 to include the following TSS % Reduction Rates.

Stormwater Control Measure (SCM)	TSS Removal % for SCM's
Pervious Pavement	65
Infiltration Bed	80
Infiltration Trench	65
Bioretention	85
Vegetated Swales	25
Vegetated Filter Strips	30
Infiltration Berms	25
Green Roofs	N/A
Runoff Capture and Reuse	N/A
Disconnection of Impervious Areas	N/A
Stormwater Planter Box	15
Manufactured Devices	50 – 80
Naturalized Basins	80
Extended Detention (w/o perm. pool of water)	40
Extended Detention (w/ perm. pool and 24-hr. min. release rate)	60
Extended Detention (w/ perm. pool and 48-hr. min. release rate)	80

When using two or more SCM's as part of a "treatment train," the TSS % removed are not directly added together, but use a "treatment train" calculation of:

$$TSS_{train} = A + B - ((A \times B)/100)$$

where: TSS_{train} = total TSS removal for treatment train (%)
A = % TSS removal of the first (upstream) SCM (from the table above)
B = % TSS removal of the second (downstream) SCM (from the table above)

For development sites where the "treatment train" provides the only stormwater treatment on the site, TSS_{train} must be equal to or greater than 80%.

p. 7-26 – For clarification, in order for Curve Numbers to be adjusted, one must actually use SOV or green infrastructure (i.e., keep the stormwater onsite). Measures used to treat the stormwater with 80% TSS reduction, such as modified green infrastructure, man-made, proprietary devices, or extended detention, will not be allowed to use adjusted CN's.

Chapter 8 – No changes.

<u>Appendices Comments:</u>

<u>Appendix A</u> – No changes.

<u>Appendix B</u> – No changes.

<u>Appendix C</u> –

<u>p. C-9</u> – Increase the pre-soak period from 1 – 2 hours, to a minimum of 24 hours. After the 24-hour pre-soak period, refill the percolation hole with 2 feet of clean water and measure the drop in water level after one hour. Repeat the procedure three (3) additional times by filling the percolation test hole with clean water and measuring the drop in water level after one hour. The infiltration rate of the underlying soil may be reported either as the average of the four readings or the value of the last observation. The infiltration rate should be reported in terms of inches per hour.

<u>p. C-9</u> – Infiltration tests should be performed at the following minimum rates based on the area of the SCM:

< 1,000 sf – 2 tests
1,000 – 10,000 sf – 4 tests
>10,000 sf – 4 test, plus 1 additional test for every 5,000 sf or fraction thereof.

Additional tests may be required when infeasibility for infiltration is being sought for a project. Infiltration testing for infeasibility verification will be required at each proposed SCM natural point of discharge in order to confirm infeasibility. The "natural point of discharge" is defined as the invert of the SCM infiltration practice.

<u>Appendix D</u> – No changes.

<u>Appendix E</u> – No changes.

<u>Appendix F</u> –

<u>p. F-3 – 5</u> – Bioretention and/or amended soil should generally be loamy sand with the following composition: 85% to 88% washed, coarse sand; 8% to 12% soil fines; and 3% to 5% organic matter from pine bark, with a P-Index between 10 to 30, a minimum infiltration rate of 0.5 inches per hour, and a clay content less than 6%. For additional information, refer to the bioretention soil requirements found in the *Tennessee Permanent Stormwater Management and Design Guidance Manual – Section 5.4.6 – Bioretention – pp. 147 – 148*.

<u>Appendix G</u> – No changes.

<u>Appendix H</u> – No changes.

<u>Appendix I</u> – No changes.

<u>Appendix J</u> – No changes.

Appendix K –

p. K -1 – 36 - As previously stated, South Chickamauga watershed no longer requires using 1.6", nor is SOV required for pervious areas. However, the rest of the information should still be accurate and useful for design purposes.

Credit and Incentives Manual Comments:

p. 12 – 5.2 – "Table of Discount Provisions" - delete the line regarding New Development in South Chickamauga.

p. 14 – 6.1(c)(1) – Delete this section since the timeframe has already passed.

p. 16 – 6.2 – "Table of Credit Provisions" - delete the line regarding New Development in South Chickamauga and all references to the Yr 1 through Yr 3 timeframes.

p. 19 – 7.2 – "Table of Fee Applicability" - delete the line regarding New Development in South Chickamauga and all references to the Yr 1 through Yr 3 timeframes.

Appendix A – "Credit and Incentives Summary Chart" - delete the line regarding New Development in South Chickamauga, as well as the footnote for Yr 1 through Yr 3.

Appendix C – The Inspection and Maintenance Agreement on this page is no longer current. Please use the ones found at the Chattanooga RMG website: http://chattanooga.gov/public-works/water-quality-program/resource-rain.

References and Additional Resources:

City of Chattanooga Rainwater Management Guide and Resource:Rain Information.
http://chattanooga.gov/public-works/water-quality-program/resource-rain

City of Nashville's Metro Stormwater Management Manual.
https://www.nashville.gov/Water-Services/Developers/Stormwater-Review/Stormwater-Management-Manual.aspx

International Stormwater BMP Database.
http://www.bmpdatabase.org/performance-summaries.html

Knox County, TN Stormwater Management Manual, Volume 2.
https://www.knoxcounty.org/stormwater/volume2.php

National Pollutant Removal Performance Database.
http://www.stormwaterok.net/CWP%20Documents/CWP-07%20Natl%20Pollutant%20Removal%20Perform%20Database.pdf

NJCAT Stormwater Technologies: Laboratory Verified.
http://njcat.org/verification-process/technology-verification-database.html

Rain Gardens for Nashville: A Resource Guide for Planning, Designing, and Maintaining a Beautiful Rain Garden.
https://ag.tennessee.edu/tnyards/Documents/Rain%20Garden%20Brochure%20Metro%20Nashville.pdf

Tennessee Invasive Plant Council – Invasive Plant List.
http://tnipc.org/invasive-plants/

Tennessee Permanent Stormwater Management and Design Guidance Manual.
http://tnpermanentstormwater.org/manual.asp

City of Chattanooga
Rainwater Management Guide (RMG) – Addendum # 2
Effective Date – 08/30/2019

This Addendum shall be used in conjunction with the December 1, 2014 edition of the City of Chattanooga's *Rainwater Management Guide* (RMG) to regulate Stormwater Control Measure (SCM) design, operation, and maintenance. The latest edition of the *Rainwater Management Guide* can be downloaded at the following web address: http://chattanooga.gov/public-works/water-quality-program/resource-rain. The addenda noted below are the City of Chattanooga's additions, clarifications, and exceptions based on the revised City Stormwater Ordinance, approved by Chattanooga City Council on November 21 and 28, 2017, and became effective upon signature by the Mayor and City Council Chairperson, as well as knowledge gained over the past five years of Stormwater Control Measures implementation.

This document shall have an effective date of August 30, 2019.

Revision history:
- Original Rainwater Management Guide – 12/01/2014
- Addendum # 1 – 11/29/2017
- Addendum # 2 – 8/30/2019

08-30-19

William C. Payne, PE — Date
City Engineer – Engineering Department
Public Works – City of Chattanooga

8-30-19

John T. Kinder, PE — Date
Site Development Manager – Land Development Office
Economic and Community Development - City of Chattanooga

Manufactured Treatment Device Information

Overview

City Code 31-313(4)(F) allows Manufactured Treatment Devices (MTD) as a treatment option for 80% TSS removal where infeasibilities exist and have been documented and approved. All MTDs must be NJCAT verified. This supplement to the RMG describes the City's process of applying NJCAT verified devices to meet this rule. This Addendum is being published in order to clear-up misunderstandings by engineers, suppliers, and manufacturers regarding application of MTDs to meet this rule.

Definition:

Stormwater Manufactured Treatment Devices (MTDs) are manufactured devices that treat stormwater by one of several technologies, including, but not limited to, gravitational separation or filtration, before it is discharged offsite or to receiving water bodies, and may be incorporated into a series of one or more stormwater control measures (SCMs) known as a treatment train to remove pollutants from stormwater runoff.

Ordinance background & intent

During the drafting, review and approval of 31-313(4)(F), Water Quality staff researched various widely accepted methods of MTD approval. The staff recommendation, subsequently recommended by the Stormwater Regulations Board (SWRB) and adopted by City Council, was written with the intent to utilize MTDs that were verified by NJCAT following an NJDEP testing protocol. NJDEP certification was not required in order to allow developers and their engineers to select from a wider array of products to meet the 80% TSS removal requirement. The administrative intent is to allow use of MTDs up to the verified removal efficiency without the artificial efficiency cap placed on such devices when certified by NJDEP. Strict adherence to the latest NJDEP testing protocol was not deemed to be significantly important. Verified technologies approved by NJCAT following earlier NJDEP protocols were deemed sufficient for the purposes of the Chattanooga Water Quality Program.

Application of NJCAT Verification Database

The City of Chattanooga Land Development Office will compare the submitted MTD information to the NJCAT verification website (see http://njcat.org/verification-process/technology-verification-database.html). Refer to RMG Addendum #1 for Site Infeasibilities and Procedures.

1. Search the website page sections labelled "Laboratory Verified and NJDEP Certified" or "Laboratory Verified" for the specified product.
    a. In the event these section names are changed in the future by NJCAT, the corresponding names assigned by NJCAT shall be used in place of the listed categories without the need for future revisions to this addendum or the RMG.
    b. If the product is not listed in the stated sections, it is assumed to not be NJCAT verified.
    c. Devices may be listed in multiple sections. Listing in more than one section does not negate inclusion in the sections listed above.
    d. Devices listed exclusively in other sections are not permissible.

2. In the column to the far right labeled "Link to Report," download the corresponding device report.
3. Device selection by Design Engineer
    a. All devices listed in the "Laboratory Verified and NJDEP Certified" section will be approved by the City.
    b. For devices listed in the "Laboratory Verified" section without corresponding NJDEP certification, the Design Engineer must review the report and determine the test protocol used to verify the product or device. Only devices that have been tested using the New Jersey Department of Environmental Protection (NJDEP) stormwater manufactured treatment devices (MTD) laboratory test protocols and procedure for verification by New Jersey Corporation for Advanced Technology (NJCAT) for 1-1,000 microns will be approved by the City. (see http://www.njcat.org/ for additional details)
    c. For devices meeting subsection a) or b) above, the Design Engineer shall review the associated report and determine the weighted TSS removal rate. This information must be listed by the Design Engineer on the Manufactured Treatment Device Submission form attached as Exhibit 1 to this addendum. The form must be completed in full and submitted as part of a Land Disturbance Permit (LDP) application.
4. Within the report, find the section with the Maximum Treatment Flow Rate (MTFR), usually in cubic feet per second (cfs), and the Weighted Annualized TSS Removal Efficiency. This TSS removal rate for the MTFR is the amount allowed by the City of Chattanooga. (Note that the TSS removal rate may be greater than 50% since Chattanooga is not limited by New Jersey state law to limit a maximum of 50% TSS removal for HDS devices.)
5. Allowable flow rates for different sizes of devices shall be determined using the "Verification Appendix," usually found near the end of the "NJCAT Technology Verification Report" for that device. For additional information see **NJDEP Laboratory Test Protocols and Verification Procedure: NJCAT Interpretations,** Section 6: Scaling, for the specific device type. http://www.njcat.org/uploads/docs/NJCATInterpretations-LabTestProtocols%20June%202017.pdf
6. Oversizing devices to achieve higher TSS removal is not allowed.
7. Oversizing devices to reduce cleaning frequency is allowed.

Use of non-verified MTD

Use of any non-NJCAT verified MTD to meet 80% TSS removal required by City Code Section 31-313 (4)(F) is not allowed.

Small Site Control TSS Compliance

Sites that qualify for Small Site Controls shall follow one of the TSS provisions under 31-313(4)(F) to be deemed in compliance with 31-313(3)(C).

Treatment Train

1. When a MTD is specified to achieve compliance with 31-313(4)(F), credit will be given for the full weighted TSS removal rate as identified according to this document.
2. If the weighted TSS removal rate equals or exceeds 80.00% no additional SCM is required for compliance with 31-313(4)(F).
3. If the weighted TSS removal rate is less than 80.00%, the Design Engineer must subtract the weighted TSS removal rate from 80.00% to determine the remaining amount of TSS removal required to comply with 31-313(4)(F). One or more additional SCMs must be selected by the Design Engineer and incorporated into the site design for submission with the LDP application to achieve at least 80.00% TSS removal.
4. Specifying a second MTD in series is only acceptable if the second MTD utilizes filtration. Specification of two hydrodynamic separators in series will not be approved to achieve compliance.

Exhibit 1

Manufactured Treatment Device Submission Form	
Project Address:	Previously Approved Infeasibility #:
Manufacturer:	Model Number or Name:
Size or Diameter:	Weighted TSS removal rate:
Design inflow rate (cfs):	Maximum Treatment Flow Rate (cfs):
NJCAT verified (Y/N)	NJDEP Certified (Y/N)
Remaining TSS removal required:	Other SCM specified:
Engineering Firm Submitting Form:	Engineer stamp/seal/signature:

City of Chattanooga

Rainwater Management Guide (RMG) – Addendum # 2 - Revision 1

Effective Date – 11/15/2019

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This document shall have an effective date of November 15, 2019.

Revision history:

Original Rainwater Management Guide – 12/01/2014
Addendum # 1 – 11/29/2017
Addendum # 2 – 8/30/2019
Addendum # 2 - Revision # 1 - 11/15/2019

11-15-19

William C. Payne, PE — Date
City Engineer – Engineering Department
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During the drafting, review and approval of 31-313(4)(F) Water Quality staff researched various widely accepted methods of MTD approval. The staff recommendation, subsequently recommended by the SWRB and adopted by City Council, was written with the intent to utilize MTD that were verified by NJCAT following an NJDEP testing protocol. NJDEP certification was not required to allow developers and their engineers to select from a wider array of products to meet the requirement. The administrative intent is to allow use of MTD up to the verified removal efficiency without the artificial efficiency cap placed on such devices when certified by NJDEP. Strict adherence to the latest NJDEP testing protocol was not deemed to be significantly important. Verified technologies approved by NJCAT following earlier NJDEP protocols are deemed sufficient for the purposes of the Chattanooga Water Quality Program.

Application of NJCAT Verification Database

The City of Chattanooga Land Development Office currently compares the submitted hydrodynamic separator (HDS) information to the NJCAT verification website (see http://njcat.org/verification-process/technology-verification-database.html). Refer to RMG Addendum #1 for Site Infeasibilities and Procedures.

1. Search the website page sections labelled "Laboratory Verified and NJDEP Certified" for the specified product.
    a. In the event this section name is changed in the future by NJCAT, the corresponding name assigned by NJCAT shall be used in place of the listed categories without the need for future revisions to this addendum.
    b. If the product is not listed in the stated section, it is assumed not to be NJCAT verified.
    c. Devices may be listed in multiple sections. Listing in more than one section does not negate inclusion in the sections listed above.
    d. Devices listed exclusively in other sections are not permissible.

2. In the column to the far right labeled "Link to Report," download the appropriate report.
3. Review by Design Engineer
   a. All devices listed in the "Laboratory Verified and NJDEP Certified" section will be approved by the City.
   b. For devices meeting subsection a) above, the Design Engineer shall review the associated report and determine the weighted TSS removal rate. This information must be listed by the Design Engineer on the Manufactured Treatment Device Submission Form attached as Exhibit 1 to this addendum. The form must be completed in full and submitted for each device as part of a Land Disturbance Permit (LDP) application.
4. Within the report, find the section with the Maximum Treatment Flow Rate (MTFR), usually in cubic feet per second (cfs), and the Weighted Annualized TSS Removal Efficiency. This TSS removal rate for the MTFR is the amount allowed by the City of Chattanooga. (Note that currently, the TSS removal rate may be greater than 50% since Chattanooga is not limited by New Jersey state law to limit a maximum of 50% TSS removal for HDS devices.) The Design Engineer shall design the site drainage system such that the specified device's proposed design matches the NJCAT tested configuration (e.g., single inlet, single outlet, no top grate, etc.).
5. Allowable flow rates for different sizes of devices shall be determined using the "Verification Appendix," usually found near the end of the "NJCAT Technology Verification Report" for that device. For additional information see **NJDEP Laboratory Test Protocols and Verification Procedure: NJCAT Interpretations,** Section 6: Scaling, for the specific device type. http://www.njcat.org/uploads/docs/NJCATInterpretations-LabTestProtocols%20June%202017.pdf
6. Oversizing devices to achieve higher TSS removal is not allowed.
7. Oversizing devices to reduce cleaning frequency is allowed.

Use of non-verified MTD

Use of any non-NJCAT verified MTD to meet 80% TSS removal in accordance with Section 31-313 (4)(F) is not allowed.

Small Site Control TSS Compliance

Sites that qualify for Small Site Controls shall follow one of the TSS provisions under 31-313(4)(F) to be deemed in compliance with 31-313(3)(C).

Treatment Train

1. When a MTD is specified to achieve compliance with 31-313(4)(F) credit will be given for the full weighted TSS removal rate as identified according to this document.
2. If the weighted TSS removal rate equals or exceeds 80% no additional SCM is required for compliance with 31-313(4)(F).
3. If the weighted TSS removal rate is less than 80%, the Design Engineer must subtract the weighted TSS removal rate from 80% to determine the remaining amount of TSS removal required to comply with 31-313(4)(F). Additional SCM must be selected by the Design Engineer and incorporated into the site design for submission with the LDP application.

Exhibit 1

Manufactured Treatment Device Submission Form

Project Address:	Previously Approved Infeasibility #:
Manufacturer:	Model #:
Size:	Weighted TSS removal rate:
Design inflow rate (cfs):	Maximum Treatment Flow Rate (cfs):
NJCAT Verified (Y/N)	NJDEP Certified (Y/N)
Remaining TSS removal required:	Other SCM specified:
Engineering Firm Submitting Form:	Engineer stamp/seal/signature:

Chapter 1 Introduction

1.1 Introduction

As the City of Chattanooga continues to grow and develop, impervious surfaces such as parking lots, rooftops, and roadways increase the amount of stormwater runoff during rainfall events, altering the natural hydrologic regime. Without a properly designed and implemented stormwater management program, increased stormwater runoff may lead to stream channel erosion, increased levels of pollutants entering the City's streams and rivers, increased flooding potential, and decreased groundwater recharge. Implementation of the practices in this manual will help protect the City's water resources, improving the benefit to human health, fish and wildlife habitat, and recreational opportunities.

Stormwater management is also critical in alleviating the impacts of stormwater runoff in the City's combined sewer overflow (CSO) areas. Reducing the amount of stormwater runoff that enters the City's CSO system through infiltration, flow reduction, and reuse helps protect the City's infrastructure system and prevent the hazards associated with flooding and sanitary sewer overflows and discharges into the City's streams and creeks and the Tennessee River.

1.2 Purpose of this Manual

This document has been named the "Rainwater Management Guide." This name signifies a change in the approach to stormwater management, specifically as it applies to the practice of land development. The term rainwater is indicative of the emphasis on smaller, more frequent rainfall events, whereas the term "guide" denotes the intent of this document to serve as a tool and aid for the developer and design professional.

The City of Chattanooga has developed the "Rainwater Management Guide," also referred to as the manual or the guide, to provide a comprehensive tool for the developer and design professional to effectively and efficiently meet required rainwater runoff standards.

This manual is also available on the City's website (http://www.chattanooga.gov/) in an interactive format to expedite and streamline the design and review process.

This manual serves to comply with the provisions of the NPDES MS4 Permit of the City of Chattanooga by providing stormwater management measures and methods designed to assist with the preservation and restoration of natural hydrologic regimes, minimizing CSO surcharges and improving the City's water quality. The practices and processes in this manual can also provide benefits to the developer that may include:

- Reducing land clearing and grading costs
- Reducing infrastructure costs (streets, curbs, gutters, sidewalks)
- Reducing stormwater management fees
- Potentially eliminating or reducing the size of detention ponds
- Increasing value and marketability

Stormwater management is critical to protecting and restoring the City's livability and improving the quality of the City's watersheds. Projects that meet the requirements of the City's runoff reduction program by implementation of the low-impact development practices in this manual will contribute to accomplishing citywide goals and comply with the State of Tennessee's water quality regulations.

1.3 Regulatory Mandates

In response to the impacts of urbanization on water quality, the United States Congress passed the Clean Water Act of 1972, as amended, which prohibits the discharge of pollutants into waters of the United States unless said discharges are compliant with a National Pollutant Discharge Elimination System (NPDES) permit. Permit requirements implemented in 1990 (Phase I) initially required only medium and large cities (cities with populations of at least 100,000) to obtain an NPDES permit for their municipal separate storm sewer system (MS4) discharges. These requirements were expanded in 2003 (Phase II) to include small regulated municipalities (with populations greater than 50,000). The Tennessee Department of Environment and Conservation (TDEC) renewed the City's NPDES MS4 Permit on December 1, 2010, and imposed additional requirements for stormwater management thereunder. The City of Chattanooga's NPDES MS4 Permit Number TNS068063 includes permit performance requirements, definitions, timelines, and other components. The permit can be accessed at http://www.tn.gov/environment/wpc/stormh2o/TNS068063.pdf.

Compliance with the current NDPES MS4 Permit requires the City to establish a comprehensive stormwater management program to develop, implement, and enforce controls to reduce the discharge of pollutants from areas of new development and redevelopment. The program includes volume management, water quality, and flow rate standards for onsite stormwater management facilities and focuses on low-impact development and green infrastructure best management practices.

1.4 Changes in Stormwater Management

The City's NPDES MS4 Permit includes a number of new stormwater management requirements. The most significant of these requires volume management for new and redevelopment projects. Specifically, the permit requires that the City develop design standards for new and redevelopment projects such that "the first inch of rainfall must be managed with no discharge to surface waters." In other words, the first inch of rainfall must be captured and infiltrated, evapotranspirated, or reused through better stormwater and land development practices. The intent is to preserve and maintain as much as possible the natural hydrology of the land. This approach of managing small, frequent rainfall events is accomplished with low-impact development or green infrastructure.

Chattanooga receives approximately 53 inches of rainfall per year on average. Approximately 86 percent of the rainfall events in Chattanooga are small, resulting in 1 inch or less of precipitation (see Figure 1-1). The volume of rain from these small rainfall events, when added cumulatively over a year, comprises approximately half of the total annual rainfall volume (see Figure 1-2).

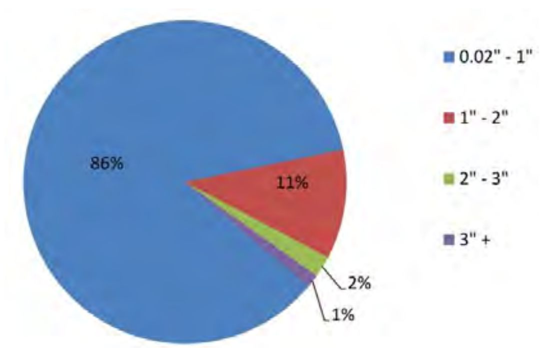

Figure 1-1. Approximately 86 percent of the rainfall events in Chattanooga are 1 inch or less in total rainfall depth.

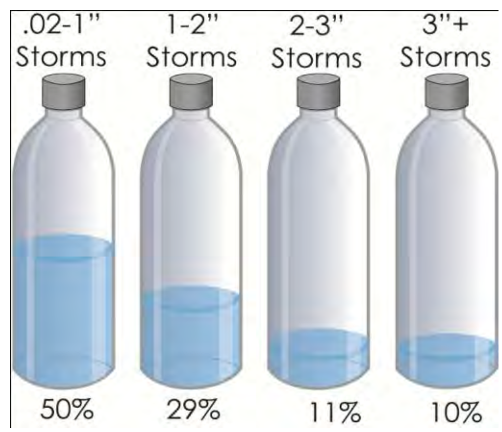

Figure 1-2. The cumulative volume of the 1-inch rainfall events, in an average year, is approximately 50 percent of the average annual volume of rainfall of 53 inches.

Before development, these small rainfall events would be absorbed by trees, vegetation, and soils, generating little or no stormwater runoff. But with the addition of impervious surfaces, stormwater runoff occurs more frequently and in larger amounts than it did under natural (undeveloped) conditions (see Figure 1-3). This increase in stormwater runoff volume and runoff frequency can cause erosion and changes in the stream channel shape (hydro-modification), contributing to water quality problems as well as increasing flooding problems (see Figures 1-4 and 1-5). The runoff also conveys pollutants from the land surface into streams and waterways. Equally important, as more runoff occurs, less water infiltrates the groundwater. Groundwater is a critical source of stream base flow (and water quality).

Figure 1-3. Typical impervious surfaces in Chattanooga generate runoff nearly every time it rains, conveying pollutants to streams.

Figures 1-4 and 1-5. The increased volume of runoff in the stream channel leads to stream channel erosion and worsened flooding.

Because small rainfall events generate little runoff under natural conditions, but almost entirely “run off” when the land surface is paved, the City’s stormwater program – as required by the City’s NPDES MS4 Permit issued by TDEC – is focused on managing these small rainfalls so there is no runoff or surface discharge. This is the basis for the City’s requirements to manage stormwater volume.

The focus on runoff volume is a regulatory requirement and represents an important change in stormwater management practice in Chattanooga. This change, however, is not unique to Chattanooga. Runoff volume management has been universally accepted and acknowledged as an important approach to prevent further damage of urban watersheds. The approach is aimed at preserving as much as possible the beneficial hydrologic balance of those watersheds by limiting hydro-modification.

In addition to volume management, the permit includes requirements for water quality management and riparian buffer establishment. The permit also allows incentives for certain redevelopment projects, such as high density (more than seven units per acre) and mixed use, while recognizing that certain areas may have limitations for volume management based on soil types, contaminants, karst, or other constraints.

This document serves as the technical guidance document for the selection, integration, design, and implementation of a number of stormwater (rainwater) management practices referred to herein as Best Management Practices (BMPs) to meet the City's stormwater management requirements for new and redevelopment projects.

Chapter 2 Use of the Manual

2.1 Organization of Manual

The practices and design methods provided in this manual are intended to inform and guide the applicant in implementing low-impact development (LID) design standards and green infrastructure (GI) practices to meet the City of Chattanooga's stormwater management performance standards. While some of the design guidance represents required minimum standards, others are simply design recommendations. The manual and the standards within may be subject to change and updates can be found on the City's website (http://www.chattanooga.gov/public-works/city-engineering-a-water-quality-program).

This document is structured to guide the developer/applicant/owner through the site design process from initial site evaluation through detailed stormwater management design elements and, ultimately, to City approval of the Final Stormwater Management Plan. This manual provides tools to assist the applicant in completing required documentation and meeting stormwater management performance standards. Tools include flow charts to guide the applicant through the design and permitting process, worksheets to assist with calculations, and checklists to ensure that the Stormwater Management Plan and associated documentation are complete.

The chapters in this manual have been organized to lead the user through a logical sequence of site selection, assessment, design, review, and approval. The chapters are as follows:

Chapter 1 – Introduction: Provides an introduction and rationale to the new runoff reduction standards and stormwater volume control as a new approach to protecting and restoring the City's streams and rivers.

Chapter 2 – Use of the Manual: Provides guidelines on manual organization and use.

Chapter 3 – Stormwater Management Performance Standards: Provides detailed information on the stormwater management performance criteria for volume, quality, and rate and for determining permit applicability.

Chapter 4 – Integrating Stormwater Management with Site Design: Discusses the integration of stormwater management practices into the site design process from initial site evaluation to site layout and design.

Chapter 5 – Stormwater Management Practices: Describes approaches for managing stormwater and includes technical design guidelines for stormwater management practices including protection practices, structural design measures, and restorative practices.

Chapter 6 – Technical Guidelines for Areas of Special Consideration: Presents technical guidance for design of stormwater management practices in constrained and technically challenging locations such as highways and roads, brownfields, and urban and CSO areas.

Chapter 7 – Stormwater Calculations and Methodology: Explains acceptable methodologies for quantifying and documenting compliance with stormwater management performance standards.

Chapter 8 – Maintenance and Performance: Provides guidance on the City's process for ensuring long-term performance of stormwater management practices, including inspections and operations and maintenance agreements.

Appendices: The appendices include standard protocols for integrated stormwater management design, such as setbacks, utility coordination and infiltration testing requirements, plant selection, and material specifications for stormwater BMP components.

2.2 Use of Manual

Figure 2-1 demonstrates how the manual is organized to guide the design and navigate the development review process.

Use Of Manual

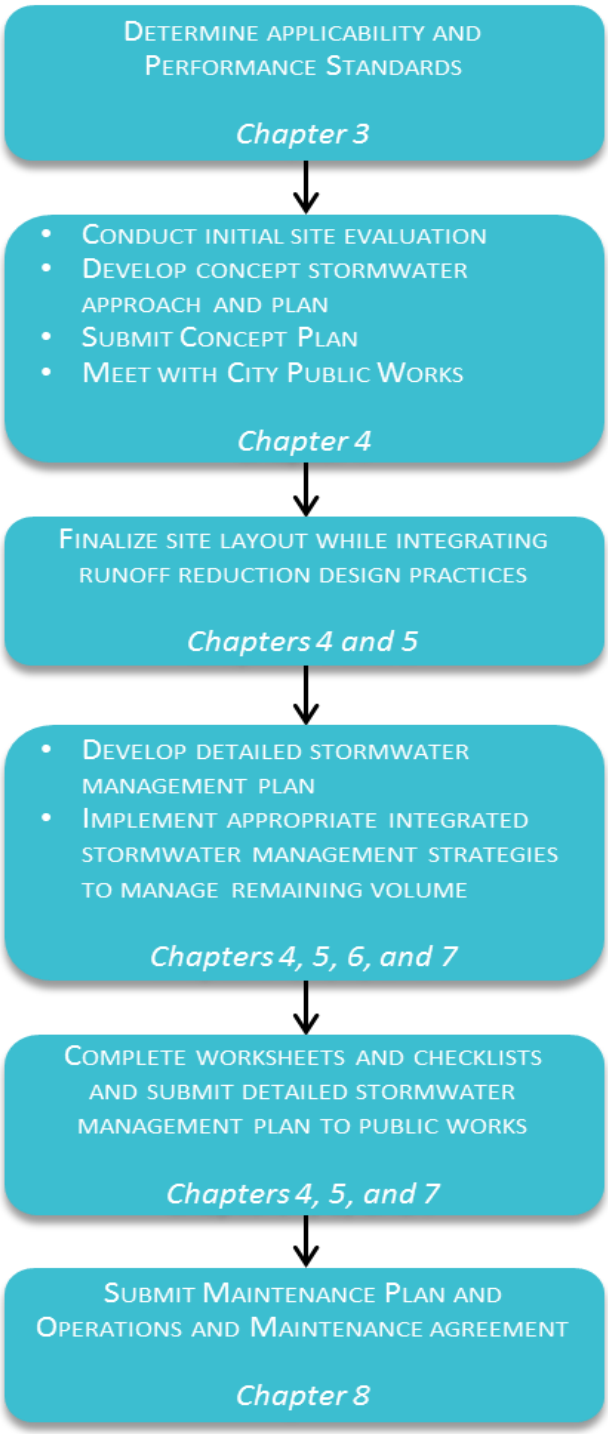

Figure 2-1. Use of this Manual

2.3 Resources

(Reserved)

Chapter 3 Stormwater Management Performance Standards

3.1 Overview

The City of Chattanooga's stormwater management program, as described in this manual, imposes requirements for new and redevelopment projects to manage stormwater runoff for **volume, water quality treatment, and peak flow rate**. LID practices and strategies such as conservation, preservation, restoration, and green infrastructure measures identified and described in Chapter 5 may be used to meet the stormwater management requirements.

The specific stormwater management requirements for a given project are determined by:

- The amount of land disturbed
- Whether the project is a new project or a redevelopment project
- Which major watershed the project is located in

Certain types of projects that incorporate beneficial land development practices (i.e., transit-oriented development or high-density development) may be eligible for reduced stormwater requirements. Additionally, certain stormwater practices – such as green roofs and pervious pavement – may provide further benefits (incentives) to the applicant when designing a stormwater management system.

A major new component of the City's stormwater program is the requirement to manage the first inch of every rainfall event such that there is no surface water discharge from the project site. Projects that are able to meet this "volume management" requirement are considered to also meet the water quality treatment requirements. Throughout this manual, the required volume to be managed is referred to as the "stay-on-volume" or SOV, as discussed later in this chapter.

For project sites unable to meet 100 percent of the SOV, *"…the remainder of the stipulated amount of rainfall must be treated prior to discharge with a technology documented to remove 80 percent of the total suspended solids (TSS).[1]"* Based on Chattanooga specific analysis of pollutant loadings, the stipulated rainfall has been determined to be the 1-year, 24-hour type II rainfall event for BMPs that treat flow rates and 2.1-inch rainfall for BMPs that treat volumes.

The treated runoff is still subject to peak rate control. For projects unable to meet SOV requirements, the City may allow an offsite mitigation project or fee-in-lieu payment in accordance with provisions in the

[1] City of Chattanooga MS4 Permit, TNS068063, 3.2.5.2 Pollutant Removal

MS4 Permit, Articles 3.2.5.2.3 and 3.2.5.2.4 (see Section 3.10). These provisions provide for "partial" volume management allowances and credits.

3.2 Design Approach

LID is a stormwater management and design strategy that is integrated into the design of development projects in order to conserve natural resources that provide valuable functions associated with controlling and filtering stormwater; minimizing and disconnecting impervious surfaces; directing runoff to natural and landscaped areas conducive to infiltration; and using distributed small-scale controls or integrated stormwater management BMPs to mimic a site's pre-project hydrologic condition. To encourage LID practices, such as limited site disturbance and the protection of important (and beneficial) natural features, the SOV and water quality requirements apply only to those portions of a project site that are disturbed. Additionally, certain restorative LID practices – such as planting natural landscapes – provide volume management.

In addition to SOV and water quality requirements, projects are required to provide mitigation of the peak rate of runoff after development. The City recognizes that the new requirements to manage stormwater volume will also have benefits for reducing peak flow rates. This document provides guidance for volume management such that discharge rate control may be adjusted to reflect the volume reduction benefits of LID.

This chapter discusses the method for determining the applicable stormwater management and permitting requirements for a project. Specific technical requirements for calculations and documentation are provided in Chapter 7.

3.3 Determining Applicability

The three factors that determine stormwater management applicability are the amount of land disturbance, whether a project is a new or redevelopment project, and the watershed location of the project.

3.3.1 Land Disturbance

All new and redevelopment projects that disturb 1,000 square feet or more of land are subject to the requirements of the City of Chattanooga's stormwater management program. The amount of land disturbance associated with a project is important in determining the level of design documentation, regulatory review, and permitting approval required for an individual project. For example, small projects with land disturbance of less than 1 acre (and more than 1,000 square feet) are required to obtain a Land Disturbing Permit from the City, acquire Erosion and Sediment Control Plan approval from the City, and comply with City stormwater regulations, but are not required to obtain an NPDES Permit for Stormwater Discharges Associated with Construction Activities from TDEC. The specific stormwater management and permitting requirements based on the area of land disturbance are summarized in Table 3-1.

Table 3-1. Permitting and Documentation Requirements Determined by Level of Land Disturbance

Note	Level of Disturbance	LDP	E&SC Plan	E&SC City Permit	Simple Method	Performance Method	TN NPDES Permit
3	≥ 1,000 square feet to 4,999 square feet disturbed area, or < 500 square feet impervious area	√	√	√			
1, 2, 3	≥ 5,000 square feet to 21,779 square feet (0.5 acre) disturbed area	√	√	√	√		
1, 2, 3	≥ 0.5 acre to < 1.0 acre disturbed	√	√	√	R	N	
	≥1.0 acre disturbed	√	√	√		√	√

Legend:

1) Simplified method must have peak rate attenuation for new development
2) Provided it is not part of a larger development
3) Combined sewer overflow (CSO) area must have peak rate attenuation for all additional impervious area as well as additional fixtures in buildings
4) LDP – Land Disturbing Permit
5) E&SC – Erosion and Sediment Control
6) R – Redevelopment
7) N – New development

Land Disturbing Activity

Chapter 31, Article VIII of the Chattanooga City Code defines Land Disturbing Activity as: "Any land change which may result in soil erosion from water and wind and the movement of sediments into community waters or onto lands and roadways within the community, including, but not limited to clearing, dredging, grading, excavating, transporting and filling of land."

For the purposes of determining stormwater management requirements, the following activities are considered land disturbance:

- Land development
- Clearing and grubbing
- Grading
- Excavation
- Creation of embankments
- Moving, depositing, or stockpiling soil, rock, or earth materials
- Constructing private roads
- Constructing vehicle paths and rock construction entrances

Activities that are not considered land disturbance (and that are not subject to the stormwater management requirements) include:

- Individual home gardening, repairs, and maintenance
- Individual service and sewer connections for single- or two-family residences
- Certain agricultural practices
- Projects under the technical supervision of the U.S. Natural Resource Conservation Service
- Installation, maintenance, and repairs of aboveground utilities
- Construction, repair, or rebuilding of railroad tracks
- Milling and repaving of roads and pavement including full depth reclamation provided that the subbase is undisturbed

BMPs for erosion and sediment control are still required to be implemented for these activities.

3.3.2 New and Redevelopment

The second factor that determines the extent of stormwater management requirements is whether a project is a new development or a redevelopment project. Both new and redevelopment projects are subject to the stormwater requirements, but the volume of stormwater management required may differ.

Construction of a new building or structure on its own lot is considered new development. Redevelopment is the alteration of developed land. For example, removal of an existing parking lot for construction of a new building is considered redevelopment for the purposes of compliance with the stormwater requirements. The term redevelopment is not intended to include such activities as exterior remodeling, which would not be expected to cause adverse stormwater quality impacts. New buildings or structures constructed on a lot that already contains existing buildings, and which are not part of a phased project, may be considered redevelopment.

3.3.3 Project Watershed

The third factor determining the stormwater management requirements is the watershed location of a project. Both new and redevelopment projects, except those located in the South Chickamauga Creek watershed, must manage the first 1.0 inch of every rainfall event. The South Chickamauga Creek watershed is a TDEC-designated Exceptional Tennessee Water, and therefore, a higher performance standard has been set for protection of this watershed.

New development projects located in the South Chickamauga watershed must manage the first 1.6 inches of every rainfall event such that no runoff leaves the site (i.e., provide volume management). Redevelopment projects in the South Chickamauga watershed are required to manage only the first 1.0 inch of each rainfall event.

The standards applicable to different projects based on project type and watershed location are indicated in Table 3-2.

This manual is intended to provide technical direction on stormwater management practices to meet the requirements of the City's MS4 NPDES Permit, and as codified in the City of Chattanooga Code, Chapter 31, Article VIII. **THESE CRITERIA MAY BE SUBJECT TO LATER CHANGE AND PROJECTS LOCATED IN WATERSHEDS DESIGNATED AS EXCEPTIONAL TENNESSEE WATERS OR AS IMPAIRED WATERS BY TDEC MAY BE SUBJECT TO MORE RESTRICTIVE REQUIREMENTS DETERMINED BY THE CITY.** The applicant is responsible for determining the current applicable stormwater requirements as defined by the tables and figures provided by the City at http://www.chattanooga.gov/public-works/city-engineering-a-water-quality-program.

Table 3-2. Applicable Rainfall Depth for Stormwater Management Based on Project Type and Watershed Location

PROJECT TYPE		RAINFALL DEPTH
REDEVELOPMENT		1.0-inch
NEW DEVELOPMENT	ALL OTHER	1.0-inch
	SOUTH CHICKAMAUGA WATERSHED (INCLUDING FRIAR BRANCH AND MACKEY BRANCH)	1.6-inches

3.4 Performance Standards

Projects that are subject to the City's stormwater management requirements must address three components of stormwater management. These performance standards include:

1. Volume Management (SOV)
2. Water Quality Treatment
3. Peak Rate Control

1. Volume Management or Stay-on-Volume

The City's MS4 Permit requires "all new and redevelopment projects to incorporate runoff reduction measures designed, constructed, and maintained to manage (infiltrate, evapotranspire, harvest and/or reuse), at a minimum, the first inch of water from every rainfall event preceded by 72 hours of no measurable precipitation with no discharge from the project site to surface waters."

SOV is the volume of stormwater (in cubic feet) that must be captured and managed onsite as required by the City's stormwater regulations with no discharge to surface waters or City storm sewers. SOV is calculated based on the rainfall depth and the land cover types within the project area. The first step in determining a site's numerical SOV requirement is to determine the depth of rainfall that must be managed, as discussed previously in this chapter and as indicated in Table 3-2. Unless otherwise stipulated, SOV will be calculated using a 1-inch rainfall event.

The methodology to calculate SOV, using rainfall depth and project land use data, is based on the Small Storm Hydrology Method. Detailed information on the methodology, as well as guidance and worksheets on calculating SOV, is provided in Chapter 7 in of this manual.

Projects that manage the SOV from 100 percent of the disturbed area are assumed to have met all water quality (pollutant removal) requirements pursuant to Section 3.2.5.2.2 of the City's MS4 Permit.

Management of SOV may be accomplished through evapotranspiration, harvesting, reuse, infiltration, or any combination thereof. Specific techniques and practices (BMPs) that can be used to manage the SOV are described in detail in Chapter 5 of this manual. Projects that implement practices to reduce the amount of site disturbance (protective BMPs) can reduce the required SOV. Practices that restore important natural features (restorative BMPs) also provide direct and quantifiable SOV benefits. The specific guidance on the design requirements for BMPs, including protective, structural, and restorative BMPs, is provided in Chapter 5.

SOV and Infiltration:

Infiltration of runoff into the soil mantle is one of a number of techniques available to manage the SOV. There are numerous water quality benefits to infiltration; however, the capacity of a project site to incorporate infiltration must be determined, and the BMPs designed accordingly. Not all project sites will be suitable for infiltration. For projects proposing infiltration of any portion of the SOV, technical documentation must be provided indicating that infiltration is feasible, and that the BMPs are appropriately designed for site conditions.

Guidance regarding infiltration testing methods, procedures, and design guidelines is provided in Protocols 3 and 4 of this manual. For permitting purposes (as described in Chapter 4), during the **concept stormwater management plan phase**, a desktop analysis is sufficient and detailed testing is not required. Detailed testing is required for final plan approval.

While more detailed guidance is provided in Protocols 3 and 4 regarding infiltration testing, feasibility, and design practices, important infiltration considerations include the following:

- Infiltration is generally not feasible or recommended on slopes greater than 15 percent.
- Infiltration is not recommended on soils consisting of fill material. Compaction of fill will impede infiltration.
- Runoff from hot spot areas cannot drain to proposed infiltration areas.
- The bottoms of proposed infiltration strategies must be separated by at least 2 feet (vertically) from any limiting layer (seasonal high water table, bedrock, etc.).

- Infiltration strategies must be located in accordance with the TDEC Division of Water Resources to ensure compliance with setbacks from any water supply well.
- Infiltration setbacks from buildings and structures must be maintained as required to be consistent with the City's Building Code and Protocol 1.

Whenever the SOV from the project area cannot be managed or achieved onsite, the applicant/owner must provide appropriate documentation to the City detailing why SOV cannot be managed.

2. Water Quality Treatment

The City's MS4 Permit requires projects that are unable to manage 100 percent of the SOV to provide water quality treatment to unmanaged water volume before it may be discharged. Projects that manage the SOV from 100 percent of the disturbed area are assumed to have met all water quality (pollutant removal) requirements. Unmanaged runoff volume must achieve 80 percent TSS reduction.

The water quality of the City's streams and waterways is adversely impacted by TSS, which originates from two primary sources. The first source is "runoff" from the land surface during storm events. This runoff conveys pollutants washed from the land surface, including TSS and pollutants that are attached to the TSS particles. The second source of TSS is stream channel erosion (hydro-modification). Stream channel erosion is a result of the increased volume of runoff from development during small and moderate rainfall events. As the channel widens and deepens to carry the increased runoff, the stream channel itself is eroded. For this reason, volume management (SOV capture) provides water quality benefits.

If 100 percent of the SOV cannot be managed, treatment of the water quality volume must be provided, and the treated water released in accordance with peak discharge requirements. Further discussed in Chapter 7, the water quality volume (WQv) is defined as the runoff resulting from the 1-year, 24-hour type II rainfall event for BMPs that treat flow rates and 2.1-inch rainfall for BMPs that treat volumes. The specific requirements for capture, treatment, and release of the WQv are also provided in Chapter 7, and can be met by BMPs described in Chapter 5.

3. Peak Rate and Flood Control Standards

Projects proposing land disturbance must implement measures as necessary to mitigate the post-development peak runoff rates to no greater than pre-development peak runoff rates for the 2-, 5-, 10-, and 25-year 24-hour storm events. In addition to peak rate attenuation for the 2-, 5-, 10-, and 25-year 24-hour storms, the peak flow rate and maximum water surface elevations must be calculated for the 100-year storm event. Please see Table 3-1.

Projects up to ½ acre of disturbance may be eligible for the Simplified Approach for stormwater calculations, as described later in this chapter.

The performance requirements for new and redevelopment projects are summarized on Figure 3-1.

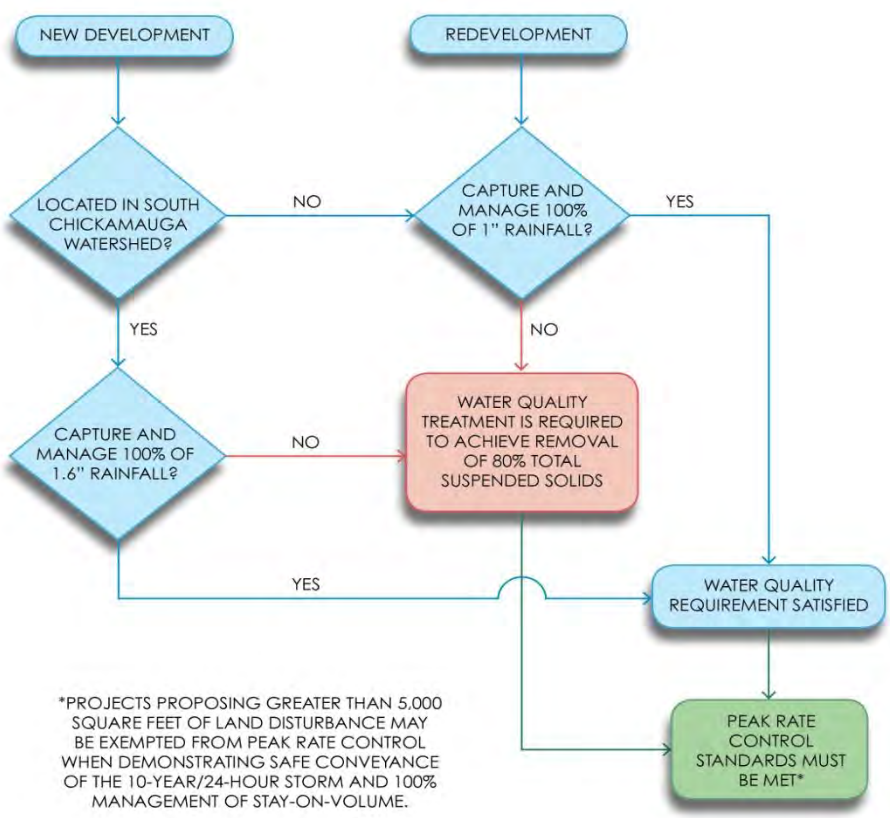

Figure 3-1. Stormwater Performance Requirements for New and Redevelopment Projects

Because BMPs and SOV practices can directly reduce the peak rate of runoff from a project site, guidance is provided in Chapter 7 regarding calculation methodologies that the applicant can use to quantify this benefit when calculating peak flow rates.

3.5 Simplified Approach

Applicants/owners seeking Land Disturbing Permits for small projects may demonstrate management of the required SOV using a Simplified Approach, with City approval.

Small Project:

A small project (see Table 3-1) is any project where less than ½ acre of land disturbance is proposed.

Simplified Approach:

The Simplified Approach to demonstrating SOV requirements allows applicants/owners proposing qualifying small projects (CSO area excluded) to construct and maintain specific LID practices without detailed engineering SOV calculations of the proposed BMPs. Small projects that do not fully meet SOV requirements must meet water quality requirements. The Simplified Approach requires applicants/owners to provide detailed site information, technical design, and performance information to demonstrate compliance with all other stormwater management regulations as also identified in Table 3-1. This is also discussed in Chapter 4.

Applicants/owners must obtain City approval to use the Simplified Approach prior to submitting a Land Disturbing Permit Application by attending a concept plan meeting with the City. The City is not required to grant the use of the Simplified Approach to any applicant/owner and may, at its discretion, deny approval to use the Simplified Approach and require adherence to the Performance Approach outlined in Section 3.6 below.

3.6 Performance Approach

Projects for which the proposed area of land disturbance is equal to or greater than ½ acre, and projects that have not received City approval to use the Simplified Approach, must implement the Performance Approach to stormwater management. The Performance Approach requires applicants/owners to provide detailed site information, technical design, and performance information to demonstrate compliance with all stormwater management regulations, including peak rate mitigation to pre-development flow rates for the 2-, 5-, 10-, and 25-year storm 24-hour events. Chapter 7 provides specific guidance.

Applicants/owners must complete and submit the supporting documentation with all preliminary and final subdivision plans and with all land development plan submissions. The City may require any applicant/owner to submit additional calculations and/or supporting documentation as necessary.

3.7 Incentives

Certain redevelopment projects may be eligible for a reduction in the required volume of stormwater that must be managed based on the City's incentive standards for redeveloped sites. Redevelopment credits will be determined by the City at the concept stormwater management phase.

The City's MS4 Permit allows incentive standards for redeveloped sites. The City **may** allow a 10 percent reduction in the volume of rainfall to be managed for the following types of development:

- Redevelopment within certain areas as defined by the City
- Brownfield redevelopment
- High density (> 7 units per acre)
- Vertical density (floor to area ratio [FAR] of 2 or > 18 units per acre)
- Mixed-use and transit-oriented development (within ½ mile of transit)

The 10 percent volume management reduction may be cumulative up to 50 percent for sites that meet multiple incentives. The approval of any incentive reduction is at the discretion of the City to determine if the site meets the intent of the incentives. The applicant/owner must demonstrate that the proposed project meets the intent of the incentives.

3.8 Offsite Mitigation and Mitigation Fee (Fee-in-Lieu)

Offsite Mitigation:

Where the SOV from 100 percent of the project area cannot be managed or achieved onsite, the applicant/owner may elect to propose offsite mitigation for City approval. Applicants/owners that have obtained City approval must manage 1.5 times the unmanaged SOV offsite at another location within the same United States Geological Survey (USGS) 12-digit Hydrologic Unit Code (HUC). Offsite mitigation projects may be located on private or public property, as approved by the City, and are subject to all Land Disturbing Permit requirements.

Mitigation Fee (Fee-in-Lieu):

Where the SOV from 100 percent of the project area cannot be managed or achieved onsite, the applicant/owner may, instead of offsite mitigation, propose to make payment into a public stormwater project fund established by the City. Payment of this fee in lieu of managing 100 percent of the SOV must be approved by the City and, at a minimum, be equal to 1.5 times the estimated cost of onsite runoff reduction controls.

Applicants/owners must obtain City approval for payment of a mitigation fee in lieu of managing stormwater. The City may at its discretion deny the use of the mitigation fee to any applicant/owner if stormwater management may be more fully implemented on a site.

Peak Rate Control:

Projects approved for offsite mitigation or fee-in-lieu must meet peak rate control and mitigation requirements for discharges from the project site as discussed in this chapter.

Considerations for Offsite Mitigation or Mitigation Fee (Fee-in-Lieu):

Whenever the SOV from 100 percent of the project area cannot be managed or achieved onsite, the applicant/owner must provide appropriate documentation to the City detailing why SOV or WQv cannot be managed. Economic hardship, site program density (lack of space for BMPs), and other similar conditions are not presumed as a basis for site inability to meet SOV and/or peak rate control requirements.

Acceptable reasons for **not** managing all of the SOV from 100 percent of the project area onsite may include:

- The depth from the existing ground surface to seasonal high groundwater or other limiting layer (i.e., till or bedrock) is less than 2 feet, or the depth from the base of a proposed infiltration SOV management strategy to seasonal high groundwater or other limiting layer is less than 2 feet **and** other volume reduction measures (i.e., reuse, restoration) cannot be implemented to meet full SOV requirements.
- Contaminated soils or other site constraints **and** other volume reduction measures (i.e., reuse, restoration) cannot be implemented to meet full SOV requirements.
- The City has identified a preferred stormwater project or location in lieu of management at the site.
- Conditions as identified and approved at the discretion of the City.

3.9 Requirements for Construction Site Runoff (Erosion and Sedimentation)

Erosion and Sediment Control Plan:

Chattanooga City Code defines an Erosion and Sediment Control Plan (E&S Plan) as a written plan, including drawings or other graphic representations, for the control of soil erosion and sedimentation resulting from a land disturbing activity. In accordance with Chattanooga City Code, an E&S Plan shall apply BMPs in accordance with the latest adopted manual for that purpose and as specified in the City Code, Chapter 31, Article VIII. The E&S Control Plan shall be approved by the manager prior to the issuance of the Land Disturbing Permit.

3.10 Resources

1. City of Chattanooga MS4 Permit Number TNS068063, accessed at: *http://www.tn.gov/environment/wpc/stormh2o/TNS068063.pdf*

2. EPA Green Infrastructure, accessed at: *http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm*

3. TDEC Green Development, accessed at: *http://tennessee.gov/environment/greendev/green_links.shtml*

4. Low Impact Development Center Urban Design Tools for Low Impact Development, accessed at: *http://www.lid-stormwater.net/index.html*

5. Natural Resources Development Council Low Impact Development, accessed at: *http://www.nrdc.org/water/pollution/storm/chap12.asp*

6. American Rivers, Clean Water for Maryland Local Ordinances for Environmental Site Design, accessed at: *http://www.americanrivers.org/assets/pdfs/clean-water-/clean-water-for-maryland.pdf*

7. 4th Edition of the **Tennessee Erosion & Sediment Control Handbook**; Editable standard drawings

8. City of Chattanooga GIS maps at: http://www.chattanooga.gov/searchresults?q=gis+maps

Chapter 4 Integrating Stormwater Management with Site Design

4.1 General Design and Review Process for New Development and Redevelopment

The design process outlined in this chapter provides guidance for implementing the runoff reduction and stormwater management strategies necessary to comply with the City's stormwater management program. The design process includes:

- Identifying and protecting sensitive environmental features
- Minimizing impervious cover
- Managing stormwater runoff at the source
- Integrating stormwater management throughout the design process
- Quantifying the benefits of soil and vegetation to achieve stormwater goals

This process requires integration of site design, natural hydrology, and smaller decentralized stormwater control measures to capture and treat stormwater runoff. This process also requires a new approach, both to site planning and to the design of specific stormwater practices for each site. Specifically:

1. The stormwater solution for a project should be designed as a distributed system that may serve multiple functions and that achieves a number of different purposes.
2. Each stormwater intervention should be designed as a part of a larger (connected) and integrated system where individual practices work together in an appropriate sequence to achieve the overall objective.
3. With this integrated approach, it is a basic assumption that in the design of the stormwater management system, soils and vegetation will be used together to achieve the required SOV and other goals.

The adoption of this approach is fundamental to successfully achieving project stormwater goals and is a shift from prior methods that may have relied on "end-of-pipe" or single measure solutions. This approach will allow the property owner/developer to achieve greater efficiency and value in the protection and development of land. This approach will also integrate the design and review process to allow for greater communication between designers and reviewers.

4.2 Concept, Preliminary, and Final Stormwater Management Plan Review Process

The design process for stormwater management involves review and approval by City staff at three phases of project development: concept, preliminary, and final. During the concept phase, applicants/owners will provide the City with a concept stormwater management plan and schedule a concept plan review meeting with City staff. The purpose of this meeting is to provide the applicant/owner and the City with an opportunity to discuss the project and potential stormwater management approaches and requirements before the applicant/owner has proceeded with detailed site investigation or design documentation. The concept stormwater management plan and concept plan review meeting are intended to ensure that all development standards are understood and that opportunities for a more site-sensitive and integrated design plan are explored and discussed with the City.

In the concept phase, the design drawings will be conceptual and diagrammatic, and supporting calculations and details are not required. While accurate property and survey data are necessary, detailed site investigation and testing are not required at the concept plan level. After comment by City staff, these ideas will be developed into comprehensive site plans in the preliminary plan phase, and then into construction drawings for the final plan submission. The final plan must be approved by the City prior to issuance of a Land Disturbing or Building Permit. The applicant/owner is responsible for obtaining all other applicable permits from state and federal agencies.

During all phases, applicants/owners will prepare and provide the City and other appropriate reviewing agencies with a submission package that includes a full set of the required site design drawings specified for that phase. A checklist detailing drawings and materials required for submission at each phase is provided in Appendix H. For the preliminary and final plan set, the drawings should include a site assessment and protection plan, a stormwater management plan, a site landscape plan, and an erosion and sediment control plan, as well as necessary details, and be packaged with supporting calculations, data, and narratives for preliminary and final stormwater management plan approval.

All plan submissions will include the specified number of paper copies as well as electronic files. The electronic file will be treated as a trade secret for purposes of protecting it from disclosure to competitors (*reference Article 202.1*). These submittals are intended to be concurrent with the existing subdivision submittal procedure.

The processes and procedures in this chapter are intended to provide performance guidance for Article 2 of the existing City of Chattanooga Subdivision Regulations as they relate directly to stormwater management. Specifications and items of procedure in Article 2 remain in force. (*Reference Article 1, 106.2.1.*)

4.2.1 Concept Phase

4.2.1.1 Concept Stormwater Management Plan and Concept Review Meeting

A concept review meeting is required for all projects subject to the City's stormwater management requirements. The concept review meeting provides the opportunity for applicants/owners to receive advice and guidance on the requirements necessary to comply with stormwater management standards and other applicable provisions of the City Code and zoning ordinances. The concept phase is intended to facilitate resolution of any potential issues while the project is in the early design phases.

A low-impact development approach to stormwater management requires integration of site design, natural hydrology, and smaller decentralized stormwater control measures to capture and treat stormwater runoff close to the source. This process also requires a new approach, both to site planning and to the design of specific stormwater practices for each site. Soils, vegetation, and natural features such as riparian buffers play an important role in achieving the stormwater management goals. The adoption of this approach is fundamental to success, and is a shift from prior methods that may have relied on “end-of-pipe” or single measure solutions.

The concept stormwater management plan should be clearly identified as “Concept Stormwater Management Plan” and should include sufficient information to adequately indicate the nature and extent of the proposed development and its relationship to existing conditions and facilities in the area in which it is located. The concept stormwater management plan should also include topographic, physical, and manmade features, as well as sensitive natural features such as steep slopes, woodlands, wetlands, and community waters. Detailed site testing, soils testing, and borings are **not** required at this stage; a desktop analysis of site conditions is acceptable.

Applicants/owners will provide the City with one electronic copy of concept stormwater management plan drawings, as well as one electronic copy each of all applicable supporting data and plans for review and comment.

4.2.1.2 Concept Stormwater Plan Contents

Concept stormwater plan submissions must include the information outlined on the Concept Stormwater Management Plan Checklist, found in Appendix H of this manual.

A signed and completed Concept Stormwater Management Plan Review Meeting Application, found in Appendix G, must be submitted with all concept stormwater management plan submissions when scheduling a concept review meeting with the City.

4.2.1.3 Concept Plan Site Assessment and Stormwater Management

At the concept stormwater management plan level, the existing site conditions assessment plan is an analysis that reflects available information regarding natural and manmade site conditions.

Detailed stormwater calculations are **not** required at the concept plan level. However, estimates of the SOV, required BMP area(s), and proposed BMP type(s) are required to ensure that sufficient and suitable site areas are reserved for BMPs. The licensed professional will benefit and is **strongly** advised to develop concept level stormwater calculations to confirm that the proposed BMPs will meet the SOV and water quality requirements in terms of proposed BMP type and concept level size, as well as any rate control devices necessary to attenuate peak runoff rate. Guidance on stormwater calculations is provided in Chapter 7.

Applicants/owners are strongly advised to select and locate BMPs that can be anticipated to meet the stormwater requirements at the specific site. If there are significant changes in stormwater management design between the concept plan and the preliminary plan, the City may require a revised concept stormwater management plan submission and approval prior to preliminary plan submission. Significant changes include substantial changes in the type and location of stormwater BMPs (i.e., the elimination of proposed green roofs and replacement with underground detention/infiltration systems). Adjustments to proposed BMPs as a result of infiltration rates or other site-specific testing data are not considered significant changes to the concept plan.

The process for concept stormwater management plan development and approval is outlined on Figure 4-1.

Concept Stormwater Management Plan Development and Approval Process

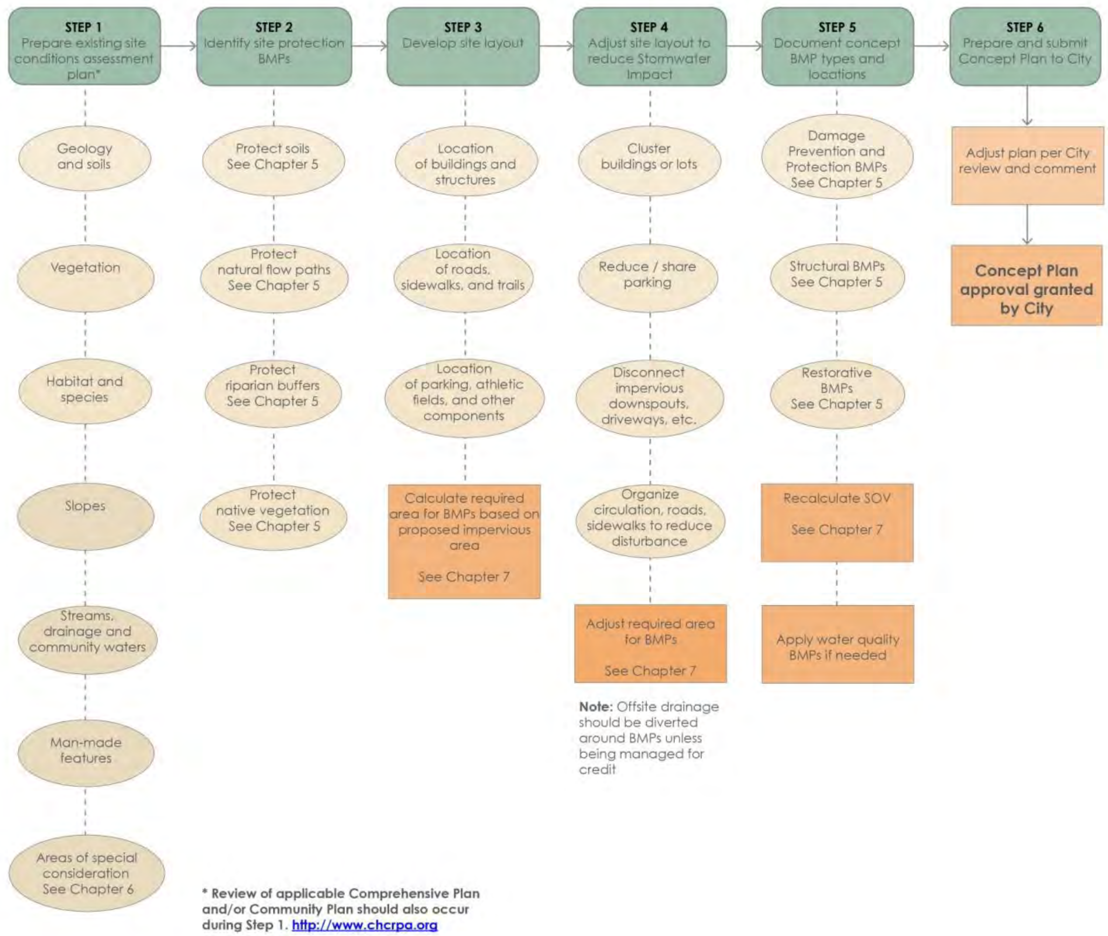

Figure 4-1. Concept Stormwater Plan Process

4.2.1.4 Concept Review Meeting

During the concept review meeting, the City can provide guidance regarding the appropriate rainfall depth for SOV calculation, applicable buffer and planting requirements, and any other relevant design standards. Reviewers may also comment on the proposed initial design ideas and evaluate their success in preserving site character and function. The applicant/owner and engineer/designer must attend the concept review meeting. The following may take place at the meeting:

- The applicant/owner will discuss the existing features, soil, vegetation, structures, and existing drainage pathways. The City will discuss opportunities to protect natural features and their potential for more effective post-construction management.
- The City and the applicant/owner will discuss ways to minimize impacts and stormwater management costs.
- The City will provide guidance regarding the review process and respond to questions the applicant/owner may have.
- The City and applicant/owner will discuss potential volume credits, economic credits, and fees.
- The City and applicant/owner may discuss potential issues related to site conditions, stormwater management, and any other concerns.
- The City and the applicant/owner may discuss concerns of all site reviewers, such as Traffic Engineering, Sanitary Sewers, Zoning, and work with the applicant/owner to resolve conflicts.

The applicant/owner may be asked to submit a revised concept stormwater management plan following the concept meeting to reflect any changes or discussion items. A second concept review meeting is not required, but may be requested by the applicant/owner if desired.

Concept stormwater plan approval is a required prerequisite for preliminary and final approval prior to permitting. Concept stormwater management plan approval by the City does not constitute fulfillment of all requirements necessary to begin construction. Concept stormwater plan approval does not relieve the applicant/owner from meeting regulatory obligations and obtaining necessary permits from all agencies with jurisdiction over the project.

Applicants/owners will provide the City with one hard copy and one electronic copy of concept stormwater management plan drawings, as well of all applicable supporting data and plans for review and comment.

4.2.2 Preliminary Phase

4.2.2.1 Preliminary Stormwater Management Plan Contents and Submission

Preliminary plan packages are submitted after site layout and design have been fully established with regard to the intended use of the site. Preliminary plan approval is a required prerequisite for final approval. The preliminary plan must provide sufficient design documentation and supporting data and calculations (i.e., soil testing data, stormwater calculations) for the City to determine whether the proposed project will meet the City stormwater management requirements.

Applicants/owners will provide the City with one hard copy and one electronic copy of preliminary stormwater management plan drawings, as well as of all applicable supporting data and plans for review and comment.

4.2.2.2 Preliminary Stormwater Management Plan Contents

Preliminary stormwater management plan submissions must include the information outlined on the Preliminary Stormwater Management Plan Checklist found in Appendix H.

4.2.2.3 Preliminary Plan Review and Approval

The City will review and provide comments on preliminary stormwater management plan submissions. The City will approve preliminary stormwater management plans when the submission has satisfied all technical requirements and City Codes. Approval of preliminary plans will not result in the issuance of any permit approval by the City.

4.2.3 Final Phase

4.2.3.1 Final Stormwater Management Plan Contents and Submission

The final stormwater management plan includes any design modifications necessary to address City review comments or to meet the stormwater management requirements. Final stormwater management plan packages should be submitted after all comments provided on the preliminary stormwater management plan package have been satisfactorily addressed.

Applicants/owners will provide the City with two paper copies of final stormwater management plan drawings, as well as two paper copies each of the applicable supporting data and plans for distribution to reviewing agencies. An electronic submission of all materials is also required.

No final plan will be approved until all applicable state and federal permits have been obtained and all applicable bonds have been posted.

4.2.3.2 Final Stormwater Management Plan Contents

Final stormwater management plan submissions must include the information outlined on the Final Stormwater Management Plan Checklist found in Appendix H.

4.2.3.3 Final Plan Review and Approval

The City will review and approve complete final stormwater management plan submissions after all applicable Chattanooga and state and federal permits have been obtained, and all applicable provisions of the City Code have been satisfied.

Following concept stormwater management plan approval by the City, preliminary stormwater management plan and final stormwater management plan approval will follow the process shown on Figure 4-2.

4.2.3.4 As-Built Drawings

Current procedures, requirements, and content with regard to as-built drawings remain in force. These are identified on the City's web page at http://www.chattanooga.gov/public-works/land-development-office/forms-and-permits.

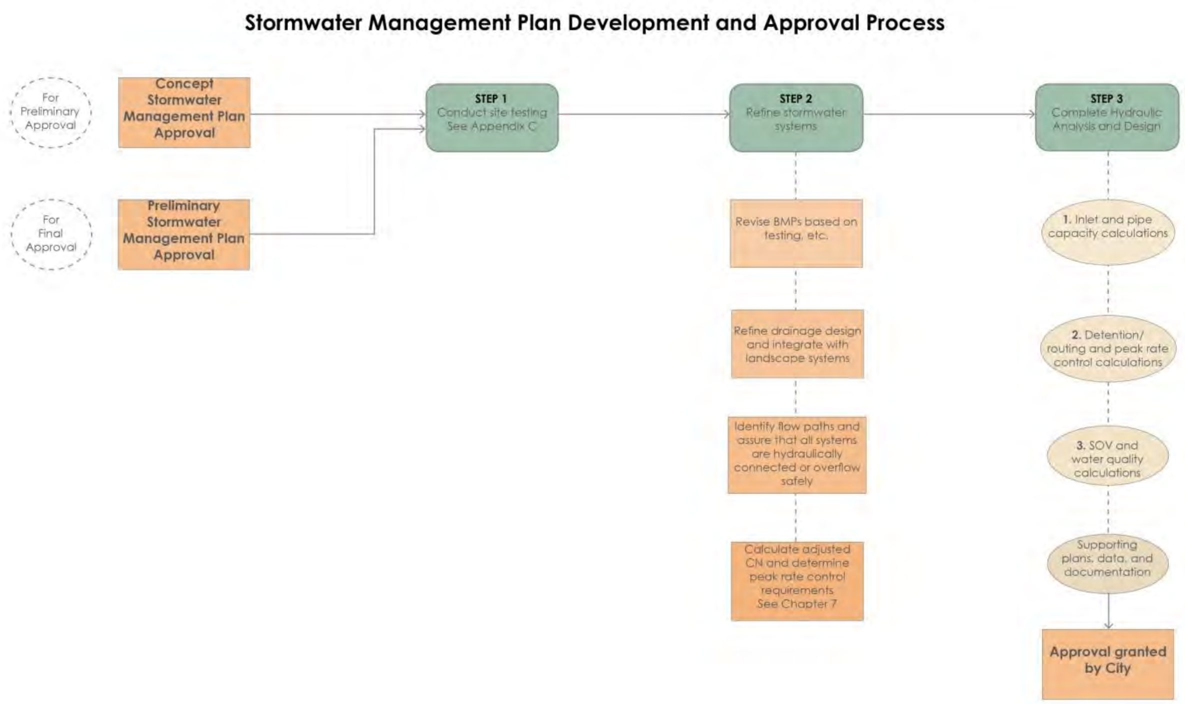

Figure 4-2. Preliminary/Final Stormwater Plan Process

Chapter 5 Stormwater Management Practices

5.1 Introduction

Chapter 4 of this manual guides the permit applicant through the site design process, including conceptual, preliminary, and final phases. This process modifies traditional practices currently in use in the City of Chattanooga—shifting the focus from "end-of-pipe" and "single-purpose solutions" to an integrated design, which includes combinations of BMP options discussed in Chapter 5. The goal of Chapter 4 is to help the applicant meet the new stormwater regulations by creating a more efficient site plan that blends preservation, restoration, building, and management practices found in Chapter 5.

Chapter 5 provides detailed guidance for the proper design and application of structural BMPs as well as BMPs that preserve and restore the intrinsic value and hydrological performance of the land. This manual incorporates the landscape itself, typically underused as a BMP. These landscape-based BMPs require a new approach to site design where landforms, soils, and vegetation are used together with structural BMPs to effectively achieve the required SOV, water quality, and other site-specific goals. Applicants/ owners are strongly encouraged to integrate and combine the BMPs presented in Chapter 5 to achieve the required stormwater management goals and to optimize preservation and restoration of natural features that play key roles in hydrologic processes.

The BMPs described in this chapter are organized into four sections and are presented in a sequential order, which reflects the development process:

(1) 5.2 Damage Prevention and Protection Practices
(2) 5.3 Structural BMPs
(3) 5.4 Restoration Practices
(4) 5.5 Management Measures

It is important to note that because Damage Prevention and Protection and Restoration Practices (the landscape-based BMPs) must take into account a number of site-specific variables, they are presented as guidelines, rather than fixed specifications. Criteria checklists and Protocol 5 are provided to ensure that effective BMPs are chosen, designed, constructed, and maintained, in accordance with site-specific constraints and opportunities. Additionally, many of the Protection and Restoration BMPs are similar in subject matter, but different enough to warrant their own section or subsection. Because of this, concepts found within the write-ups may be repetitive.

The write-up of each BMP provides an overview of the BMP in fact sheet summary and then reviews in detail the functions, design, and construction requirements, as well as necessary management of the BMPs under the following headings:

(1) Description
(2) Applicability Matrix Summary
(3) Applicable Protocols
(4) Design Considerations
(5) Construction Considerations or Sequence
(6) Operations and Maintenance
(7) Criteria Checklists

The BMPs presented in Chapter 5 are the most relevant to the Chattanooga region and provide guidance for a developer or large property owner to meet Chattanooga's recently adopted stormwater management regulations.

5.2 Damage Prevention and Protection Practices

Protective BMPs are tested ways to preserve the hydrologic functions of existing site resources. They are to be integrated into the overall design before the program and plans are fixed, hence, they are the first grouping of BMPs discussed in Chapter 5. If not planned for in advance, the stormwater benefits these resources provide may be lost during development.

Landscape-based BMPs are often the least familiar and most underutilized stormwater management practices. Preservation of existing areas with key hydrologic functions, floodplains, forests, meadows, existing natural drainage, etc., can be some of the most economical and efficient BMPs available. It is also understood that during the construction process, some protected areas may need to be temporarily accessed. These "areas of minimal disturbance" are accounted for within each of the Damage Prevention and Protection BMPs. Any disturbance within a protected area will require some level of remediation.

Because these measures must take into account a number of site-specific variables, they are presented as a discussion of options. Criteria checklists and Protocol 5 are available to help determine if the protected area in question is applicable for preservation or will need additional restoration measures discussed in Section 5.4.

When calculating the stormwater benefits of specific protective BMPs, the applicant should note that **the area of the protective BMPs is <u>excluded</u> from the project area used to calculate the SOV and water quality requirements**. **Chapter 7 provides detailed information regarding calculations.**

5.3 Structural Design Measures

Structural design measures presented herein are engineered BMPs designed to capture and manage a given SOV, through infiltration, slow release, and/or capture and reuse. These BMPs are widely prevalent and in common use throughout the southeastern region of the United States. However, as with any constructed system, and as with all BMPs presented, they depend on proper design, siting, application, construction, and maintenance.

Thirteen structural BMPs are described in this section. Many of these "structures" are natural system-based and include both planted vegetation and engineered soil as part of their function management. Although classified as "structural," they can and should be viewed as "green structures" or "green infrastructure."

The effective application of engineered BMPs can provide significant stormwater benefits. When calculating stormwater benefits of specific structural BMPs, the applicant should note that **calculation support for demonstration of SOV and water quality is found under the Design Considerations heading of each structural BMP write-up. Chapter 7 provides detailed information regarding calculations.**

5.4 Restorative Practices

Although restorative measures are not typically considered a BMP or included as part of the site development process, they offer the potential to solve a variety of hydrologic issues. Restoration of soils and natural vegetation can increase the ability of a landscape to naturally reduce runoff volume and velocity. Restorative BMPs include reestablishing natural flow paths, naturalizing existing swales and drainage ditches, enhancing existing natural cover types or establishing new natural cover types, and amending disturbed soils.

Because these measures must take into account a number of site-specific variables, they are presented as a discussion of options. Criteria checklists and Protocol 5 are available to determine appropriate actions required for the proposed restoration area and continued maintenance efforts. Restoration is a practice that happens over time. Much of the maintenance includes monitoring and removal of non-native invasive species, especially during the establishment period.

When calculating the stormwater benefits of specific restorative BMPs, the applicant should note that **a percentage of the area slated for a restorative BMP can be counted toward a reduction of the total SOV of the project area as well as any tree over 1 inch in caliper planted. Additionally, the curve number used to calculate water quality requirements is adjusted. Chapter 7 provides detailed information regarding calculations.**

5.5 Management Measures

Each of the first three BMPs discussed has its own management measures. Additional management strategies, not specific to any one BMP, can significantly improve water quality.

Management measures include programs and activities that may be implemented to support pollutant removal efforts by the City.

When evaluating the stormwater benefits of management measures, the applicant should consult the BMP narrative during development of the proposed management activity.

Benefits

SOV credits are associated with each BMP and the use of these measures can reduce the hydrologic curve number, thereby reducing water quality requirements. However, there are a number of other benefits beyond reduction of requirements that should be taken into account when choosing which combination of BMPs to employ. Below is a perfunctory discussion of the benefits of this type of approach. Primary benefits include project profitability after construction, reduced construction costs, and improved stormwater performance.

1. Using BMPs as site amenities and as green infrastructure may add value to the development, generating higher sales or rents.

2. Reducing project SOV with landscape-based BMPs lessens the need for more expensive stormwater management interventions (i.e., structural BMPs) and can lower construction costs.

3. Using less infrastructure by treating stormwater close to the source (less subsurface piped conveyance) and reducing pervious surface (e.g., narrower and shorter roads) can fulfill the same site program and potentially lower construction costs.

4. An integrated design approach that connects the BMPs used on the site into a system creates redundancy, thereby adding resilience to the system.

5. BMPs can serve multiple purposes. For example, protected areas can also be parks or nature trails.

6. BMPs that mimic and/or incorporate existing hydrologic regimes take advantage of what works best on a particular site and adapt to natural stormwater systems beyond the site.

Applicability Matrix

All sections within Chapter 5 include a discussion of the BMP selection process, including a matrix that compares the key applications and functions of each BMP to help applicants/owners choose BMPs that are appropriate for their project site. Figure 5-1 provides an overview of BMP applicability from which applicants/owners may begin to consider which BMPs are appropriate for their project site.

BMP	Applicability	Volume Reduction	Water Quality[1]	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden[2]	Cost[3]
Protect Undisturbed & Healthy Soils; 5.2.1	U/S/R	H	H	H	H	M	M	H	L	L
Preserving Land Forms; 5.2.1.1	U/S/R	H	H	H	H	M	M	H	L	L
Protecting Erodible Soils on Steep Slopes; 5.2.1.2	U/S/R	H	M	H	H	M	M	H	L	L
Protect/Incorporate Natural Flow Paths; 5.2.2	U/S/R	H	H	M	H	M	M	H	L	L
Protect and Preserve Riparian Corridors; 5.2.3	U/S/R	H	H	M	L	M	M	H	L	L
Protect and Preserve Natural Vegetation; 5.2.4	U/S/R	H	H	H	H	H	H	H	L	L
Protect Historic or Specimen Trees; 5.2.4.1	U/S/R	M	L	M	M	H	H	M	L	L
Pervious Pavement; 5.3.1	U/S/R	H	H	H	H	H	M	L	L	M
Infiltration Bed; 5.3.2	U/S/R	H	H	H	H	H	L	L	L	M
Infiltration Trench; 5.3.3	U/S/R	H	H	M	H	H	M	L	L	M
Bioretention; 5.3.4	U/S/R	L/H	H	M	L/H	H	M	H	L/M/H	L/M/H
Vegetated Swale; 5.3.5	U/S/R	H	H	M	M	M	M	M	L	L
Vegetated Filter Strip; 5.3.6	U/S/R	L	M	M	L	M	M	L	L	L
Infiltration Berm; 5.3.7	S/R	H	H	H	H	M	M	M	L	L
Green Roof; 5.3.8	U/S/R	M	H	H	L	H	H	M	L/M	M/H
Runoff Capture and Reuse; 5.3.9	U/S/R	H	H	H	L	H	L	L	M/H	M/H
Disconnected Impervious Area; 5.3.10	U/S/R	H	L	H	H	H	H	L	L	M
Stormwater Planter Box; 5.3.11	U/S	L	M	H	M	H	M	L	M/H	L/M
Manufactured Devices[4] ; 5.3.12	U/S/R	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H
Naturalize and Retrofit Existing Detention Basins; 5.3.13	U/S/R	H	H	H	H	H	H	H	L	L
Recreate Natural Flow Patterns; 5.4.1	U/S/R	M/H	M/H	M	M	M	M	H	M	L/M/H
Naturalize Swales and Drainage Ditches; 5.4.1.1	S/R	H	H	M	M	H	H	M	M	L/M/H
Enhance Native Cover Types; 5.4.2	U/S/R	H	H	M	M	H	H	H	L	L
Cover Type Change; 5.4.2.1	U/S/R	H	H	M	H	H	H	M	M	L
Amend and Restore Disturbed Soils; 5.4.3	U/S/R	H	H	M	H	M	M	H	L	L
Street Sweeping; 5.5.1	U/S	L	M	L	L	L	L	L	M/H	L/M

[1]In the context of this chapter, water quality refers to Total Suspended Solid reduction. Additional water quality ratings for other pollutants of concern are found in Chapter 7 of this guide.
[2]Maintnenance burden varies with complexity of design options.
[3]Cost may vary - initial costs may be relatively high and low over long-term.
[4]Ratings vary widely depending on type and application of manufactured device.

Figure 5-1. BMP Applicability Matrix

5.2.1 Protect Undisturbed and Healthy Soils

Description

Undisturbed soils are soils that have developed over long periods of time through the influence of climate (temperature, precipitation), landforms, and biological organisms on the original mineral substratum (bedrock). Found between vegetation and the bedrock, undisturbed soils generally consist of visually and texturally distinct parallel layers (soil horizons), which can range from a few inches to several feet in depth. Typical soil horizons consist of the following:

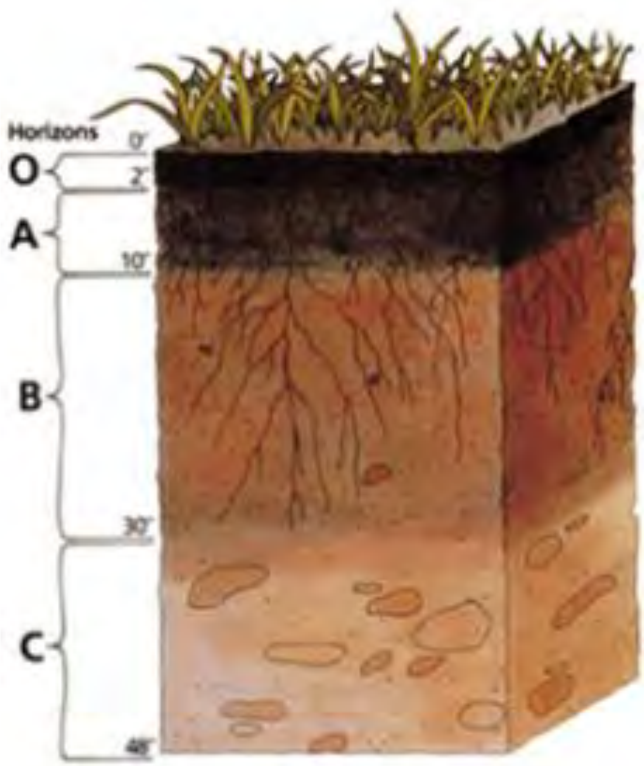

Figure 5.2.1-1. Soil horizons.

O - Organic matter: The uppermost layer on the surface of the ground composed mainly of relatively un-decomposed plant and animal residues (leaves, stems, fur, bones, etc.).

A - Topsoil: The top layer of soil. It has the highest concentration of organic matter and soil life, and is where most of the earth's biological soil activity occurs.

B - Subsoil: A layer of generally coarser mineral soil http://en.wikipedia.org/wiki/Soilunder the topsoil. This layer accumulates iron, clay, aluminum, and organic compounds.

C - Parent rock: Below the subsoil is a layer of residual, unbroken rocks or windblown or water-carried sediments. This layer often forms a major constituent of the other soil layers. Plant roots generally do not penetrate this layer.

Undisturbed soils are generally healthy soils that have the functions and characteristics (texture, structure, density, water holding capacity, etc.) of comparable, known, undisturbed soils in the region.

Soil Attributes:

Healthy soils have three key attributes. The following recommendations will help ensure that all three key soil characteristics are protected from damage during construction and maintenance.

Figure 5.2.1-2. Optimal soil properties.

- Physical Structure – In all soil types, which consist of percentages of sand, silt, clay, and organic matter, it is the organic matter that helps form particle aggregates. These aggregates, called "peds," create pore spaces, which enable the soil to hold and clean water. Compaction increases "bulk density" as pore spaces are compressed. The result is poor root penetration and poor water absorption. Runoff increases, pollutants and sediments are carried into streams, and little water soaks into the ground to replenish the water table.

- Chemical Makeup – Certain chemicals such as salt, when added to the soil, cause aggregates to disintegrate and pore spaces to collapse. Conversely, some chemicals are required as key nutrients that support the life found in soil, which help create aggregations of particles.

- Biological Communities – A living, functioning soil biota influences both structure and chemistry. Biological processes are critical in stabilizing soil aggregates. Burrowing animals break up clods and push particles together, fine roots and fungi exude sticky substances, and microorganisms produce organic "glues."

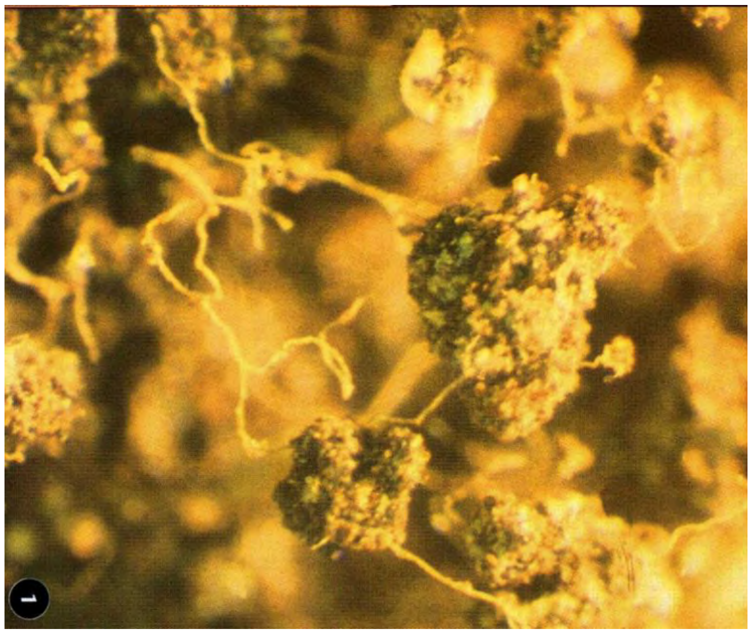

Figure 5.2.1-3. Soil Peds.

Protecting healthy/undisturbed soils, in order to maintain infiltration capacity, requires preservation of the above three main attributes. It also necessitates safeguarding site soils from the impacts of grading, compaction, and contamination before, during, and after construction.

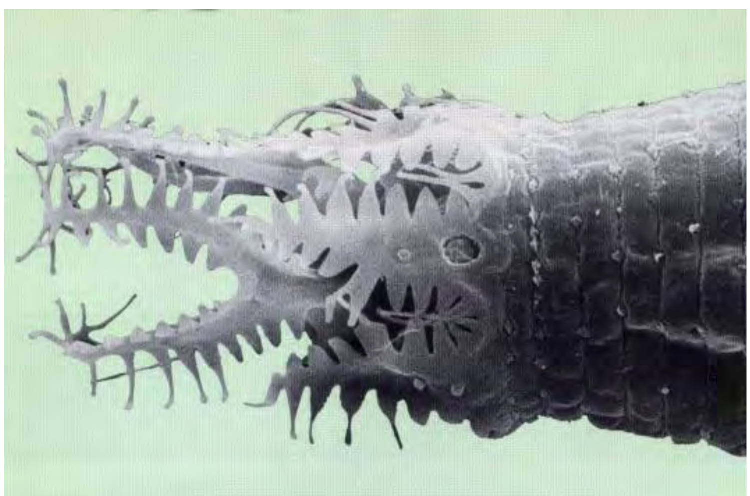

Figure 5.2.1-4. Nematode found in soil.

General characteristics of healthy/undisturbed soils are as follows:

- Soil horizons similar to an undisturbed native soil within the Chattanooga region with native vegetation, unaltered topography, and soil characteristics similar to the site
- Bulk densities that do not exceed the value at which growth limitations are expected
- Organic matter content that is equal to or exceeds that of similar local undisturbed soils

- Soil chemical characteristics (such as pH, salinity, cat-ion exchange capacity, and nutrient profiles) similar to local undisturbed soils
- Absence of construction debris and toxic compounds

When soils are compacted and permeability is drastically reduced, these critical characteristics of healthy soils are lost and with them the ability of the soil to absorb stormwater runoff (Hanks and Lewandowski 2003). The runoff response of areas with highly compacted soils closely resembles that of impervious areas, especially during large storms. Compacted soils have been shown to have runoff percentages as high as 95 percent (as high as some pavements), increasing stormwater flows (Schueler, undated). The purpose of this BMP is to prevent or at least minimize the degree and extent of compaction in areas that are to be considered "pervious" following development.

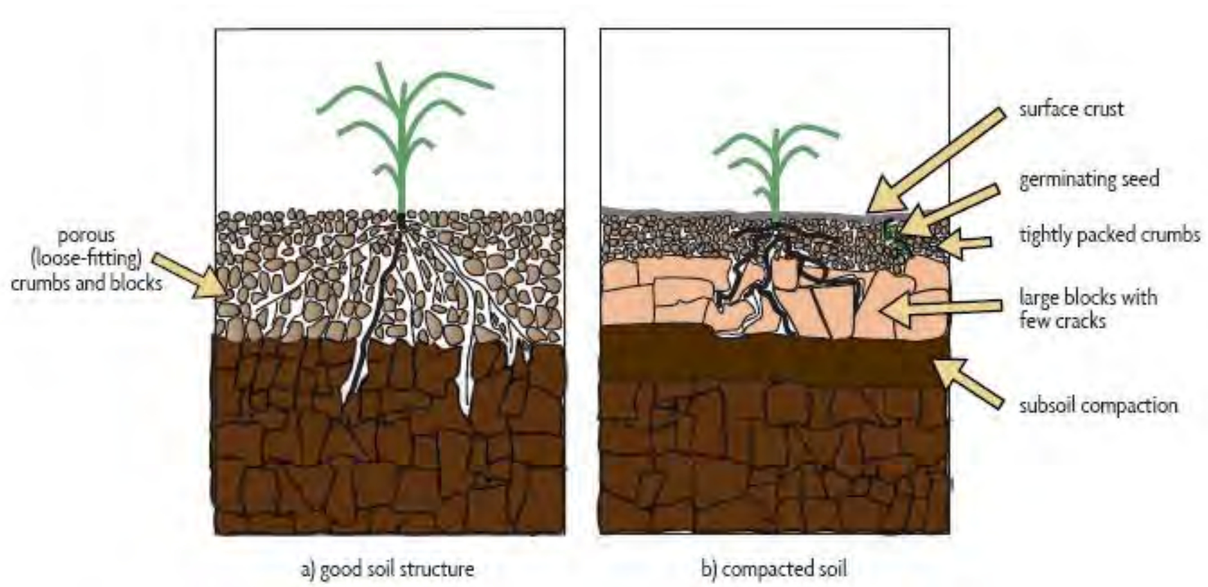

Figure 5.2.1-5. Soil compaction diagram (BSBC).

BMP Functions Table

Undisturbed, healthy soils are an important and low-cost BMP. Protecting site soils by minimizing damage from erosion and compaction, and preserving soil functions before, during, and after construction, is a very cost-effective stormwater management strategy, conserving infiltration capacity and reducing runoff.

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Undisturbed Soil	U/S/R	H	H	H	H	M	M	H	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Guidelines

- Understand the importance of undisturbed soils as an irreplaceable resource. Once disturbed, soil can never be fully brought back to its original state.
- Identify soils to protect based on their functionality early in the design process.
- Where possible, preserve existing native plants, historical plant groups, and specimen trees, which often grow on less disturbed soils.
- Reduce impervious footprint.
- Minimize required grading.
- Designate "Protected Areas" and "Areas of Minimal Disturbance" on the Existing Conditions Assessment and Site Protection Plan, Grading and Soils Plan, Erosion and Sediment Control Plan, and Stormwater Plan.
- Designate construction activity and construction traffic routes on the Site Protection Plan and Stormwater Plan.
- Place, monitor, and enforce protection fencing.
- On protected soils, design for lower maintenance and restricted traffic and limited access.

Applications

- Any land with healthy, undisturbed soils that can be proposed for preservation.

Advantages

- Cost-effective:
  - Preserving soil horizons reduces the need for soil restoration and for additional stormwater management measures.
  - By limiting grading, costs can be reduced for construction machinery and purchase and transport of imported soils.
- Healthy soil:
  - Stores carbon as organic matter.
  - Minimizes runoff and maximizes soil water holding capacity.
  - Absorbs and removes nutrients, sediments, and pollutants.
  - Supports healthy plant roots.

Disadvantages

- Minimal site intervention during design and construction presents challenges to owner/developer and design team.
- Protection requires fencing that is kept standing and in good repair during construction.

Applications

This BMP can be applied to any development that has existing areas of relatively healthy soil proposed for preservation. Even abandoned properties/vacant lots, etc., may have areas of undisturbed soils.
Areas with damaged soils can be remediated (see Section 5.4.3, Restore and Amend Disturbed Soils, in this manual).

Figure 5.2.1-6. Construction site fencing protecting healthy soil under forest cover.

Protocols and Specifications

Protocol 3 Soil Testing

Design Considerations

- Preserving healthy soils in place impacts both design and construction options. Successful soil preservation requires attention throughout the entire design, permitting, and construction process. **Non-disturbance is the most effective strategy for preserving soil functions.** Not only are soil functions maintained, but living organisms in undisturbed soil can colonize adjacent, disturbed soils after construction.
- There are a number of circumstances and BMP **requirements for soil compaction,**

Figure 5.2.1-7. Soil samples taken with different devices.

for example, the cores of infiltration berms. These special situations are flagged in each BMP, and are **not restricted** by soil protection requirements.

- Determine areas of high-value soils and identify areas of undisturbed soil. Delineate these soils clearly on the Existing Conditions Assessment and Site Protection Plan, Grading and Soils Plan, Erosion and Sediment Control Plan, and Stormwater Plan. Where possible, integrate these soil areas into the proposed open space plan and/or into the stormwater design.
  - Look for soils that have the following characteristics:
    - Clearly visible soil horizons that are similar to an undisturbed native soil within the Chattanooga region with native vegetation, unaltered topography, and soil characteristics similar to the site
    - Sites with mature vegetation, which are less likely to be disturbed and are a good indicator of undisturbed soils
    - Bulk densities that do not exceed the value at which growth limitations are expected, see Protocol 3, Soil Testing
    - Organic matter content that is equal to or exceeds that of similar local undisturbed soils
    - Soil chemical characteristics (such as pH, salinity, cat-ion exchange capacity, and nutrient profiles) similar to local undisturbed soils
    - Absence of construction debris and toxic compounds
- Identify easily damaged soils and soils on sensitive areas, especially on steep slopes. For example, deep, spongy soils underneath relatively undisturbed, mature forests typically have a high infiltration capacity and can be destroyed easily. These soils are a priority for protection. Excessive stormwater should not be directed onto these soils.
- Take soil samples from representative areas on the site. Do not mix these soils together, rather, test each individual sample separately. Send samples to the University of Tennessee Extension for analysis (Hamilton County, 6183 Adamson Circle, Chattanooga, TN 37416-3648). Laboratory tests often include professional interpretation of results and recommendations.

Figure 5.2.1-8. Soil protection at woodland edge.

Website:
https://utextension.tennessee.edu/hamilton/Pages/Soil-Testing.aspx

Recommended Soil Tests:

Texture Class
Organic Matter
Bulk Density

- Identify “Protected Areas” and “Areas of Minimal Disturbance”

  “Protected Areas” are those areas where there will be no construction disturbance by machinery, dumping or other means. Protected Areas must be clearly delineated on the Existing Conditions Assessment and Site Protection Plan, Grading and Soils Plan, Erosion and Sediment Control Plan, and Stormwater Plan. This includes areas intended for suggested BMPs.
  - Include in the specifications that the contractor is responsible for maintaining the protection fencing.
  - Where appropriate, explore the use of conservation easements, deed restrictions, or other legal measures for protected areas on private property. Legal status can help ensure lasting protection. In addition, the owner can be rewarded with a tax write-off.

  “Minimal Disturbance Areas” are protected areas where limited construction will temporarily take place because of site constraints. These areas are to be restored at the end of construction to be considered fully pervious after development. Indicate on plans areas of soil remediation, amendments, etc. (where such areas are to be considered permeable after construction). Minimal Disturbance Areas must be clearly delineated on the Existing Conditions Assessment and Site Protection Plan, Site Design, Erosion and Sediment Control Plan, and Construction Plan.

  These **temporary** areas include:
  - Areas where vegetation needs to be removed for equipment access. Where possible, do not remove stumps to leave root systems to hold soil and possibly regenerate.
  - Areas that require small amounts of grading (including excavating, filling, moving, and dumping) for utilities, etc.
  - Area of remediation such as erosion and/or gully repair.

  These areas should use:
  - The lightest equipment possible to do the job.
  - Protection measures discussed below.
  - The smallest possible construction space.

- Provide durable protection fencing.
- During the site design process, make every effort to avoid placing buildings and roads on Protected Areas and Areas of Minimal Disturbance. During concept and preliminary stormwater management plan phases, reexamine proposed site plans to reduce site disturbance. Revisions should include minimizing impervious

surfaces of all kinds, including circulation and building footprints, and wherever possible, minimizing land disturbance. (See Section 5.2.1.1, Preserving Landforms, in this manual.)

- Design to protect designated areas. Rogue trails are created and site resources are damaged where circulation is poorly planned. Buffer areas of healthy and undisturbed soils by maintaining existing strips or creating new strips of vegetation that people would not care to walk through. These buffers will safeguard from damage by runoff and also help to direct users to designated access routes after the project is implemented. Soil degradation can also result from trampling and extensive maintenance activities. (See Structural BMP 5.3.6 Vegetated Filter Strips, in this manual.)

Construction Strategies

- The best way to preserve topsoil is to leave it in place. Where high-value soils must be disturbed, topsoil should be separated from the subsoil and stockpiled for reuse. While this is the easiest and most familiar method, a less conventional but more effective way to preserve soil structure, microorganisms, and seed reservoirs, etc., is to cut and stockpile the upper soil layers as a "sod" (See Restorative BMP 5.2.4.2 Soil and Plant Salvage, in this manual.)
- Designate undisturbed soils as "Protected Areas" or as "Areas of Minimal Disturbance" onsite.
- Consider preserving a buffer strip of existing vegetation between "Construction Areas," "Protected Areas," and "Areas of Minimal Disturbance." See Structural BMP 5.3.6 Vegetated Filter Strips, in this manual.
- Preserve existing vegetated areas for as long as possible during construction (even if they are to be removed eventually). Existing vegetation acts as a barrier, making it less likely for an area to be suddenly usurped for construction activities.
- Safeguard protected areas from sediment and stormwater loads from disturbed, upgradient parts of the site.
- Restrict access through protection and minimal disturbance areas. If access by construction equipment through a minimal disturbance area is required, or if it is necessary to work in sensitive areas:
  - Avoid grading and allowing access over any soil under extreme conditions—when soil is either extremely wet or extremely dry. Most critically, do not cross or work soil in wet weather. This should be noted on the Erosion and Sediment Control Plan.
  - Use small equipment and always use the lightest machinery available. Consider alternatives for moving materials, including the use of planks and rollers, pole slings, dollies, etc.
  - If storage or access is unavoidable in areas designated as "Areas of Minimal Disturbance", the contractor should lay down a thick, protective layer over the soil to absorb and spread compressive forces.

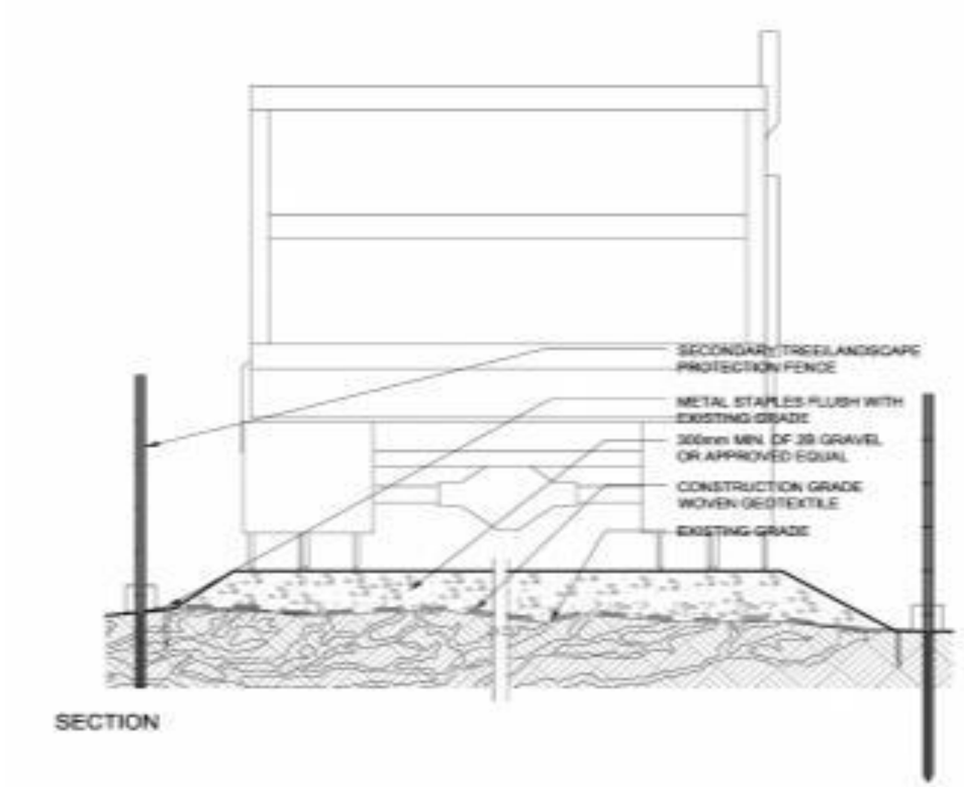

Figure 5.2.1-9. Gravel mat – large vehicle access.

Choices for this layer include:

- 10 inches of woodchips.
- Wood planks, plywood, or metal mats.
- Pre-engineered systems, designed for this purpose.
- A layer of geotextile fabric should be laid under the other suggested protective layers when using very heavy construction equipment.

- When the protective layer/layers are removed at the end of construction, a light tilling of the soil may be necessary to prevent surface crusting.
- If areas impacted by construction activities are to be

Figure 5.2.1-10. Using wood mats to protect soil from compaction.

counted as permeable at the completion of the project, soil restoration (including compost tea and other amendments) will be required (see Section 5.4.3, Amend and Restore Disturbed Soils, in this manual).

Operations and Maintenance

Sites with minimal soil disturbance require less maintenance. Minimizing the compaction of soils that will later be planted or used as part of a recommended BMP will save time, money, and materials. Vegetation will be healthier, have a higher survival rate, and look more attractive. BMPs will be less expensive.

Soil health and stormwater management potential can also be damaged by end users and by conventional maintenance techniques, especially for turf areas. Soil compaction after construction can be reduced in a number of ways:

- Reduce mowing frequencies. Let turf grasses grow to a height of 3 to 4 inches before mowing. (This approach will also allow the grass to shade itself, which, in turn, reduces evapotranspiration losses and the need for irrigation.)
- Use specialized grass seed mixes, such as “No-Mow” mix.
- Amend topsoil with organic matter and compost teas.
- Aerate turf on a regular basis.
- Keep users out of sensitive areas or restrict users to routes that encourage them to remain on designated paths.

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5.2.1 Protect Undisturbed and Healthy Soils Criteria Checklist

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance by the owner/applicant for successful implementation.		
• Soil samples are taken from representative areas onsite and tested separately. Tests show: – Soil bulk density does not exceed the value at which growth limitations are expected. – Organic content is equal to or exceeds that of similar, local undisturbed soils. – Soil chemical characteristics (such as pH, salinity, cat-ion exchange capacity, nutrient profiles) are similar to local undisturbed soils.	☐ ☐ ☐	☐ ☐ ☐
• Absence of construction debris and toxic compounds in soil preservation areas. Provide photo documentation.	☐	☐
• Soil horizon similar to undisturbed native soil with native vegetation and unaltered topography. Provide photo documentation of soil pits showing distinctive horizons.	☐	☐
• Where possible, existing native plants and specimen trees are preserved.	☐	☐
• Areas of high-value soils, including soils on sensitive areas, especially on steep slopes, have been designated "Protected Areas" and/or "Areas of Minimal Disturbance" and are delineated clearly on the Existing Conditions Assessment, Site Protection Plan, Grading and Soils Plan, Erosion and Sediment Control Plan, and Stormwater Plan.	☐	☐
• "Protected Areas" and/or "Areas of Minimal Disturbance" are safeguarded from sediment and stormwater loads.	☐	☐
• Protections fencing details and associated signage details for "Protected Areas" and/or "Areas of Minimal Disturbance" have been provided.	☐	☐
• Protected soil areas have been designed for end-user avoidance. (Existing strips of vegetation are maintained or created to discourage pedestrian circulation over disturbed soils.)	☐	☐
• Areas for site access, storage, and equipment use the smallest possible construction space, and minimize impervious surfaces, building footprints, and site disturbance.	☐	☐
• Where high-value soil must be disturbed, it is separated from the subsoil and stockpiled appropriately for reuse.	☐	☐
• Notes on Existing Conditions Assessment, Site Protection Plan, Grading and Soils Plan, Erosion and Sediment Control Plan, and Stormwater Plan state: Grading in extreme wet or dry conditions is avoided entirely.	☐	☐
• Provide written description of any work that may need to be performed within "Areas of Minimal Disturbance."	☐	☐
• Smallest and lightest machinery is to be used in "Areas of Minimal Disturbance."	☐	☐
• Details provided for protective layer on soil to absorb and spread compressive forces for work done in "Areas of Minimal Disturbance."	☐	☐
• Notes on drawing clearly provide sequence for removal of protective layers and soil restoration if required in "Areas of Minimal Disturbance." (Once removed, contractor performs a light tilling of soil to prevent surface crusting, including compost tea and other amendments.)	☐	☐

5.2.1.1 Preserving Landforms

Description

Clearing and grading changes the surface and shape of the land. Conventional approaches force the site to adapt to the owner's development program. However, existing landforms play a critical role in maintaining natural processes, particularly the movement of water across or even under a site, and should be preserved and integrated into the development program. Natural landforms can provide functional and aesthetic benefits.

Figure 5.2.1.1-1. Clearing and grading a hilltop removes the ecosystem services inherent in undisturbed soils and vegetative cover.

Minimizing the amount of earth-moving and grading on a development site can preserve existing landforms, soil, drainage patterns, and plants. These areas can be protected in three major ways:

- Identify and protect existing landforms, site vegetation, soils, and drainage patterns where possible.
- Readjust the site program and redesign the site plan to take advantage of the site's existing topography.
- Work with existing landforms in the design of buildings and circulation.

Minimizing soil compaction and disturbance by designing site program(s) (buildings, open space, parking, and circulation network) to work with the existing contours will help to maintain the hydrologic function inherent in an undisturbed site and to minimize the impact of development. Minimizing the developed land area and total land disturbance will:

- Minimize the actual stormwater generated (volume and peak flow).
- Lower discharge rates significantly (by slowing runoff and increasing onsite storage).
- Improve water quality preventively (by reducing sediment-laden runoff from eroding surfaces).
- Provide more opportunities for the most effective location of proposed BMPs.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Preserving Landforms	U/S/R	H	H	H	H	M	M	H	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Guidelines

- Identify areas that may require extensive grading and/or earth moving early in the design process.
- Rework initial building program to better "fit" the capacity of the site.
- Redesign major site components to better "fit" the unaltered terrain.
- Reduce impervious footprints where possible *(*see Section 5.3.1, Pervious Pavement, in this manual).
- Reduce grading by integrating buildings, roads, parking, and stormwater management facilities into the terrain (e.g., use the building as a retaining wall or as multilevel access on steep sites, or use flat roofs as extensions of circulation system or open space).

Advantages

- Costs may be reduced by:
  - Preserving existing topography and healthy soils and vegetation.
  - Reducing volume and velocity of site stormwater, minimizing the need for extensive stormwater management facilities.
  - Reducing proposed grading, which minimizes labor and construction machinery costs.
  - Reducing or eliminating the need for retaining walls.
- Undisturbed soils offer the following advantages:
  - Minimize stormwater runoff by maximizing water-holding and infiltration capacity of site vegetation and soils.
  - Can effectively store and cycle nutrients.
  - Sequester carbon as organic matter.

Disadvantages

- Requires greater collaboration between design teams and contractors.
- New approaches to grading can take time to adopt and can meet natural resistance to change.
- Construction staging areas and traffic routes may be tighter.
- Imaginative solutions are required to achieve potential cost savings and programmatic objectives.

Applications

Any site where there are significant topographic changes or distinctive resources (such as rock outcroppings, mature woodlands, wetlands) to be preserved.

Figure 5.2.1.1-2. Using existing topography to create an outdoor amenity.

Design Considerations

<u>Site Analysis</u>:

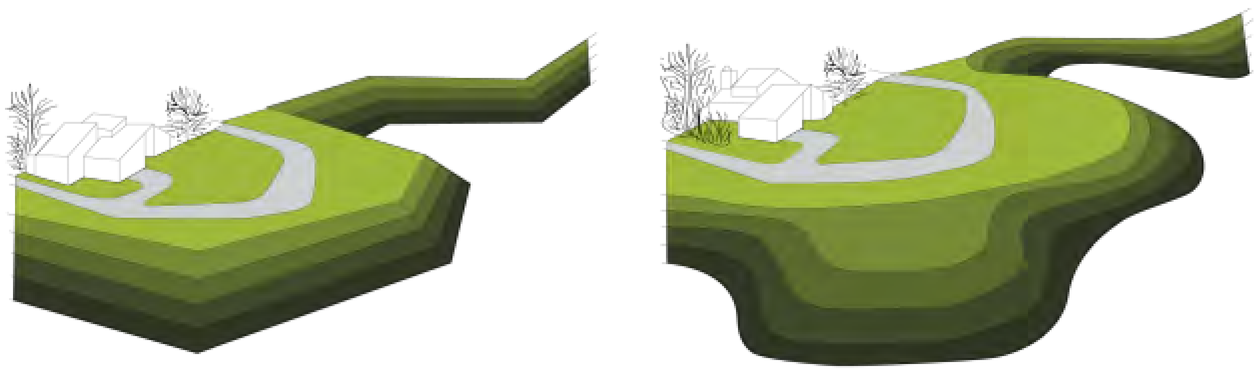
- Use the contours from the site survey to analyze (with a quick site diagram) the existing landforms, e.g., ridge, hill, valley bottom, valley sides etc.
- Identify areas of extreme/abrupt topographic change.
- Distinguish between manmade topographic changes and natural forms. Historic changes may or may not be worth keeping.
- Identify existing flow patterns for sub-watersheds onsite, including where water presently drains and whether water sheet flows across the site and/or concentrates in channels. Some stormwater solutions may require an understanding of offsite stormwater discharges beyond the property boundaries.

Figure 5.2.1.1-3. Design road alignments with topography.

Figure 5.2.1.1-4. Bridges over valleys to facilitate access.

Design Strategies:

- Identify significant topographic changes or distinctive resources (such as rock outcroppings) and design to safeguard these areas by including them in a “Protected Area” or “Area of Minimal Disturbance” (see Section 5.2.1, Protect Undisturbed and Healthy Soils, in this manual).
- Review site plans to determine whether proposed earth-moving or site grading is necessary to achieve the program or whether land disturbance can be minimized through redesign or plan modifications. Consider adjustment of the location and layout of buildings and roads to minimize proposed site grading, removal of existing vegetation (clearing and grubbing), and soil removal or compaction. Allowing the building or site program to “fit” the topography, as opposed to shaping the topography to “fit” the program, can create a more attractive site with greater site amenities and fewer stormwater management measures needed.
- Design strategies to achieve reduced disturbance include:
  - Using cluster design and concentrating uses, encouraging greater amounts of open space.
  - Integrating multiple functions for site facilities, such as a complete street that combines traffic and stormwater management.
  - Using bridges rather than cutting or filling to navigate steep slopes.
  - Integrating buildings into steep slopes (as bridges, retaining walls, etc.).
  - Eliminating hard edge engineering grading where the built project meets the landscape.
  - Encouraging plans that preserve surface irregularities beyond the building project landscape. These irregularities contribute to slowing and infiltrating stormwater.



Unacceptable
Regular Slopes - Sharp Cut or Fill

Acceptable
Varied Slopes - Smooth cut or Fill

Figure 5.2.1.1-5. Grading example; regular vs. varied slopes.

- Limiting grading, where possible, to preserve site landforms. If this approach is not feasible, grade to **modify but not obliterate the landforms.** Additional grading can mimic, formalize or dramatize typical landforms, e.g., grade long slopes in “terraced” benches to hold runoff and prevent erosion.
- Avoiding abrupt changes where new grades meet existing grades. These areas can erode or gather debris and sediment later.
- Where possible, allowing roads and pedestrian circulation to follow existing contours (always adjusting grades and alignments to comply with safety requirements) and avoiding crossing and/or fragmenting sensitive site habitats and features.

Figure 5.2.1.1-6. Example of abrupt transition between new and existing grade

Construction Strategies:

- Minimize construction traffic routes, both in width and length.
  - Identify designated routes with signs and fencing, and provide emergency pull-offs where necessary.
  - Enforce traffic requirements to remain within fenced areas.
- Locate both traffic routes and building footprints on already disturbed areas, where possible.
- Distribute stockpiles and storage into smaller, more flexible areas.
- Reduce construction areas needed to construct individual facilities where possible.
- Sheet and shore areas to temporarily support the sides of excavations. This will allow for a reduction in the size of the excavation area and a reduction in the amount of grading required to construct surface elements.
- Minimize disturbance adjacent to sensitive/fragile protected areas. Leave a buffer (open space, construction barrier, or vegetative buffer) between development and protected areas.

Construction Sequencing

- Fence off "Protected" and "Minimal Disturbance" areas with approved durable fencing as identified on the Site Protection Plan.
- Areas designated as "Protected" or "Minimal Disturbance" must also be protected from sediment and stormwater loads from disturbed, upgradient parts of the site, as well as from construction traffic.
- Protection measures for areas designated as "Protected" or "Minimal Disturbance" must be strictly enforced. For example, if knocked down, fencing must be immediately set up again; if broken, fencing must be immediately repaired.

Operations and Maintenance

Sites with minimized earth-moving and grading during site construction typically require less maintenance; however, regular monitoring is required after project completion:

- Regraded terrain requires monitoring of surface water flow to ensure that slope integrity is maintained.
- Locations where new grades meet existing grades also require monitoring to ensure that these areas do not erode or collect sediment and debris.
- Monitor health of vegetation on steep slopes. Irrigation may be required to establish new vegetation. Plants that are dying should be replaced with stronger, more aggressive species.

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Urban, James. 2008. *Up by Roots: Healthy Soils and Trees in the Built Environment.* International Society of Arboriculture.

5.2.1.1 Preserving Landforms Criteria Checklist

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance by the owner/applicant for successful implementation.		
• Significant topographic changes or distinctive resources (such as rock outcroppings) identified and included in a "Protected Area" or "Area of Minimal Disturbance." Provide photo documentation. • Distinguish between manmade topographic changes and natural forms (manmade need not be saved).	☐ ☐	☐ ☐
• Site plans reviewed to determine whether proposed earth-moving or site grading is necessary to achieve the program or whether land disturbance can be minimized through redesign or plan modifications. • Major site components arranged to better "fit" the unaltered terrain. • Cluster design employed or uses concentrated (e.g., integrate multiple functions for site facilities, such as a complete street that combines traffic and stormwater management).	☐ ☐ ☐	☐ ☐ ☐
• Buildings integrated into steep slopes as opposed to flattening the site to accommodate building pads.	☐	☐
• Bridges used rather than cutting or filling to navigate steep slopes.	☐	☐
• Grading plans eliminate unnatural looking, unvarying slopes as well as mathematically generated patterns of conventional grading.	☐	☐
• Grade to preserve site landforms. If this approach is not possible, grade to modify but **not** obliterate the landforms.	☐	☐
• Abrupt changes avoided where new grades meet existing grades.	☐	☐
• Roads and pedestrian circulation follow existing contours (always adjust grades and alignments to comply with safety requirements) and avoid crossing and/or fragmenting sensitive site habitats and features.	☐	☐
• Existing erosion problems have been identified and provisions for their repair are incorporated in design plans	☐	☐
• "Protected Areas" and/or "Areas of Minimal Disturbance" are safeguarded from sediment and stormwater loads.	☐	☐
• Protection, fencing details, and associated signage details for "Protected Areas" and/or "Areas of Minimal Disturbance" have been provided.	☐	☐
• Areas for site access, storage, and equipment use the smallest possible construction space, and minimize impervious surfaces, building footprints, and site disturbance.	☐	☐

5.2.1.2 Protect Erodible Soils on Steep Slopes

Description

The United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) has identified a method of classifying "highly erodible soils." In the Lower Tennessee Valley, new soils generated from the underlying parent material on undisturbed land replace about three tons of soil eroded per acre per year. Erosion rates lower than the rate of soil development are considered "tolerable." Erosion rates higher than the amount of soil formed yearly are considered either "potentially highly erodible" or "highly erodible." A "highly erodible soil" can erode at eight times the "tolerable" erosion rate or more.

A number of factors determine susceptibility to sheet and rill erosion on slopes—in particular, rainfall, soil characteristics, depth to bedrock and bedrock composition, vegetative type, condition and extent of cover, and length and steepness of the slope. In combination with other factors, a long, steep slope increases the likelihood of soil erosion, particularly where the natural slope exceeds 15 percent. Even on shallower slopes of only 3 percent to 8 percent, many soils are susceptible to damage and removal by wind, water, animal, and manmade forces.

Protecting these fragile areas by ensuring minimal earth-moving and minimal removal of natural vegetative cover, especially on slopes greater than 15 percent, is essential. If disturbance is unavoidable, erosion control practices must be put in place prior to beginning the disturbance. It is critical to consider the effect of proposed grading on slope stability. Changes in grading above, below, and on steep slopes can trigger responses that range from minor soil failure such as eroded channels (accompanied by increased sedimentation of flow paths) to catastrophic failures, such as landslides, which can bury roads and buildings below.

BMP Functions Table

Deep, stable soils are an important and cost-effective BMP. Shallow soils on eroded slopes can no longer store and infiltrate stormwater. Eroding soils are often a source of sediments and pollutants that degrade water quality.

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Protect Erodible Soils on Steep Slopes	U/S/R	H	M	H	H	M	M	H	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Guidelines

- Distinguish erodible soils on the site (as identified by NRCS Land Capability Classification) http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx.
- Make efforts to preserve the existing vegetative cover.
- Reduce the amount of proposed impervious cover.
- Minimize any earth-moving (see Section 5.2.1.1, Preserving Landforms, in this manual).

Advantages

- Stable soils minimize erosion and sedimentation, as well as minimize/prevent the risk of catastrophic slope collapse.
- Uneroded soils are often deep with a well-developed organic layer that supports nutrient recycling, water storage, and infiltration processes.

Disadvantages

- May require creative design to overcome perceived or actual restrictions on the amount of available developable land within an individual parcel.

Applications

- This BMP can be applied to any land development that has existing areas of erodible soil on steep slopes ranging from 15 percent and steeper.

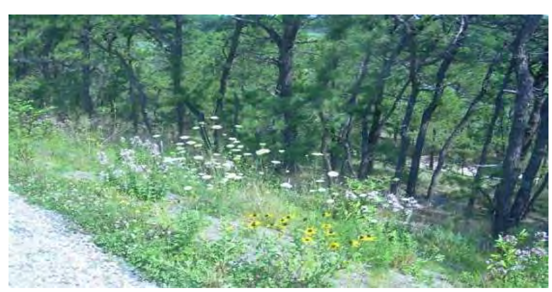

Figure 5.2.1.2-1. Steep slope erosion management with established vegetation.

Applicable Protocols and Specifications

Protocol 4 Infiltration System Design and Construction Guidelines
Protocol 5 Planting Guidelines

Design Considerations

Site Analysis:

- Determine soil erodibility by checking NRCS soil maps. Use the NRCS web tool to map the development area and soil characteristics: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx.
    - Create an "Area of Interest" (AOI) using the Quick Navigation, Soil Survey Area tab on the left hand side of the screen. AOI can also be created by drawing a polygon around a particular area using the tools on the top left-hand side of the interactive map.
    - Click the Soil Data Explorer tab on the top of the map. A sub-section of tabs should appear below.
    - Click the Soil Reports tab to the far right within that sub-section. A list of soil reports will appear on the left hand side of the screen.
    - Chose Land Classification and then Land Capability Classification.
    - Click the View Soil Report. A report will be compiled at the bottom of the screen, below the soil map for the chosen AOI.
    - This will provide the applicant with a soil map of the proposed development site, a report that lists soil component symbol and name along with the land capability class and sub-class. Descriptions of the classes and sub-classes are provided below the spreadsheet data on screen.
    - Land capability classes are divided in eight categories and range from few limitation in their use to severe limitations. These are based off of ability for cultivation.
    - Land capability sub-classes are divided in 4 categories; e = erosion and runoff, w = excess water, s = root zone limitations, c = climatic limitations)
    - The land capability classes and sub-classes provide information about the degree of limitations for use, soil potentialities and management problems for broad programing and conservation planning. This level of information is suited for concept level investigation.
- Confirm this data with a visual site survey as part of the initial site analysis. Are there existing gullies onsite? Are these gullies old and stable or currently eroding?
- Determine slope steepness from topographic survey of the site.

- The stability of existing steep slopes (more than 15 percent) should be reviewed by a geotechnical engineer or qualified civil engineer in the preliminary phase of the design process to ensure that the design and drainage do not impact the stability of soils or geology. Determine if existing slopes need to be altered to accommodate proposed development. Where possible, revise design so that steep slopes are not impacted.
- Drainage – Using a site topographic survey, identify existing flow patterns within each sub-watershed (smaller drainage areas) within the site to identify how water presently drains off steep slopes. Document whether stormwater sheet flows over each slope and/or is concentrated in channels.
- The water system does not stop at the project site. Identify whether significant amounts of stormwater are entering the site from beyond the property boundaries. Locate main entry points for this stormwater and determine its volume and velocity for various storm events.
- Existing Vegetation – Document the vegetation presently found on steep slopes. Identify and show the cover type and/or landscape type on the preliminary site plan (lawn, ornamentals, meadow, old field, savannah, woodland, or forest). Also identify the condition (health) and density of the existing vegetation.
- Proposed Vegetation – Identify proposed cover type (landscape) on plan and design in concert with proposed soil stabilization measures. Ensure that the measures chosen support each other and are not in conflict.

Design Strategies:

- Site Selection – The least expensive and easiest method to protect steep slopes with erodible soils is to avoid development on and around these slopes. This presents a challenge in Chattanooga. If possible, avoid development or regrading of areas immediately adjacent to the top and bottom of existing slopes and the slopes themselves. Do not direct concentrated flow onto these areas. Planning for this is done early in the design process. Strategies for fitting the owner/developer's program to site features apply here and are discussed in Section 5.2.1, Protect Undisturbed and Healthy Soils and Section 5.2.1.1, Preserving Landforms.
Where possible, make every effort to avoid clearing and grubbing slopes greater than 15 percent.

5.2.1.2-2. Steep slope stone wall.

- Develop Proposed Protection/ Prevention and Repair Measures – For the concept plan, identify broad outlines of an approach and proposed measures to ensure slope stability and appropriate drainage. Provide design details and specifications in later phases. Strategies include:
  - Protection above and below slope
    - Protect bottom of slope from being undermined by reinforcing with large stones, built structures, and/or planted or bioengineered vegetative structures or vegetated buffers.
    - When developing on hilltops or terraces within a hillside, be aware of any new drainage directed toward the slope. Use piping or swales to collect and convey diverted stormwater around the slope to designed discharge points. Depending on the maximum design velocity and volume of the stormwater runoff, and if there is no chance that slope stability will be undermined, this water can be infiltrated into the slope using underground level spreaders placed along the top of the slope. This option promotes groundwater recharge and irrigates the vegetation on the slope.
    - Protect top of slope from excess soil being pushed over the existing slope edges unless properly placed in compacted layers. Leaving a vegetated buffer along the top of the slope is a good deterrent. *(*See Section 5.5.6, Vegetated Filter Strips, in this manual.)

5.2.1.2-3. Level spreader along contour of slope.

  - Repair measures
    - Repair existing gullies and drainage problems on the slope before proceeding with other construction.
    - Small checkdams can be used both to repair existing gullies and to prevent future gullying.
    - Regrading the slope to close the gully channels, and then stabilizing the slope, is an alternate solution. However, this solution will not prevent future runoff from recreating the same gullies. Drainage from above must be addressed first.
    - Consider bioengineering solutions to stabilize the slope if required. These include live staking, fascines, branch-packing, brushlayer in-fill, shrub mats, etc.

5.2.1.2-4. Gulley created by pedestrian cut-through.

- The USDA *Engineering Field Handbook*, Chapter 18, Soil Bioengineering for Upland Slope Protection and Erosion Reduction, illustrates these techniques: http://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21429.

5.2.1.2-5. Eroded clearing and gulley on steep slope.

- Manage erosion – If disturbed or regraded, cover bare soil on slope with erosion management blankets and/or establish dense, deep-rooted vegetative cover as soon as possible.
  - In the event that steep slopes are modified or created, barren, steep slope areas should be stabilized as soon as possible.
  - See Protocol 5, Planting Guidelines, for species and recommended planting methods including meadow and woodland cover types.
    - Seeding on steep slopes: Most lawn grasses and ornamental ground covers are **not** suitable for this purpose. Do not use lawn grasses to stabilize steep slopes. Use deep-rooted meadow grasses and wildflowers for a quick cover. Ultimately, woody vegetation provides the best protection for steep slopes.

5.2.1.2-6. Live staking on steep slope.

      Steep slopes require higher seeding rates, including cover crop rates, than typical seed mixes. To avoid disturbance, a two-part seeding process can be minimally invasive and economical. This system includes hydroseeding the slope with seed, starter fertilizer, tackifier, and fiber mulch on the bare soil of the slope, and then following with a fine and light layer of organic mulch applied hydraulically. Check with the seeding supplier to verify that the seed being purchased is suitable for hydroseeding. Some native species cannot be hydroseeded.

If the timing of seeding is outside the window of the preferred seeding season, consider using a cover crop such as grain oats to stabilize the slope until the proper seeding time. Do not use cover crops that are invasive. Typical cover crops are annuals and should be eliminated at least two weeks before planting. Cover crops should be killed before they go to seed. Mechanical removal, such as mowing or rolling, can be utilized. Use chemical methods sparingly and cautiously, especially around water bodies.

5.2.1.2-7. Steep slope erosion management installation.

- Temporary erosion control blankets can successfully limit soil erosion and help to establish vegetation on steep slopes. Blankets provide immediate erosion protection from precipitation impact, sheet flows, and moderate shear concentrated flows.
  - Use only temporary blankets made from biodegradable, organic materials. These mats are degradable and are typically made of a variety of organic matrixes including straw, coir fiber, and a blend of both.

5.2.1.2-8. Jute fabric over straw.

– Blankets have many benefits. Blankets will:

Reduce daily temperature swings

Moderate seasonal soil temperatures – cooler in hot weather and warmer in spring/fall

Reduce moisture loss from evaporation or wind dessication

Reduce water velocity and protect bare slopes from erosion

- Properly Size Stormwater Management BMPs – Stormwater moving in large concentrations or at high velocities can erode the inflow and storage areas of BMPs placed on, or at the bottom of, a steep slope.
  - BMPs should be designed to prevent erosion by considering entrance velocities and sediment settling capabilities as well as the potential for accumulated sediment from contributing land uses.
  - Drainage conditions should be evaluated and velocities of stormwater calculated on a case-by-case basis.
  - All BMPs must be designed to hold up under maximum design stormwater velocities. On steep slopes, it may be necessary to limit the amount of flow that can enter a specific BMP in order to prevent erosion.
  - Infiltration BMPs should be designed and constructed with level bottoms (not sloped). Creating level bottoms for BMPs on steep hillsides may require an increased BMP area since the effective depth of water is not uniform and will decrease as a function of slope.
  - High runoff velocities may require terracing the hillside and/or constructing small "check dams" (with weirs). The location and spacing of check dams and weirs are a function of the slope and the desired maximum ponding depth (steeper slopes require more frequently spaced structures). Check dams and weirs may be constructed from a variety of materials including stone, metal, wood, concrete, or unexcavated subsoil.

5.2.1.2-9. Check dams below outlet on steep slopes.

Construction Sequencing

Before construction can begin, the site must be properly prepared and protected. After construction is complete, new interventions must be stabilized and monitored. Basic protocols can be implemented that, if followed, will greatly reduce the risk of future complications:

- Soon before actual construction
  - Mark limits of soil disturbance on the ground.
  - Put protection measures in place – slope stability, erosion and sediment controls, site protection fencing, tree protection fencing, etc. will help ensure the protection of existing site resources.
- During construction
  - Ensure that fencing remains standing and without holes.
  - Ensure that erosion control strategies are in place and functional.
- After construction
  - Stabilize all disturbed slopes greater than 5 percent as soon as the work is finished. Stabilize all existing or newly installed swales and/or channels, especially on steep slopes with highly erodible soils.
  - Remove protective fencing unless requested otherwise by owner.
  - Repair any accidental damage to protected areas.

Operations and Maintenance

Steep terrain requires monitoring to ensure that slope integrity is maintained after adjacent lands have been modified. Locations where new grades meet steep slopes also require monitoring to ensure that the transition remains seamless.

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5.2.1.2 Protect Highly Erodible Soils on Steep Slopes Criteria Checklist

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance by the owner/applicant for successful implementation.		
• Determine soil erodibility by checking NRCS soil maps. Use the NRCS web tool to map the development area and soil characteristics: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx. Confirm this data with a visual site survey as part of the initial site analysis.	☐	☐
• Determine slope steepness from topography survey of the site.	☐	☐
• Review stability of **existing** steep slopes (more than 15 percent) in the preliminary phase of the design process to ensure that the design does not impact the stability of soils or geology. Design so that steep slopes are not impacted.	☐	☐
• Identify existing flow patterns within the site to identify how water presently drains off steep slopes. Document whether stormwater sheet flows over each slope and/or is concentrated in channels.	☐	☐
• Identify stormwater entering the site from beyond the property boundaries. Locate main entry points for this stormwater and determine its volume and velocity.	☐	☐
• Stability of any **proposed** steep slope (more than 15 percent) should be reviewed to determine the potential impacts of proposed changes to existing site drainage that could undermine slope stability.	☐	☐
• Document the vegetation presently found on the steep slopes. Identify and show on the preliminary site plan, the cover type/or landscape type (lawn, ornamentals, meadow, old field, savannah, woodland or forest). Also identify the condition (health) and density of the existing vegetation. Provide photo documentation.	☐	☐
• Identify proposed cover type (landscape) on plan and design in concert with proposed soil stabilization measures. Ensure the measures chosen support each other and are not in conflict.	☐	☐
• Avoid development or regrading of areas immediately adjacent to the top and bottom of existing slopes and the slopes themselves. Do not direct concentrated flow to these areas.	☐	☐
• No clearing and grubbing will occur on slopes greater than 15 percent.	☐	☐
• Develop Proposed Protection/Prevention and Repair Measures – For the preliminary plan submission, identify broad outlines of your approach and proposed measures to ensure slope stability and appropriate drainage.	☐	☐
• If necessary, protect bottom of slope from being undermined by reinforcing with large stones, built structures, and/or planted or bioengineered vegetative structures or vegetated buffers.	☐	☐
• When developing on hilltops, or terraces within a hillside, be aware of any new drainage directed toward the slope. Convey any diverted stormwater around the slope to designed discharge points with appropriate erosion control and energy dissipation.	☐	☐

• Protect top of slope with a 10-foot minimum vegetated buffer.	☐	☐
• Repair existing gullies and drainage problems on the slope before proceeding with other construction. • Consider bioengineering solutions to stabilize the slope if required. These include live staking, fascines, branch-packing, brush layer in-fill, shrub mats, etc.	☐ ☐	☐ ☐
• Cover bare soil on slope with erosion management blankets and/or establish dense, deep-rooted vegetative cover as soon as possible.	☐	☐
• Seeding on steep slopes uses deep-rooted meadow grasses and wildflowers for a quick cover and is ultimately wooded.	☐	☐
• Use temporary erosion control blankets made from biodegradable, organic materials to limit soil erosion and help to establish vegetation on steep slopes.	☐	☐

5.2.2 Protect and Incorporate Natural Flow Paths

Description

Most sites have discernible topographical drainage features that direct stormwater generated on the site. By identifying, protecting, and preserving these natural flow paths, a development can minimize its stormwater impacts. Rather than ignoring or replacing natural drainage features with engineered systems that capture runoff and convey it downstream, designers can preserve these features, thereby reducing or eliminating the need for structural drainage systems.

Natural drainage features include:
- Swales
- Ephemeral and intermittent streams
- Headwater springs
- Depressions

The natural meandering pattern of water slows the velocity of runoff and provides opportunities for infiltration, uptake, storage, and filtration by plants and soil. The greatest difference in runoff between a natural and an altered site occurs during small storms (rainfall events) and early on in a larger storm. Most of the increase in runoff volume occurs because altered soils and horticultural plantings (turf, etc.) cannot absorb this first portion of the rainfall and because natural drainage channels have been straighten, lined, buried, or “graded away,” allowing water to drain quickly.

To effectively protect natural drainage features, they should be integrated in designs and used to organize the site program. Design additions to natural drainage features can make them more effective. For example, constructing low earthen berms around natural depressions creates additional flood storage; installing check dams within a drainage flow path slows runoff, fills gullies, and catches sediment; and planting additional native vegetation helps stabilize the banks and increase biofiltration.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Protect and Incorporate Natural Flow Paths	U/S/R	H	H	M	H	M	M	H	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Guidelines

- Identify site location within the watershed (floodplain, headwater stream, etc.).
- Identify and locate on site survey and site plan the natural drainage features of the site (swales, channels, ephemeral streams, depressions, etc.), for protection early in the design process.
- Preserve existing plant material within the state-mandated buffer zone and at the edge of these flow paths. The NPDES general stormwater permit for Tennessee requires a 30-foot average buffer along all streams (60 feet on 303d-listed or high-quality streams).
- Reduce proposed or existing impervious footprints, where possible, to maintain natural flow paths. Use natural drainage features to guide site design.
- Do not bury or “grade away” natural drainage flow paths.
- Minimize filling, clearing, or other disturbance of natural drainage features.
- Utilize natural drainage features instead of creating engineered systems whenever possible.
- Distribute least erosive surface flow to natural drainage features.
- Plant native vegetative buffers around drainage features.

Advantages

Retaining the natural configuration of drainage channels and their deep-rooted vegetation can:

- Slow runoff.
- Reduce stormwater runoff by providing dispersed, small-scale storage.
- Reduce peak discharges.
- If preserving a stream and buffer, avoid the need for an Aquatic Resource Alteration Permit (ARAP) and stream mitigation measures.
- Improve water quality through biofiltration, treating stormwater before it enters wetlands, lakes, and streams.
- Allow some infiltration and evapotranspiration.
- Provide recreational open space and place for site trails.
- Provide wildlife habitat.
- Improve site organization and aesthetics by treating drainage as an aesthetic feature.
- Raise property values.
- Natural drainage pathways can replace structural drainage systems and lower stormwater management costs.

Figure 5.2.2-1. Open water channels for drainage (either natural or manmade) are still common within the Chattanooga region. In some cases, these channels have been straightened and lined with rip-rap or concrete. They can be found even on very urban sites, such as this one at the Hamilton Place Mall.

Disadvantages

- Additional time may be required to identify and integrate natural drainage features into the design. (However, these costs may be offset by reductions in "structured" stormwater facilities and site grading.)

Applications

- Any land development—large or small, urban, suburban, or rural—with identifiable natural or culturally significant drainage features.

  Design measures to protect natural flow paths can be applied at multiple scales and with varying levels of formality and therefore are applicable for most types of projects (residential, commercial, industrial) at any scale and in any location (urban, suburban, or rural). The most obvious use of these strategies is within a residential, corporate, or institutional campus with increasing degrees of formality (geometric design). Protection of drainage flow paths can be applied to major streets or dense urban developments.

Figure 5.2.2-2. In densely urban areas—on streets, plazas, side yards, parking areas, etc.—drainage can be reinterpreted and integrated as a formal design with formal and ornamental plantings into the site amenities offered.

Applicable Protocols and Specifications

Protocol 5 Planting Guidelines

Design Considerations

Site Analysis

Identify and incorporate the site's fundamental hydrologic patterns as part of the overall stormwater design. This can include the restoration of remnants or recreation of historic natural drainage features (swales, depressions, watercourses, ephemeral streams, etc.). These restoration strategies are discussed in Section 5.4.1, Recreate Natural Flow Patterns. However, existing site features should be

Figure 5.2.2-3. Existing drainage corridors and their buffering vegetation can be expressed as a rural drainage ditch.

protected and may be enhanced for stormwater performance. The creation of a number of strategies and measures to increase functions (slow down, retain, and infiltrate runoff, etc.) are discussed in the next section. In order to implement any of the above-mentioned strategies, a site analysis must be performed.

- Understand the location of the site within the local watershed. Identify whether the site is within (or includes) a headwater stream, a floodplain, etc. This will provide clues as to how the water moves through the site. For example, headwater areas have soils and topography that are more likely to infiltrate, whereas slow conveyance is a strategy in floodplains and areas with high water tables.
- Survey and map natural existing drainage features (swales, channels, ephemeral streams, wet depressions, etc.).

  – Using a site topographic survey, identify the context of existing flow patterns and volumes for mini-watersheds/drainage areas, including where water presently drains and whether it sheet flows and/or concentrates in channels.
  – Natural waterways that are providing important woody wildlife cover and if not seriously eroding should not be disturbed (they are of high value).

Design Strategies

The design goal is to identify and use the site's fundamental hydrologic patterns to create dispersed, decentralized, small-scale stormwater management measures that work with the natural hydrology wherever possible.

- Use natural drainage features to help structure and organize the site design based on a site analysis of existing drainage patterns (from topographic survey, etc.). Where possible, design proposed site drainage patterns to protect and support natural surface (and subsurface) hydrology.

  – Avoid building over or burying drainage areas by using cluster design, or concentrating uses to serve multiple functions including roads, buildings, and parking around drainage pathways.
  – Set aside drainage pathways in "Protected Areas" or "Minimal Disturbance Areas" and integrate them with open space networks.
  – Minimize filling, clearing, straightening, or other disturbance of drainage features to be protected.

- Using the natural drainage pathways to accept additional runoff from new development is appropriate. Utilize natural drainage features instead of hard engineered systems whenever possible.

– If an existing natural drainage pathway is to be used, it may need to be selectively cleared, shaped, or enlarged to accommodate the design flow. It also must be checked to ensure stability. Provide measures to reduce volume and velocity within or before the water reaches these flow pathways.
    - Engineer stormwater volume and velocity to ensure that the existing drainage features are sustained, and not degraded over time.
    - Reinforce the bottom of the swale, with porous materials, where necessary.

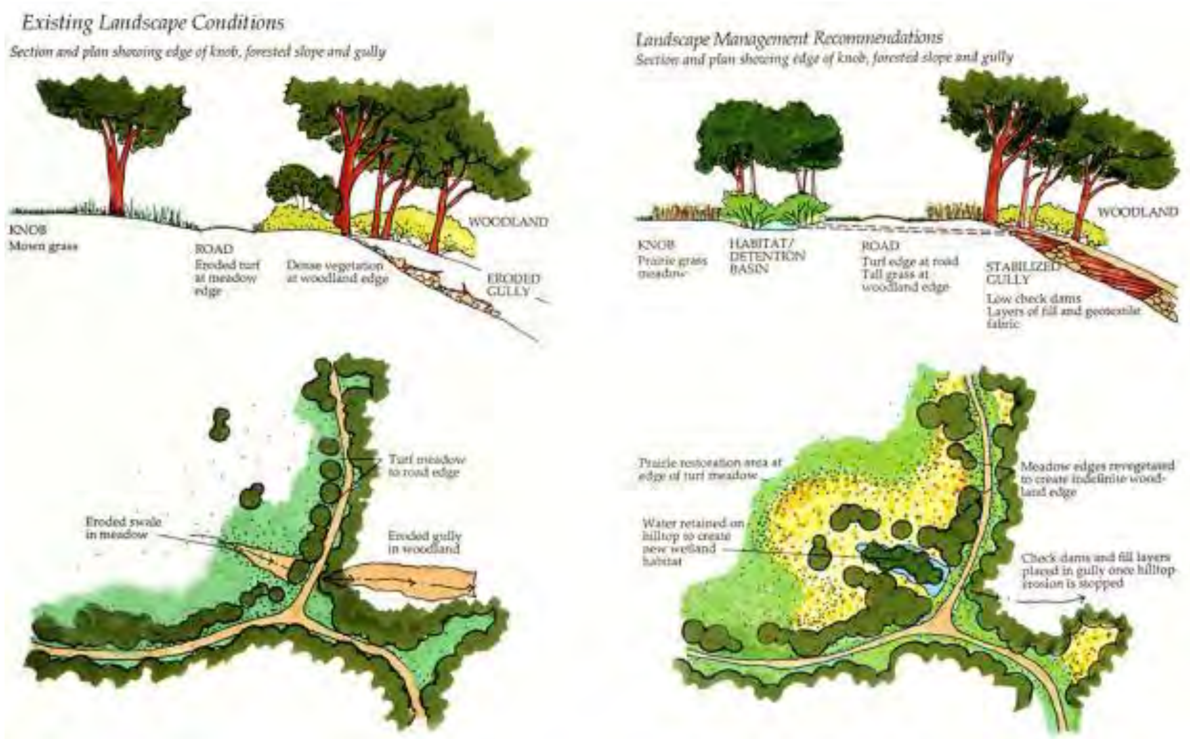

Figure 5.2.2-4. Enhancing existing flow patterns for stormwater performance.

Figure 5.2.2-5. Stone reinforced swale.

Figure 5.2.2-6. Reinforced swale bottom and check dam.

- Direct the least-erosive stormwater flows to natural drainage pathways. Use level spreaders, energy dissipaters, check dams, etc. to slow down and disperse water flow, especially at points of inflow.
- Buffer flow path banks and bank edges with the appropriate, deep-rooted vegetation to treat stormwater runoff and stabilize channel sides. Protect or establish a buffer of meadow or woodland adjacent to the channel to slow water and provide biofiltration (manage non-point source pollution).

Figure 5.2.2-7. Buffer vegetation along flow path banks.

- Channel design—Wherever possible, preserve natural meanders. Use rocks and logs to create deflectors that modify the speed and direction of the water flow, or low dams to create small pools. See Sections 5.4.1, Recreate Natural Flow Patterns and 5.4.1.1, Naturalize Swales and Drainage Ditches, in this manual for more information about reconfiguring channel design.

  – If the drainage flow path is presently in turf or bare soil, or has fragmented vegetative cover, reinforce vegetation with appropriate new plantings. See Section 5.4.1, Recreate Natural Flow Patterns.

- Link drainage flow paths and other stormwater management features together as a mutually reinforcing system.

  – Look for opportunities to divert flow out of existing engineered structures, or repurpose existing engineered structures as overflows.

- Take advantage of opportunities to create even very small-scale storage of water (reusing even small swales or small basins to act as wetlands to provide water storage and infiltration).

- Preserving and protecting wet depressions will encourage recharge of groundwater over the site and will help restore historic flow in streams that now appear dry.

- Careful use of natural flow paths can lengthen the Time of Concentration (Tc) value used in calculating peak flow rates. Correspondingly, decreasing the Tc will reduce the peak rate of flow. This may reduce the required detention storage volume, and may also reduce the size of stormwater structures such as pipes.

Figure 5.2.2-8. Channel design in construction.

Figure 5.2.2-9. Rain garden during construction using existing stormwater pipes as overflow (note domed riser at center).

Figure 5.2.2-10. Incorporate small-scale storage features.

Construction Sequence

- At the start of construction, natural drainage features to be protected should be identified and surveyed. These features must be included on both the site plan and the construction protection plan drawings.
- Immediately before construction, these features should be flagged and fenced.
- “Protected Areas” and “Areas of Minimal Disturbance” should be strictly delineated and enforced.
- Natural drainage features should be protected from additional sediment and stormwater loads generated by site disturbance during construction. Additional sediments from construction can form a limiting layer or soil crust that inhibits stormwater infiltration.

Operations and Maintenance

Natural drainage features that have been properly protected and integrated into the site development will still require occasional management to ensure that they remain attractive and functional. Periodic inspections, as well as targeted yearly maintenance, are important and must be included in the maintenance program agreements. Inspections should assess any developing problems—erosion, bank stability, sediment/debris accumulation, infested or dying plants, and also the presence of invasive species (both plant and animal). Problems should be corrected in a timely manner to avoid compounding these effects.

For new planting, watering, weeding, mulching, replanting, etc. may be required especially during the first year after planting. In addition, if the region is suffering from a prolonged drought, fragile areas with important stormwater functions should be watered to ensure that the vegetation lives. Invasive exotics (see list in Planting Protocol) should be removed and the flow path replanted with desirable replacements.

Placing protected drainage features on private property under easement, deed restrictions, or other legal measures will help prevent future impacts and will provide tax abatements for the property owner.

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USDA NRCS, Engineering Field Handbook, Online
http://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21429.

Criteria Checklist BMP 5.2.2

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance by the owner/applicant for successful implementation.		
• Identify site location within the watershed (floodplain, headwater stream, etc.).	☐	☐
• Identify and locate on site survey and site plan the natural drainage features of the site (swales, channels, ephemeral streams, depressions, etc.).	☐	☐
• Natural drainage features have been designated "Protected Areas" and/or "Areas of Minimal Disturbance" and are delineated clearly on the Existing Conditions Assessment, Site Protection Plan, Grading and Soils Plan, Erosion and Sediment Control Plan, and Stormwater Plan.	☐	☐
• Natural flow pathways in "Protected Areas" or "Areas of Minimal Disturbance" are integrated with open space networks.	☐	☐
• "Protected Areas" and/or "Areas of Minimal Disturbance" are safeguarded from sediment and stormwater loads during construction and opened only after construction is finished and vegetation has been established.	☐	☐
• Protection, fencing details, and associated signage details for "Protected Areas" and/or "Areas of Minimal Disturbance" have been provided.	☐	☐
• No filling, clearing, straightening or other disturbance of drainage features to be protected.	☐	☐
• Additional stormwater, directed to existing natural flow path, have been engineered for volume and velocities to ensure they are not degraded over time.	☐	☐
• Reinforce the bottom of the swale, with pervious materials, where necessary.	☐	☐
• Direct the least-erosive stormwater flows to natural drainage pathways. Use level spreaders, energy dissipaters, check dams, etc. to slow down and disperse water flow, especially at points of inflow.	☐	☐
• Buffer flow path banks and bank edges with the appropriate, deep-rooted vegetation to treat stormwater runoff and stabilize channel sides. Protect or establish a buffer of meadow or woodland adjacent to the channel, to slow water and provide biofiltration (manage non-point source pollution).	☐	☐
• Channel design—wherever possible, preserve natural meanders. Enhance existing flow paths with rocks (not rip-rap) and logs to create deflectors that modify the speed and direction of the water flow, or low dams to create small pools.	☐	☐
• If the drainage flow path is presently in turf, or bare soil, or has fragmented vegetative cover, reinforce vegetation with appropriate new plantings.	☐	☐
• Drainage flow paths and other stormwater management features are linked together, as a mutually reinforcing system, and small-scale storage is incorporated.	☐	☐

5.2.3 Protect and Preserve Riparian Corridors

Description

A riparian corridor (sometimes called a "riparian buffer" or "riparian zone") is the land along the margins of rivers, streams, creeks, or other natural or manmade watercourses that marks the transition between aquatic and upland terrestrial habitats. These corridors vary in width, configuration, species composition, and condition, depending on the size of the watercourse and the breadth of the floodplain, as well as a number of other factors. Corridors cutting through parcels may vary in size and shape. Onsite reconnaissance is crucial to determine the appropriate land to preserve or restore. City standards and requirements take these factors into account. The applicant should review applicable rules and ascertain site-specific requirements at the concept plan review stage. Please refer to the discussion below on corridor sizing.

Figure 5.2.3-1. Highly disturbed stream with an intermittent riparian buffer.

In many cases, riparian buffers have been fragmented, drastically reduced, or removed altogether. Many streams in the Tennessee Valley suffer from disturbance caused by stormwater runoff exacerbated by development within the watershed. Bank cutting, erosion gullies, sediment muddying the water, and tree toppling along the banks are symptoms of an unstable watercourse seeking to readjust its width and depth to accommodate the increased amount and speed of water flow. Healthy riparian corridors will not solve this problem, but will help ameliorate the effects. Note: The State of Tennessee mandates an undisturbed 30- or 60-foot stream buffer on all waters of the state, which includes everything except wet weather conveyances (ditches).

Figure 5.2.3-2. Stream with a continuous riparian corridor.

A healthy riparian corridor in the southeastern United States is fully vegetated, with an unbroken band of native trees, shrubs, ferns, and wildflowers or well-established tall grasses. Plant communities along the margins of watercourses/bodies are called "riparian vegetation." This vegetation must tolerate occasional flooding and occasionally saturated soils. However, riparian corridors generally are not wetlands and the vegetative cover generally is not wetland vegetation, although wetlands can be found in riparian buffer zones. When lawn is the only vegetation in the riparian zone, it adds to the amount of stormwater runoff that reaches the stream. With a shallow root system, lawn grasses cannot stabilize the bank or perform other stormwater functions.

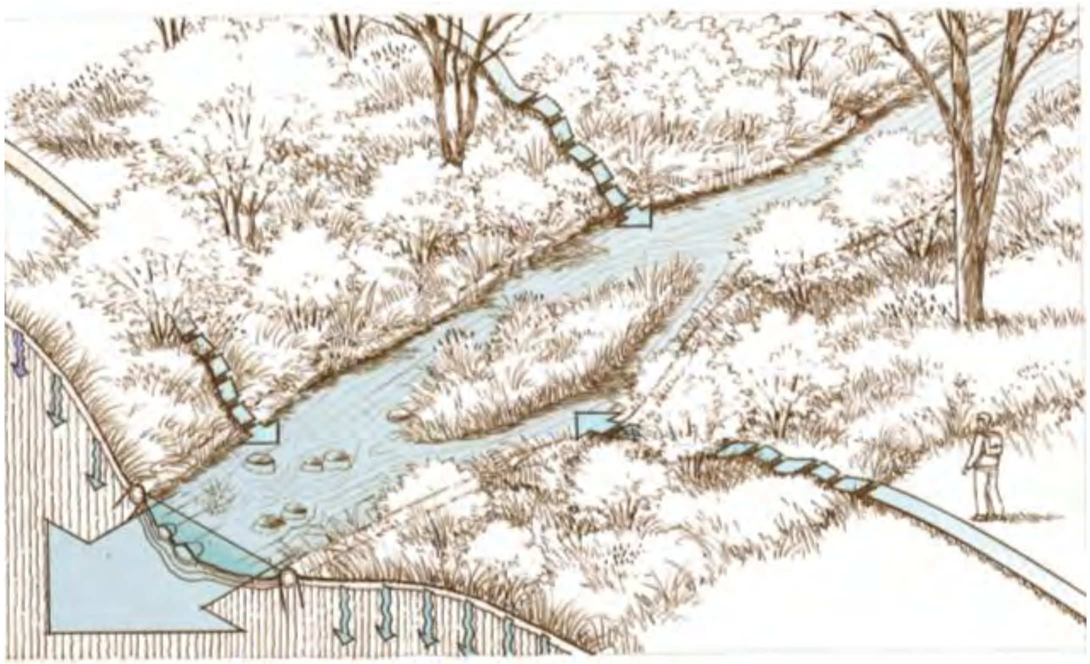

Figure 5.2.3-3. Riparian corridor – healthy.

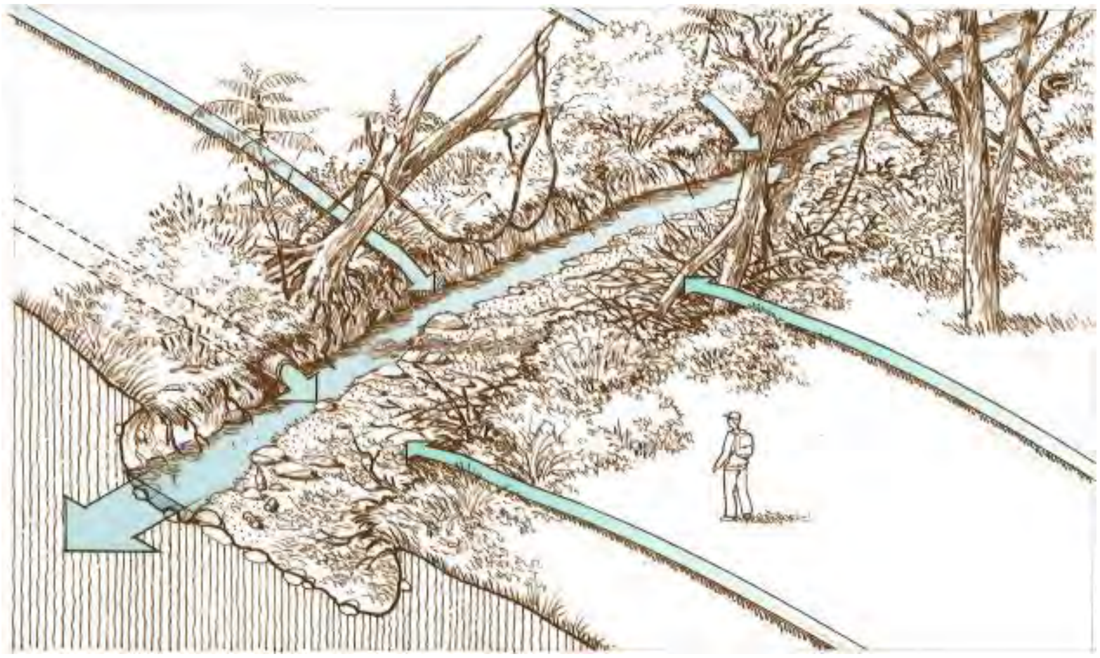

Figure 5.2.3-4. Riparian corridor – unhealthy.

Table 5.2.3-1. Table of Characteristics – Stable vs. Unstable Streams

Stable Stream	Unstable Stream
Constant cross-sectional area and bed elevation	Irregularities in cross-sectional area and bed elevation
Low streambank erosion	Severe streambank erosion
Sloping banks with vegetation	Vertical banks with no vegetation
Floodplain	Floodplain no longer available

It should also be noted that riparian corridors are not floodplains. Although riparian corridors occur within the floodplain, floodplains typically extend well beyond riparian corridors.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Protect and Enhance Riparian Corridors	U/S/R	H	H	M	L	M	M	H	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

A healthy, continuous strip of vegetation adjacent to waterbodies large and small (i.e., a riparian corridor) performs many valuable stormwater management functions:

Water Quality Benefits

- Intercepts, absorbs, and filters out excess nutrients, sediments, and pollutants.
- Reduces volume and velocity of stormwater runoff, absorbing surface water runoff and slowing water velocity, which reduces bank cutting and deposition.
- Increases structural stability of the stream banks and reduces siltation.
- Riparian buffers store floodwaters within backwater channels. These channels intercept overland flow before it reaches the main stem. The increase in runoff travel time helps reduce flood peaks.

Additional Ecosystem Health Benefits

- Creates shade, which lowers water temperature and increases the ability of the water to hold greater amounts of dissolved oxygen.
- With less turbidity (muddy water) and cooler temperatures, the dissolved oxygen content of the water can be higher to support a diverse and stable aquatic ecosystem.
- Provides woody debris, detritus, and other organic materials that form the basis of food webs for fresh water aquatic organisms. Fallen, woody vegetation provides substrates for insects, and food and shelter for a variety of fish, reptiles, amphibians, birds, and small mammals. "Snags" (dead, standing timber) can be used for shelter and nesting areas.
- The corridor itself furnishes a visual and noise buffer from surrounding development and offers protected movement routes and habitat for animals.

Encroachment into a riparian corridor or removal of either the canopy trees or the understory layers of vegetation can negatively affect any or all of these important functions. Protecting existing riparian corridors is an important and low-cost BMP.

Key Design Guidelines

- Identify watercourses and their riparian corridors on a site. A surveyor should locate a water channel accurately on the site survey. The surveyor (or qualified person) should also note the extent and plant type (trees, shrubs, grasslands, etc.) of existing vegetation along these corridors.
- Designate the proposed riparian corridor(s) and design to minimize impact of buildings, roads, parking, etc.
- Find design solutions that minimize the need to encroach on or fragment the designated riparian corridor.
- During construction, protect watercourses and their riparian corridors, especially those with undisturbed soil and natural woody vegetation. Every effort should be made to ensure that trees, shrubs, and existing tall grass and wildflower meadows are not damaged or removed.
- Identify the methods that will be used during construction to protect the riparian corridor, including construction fencing around areas to be protected, with site access routes located to avoid or minimize crossing this area. In addition, do not locate a storage area or vehicle parking area, or dump construction debris, within a riparian corridor zone. Trampling, depositing trash, and spilling toxic materials, etc., should also be prohibited within the riparian zone.

Advantages

- Healthy riparian corridors are the base of the food chain for aquatic life.
- Management of runoff in the headwaters is the most effective.
- See Water Quality Benefits and Additional Ecosystem Health Benefits described in the previous paragraphs.
- Avoids the need for ARAP and 404 permits, and avoids difficulty and cost of stream mitigation measures.

Disadvantages

- Requires early determination in concept stage and may present challenges to the status quo.
- Buffers and protective measures may limit physical or visual access to the waterbody.

Applications

Riparian buffers exist in a variety of landscape settings, including agricultural, forested, suburban, and urban areas. Open watercourses and their buffering vegetation can be preserved and integrated into any type of site or any type of site use.

Figure 5.2.3-5. Urban Example – Cheonggyecheon River Restoration Project.

Figure 5.2.3-6. Suburban Example – Brownstone Creek Project.

Applicable Protocols and Specifications

Protocol 5 Planting Guidelines

Design Considerations

<u>Site Analysis</u>

The site survey must locate any watercourse and remaining riparian vegetation existing onsite.

When analyzing a stretch of riparian zone, consider the stream and riparian zone as a **system** that is affected by watershed conditions. The extent, health, and sources of erosion along a riparian stretch are directly related to its watershed and stream characteristics. An analysis of stream and watershed conditions should include historical information on land use changes, hydrologic conditions, and natural disturbances that might influence stream behavior. It should anticipate the changes most likely to occur or that are planned for in the near future.

Items to consider that will influence protection or enhancement of the riparian buffer include:

- Watershed Data
  - History of land use, prior stream modifications, past stability problems, and previous treatments.
  - Overland drainage area that flows to the riparian buffer.
  - Outlets (if any) that discharge into the riparian buffer or stream.

- Cause and Extent of Erosion Problems
  - The degree of degradation of the existing corridor. Many urban streams are severely impacted by upstream development. Stream bank restoration may be needed before protection of the riparian corridor.
    - If bank failure problems are the result of widespread bed degradation/headcutting or aggradation (excessive deposition), determine what triggered the problem.
  - Signs of disturbance or erosion. Visually inspect the corridor, and if erosion problems are localized, determine the cause of erosion at each site.
- Hydrologic Data
  - Physical extent, average occurrence, and duration of flooding events.
- Stream Order
  - Location within the watershed. Headwater vs. 12^{th} order streams act very differently and have different floodplain forms and extents.
- Soils and Geology
  - Gradient and orientation (e.g., north-facing) of slopes that exist within the buffer itself and the adjacent contributing watershed.
  - Slope and formation of floodplain and any modifications that have been made to it.
  - Soil type.
  - Depth to water table.
- Vegetative Condition
  - Type and extent of vegetation found on the banks and within the floodplain. Show the extent of this vegetation and note health and whether this vegetation includes trees, shrubs, or tall grasses.
  - Extent and types of invasive species.
- Habitat characteristics
  - The least-understood aspect of designing and analyzing protection measures is often the impact of the protective measures on in-stream and riparian habitats. Commonly, each stage of the lifecycle of aquatic species requires different habitats, each having specific characteristics. These diverse habitats are needed to meet the unique demands imposed by spawning and incubation, summer rearing, and overwintering. The productivity of most aquatic systems is directly related to the diversity and complexity of available habitats.

<u>Corridor Sizing</u>

The City's MS4 Permit specifies the following standards for riparian buffers:

> "Streams or other waters with drainage areas less than 1 square mile will require buffer widths of 30 feet minimum. Streams or other waters with drainage areas greater than 1 square mile will require buffer widths of 60 feet minimum. The 60-feet criterion

for the width of the buffer zone can be established on an average width basis at a project, as long as the minimum width of the buffer zone is more than 30 feet at any measured location. The MS4 must develop and apply criteria for determining the circumstances under which these averages will be available. A determination that standards cannot be met may not be based solely on the difficulty or cost associated with implementation." – MS4 Permit Language

In determining the appropriate and necessary riparian buffer, the above MS4 standards will be considered the baseline requirement. However, the following USDA methodology may be determined appropriate and necessary given the site-specific conditions and watershed conditions.

Although the U.S. Army Corps of Engineers has specific guidelines to delineate jurisdictional wetlands, there are no standardized criteria to delineate the boundaries of riparian corridors. As a result, there is widespread confusion, among scientists and in the literature, about the appropriate size and configuration of these corridors. Studies suggest that a minimum of 50 feet (on both sides of a stream) is necessary for bank stabilization and that 100 feet (on both sides of a stream) is actually needed to filter runoff.

However, the designer should consider adjacent land uses. Site program and adjacent land uses affect decisions about buffer width and choice of vegetation. While a three-zone riparian buffer (described below) is the most effective solution, it may not be suitable for all sites (particularly dense urban areas or tight campuses).

USDA proposes that riparian buffers be designed/restored in three zones:

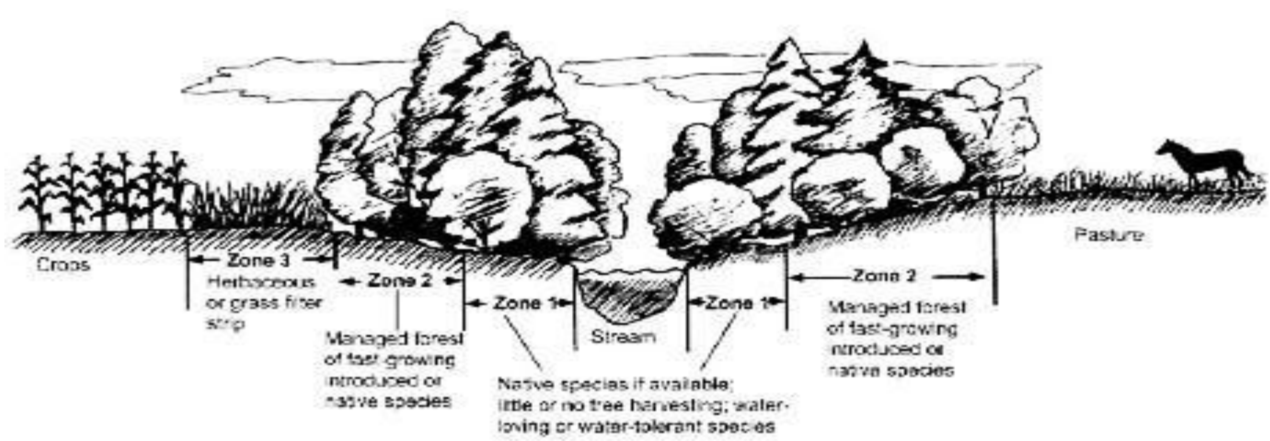

Figure 5.2.3-7. USDA buffer zones.

- Zone 1: Mature forest extending undisturbed for at least 10 to 15 feet from the waterbody edge.
  - Used to provide stream bank and channel stabilization with shading from the tree canopy used to decrease the water temperature. Cooler water temperatures, fallen logs, and leaves provide an environment conducive to certain aquatic life, especially macro-invertebrates, which act as a vital link in the food chain between producers and higher organisms such as fish. Leaves, twigs, and branches that fall from forest trees into the stream are an important source of food and shelter for aquatic macro-invertebrates.

- Zone 2: A layer of managed forest that extends upland from Zone 1 for a minimum of 50 to 60 feet.
  - Where shallow groundwater flows through the root zones of trees, nitrate removal can occur as the trees uptake the nutrients. Trees, vegetation, and fallen organic debris slow stormwater runoff and capture sediment, nutrients, and chemical pollution, allowing the runoff to infiltrate into the ground. Intermittent harvesting of trees is necessary in Zone 2 to encourage rapid tree growth and to remove nutrients that have been sequestered, if it is a concern.

- Zone 3: The first phase in mitigating stormwater runoff, Zone 3 should be a 10- to 20-foot strip of non-forested buffer, located upland of Zone 2.
  - The main function of this zone is to spread concentrated flow before it reaches Zone 2. Some initial infiltration and pollutant removal also occur in Zone 3.
  - Buffers, especially dense grassy or herbaceous buffers on gradual slopes, intercept overland runoff, trap sediments, remove pollutants, and promote groundwater recharge. For low to moderate slopes, most filtering occurs within the first 10 to 20 feet, but greater widths are necessary for steeper slopes.

<u>Design Strategies</u>

- Every effort should be made to keep, protect, and expand riparian corridors, especially those with undisturbed soil and mature woody vegetation. All efforts should be made to ensure that the trees, shrubs, native grasses, and ground covers are protected from damage during construction.
  - Protection of continuous buffers should be given higher priority than protection of piecemeal/fragmented buffers.
  - Buffers should be prioritized by stream order. Establishment of riparian buffers along headwater or source water streams should be given the highest priority. Small

Figure 5.2.3-8. Before stream and buffer restoration.

streams are more easily impacted by land development, and headwater streams cover the majority of the watershed and influence all downstream stormwater management issues.

- In the Army Corp of Engineer's publication, "Design Recommendations for Riparian Corridors and Vegetated Buffer Strips" (Fisher et al. 2000) (http://el.erdc.usace.army.mil/elpubs/pdf/sr24.pdf), the authors provide the following general recommendations for corridor restoration and management:
  - Corridors that maintain or restore natural connectivity are better than those that link areas historically unconnected.
  - Continuous corridors are better than fragmented corridors.
  - Wider corridors are better than narrow corridors.
  - Several corridor connections are better than a single connection.
  - Structurally diverse corridors are better than structurally simple corridors.
  - Native vegetation is better than non-native vegetation.

Figure 5.2.3-9. After stream and buffer restoration.

- Examine the proposed site program and plans. Make all possible efforts to avoid encroaching on the riparian corridor. Find design solutions that minimize the need for proposed site structures, roads, and parking lots to cross or encroach on the watercourse and its vegetative buffer.
- Designate a continuous strip on both sides of perennial or intermittent streams. A riparian corridor should be designated even if the existing vegetation is fragmented or entirely removed.
  - It is desirable to leave a buffer strip of at least 4 feet on either side of any swale, manmade channel, or tiny (1 foot to 18 inches) watercourse (see Section 5.4.1.1, Naturalize Swales and Drainage Channels).
- On the concept plan, identify the methods that will be used before, during, and after construction to protect the riparian corridor. On the final plans and construction drawings, show details and specifications if using methods unfamiliar to local contractors.
  - Divert sediment-laden stormwater from the construction site away from the riparian buffer.
  - Dissipate any concentrated flow using a level spreader, or similar tool. Sheet flow is preferred.
- Do not use permeable paving in a riparian zone—permeable paving is ineffective within any area of high water table or area that floods regularly, as stormwater is unable to infiltrate into the ground.
- If walks or structures are required in this area, consider keeping them off the ground, e.g., use boardwalks with pile foundations.
- Provide a plan to stabilize any bare soil areas and replant where vegetation is damaged, missing, dying, or invasive.

- To encourage the regrowth of native vegetation where the designated corridor was previously in turf or bare soil, remove the turf, loosen compacted soil to a depth of 6 inches, and rake soil smooth. Cover bare soil areas with straw or leaf litter to a depth of no more than 1½ inches. Then cover mulch with a single sheet of "Dutch" (open weave) burlap. Stake burlap with wooden stakes to hold. Plant through the burlap, and then cover burlap with a second thin layer of leaves or straw.
  - Save any removed existing woody vegetation and store it so that it may be used later in the project for bioengineering if needed.
- Utilize the ability of riparian buffers to assist in pollutant removal. Appropriately sized riparian buffers have the greatest ability to remove pollutants, nutrients, and sediment loading.

<u>Bioengineering Strategies</u>

Bioengineering uses a system of living plant materials as structural components to mitigate erosion and restore planting. Adapted types of woody vegetation (shrubs and trees) are initially installed in specified configurations that offer immediate soil protection and reinforcement. In addition, bioengineering systems create resistance to erosion as they develop roots or fibrous inclusions.

Chapter 16 of the USDA NRCS Engineering Field Handbook describes the following bioengineering techniques and provides guidance for the implementation of these techniques: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17553.wba.

- Live stakes
- Live fascines
- Branchpacking
- Vegetated geogrid
- Live cribwall
- Joint planting
- Brushmatress
- Tree revetment
- Rootwards
- Dormant post
- Piling revetment
- Slotted board fence
- Concrete
- Wooden jack field
- Coconut fiber roll
- Stream jetty
- Stream barb
- Vegetated rock gabion details
- Live siltation construction
- Reed clump

Construction Considerations

Damages to existing riparian buffers can be limited by:

- Using small equipment and hand labor.
- Limiting access.
- Locating staging areas outside work area boundaries.
- Not trampling, depositing trash, or spilling toxic materials, etc., within the buffer or within the buffer's immediate drainage area.

- Avoiding or altering construction procedures during critical times, such as fish spawning or bird nesting periods.
- Coordinating construction along a stream that involves more than one job or ownership.
- Scheduling construction activities to avoid expected peak flood season(s).

Construction Sequencing

- Stake out proposed riparian buffer before construction.
- Stake out the location and configuration of construction access, turnarounds, parking, and storage of materials (including soil stockpiles and dumps) from the construction plan.
- Divert construction runoff from riparian buffer areas.
- At the end of construction, carefully match grades from the developed areas meeting the riparian corridor and stabilize all bare soil.

Operations and Maintenance

In general, the least expensive management of riparian corridors is with large-scale measures, modeled on local, natural processes, such as controlled burns and periodic flooding. In addition, broad-brush measures to remove invasive exotics, selective thinning of native vegetation, and replanting either meadow or woodland can help to create riparian buffers that manage stormwater most effectively and are attractive components of the landscape. If designing a corporate or residential community (including retirement complexes), consider having the tenants manage for wildlife. Specific maintenance issues are addressed below:

- Do not harvest trees in Zone 1; dead wood in the stream provides important food for microorganisms in a healthy aquatic system.
- Zones 2 and 3 should be managed to prevent takeover by exotic, invasive vegetation (especially smothering vines) or by a single, aggressive native species.
- Protect Zones 1 and 2 from runoff channeled by swales. Use a level spreader, or similar tool, in the meadow (Zone 3) to convert concentrated flow to sheet flow. Any level spreader or similar tool used should be inspected periodically to repair any developing rills or standing pools of water. Sediment and debris should be removed from below the level spreader semiannually.
- On larger campuses, parks, subdivisions etc., some sort of farm or ranch fencing may be desirable around the perimeter of Zone 3 to protect from damage (loss of vegetation and compaction) by vehicular traffic or pedestrians.
- In areas overrun by white-tailed deer, deer fencing (18 feet high open, wire or plastic) may be necessary. Alternate deer management could involve organized “culls” or private bow-hunting permits. Damage to Zone 3 will limit the buffer’s ability to spread out concentrated flow and to filter nutrients, sediments, toxins, etc.
- Watering during the establishment period (first growing season) will be necessary if there are new plantings.

- Any level spreading device used to ensure that concentrated flow is spread into sheet flow should be inspected periodically for any channelization or standing pools of water below the level spreader. Sediment and debris should be removed semiannually.

All three zones should be periodically inspected for evidence of gully formation after large storms, denuded areas, and bare soil, or any other signs of damage. Gullies should be filled and regraded, and bare spots replanted and protected.

Resources

The USDA Forest Service has developed a riparian buffer specification and guidance, which can be accessed at the following link: http://www.na.fs.fed.us/spfo/pubs/n_resource/buffer/cover.htm.

The USDA Natural Resource Conservation Service has a good resource for stream bank protection (a specific part of the riparian buffer) that includes planting techniques and selections in Chapter 16 of its Engineering Field Handbook, which can be downloaded here: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17553.wba.

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Criteria Checklist BMP 5.2.3

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance by the owner/applicant for successful implementation.		
• Concept level site analysis includes watershed data, cause and extent of erosion problems, hydrologic data, stream order of all streams, soils and geology data, vegetative condition, and habitat characteristics. Photo documentation is required.	☐	☐
• The required size of the riparian corridor has been established and has been designated a "Protected Area."	☐	☐
• Protected areas are delineated clearly on the Existing Conditions Assessment, Site Protection Plan, Grading and Soils Plan, Erosion and Sediment Control Plan, and Stormwater Plan.	☐	☐
• Protected areas are safeguarded from sediment and stormwater loads during construction.	☐	☐
• Protection, fencing details, and associated signage details for protected areas have been provided.	☐	☐
• If construction activity is necessary within riparian protected area, activities are noted and outlined in sequence (include a description of the activity, why necessary, and proposed time of year/ month of activity).	☐	☐
• If activity is necessary within riparian protected area, remediation activities are outlined in the specifications and drawings.	☐	☐
• Disturbance within riparian corridor avoided or design solutions were utilized to minimize encroachment on the corridor.	☐	☐
• Proposed planting plan of corridor enhancement is appropriate for the three zones of the riparian corridor.	☐	☐
• Permeable paving was not utilized in the riparian zone.	☐	☐
• If walks and structures are proposed in the riparian zone, their footprint was minimized (e.g., pile foundations).	☐	☐
• Bioengineering techniques were utilized within the riparian zone to protect eroding slopes and/or sloped areas.	☐	☐

5.2.4 Protect and Preserve Natural Vegetation

Description

Natural vegetation, especially vegetation growing along flow paths and on steep hillsides, plays a major role in protecting Chattanooga from flooding, erosion, and landslides.

Typical development often begins with mass clearing, grubbing, and leveling of a project site to provide flat locations for large buildings. In the process, vegetation is removed, soils damaged, and drainage pathways obliterated. Remnant natural vegetation is often found on environmentally sensitive areas, such as steep slopes, wet areas, and rocky outcrops, where development was previously difficult and expensive. Destabilization of steep slopes can increase the cost of the project and ultimately impact the health and safety of the development.

The purpose of this BMP is to provide alternatives to the owner, designer, and contractor to avoid encroachment upon, disturbance to, and alteration of natural vegetation and to preserve these areas in a manner that benefits the development and reduces costs.

Because the term "Native Vegetation" is widely misunderstood and defined in a number of different ways, this BMP description explains several commonly used phrases that characterize different components of native vegetation. The term "Natural Vegetation" is used in this BMP to allow for naturalized plants, cultivars, and ornamentals as discussed below:

- Native Vegetation is not used to describe a single plant, but is understood to mean a community of plant species, growing together under similar environmental conditions. In general, this group of plants has adapted to a particular site and to its companions over a long period of time. Native vegetation found on a project site may be only a small portion or remnant of a former intact plant community. These remnants may be as small as a leftover grove of trees or as large as a mountain forest.

  Human impact is global and there is no pristine untouched landscape. The somewhat disturbed pieces of vegetation likely to be found on a development site in Chattanooga consist of native plants, exotic naturalized plants, and exotic invasive plants. Because there is considerable confusion about the meaning of these terms, they are defined briefly below:

  - In this manual, "Native Plants" are defined as those plants that have evolved with other plants and animals in response to specific conditions of climate, geology, landforms, soils, and water, and have not been seriously disturbed by human beings.

  - "Exotic Plants" are defined as plant species carried away from their native habitats and introduced to new places, by intention or by accident. Again, this definition is fuzzy because in many cases, the specific origin of a plant is not known. These plants can simply naturalize and become a balanced member of the community, or they can overwhelm the other vegetation, becoming destructively invasive.

“Cultivars” and “Ornamentals” are non-native, exotic plants. Cultivars are plant varieties produced in cultivation by selective breeding. These plants are selected for particular characteristics, and when propagated, pass on these qualities.

- “Naturalized Plants” are non-native, exotic plants that do not need human help to survive and thrive over time in areas where they historically do not naturally occur. There is a general consensus in the scientific community that an “exotic plant,” which does not spread aggressively in the landscape or significantly alter existing environmental conditions, is relatively harmless and can be planted and should be protected.

- “Invasive Plants” are non-native, exotic plants that are able to establish on many sites, grow quickly, and spread to the point of disrupting plant communities or ecosystems. Invasion by non-native plants reduces native plant diversity and abundance, and alters the species, structure, and functions of long-established plant communities. The much altered landscape of our urban and suburban areas encourages these species, which tolerate and even thrive in and around disturbance. At the same time, populations of more sensitive native species shrink, reducing competition and further encouraging the spread of disruptive species.

  “An invasive species is defined as a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health.”
  Presidential Executive Order 13112 (February 1999)

  Invasive exotic plants frequently found in eastern Tennessee are listed at: http://www.tneppc.org/invasive_plants.

  The USDA Federal and State Lists of Invasive and Noxious Weeds can be found at: http://plants.usda.gov/java/noxiousDriver#state.

- Flow paths are corridors where surface water (sheet flow) concentrates and travels from one place to another. These paths range from shallow swales to large river corridors. These flow paths may or may not be documented as drainage channels or intermittent or perennial streams on USGS maps, but can be identified by using the contours on the site survey with additional field verification.

- Steep slopes are generally defined as land with a slope angle of 15 percent or greater for a minimum of 100 feet horizontally. Development on steep slopes can create problems:

- Construction on steep slopes is costly and can include the expense of cut and fill, earthwork, retaining walls, erosion prevention, etc.
- Cities and towns can be left with heavy costs for erosion and pavement failure.
- Landslides include not only the direct costs associated with property damage, but also the indirect costs of loss of tax revenues, reduced real estate values, and degraded water quality.
- If development is allowed on steep slopes, care should be taken not to disturb natural scenic features, such as escarpments, cliffs, or rock outcroppings.
- Steep slopes are the places that most often have remnant natural vegetation.

- Critical Habitat Areas − Tennessee Wildlife Resources Agency has produced a comprehensive wildlife conservation strategy report with maps indicating priority terrestrial, aquatic, and subterranean habitats to be protected: http://www.state.tn.us/twra/cwcs/tncwcs2005.pdf.

BMP Functions Table

Many stormwater best management practices seek to mimic the stormwater management function of existing, mature plant communities, using infiltration, filtration, and evapotranspiration, etc. Preserving existing natural vegetation can be a very cost-effective BMP. High-quality existing vegetation can reduce peak discharge and runoff, minimize erosion and sedimentation, sequester carbon, reduce the heat island effect, and be aesthetically pleasing.

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Protect and Preserve Natural Vegetation	U/S/R	H	H	H	H	H	H	H	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

<u>Vegetation along Flow Paths</u>

Vegetation protects the integrity of these flow paths by:

- Stabilizing banks and binding soil particles in place.
- Reducing the velocity of runoff.
- Enhancing and maintaining infiltration capacity.

Vegetation on Steep Slopes

Vegetation stabilizes slopes prone to surface sliding and/or movement of soil and loose rocks by:

- Reinforcing the soil with roots.
- Depleting excess soil water through transpiration.
- Reducing stormwater velocity by leaf interception.
- Reducing nutrient runoff into water bodies.
- Preserving existing drainage patterns.

Key Design Guidelines

- Identify steep slopes 15 percent and over, flow paths, and significant natural vegetation (even small remnants).
- Prioritize protection of vegetation based on critical locations within the drainage area and by the health of the vegetation.
- Plan and design the development project to preserve existing vegetation.
- Existing vegetation on the site may be highly disturbed, making protection a lower priority.
- Create measures to ensure that construction disturbance does not impact protected vegetation.

Advantages

- Low-cost and low-maintenance BMP.
- Stabilizes slopes.
- Reduces flooding hazards.
- Reduces erosion and sedimentation.

Disadvantages

- Can conflict with development goals or construction activities.
- Requires unfamiliar efforts and practices.

Applications

This BMP can be applied to sites with a broad range of scales and functions:

- This BMP is most applicable to sites with pronounced topographic change and identifiable streams, creeks, drainage channels, and swales.
- It is always applicable in rural areas and more applicable in areas of suburban or light urban development than the dense downtown.

If the site does not have existing vegetation, or the existing vegetation is of low quality (e.g., the majority of the species are invasive or the majority of the species are diseased or infested with pests), see section 5.4.2, Improve Native Cover Types, in this manual.

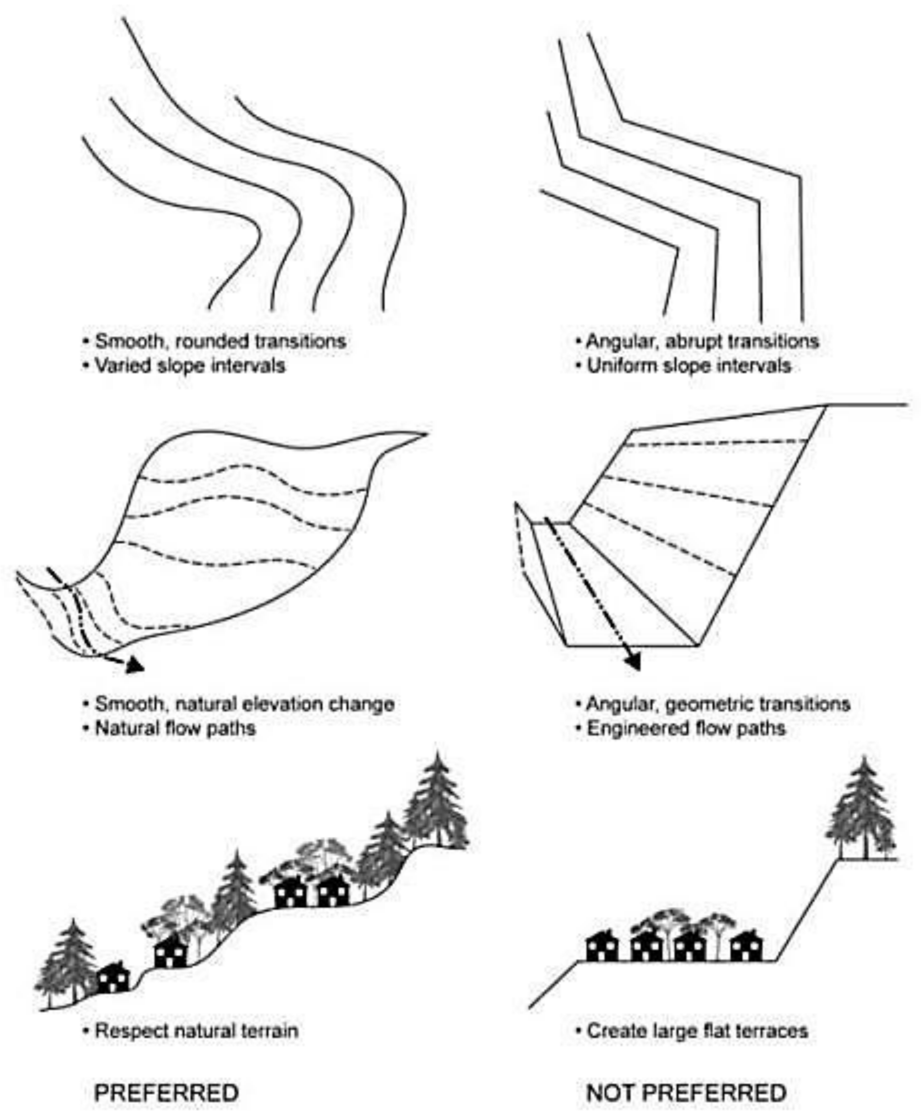

Figure 5.2.4-1. Protect existing slopes and flow paths.

Applicable Protocols and Specifications

Protocol 5 Planting Guidelines

Design Considerations

The overall purpose of this BMP is to discourage mass clearing and grubbing and unnecessary land disturbance of any kind. Vegetated areas, particularly in environmentally sensitive areas, such as steep slopes, along flow paths, and in critical habitats, should be a priority consideration throughout the design process and should be carefully evaluated for impacts throughout the development process.

- See Section 5.2.1.2 for detailed information regarding protection of steep slopes.
- See Section 5.2.2 for detailed information regarding protection of natural flow paths.
- See Section 5.2.3 for detailed information regarding protection of riparian corridors.

Figure 5.2.4-2. Protect environmentally significant areas such as flow paths.

Analyze Existing Vegetation

- Desktop Analysis
  In the concept phase, evaluate existing vegetation onsite by reviewing topographical surveys, aerial photography, and other resources (Google Earth Historic Photo Viewer, ArcGIS, archives of local historical societies, NRCS soil data, etc.). Delineate roughly the areas of:
  – Vegetation
  – Steep slopes – 15 percent and greater
  – Drainage patterns (see Section 5.2.2, Protect and Incorporate Natural Flow Paths, in this manual)

- Field Assessment
  With a rough overview of the site from the existing data, evaluate vegetation in the field in the preliminary phase. Determine and identify:
  – The location and condition of steep slopes greater than 15 percent, drainage pathways, and critical habitat areas.
  – Plant community type (i.e., red maple swamp).
  – Companion plants for that community.
  – Predominant species composition in the over-story, mid-canopy, understory, and ground layer.
  – Plant community age (successional stage or age of landscape – field to forest).

- Vegetation condition (healthy, declining, dying, non-native invasives, etc.). Note the presence of emerging diseases and pests (emerald ash borer, oak wilt, southern pine beetle, hemlock wooly adelgid, etc.).
- Ground condition (presence of fill, dumping, lack of organic matter, erosion, etc.).

The team landscape architect in coordination with an arborist or ecologist familiar with local ecosystems can determine the existing or remnant plant communities of the site.

Reference *U.S. Terrestrial Vegetation of the United States* (Grossman et al. 1998), Nature Serve and its State Natural Heritage partners http://www.natureserve.org/.

Field assessments of vegetation systems and species may also provide clues as to what species perform well on a site.

<u>Prioritize Areas To Be Protected</u>

Chose areas with:

- Higher conservation status, as defined by Nature Serve and the Tennessee State Natural Heritage program, http://www.tn.gov/environment/na/nhp.shtml.
- Mature forest stands.
- Systems in hydrologically significant areas (wetlands, areas immediately downhill from large impervious areas, natural flows paths, etc.).
- Systems in environmentally sensitive areas as defined by a local, state, or federal agency or areas that provide habitat for endangered or threatened species, http://www.state.tn.us/twra/cwcs/cwcsindex.html.
- Vegetation on steep slopes and ridge tops.
- Vegetation in flow paths.
- Vegetation in culturally significant areas, including view sheds (as defined by a local, state, or federal agency), http://www.chcrpa.org/divisions_and_functions/Comprehensive_Planning/CompPlan2030/Full_w_Appendices.pdf.
- Areas that maintain connectivity within a regional vegetated corridor, such as riparian or migratory corridors.

<u>Design Strategies</u>

- Incorporate Protection in Site Design
  - Identify and designate “Protected Areas” and “Areas of Minimal Disturbance” (see Section 5.2.1, Protect Undisturbed and Healthy Soils, in this manual for a description of these areas). Show these areas on the Existing Conditions Assessment and Site Protection Plan, the Grading and Soils

  Plan, the Erosion and Sediment Control Plan, and the Stormwater Plan for both preliminary and final phases.
  - Areas of Minimal Disturbance will require application of Section 5.4.3, Restore and Amend Disturbed Soils, in this manual to receive credit.
  - Incorporate these areas into the overall landscape design plan for the site. Existing and proposed landscape types should work together to create functional and beautiful spaces.

- During the site design process, make every effort to avoid placing buildings and roads on Protected Areas and Areas of Minimal Disturbance. During the concept and preliminary stormwater management plan phases, reexamine proposed site plans to reduce site disturbance. Revisions should include minimizing impervious surfaces of all kinds, including circulation routes and building footprints, and minimizing land disturbance wherever possible (see Section 5.2.1.1, Preserving Landforms, in this manual).

- Design to protect designated areas. Rogue trails are created, and site resources are damaged, where circulation is poorly planned. Buffer protected areas by maintaining existing strips or creating new strips of vegetation that people would not care to walk through. These buffers will safeguard protected areas from damage by runoff and also help direct users to designated access routes after the project is implemented. (See Structural BMP 5.3.6, *Vegetated Filter Strips*, in this manual).

Construction Considerations

Site Protection

- The City of Chattanooga requires chain link fence around all protected areas.

Mitigate Impact from New Construction

- Edge conditions − Construction often leaves transition areas between remnant natural vegetation and building sites in a highly disturbed condition.
  - Locations where new grades meet steep slopes require sensitive grading to ensure a seamless transition.

Figure 5.2.4-3. Erosion at steep slope transition.

- Do not push excess soil over a slope edge when leveling areas above.
- Stabilize edges where a remnant natural area meets a manmade landscape.
- Where portions of a natural landscape, such as a forest, have been cut away to accommodate development, leaving islands of remnant vegetation and repair of the newly exposed edges are critical.
  - Regrade where necessary, stabilize the soil, and replant with fast-growing, tough native edge species.
  - Repairing damaged edges will protect the health of the natural landscape and enhance its stormwater benefits.
  - Where forest edges have been cut, trees are often vulnerable to wind throw. Replant a strip of fast-growing trees along newly exposed edges to buffer the remaining native landscape from increased wind, light, noise, and other impacts.

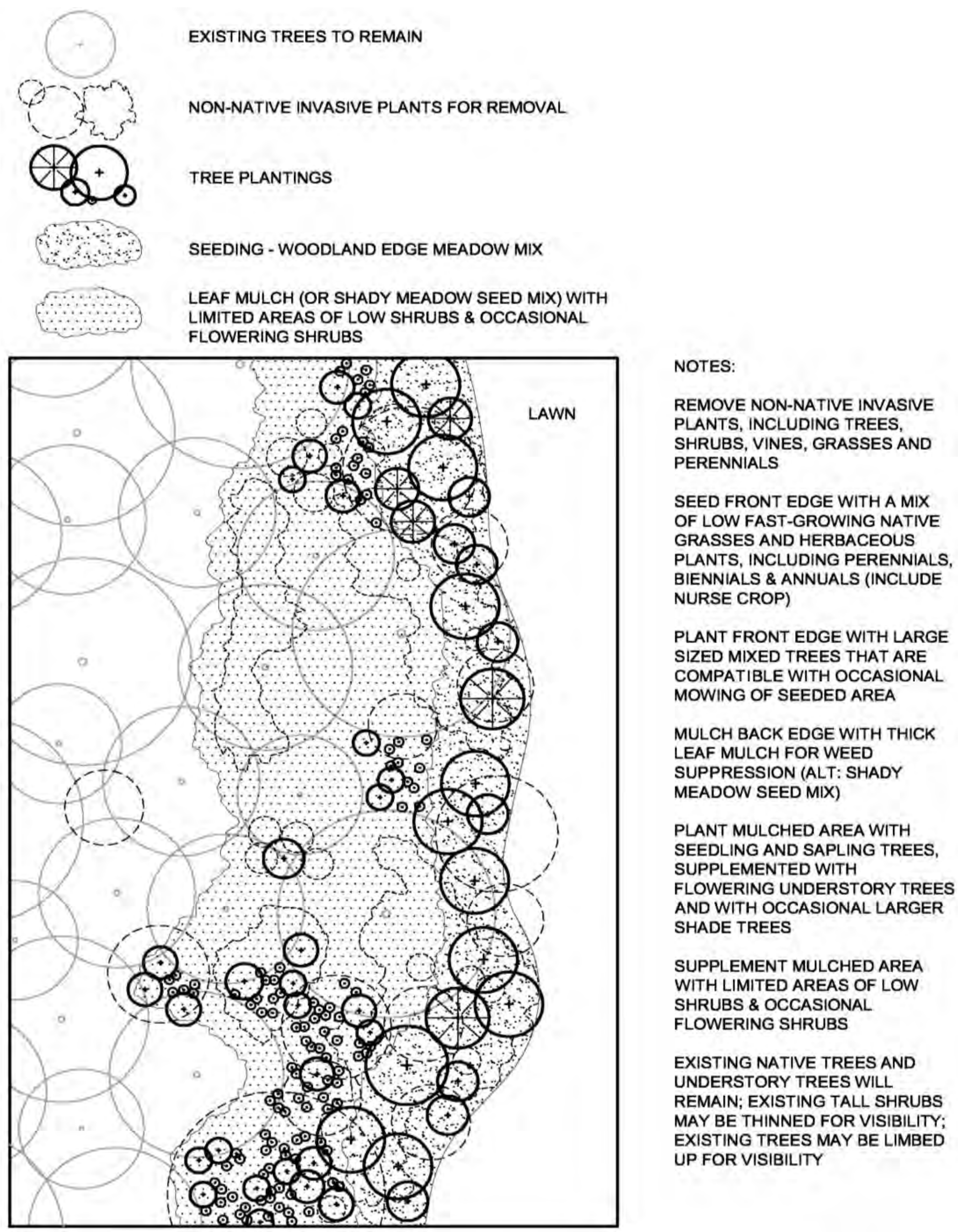

Figure 5.2.4-4. Repair forest edge – sunny.

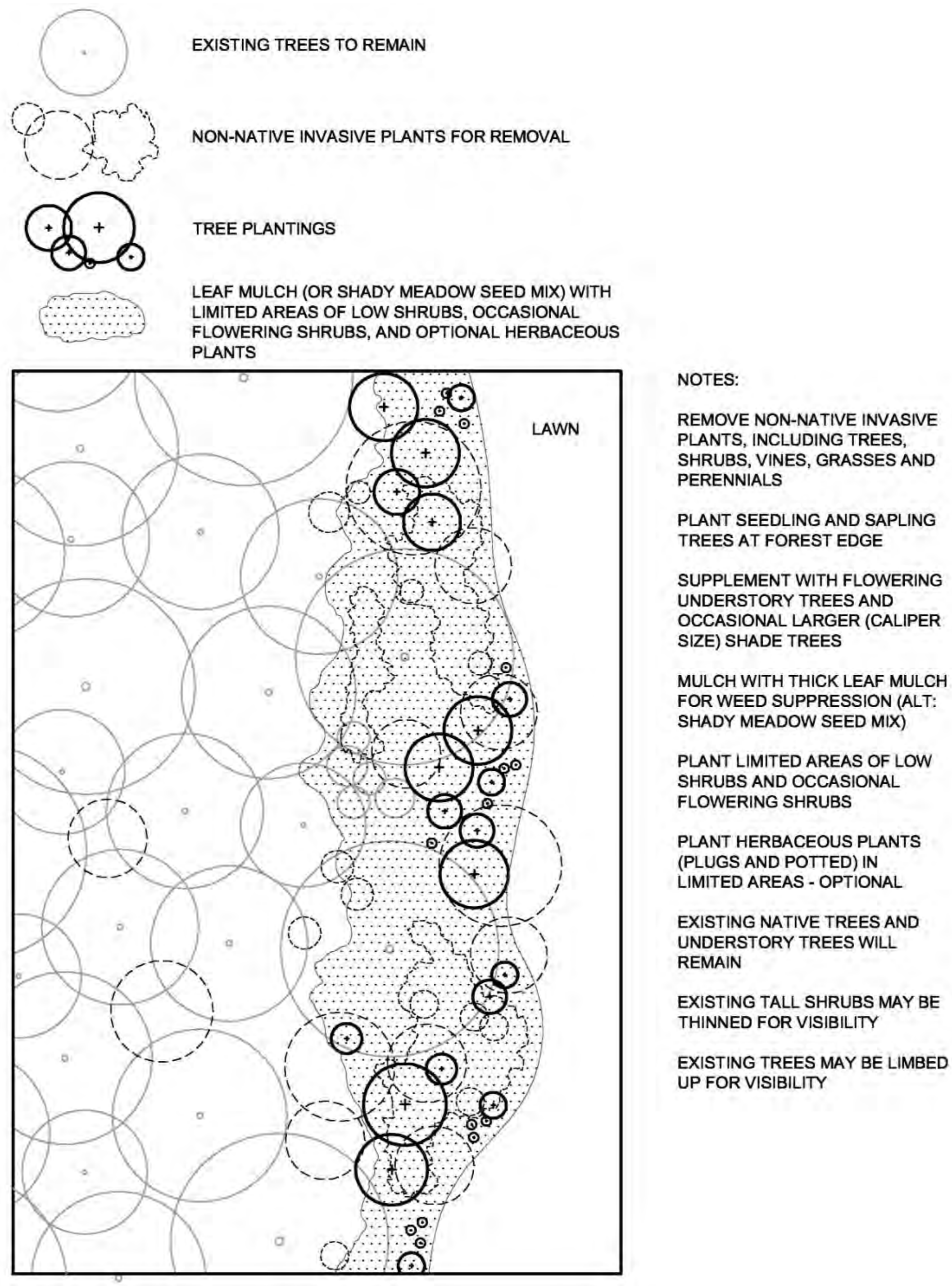

Figure 5.2.4-5. Repair forest edge – shady.

- See Section 5.2.1, Protect Undisturbed and Healthy Soils, in this manual, for steps in concept and preliminary design phases.
- Monitor areas designated as Protected Areas for impacts throughout the development and construction of the project design.

Operations and Maintenance

Although established native vegetation requires little maintenance, some additional steps may be necessary:

- Evaluate the need for additional temporary irrigation during drought conditions for at least a two-year recovery period, especially around disturbed edges.
- Monitor before, during, and after construction for any signs of erosion, disease, and invasive species and take corrective action.

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Criteria Checklist BMP 5.2.4

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance by the owner/applicant for successful implementation.		
• Steep slopes above 15 percent, drainage flow paths, and critical habitat areas if any are identified and included in documentation for all three design phases: concept, preliminary, and final.	☐	☐
• Vegetative cover has been evaluated by aerial photograph in concept phase.	☐	☐
• Vegetative cover has been evaluated by field assessment in preliminary phase. Photo documentation required. Plant community type, predominant species composition, community age, vegetation condition, and ground condition noted as narrative on site assessment.	☐	☐
• Prioritize protection of vegetation based on critical locations within the drainage area and by the health of the vegetation.	☐	☐
• Prioritized vegetation areas are designated “Protected Areas” and/or “Areas of Minimal Disturbance” and are delineated clearly on the Existing Conditions Assessment, Site Protection Plan, Grading and Soils Plan, Erosion and Sediment Control Plan, and Stormwater Plan.	☐	☐
• “Protected Areas” and/or “Areas of Minimal Disturbance” are safeguarded from sediment and stormwater loads during construction.	☐	☐
• Protection, fencing details, and associated signage details for “Protected Areas” and/or “Areas of Minimal Disturbance” have been provided.	☐	☐
• Provide written description of any work that may need to be performed within “Areas of Minimal Disturbance.”	☐	☐
• Smallest and lightest machinery is to be used in “Areas of Minimal Disturbance.”	☐	☐
• Details provided for protective layer on soil to absorb and spread compressive forces for work done in “Areas of Minimal Disturbance.”	☐	☐
• Notes on drawing clearly provide sequence for removal of protective layers and soil restoration if required in “Areas of Minimal Disturbance.” (Once removed, contractor performs a light tilling of soil to prevent surface crusting, including compost tea and other amendments.)	☐	☐
• Newly exposed forest edges have planting plan and maintenance strategy.	☐	☐
• Removal and management plan for invasive exotics within protected and minimal disturbance areas has been submitted during preliminary and final review phases along with schedule of tasks per season and timeline.	☐	☐
• Replanting plan for bare areas or those area left exposed by removal of invasive exotics has been incorporated into the Preliminary and Final planting plan.	☐	☐

5.2.4.1 Protect Historic or Specimen Trees

"The best time to plant a tree is twenty years ago. The second best time is now."

Description

Individual trees may be considered important resources because of unique or noteworthy characteristics or values such as size, age, species, historic significance, ecological value, aesthetics, location, trees planted as code requirements, or other characteristics or associations that make them special.

Tree well-being is often overlooked during construction and can result in fatal damage. A single, medium-sized U.S. city is estimated to lose $800,000 annually as a result of damage to trees during construction (Hauer et al. 1994). Damage is preventable and tree preservation is an important stormwater management measure, especially in dense urban areas.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Protect Historic Trees	S/R	M	L	M	M	H	H	M	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Guidelines

- Protect existing trees from disturbance.
- Prioritize protection and/or enhancement of large, mature trees based on location within the drainage area, quality of surrounding vegetation and soils, and cultural, historical, or aesthetic significance.
- Give special attention to protecting trees next to large areas of impervious surfaces.

Applications

- The BMP is applicable to any size of land development with existing, high-quality, mature trees or rare or culturally significant trees. These trees should be in good health.

Advantages

- Protecting and enhancing large mature trees will provide a head start for overall stormwater management of the site, as mature vegetation and high-quality soil take many years to establish.
- Protecting and enhancing quality of existing trees adds aesthetic value.
- Existing trees often require low maintenance.

Figure 5.2.4.1-1. Tree protection fence.

Disadvantages

- Protecting and enhancing existing trees may conflict with development goals or construction activities.
- Existing specimen trees on a site may be minimal or be of low quality, making enhancement uneconomical or unfeasible.
- Preservation and enhancement require initial site investigation and protection activities during design and construction, which can add labor, time, and cost to the project.

Figure 5.2.4.1-2. Tree protection fence with sign.

Design Considerations

<u>Tree Protection Zones</u>

Trees considered for protection from construction activity should be part of a larger site protection strategy. Construction areas containing trees to be preserved require additional restrictions on excavation and trenching. The tree protection zone includes both the structural and feeder roots, which can extend well beyond the drip line (canopy extent) of the tree. The outer portion of the tree protection zone represents the area where the feeder roots are concentrated. The majority of these roots lie within the top 18 inches of the soil and collect water and nutrients for the tree. The inner portion of the tree protection zone represents the area where structural (supporting) roots are concentrated. Both feeder and structural root zones are important to tree preservation and long-term health. Because the majority of a tree’s roots lie close to the ground surface, construction activities should avoid the entire tree protection zone. Fencing and signage to protect these areas are required.

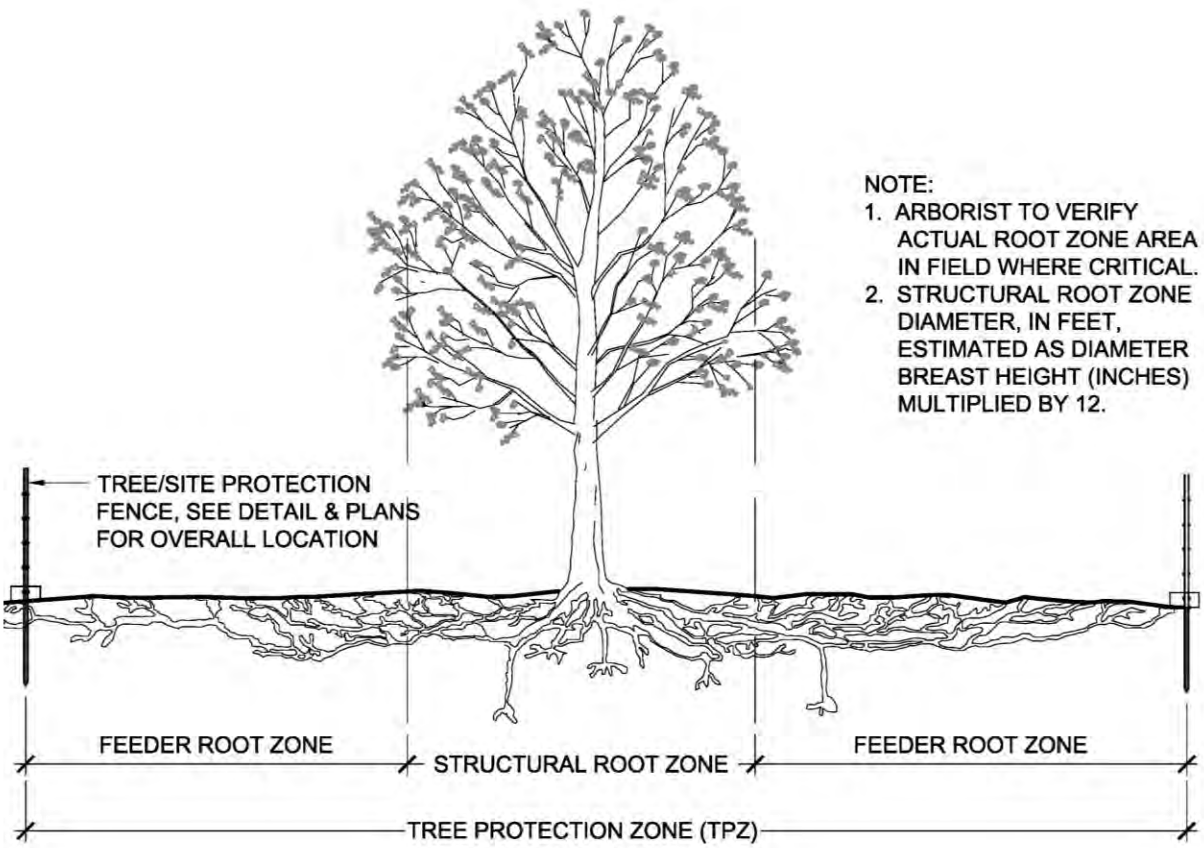

Figure 5.2.4.1-3. Tree protection zone detail.

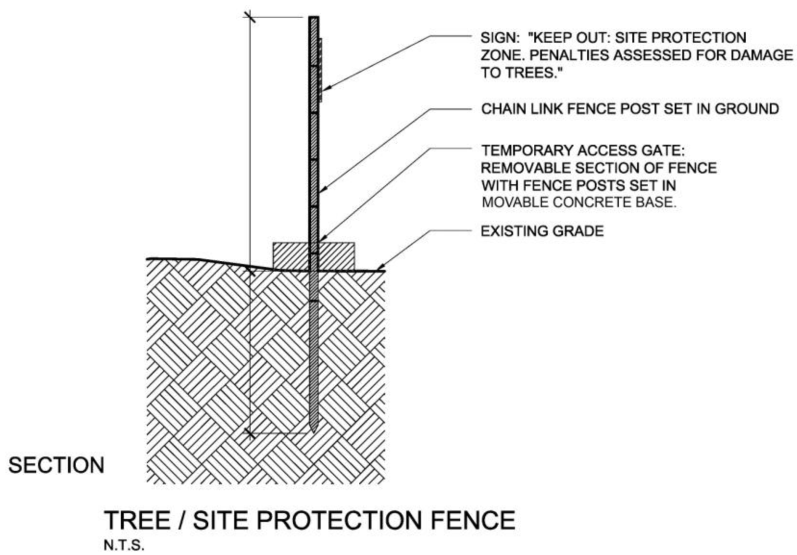

Figure 5.2.4.1-4. Tree protection zone fence detail.

When preserving trees within construction sites, it is important to define the tree protection zone as realistically as possible:

- With a large or specimen tree (native species 12 inches or greater, or as defined by the City Forester), air spading or carefully digging around the tree to investigate the true extent of the root zone is recommended.
- Alternatively, where possible, calculate the approximate tree protection zone using the Matheny and Clark method (1998). This methodology is based on tree size, age class, and the tolerance of the species to construction disturbance. See references.
- Where these methodologies are not feasible, use the drip line of the tree to approximate the root zones as a minimum.

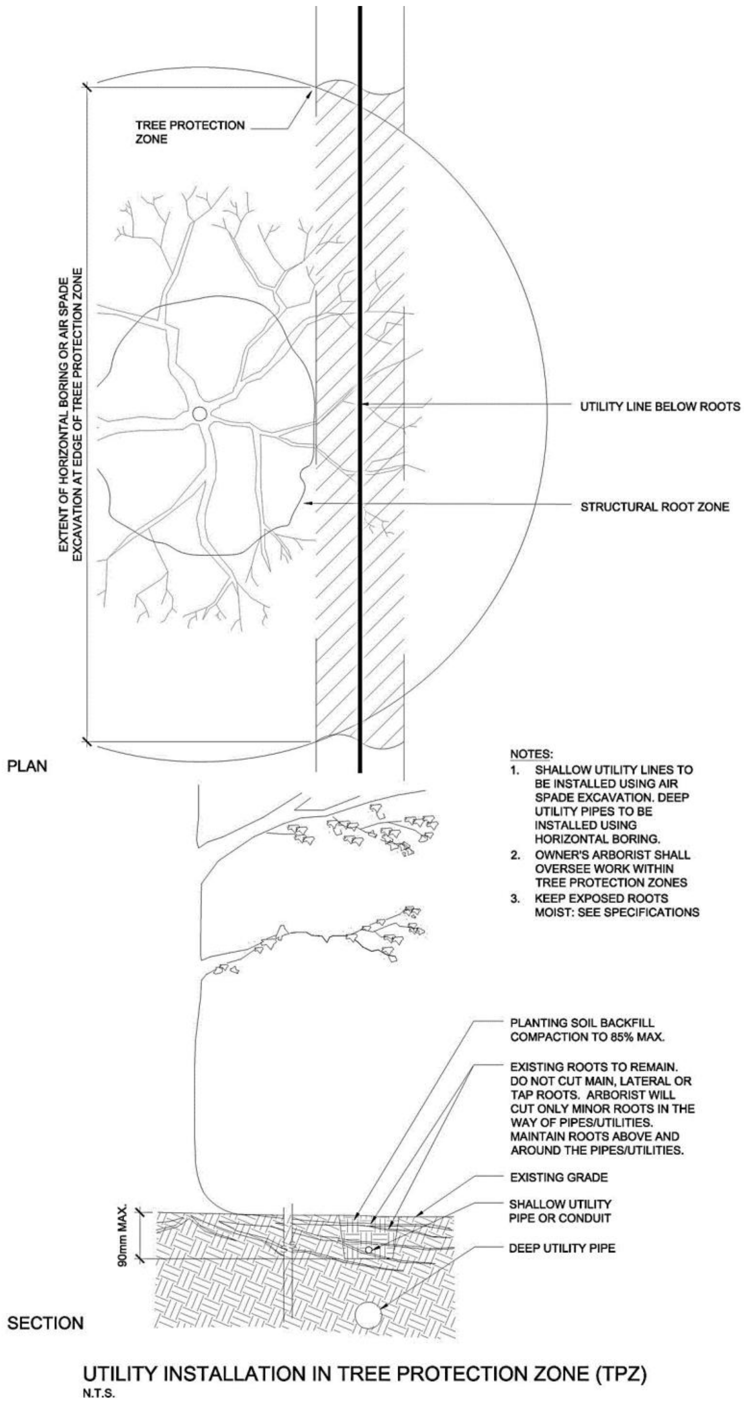

Figure 5.2.4.1-5. Utility installation detail.

Preconstruction Preparation

Trees that are "prepared" in advance for the stresses of nearby construction have a higher probability of surviving and thriving in the long term. Initial protection methods should be started one growing season before actual construction. Typical activities include:

- Treatments with plant growth regulators to promote root development and reduce drought stress.
- Advance root pruning where excavation is anticipated.
- Fertilization and other measures aimed at promoting overall tree health.
- Advance canopy pruning of existing trees located near areas of architectural construction and renovation to minimize canopy damage and allow vertical access to the façade.

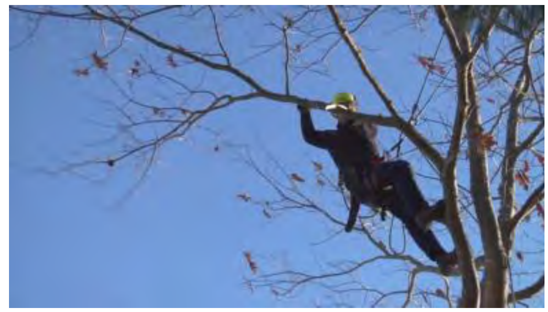

Figure 5.2.4.1-6. Tree pruning.

Figure 5.2.4.1-7. Root pruning.

Irrigation

Irrigation should be considered only when absolutely necessary. It should be a temporary measure to solve specific problems, including:

- Trees extremely close to construction activities.
- Trees within proximity to deep excavation.
- Prolonged drought during the construction process.

Where irrigation is necessary within tree protection zones, the following must be considered in the design:

- Do not drastically alter the existing hydrological conditions of the area.
- Where possible, use harvested rainwater for irrigation.
- Spray from irrigation heads should not be directed to the aboveground parts of the trees; drip irrigation is preferred.
- Plot the least disruptive route for the irrigation lines located outside of the tree protection zones.
- Consider irrigation software that is capable of sensing the current climatic conditions or has a convenient manual override system to prevent unnecessary irrigation after rain. Examples include soil moisture sensors, digital rain gauges, and remote access irrigation software, which can be viewed and controlled from any computer with internet access.

Grade Beams, Piers, and Cantilevered Foundation Walls

Consider a specialized foundation design for small building additions and other site structures as an alternative to continuous footings near trees to be protected. Point footings, grade beams, and cantilevers require limited excavation, which will reduce the impact on root systems of adjacent trees.

Grading Design within Tree Protection Zones

Site and architectural design should preserve existing grades within tree protection zones to the extent possible to minimize damage to root systems. To minimize pavement impact, designs can be built slightly above existing grade to minimize excavation within the root zone. Where grade changes are unavoidable, slight increases in elevation (up to 12 inches of fill) are preferable, where the tree species can survive an increase in soil cover. Cut conditions, which sever roots, are not desirable. "Adventitious roots" originate from the tree trunk, branches, and leaves or old woody surface roots, rather than the underground root system. Trees with the ability to grow adventitious roots (e.g., ash, sycamores, certain maples, etc.) can survive large amounts of fill. Other species require tree wells or low retaining walls to maintain air circulation around the trunk to prevent rot.

Walkway Design within Tree Protection Zones

Walkways and other types of paving have the potential to cause damage to tree roots due to excavation and compaction for the sub-base construction. Impacts to adjacent trees can be reduced with the following measures:

- Where possible, avoid high-load-bearing (vehicular) pavements, which have thicker sub-bases, within tree protection zones.
- Where possible, use low-load-bearing (pedestrian) pavements.
- Design shallow pavement sections to minimize excavation.
- Design for finish grades slightly above existing grade to reduce excavation.
- Retain existing roots in the aggregate base course.
- Curved walkway alignments can skirt trunk flare and minimize future pavement upheaval.
- Consider flexible pavements with supporting geotextiles and minimal compaction.

Post-Construction Care

- Protection from "drought stress" post construction:
  - Proactive irrigation is beneficial during drought periods, since the recovering tree will have fewer reserves to combat subsequent stresses.
  - Irrigation needs to be carefully applied so as not to change the hydrology of the soil.
  - An effective treatment for water loss is the applications of paclobutrazol (PBZ), which retards plant growth. It is used as a foliar spray to reduce water loss from leaves (Rainbow Tree Care 2010).

- Soil chemistry remediation (fertilizing and other health boosts):
  Fertilizing, via top dressing with compost or compost teas, can benefit the tree and soil biota. For certain species, it may be beneficial to inoculate tree roots with mycorrhizae.

- Pruning:
  Dead wood and crossing branches should be pruned for tree health and safety.

Individual Trees – Relocation

Transplanting large trees may be called for in select cases. This is a very expensive protection measure and requires lead time, in advance of construction, to prepare the tree for relocation. Advance planning should be coordinated with an experienced contractor specializing in large tree moving. Considerations include:

- Proposed site characteristics: the slope, aspect, and soil conditions of the new site should match the original site as closely as possible.
- Preparation work includes root pruning, canopy pruning, chemical treatments, and other measures to improve tree health. This preparation is most effective if done throughout the growing season prior to the move, 9 to 14 months in advance.
- Moving large trees during the dormant season (approximately November to February) is most desirable. Transplanting at other times of the year is possible with sufficient care.
- A professional arborist with experience in large tree moving can provide an opinion of survivability and transplant feasibility for the specific species of the tree in question.
- Existing underground utilities may conflict with proposed root ball excavation. Sufficient overhead clearance should be confirmed along the moving route.
- Post-transplant care should be contracted for at least two years following the move. Care will need to include irrigation and monitoring.

Construction Considerations

Key tree protection measures during construction include:

- Restrict construction activity within tree protection zones, which includes no parking, vehicular use, stockpiling, storage, and staging within the designated root zone.
- Plan for temporary access for construction of specific, permanent features within the tree protection zone and protect with secondary fencing.
- Protect root zone from compaction:

Figure 5.2.4.1-8. Do not place heavy equipment in root zone.

- Access routes that cross through tree protection zones must include measures to protect the soil from compaction, contamination, and other disturbances.
- Limit potential access and design protection details.
- Avoid using large equipment where space is limited near existing trees to be retained.
- Route construction traffic where permanent sidewalks or roads are to be located, unless these routes will become BMPs with infiltration requirements. In other areas, use a matting system or other protective layers to buffer the soil from compaction (see Section 5.2.1, Protect Undisturbed and Healthy Soils, in this manual).

Figure 5.2.4.1-9. Do not stockpile in root zone.

References

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5.2.4.1 Protect Historic or Specimen Trees Criteria Checklist

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance by the owner/applicant for successful implementation.		
• Protected trees are native species of at least 12 inches in diameter breast height or as defined by the City Forester.	☐	☐
• Trees are saved within proximity to proposed new impervious surfaces to provide canopy interception and exfiltration benefits.	☐	☐
• Delineate and label existing trees to be retained on Landscape and Stormwater Management Plan noting species and diameter breast height.	☐	☐
• Show tree protection zones with both structural and feeder root zones on plan(s).	☐	☐
• Provide detail or description of protective tree fencing.	☐	☐
• Provide written description of preconstruction preparations.	☐	☐
• Provide written description of any work that may need to be performed within the tree protection zone if necessary and methods to be used.	☐	☐
• Provide type and location of protected area signs. Signs should be in English and Spanish and should read "Stay Out" ("No Entrada") or "Tree Save" ("Salve un Arbol").	☐	☐
• Provide note on plans: *"Topping trees is not allowed. Trees removed or having their tops cut shall be replaced with the equivalent inches of removed trees."*	☐	☐
• Provide note on plan: *"Thinning is allowed and may include manual removal of non-specimen trees within the tree protection zone of the specimen tree. (NO motorized/ wheeled or track vehicles allowed within tree protection zone of the specimen tree)."*	☐	☐
• Note on plans: *"Tree protection measures will be maintained at all times. Additional tree protection measures will be installed if deemed necessary by on-site inspection."*	☐	☐

5.2.4.2 Soil and Plant Salvage

Description

Plant and soil salvage involves harvesting onsite, or from another available construction site, and saving, storing, and replanting plants and as much soil with these plants as possible. Plants to be reclaimed for use in a project are cut as blocks of soil from their growing site.

As much length, width, and depth of soil as is economically feasible should be included. The cut block of soil and plants, or "sod," can vary from 4 to 6 inches deep for small woody and herbaceous plants, to up to 18 inches or more when salvaging medium-sized trees and shrubs. The length and width of each soil block are dependent on the technique chosen for moving the sods. Salvaging soil blocks is an alternative to stockpiling topsoil and to conventional transplanting techniques, such as digging and preparing balled and burlapped, container, or bare root plants. The salvage method is the fastest way to cover a site with living plants. If the necessary machinery is readily available, this method is also the most economical way to stabilize or re-vegetate large areas of bare soil.

Additional benefits include retaining a wide diversity of plants, often not available in the commercial nursery trade, with soils containing a full complement of biological life, including associated fungi, micro and macro organisms, seeds, and seedlings.

This method is most effective in stabilizing and re-vegetating stream banks and riparian corridors, or steep slopes, where a local source of retrievable plants is available.

BMP Functions Table

Native vegetation salvaged with its native soil can be immediately placed on a new site and establishes very quickly. It provides instant stormwater benefits including reduced peak discharge and runoff, slope and water channel stabilization, and reduced erosion and sedimentation. In addition, it provides habitat, sequesters carbon, and reduces the urban heat island effect.

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Soil and Plant Salvage	S/R	H	H	H	H	H	L	H	L	M

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Guidelines

- Salvage existing vegetation and soil that would otherwise be lost during construction.
- Prioritize salvage based on quality of vegetation and soils, ease of access, ease of removal, and establishment in a new site.
- Match salvage vegetation to the physical conditions of the new site (wet/dry, sunny/shady, and exposed/sheltered).
- Work with existing resources to salvage and replace plant blocks, understanding the contractor's existing or available machinery, onsite resources, local skills, budget, etc.

Advantages

- Vegetation and high-quality soil take many years to establish and to reach their full stormwater management potential. Salvaging existing soil and vegetation provides immediate stormwater management benefits compared to a new installation.
- Recycling resources is more sustainable than importing new material.
- Salvaging plants where they would otherwise be destroyed can provide species that are not available commercially and plant material that is inexpensive for the project.
- Existing materials are already adapted to specific site conditions.
- A natural aesthetic can be more easily recreated with salvaged plant material.

Figure 5.2.4.2-1. Greenfield meadow with golden groundsel slated for construction.

Disadvantages

- Salvage is unfeasible or uneconomical if existing vegetation onsite is minimal or of low quality.
- Initial site investigation is necessary to determine salvage possibilities.
- Removal, planting, and maintenance of plant blocks require forethought and training.

Figure 5.2.4.2-2. Trees in suburban development slated for construction.

Applications

Sites with existing, excellent to fair quality soil and vegetation that will be removed or impacted by the site program. The size of the property and the site functions are not determinants. However, this method is most cost-effective for large sites with newly created or denuded steep slopes that will not be maintained as lawn.

Applicable Protocols and Specifications

Protocol 3 Soil Testing

Design Considerations

Soil salvage is only worthwhile when the existing soil and ground layer are in good condition. The advantage of this technique is that the transplanted soil is biologically intact. Soil sods may be reset from the same place from which they have been removed—to restore a temporary disturbance (e.g., utility corridor)—or moved to a new location as part of a re-vegetation strategy. Additionally, soil blocks may be placed in a staggered pattern to save on manpower and materials with seeding in areas between blocks.

Figure 5.2.4.2-3. Modified backhoe.

Figure 5.2.4.2-4. Meadow salvage.

Figure 5.2.4.2-5. Meadow salvage truck.

<u>Transplanting Soil "Blocks"</u>

- Choose areas slated for disturbance that also have high-quality natural soil and desirable but movable vegetation. Such vegetation is often found in open meadows, old fields, or successional woodlands, where sufficient areas of young native species are the predominant ground layer.
- Cut the block to the required depth.
- Dig up blocks by machine (backhoe or modified backhoe) or by hand if labor is available or the area to be covered is small.
- Size the dimensions of the block to the method of transportation as well as to the size and requirements of the roots of the plants to be moved.
- Wooden pallets of 4 feet by 4 feet are often the cheapest and most easily available method of moving the blocks.
- Place excavated blocks on the palettes and move them with a forklift to a nearby site, or place them on a flatbed truck, depending on the proximity of the replacement site.

<u>Salvage Timing</u>

- Ideally, plant blocks should be moved **only once**—directly to the planting site. Minimal storage is best for the plants and minimizes operational costs.
- Ideally, plants should be salvaged during their dormant period (from leaf drop in fall to just before leaf out in spring).

- Planting should be done as soon as the ground is workable. If construction or other activities are still taking place and the planting site is unavailable during the optimum planting season, plants must be stored carefully in the shade, protected from construction damage, and watered weekly until planted.
- Of all planting methods, plant blocks adjust most easily to out-of-season planting.

Forest Soil and Leaf Layer Salvage

Salvaging forest soil and the leaf layer from areas of future clearance where buildings, etc. will be sited protects a valuable resource that can be used to revitalize damaged soils in natural or naturalized areas. Installing this soil will reintroduce organic matter and beneficial soil biota back into disturbed areas.

Transplanting Meadow Sods

Salvaged meadow sods provide immediate meadow cover at restoration sites, help absorb runoff, promote regrowth of trees from existing seedlings and/or dormant seed, and provide a source of diverse native plants and seeds not generally available from a nursery. Meadow sods are similar to thick-cut sod, with a depth of at least 6 to 8 inches.

Figure 5.2.4.2-6. Meadow sod on pallet.

Transplanting Small Trees and Herbaceous Perennials and Grasses

Salvaging seedling trees and herbaceous plants where they would otherwise be destroyed can provide the project with inexpensive plant material including species that often are not commercially available.

Transplanting Medium Trees and Shrubs

Medium trees represent a balance between appreciable size and economics. Medium trees include trees that are up to 10 feet tall and up to 4 inches in caliper diameter at breast height (DBH). These trees are too large for plant blocks, but can be salvaged through a variety of means including hand digging, tree spading, etc.

Transplanting Large and Very Large Trees

See Section 5.2.4.1, Protect Historic or Specimen Trees in this manual for further information.

Construction Sequencing

Soil Management

Soil management is often overlooked during conventional construction operations. Quality control for salvaged soil and imported replacement soil is also critical. Specific tasks related to soil management during construction include:

- Restrictions on construction activity within site protection zones.
- Soil salvage.

- Evaluation of rough subgrade water infiltration.
- Planting soil material acquisition.
- Testing and analysis for specification conformance.
- Inspection and testing of subgrade for preparation of subgrade.
- Preparation of mixes and testing for conformance.
- Installation and placement of soils.
- Decompaction of soils.
- Mock-up of planting soil profiles.
- Final in-place testing of soils.

Recommended Sequence for All Salvage Techniques

- Identify salvage sites and destination planting areas.
- Confirm that unit prices for the salvage operation are economical given the quantities.
- Delineate the salvage material and planting sites for the contractor's convenience.
- Perform sod removal operations (fall, winter or early spring).
- Move salvaged material to a staging area, if necessary.
- Move salvaged plants to final location and install (ideally in the fall).

Forest Soil and Leaf Layer Salvage Sequence

- Follows tree removal, but precedes clearing and grubbing.
- Push the top 3-inch layer of soil, containing semi-decomposed organic matter, leaves, nuts, seeds, corms, etc., into piles.
- Extract large woody branches and roots for chipping (chips can be mixed in if desired).
- Load and haul the mixed soil and organic matter directly to the planting site. "Scrapings" must not be stored for longer than two weeks.
- Spread the "scrapings" in a 1-inch (minimum) layer over the bare subsoil on the planting site.
- Cover with open weave burlap, plant through the burlap, and apply additional leaf litter mulch.

Figure 5.2.4.2-7. Forest soil salvage.

Meadow Sod Transplant Sequence

- Precedes tree removal, clearing, and grubbing.
- Confirm the salvage and planting locations in the field (by landscape architect or owner's representative).

- Cut and lift soil sods with a chainsaw or modified backhoe blade. Meadow sods are approximately 4 feet by 4 feet by 6 to 8 inches deep (thick enough to lift the root mat plus some soil).
- Place soil sods on a pallet. The sliding of the soil block off the backhoe blade should be at a low angle. A vibrator attached to the hoe and/or wax coating on the blade surface can facilitate the transfer of the soil sod "block" without crumpling.
- Transport pallets directly to the planting site.
- Prepare the planting site with a shallow trench, wide and deep enough to accept the sod mat. Excavated soil is placed on both sides of the trench. **Trench bottom should be rough**, not smooth and shiny.
- Unload pallets and carry by forklift to the edge of the trench. Gently slide sods off the pallets into the trench.
- Gently tamp soil sods (by foot) into the underlying soil. Backfill exposed edges of the soil sods with the stockpiled soil at the edge of the trench.
- Water in the soil sods. Provide supplemental water during dry weather (approximately one week of no rain), as needed, during the establishment period.

Figure 5.2.4.2-8. Meadow sod placement – foot tamping.

Figure 5.2.4.2-9. Meadow sod placement.

Small Tree and Herbaceous Perennials and Grasses Salvage Sequence

- Precedes tree removal, clearing, and grubbing.
- Confirm salvage and planting locations in the field (by landscape architect or owner's representative).
- Individual seedlings or saplings, small shrubs, and herbaceous plants may be dug by hand or machinery.
- Individual plants may be placed in small pots, trays, or frames. Keep soil intact and moist during the entire salvage process.
- Transport plants directly to final planting site or staging area.
- If transporting to staging area, place plants in areas with similar conditions to their original site. Protect plants from desiccation by wind. Provide supplemental irrigation during staging period.
- If transporting single plants in containers or individually balled and bagged to final planting site, dig planting hole 1.5 times the original root ball size. Locate plants in areas that are similar in exposure and slope to their original site. After planting, add "root dip" or "mycorrhizae" to soil to increase the rate of success. Protect small trees planted in a meadow (from mowing and herbivore damage) with wooden stakes, plastic tree tubes, or wire fencing.

- Compost may be tilled into the soil before planting or added to the soil after planting. Ensure that the compost material is cured and **not hot** (at same temperature as surrounding soil) before adding.
- Water plants and press soil around the roots to ensure there are no air pockets in the soil.
- Provide supplemental water during dry weather (no rain for one week), as needed during the establishment period.

<u>Medium Tree and Shrub Salvage Sequence</u>

- Precedes timbering tree removal, clearing, and grubbing.
- Preparation work for specific woody plants includes root pruning, canopy pruning, chemical treatments, and other measures to improve health. This preparation is most effective if done throughout the growing season prior to the move, 9 to 14 months in advance.
- Confirm the salvage locations and planting locations in the field (by landscape architect or owner's representative).
- Dig individual trees by hand or with small machinery.
- Place individual plants in pots, bags, or burlap. It is important to keep the soil intact and prevent drying out during the entire transplant process.
- Transport plants directly to final planting site or staging area.
- If transporting to staging area, place plants in areas that are similar in exposure to their original site and protect them from wind. Provide supplemental irrigation during staging period.

Figure 5.2.4.2-10. Small tree salvage.

- For planting, dig a hole that is 1.5 times the original root ball size and locate plants in areas that are similar in exposure and slope to their original site. The top of the root ball (trunk flare) should be set at a maximum of 1 inch above finished grade. Adding "mycorrhizae" to the soil will increase the success rate of transplants.
- To mulch individual trees, **do not create "mulch pyramids."** Instead create a hollow saucer encircled with a low mulch berm around the tree to hold in water.

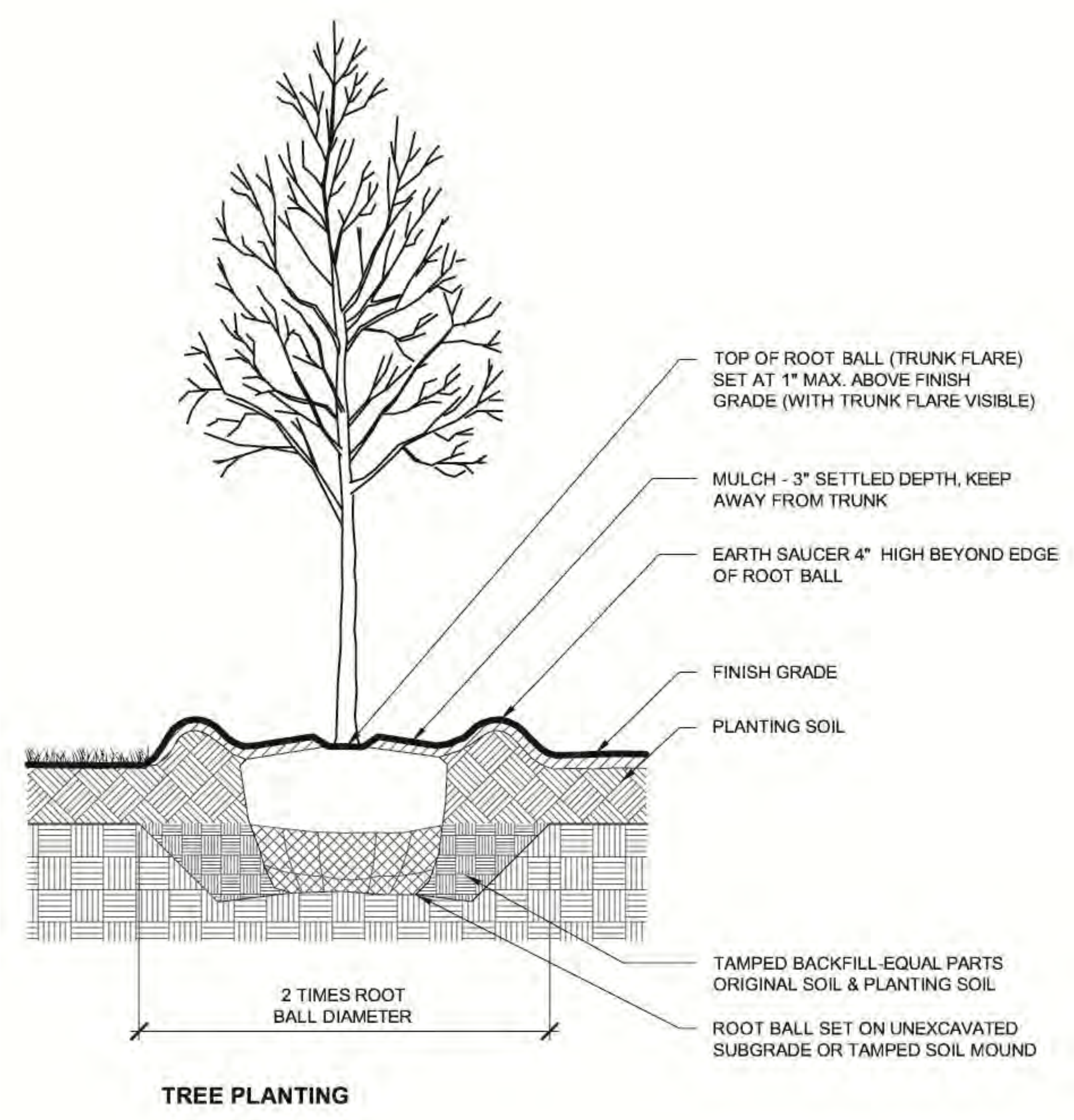


Figure 5.2.4.2-11. Tree planting detail.

- Compost may be tilled into the soil before planting or added to the soil after planting. Ensure that the material is cured and **not hot** (at same temperature as surrounding soil) before adding.
- Water plants and press soil around the roots to ensure there are no air pockets in the soil.
- Provide supplemental water during dry weather (no rain for one week), as needed during the establishment period.

Operations and Maintenance

Establishment

Newly transplanted sods or individual plants will require supplemental water during dry weather (no rain for one week), as needed during the establishment period.

Transplant Shock

The larger a tree is at the time of planting, the longer it will take to recover from transplant shock. The time to recover from transplanting is estimated to be between 6 and 12 months per caliper inch, depending on the project's latitude and elevation (6 months in Florida versus 12 months in Chicago). A tree will need water regularly during the recovery period. Monitor to ensure health.

Criteria Checklist BMP 5.2.4.2

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance by the owner/applicant for successful implementation.		
• Confirm salvage area(s) and placement area(s) in the field with a landscape architect or owner's representative.	☐	☐
• Consult an arborist to determine what trees are eligible for salvage. Note species and caliper. Illustrate what percentage of eligible trees will be salvaged. Provide arborist report.	☐	☐
• Salvage area(s), salvage trees, placement area(s), and corresponding protection zones shall be clearly identified.	☐	☐
• Illustrate what percentage of the overall area of disturbance is eligible for salvage and compare that to the identified salvage area.	☐	☐
• Provide written description of any work that may need to be performed within salvage, placement, and tree protection zones and methods to be used.	☐	☐
• Provide note on plans: *"Topping trees is not allowed. Trees removed or having their tops cut shall be replaced with the equivalent inches of removed trees."*	☐	☐
• Provide note on plans: *"Thinning is allowed and may include manual removal of non-salvaged trees within the tree protection zone of the salvaged trees. NO motorized/wheeled or track vehicles allowed within tree protection zone of the salvaged trees."*	☐	☐
• Note on plans: *"Salvage area and tree protection measures will be maintained at all times. Additional protection measures will be installed if deemed necessary by onsite inspection."*	☐	☐
• If salvaged material will be transported to a staging area prior to installation, ensure that the staging area is in an area of similar condition to the salvage site.	☐	☐
• Ensure that salvaged material placed in staging areas is protected from wind desiccation.	☐	☐
• Ensure that salvaged material placed in staging area will be provided with supplemental irrigation during the staging period.	☐	☐
• Provide supplemental water during dry weather as needed during the establishment period.	☐	☐
• Monitor salvaged material to ensure health.	☐	☐
• Retain a certified arborist to perform tree and root pruning necessary for tree transplanting.	☐	☐

5.3.1 Pervious Pavement

Description

Pervious pavement consists of a pervious (permeable) surface typically composed of asphalt, concrete, pavers, reinforced turf, or rubber play surface overlain on a subsurface typically composed of open-graded stone storage or infiltration bed. Stormwater drains through the surface (see Figure 5.3.1-1), is temporarily held in the voids of the infiltration bed, and then slowly infiltrates into the underlying, uncompacted soils.

Figure 5.3.1-1. Rainfall drains directly through pervious asphalt pavement (left side of photo) but can be seen as runoff on standard impervious asphalt pavement (right side of photo).

Pervious pavement areas are well suited for parking lots, playgrounds, plazas, pathways, and other hardscape pavement areas. Stormwater runoff from other portions of the site can be conveyed into the stormwater bed for management. Pervious pavement can be used on low volume streets if conditions are suitable to control sediment and maintain the pervious pavement. If infiltration is not feasible or is limited, the subsurface bed can include an underdrain system for slow release. Pervious pavement systems can be designed to provide SOV, rate control, and water quality.

Pervious pavement should not be used in “hot spot” areas or areas where material may be stored on the pavement. It should be used with caution in high-traffic parking areas, such as convenience stores, due to traffic levels and high pollutant loads. It can be used in areas of heavy vehicle use, such as industrial areas, provided that the pervious pavement is properly designed for the loads it will carry. Pervious pavement often has limited shear strength and is not suitable for vehicles with heavy point loads (such as airplanes) or for use on steep slopes (greater than 6 percent).

BMP Functions Table

BMP	Applicability*	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Pervious Pavement	U/S/R	H	H	H	H	H	M	L	L	M

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Rating varies based on design considerations.

Key Design Features

- Pervious surface pavement material.
- Clean-washed, open-graded stone storage bed with minimum of 40 percent void space.
- Additional storage may be achieved through the use of perforated pipes set in the stone bed or proprietary stormwater storage products.
- Can be designed to capture entire volume of small storms and to provide peak rate control for larger storms.
- Often manages runoff from other portions of the site that can be conveyed into the stormwater bed.
- Large impervious areas should **not** be designed to discharge onto the pervious pavement because clogging may occur. These areas should be treated by vegetated BMPs (i.e., swales or filter strips) or sediment removal systems before discharge into the stormwater bed.
- Surface and stone bed must be designed for anticipated traffic loads.
- Level, uncompacted subgrade (see Figure 5.3.1-2).
- Nonwoven geotextile at soil/stone interface.
- Generally not recommended for traffic surfaces with slopes greater than 6 percent.
- Designed with alternate method to convey water into stormwater bed if pavement clogs.
- May include pipe distribution network.
- Always includes positive overflow.
- Should not be placed on compacted fill (fill with stone, as needed).
- When possible, infiltration beds should be placed on upland soils.

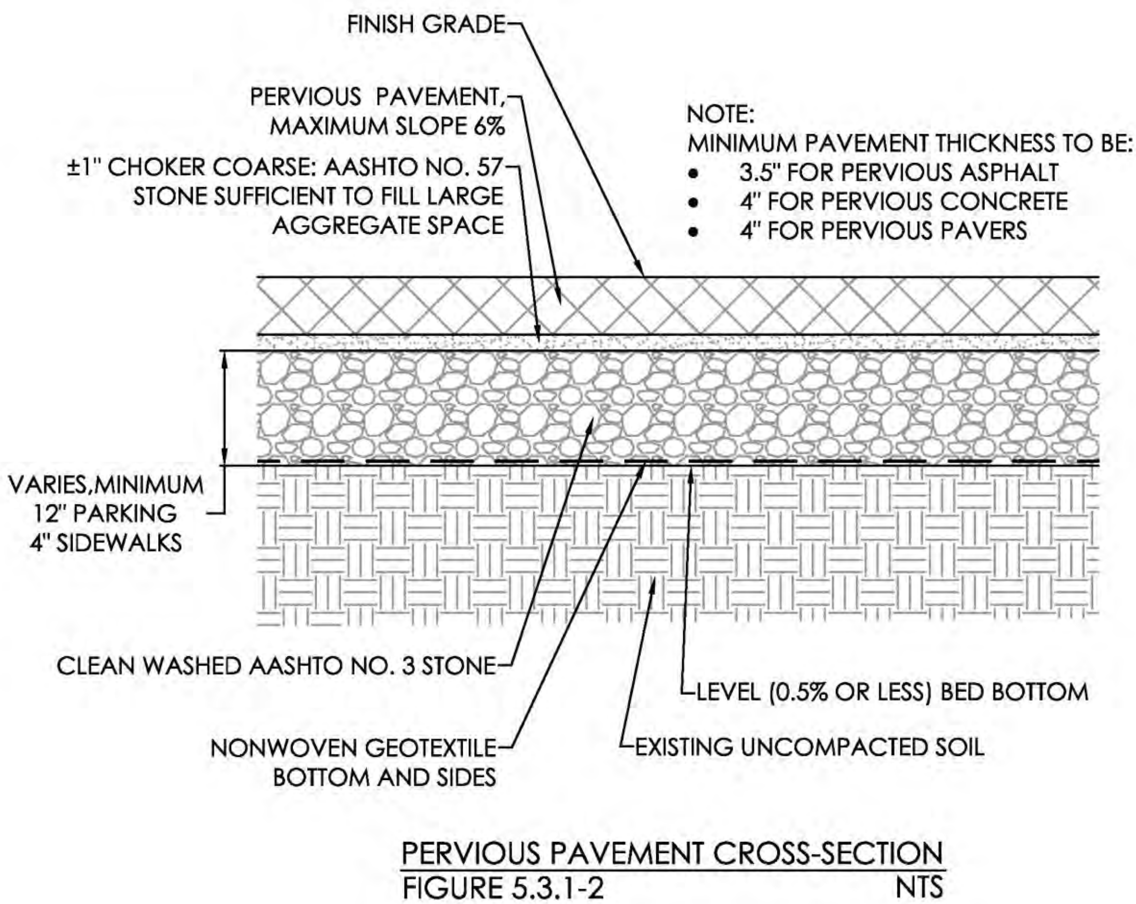


Figure 5.3.1-2. Pervious pavement cross-section. Pervious pavement beds should always be placed on level (0.5 percent slope or less) bed bottoms to prevent ponding in one area of the bed.

Applications

- Roadways, walkways, parking stalls
- Parking lots
- Playgrounds, plazas, terraces, and basketball and tennis courts
- Low volume streets
- Not suitable for hot spot areas unless designed for spill containment
- Not suitable for areas subject to high levels of sediment and debris

Advantages

- When used to provide volume reduction (SOV), may provide a Curve Number reduction and may reduce the peak rate requirements for the site.
- Reduces the space required for stormwater management by incorporating stormwater into the building program (parking, hardscape).
- Can manage a significant quantity of runoff and function as a regional system.
- Well suited to directly receive “clean” roof runoff.
- Can be designed to include peak rate control.
- Effective in contaminant reduction such as total suspended soils, metals, and oil and grease.
- Can be benched or terraced to accommodate slopes.
- Withstands freeze-thaw cycles and generally requires less winter maintenance than standard pavement.
- Lifespan comparable to traditional pavements and cost-effective when used to meet SOV requirements.

Disadvantages

- High clogging potential if runoff from high-sediment areas is not pretreated.
- Not suitable for pavements with high shear stress requirements or steep slopes.
- Requires alternate maintenance requirements from traditional asphalt (i.e., vacuuming, removal of vegetation between pavers, etc.).
- Must be offset from foundations/basements.
- Not applicable with high bedrock, high groundwater, or contaminated soils.
- Infiltration requires suitable site conditions.

Applications

Pervious pavement can be used in myriad ways in the urban and suburban environments, on residential, institutional, and commercial properties and within the public right-of-way. Potential applications include parking lots, parking stalls on roadways, alleys, sidewalks and paths, plazas, playgrounds, and athletic fields and courts. If pervious pavement is applied on residential lots, the property owner must be made aware that pavement is pervious.

Sidewalk: Pervious Concrete Pavement

Figure 5.3.1-3. Pervious concrete sidewalk. Constructing sidewalks with pervious concrete reduces impervious area. The sidewalk can also be designed to include a stormwater bed with capacity to receive runoff from adjacent impervious areas (i.e., driveways, roads). This is most applicable where sidewalks are level or mildly sloped (less than 3 percent).

Plaza: Pervious Pavers

Figure 5.3.1-4. Pervious concrete pavers for terrace area. Pervious pavers are ideal for plaza and terrace areas.

Parking Lot: Pervious Asphalt and Pervious Concrete Parking Lot

Figure 5.3.1-5. Pervious asphalt and pervious concrete parking lot. The University of North Carolina Chapel Hill park and ride lots include both pervious concrete and pervious asphalt.

Basketball Court: Pervious Asphalt

Figure 5.3.1-6. Pervious asphalt basketball court. Pervious asphalt on play surfaces does not form puddles and is quieter when balls bounce.

Types of Pervious Pavement

Figure 5.3.1-7a. Pervious Asphalt

Figure 5.3.1-7-b. Pervious Concrete

Figure 5.3.1-7-c. Concrete Pavers

Figure 5.3.1-7-d. Brick Pavers

Figure 5.3.1-7-e. Reinforced Turf or Gravel

There are several types of pervious pavement available, including proprietary products. The type of pervious pavement selected by the designer is a function of:

- Use and durability: This includes whether the pervious pavement will be subject to traffic loads, and the nature and extent of anticipated traffic loads.
- Appearance: Pervious pavers can be quite attractive while pervious concrete often has a coarse texture and cannot be "finished" like standard concrete.
- Cost: Pervious asphalt pavement is often the least expensive material, while pavers are often the most expensive.
- Maintenance: The amount of trash and debris may affect pervious pavement selection. Asphalt and concrete can be maintained by vacuum sweeping. Pervious pavers may require more maintenance for

debris removal (i.e., cigarette butts and small debris) and for the removal of vegetation between pavers.

Pervious Bituminous Asphalt

Pervious asphalt is similar to standard asphalt except that the aggregate fines (particles less than 0.60 micrometers [µm], or the No. 30 sieve) are kept to a maximum of 5 percent within the asphalt. Because of reduced fines, pervious asphalt has less shear strength than standard asphalt and is not suitable for heavy point loads. Improvements in open-graded highway overlays have led to improvements in pervious asphalt, including additives that increase the durability of the asphalt (i.e., PG 76-22 as specified by the American Association of State Highway and Transportation Officials [AASHTO], which includes a styrene-butadiene-styrene elastomer polymer binder). The use of fiber additives may also increase the shear strength of pervious asphalt.

Figure 5.3.1-8. It is important that pervious pavement be placed at the correct temperature as determined by the drain-down test for the asphalt mix.

One of the most critical components of a successful pervious asphalt installation is the application of a drain-down test (ASTM D6390) to determine the optimum asphalt temperature for placement. Asphalt binds differently to different types of aggregate (i.e., it binds better to limestone than granite). It is important to determine the optimum placement temperature for the aggregate in use to prevent drain-down (see Figure 5.3.1-8). Drain-down reduces the durability of the pavement at the surface and may create a clogging layer below the pervious asphalt.

Figure 5.3.1-9. Pervious asphalt at this commercial parking lot includes recycled rubber in the bituminous mix.

Pervious pavement may also include recycled asphalt or recycled rubber (see Figure 5.3.1-9). Detailed specifications and installation guidance on pervious asphalt can be obtained from the National Asphalt Pavement Association (NAPA) (http://www.asphaltpavement.org/).

Pervious Concrete

Pervious concrete has a reduced amount of fines and may have a different aggregate gradation than standard concrete. It has a coarser texture than standard concrete and has different requirements for mixing and placing. As with standard concrete, formwork is required for placement. Pervious concrete must be carefully rolled to prevent the concrete from forming an impermeable layer at the surface. Detailed specification and placement guidance is available from the National Ready Mix Concrete Association (http://www.nrmca.org/) and the Florida Concrete Association (http://www.fcpa.org/).

Pervious Concrete Pavers and Brick Pavers

Pervious concrete and brick pavers include openings or gaps filled with clean gravel for water to move into the gravel bed below the paver. The pavers may be interlocking or offset. There are a number of products available from different manufacturers, each with different guidance for installation. However, as with any paver, the pavers must include an edge restraint for installation. If the subgrade below the paver is compacted during construction, the pavers cannot infiltrate.

Figure 5.3.1-10. This standard asphalt path is 8 feet wide and includes a stone stormwater bed that is 14 feet wide to support an emergency vehicle. The grassed edges are constructed of reinforced turf grids over the stormwater bed. The bed receives runoff from the roof leaders of the adjacent building.

Reinforced Turf and Gravel

A number of products are available that consist of plastic grids that can be filled with either a sand/turf mix or a clean gravel mix. These products are especially useful in low-traffic areas, such as overflow parking lots or fire lanes (see Figure 5.3.1-10). Soil mixes must be carefully designed to allow drainage while also supporting vegetation. The designer may use the bioretention soils specifications for this purpose.

Pervious Rubber and Manufactured Pervious Mixes

In addition to manufactured grids and structural products to create pervious pavements, various manufactured materials are available for pervious pavements, including polymer bound pervious mixes composed of recycled rubber, glass, stone, and other materials. These products tend to be more costly but also provide an aesthetic that is often desired or needed. The products may or may not be suitable for traffic loads as indicated by the manufacturer. The use of pervious rubber surfaces (which are traditionally used in splash pools and similar installations) can provide an ideal stormwater management system and safe play surface in playground areas (see Figure 5.3.1-11).

Figure 5.3.1-11. Pervious rubber is an ideal material for a stormwater BMP constructed as part of a playground.

ITEM	RECOMMENDATION	REFERENCE SECTION
Drainage Area and Location Recommendations	Locate the pervious pavement so sediment laden runoff will not drain onto pavement surface. Locate so that bed bottoms are flat or have a maximum of 0.5% slope. Do not locate on fill material.	5.3.1.1
Concept Phase Loading Ratio (LR) (Recommended)	1:8 for South Chickamauga Watershed 1:10 for all other Watersheds	5.3.1.5
Concept Phase Surface Area Size (ft^2) (Recommended)	Impervious Drainage Area Managed (ft^2) / Loading Ratio	5.3.1.5
Entrance/Flow conditions	Surface Dispersed: Direct rainfall, sheetflow from standard pavement, or combined with pre-treatment (i.e., filter strip). Direct Connection (into stone bed): Recommended only for "clean" runoff such as roofs	5.3.1.2
Pretreatment/Management of Sediment Trash and Debris	Required for high sediment drainage areas. See Filter Strip (BMP 5.3.6)	5.3.1.3
SOV Volume or Water Quality Volume Credit	Static Storage provided by Stone Storage (if applicable), Other structures (pipes, rain storage units, etc.)	5.3.1.4
Stone Storage Coefficient and Volume	0.4 Storage Volume = Stone Depth (ft) x Stone Area (ft2) x 0.4	5.3.1.4
Manufactured Storage Units Coefficient and Volume	0.85 - 0.95 Storage Volume = Manufactured Unit Depth (ft) x Manufactured Unit Area (ft2) x 0.85	5.3.1.4
Perforated Pipes Storage Coefficient and Volume	1.0 Storage Volume = Perforated Pipe Length (ft) x Perforated Pipe Area (ft2) x1.0	5.3.1.4
Stone Depths	Sidewalks and pedestrian paths: 4 inches minimum Vehicular paths: 12 inches minimum	5.3.1.5
Pipe sizes for Overflow and Peak Rate	Minimum size 12 inch diameter. See Stormwater System Specifications	5.3.1.6
Freeboard in Stormwater Bed	2 inch minimum on smaller systems 4 inch minimum on larger systems	5.3.1.7
Conveyance Capacity	Peak rate 10-year, 24-hour rainfall event	5.3.1.6
Underdrain	Required if Infiltration Rate < 0.1 inches per hour	5.3.1.8
Setback from Structures	Required. See Stormwater Specification for Impervious Liner	Protocol 1
Coordination with Other Utilities	Required	Protocol 2
Infiltration Testing	Required	Protocol 3
Infiltration System Setbacks	Required	Protocol 4
Vegetation and Mulch	Required	Protocol 5
Inspection and Longterm Maintenance	Required	Chapter 8

Table 5.3.1-1. Pervious Pavement Design Criteria

Applicable Protocols and Specifications

The following Protocols and Specifications (see Appendices A through F) are applicable to pervious pavement and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 2 Coordination with Other Utilities
- Protocol 3 Site Evaluation and Infiltration Testing
- Protocol 4 Infiltration System Design and Construction Guidelines
- Stormwater System Specifications
  - Aggregates and Drainage Layers
  - Pipes
  - Control Structures
  - Geotextiles
  - Impervious Liners and Waterproofing

Design Considerations for Pervious Pavement

Pervious pavement can be a cost-effective and durable water management BMP that serves traditional functions. It is imperative that pervious pavement be designed and constructed properly. It is not applicable to all project types and locations.

1. Location and Capture Area

Pervious pavement can be located:

- Close to the source of runoff to minimize the need for additional stormwater structures.
- As part of a "regional" or site stormwater management system, designed to capture runoff from a larger drainage area. This is especially applicable for large parking lot areas.

Pervious pavements are **not** recommended within floodplain areas where the deposition of fine sediment from flood events may damage the pervious nature of the material.

Drainage Area

Figure 5.3.1-12. The stormwater bed beneath this pervious concrete plaza was used as a temporary sediment basin (with basin bottom at least 2 feet above final stormwater bed bottom elevation) during construction of the site. After the surrounding site work was completed, the sediment was removed and the bed excavated to its final depth. The stormwater bed and overlying pervious pavement were then installed.

- It is critical that all pervious pavements be located so that sediment-laden runoff does **not** drain onto the pavement surface (see Figure 5.3.1-12). During construction, erosion and sediment control measures must be maintained until the site is fully stabilized. Sediment-laden runoff can clog both the pervious pavement surface and the underlying infiltration bed.
- Pervious pavement captures direct rainfall, however, runoff from adjacent areas can be directed into the subsurface bed for storage and management. The subsurface bed often has a greater stone subbase thickness for structural stability than is required for direct rainfall capture. Clean roof runoff can be discharged directly into a subsurface bed beneath a pervious parking lot (catch basins with sumps are recommended to capture sediment). Surface runoff from other impervious areas should be addressed with measures (i.e., filter strips, vegetated swales) to reduce excessive sediment before the runoff is discharged (usually via pipe) into the bed.
- It is **not** recommended that large impervious pavement areas drain directly onto a smaller pervious pavement area, because the sediment will tend to clog the smaller pervious pavement area.
- Pervious pavement with infiltration should not be used in hot spot areas where there is the potential for runoff with higher than average pollutant levels to enter the groundwater. Only the hot area is precluded from pervious pavement use; other portions of the site may be well-suited for pervious pavement use.

Slope

- Pervious pavement with infiltration should not be constructed on fill material, because compacted fill prevents infiltration.
- The bed bottom must be level or with a slope less than 0.5 percent. If needed, the subsurface infiltration bed may be benched or terraced on slopes (see Figures 5.3.1-13 and 5.3.1-14).

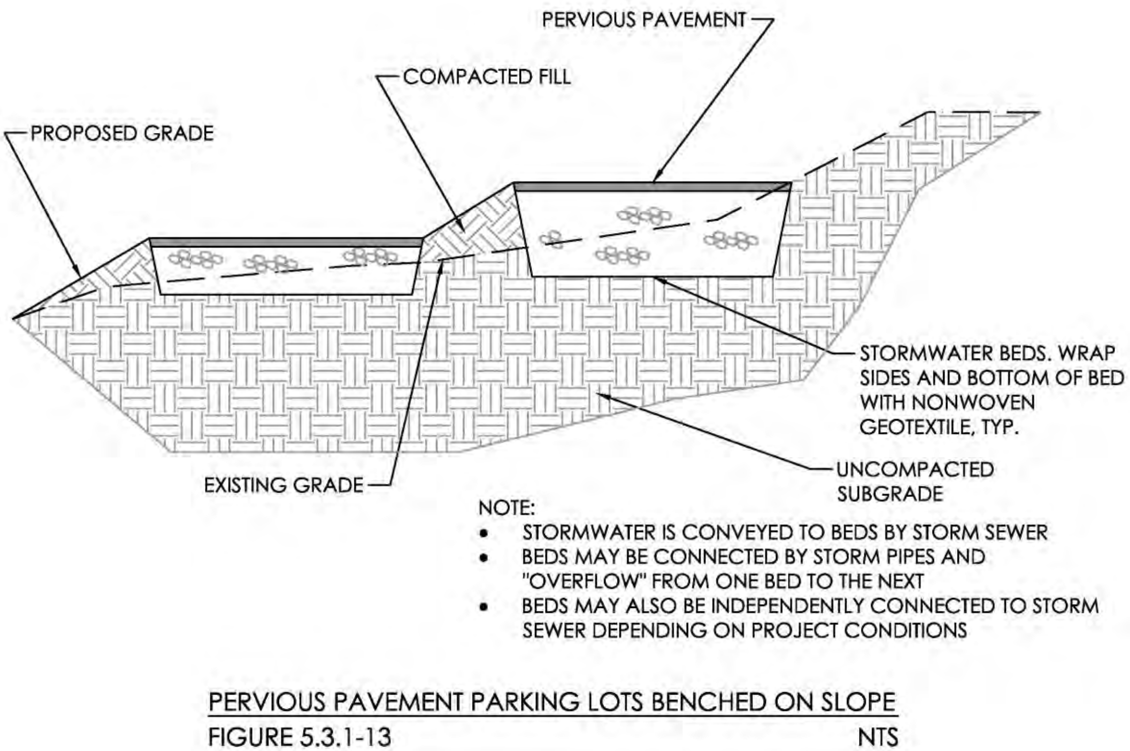


Figure 5.3.1-13. Pervious pavement beds can be terraced on a slope to provide level infiltration bed bottoms and to reduce the pavement slope.

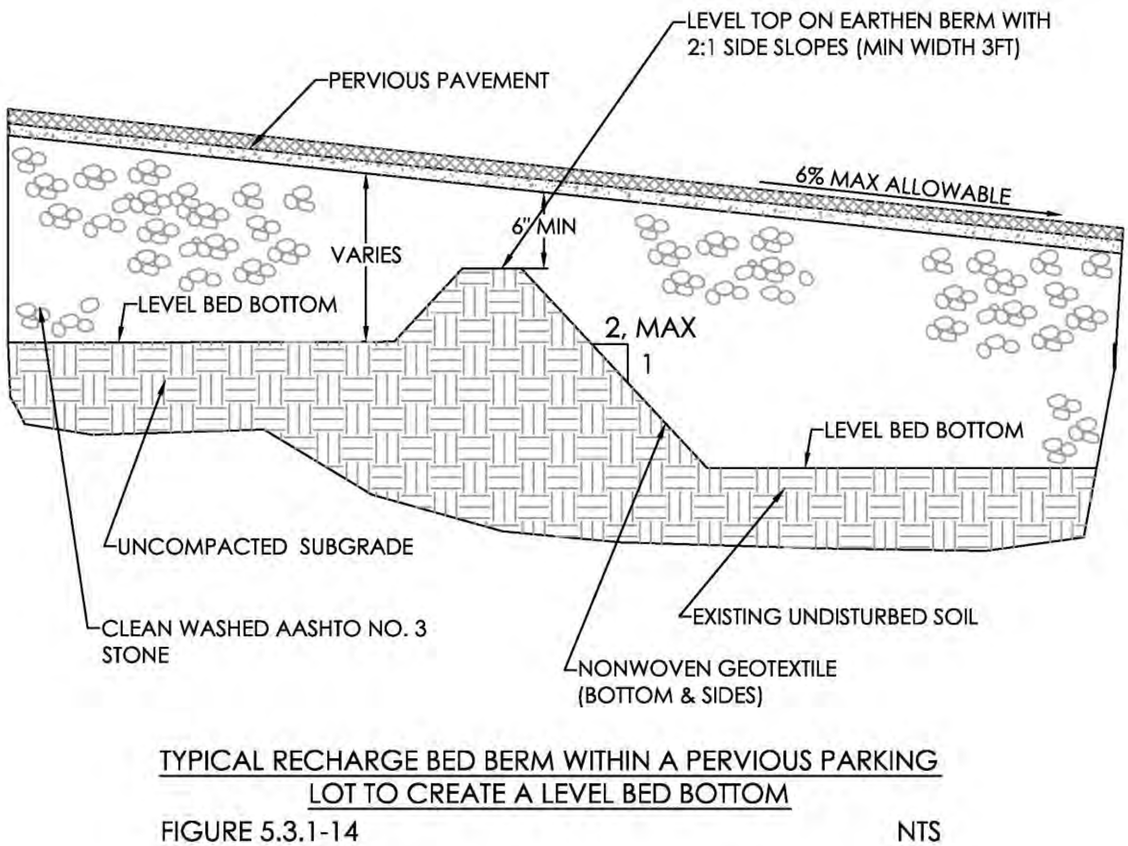


Figure 5.3.1-14. Berms can be used within a pervious pavement bed to create level infiltration areas within a single infiltration bed.

2. Entrance/Flow Conditions

Figure 5.3.1-15. Pervious pavement can be constructed with an unpaved pervious edge treatment. In the event that the pavement is seal coated, clogged, or not functioning, runoff from the pavement can still enter the stormwater bed.

- It is recommended that pervious pavement systems be designed with an alternate method for water to enter the stormwater bed, especially for larger systems such as parking lots. Options include open-graded stone edge treatments or inlets and trench drains. In the event that the bed surface is accidentally seal coated or becomes clogged, water can still enter the stormwater bed (see Figure 5.3.1-15).
- If runoff is collected from other surface drainage areas and discharged into the stormwater bed, it should be treated via a sumped inlet, water quality inlet, or other measure.
- It is **not** recommended that large impervious areas be discharged directly onto pervious pavement. The sediment loads may result in pavement clogging. Large impervious areas may be managed within the stormwater bed, but should be pre-treated.
- If large impervious areas will drain toward a pervious pavement, a vegetated filter strip should be used to reduce sediment flowing onto the bed. Alternately, water can be directed around the pavement via a berm or other grading design measure.

3. Management of Sediment, Trash, and Debris/Potential Clogging Issues

Figure 5.3.1-16. Extending the geotextile over the stone bed during construction of this pervious concrete sidewalk prevents sediment from entering the bed. In this example, the stone bed is wider than the sidewalk. It is designed to manage street runoff (from left) after treatment through a vegetated swale. Runoff sheet flows into the swale over the curb after construction of the final pavement course.

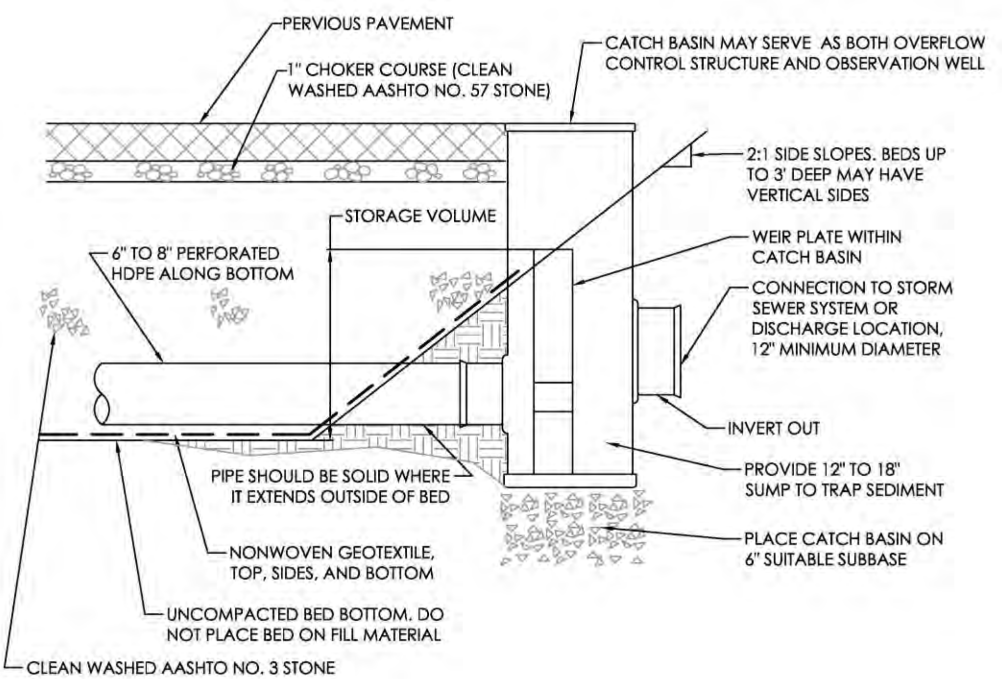
- Construction is the most critical period for pervious pavement, and it is essential that sediment-laden runoff be prevented from entering the bed or washing onto the pavement. Unstabilized areas cannot be allowed to discharge onto the pervious pavement.
- Pavement can be vacuumed to remove any sediment deposition from pervious asphalt or concrete. This should be done as soon as sediment deposition is observed.
- It is recommended that pervious asphalt and concrete be vacuumed twice per year.
- Roof runoff is generally lower in sediment and can be conveyed directly into a bed; however, a cleanout for roof leaders is required in the event that pipe clogging occurs.
- Runoff from roof areas that receive high amounts of leaf debris or other materials (such as deposition from equipment) should include sediment traps, or should be reconsidered. It may be preferable to discharge these roof areas to a vegetated swale or filter strip prior to discharge into the bed.

- Pervious pavement should **not** be pressure washed; pressure washing will only force sediment farther into the pavement or into the stormwater bed.

4. Storage and Stay-on-Volume

Pervious pavement that **only manages the rainfall that lands on the pavement can be excluded from the impervious area for purposes of calculating SOV**. This is especially applicable for pervious pavements such as pervious paver walkways.

For pervious pavement that includes a stormwater bed and that receives runoff from other areas, the **storage** capacity of the pervious pavement bed is measured as the volume **below** the lowest discharge invert (overflow) (see Figure 5.3.1-17).



PERVIOUS PAVEMENT INFILTRATION BED AND OVERFLOW CONTROL STRUCTURE WITH WEIR
FIGURE 5.3.1-17 NTS

Figure 5.3.1-17. A catch basin with a weir can serve as an overflow control structure for the stormwater bed beneath a pervious pavement. The SOV depth is controlled by the weir. Larger storms overtop the weir and are conveyed to the storm sewer or appropriate discharge point. The designer should always confirm that the water level will never be high enough to saturate or move upward through the pervious pavement.

Storage Volume (ft^3) =

Bed Length (ft) x Bed Width (ft) x Bed Depth (ft) Below Overflow Elevation x Void Ratio

Void ratios are generally:

- 0.40 for clean-washed aggregate such as AASHTO No. 3
- 0.85 to 0.95 for manufactured storage units depending on manufacturer
- 1.0 for the interior volume in perforated pipes within the bed

The **SOV** is a function of the storage volume available for the 1-inch or 1.6-inch storm. See Chapter 3 for more information on SOV.

5. Area, Stone Bed Depth, and Dimensions

The size and surface area of the pervious pavement area and infiltration bed are usually a function of the pavement requirements rather than the stormwater needs. The amount of parking, paths, and other pavements required for site program needs usually determine the extent of pervious pavement area.

The minimum depth of the stone bed beneath the pavement is a function of the structural stability needs of the pavement, and should be determined by the design engineer based on anticipated use. The stone bed depth may be increased as needed to accommodate additional stormwater storage volume. As a general rule, the aggregate bed for a light vehicle area constructed on uncompacted subgrade should not be less than 12 inches in depth, provided that the aggregate (such as a clean-washed AASHTO No. 3 [angular 1½- to 2½-inch aggregate]) can provide stability. Higher traffic loads may require additional bed depth. Sidewalks and paths should not be constructed with less than 4 inches of aggregate. In each application, the appropriate bed depth for stability and traffic load must be determined by the designer.

Alternate storage media designed for stormwater systems (i.e., modular units) may be used; however, the designer must verify that all such products are suitable for use when traffic loads apply. The designer is responsible for the proper structural design of each installation according to material selected and project traffic loads.

Because the aggregate subbase will often provide more volume storage than is necessary to manage the direct rainfall onto pervious pavement, the stormwater bed can be designed to serve as a site BMP that captures runoff from other impervious areas and portions of the site. This is often very cost-effective. For infiltration systems, it is important **not** to concentrate too much stormwater in one location for management. This can lead to accelerated clogging from sediment, high water depths that may compress soils, and soils that do not dry out between storms (and change structure). It also provides soil/water contact for water quality improvement. A basic design rule is to design pervious pavement with a surface area that is a ratio of the impervious and compacted pervious areas draining to the stormwater bed. The amount of rainfall volume must also be considered. The following ratios based on design rainfall depth can be used to estimate pervious pavement area:

1-inch Rainfall
1:10 ratio of surface area to impervious drainage area

1.6-inch Rainfall
1:8 ratio of surface area to impervious drainage area

Stormwater beds can be designed for deeper water depths during the larger, and less frequent, peak rate storm events (if necessary) to provide peak rate mitigation. The detention capacity of the bed can be analyzed and a hydrograph routed through the bed in the same manner as for a detention basin (taking into account the volume as a function of stone or media porosity).

The bed depth of water storage is primarily determined by the rainfall depth managed and the loading ratio, and influenced to a lesser extent by the infiltration rate. **There is no specific limit on the maximum width or length of an infiltration bed beneath pervious pavement. However, designers are discouraged from designing excessively deep infiltration beds (more than 5 feet for the SOV capacity), even in areas with high infiltration rates, due to concerns that the pressure at greater water depths may compact or alter the underlying soil.** There is no depth limit on non-infiltrating, slow-release beds.

Beds can be designed for short-term, deeper water depths during the larger, and less frequent, peak rate storm events if necessary to provide peak rate mitigation.

Proprietary products may be used as storage media, and as a substitute for stone subbase; however, all products must be approved by the City. There are a number of modular subsurface, plastic, interlocking storage units that provide higher void space and comparable structural stability as AASHTO No. 3, but they may be more costly.

6. Overflow and Peak Rate

All stormwater beds beneath pervious pavements must provide a safe means for water to exit the system when large storms generate more stormwater runoff than the bed can hold. The inclusion of a positive overflow route ensures that flooding risks and related property damage are minimized. The positive overflow route is often in the form of a modified inlet box with an internal concrete weir (or weir plate, see Figure 5.3.1-18), or simply an overflow pipe at an invert higher than the inlet pipe invert. This maximizes the volume managed by the bed, while providing sufficient cover for overflow pipes. When water overtops the weir, it discharges via a pipe to the storm sewer or to another approved discharge point.

Figure 5.3.1-18. Structures can be purchased with weirs at the desired elevations that allow the small storm volume to be retained while larger flows can safely be conveyed (also see Figure 5.3.1-17).

The overflow structure can be designed to function as a detention rate control structure for peak rate control, and can be modeled or evaluated as a detention system. Temporarily higher effective water depths are acceptable during large storm events managed for peak rate control. The catch basins can be used as overflow structures in large storms, and as rate control structures in larger storm events if the bed is constructed with sufficient capacity.

The minimum allowable diameter of an overflow pipe is 12 inches unless otherwise approved by the City.

<u>Peak Rate Control and Infiltration Credit</u>

For the purposes of site peak rate control, the designer may adjust the Curve Number value based on the volume managed by both the SOV and the infiltration volume that occurs during a portion of a 24-hour storm event. This allows the designer to account for runoff that was captured by applying low-impact development and to develop a representative lower Curve Number. This procedure is described in Chapter 7.

When adjusting the Curve Number, the infiltration volume can be estimated as the infiltration that occurs during 12 hours of a 24-hour design storm. This will ensure that estimated infiltration volumes are not greater than the actual volume captured within the BMP.

Infiltration Volume (ft^3) = Pervious Pavement Bottom Area (ft^2) x Infiltration Rate (in/hr) x 1/12 x 12 hours

7. Freeboard

It is essential that pervious pavement systems be designed so that there is **never an opportunity for the water level to saturate the pervious surface material**. This is essential to the long-term stability and durability of the pervious surface. For this reason, it is recommended that all pervious pavement be designed with a freeboard within the stormwater bed such that the water level never reaches the top of the bed or surcharges the bed. A minimum freeboard of 2 inches is recommended on smaller systems such as sidewalks and 4 inches on larger systems such as parking lots.

8. Underdrain

An underdrain system is used to ensure that water moves through the system when the native soil infiltration rate is not high enough to empty the bed of water, or if the bed is underlain by an impervious liner and designed only for slow release. Underdrain systems should discharge to the existing stormwater system or a location approved by the City. Underdrain systems must be included in the design if the native soil infiltration is less than 0.1 inch per hour, or if the bed is designed for slow release. See Protocol 3 for the infiltration testing procedure and Protocol 4 for infiltration system guidelines.

9. Waterproofing

In some instances where pervious pavement systems are designed to infiltrate, there may be concerns about impacts on adjacent structures such as basements or on the subbase of adjacent paved surfaces. The system may also be designed with an underdrain for slow-release of flows rather than infiltration if there are concerns regarding lateral movement of water from the sides or bottom of the subsurface infiltration beds. For all pervious pavement systems, the designer must evaluate the impact of the system on adjacent structures and utilities as defined in Protocol, 1 Setbacks from Structures and Protocol 2, Coordination with Other Utilities. The liner if applied must meet the guidelines provided in the Stormwater Specification.

Where pervious pavement immediately adjoins standard pavement, a liner or waterstop should be employed to prevent water from entering the standard pavement subbase (see Figure 5.3.1-19).

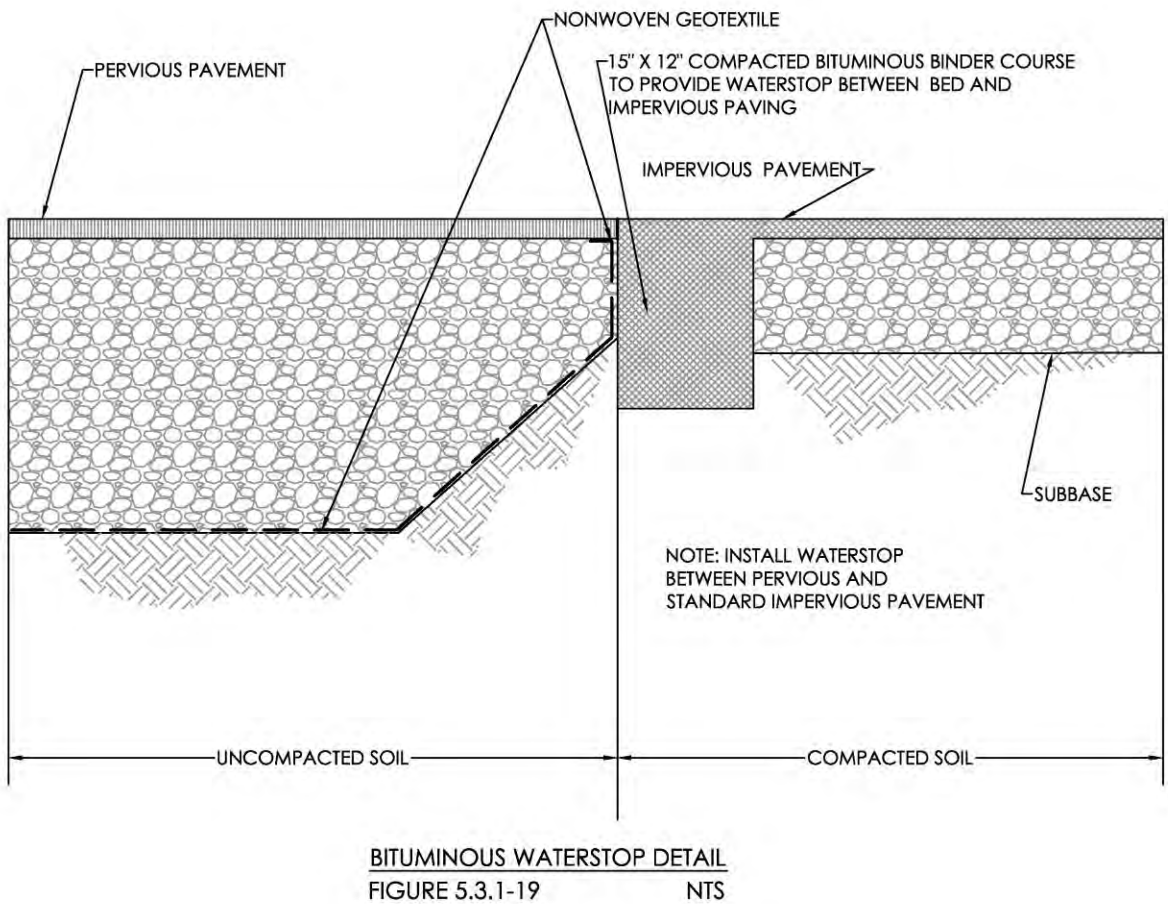


Figure 5.3.1-19. A bituminous waterstop can be used to prevent lateral movement of water between standard and pervious asphalt.

10. Water Quality/Total Suspended Solids

Pervious pavement systems that can capture and manage the required SOV through infiltration are considered to meet all water quality requirements. Pervious pavement beds that are underdrained, but can capture the required water quality volume as defined in Chapter 7, are also considered to provide water quality treatment. See Chapter 7 for additional discussion, and the Subsurface Infiltration Bed Worksheet for calculations.

Sizing Calculations Worksheet for Pervious Paving

(Link to Worksheet)

Construction Considerations

For the best success, pervious pavement systems should not be installed until site construction is complete and site stabilization has occurred. Pervious pavement systems completed before site stabilization **must** be protected from receiving sediment-laden runoff. Runoff should be directed around the completed pervious pavement system until site stabilization has occurred. **Sediment-laden water must not be allowed to enter pervious pavement systems or to drain onto pervious pavement surfaces.**

The excavated capacity of the stormwater bed may be used as a temporary sediment trap area during construction. The bed should not be excavated to final grade until the system is converted from a sediment trap to a stormwater bed. It is recommended that the sediment trap bottom elevation be 2 feet above the final stormwater bed elevation. Underdrained infiltration beds may be used as sediment traps during construction to the final bed bottom elevation.

Construction Sequence Example

Step 1 Excavate and Prepare Subgrade

a. Do **not** compact or subject pervious pavement locations to excessive construction equipment traffic during construction. Protect areas from vehicle traffic during construction with construction fence, silt fence, or compost sock.
b. Initial excavation of infiltration beds can be performed during rough site grading. When performing initial excavation, do not grade bottom beyond 2 feet above the final bed bottom elevation. Complete final excavation only after all disturbed areas in the drainage area have been stabilized, or after the bed is adequately protected from receiving sediment-laden water (i.e., with erosion and sediment control measures around the BMP).
c. Remove fine materials and/or surface ponding in the grading bottom, caused by erosion, with light equipment and scarify the underlying soils to a minimum depth of 6 inches with a York rake or equivalent by light tractor.
d. Leave earthen berms between infiltration beds (if used) in place during excavation. These berms do not require compaction if proven stable during construction. Constructing berms with fill is discouraged. If necessary, key constructed berms into the subbase and compact to 95 percent density. All constructed berms shall be designed by a qualified engineer.
e. Bring subgrade of infiltration bed to line, grade, and elevations indicated. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All infiltration beds should be level grade on the bottom.
f. Halt excavation and notify engineer immediately if evidence of sinkhole activity or unanticipated bedrock or groundwater conditions are encountered, or other site conditions that may affect infiltration bed design or performance become evident.

Step 2 Install Overflow Structure and Other Stormwater Structures

a. Place the stormwater overflow structure on suitable subgrade to prevent settling. Install overflow structure, inlet pipes, curbs, and other stormwater structures as appropriate before placement of stone storage bed.
b. Close and secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering the infiltration bed before completion and site stabilization.
c. Maintain drainage overflow pathways during construction, while infiltration bed is closed, to provide for drainage during storm events.
d. Infiltration bed conditions should be observed by the design engineer, following excavation and grading and prior to placement of geotextile and aggregate materials, to confirm that construction requirements have been met. Documentation must be provided to the City (see Appendix I).

Figures 5.3.1-20a and b. Geotextile and perforated distribution pipes are placed on an uncompacted subgrade, and stone is placed without compacting the bed bottom. Distribution pipes can be designed to extend through berms within the bed.

Step 3 Install Infiltration Bed

a. Place geotextile and bed aggregate immediately after approval of subgrade preparation and installation of structures. Install geotextile in accordance with manufacturer’s standards and recommendations. Overlap adjacent strips of geotextile a minimum of 16 inches and secure at least 4 feet outside of the bed to prevent any runoff or sediment from entering the storage bed. This edge strip should remain in place until all bare soils contiguous to beds are stabilized and vegetated. Once the site is fully stabilized, cut excess geotextile along bed edges back to gravel edge.

Figure 5.3.1-21: Although the subgrade is uncompacted to allow for infiltration, the stone bed is placed in layers and rolled to provide a suitable subbase for construction vehicles and future traffic loads.

b. Place clean-washed, uniformly graded aggregate in the bed in maximum 8-inch lifts. Compact each layer lightly while keeping construction equipment off the bed bottom as much as possible.
c. Once bed aggregate is installed to the desired grade, install a 1-inch layer of choker base course (AASHTO No. 57) aggregate uniformly over the surface. This ensures an even surface for paving.

Step 4 Install Pervious Pavement

a. Install pervious pavement in accordance with specifications and/or manufacturer's requirements.
b. Test the pavement surface for permeability by applying clean water at the rate of at least 5 gallons per minute per square foot (gpm/ft^2) over the surface, using a hose or other distribution device. All applied water should directly infiltrate without ponding or creating surface runoff.
c. As required for pervious asphalt and concrete, protect pervious pavement from vehicle access for the duration indicated in the specifications.

Operations and Maintenance

It is recommended that signage be installed at all pervious pavement installations to ensure institutional memory that the pavement is pervious and should not be repaved, seal-coated, etc.

Special Maintenance Considerations:

- Prevent Clogging of Pavement Surface with Sediment
  - Vacuum pavement twice per year.
  - Maintain planted areas adjacent to pavement.
  - Immediately clean any soil deposited on pavement.
  - Do not allow construction staging, soil/mulch storage, etc. on unprotected pavement surface.
  - Clean inlets draining to the subsurface bed twice per year.
- Snow/Ice Removal
  - Pervious pavement systems generally perform better and require less treatment than standard pavements.
  - Abrasives such as sand or cinders should not be applied on or adjacent to pervious pavement.
  - Snow plowing is acceptable but should be done carefully (i.e., the blade should be set slightly higher than usual).
  - Salt application is acceptable, although more environmentally benign deicers are preferable.
- Repairs
  - The surface should never be seal coated.
  - Damaged areas less than 50 square feet can be patched with pervious or standard asphalt.
  - Larger areas should be patched with an approved pervious asphalt.

Winter Maintenance

Winter maintenance for a pervious parking lot may be necessary, but is usually less intensive than that required for a standard asphalt lot. By its very nature, a pervious pavement system with a subsurface aggregate bed has superior snow melting characteristics than standard pavement. The underlying stone bed tends to absorb and retain heat so that freezing rain and snow melt faster on pervious pavement. Therefore, ice and light snow accumulation are generally not as problematic. However, snow will accumulate during heavier storms. Abrasives such as sand or cinders should not be applied on or adjacent to the pervious pavement. Snow plowing is acceptable, provided it is done carefully (i.e., by setting the blade slightly higher than usual, about an inch). Salt is acceptable for use as a deicer on the pervious pavement, although nontoxic, organic deicers, applied either as blended, magnesium chloride-based liquid products or as pretreated salt, are preferable.

Repairs

Potholes in the pervious pavement are extremely unlikely, although settling might occur if a soft spot in the subgrade is not removed during construction. For damaged areas of less than 50 square feet, a declivity could be patched by any means suitable with standard pavement, with the loss of porosity of that area being insignificant. The declivity can also be filled with pervious mix. If an area greater than 50 square feet is in need of repair, approval of patch type must be sought from either the engineer or the owner. Under no circumstance is the pavement surface to ever be seal coated. Any required repair of drainage structures should be done promptly to ensure continued proper functioning of the system.

5.3.2 Infiltration Bed

Description

An infiltration bed captures and temporarily stores stormwater runoff in a media bed that is located beneath an impervious surface or beneath an engineered layer of soil and vegetation. Infiltration beds capture and store stormwater runoff until it infiltrates into the subsurface below. The storage media may consist of clean-washed, open-graded stone aggregate, proprietary stormwater products, or perforated pipes set in a stone bed.

Infiltration beds are well suited for expansive level areas such as athletic fields, plazas, and pavement areas that are not suitable for a porous pavement surface (see Figures 5.3.2-1a and b). Infiltration beds can also be located under landscaped areas. Stormwater runoff from other portions of the site can be conveyed into the stormwater bed for management. If infiltration is not feasible or is limited, an infiltration bed can include an underdrain system for slow release. Infiltration beds can be designed to provide SOV, rate control, and water quality.

Figures 5.3.2-1a and b. An infiltration bed beneath a school athletic field provides stormwater management for the site and building while providing a level playfield area. Storm drain pipes convey roof runoff to the bed, and perforated pipes distribute the runoff through the bed. Small storms infiltrate while large storms discharge to the storm sewer at a mitigated flow rate.

BMP Functions Table

BMP	Applicability*	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Infiltration Bed	U/S/R	H	H	H	H	H	L	L	L	M

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Rating varies based on design considerations.

Key Design Features (See Figure 5.3.2-2)

- Often designed to capture volume of small storms and to provide peak rate control for larger storms.
- Often built to provide regional stormwater management.
- Clean-washed, open-graded stone storage bed with minimum of 40 percent void space.
- Additional storage may be achieved through the use of perforated pipes set in the stone bed or proprietary stormwater storage products.
- Surface material above bed may be pervious or impervious.
- Compacted fill material **may** be placed above bed.
- Level, uncompacted subgrade.
- Nonwoven geotextile at soil/stone interface, including top of bed to prevent soil movement into stormwater bed.
- Designed with method to convey water into stormwater bed.
- May include perforated pipe distribution network within bed.
- Sediment removal required for runoff from parking lots, roads, or other high pollutant source drainage areas.
- Always includes positive overflow.
- Should not place on compacted fill (fill with stone, as needed).
- When possible, place infiltration beds on upland soils.

Applications

- Athletic and recreational fields
- Parking lots and driveways where porous pavement is not appropriate or feasible
- Plazas and open spaces

- Below existing or proposed open space areas
- Beneath areas of fill material to achieve infiltration where major grade changes are required, such as on slopes
- Between impervious areas and downslope vegetation, such as woods or wetlands, where it is important to maintain soil moisture conditions after development

Advantages

- When used to provide volume reduction (SOV), may provide a Curve Number reduction and may reduce the peak rate requirements for the site.
- Well suited to directly receive “clean” roof runoff.
- Does not preclude use of the space (active recreation/parking).
- Can manage a significantly large quantity of runoff and function as a regional system.
- Effective for maintaining soil moisture conditions for downslope planting areas, wooded slopes, or wetlands.
- Flexible dimensions to fit conditions.
- Excellent retrofit capability (see Figure 5.3.2-5)
- Can be benched or terraced to accommodate slopes.
- Cost effective

Disadvantages

- High clogging potential if runoff from high sediment areas is not pretreated.
- Not visible and may be “forgotten.”
- Must be offset from foundations/basements.
- Infiltration requires suitable site conditions (i.e., adequate soil infiltration rate).

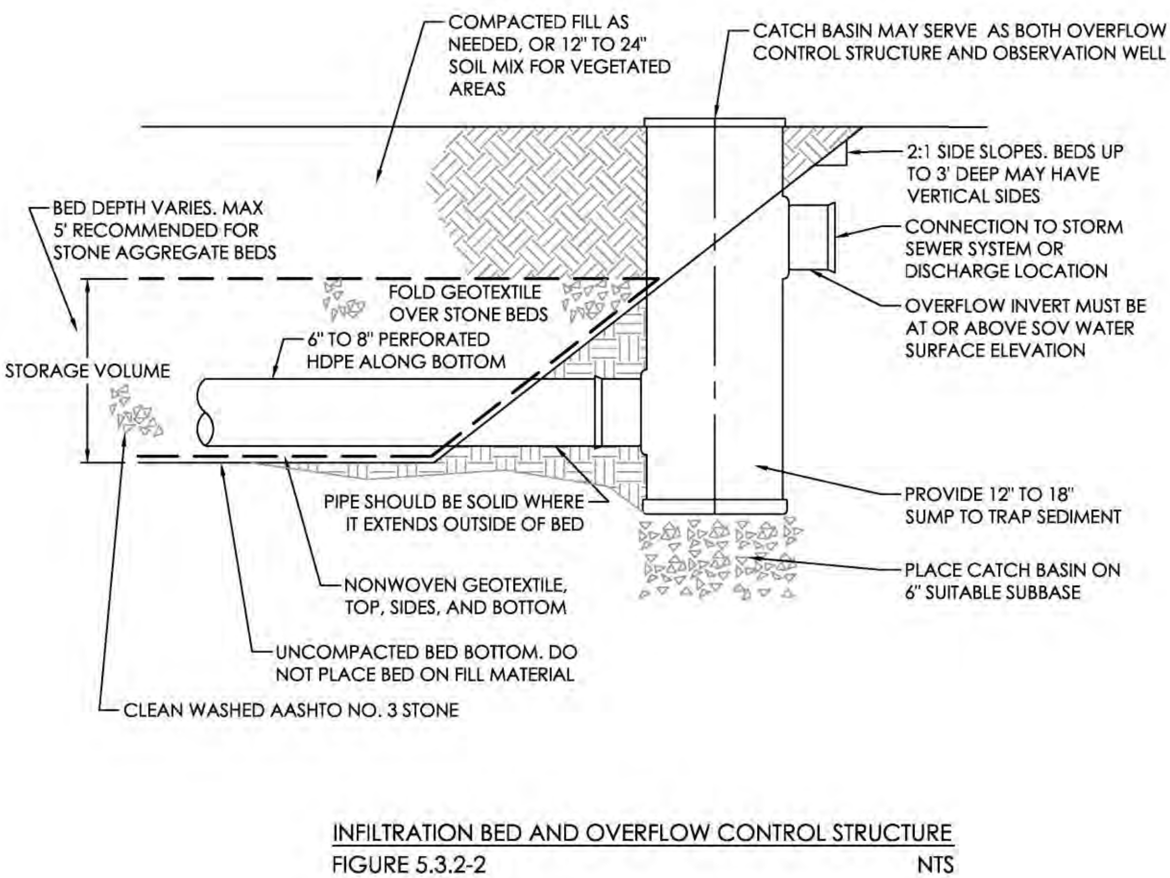


Figure 5.3.2-2. Infiltration bed cross-section. This cross-section shows an infiltration bed at the overflow structure. Runoff from the SOV fills the stormwater bed. In this example, the outflow pipe invert is at the top of the bed and serves to "back up" the water within the bed. Once the bed is full, larger storms discharge from the overflow pipe. A weir across an outflow pipe or within the outflow structure can also achieve the goal. The perforated pipe connection to the catch basin structure ensures that water will pass into the structure directly once the bed is full.

Applications

An infiltration bed can be "hidden" beneath a variety of surfaces such as athletic and other recreational fields, driveways, parking lots, and plazas. They are ideal in areas with limited space for stormwater management. Combining uses, such as integrating an infiltration bed into a design for a basketball court or rubber surface playground, can also be cost-effective.

Residential Infiltration Bed

Figures 5.3.2-3a and b. Infiltration beds were incorporated into standard asphalt driveways in this suburban residential development. Standard asphalt was chosen for ease of maintenance and to prevent homeowners from inadvertently "seal coating" porous pavement. Roof leaders convey runoff directly into beds. The sumped catch basin serves to connect the bed to the storm sewer and may also collect driveway and surface runoff. The roof leaders from the house include cleanouts.

Institutional Infiltration Bed

Figure 5.3.2-4. An infiltration bed beneath large athletic fields at Purdue University serves as a regional stormwater system for the campus. The two football practice fields are nearly 3 acres in area and capture runoff from the fields as well as nearly 10 acres of parking lots and roads. Runoff from parking lots and roads is pretreated with bioretention and vegetated swales before being discharged into the bed.

Landscaped Areas

Figure 5.3.2-5. This landscaped area is underlain by an infiltration bed. The bed receives runoff from the upslope impervious areas.

Urban Greening Infiltration Bed

Figure 5.3.2-6. This urban park plaza is built above an infiltration bed that completely underlies the plaza. Runoff is both piped into the bed from adjacent areas and is able to enter the bed through the porous pavers around the perimeter of the plaza.

Applicable Protocols and Specifications

The following Protocols and Specifications (see Appendices A through F) are applicable to infiltration beds and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 2 Coordination with Other Utilities
- Protocol 3 Site Evaluation and Infiltration Testing

- Protocol 4 Infiltration System Design and Construction Guidelines
- Stormwater System Specifications
  - Aggregates and Drainage Layers
  - Pipes
  - Control Structures
  - Geotextiles
  - Impervious Liners and Waterproofing

Design Considerations for Infiltration Beds

Infiltration beds can be designed beneath various surfaces, from vegetated to impervious. They can be integrated into new development or as part of a retrofit project in both urban and suburban areas. The key design components for infiltration beds discussed below allow design flexibility to ensure maximum performance.

1. Location and Capture Area

Infiltration beds can be located:

- Close to the source of runoff to minimize the need for additional stormwater structures.
- As part of a “regional” or site stormwater management system, designed to capture runoff from a larger drainage area (see Figure 5.3.2-7).

In both instances, stormwater is conveyed into the bed via pipes or other measures.

Figure 5.3.2-7. This diagram of the athletic fields at Purdue indicates how runoff from streets and parking areas is directed through bioretention areas and vegetated swales before being directed to the infiltration bed. Overflow from the vegetated systems is piped into the bed in this "treatment train" approach.

<u>Slopes</u>

- Infiltration beds should not be constructed on fill material, because compacted fill will prevent infiltration.

- Where fill is required to achieve desired site grades, infiltration beds can be located beneath the compacted fill. This allows the bed to be constructed on native soil material (see Figure 5.3.2-8).
- The bed bottom must be level or with a slope less than 0.5 percent. If needed, the infiltration bed may be benched or terraced on slopes, similar to the examples for porous pavement (see Figure 5.3.2-9).

Figure 5.3.2-8. This supermarket parking lot required a level surface. Infiltration beds were placed at the native soil interface, beneath the fill material and parking lot.

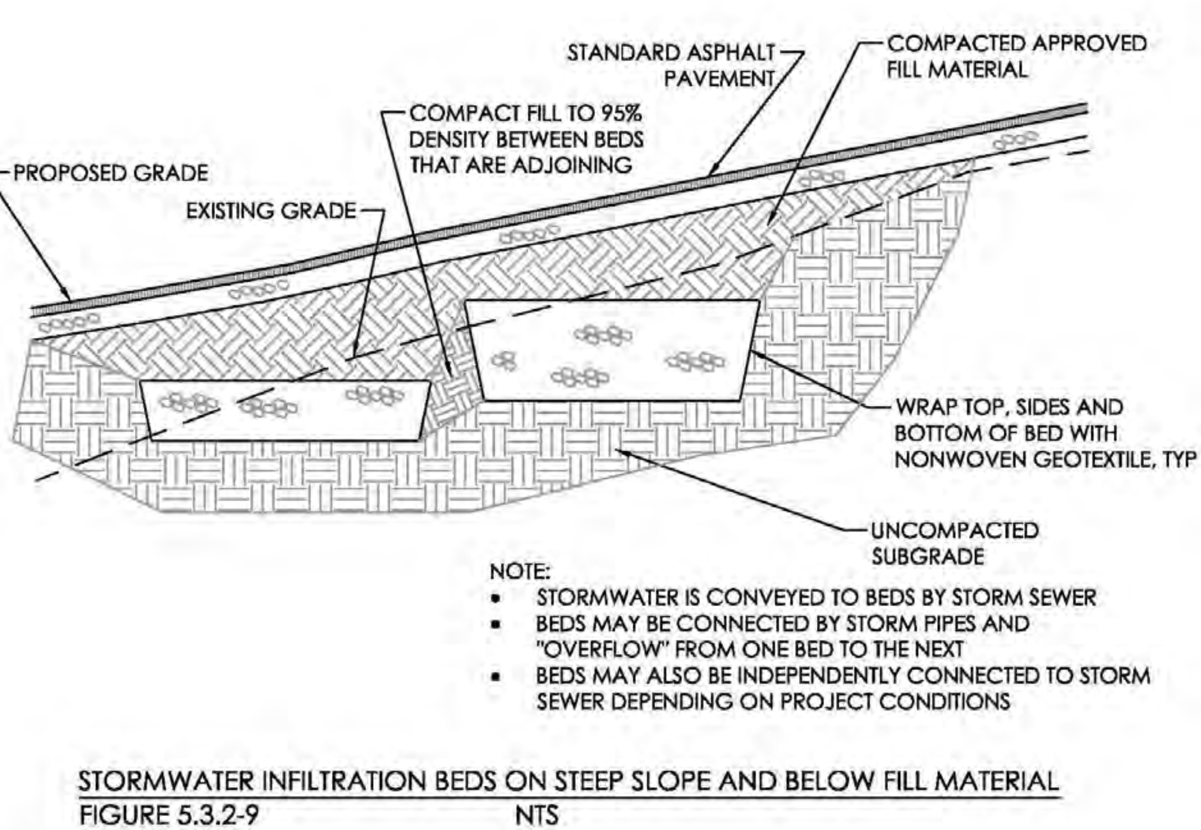


Figure 5.3.2-9. Cross-section of infiltration beds on slope and beneath fill material.

<u>Drainage Area</u>

- The type of land use in the drainage area must be carefully considered. Roof runoff is generally "clean" with regard to sediment and is ideal for discharge to an infiltration bed. Runoff from other areas such as parking lots must be treated with sediment-reduction measures (such as vegetated swales and filter strips) before runoff is discharged into the bed.
- Infiltration beds should not be used in hot spot areas where there is the potential for runoff with higher than average pollutant levels to enter the groundwater. Only the hot spot area is precluded from the infiltration bed; other portions of the site may be well-suited for infiltration bed use.

2. Entrance/Flow Conditions

Stormwater runoff must be conveyed into an infiltration bed, usually with storm sewer pipes. Pipes may end within and discharge directly into a small bed, or continue through the bed as a continuously perforated pipe to better distribute water in a large bed (see Figure 5.3.2-10).

If the surface of the bed is vegetated, adequate soil cover (a minimum of 12 to 24 inches) must be installed to support the proposed landscape vegetation. The soil cover can allow surface runoff to permeate through the soil and into the infiltration bed. An infiltration bed may be placed below compacted fill material and impervious surfaces. When a bed is placed below compacted fill, stormwater must be conveyed into the bed via pipes and structures.

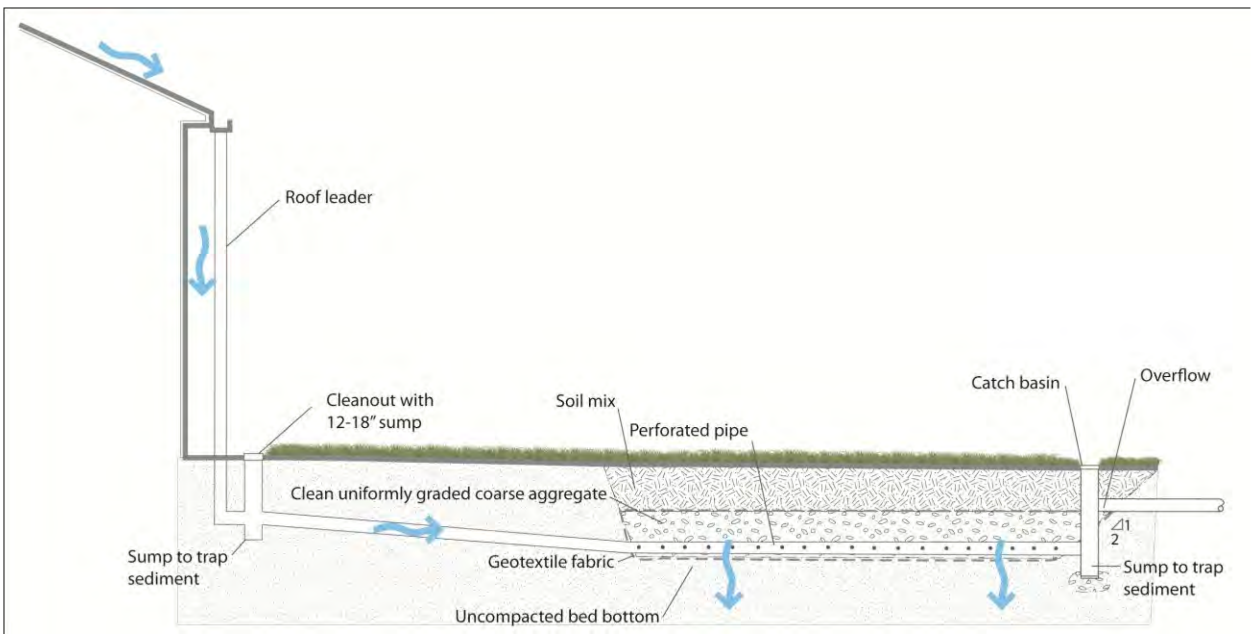


Figure 5.3.2-10. Conveyance of runoff into stormwater infiltration bed. Pipes may discharge directly into the bed or continue through the bed as a continuously perforated pipe.

3. Management of Sediment, Trash, and Debris

In areas of high sediment load, measures should be provided to prevent the movement of suspended material into the infiltration bed. Sediment can clog an infiltration bed and limit its functional lifespan.

- Roof runoff is generally lower in sediment and can be conveyed directly into a bed; however, a cleanout for roof leaders is required in the event that pipe clogging occurs.

- Runoff from roof areas that receive high amounts of leaf debris or other materials (such as deposition from equipment) should include sediment traps, or should be reconsidered. It may be preferable to discharge these roof areas to a vegetated swale or a filter strip prior to discharge into the bed.
- In areas of high trash or with specific concerns such as plastic shopping bags, entrance conditions should include a screen to prevent material from entering the infiltration bed. The designer must consider the site-specific conditions and adjacent land uses in each application.
- Water quality inserts or sumped inlets can reduce the amount of sediment from parking areas and low-traffic streets (see Figure 5.3.2-11). For high-traffic streets, the designer may wish to consider discharge to a vegetated system such as a filter strip or vegetated swale before discharge into the infiltration bed. Water quality inserts can also be used but must be maintained. Clogging of unmaintained inserts may result in ponding on the roadway. This potential hazard should be considered by the design engineer.

Figure 5.3.2-11. Water quality inserts can be used to reduce sediment and prevent trash from entering a stormwater infiltration bed. Water quality inserts require regular maintenance. (http://www.gaelwolf2.com/dnrec/trib_times_2004_4_catch_basin_inserts.htm, Aug. 24, 2012)

- If a large infiltration bed includes a perforated pipe distribution system, one or more cleanouts should be installed to allow access to the distribution pipes.

4. Storage and Stay-on-Volume

As shown on Figure 5.3.2-12, the **storage** capacity of an infiltration bed is measured as the volume **below** the lowest discharge invert (overflow).

Storage Volume (ft^3) =

Bed Length (ft) x Bed Width (ft) x Bed Depth (ft) Below Overflow Elevation x Void Ratio

Void ratios are generally:

- 0.40 for clean washed aggregate such as AASHTO No. 3
- 0.85 to 0.95 for manufactured storage units depending on manufacturer
- 1.0 for the interior volume in perforated pipes within the bed

The SOV is a function of the storage volume available for the 1-inch or 1.6-inch storm.

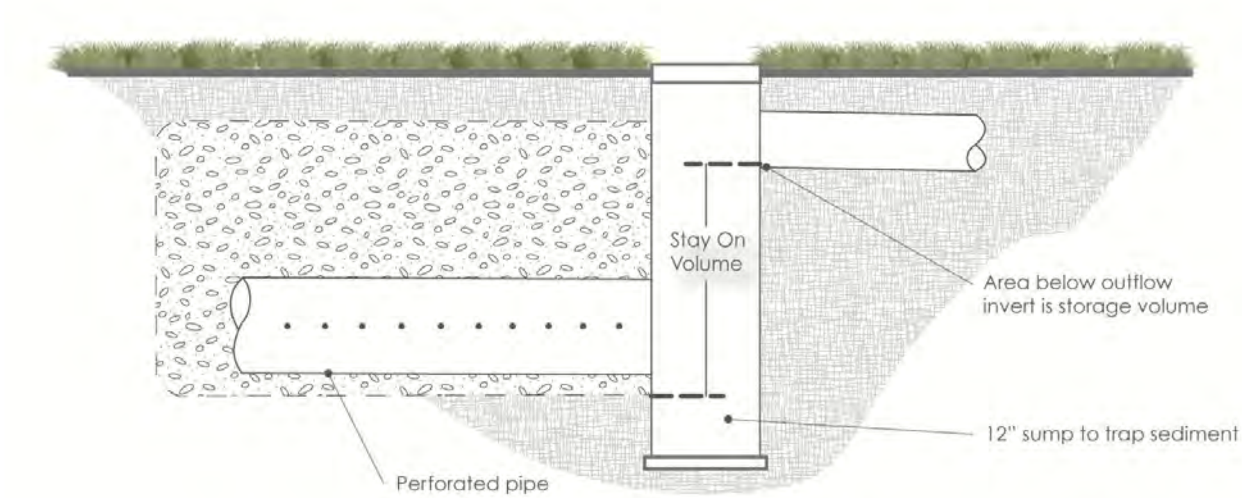


Figure 5.3.2-12. Storage capacity of stormwater infiltration bed is estimated below the overflow elevation.

5. Area and Dimensions

The size and area of an infiltration bed are a function of the drainage area that will discharge into the bed. For infiltration systems, it is important **not** to concentrate too much stormwater in one location for management. This can lead to accelerated clogging from sediment, high water depths that may compress soils, and soils that do not dry out between storms (and change structure). It also provides soil/water contact for water quality improvement. A basic rule-of-thumb is to design an infiltration bed with a surface area (footprint) that is a ratio of the impervious and compacted pervious areas that drain to it. The amount of rainfall volume must also be considered. The following ratios based on design rainfall depth can be used to estimate the surface area of a subsurface infiltration bed:

<u>1-inch Rainfall</u>

1:10 ratio of infiltration bed surface area to impervious drainage area

1.6-inch Rainfall

1:8 ratio of infiltration bed surface area to impervious drainage area

The land use type draining into an infiltration bed should be considered in bed area design. It is **strongly** discouraged that beds receiving runoff from high-sediment areas such as streets and high-use parking lots exceed the recommended ratios. The recommended ratios can be increased when managing runoff from clean roof areas, especially in areas with high (greater than 1 inch per hour) infiltration rates. “Clean” and “dirty” runoff should not be mixed if possible, although this is not always feasible.

The bed depth of water storage is primarily determined by the rainfall depth managed and the loading ratio, and influenced to a lesser extent by the infiltration rate. **There is no specific limit on the maximum width or length of an infiltration bed. However, designers are discouraged from designing excessively deep infiltration beds (greater than 5 feet for the SOV capacity), even in areas with high infiltration rates, because of concerns that the pressure at greater water depths may compact or alter the underlying soil.** There is no depth limit on non-infiltrating, slow-release beds.

Beds can be designed for short-term, deeper water depths during the larger, and less frequent, peak rate storm events if necessary to provide peak rate mitigation.

Proprietary products may be used as storage media and as a substitute for stone subbase; however, all products must be approved by the City. A number of modular subsurface, plastic, interlocking storage units provide higher void space and comparable structural stability as AASHTO No. 3, but may be more costly (see Figures 5.3.2-13).

Figures 5.3.2-13(a and b) This “on-line” infiltration bed is constructed of “RainStore” units to increase storage capacity. This bed was installed as a retrofit to reduce downstream erosion and flooding.

6. Overflow and Peak Rate

All infiltration beds must provide a safe way for water to exit the system when large storms generate more stormwater runoff than the bed can hold. The inclusion of a positive overflow route ensures that flooding risks and related property damage are minimized. The positive overflow route is often in the form of a modified inlet box with an internal weir plate, or simply an overflow pipe at an invert higher than the bottom of the infiltration bed. This maximizes the volume managed by the bed, while providing sufficient cover for overflow pipes. When water overtops the weir, it discharges via a pipe to the storm sewer or to another approved discharge point.

The overflow structure can be designed to function as a detention rate control structure for peak rate control, and can be modeled or evaluated as a detention system. Temporarily higher effective water depths are acceptable during large storm events managed for peak rate control. The catch basins can be used as overflow structures in large storms, and as rate control structures in larger storm events if the bed is constructed with sufficient capacity.

The minimum allowable diameter of an overflow pipe is 12 inches unless otherwise approved by the City.

<u>Peak Rate Control and Infiltration Credit</u>

For the purposes of site peak rate control, the designer may adjust the Curve Number value based on the volume managed by both the SOV and the infiltration volume that occurs during a portion of a 24-hour storm event. This allows the designer to account for runoff that was captured by applying LID, and to develop a representative lower Curve Number. This procedure is described in Chapter 7.

When adjusting the Curve Number, the infiltration volume can be estimated as the infiltration that occurs during the first 12 hours of a 24-hour design storm. This will ensure that estimated infiltration volumes are not greater than the actual volume captured within the BMP.

Infiltration Volume (ft^3) = Bioretention Bottom Area (ft^2) x Infiltration Rate (in/hr) x 1/12 x 12 hours

7. Freeboard

Infiltration beds can be designed without freeboard and be allowed to completely fill provided that other conditions, such as adjacent pavement subbase, are considered. Because infiltration beds often serve as peak rate detention facilities, they are often designed with additional capacity above the SOV storage volume. The designer should always confirm that an infiltration bed will not surcharge, but has adequate capacity for conveyance of large events.

8. Underdrain

An underdrain system is used to ensure that water moves through the system when the native soil infiltration rate is not high enough to empty the bed of water, or if the bed is underlain by an impervious liner and designed only for slow release. Underdrain systems should discharge to the existing stormwater system or to a location approved by the City. Underdrain systems must be included in the design if the native soil infiltration rate is less than 0.1 inch per hour, or if the bed is designed for slow release. See Protocol 3 for the infiltration testing procedure and Protocol 4 for infiltration system guidelines.

9. Waterproofing

In some instances, infiltration beds may be designed to infiltrate, but there may be concerns about impacts on adjacent structures such as basements, or impacts on the subbase of adjacent paved surfaces. For all subsurface infiltration beds, the designer must evaluate the impact of the system on adjacent structures and utilities as defined in Protocol 1, Setbacks from Structures and Protocol 2, Coordination with Other Utilities. The liner, if applied, must meet the guidelines provided in the Stormwater Specification. In many situations, a partial liner (i.e., one side of a bed) will adequately protect structures.

Utility pipes or conduits may pass through the bed if required, but the designer is encouraged to avoid utility crossings if possible. Where a new or existing utility passes through a stormwater bed, a waterstop should be installed along the utility as it exits the bed to prevent movement of water along the utility bedding material.

10. Water Quality/Total Suspended Solids

Infiltration beds that can capture and manage the required SOV through infiltration are considered to meet all water quality requirements. Infiltration beds that are under drained but can capture the required water quality volume as defined in Chapter 7 are also considered to provide water quality treatment. See Chapter 7 for additional discussion, and the Infiltration Bed Worksheet for calculations.

Sizing Calculations Worksheet for Subsurface Infiltration Beds

(Link to Worksheet)

Construction Considerations

Infiltration beds can be installed:

1. Early in the construction process, but should not receive **any** site runoff until site construction is complete and site stabilization has occurred. Runoff should be directed around the completed infiltration bed until site stabilization has occurred. Sediment-laden water should not be allowed to enter infiltration beds. The designer must consider stormwater management during construction.

2. The stormwater bed may be constructed after site construction is substantially complete and site stabilization has occurred. During construction of the site, areas reserved for infiltration beds **must** be protected and should be fenced or barricaded to prevent the movement of equipment over the proposed infiltration area. This is similar in practice and intent to protecting an onsite septic system disposal field from vehicle compaction.

The excavated capacity of an infiltration bed may be used as a temporary sediment trap/stormwater measure during construction. The bottom elevation during use as a sediment measure should be a minimum of 1 foot higher than the final infiltration bed bottom elevation. At the time of conversion from a sediment measure to an infiltration bed, any sediment and the remaining 1 foot of material should be removed for construction of the infiltration bed.

Construction Sequence Example

Step 1 Excavate and Prepare Subgrade

a. Do **not** compact or subject pervious pavement locations to excessive construction equipment traffic during construction. Protect areas from vehicular traffic during construction with construction fence, silt fence, compost sock, or other means acceptable to the City (see Figure 5.3.2-13, which shows a construction area delineated with construction fence to keep vehicular traffic isolated).
b. If alternate storage media is used in lieu of stone aggregate, provide a suitable stone subbase and do **not** compact bed bottom.
c. Infiltration beds can be installed at any time during the construction process provided that sediment-laden runoff is prevented from entering the bed. Do not allow runoff from any disturbed areas in the drainage area to discharge into the bed until these areas have been stabilized.
d. Remove fine materials and/or surface ponding in the graded bottom, caused by erosion, with light equipment and scarify the underlying soils to a minimum depth of 6 inches with a York rake or equivalent by light tractor.
e. Construct earthen berms (if used) between infiltration beds by excavating the beds and leaving existing material in place between the beds as a “berm.”
f. Bring subgrade of infiltration bed to line, grade, and elevations indicated on the plans. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All infiltration beds shall be level grade on the bottom (not greater than 0.5 percent slope).
g. Halt excavation and notify engineer immediately if evidence of sinkhole activity, unanticipated bedrock or groundwater conditions, or other site conditions that may affect infiltration bed design or performance are encountered.

Step 2 Install Overflow Structure and Other Stormwater Structures

a. Place the stormwater overflow structure on suitable subgrade to prevent settling (i.e., compacted subgrade and compacted suitable subbase material). Install overflow structure, inlet pipes, curbs, and other stormwater structures as appropriate before placement of stone storage bed.
b. Close and secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering the infiltration bed before completion and site stabilization.
c. Maintain drainage overflow pathways during construction, while the infiltration bed is closed, to provide for drainage during storm events.
d. Infiltration bed conditions should be observed by the design engineer, following excavation and grading and prior to placement of geotextile and aggregate materials, to confirm that construction requirements have been met. Documentation must be provided to the City (see Appendix I).

Step 3 Install Infiltration Bed

a. Place geotextile and bed aggregate immediately after approval of subgrade preparation and installation of structures. Geotextile shall be placed in accordance with the manufacturer's standards and recommendations. Overlap adjacent strips of geotextile a minimum of 16 inches.
b. Place clean (washed), uniformly graded aggregate or other storage media in the bed in maximum 8-inch lifts. Spread the aggregate with equipment running over the aggregate and pushing toward bare soil. Lightly compact each aggregate layer while keeping construction equipment off the bed bottom as much as possible.
c. Following placement of storage media, place geotextile over the **top** of the bed to prevent soil movement into the bed. Place and secure geotextile to prevent soil movement through the overlap areas.
d. Place soil or other material above the storage bed.

Operations and Maintenance

All properly designed and installed subsurface infiltration beds will require annual maintenance, although they require less maintenance than other BMPs.

- Inspect and clean all inlets and catch basins biannually.
- Confirm that standing water does not remain in the bed after more than 96 hours without precipitation.
- Clean any pipes of connections that contain debris using a vacuum system. Do not wash material and debris into the bed.

5.3.3 Infiltration Trench

Description

An infiltration trench consists of a linear trench of open-graded aggregate or media that can capture, hold, and infiltrate stormwater (see Figures 5.3.3-1a and 1b). Its functions are similar to a stormwater infiltration bed except that it may also serve as part of a conveyance system, especially during larger storm events. Infiltration trenches capture and store stormwater runoff until it infiltrates into the subsurface below. The storage media may consist of clean-washed, open-graded stone aggregate, proprietary stormwater products, or perforated pipes set in a stone trench.

Very often, an infiltration trench is an effective method for conveying stormwater while also providing stormwater volume capture. In suitable areas, a stormwater pipe can be constructed as an infiltration trench. For an “on-line” trench that is part of a conveyance system, small storms are captured by the trench while large storms are conveyed through the BMP (infiltration trench). As a result, infiltration trenches, when used as part of a larger stormwater conveyance system, can be one of the most cost-effective BMPs.

Infiltration trenches are well suited to linear areas such as along roads, where they may be “on-line” (where all flows go through the trench) or “off-line” (where larger storms are intended to bypass the trench).

Infiltration trenches that are parallel to the road are generally only cost-effective on slopes of 5 percent or less. On steeper roads, infiltration trenches can be constructed perpendicular to the road and along the contour if space is available.

In situations where infiltration is not feasible, a stormwater trench may include an underdrain system for slow release. Underdrained trenches can work very well as roadside retrofits in urban areas, and are highly beneficial in CSO areas to reduce runoff volume during rainfall periods.

Figures 5.3.3-1a and b. Infiltration trench during installation and afterwards.

BMP Functions Table

BMP	Applicability*	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Infiltration Trench	U/S/R	H	H	M	H	H	M	L	L	M

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Rating varies based on design considerations.

Key Design Features (see Figure 5.3.3-2)

- Linear in nature and generally designed to capture runoff from small (1.6 inches or less) rainfall events.
- The trench may capture all or only a portion of the SOV.
- Often built “on-line” as part of a stormwater conveyance system.
- Water is conveyed into the trench, usually with pipes or other structures.
- Always includes an overflow control structure and the capacity to safely convey or bypass larger storm events.
- Usually limited in maximum width (6 feet or less) and depth (4 feet or less), although this may vary according to conditions.
- Minimum trench width is 3 feet.
- The length, width, and depth may be a function of “available space” for the infiltration trench.
- Clean-washed, open-graded aggregate storage trench with minimum of 40 percent void space.
- Perforated pipe is used within the trench.
- Surface material above trench may be pervious or impervious.
- Compacted fill material may be placed above the trench.
- Level, uncompacted subgrade in the trench bottom.
- Nonwoven geotextile at soil/stone interface, including top of trench to prevent soil movement into the trench.
- Designed with a method to convey water into the stormwater trench.
- Prior sediment removal is required for runoff from parking lots, roads, or other high sediment source drainage areas.
- Should not be placed on compacted fill if designed for infiltration.
- When possible, place infiltration trenches on upland soils.

Applications

- As part of a stormwater conveyance system in segments where there is limited grade change
- Road shoulders, medians, alleys, and sidewalks
- Parking lot edges
- Individual home lots
- As a component to “connect” larger BMPs
- Useful as a retrofit when replacing sidewalks, repairing roads, etc.

Advantages

- Very cost-effective when part of a stormwater conveyance system.
- When used to provide volume reduction (SOV), may provide a Curve Number reduction and may reduce the peak rate requirements for the site.
- Well suited to directly receive “clean” roof runoff.
- Effective for maintaining soil moisture conditions for planting areas or wooded slopes.
- Can enhance health and longevity of street trees if properly designed.
- Landscape features may be built above an infiltration trench; it does not preclude other uses of the surface space.

Disadvantages

- High clogging potential if runoff from high-sediment areas is not pretreated.
- Limited capacity for volume storage due to size.
- Not visible and may be “forgotten.”
- Must be offset from foundations/basements.
- May encounter utility conflicts in roadway right-of-way applications, especially in retrofit situations.
- Must be designed to prevent damage to pavement subbase material from infiltration.

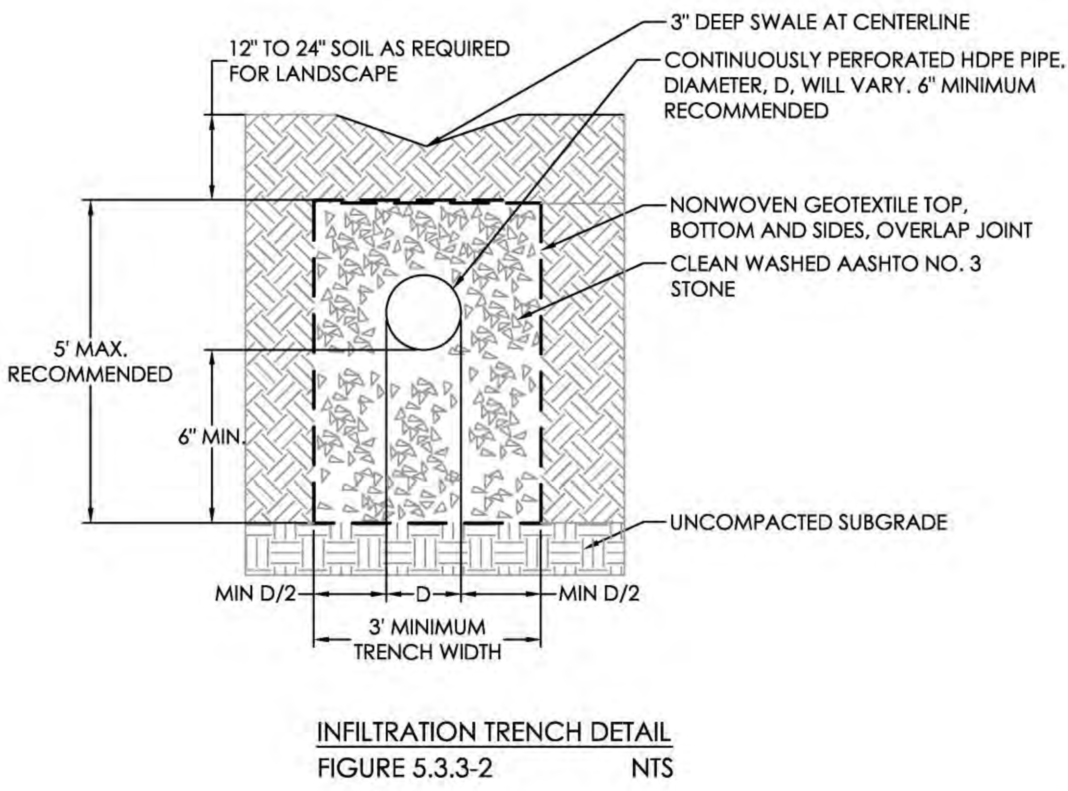


Figure 5.3.3-2. Typical infiltration trench cross-section.

Applications

An infiltration trench is often a "leaky pipe" by intention. In small, linear areas, the stormwater conveyance system can be designed to reduce runoff volume by allowing small storm events to partially or entirely infiltrate within the trench. Infiltration trenches are well-suited to the linear nature of roads.

Roadside Infiltration Trench

Figures 5.3.3-3a and b. Infiltration trenches were incorporated into an existing storm sewer system within the road at the Washington National Cathedral (Washington, DC). The trench is lined with an impervious liner along the asphalt edge to prevent damage to the roadway subbase from water movement. Overlain by standard asphalt, runoff enters the trench through stormwater inlets.

Infiltration Trench as Part of Conveyance System

Figure 5.3.3-4. The subgrade storm sewers beneath the lawn at this university campus include infiltration trenches "on-line" as part of the storm sewer system. This is appropriate where the grade is relatively level and the storm sewer is constructed along the contour, as shown here.

Urban Greening Infiltration Trench

Figure 5.3.3-5. Tree trenches capture street runoff, via curb inlets, and improve urban greening and streetscapes, especially in ultra-urban locations.

Applicable Protocols and Specifications

The following Protocols and Specifications (see Appendices A through F) are applicable to infiltration trenches and must be addressed:

- Protocol 2 Coordination with Other Utilities
- Protocol 3 Site Evaluation and Infiltration Testing
- Protocol 4 Infiltration System Design and Construction Guidelines
- Protocol 5 Planting Guidelines

- Bioretention Soil Specifications
- Stormwater System Specifications
  - Aggregates and Drainage Layers
  - Pipes
  - Control Structures
  - Geotextiles

  Impervious Liners and Waterproofing

Design Considerations for Infiltration Trenches

Infiltration trenches are a linear BMP. The key design components for infiltration trenches discussed below allow design flexibility to ensure maximum performance. A trench may capture only a portion of the SOV, but be part of a larger system that meets volume requirements.

1. Location and Capture Area

Locate infiltration trenches:

- Close to the source of runoff (if possible) to minimize the need for additional stormwater structures.
- Between larger BMPs or as part of the stormwater conveyance system.
- To capture small drainage areas, generally less than 10,000 square feet. If necessary, use several connected infiltration trenches or combine with other BMPs to address larger areas.

Infiltration trenches can be located beneath or within roadways or impervious paved areas with proper design. When located in or adjacent to pavement, the following site-specific conditions should be considered:

- Saturated conditions in the trench cannot create saturation under or within the impermeable pavement subbase. This is especially important when infiltration trenches are adjacent to standard impervious pavement.

Figure 5.3.3-6. Impervious liners can be used to prevent lateral movement of water beneath standard pavement.

- Water levels in the trench should never be high enough to saturate the subbase of overlying impervious areas (through the top of the trench). Provide for controlled overflow and maximum water surface elevation.
- When located adjacent to pavement, the maximum water level must be lower than the pavement subbase. Alternatively, a secured impervious liner can be used to prevent lateral water movement (see Figure 5.3.3-6).

Slopes

- Infiltration trenches should not be constructed on fill material, because compacted fill will prevent infiltration. Slow release (underdrained) infiltration trenches may be built in fill material.
- The trench bottom must be level or with a slope less than 0.5 percent. If needed, the infiltration trench may be benched or terraced on slopes.
- Grade changes can often be accommodated by a series of connected infiltration trenches that “step” down the hill. (See BMPs 5.3.1 and 5.3.2 for “stepped” details.)

Drainage Area

- The type of land use in the drainage area must be carefully considered. Roof runoff is generally “clean” with regard to sediment and is ideal for discharge to an infiltration trench. Runoff from other areas, such as parking lots, must be treated with sediment-reduction measures, such as sediment traps in inlets or inlet water quality inserts, before runoff is discharged into the trench (see Figure 5.3.3-7).
- Infiltration trenches should not be used in hot areas where there is the potential for runoff with higher than average pollutant levels to enter the groundwater. Only the hot area is precluded from infiltration; other portions of the site may be well-suited for infiltration trench use.

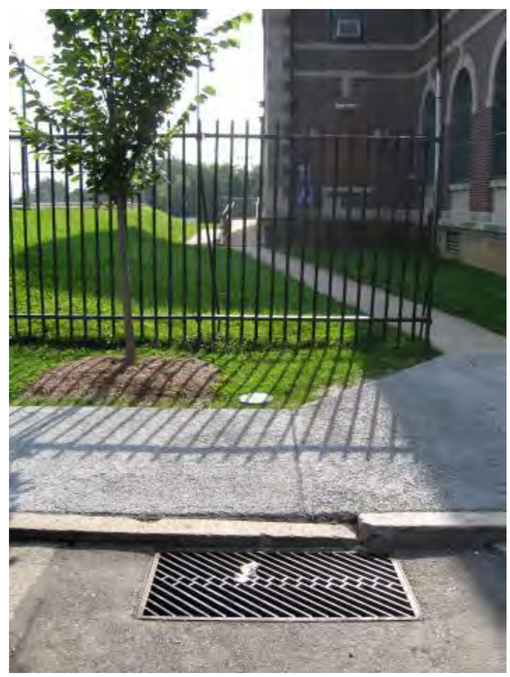


Figure 5.3.3-7. If a catch basin is used to collect street runoff into a tree trench, the inlet must include a sump and a water quality insert to control sediment. This tree trench is built with a porous pavement sidewalk. (Also see Figures 5.3.11a and b.)

2. Entrance/Flow Conditions

Stormwater runoff must be conveyed into an infiltration trench, usually with storm sewer pipes. Pipes usually continue through the trench as a continuously perforated pipe. A cleanout or pipe access through a structure should always be provided for future pipe cleaning if necessary. **The minimum diameter of the continuously perforated pipe within the trench is 6 inches.** If the trench must convey large storms ("on-line" infiltration trench), the designer must confirm that the overflow capacity from the trench is adequate to meet City conveyance requirements (see Overflow discussion). For "on-line" infiltration trenches, it is recommended that the pipe be located in the upper portion of the trench, with storage provided below.

Trenches that are "off-line" receive runoff until the trench is full, at which point stormwater runoff must be designed to "bypass" the trench and be managed by other methods (see Figure 5.3.3-8). A trench may also be designed with entrance conditions that constrict the rate of flow into the trench, such that high flow rates from high-intensity rainfall cannot enter the trench.

Figure 5.3.3-8. This roadway trench is designed with catch basins to capture and convey runoff into the trench. When the trench is full, flows cannot enter the trench and continue to the next catch basin that conveys the runoff to the larger combined sewer system.

3. Management of Sediment, Trash, and Debris

In areas of high sediment load, all infiltration trenches **must** include measures to prevent the movement of material into the trench. Sediment can clog an infiltration trench and limit its functional lifespan (see Figure 5.3.3-9).

- Roadside infiltration trenches **must** include sediment-reduction practices (such as sumps, water quality inserts, and trash screens). Additionally, roadside trenches must be approved with a maintenance plan that identifies the method and frequency of maintaining the roadside trench.
- Roof runoff is generally lower in sediment and can be conveyed directly into a trench; however, a cleanout for roof leaders is required in the event that pipe clogging occurs.
- Runoff from roof areas that receive high amounts of leaf debris or other materials (such as deposition from equipment) should include sediment traps, or should be reconsidered. It may be preferable to discharge these roof areas to a vegetated swale or a filter strip prior to discharge into the trench.

- In areas of high trash or with specific concerns such as plastic shopping bags, entrance conditions should include a screen to prevent material from entering the infiltration trench. The designer must consider the site-specific conditions and adjacent land uses in each application.
- Water quality inserts or sumped inlets can reduce sediment from parking areas and low-volume streets. High-volume streets should discharge to a vegetated system such as a filter strip or vegetated swale before discharge into the trench.
- Cleanouts should be installed as necessary to allow access at "both ends" of the distribution pipes, if these pipes cannot be accessed through inlets or other structures.

Figure 5.3.3-9. Lack of inlet maintenance can prevent water from entering an urban tree trench.

4. Storage and Stay-on-Volume

An infiltration trench may be designed to capture the SOV, but often the trench may be able to capture only a portion of the SOV. In this situation, the remaining SOV and water quality volume must be managed by downstream BMPs.

The storage capacity of an infiltration trench is measured as the volume below the lowest discharge invert (overflow).

Storage Volume (ft^3) =

Trench Length (ft) x Trench Width (ft) x Trench Depth (ft) Below Overflow x Void Ratio

Void ratios are generally:

- 0.40 for clean-washed aggregate such as AASHTO No. 3
- 0.85 to 0.95 for manufactured storage units depending on manufacturer
- 1.0 for the interior volume in perforated pipes within the trench

The **SOV** is a function of the storage volume available for the 1-inch or 1.6-inch storm.

Infiltration Volume (ft^3) = Trench Bottom Area (ft^2) x Infiltration Rate (in/hr) x 12 hours x 1/12

5. Surface Area and Dimensions

The size and surface area of an infiltration trench may be a function of the drainage area that will discharge to the trench. It is important **not** to concentrate too much flow in one location. This can lead to accelerated clogging from sediment, high water depths that may compress soils, and soils that do not dry out between storms (and change structure). A basic rule-of-thumb is to design an infiltration trench with a surface area that is a ratio of the impervious and compacted pervious areas draining to it. The amount of rainfall volume must also be considered. The following ratios based on design rainfall depth can be used to estimate the dimensions for an infiltration trench:

<u>1-inch Rainfall</u>

1:10 ratio of trench surface area to impervious drainage area

<u>1.6-inch Rainfall</u>

1:8 ratio of trench surface area to impervious drainage area

For example, an infiltration trench that receives runoff from 5,000 square feet of roadway and is designed for the 1-inch rainfall would be:

5,000 square feet / ratio of 10 = 500 square feet of infiltration trench

The trench depth of water storage is a function of the rainfall depth managed and the loading ratio, and influenced to a lesser extent by the infiltration rate. Very often the storage depth of an infiltration trench will be limited by site conditions (i.e., the elevation of the downstream stormwater system to which the trench connects). Trench depth may also be limited by topography and slope.

The minimum recommended width for infiltration trenches is 3 feet. Designers are strongly discouraged from designing infiltration trenches that are more than 5 feet deep. Excavation and placement of trench material may become difficult at deeper depths. Applicable health and safety requirements must be adhered to in the installation of any trench.

A 5-foot-deep stone infiltration trench (with 40 percent void space) can provide 2 feet of runoff storage:

2 feet of water / 0.40 void space = 5-foot stone storage trench

Additional storage may be available in the conveyance pipe if the pipe volume is lower than the control invert from the trench (see Overflow discussion).

Proprietary products may be utilized as storage media and as a substitute for stone subbase; however, all products must be approved by the City. An example is use of modular subsurface, plastic, interlocking storage units, which provide higher void space and structural stability comparable to AASHTO No. 3 aggregate, but may be more costly.

The land use type draining into an infiltration trench should be considered in trench area design. It is **strongly** discouraged that trenches receiving runoff from high-sediment areas such as streets and high-use parking lots exceed the recommended loading ratios. The recommended ratios can be significantly increased when managing runoff from clean roof areas. “Clean” and “dirty” runoff should not be mixed if possible.

If the surface of the trench is vegetated, adequate soil cover must be maintained above the infiltration trench to support successful vegetation. Minimum cover over pipes for structural integrity is required.

6. Overflow and Peak Rate

All infiltration trenches must provide a safe way for water to exit the system when large storms generate more stormwater runoff than the trench can hold. The inclusion of a positive overflow route ensures that flooding risks and related property damage are minimized.

The positive overflow route is often in the form of a modified inlet box with an internal concrete weir (or weir plate), or simply an overflow pipe at a higher invert elevation. This maximizes the volume managed by the trench, while providing sufficient cover for overflow pipes. When water overtops the weir, it discharges via a pipe to the storm sewer or to another approved discharge point (see Figure 5.3.3-10).

The overflow structure can be designed to function as a detention rate control structure for peak rate control, and can be modeled or evaluated as a detention system. Temporarily higher effective water depths are acceptable during large storm events managed for peak rate control. Infiltration trenches do not usually have sufficient capacity for significant detention storage/mitigation.

The minimum allowable diameter of an overflow pipe is 12 inches unless otherwise approved by the City. The overflow structure must have capacity to meet the conveyance requirements of the City.

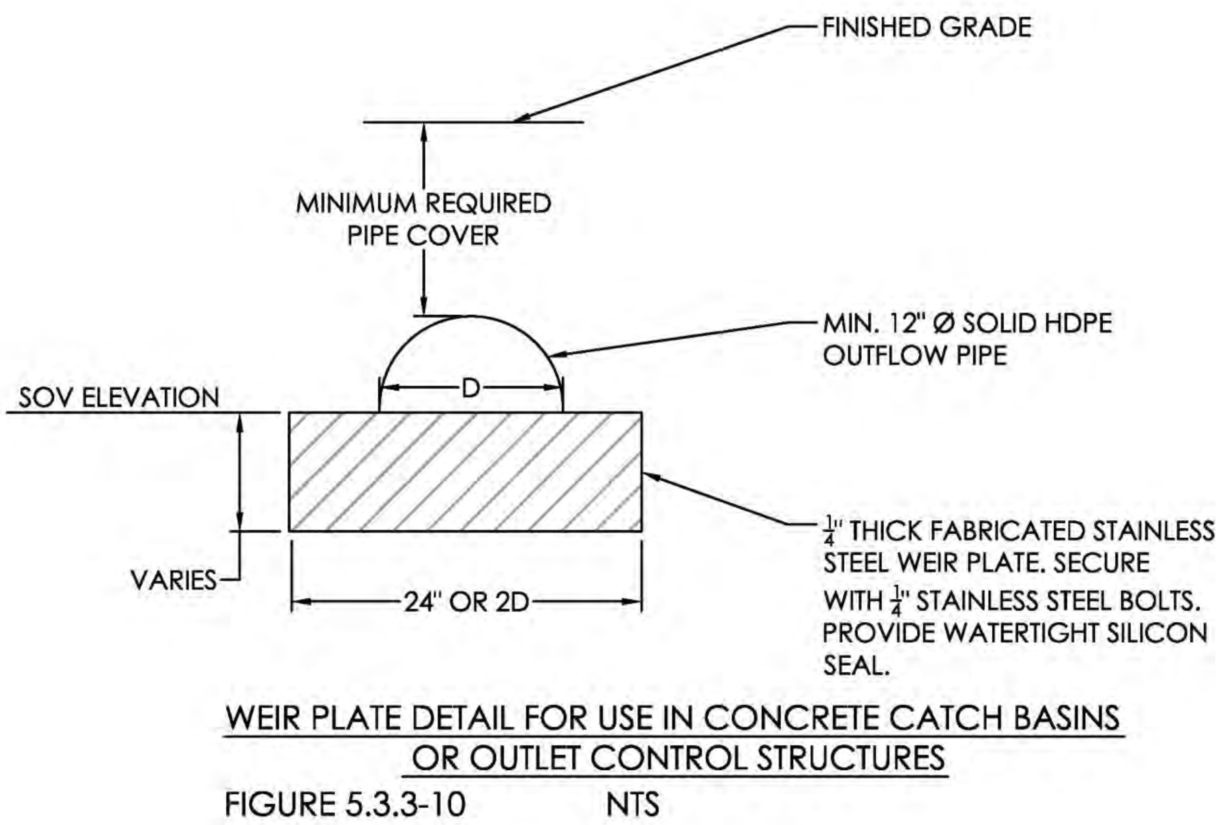


Figure 5.3.3-10. In an infiltration trench, placement of a weir plate over a portion of the outflow pipe allows the trench to capture small storms and maintain minimum cover over the pipe. The designer must confirm that large storms are conveyed through the trench.

Peak Rate Control and Infiltration Credit

For the purposes of site peak rate control, the designer may adjust the Curve Number value based on the volume managed by both the SOV and the infiltration volume that occurs during a portion of a 24-hour storm event. This allows the designer to account for runoff that was captured by applying LID, and to develop a representative lower Curve Number. This is described in Chapter 7.

When adjusting the Curve Number, the infiltration volume can be estimated as the infiltration that occurs during 12 hours of a 24-hour design storm. This will ensure that estimated infiltration volumes are not greater than the actual volume captured within the BMP.

Infiltration Volume (ft^3) = Trench Bottom Area (ft^2) x Infiltration Rate (in/hr) x 1/12 x 12 hours

7. Freeboard

Infiltration trenches can be designed without freeboard and be allowed to completely fill provided that other conditions, such as adjacent pavement subbase, are considered. The designer must always provide an alternate means to manage flows that bypass or overflow a trench.

8. Underdrain

The underdrain system is used to ensure that water moves through the system when the native soil infiltration rate is not high enough to empty the trench of water. If water does not exit the trench quickly enough, the system will back up through the inlet structures, and water may remain in the trench between storm events. Underdrain systems should discharge to the existing stormwater system or to a location approved by the City. Underdrain systems must be included in the design if the native soil infiltration is less than 0.1 inch per hour. See Protocol 3 for the infiltration testing procedure and Protocol 4 for infiltration system guidelines.

9. Waterproofing

In some instances, infiltration trenches may be designed to infiltrate, but there may be concerns about impacts on adjacent structures, such as basements, or impacts on the subbase of adjacent paved surfaces. For all infiltration trenches, the designer must evaluate the impact of the system on adjacent structures and utilities as defined in Protocol 1, Setbacks from Structures and Protocol 2, Coordination with Other Utilities. The liner, if applied, must meet the guidelines provided in the Stormwater Specification. In many situations, a partial liner (i.e., one side of a trench) will adequately protect structures.

10. Water Quality/Total Suspended Solids

Infiltration trenches that can capture and manage the required SOV through infiltration are considered to meet all water quality requirements. Infiltration trenches that are underdrained must be sized to provide water quality treatment. See Chapter 7 for additional discussion, and the Infiltration Trench Worksheet for calculations.

11. Stormwater Tree Trenches and Green Infrastructure

Stormwater tree trenches are a variation of infiltration trenches that are especially applicable in urban areas and as urban roadway retrofits. An infiltration trench can incorporate tree planting areas within the trench or between connected segments of the trench. Specific design considerations for tree trenches include the following (see Figures 5.3.3-11a and b):

- Urban trees require sufficient soil volume for growth and health. This can be achieved by providing adequate soil volume within the tree pit, or by providing adequate soil above the infiltration trench so that the root systems can extend into this soil (see Figure 5.3.3-12).
- Placing tree trenches adjacent to pervious areas (or extending the soil) will also improve tree health and success.
- The stormwater tree trench should not create extended saturated conditions for the root systems.
- The tree trench soil must have sufficient structural stability for placement under pavements and other structures. Soils used in tree trench applications must meet Bioretention Soil Specifications (Appendix F).

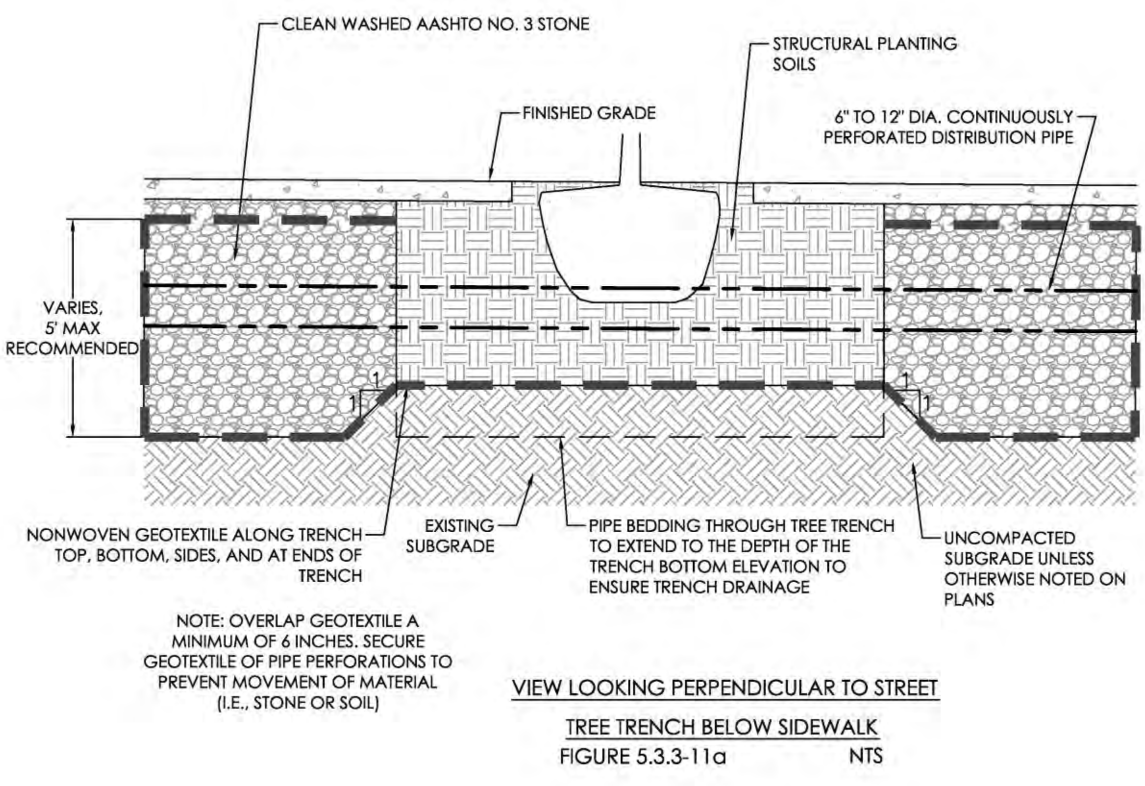
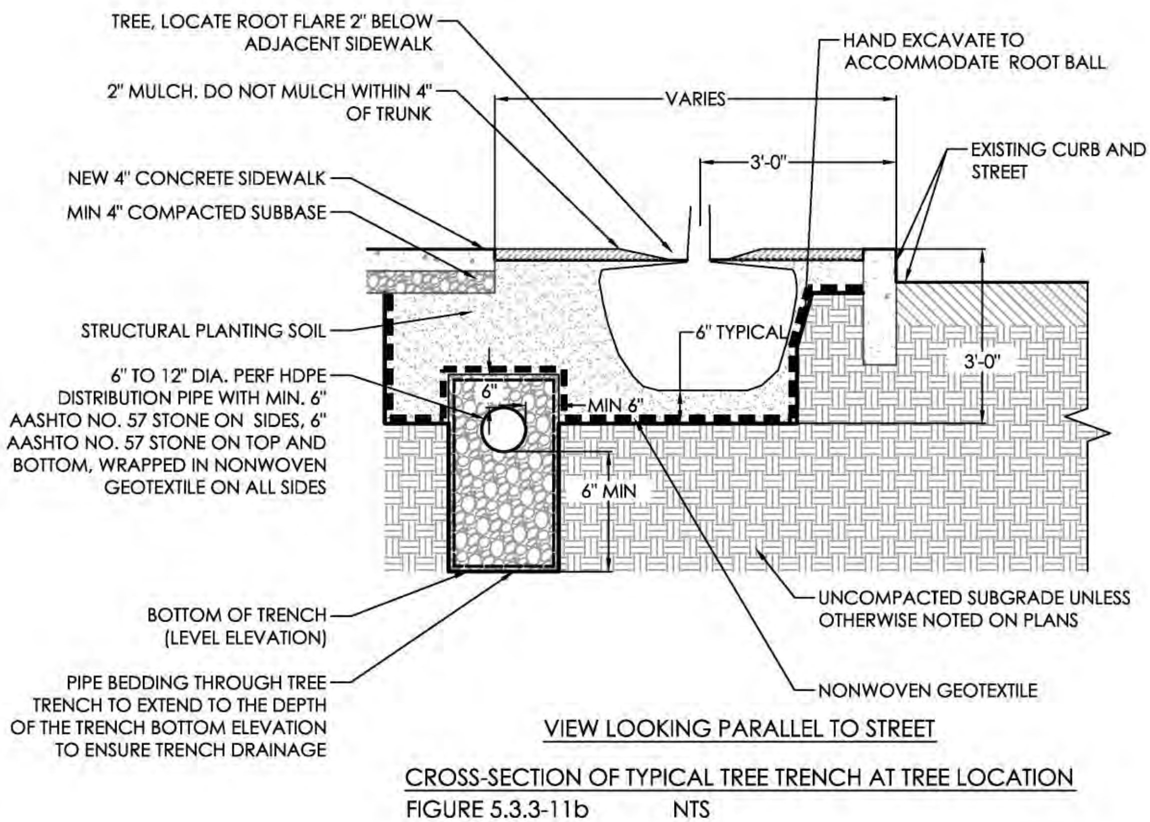


Figure 5.3.3-11a. Typical urban tree trench detail.



Figures 5.3.3-11b. Typical urban tree trench detail.

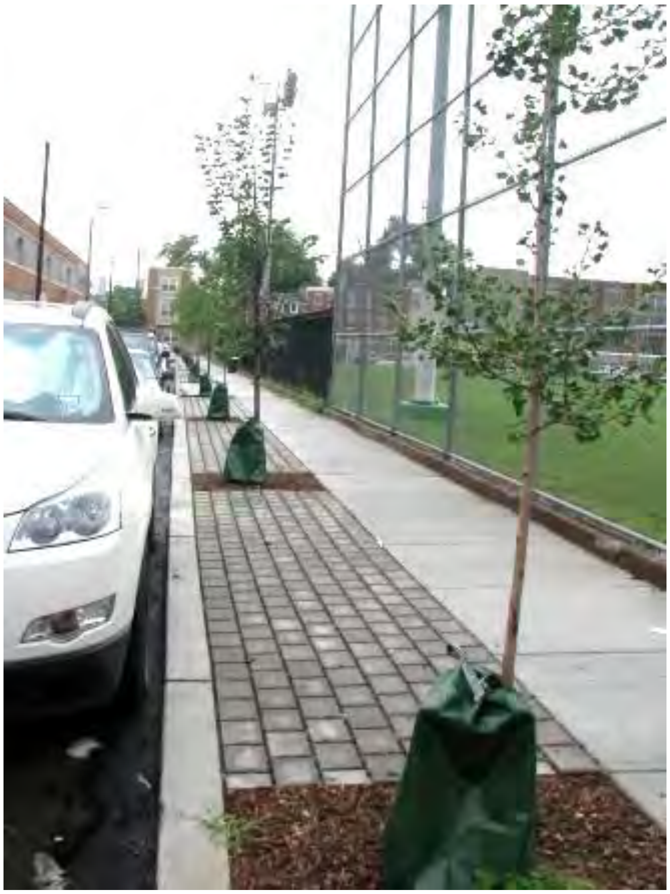


Figure 5.3.3-12. Between the trees in this stormwater tree trench, the soil is extended beneath the porous pavers to provide additional soil volume for the trees.

Sizing Calculations Worksheet for Infiltration Trenches

(Digital link to worksheet or reference on where to find worksheet on City web page)

Construction Considerations

Infiltration trenches can be installed:

1. Early in the construction process, but should not receive any site runoff until site construction is complete and site stabilization has occurred. Runoff should be directed around the completed trench until site stabilization has occurred. Sediment-laden water should not be allowed to enter infiltration trenches.

2. The infiltration trench may be constructed after site construction is substantially complete and site stabilization has occurred. During construction of the site, areas reserved for infiltration beds **must** be protected and should be fenced or barricaded to prevent the movement of equipment over the proposed infiltration area. This is similar in practice and intent to protecting an onsite septic system disposal field from vehicle compaction.

Construction Sequence Example

Step 1 Excavate and Prepare Subgrade

a. Do **not** compact or subject pervious pavement locations to excessive construction equipment traffic during construction. Protect areas from vehicle traffic during construction with construction fence, silt fence, or compost sock.
b. If alternate storage media is used in lieu of stone aggregate, provide a suitable stone subbase for material but do **not** compact trench bottom.
c. Infiltration trenches can be installed at any time during the construction process provided that sediment-laden runoff is prevented from entering the trench. Do not allow runoff from any disturbed areas in the drainage area to discharge into the bed until these areas have been stabilized.
d. Remove fine materials and/or surface ponding in the graded bottom, caused by erosion, with light equipment and scarify the underlying soils to a minimum depth of 6 inches with a York rake or equivalent by light tractor.
e. Leave earthen berms (if used) between infiltration trenches in place during excavation. These berms do not require compaction if the berms were constructed by excavating the trenches between the berms, and are comprised of native material that is collected during construction. The construction of berms by placing fill is discouraged. If necessary, constructed berms shall be keyed into the subbase and compacted to 95 percent density.
f. It is recommended to place trees on native material in tree trenches to avoid settlement.
g. Bring subgrade of infiltration trench to line, grade, and elevations indicated on the plans. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All infiltration trenches shall be level grade on the bottom.
h. Halt excavation and notify engineer immediately if evidence of sinkhole activity, unanticipated bedrock or groundwater conditions, or other site conditions are encountered that may affect infiltration trench design or performance. Unanticipated utility crossings may be encountered in urban tree trenches along roadways.

Step 2 Install Overflow Structure and Other Stormwater Structures

a. Place the stormwater overflow structure on suitable subgrade to prevent settling. Install overflow structure, inlet pipes, curbs, and other stormwater structures as appropriate before placement of stone storage bed.
b. Close and secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering infiltration trench before completion and site stabilization.
c. Maintain drainage overflow pathways during construction, while infiltration trench is closed, to provide for drainage during storm events.
d. Infiltration trench conditions must be observed by the design engineer, following excavation and grading and prior to placement of material, to confirm that construction requirements have been met (see Figure 5.3.3-13). Documentation of engineering observation must be provided to the City (see Appendix I).

Figure 5.3.3-13. The bottom of an infiltration trench is level and uncompacted. The design engineer should observe conditions before the trench material is placed.

Step 3 Install Infiltration Trench

a. Place geotextile and trench aggregate immediately after approval of subgrade preparation and installation of structures (see Figure 5.3.3-14). Geotextile shall be placed in accordance with the manufacturer's standards and recommendations. Overlap adjacent strips of geotextile a minimum of 16 inches.
b. Place clean-washed, uniformly graded aggregate or other storage media in the trench in maximum 8-inch lifts. Compact each layer while keeping construction equipment off the trench bottom as much as possible.

Figure 5.3.3-14. Non-woven geotextile placed between trench and soil prevents movement of soil into trench.

c. Following placement of storage media, place geotextile over the top of the trench to prevent soil movement into the trench. Place and secure geotextile to prevent soil movement.

Operations and Maintenance

All properly designed and installed infiltration trenches require regular annual maintenance, although they require less maintenance than other BMPs:

- Inspect and clean all inlets and catch basins annually.
- Maintain overlying vegetation in good condition and immediately revegetate any bare spots.
- Prohibit vehicular access on vegetated infiltration trenches and avoid excessive compaction by mowers. If access is needed, use of permeable, turf reinforcement should be considered.

5.3.4 Bioretention

Description

Bioretention areas are vegetated, shallow surface depressions that use the interaction of plants, soil, and microorganisms to store, treat, and reduce runoff volume, and to reduce the flow rate of stormwater runoff. Small bioretention areas are often referred to as rain gardens. Bioretention areas designed for infiltration can also be referred to as bioinfiltration areas, while those that cannot infiltrate and must discharge via an underdrain are sometimes referred to as biofiltration areas.

Bioretention areas are generally flat and include engineered or modified soils that allow drainage of stormwater through soils. Plants are a critical component of bioretention and improve the soil structure and porosity through the establishment of root systems and microbial communities.

Bioretention provides stormwater management by capturing runoff in the shallow surface depression. Water then drains through the bioretention soils during small, frequent rainfall events. A bioretention area may include a stone storage bed beneath the soils. Bioretention systems **always** include a positive drainage overflow structure to safely convey large rainfall events from the bioretention area.

Water that has drained through a bioretention area may infiltrate into the subsoil or discharge at a controlled flow rate through an underdrain system (or a combination of both).

Figures 5.3.4-1a and b. Bioretention area immediately following construction and after three years of establishment.

BMP Functions Table

BMP	Applicability*	Volume Reduction*	Water Quality (TSS)	Peak Rate Reduction	Recharge*	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden*	Cost*
Bioretention	U/S/R	L/H	H	M	L/H	H	M	H	L/M/H	L/M/H

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Rating varies based on design considerations.

Key Design Features

- Shallow ponding of water (surface storage) is limited in depth and duration. Standing water does not remain visible for more than a few hours after rainfall has ceased.
- Captures the runoff from small (1.6 inches and less) rainfalls events, and the first portion of larger rainfall events.
- Always includes an overflow control structure or design to allow large storm events to bypass or discharge at a controlled flow rate without passing through the soils.
- The surface area and size are directly correlated to the contributing drainage area size and land use, especially impervious surfaces.
- Are generally small (less than 1,000 square feet) or comprised of several interconnected bioretention areas.
- Are generally level at the water surface. Constructed on a level uncompacted subgrade.
- May include an underlying aggregate drainage bed.
- Should not be placed on compacted fill if infiltration is required.
- When possible, bioretention should be placed on upland soils.
- Biofiltration areas that cannot infiltrate must include a low-flow slow-release system. Lined and slow-release systems may be constructed on compacted fill material.

Applications

- Road shoulders, medians, and cul-de-sacs
- Parking islands and edges
- Individual home lots
- Shared facilities in common areas for individual lots
- Common areas in multifamily housing and commercial office areas

- Institutions, such as schools, libraries, and public facilities
- In parks and along open space edges

Advantages

- Integrates stormwater into the landscape
- Improves aesthetics
- Flexible dimensions to fit conditions
- Creates habitat
- Excellent retrofit capability
- Cost-effective

Disadvantages

- Built on areas that are generally level (or graded level).
- Steep slopes may require larger footprint to create level grading.
- Vegetation and soils must be protected from damage and compaction.
- Infiltration requires suitable site conditions.
- Salt use may impact vegetation and soils.
- Maintenance is required to maintain both performance and aesthetics.

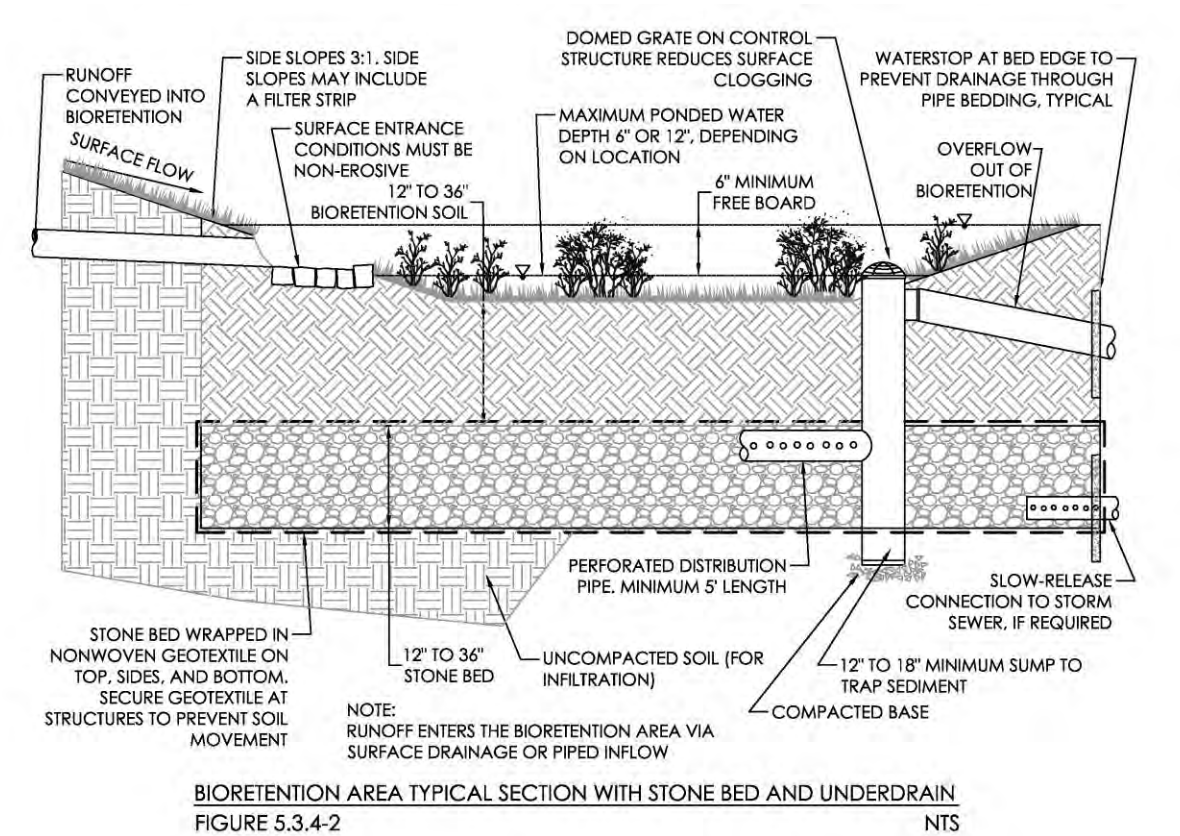


Figure 5.3.4-2. Typical bioretention detail (infiltration).

Applications

Bioretention basins are versatile, effective, and aesthetically pleasing stormwater management devices that are applicable to a variety of site characteristics.

Residential Bioretention Area

Figure 5.3.4-3. Residential bioretention that manages runoff from a single home. Roof leaders are directly connected to the bed.

Roadside Bioretention Area

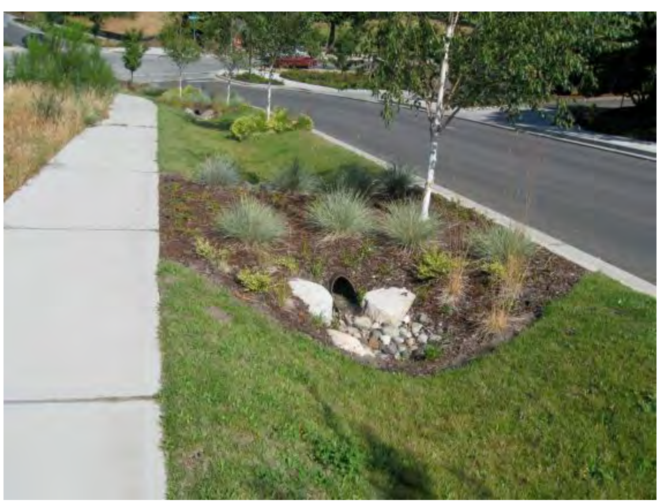


Figure 5.3.4-4. Roadside bioretention in a residential neighborhood that manages street runoff (located in public right-of-way).

Institutional Bioretention Area

Figure 5.3.4-5. Institutional bioretention area at an urban schoolyard (adjacent to porous rubber play surface).

Commercial Bioretention Area

Figure 5.3.4-6. Commercial bioretention (rain garden) in parking lot.

Applicable Protocols and Specifications

The following Protocols and Specifications (see Appendices A through F) are applicable to bioretention and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 2 Coordination with Other Utilities
- Protocol 3 Site Evaluation and Infiltration Testing
- Protocol 4 Infiltration System Design and Construction Guidelines
- Protocol 5 Planting Guidelines
  - Bioretention Soil Specifications
  - Stormwater System Specifications
  - Aggregates and Drainage Layers
  - Pipes
  - Control Structures
  - Geotextiles
  - Impervious Liners and Waterproofing

Bioretention Design Criteria

ITEM	RECOMMENDATION	REFERENCE SECTION
Maximum Drainage Area (Recommended)	Generally 10,000 square feet or less of impervious area per bioretention area. Several bioretention areas may be interconnected or placed in series to create larger systems.	5.3.4.1
Concept Phase Loading Ratio (LR) (Recommended)	1:8 for South Chickamauga Watershed 1:10 for all other Watersheds	5.3.4.5
Concept Phase Surface Area Size (ft^2) (Recommended)	Impervious Drainage Area Managed (ft^2) / Loading Ratio	5.3.4.5
Entrance/Flow conditions	Surface Dispersed: Grading must prevent concentrated flow paths Surface Concentrated: Provide erosion control at entrance Direct Connection (into stone bed): Recommended only for "clean" runoff such as roofs	5.3.4.2
Pretreatment/Management of Sediment Trash and Debris	Required for high sediment drainage areas (i.e. parking lots). See Filter Strip (BMP 5.3.6)	5.3.4.3
SOV Volume or Water Quality Volume Credit	Static Storage provided by: Surface Ponding, Soil Storage, Stone Storage (if applicable), Other structures (pipes, rain storage units, etc.)	5.3.4.4
Surface Ponding Depths	Maximum 6 inches for high use areas (near pedestrians and public) Maximum 12 inches for less used areas (limited access)	5.3.4.5
Soil Storage Coefficient and Volume	0.2 Storage Volume (ft^3) = Soil Depth (ft) x Soil Area(ft^2) x 0.2	5.3.4.4
Bioretention Soil Layer Depths	Minimum 12 inches Maximum 36 inches	5.3.4.5
Stone Storage Coefficient and Volume	0.4 Storage Volume = Stone Depth (ft) x Stone Area (ft^2) x 0.4	5.3.4.4
Stone Depths	Minimum 12 inches Maximum 36 inches	5.3.4.5
Pipe sizes for Overflow and Peak Rate	Minimum size 6 inch diameter. See Stormwater System Specifications	5.3.4.6
Freeboard	6 inches	5.3.4.7
Conveyance Capacity	Peak rate 10-year, 24-hour rainfall event	5.3.4.6
Underdrain	Required if Infiltration Rate < 0.1 inches per hour	5.3.4.8
Setback from Structures	Required. See Stormwater Specification for Impervious Liner	Protocol 1
Coordination with Other Utilities	Required	Protocol 2
Infiltration Testing	Required	Protocol 3
Infiltration System Setbacks	Required	Protocol 4
Vegetation and Mulch	Required	Protocol 5
Inspection and Longterm Maintenance	Required	Chapter 8

Design Considerations for Bioretention

Designed appropriately, bioretention can be implemented on a myriad of development sites. The key design components for bioretention discussed below allow design flexibility to ensure maximum performance from this multi-purpose BMP.

Figure 5.3.4-7. Bioretention in a supermarket parking lot takes advantage of typically underutilized space between parked vehicles.

1. Location and Capture Area

Human activity influences the location of bioretention areas. The following site-specific conditions should be considered:

- Select location to prevent vegetation damage and soil compaction from pedestrian traffic or unintended vehicle compaction. Ideal locations are often located to the side or downhill of high vehicle or pedestrian traffic areas. Consider locating bioretention areas in places that are generally “not used” such as traffic islands; between parked cars in parking lots; along edges of public playgrounds, school yards, and plazas; in courtyards; and in place of traditional landscape planting areas.
- If necessary, provide for pedestrian passage and maintenance access. This will prevent unintended damage to soils and vegetation.
- Use structures, barriers, and plantings to limit access and prevent damage to soils and vegetation. Low fences, curbs, and woody vegetation are examples.
- Locate bioretention area to prevent future conflicts for space, and provide public access if necessary. Long-term maintenance is more likely if bioretention area is readily visible.

Figure 5.3.4-8. Cobbles in the bioretention area allow for easy and safe pedestrian crossing without disturbing soils and vegetation.

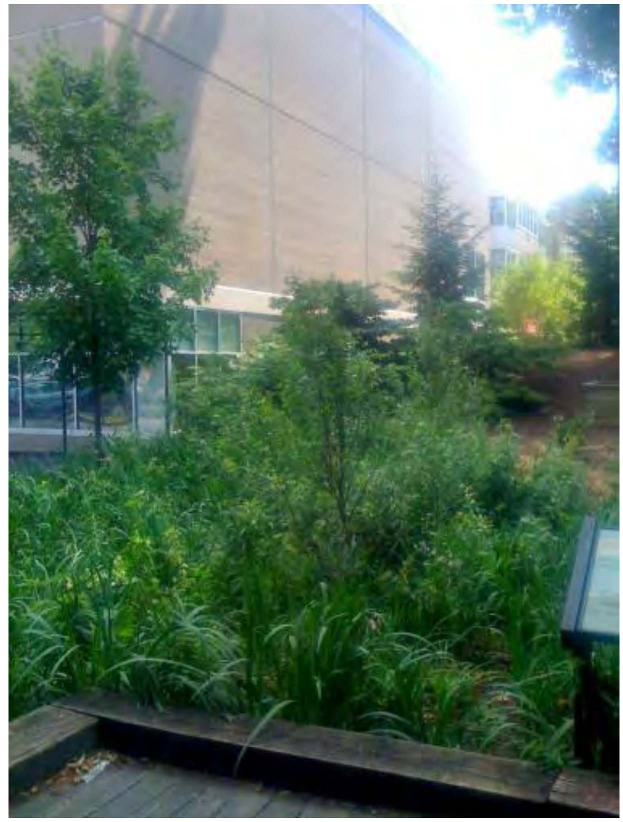


Figure 5.3.4-9. A low wood curb along a bioretention area protects the vegetation.

Locate bioretention areas:

- Close to the source of runoff. Bioretention areas should not receive excessive amounts of drainage from undisturbed areas.
- To capture runoff from impervious areas and highly compacted pervious areas such as athletic fields and lawns.
- To capture smaller drainage areas. If necessary, use several connected bioretention areas to address larger areas.

Figure 5.3.4-10. A bioretention area in the public right-of-way avoids homeowner conflicts such as decks, pools, and swing sets and also allows for public access and visibility.

2. Entrance/Flow Conditions

Captured runoff may enter a bioretention area in one of three ways:

a. Through dispersed surface flow such as along a depressed curb, lawn area, or edge of pavement. Careful grading is essential to prevent concentrated flow points and potential erosion. For bioretention adjacent to existing impervious pavement, such as in a retrofit installation or modification to an existing site, it is recommended that the adjacent pavement be milled and repaved/replaced to provide a uniform edge and dispersed sheet flow into the bioretention area.
b. Through a concentrated discharge location such as a trench drain, outlet pipe, or curb cut. Bioretention soils and mulch are highly erosive. Entrance velocities should not exceed 1 foot per second unless designed with entrance measures to prevent erosion. Cobble splash blocks, small level spreaders, and turf reinforcement materials are options. Supporting entrance velocity calculations are required for all concentrated surface discharges into bioretention areas.

c. Via a direct connection (such as a pipe) into the underlying stone storage bed. This is a good option for “clean” runoff discharging at high velocities. For example, a roof leader may be connected directly to a stone storage bed (see Figure 5.3.4-14).

Figure 5.3.4-11. Edge conditions at a school allow for direct surface flow from the play area to the adjacent bioretention area.

Figure 5.3.4-12. Edge conditions in a commercial parking lot allow for direct and unconcentrated surface flow into the adjacent bioretention area.

3. Management of Sediment, Trash, and Debris

In areas of high sediment load, bioretention areas should include measures to prevent the movement of material into the bioretention area. Sediment can clog a bioretention area and limit its functional lifespan.

For surface runoff into a bioretention area, a vegetated filter strip (BMP 5.3.6) can reduce sediment. For aesthetic purposes in manicured landscapes, the filter strip should be incorporated along the edges and within the bioretention landscape area.

For piped runoff into the surface of a bioretention area, a small sump within a cobble splash block or similar measure will provide for ease of maintenance in sediment removal.

Storm sewer pipes are not recommended for conveyance of stormwater with high levels of trash, debris, leaf litter, or other materials that may cause clogging unless regular maintenance and cleaning of pipes are ensured. Trench drains, curb cuts, and visible surface entrances require maintenance. Maintenance is more likely to occur if clogging conditions are visible.

In areas of high trash or with specific concerns such as plastic shopping bags (a common concern in commercial areas), entrance conditions may include a screen to prevent material from entering the bioretention area. Plant selection should consider the amount and type of trash that may enter the bioretention area. Items such as windblown plastic shopping bags that adhere to vegetation should be considered when selecting plants. Relatively deep (greater than 6 inches) bioretention areas in commercial shopping areas and along busy roadways tend to inadvertently collect shopping carts and debris. The designer must consider the site-specific conditions and adjacent land uses in each application.

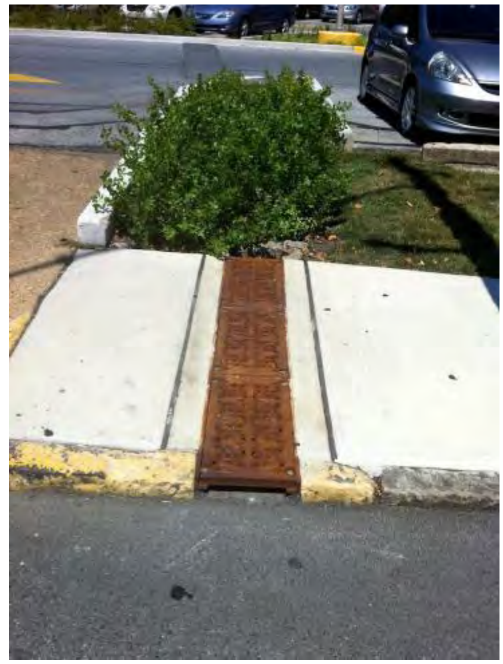


Figure 5.3.4-13. A trench drain collects and directly conveys street runoff into the bioretention area.

Figure 5.3.4-14. Roof leaders convey runoff below the walkway directly into an adjacent bioretention area. The walk is graded so that runoff sheet flows into the bioretention area. A small filter strip captures any coarse sediment from the walk.

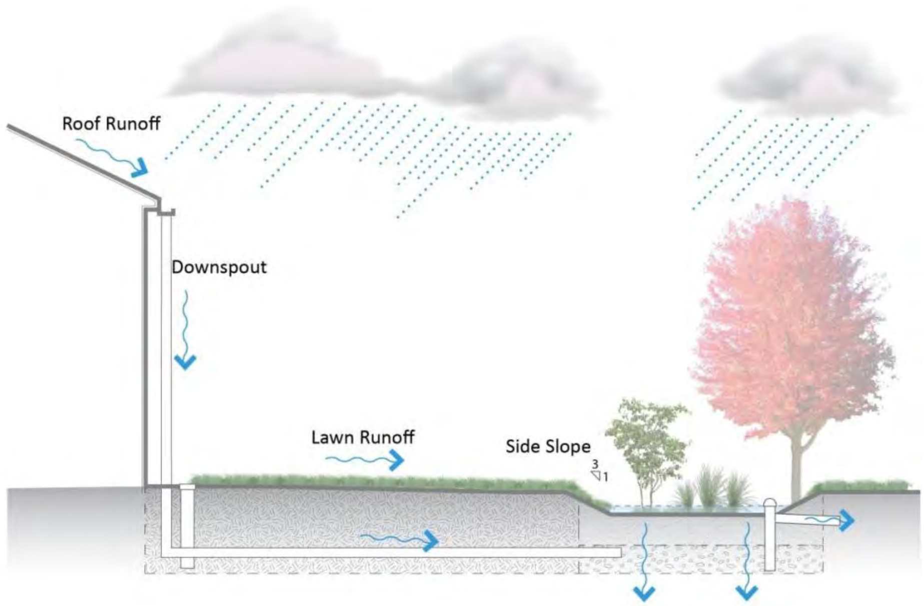


Figure 5.3.4-15. Roof leaders can convey high-velocity flows from the roof directly into the stone bed to prevent erosive conditions.

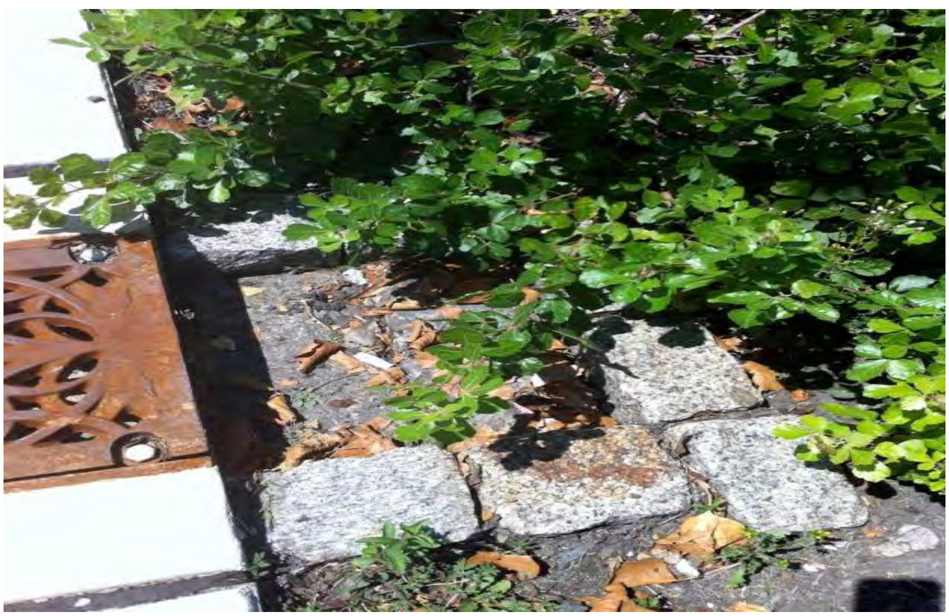


Figure 5.3.4-16. A cobble splash block prevents the movement of sediment into the bioretention area and also allows for routine cleaning and maintenance.

4. Storage and Stay-on-Volume

A bioretention system provides volume management within the surface ponding area, the bioretention soil area, and the stone storage bed (if applicable). Because water must move **through** the bioretention soils, the storage volume is **not** defined by the discharge pipe invert. This is different than non-vegetated BMPs.

The **SOV** is a function of the storage volume available for the 1-inch or 1.6-inch storm.

Storage Volume (ft^3) =

Surface Water Volume + Soil Storage Volume + Stone Storage Volume

<u>Surface Water Volume:</u> Available surface water storage between soil surface and overflow structure (always equal to or less than 12 inches). The designer should consider the bed side slopes when estimating volume.

<u>Soil Storage Volume:</u> This is the bioretention soil volume x 0.20 void space ratio.

Soil Storage Volume (ft^3) = Soil Area (ft^2) x Soil Depth (ft) Below Overflow x Void Ratio

<u>Stone Storage Volume:</u> This is the stone storage volume x 0.40 void space ratio.

Stone Storage Volume (ft^3) = Stone Area (ft^2) x Stone Depth (ft) Below overflow x Void Ratio

Void ratios are generally:

- 0.20 for bioretention soils
- 0.40 for clean-washed aggregate such as AASHTO No. 3
- 0.85 to 0.95 for manufactured storage units depending on manufacturer

5. Surface Area and Dimensions

The size and surface area of a bioretention system may be a function of the drainage area that will discharge to the bioretention system. It is important not to concentrate too much flow in one location. A basic rule-of-thumb is to design a bioretention system with a surface area that is a ratio of the impervious and compacted pervious areas draining to it. The amount of rainfall volume must also be considered. The following ratios based on design rainfall depth can be used to estimate a bioretention area:

1-inch Rainfall

1:10 ratio of surface area to impervious drainage area

1.6-inch Rainfall

1:8 ratio of surface area to impervious drainage area

One of the benefits of bioretention is that the dimensions of the system may be adjusted to fit into an available location. A bioretention area may be long and linear when located in a parking lot, circular when located within a cul-de-sac, or varied in dimensions to support a landscape design. As long as the runoff can disperse through the bioretention system and sufficient surface area is provided, dimensions can be flexible.

With an estimate of the required bioretention area and SOV, the designer can estimate the depth of water, soil, and if necessary, stone storage using the Sizing Calculations Worksheet.

The recommended depths for surface water storage, soil storage, and stone storage are:

Surface Water Storage Depth:

- **6 inches maximum in high-use areas** (along streets, at schools, in public landscapes, etc.)
- **12 inches in less used areas** (away from frequent public access)

Bioretention Soil Depth: Between 12 and 36 inches

Stone Storage Depth: Between 12 and 36 inches

6. Overflow and Peak Rate

Bioretention designs must provide a safe way for water to exit the system when large storms generate more stormwater runoff than the depression can hold. The inclusion of a positive overflow route ensures that flooding risks and related property damage are minimized.

The positive overflow route is often in the form of a domed riser, with an invert at the maximum allowable surface ponding level. The overflow must discharge to the storm sewer or to another approved discharge point. **The minimum allowable diameter of an overflow pipe is 6 inches for bioretention areas.**

A structure (i.e., outlet or weir) or vegetated swale that discharges to an approved discharge point may also be used. An inlet with an internal weir maximizes volume storage when the outlet pipe and inlet pipe cannot be placed to ensure sufficient storage (i.e., the bed is shallow, or slopes do not permit), as shown on Figure 5.3.4-17.

All overflows must safely convey the 10-year/24-hour storm.

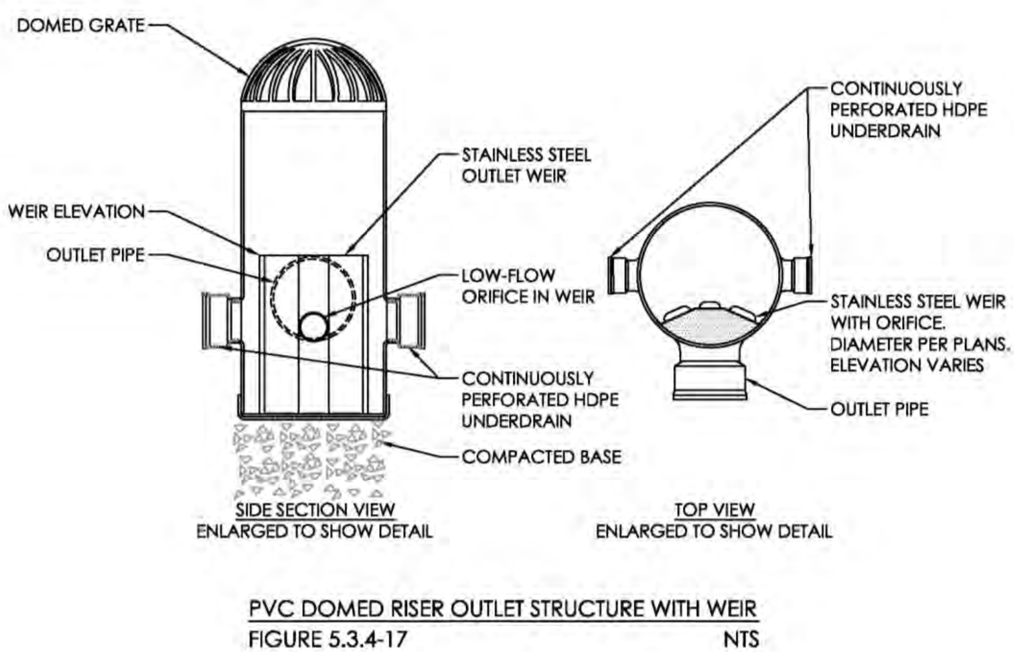


Figure 5.3.4-17. An inlet with an internal weir can also provide maximum volume storage within a bioretention or other area while allowing for safe conveyance. A number of manufactured products are available for this purpose.

The overflow structure should be easily visible from outside the bioretention area. Bioretention control structures can become clogged with vegetation at the inlet grate if maintenance is neglected. A domed inlet will reduce the likelihood of this problem occurring. A visible structure will facilitate ease of maintenance and ensure awareness of clogged inlet grates.

<u>Peak Rate Control and Infiltration Credit</u>

For the purposes of site peak rate control, the designer may adjust the Curve Number value based on the volume managed by both the SOV and the infiltration volume that occurs during a portion of a 24-hour storm event. This allows the designer to account for runoff that was captured by applying LID, and to develop a representative lower Curve Number. This procedure is described in Chapter 7.

When adjusting the Curve Number, the infiltration volume can be estimated as the infiltration that occurs during 12 hours of a 24-hour design storm. This will ensure that estimated infiltration volumes are not greater than the actual volume captured within the BMP.

Infiltration Volume (ft^3) = Bioretention Bottom Area (ft^2) x Infiltration Rate (in/hr) x 1/12 x 12 hours

7. Freeboard

It is recommended that bioretention areas include a minimum of 6 inches of freeboard above the overflow route.

8. Underdrain

The underdrain system is used to ensure that water moves through the system when the native soil infiltration rate is not high enough to empty the basin of water**. Underdrain systems must be included in the design if the native soil infiltration is less than 0.1 inch per hour or if the system is lined with an impervious liner** and intended for slow release only. Underdrains must be located at the intended bottom of the bioretention system (i.e., below soils and stone if applicable). See Protocol 3 for the infiltration testing procedure and Protocol 4 for infiltration system guidelines.

Bioretention systems may require very low discharge rates to achieve water quality discharge between 48 and 72 hours. Constructing a very small orifice will often achieve this, but a small orifice is easily subject to clogging.

One method for achieving a low discharge rate is to install a perforated pipe at the bottom elevation of the bioretention area. If the pipe is located in the bioretention soils, it must be set in clean-washed gravel and wrapped in non-woven geotextile to prevent soil movement. A perforated low-flow pipe can be set directly in a stone stormwater bed. The perforated pipe connects to a stormwater structure (such as a catch basin) with a transition coupling for a very small orifice. Various products are available for this purpose.

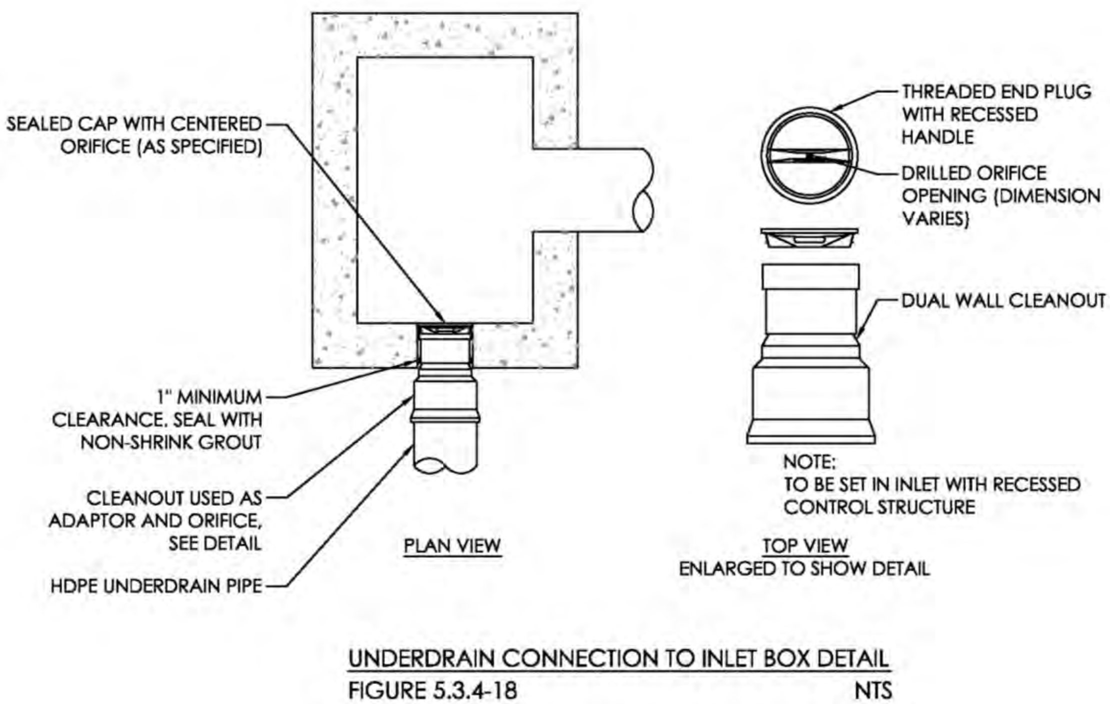


Figure 5.3.4-18. This coupling device can allow an "orifice" connection to a storm structure, providing an extended low discharge rate for underdrained systems.

9. Waterproofing

In some instances, bioretention areas may be designed to infiltrate, but there may be concerns about impacts on adjacent structures, such as basements, or on the subbase of adjacent paved surfaces. The system may be designed with an underdrain for slow release of flows rather than infiltration, but there may be concerns regarding lateral movement of water from the sides of the bioretention area. For all bioretention areas, the designer must evaluate the impact of the system on adjacent structures and utilities as defined in Protocol 1, Setbacks from Structures and Protocol 2, Coordination with Other Utilities. The liner, if applied, must meet the guidelines provided in the Stormwater Specification. In many situations, a partial liner (i.e., one side of a trench) will adequately protect structures.

10. Bioretention Soils

The soils used in the bioretention basin are a crucial factor in determining its performance. If an inadequate soil specification is used, or if the specification is prepared, installed, or maintained poorly, the runoff may infiltrate either too quickly or not quickly enough. If the soil infiltration rate is too low, the result is that runoff short-circuits the system and exits via the overflow without treatment or detention. If the soil infiltration rate is too high, the runoff will not have enough contact with the soil media to provide adequate water quality treatment, and it may be difficult to maintain healthy vegetation.

The Bioretention Soil Specification detailed in Appendix F of this document is required for use in all bioretention designs.

To provide adequate water quality treatment, the bioretention soil layer must be a minimum of 12 inches deep; however, greater depths of up to 36 inches are preferred.

Bioretention soils must never be placed when wet or during wet weather. Soils should be protected from saturation until plant installation, and from sediment deposition into the bioretention area. If necessary, the bioretention area can be protected by installing erosion and sediment control measures immediately upslope. Compost socks works very well for this purpose.

11. Bioretention Mulch

The type and application of mulch used in bioretention systems are important, and all systems must use mulch that meets the requirements of the Planting and Mulching Guidelines in Protocol 5 (Appendix E). The use of woodchips, which may “float,” is directly prohibited.

12. Vegetation

The type of plant and planting plan for bioretention systems must comply with Protocol 5 (Appendix E) of this manual.

Zone 1: Soils subject to both flooding and periodic drought.

Zone 2: Soils periodically moist or saturated during heavier storms.

Zone 3: Frequently saturated soils and occasional standing water (not for periods beyond 72 hours). An area of periodic or frequent standing or flowing water. Plants must tolerate periods of drought.

13. Water Quality/Total Suspended Solids

Bioretention systems that can capture and manage the required SOV through infiltration are considered to meet all water quality requirements. Bioretention systems that are underdrained must be sized to provide water quality treatment. See Chapter 7 for additional discussion.

Sizing Calculations Worksheet for Bioretention

(Digital link to worksheet or reference on where to find worksheet on City web page)

Bioretention Project Example

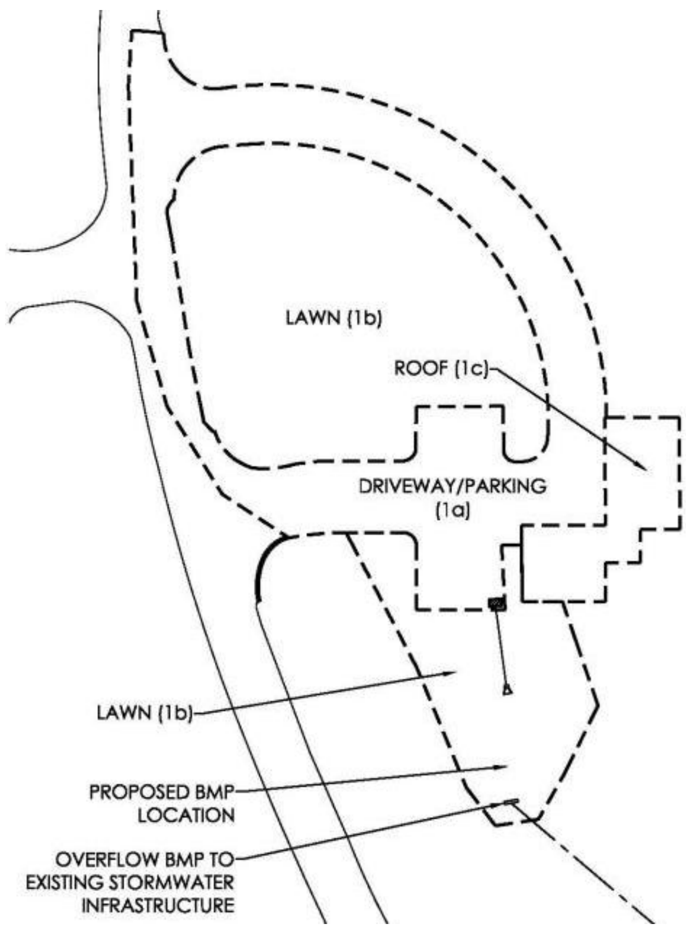


Figure 5.3.4-19. Bioretention project example.

Construction Considerations

For the best success, bioretention areas should not be installed and planted until site construction is complete and site stabilization has occurred. Bioretention areas completed before site stabilization **must** be protected from receiving sediment-laden runoff. Runoff should be directed around completed bioretention areas until site stabilization has occurred. Sediment-laden water should not be allowed to enter bioretention soils or infiltration beds.

The excavated capacity of an infiltration bioretention area may be used as temporary sediment trap areas during construction as long as the temporary grade is not within 2 feet of the final infiltration bottom elevation. Underdrained bioretention areas may be used as sediment traps during construction to the final bed bottom elevation.

Figure 5.3.4-20. A trench drain outlet is closed to prevent sediment-laden water from entering the bioretention area until site stabilization occurs.

Construction Sequence Example

Step 1 Excavate and Prepare Subgrade

a. Do **not** compact or subject bioretention system locations to excessive construction equipment traffic during construction. Protect areas from vehicle traffic during construction with construction fence, silt fence, or compost sock.

b. Initial excavation of bioretention areas can be performed during rough site grading. When performing initial excavation, do not grade beyond 2 feet above the final bioretention bottom elevation. Complete final excavation only after all disturbed areas in the drainage area have been stabilized.
c. Remove fine materials and/or surface ponding in the graded bottom, caused by erosion, with light equipment and scarify underlying soils to a minimum depth of 6 inches with a York rake or equivalent by light tractor.
d. Bring subgrade of bioretention area to line, grade, and elevations indicated on the plans. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All bioretention areas shall be level grade on the bottom.
e. Halt excavation and notify engineer immediately if evidence of sinkhole activity, unanticipated bedrock or groundwater conditions, or other site conditions that may affect infiltration trench design or performance are encountered. Unanticipated utility crossings may be encountered in urban bioretention areas along roadways.

Figure 5.3.4-21. An underdrained bioretention area is used as a sediment trap during construction.

Step 2 Install Overflow Structure and Other Stormwater Structures

a. Place the stormwater overflow structure on suitable subgrade to prevent settling. Install overflow structure, inlet pipes, curbs, and other stormwater structures as appropriate before placement of stone storage bed and bioretention soils.
b. Close and secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering infiltration trench before completion and site stabilization.
c. Maintain drainage overflow paths during construction, while bioretention area is closed, to provide for drainage during storm events.
d. Bioretention conditions must be observed by the design engineer following excavation and grading, and prior to placement of material, to confirm that construction requirements have been met. Documentation must be provided to the City (see Appendix I).

Figure 5.3.4-22. Installation of distribution pipes in bioretention area.

Figure 5.3.4-23. A curb cut is closed to prevent sediment-laden water from entering the bioretention area until site stabilization occurs.

Step 3 Install Bioretention Area

a. For bioretention areas with a subsurface storage/infiltration bed, place geotextile on the bottom and sides of excavated area immediately after approval of subgrade preparation and installation of structures. Place geotextile in accordance with manufacturer's standards and recommendations. Overlap adjacent strips of geotextile a minimum of 16 inches.
b. Place clean-washed, uniformly graded aggregate (AASHTO No. 3, No. 57 or approved substitute with at least 40 percent void space) or other storage media in the trench in maximum 6-inch lifts. Lightly compact each layer with a hand roller or tamp while keeping construction equipment off the trench bottom as much as possible.
c. Following placement of storage media, place geotextile over the top of the trench to prevent soil movement into the trench. Place and secure geotextile to prevent soil movement.
d. Place planting soil immediately after approval of subgrade preparation/stone bed installation. Remove any accumulation of debris or sediment that takes place after approval of subgrade and prior to installation of planting soil at no extra cost to the owner.
e. Install planting soil (exceeding all criteria) in 8-inch maximum lifts and lightly compact (tamp with backhoe bucket). Keep equipment movement over planting soil to a minimum – do not over compact. Install planting soil to grades indicated on the drawings.
f. Plant trees and shrubs according to the supplier's recommendations and only from early April through the end of June or from early September through late October.
g. Install 2 to 3 inches of shredded hardwood mulch (minimum age of 6 months) or compost mulch evenly as shown on plans. Do not apply mulch in areas where ground cover is to be grass or where cover will be established by seeding.

h. Protect bioretention areas from sediment at all times during construction. Hay bales, diversion berms, and/or other appropriate measures shall be used at the toe of slopes adjacent to bioretention areas to prevent sediment from washing into these areas during site development.
i. Notify engineer when the site is fully vegetated and the soil mantle is stabilized. The engineer shall inspect the bioretention basin drainage area at his/her discretion before the area is brought online and sediment control devices are removed.

The contractor shall provide a one-year 80 percent care and replacement warranty for all planting beginning after installation and inspection of plants.

Figure 5.3.4-24. Planting soil is carefully placed in 8-inch lifts to avoid over compaction.

Figure 5.3.4-25. Inlet protection is placed over a domed riser to prevent sediment from entering the system.

Operations and Maintenance

All properly designed and installed bioretention systems require regular annual maintenance:

- While vegetation is being established, pruning and weeding may be required.
- Detritus may need to be removed approximately twice per year. Perennial grasses can also be cut down or mowed at the end of the growing season.
- Mulch should be replaced when erosion is evident. Once every two to three years, the entire area may require mulch replacement (remove old mulch first).
- Bioretention systems should be inspected annually for sediment buildup, erosion, vegetative conditions, etc.
- During periods of extended drought, bioretention systems may require watering approximately every 10 days.
- Bioretention systems should not be mowed on a regular basis, but mowed according to the maintenance schedule if indicated.
- Trees and shrubs should be inspected twice per year to evaluate health.
- Vegetation should be controlled and maintained as needed.
  - To avoid soil compaction, weeds should be removed by hand.
- Debris and sediment should be removed as needed.
- Mulch or soil should be replaced when evidence of erosion is encountered.

5.3.5 Vegetated Swales

Description

A vegetated swale is a landscaped channel, often broad and shallow with trapezoidal or parabolic geometry and a slight longitudinal slope, used to convey and treat stormwater runoff. Vegetated swales are densely planted with grasses, shrubs, and often trees, and can be used to improve water quality and reduce flow rates (see Figure 5.3.5-1). Vegetated swales are a commonly used first BMP in a "treatment train" approach to improve water quality. Depending on design, vegetated swales can also reduce volume. Specifically, if the swale includes berms or check dams such that water is retained and allowed to infiltrate, a vegetated swale can provide volume management.

Figure 5.3.5-1. This vegetated swale in a residential area is broad and shallow. Curb cuts allow street runoff to enter the swale.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Vegetated Swales	U/S/R	H	H	M	M	M	M	M	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Features

- Minimum flat bottom width of 2 feet (see Figure 5.3.5-2).
- Maximum bottom width of 10 feet.
- Side slopes at 3:1 maximum, 4:1 adjacent to pedestrian areas.
- Longitudinal slope at 2 percent maximum; up to 8 percent with check dams.
- Average recommended flow depth of 4 inches.
- Maximum ponding depth of 12 inches behind check dams.
- Minimum freeboard of 4 inches.
- Overall depth from top of sidewalls to bottom is generally not less than 10 inches or more than 24 inches.
- Planted in grasses and shrubs, and may include trees.
- Bioretention soil criteria apply.
- Minimum vegetation height of 4 inches is recommended.
- Trapezoidal or parabolic in shape (equations provided may be used for either).
- Entrance and conveyance flow conditions must be controlled to minimize erosion.
- Recommended maximum flow rate at entrance is 2 feet per second. Higher flow rates may be accepted with use of turf reinforcement mats or other materials to prevent erosion.
- Curb cuts and pipes may be used to direct runoff into the swale; however, the designer must demonstrate that entrance conditions will not be erosive. Splash blocks and other measures should be used at entrance locations as needed.
- Must convey 10-year/24-hour storm flow rate at non-erosive velocities. Alternatively, the swale may be designed to limit the flow rate of water entering the swale to maintain non-erosive conditions.
- The surface area, size, and slope are a function of the flow rates from the contributing drainage area.
- Erosive conditions must be prevented during germination and establishment of vegetation.
- The use of temporary or permanent stabilization fabrics or materials is recommended.

- May be designed to intentionally lengthen time of concentration and corresponding peak flow rate.
- Vegetated swales may include berms and check dams to facilitate shallow ponding of water (surface storage) that is limited in depth and duration. Standing water does not remain visible for more than a few hours after rainfall has ceased. Vegetated swales that include berms or check dams can provide volume reduction.
- Earthen check dams function best when constructed by excavation. Swales constructed of fill may be prone to failure.

Applications

- Pretreatment for a volume-reducing BMP (such as upstream of an infiltration trench or bioretention area)
- Road and highway shoulders and medians
- Parking islands and edges
- To convey water to or from a BMP, and to connect BMPs
- As an alternative to a curb and gutter system

Advantages

- Improves water quality and reduces flow velocities.
- Integrates stormwater into landscape.
- Improves aesthetics.
- Flexible dimensions to fit conditions.
- Reduces temperature impacts from impervious surfaces.
- Excellent retrofit capability.
- Cost-effective.
- May be designed to manage SOV.

Disadvantages

- Can create erosion problems if not properly designed, constructed, and maintained.
- Limited flow velocities permitted.
- Should not convey large drainage areas. Multiple swales (in segments) may be required.
- Not appropriate for project sites where spills may occur.
- Vegetation and soils must be protected from damage and compaction.
- Salt use may impact vegetation and soils.

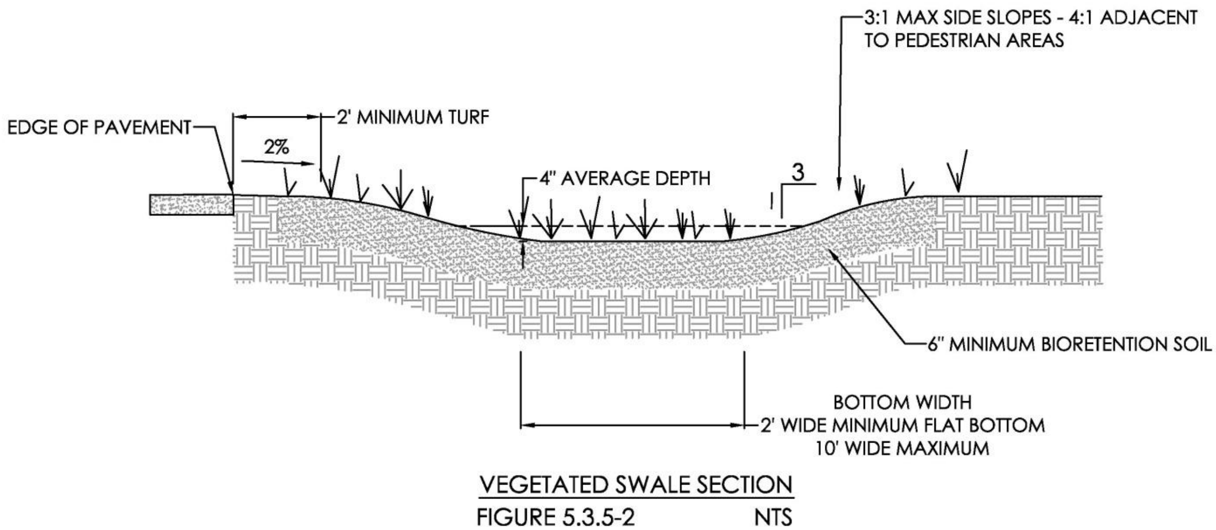


Figure 5.3.5-2. Cross-section of a vegetated swale.

Applications

Industrial Vegetated Swales

Figure 5.3.5-3. This manufacturing facility includes vegetated swales between parking areas to manage runoff.

Swales with Check Dams on Slopes

Figure 5.3.5-4. This vegetated swale on a slope includes stone check dams to slow runoff and earthen check dams to retain runoff.

Residential Vegetated Swales

Figure 5.3.5-5. Curb cuts allow street runoff into a vegetated swale in a residential neighborhood.

Commercial Vegetated Swales

Figure 5.3.5-6. The parking lot vegetated swale at this commercial center is designed for pedestrian crossings.

Applicable Protocols and Specifications

The following protocols and specifications (see Appendices A through F) are applicable to vegetated swales and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 2 Coordination with Other Utilities
- Protocol 3 Site Evaluation and Infiltration Testing (for swales intended to infiltrate)
- Protocol 4 Infiltration System Design and Construction Guidelines (for swales intended to infiltrate)
- Protocol 5 Planting and Mulching Guidelines
- Appendix F Bioretention Soil Specifications
- Stormwater System Specifications

- Aggregates and Drainage Layers
- Pipes
- Control Structures
- Geotextiles
- Impervious Liners and Waterproofing

Design Considerations for Vegetated Swales

1. Location and Capture Area

- Vegetated swales may be subject to erosion and channelization if flow velocities create erosive conditions. Depending on slope and available space for a vegetated swale, it may be necessary to limit the drainage area directed to the swale.
- If necessary, a series of swales separated by berms or check dams may limit velocity (see Figure 5.3.5-7). Berms can also provide locations for pedestrian crossings.
- When located adjacent to pedestrian areas, the side slopes of the swale are recommended to be 4:1.
- When located adjacent to parking areas, a recommended setback width of 2 feet (minimum) of lawn or level area adjacent to the swale allows passengers to exit vehicles without stepping into the swale.
- Areas where side slopes or berms would need to be constructed with fill should be avoided. Such slopes are prone to erosion and/or structural damage.
- Pedestrian passage and maintenance access should be provided for, if necessary. This will prevent unintended damage to soils and vegetation.

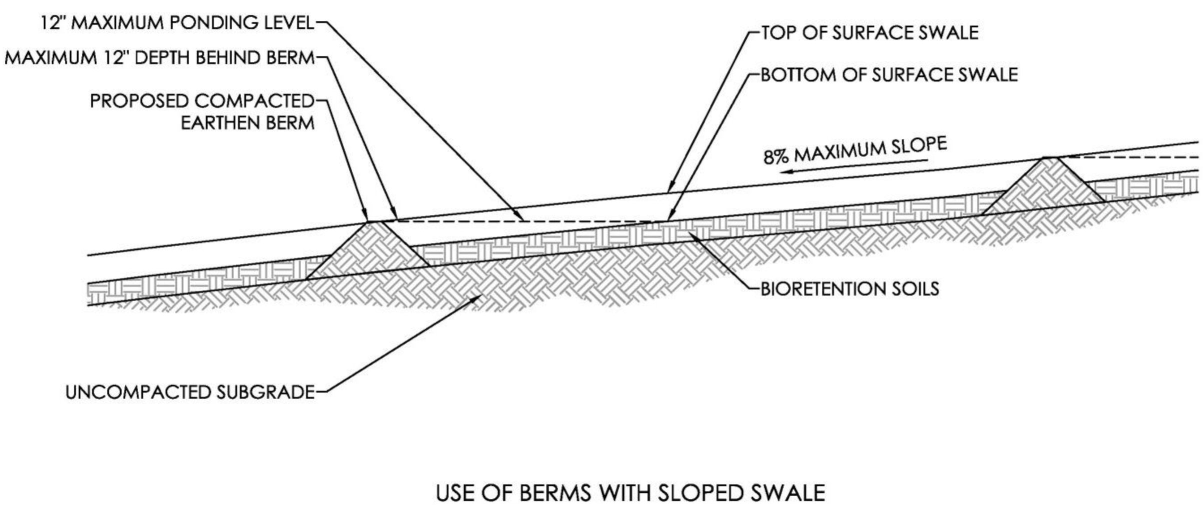


Figure 5.3.5-7. Longitudinal section of a swale with berms.

2. Entrance/Flow Conditions

It is important that entrance conditions or distributed flow into a vegetated swale be non-erosive.

- Dispersed surface flow (sheet flow) along a depressed curb, lawn area, or edge of pavement with careful grading will prevent concentrated flow points and potential erosion.
- Concentrated discharge velocities into vegetated swales (i.e., through a trench drain, outlet pipe, or curb cut) should not exceed 2 feet per second unless the entrance is designed with erosion prevention measures such as cobble splash blocks, level spreaders, and/or turf reinforcement materials.
- A turf reinforcement mat (TRM) or other stabilization fabric is recommended on slopes greater than 6 percent or when flows into the vegetated swale exceed 2 feet per second and are not slowed by other measures.
- Supporting entrance flow velocity calculations are required for all concentrated discharges into vegetated swales to demonstrate non-erosive conditions.

Figure 5.3.5-8. A series of splash blocks prevents erosion on the side of this vegetated swale as runoff enters from a parking lot via a trench drain.

3. Management of Sediment, Trash, and Debris

In areas of high sediment load, vegetated swales must include measures to prevent the movement of material into the swale. Sediment can clog a vegetated swale and limit its functional lifespan.

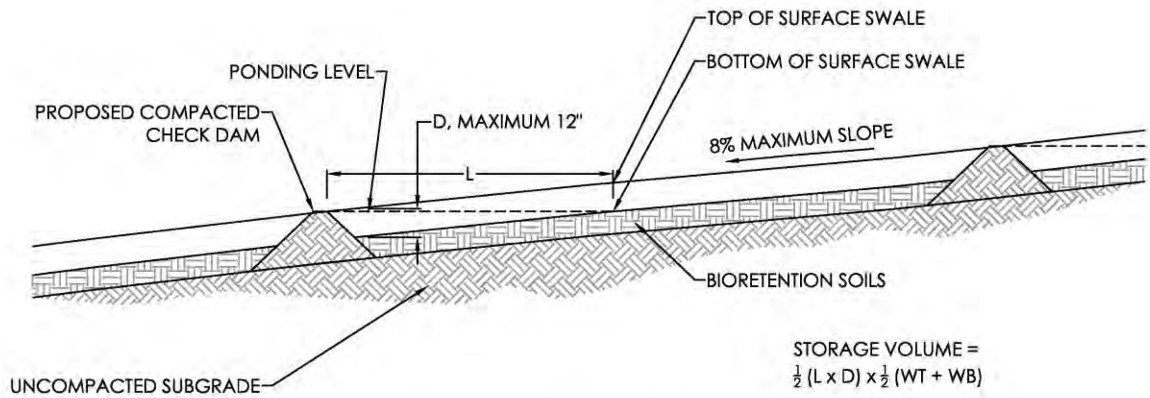
- Trench drains, curb cuts, and visible surface entrances require maintenance. Maintenance is more likely to occur if clogging conditions are visible. In areas of high trash or with specific concerns such as plastic shopping bags, entrance conditions may include a screen to prevent material from entering the vegetated swale. The designer must consider the site-specific conditions and adjacent land uses in each application.
- Site conditions should be considered when choosing vegetation. In areas of high debris, avoid plantings that will trap materials such as trash and paper bags.

4. Storage and Stay-on-Volume

A vegetated swale is generally a conveyance and water quality BMP. However, swales with check dams may be designed to capture SOV behind the check dam.

- Water depth behind a check dam should not exceed 12 inches.
- Both surface storage and bioretention soil storage can be considered. The expected void ratio for bioretention soils is 0.20.
- The designer must consider the slope of the swale and the depth of water storage at the check dam when calculating SOV.

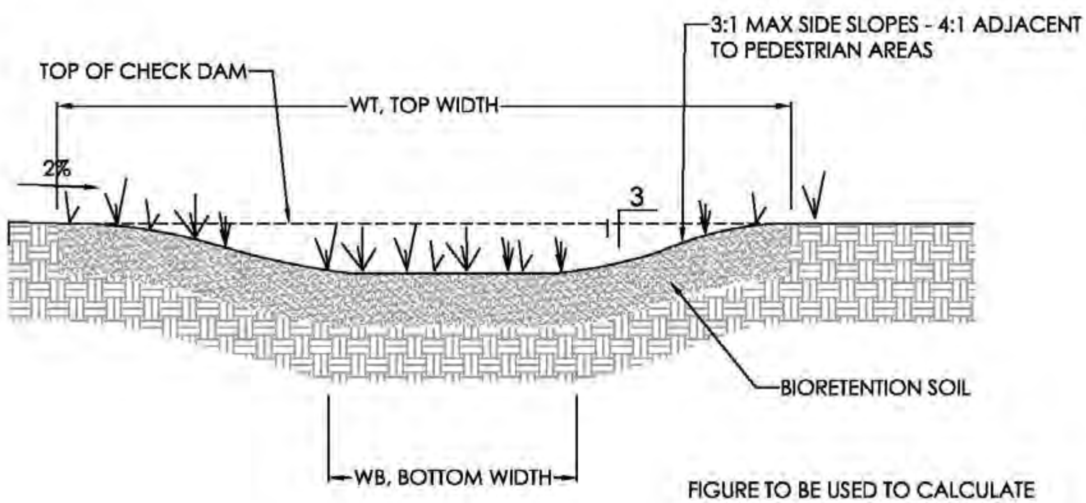
  Storage Volume = ½ (Length of Swale Impoundment Area (L) x Depth of Check Dam (D)) x ½ (Top Width of Check Dam (WT) + Bottom Width (WB) of Check Dam)



LONGITUDINAL SECTION

USE OF CHECK DAMS WITH SLOPED SWALE

FIGURE 5.3.5-9a NTS



CROSS SECTION

USE OF CHECK DAMS WITH SLOPED SWALE

FIGURE 5.3.5-9b NTS

Figures 5.3.5-9a and b. Section of a vegetated swale with check dams.

Figures 5.3.5-10. A simple level spreader of perforated pipe can direct flow into a vegetated swale and prevent erosive conditions at the entrance.

5. Swale Dimensions

The dimensions of a vegetated swale must convey the required flow rate at a velocity that is non-erosive. A swale should be sized to convey the 10-year/24-hour storm (or 10 year peak runoff if using the Rational Method) for swale sizing)unless an alternate conveyance path for high flows is available. It is recommended that the velocity not exceed 1 foot per second unless supporting calculations are provided to demonstrate that erosive conditions will not occur through the use of TRMs or other measures.

Determining swale dimensions can be an iterative process. The flow capacity of a vegetated swale is a function of the longitudinal slope, resistance to flow (Manning's n), and cross-sectional area. The flow depth should not exceed 4 inches. The swale bottom width is calculated based on Manning's equation for open channel flow:

$$Q = 1.49 / n\ A\ R^{0.67}\ S^{0.5}$$

Where:

Q = flow rate (cubic feet per second)

n = Manning's roughness coefficient (unitless; assume 0.15 for grass, 0.20 for dense vegetation)
A = cross-sectional area of flow (ft^2)
R = hydraulic radius (ft) = area/wetted perimeter
S = longitudinal slope (ft/ft)

The first step is to estimate the swale bottom width. For shallow flow depths in swales, channel side slopes are ignored and the swale bottom width is estimated as:

$$b = Q\,n/1.49\,y^{0.67}\,s^{0.5}$$

Where:
b = bottom width of swale (ft)
Q = design flow rate (cubic feet per second)
n = Manning's roughness coefficient (unitless; assume 0.15 for grass, 0.20 for dense vegetation)
y = design depth (ft)
s = slope (ft/ft)

If the bottom width is less than 2 feet, adjust the flow depth. If the bottom width is more than 10 feet (or allowable width per site conditions), it may be necessary to limit the flow rate or adjust the slope (if feasible).

If the bottom width is between 2 feet and 10 feet, the second step is to determine the flow velocity:

$$V = Q / A$$

Where:
V = design flow velocity (feet per second)
Q = design flow rate (cubic feet per second)
A = cross-sectional area determined by:

A = by + zy where
z = side slope (ft/ft)
y = design depth (ft)
b = bottom width of swale (ft)

If the velocity exceeds 2 feet per second, or the channel bottom width is less than 2 feet or more than 10 feet, the designer must modify the proposed dimensions until the design criteria are met.

Figure 5.3.5-11. Vegetated swales may be planted in grasses or denser vegetation.

6. Freeboard

Vegetated swales must contain a minimum of 4 inches of freeboard without creating erosive velocities.

7. Underdrain

An underdrain system is used in swales with check dams to ensure that water moves through the system when the native soil infiltration rate is not high enough to empty excess ponded water, or if infiltration is not feasible. If water does not exit the swale quickly enough, the system will back up and flood adjacent properties. It is not recommended that surface water remain visible in residential areas for more than

24 hours. All underdrain systems must discharge the water quality volume (WQv) between 48 and 72 hours. See Chapter 7 for more information on WQv.

Underdrain systems must be included in the design if native soil infiltration is less than 0.1 inch per hour. See Protocol 3 for the infiltration testing procedure and Protocol 4 for infiltration system guidelines.

8. Check Dams

Check dams are used to create shallow pools of water that reduce the velocity of runoff through the swale while also promoting infiltration. Check dams may measure 4 to 12 inches in height and extend the full width of the swale. Quantity and placement of check dams depend on the slope and required volume storage. Earthen check dams created by excavation, rather than by placement of fill, are recommended. For constructed check dams, stone is recommended.

Flows through a stone check dam vary based on stone size, flow depth, flow width, and flow path length through the dam. Flow through a stone check dam shall be calculated using the following equation:

$$q = h^{1.5} / (L / D + 2.5 + L^2)^{0.5}$$

Where:

q = flow rate exiting check dam (cubic feet per second/ft)
h = flow depth (ft)
L = length of flow (ft)
D = average stone diameter (ft) (more uniform gradations are preferred)

For low flows, check-dam geometry and swale width are actually more influential on flow than stone size. The average flow length through a check dam as a function of flow depth can be determined by the following equation:

$$L = (ss) \times (2\, d - h)$$

Where:

ss = check dam side slope (maximum 3:1)
(side slope is entered into the equation as rise over run, so a maximum 3:1 side slope would be entered as 3)
d = height of dam (ft)
h = flow depth (ft)

When swale flows overwhelm the flow-through capacity of a stone check dam, the top of the dam should act as a standard weir (use standard weir equation, although a principal spillway, 6 inches below the height of the dam, may also be required depending on flow conditions). If the check dam is designed to be overtopped, appropriate selection of aggregate will ensure stability during flooding events. In general, one stone size for a dam is recommended for ease of construction. However, two or more stone sizes may be used, provided a larger stone (e.g., R-4) is placed on the downstream side, since flows are concentrated at the exit channel of the weir. Several feet of smaller stone (e.g., AASHTO #57) can then be placed on the upstream side. Smaller stone may also be more appropriate at the base of the dam for constructability purposes.

9. Waterproofing

Infiltration from vegetated swales, in certain applications, may raise concerns about the impact on nearby structures, such as basements, or adjacent paved surfaces. In all vegetated swale designs, the designer must appraise the effect of the design on adjacent structures and utilities. See Protocol 1, Setbacks from Structures and Protocol 2, Coordination with Other Utilities for further guidelines. If an impervious liner is incorporated into the design, the liner must meet the criteria provided in the Stormwater Specifications.

10. Water Quality/Total Suspended Solids

Vegetated swales designed to capture and manage the required SOV through infiltration are considered to meet all water quality requirements.

Construction Considerations

For the best success, vegetated swales should not be installed until site construction is complete and site stabilization has occurred. Vegetated swales completed before site stabilization **must** be protected from receiving sediment-laden runoff. Runoff should be directed around the completed vegetated swale until site stabilization has occurred. Sediment-laden water should not be allowed to enter swales.

Construction Sequence Example

Step 1 Excavate Swale

a. Do **not** compact or subject existing subgrade in vegetated swale locations to excessive construction equipment traffic. Protect areas from vehicle traffic during construction with construction fence, silt fence, or compost sock.
b. Rough grade the vegetated swale. Excavating equipment should operate from the side of the swale and never on the bottom. If excavation leads to substantial compaction of the subgrade (where an

infiltration trench is not proposed), 18 inches shall be removed and replaced with a blend of topsoil and sand to promote infiltration and biological growth. At the very least, topsoil shall be thoroughly deep-plowed into the subgrade in order to penetrate the compacted zone and promote aeration and the formation of macropores. Following this, the area should be disked prior to final grading of topsoil.

c. Halt excavation and notify the engineer immediately if evidence of sinkhole activity, unanticipated bedrock or groundwater, or other site conditions are encountered that may affect infiltration bed design or performance.

Step 2 Install Overflow Structure and Other Stormwater Structures

a. Close and secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering the vegetated swale before completion and site stabilization.
b. Maintain drainage overflow pathways during construction, while the vegetated swale is closed, to provide for drainage during storm events.

Step 3 Install Vegetated Swale and Check Dams

a. Construct check dams, if required.
b. Grade vegetated swale to line, grade, and elevations indicated. Accurate grading is essential for swales. Even the smallest non-conformities may compromise flow conditions. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. Bioretention soil shall be placed immediately after approval of subgrade preparation.
c. Remove any accumulation of debris or sediment that takes place after approval of subgrade prior to installation of planting soil at no extra cost to the owner.
d. Install bioretention soil in 8-inch maximum lifts and lightly compact (tamp with backhoe bucket). Keep equipment movement over planting soil to a minimum – do not over compact. Install planting soil to grades indicated on the drawings.
e. Seed and vegetate according to plans, and stabilize bioretention soil. Plant the swale at a time of the year when successful establishment without irrigation is most likely. Temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.
f. Stabilize freshly seeded swales with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blankets. Erosion control for seeded swales shall be required for at least the first 75 days following the first storm event of the season. If runoff velocities are high, consider sodding the swale or diverting runoff until vegetation is fully established.
g. Protect the vegetated swale from sediment at all times during construction. Hay bales, diversion berms, and/or other appropriate measures shall be used at the toe of slopes adjacent to the vegetated swale to prevent sediment from washing into these areas during site development.

h. Notify engineer when the site is fully vegetated and the soil mantle stabilized. The engineer shall inspect the vegetated swale drainage area at his/her discretion before the area is brought online and sediment control devices are removed.

   If a vegetated swale is used for runoff conveyance during construction, regrade and reseed immediately after construction and stabilization have occurred. Any damaged areas must be fully restored to ensure future functionality of the swale.

Figure 5.3.5-12. This vegetated swale is stabilized with a temporary turf reinforcement mat until vegetation is established. Careful erosion control is maintained through erosion control materials on the other portions of the site.

Operations and Maintenance

A properly designed and installed vegetated swale requires relatively minimal maintenance.

- While vegetation is being established, pruning and weeding may be required.
- Detritus may also need to be removed approximately twice per year. Perennial grasses can be cut down or mowed at the end of the growing season.

- Inspect vegetated swales annually for sediment buildup, erosion, vegetative conditions, etc.
- Inspect for pools of standing water; dewater and discharge to a sanitary sewer at an approved location.
- Mow and trim vegetation according to maintenance schedule to ensure safety, aesthetics, and proper swale operation, or to suppress weeds and invasive species; dispose of cuttings in a local composting facility.
- Mow only when swale is dry to avoid rutting.
- Inspect for uniformity in cross-section and longitudinal slope, and correct as needed.
- Inspect swale inlet (curb cuts, pipes, etc.) and outlet for signs of erosion or blockage, and correct as needed.

The following should be done only as needed:

- Plant alternate grass species in the event of unsuccessful establishment.
- Reseed bare areas and install appropriate erosion control measures when native soil is exposed or erosion is observed.
- Rototill and replant swale if drawdown time is less than 48 hours.
- Inspect and correct check dams when signs of altered water flow (channelization, obstructions, etc.) are identified.

5.3.6 Vegetated Filter Strips

Description

Vegetated filter strips are permanent areas of dense vegetation located between runoff pollutant sources (such as parking lots) and other BMPs or receiving water bodies. Vegetated filter strips may be constructed of turf, meadow grasses, or other vegetation such as landscape plantings (see Figure 5.3.6-1). Vegetated filter strips act to impede the velocity of stormwater runoff (thereby allowing sediment to settle out), reduce the impacts of temperature, and encourage infiltration. Vegetated filter strips are a water quality BMP to slow the rate of runoff and reduce peak flows. They do not provide SOV, although some infiltration will occur.

Figure 5.3.6-1. A meadow grass filter strip (long grass in the center of the image) provides a water quality buffer between a residential neighborhood and naturalized basin (far right).

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Vegetated Filter Strips	U/S/R	L	M	M	L	M	M	L	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Features

- Runoff sheet flows across vegetation.
- It is important to provide uniform sheet flow conditions at the interface of the filter strip and the adjacent land cover.
- Pretreatment for other volume-reducing BMPs (such as infiltration bed).
- Are part of a “treatment train” approach for BMPs.
- Designed to decrease the velocity of runoff from small storms and improve water quality.
- For best performance, contributing capture areas should be small and localized.
- Maximum contributing drainage area slope is generally less than 5 percent, unless energy dissipation is provided.
- Minimum slope of 1 percent, maximum slope of 8 percent, target slope of 2 to 5 percent
- Filter strip length is influenced by the slope, soil type, and vegetation type (see Figures 5.3.6-2 and 5.3.6-3.a through 5.3.6-3.e).
- Minimum recommended length of filter strip is 25 feet (in the direction of flow); however, shorter lengths provide some water quality benefits as well, especially adjacent to BMPs such as rain gardens (small bioretention areas).
- Filter strip width should always consider the width of the contributing drainage area. It is important to avoid conditions that create concentrated flow.
- Concentrated flow should **not** be discharged directly onto a filter strip.
- Construction of filter strip shall entail as little disturbance to existing vegetation and soils at the site as possible.
- See Appendix E for list of acceptable filter strip vegetation.
- Filter strips should **never** be mowed to less than 4 inches in height.

Applications

- Better suited for less densely developed locations on a site due to surface area requirements
- Used in combination with other BMPs (especially when treating runoff from highly impervious areas)
- Pretreatment or overflow discharge point for other BMP (such as infiltration trench or bioretention area)
- To receive runoff from roof leaders or as divisions between individual lots (see Figure 5.3.6-4)
- Placement in underutilized areas of parks or other open space to receive runoff from compacted pervious areas
- Road and highway shoulders and medians
- Parking edges
- Riparian buffers

Advantages

- Integrates stormwater into landscape.
- Improves aesthetics.
- Flexible dimensions to fit conditions.
- Creates habitat for wildlife.
- Excellent retrofit capability.
- Cost-effective.

Disadvantages

- Volume reduction not quantifiable for SOV purposes.
- Maintenance must be clearly defined to avoid mowing. Signage is recommended, or a maintenance plan should be provided to maintenance personnel.
- Vegetation and soils must be protected from damage and compaction.
- Salt use may impact vegetation and soils.
- Vegetation must be firmly established and densely spaced, to avoid potential for erosion.

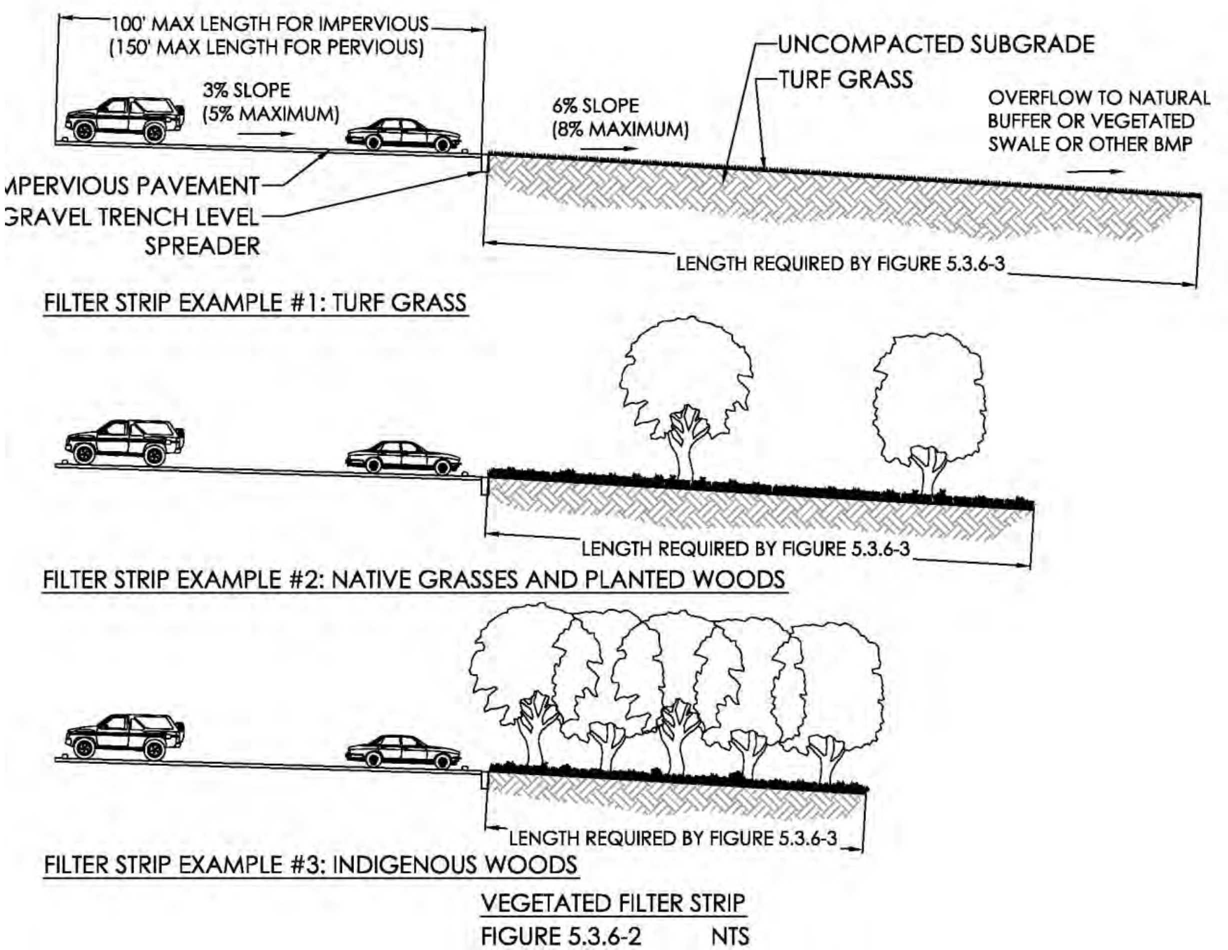


Figure 5.3.6-2. The width of a vegetative filter strip is determined by the slope, soil type, and vegetation type. For example, more densely vegetated strips are shorter in length than grass strips.

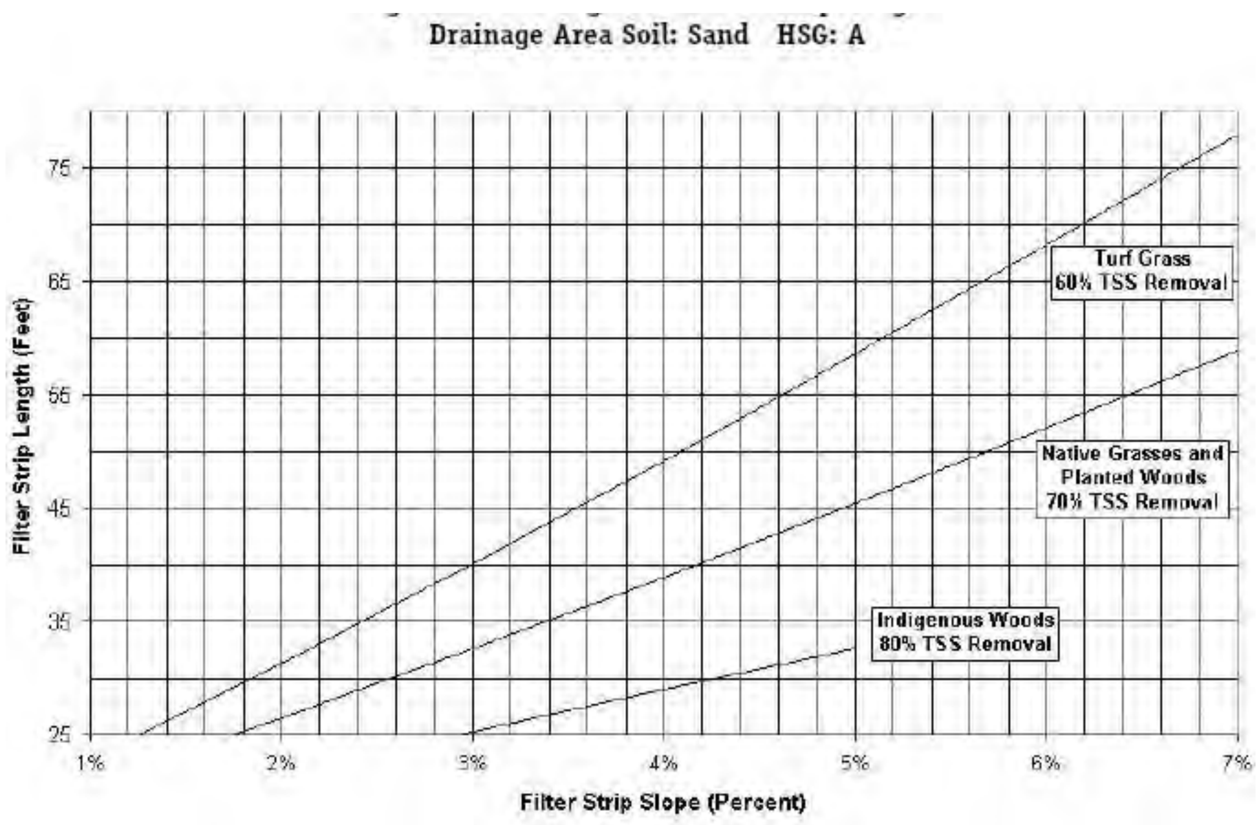


Figure 5.3.6-3.a. Graph may be used to estimate filter strip width based on soils, slope, and vegetation. Adapted from New Jersey Stormwater Management Practices Manual, Chapter 9, 2004.

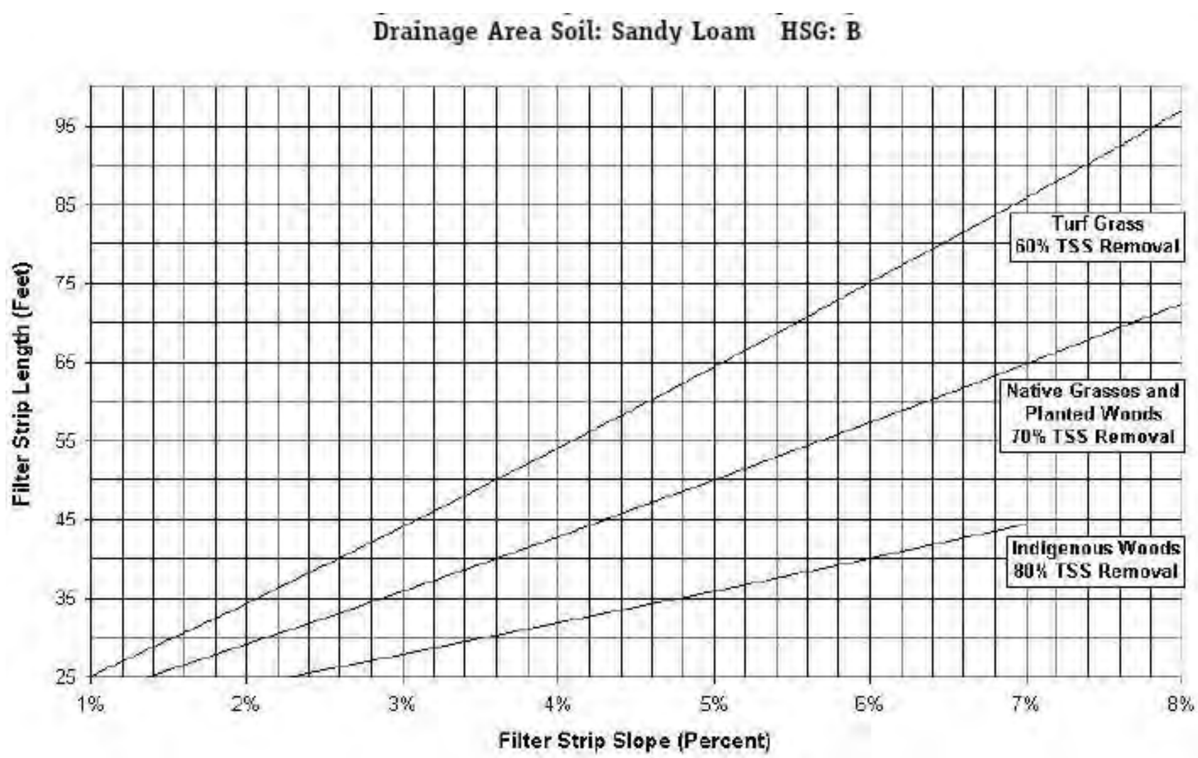


Figure 5.3.6-3.b. Graph may be used to estimate filter strip width based on soils, slope, and vegetation. Adapted from New Jersey Stormwater Management Practices Manual, Chapter 9, 2004.

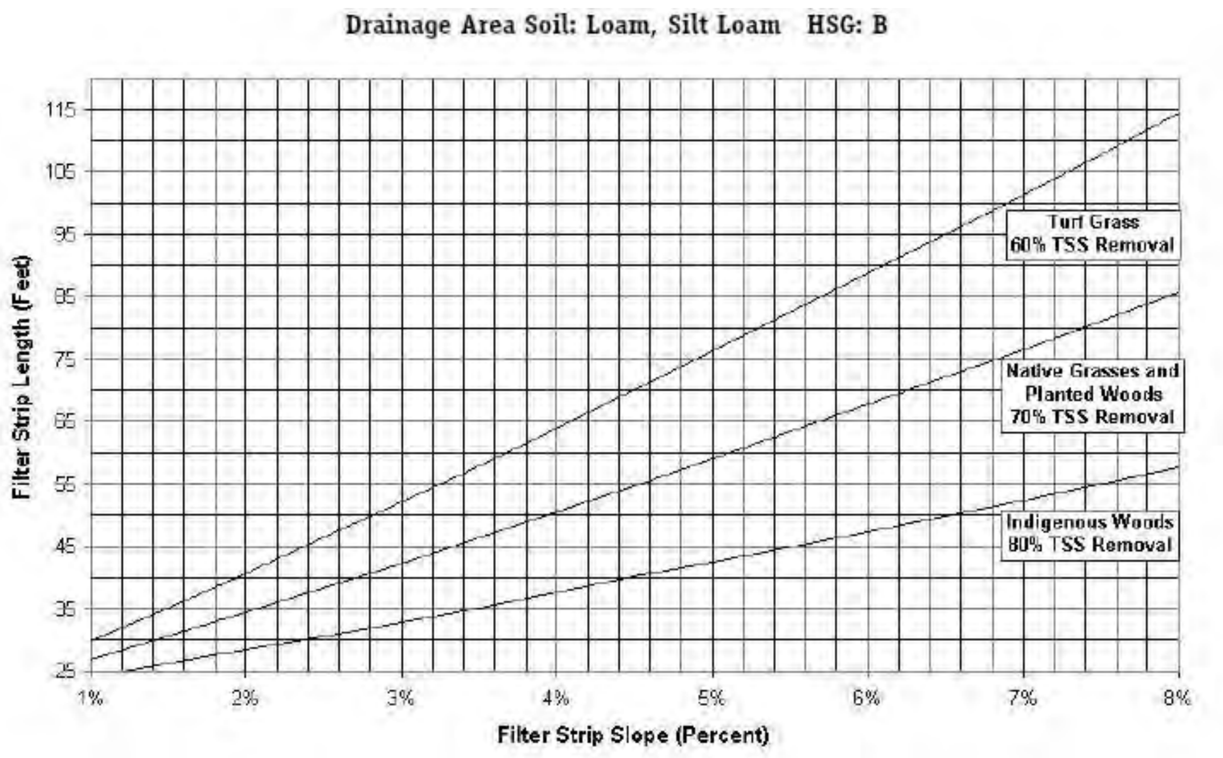


Figure 5.3.6-3.c. Graph may be used to estimate filter strip width based on soils, slope, and vegetation. Adapted from New Jersey Stormwater Management Practices Manual, Chapter 9, 2004.

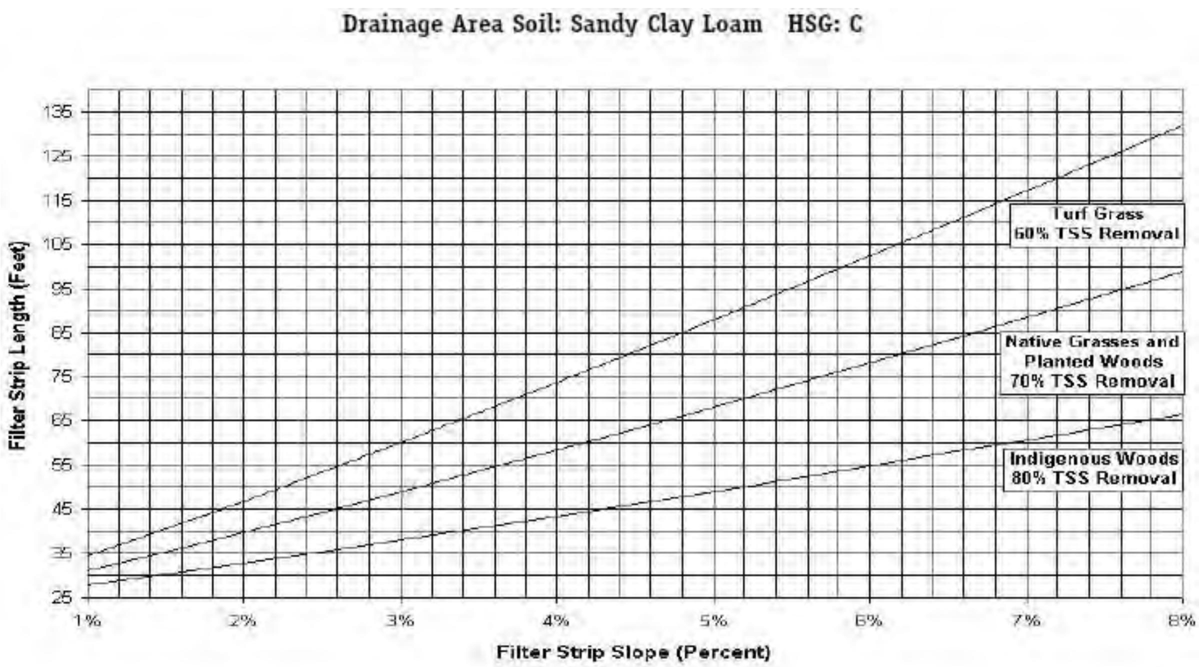


Figure 5.3.6-3.d. Graph may be used to estimate filter strip width based on soils, slope, and vegetation. Adapted from New Jersey Stormwater Management Practices Manual, Chapter 9, 2004.

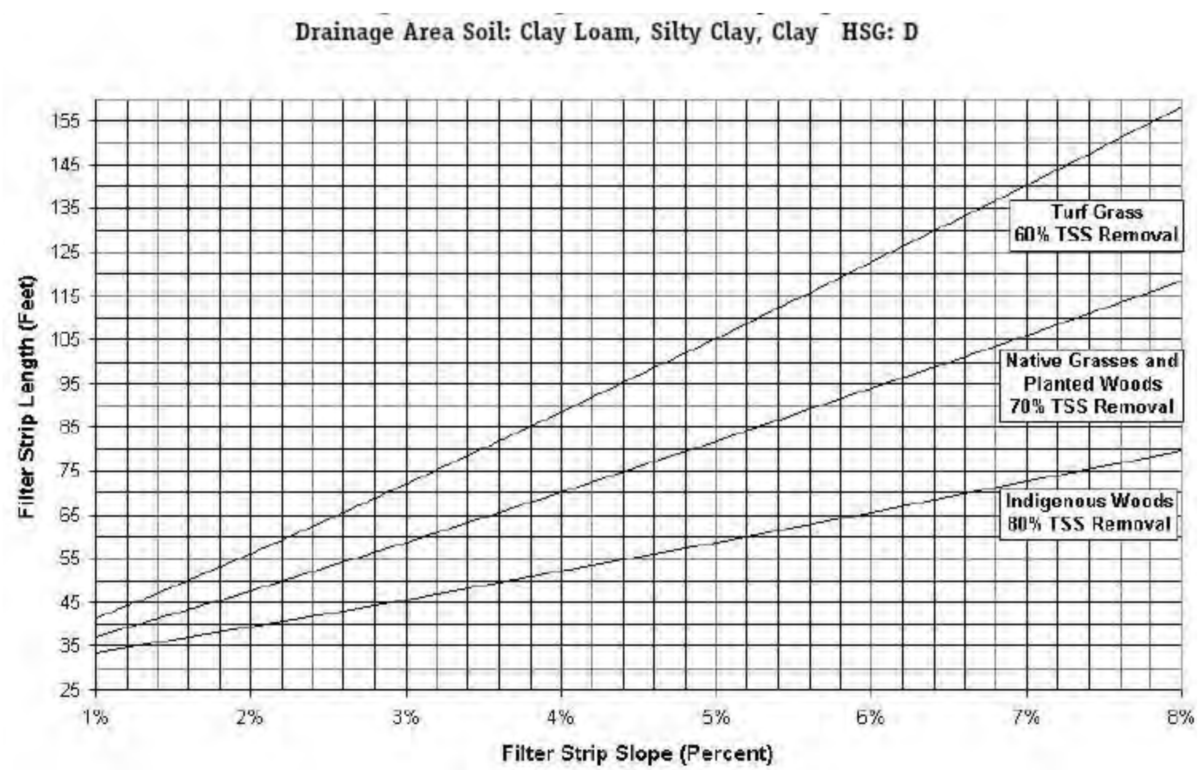


Figure 5.3.6-3.e. Graph may be used to estimate filter strip width based on soils, slope, and vegetation. Adapted from New Jersey Stormwater Management Practices Manual, Chapter 9, 2004.

Figure 5.3.6-4. Roof leaders convey runoff to a vegetated filter strip in a residential neighborhood.

Applicable Protocols and Specifications

The following Protocols and Specifications (see Appendices A through F) are applicable to vegetated filter strips and must be addressed:

- Protocol 5 Planting and Mulching Guidelines

Design Considerations for Vegetated Filter Strips

1. Location and Capture Area

Human activity influences the location of vegetated filter strips, as well as slopes and soil type. The following site-specific conditions should be considered:

- Select location to prevent vegetation damage and soil compaction from pedestrian traffic or unintended vehicle compaction. Optimum filter strip locations are often located to the side or downhill of high-volume vehicle or pedestrian traffic areas. Consider locating vegetated filter strips in places that are generally “not used” such as road/highway shoulders and medians; between parked cars in parking lots; along edges of public playgrounds, school yards, plazas, and courtyards; and in place of traditional landscape planting areas around buildings and structures (see Figure 5.3.6-5).

Figure 5.3.6-5. The parking lots at this truck stop discharge to filter strips before being conveyed to bioretention and infiltration areas.

- Select locations where existing maintenance is difficult. Although locating filter strips on slopes will reduce the ability for infiltration, converting traditional lawn to a denser vegetative cover still provides significant stormwater benefits.
- Avoid placing filter strips in locations that will disturb existing forest or meadows. Such areas should be addressed by protective BMPs.
- Locate filter strips to prevent future conflicts for space, and provide public access if necessary.

- Vegetated filter strips are generally most effective when used to manage a small capture area, or in conjunction with other BMPs.

2. Entrance/Flow Conditions

It is important for entrance conditions or distributed flow into a filter strip to be as sheet flow. Concentrated flows of runoff should always be avoided to prevent erosion, gully formation, and preferential flow paths through a filter strip. When runoff travels across a surface for long distances, flows can begin to concentrate. For pervious contributing areas, flow path lengths greater than 150 feet should be avoided. For impervious contributing areas, flow path lengths greater than 100 feet should be avoided.

- The upstream edge of a filter strip should be level and directly abut the contributing drainage area. A gravel trench level spreader (see Figure 5.3.6-6) can be used for this purpose.

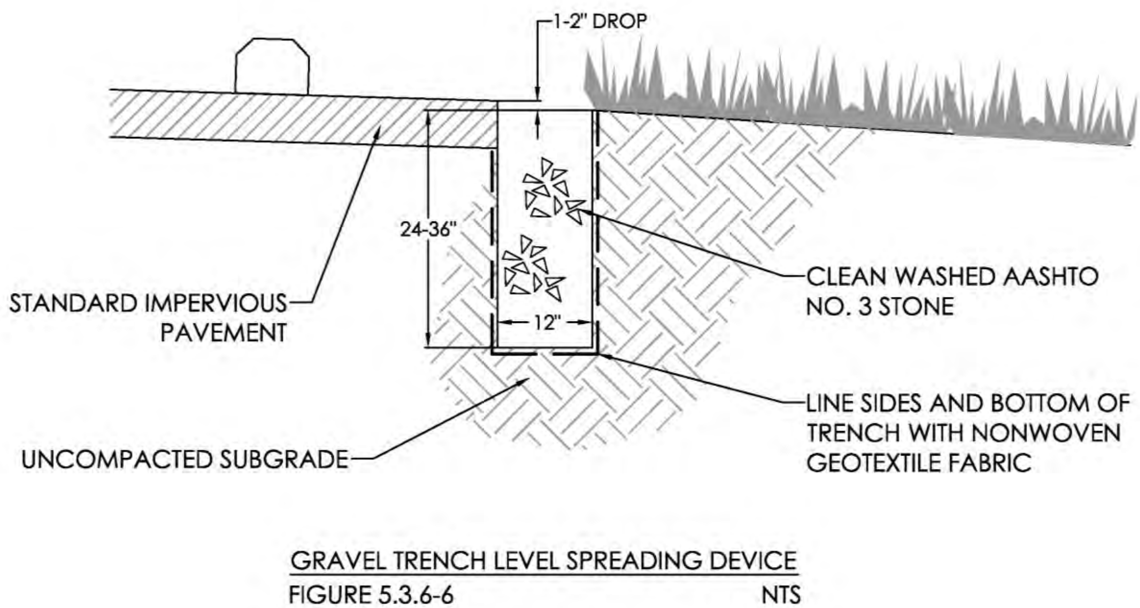


Figure 5.3.6-6. A gravel trench filter strip can be used as a level spreader to disperse flow and prevent the creation of rills and gullies.

3. Access and Protection

- If necessary, provide for pedestrian passage or maintenance access.
- Use structures, barriers, and plantings to limit access and prevent damage to soils and vegetation. Low fences, curbs, and woody vegetation are examples.

- Identify large filter strips on maintenance plans and with signage. This is especially important since vegetated filter strips can easily be overlooked or forgotten over time. As a result, maintenance personnel may inadvertently mow or remove vegetation.

Construction Considerations

For best success, vegetated filter strip areas should be protected during construction and should not be installed until site construction is complete and site stabilization has occurred.

Construction Sequence Example

Step 1 Excavate Strip

a. Existing subgrade in vegetated filter strips shall **not** be compacted or subject to excessive construction equipment traffic. Protect areas from vehicle traffic during construction with construction fence, silt fence, or compost sock.
b. Clear and grub site as needed. Disturb as little existing vegetation as possible and avoid compaction.

Step 2 Install Vegetated Filter Strip

a. Rough grade the filter strip area, including the berm at the toe of the slope, if included (see Section 5.3.7). Use the lightest, least disruptive equipment possible to avoid excessive compaction and/or land disturbance.
b. Construct level spreader device at the upgradient edge of the strip. For level spreaders and other gravel trenches, do not compact subgrade (follow construction sequence for infiltration trench; see Section 5.3.3).
c. Fine grade vegetated filter strip area to line, grade, and elevations indicated. Accurate grading is essential for filter strips. Even the smallest nonconformities may compromise flow conditions.
d. If testing indicates that the soil infiltration rate has been compromised (by excessive compaction), rototill the area prior to establishment of vegetation. Note: tilling will benefit only the top 12 to 18 inches of topsoil.
e. Seed and vegetate according to plans, and stabilize topsoil. Plant the strip at a time of the year when successful establishment without irrigation is most likely. Temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.
f. Concurrently with step “e,” stabilize seeded filter strips with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blankets. Erosion control for seeded filter strips shall be required for at least the first 75 days following the first storm event of the season. If

runoff velocities are high, consider sodding the filter strip or diverting runoff until vegetation is fully established.

g. Protect vegetated filter strip from sediment at all times during construction. Hay bales, diversion berms, and/or other appropriate measures shall be used at the toe of slopes that are adjacent to vegetated filter strips to prevent sediment from washing into these areas during site development.
h. When the site is fully vegetated and the soil mantle stabilized, the engineer shall be notified and shall inspect the filter strip drainage area at his/her discretion before the area is brought online and sediment control devices removed.

Operations and Maintenance

A properly designed and installed vegetated filter strip requires relatively little maintenance, much of which may overlap with standard landscaping requirements.

- While vegetation is being established, pruning and weeding may be required.
- Detritus may need to be removed approximately twice per year. Perennial grasses can also be cut down or mowed at the end of the growing season.
- Inspect vegetated filter strips annually for sediment buildup, erosion, vegetative conditions, etc.
- Inspect for pools of standing water; dewater and discharge to an approved location. Regrading may also be required. If a filter strip exhibits signs of poor drainage and/or vegetative cover, periodic soil aeration may be required. In addition, depending on soil characteristics, the strip may require periodic liming.
- Mow and trim vegetation to a minimum height of 4 to 6 inches.
- Mowing and maintenance must occur to ensure safety, aesthetics, and proper filter strip operation, or to suppress weeds and invasive species; dispose of cuttings in a local composting facility; mow only when filter strip is dry to avoid rutting. Fall mowing should be kept to a grass height of 6 inches to provide adequate winter habitat for wildlife.
- Inspect filter strip inlet (gravel trench level spreader, curb cuts, etc.) and outlet for signs of erosion or blockage, and correct as needed.
- Inspection should confirm that vegetation has been maintained as designed and not removed or replaced.

5.3.7 Infiltration Berms

Description

Infiltration berms are compacted linear mounds of earth constructed along contours that are used to reduce stormwater velocities and detain runoff volume on hillsides with gentle to moderate slopes. By creating gentle variations in the topography of a hillside, infiltration berms slow the flow of runoff to allow ponding on the soil surface and storage of runoff in modified soils or in a stone trench, and promote infiltration behind the berm. Infiltration berms can aid in slope stabilization and prevent erosion, add interest to uniform landscapes, filter pollutants in runoff, and create habitat. Infiltration berms are often referred to as retentive grading. Infiltration berms may be used in conjunction with vegetated swales (Section 5.3.5) or infiltration trenches (Section 5.3.3) to provide additional stormwater management.

Figure 5.3.7-1. Infiltration berm constructed along the contour in a wooded area receives runoff from a large-lot residential area.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Infiltration Berm	S/R	H	H	H	H	M	M	M	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Features

- Infiltration berms should be constructed parallel to contours to intercept and detain runoff.
- The end sections of the berm should taper into the uphill grade to prevent flow channelization around the ends of the berm.
- An overflow weir or bypass mechanism must be provided for larger storms.
- On the uphill side of the infiltration berm, surface ponding, modified soils, and/or an infiltration trench should be used to capture and infiltrate stormwater.
- The depth of ponding behind berms should be limited to 6 inches or less.
- The maximum side slope of berms should be 3:1; 4:1 if they are to be mowed.
- The berm core is keyed and compacted to prevent berm failure, but covered with topsoil and densely planted.
- Preferably, berms should be vegetated with tall grasses, shrubs, and trees, but at a minimum, must be planted with turf.
- Infiltration berms can be used as a standalone BMP or as pretreatment for other BMPs (such as a vegetated swale or bioretention area).
- The berms must be carefully constructed along a contour to avoid low points where overflow may concentrate and erosion may occur.
- The use of turf reinforcement mats (TRMs) or other stabilization materials will prevent erosion of the berms.
- Infiltration berms should only be used to treat small, localized drainage areas (generally less than 5,000 square feet), and usually complement other BMPs as part of a treatment train and volume reduction system.
- Subsoils excavated from behind berms can be used for berm core construction. These soils can also be modified in place uphill of the berm to increase absorptive properties for stormwater volume storage.
- Infiltration berms can be used on already vegetated hillsides with trees if care is taken not to disturb existing root structures.

- Berms can be placed in series along parallel contours to break up large drainage areas into smaller sub-drainage areas.

Figure 5.3.7-2. This berm is combined with an infiltration trench (BMP 5.3.3) to capture runoff from a grassed overflow parking area.

Applications

- Best suited for less densely developed areas, on vegetated hillsides.
- Used in inactive park space and other open space to receive runoff from compacted pervious areas.
- Used for slope stabilization and erosion prevention.
- Can be used in combination with other BMPs (especially in highly impervious areas).
- Can be used as pretreatment for other BMPs (such as vegetated swale or bioretention area).

- Best applied on gentle to moderate slopes (15 percent or less).
- Used to receive runoff from roof leaders or divisions between individual lots.

Advantages

- Integrates stormwater into landscape.
- Improves aesthetics.
- Designed to decrease the velocity of runoff from small storms, improve water quality, and provide volume reduction.
- Cost-effective.
- Low-maintenance and minimal structure requirements.

Disadvantages

- Infiltration requires suitable site conditions.
- Vegetation and soils must be protected from damage and compaction.
- Salt use on tributary pavements may impact berm vegetation and soils.
- Vegetation must be firmly established and densely spaced to avoid potential for erosion.
- Applicable only to small drainage areas.
- **Must** be constructed properly to avoid creating conditions of concentrated flow.

Variations

- **Live Fascine Bundles** are a variation to infiltration berms used for slope stabilization, velocity reduction, and erosion control. Live Fascine Bundles are bundles of live cuttings of woody plant species installed in shallow trenches at regular intervals along hillsides and secured with live stakes. They provide soil stabilization with their root structure and increase surface roughness to intercept and slow the velocity of stormwater runoff and also reduce erosion. For details on the construction of Live Fascine Bundles, see the *USDA & NRCS Engineering Field Handbook (1992),* Chapter 18, Soil Bioengineering for Upland Slope Protection and Erosion Reduction, for guidance.

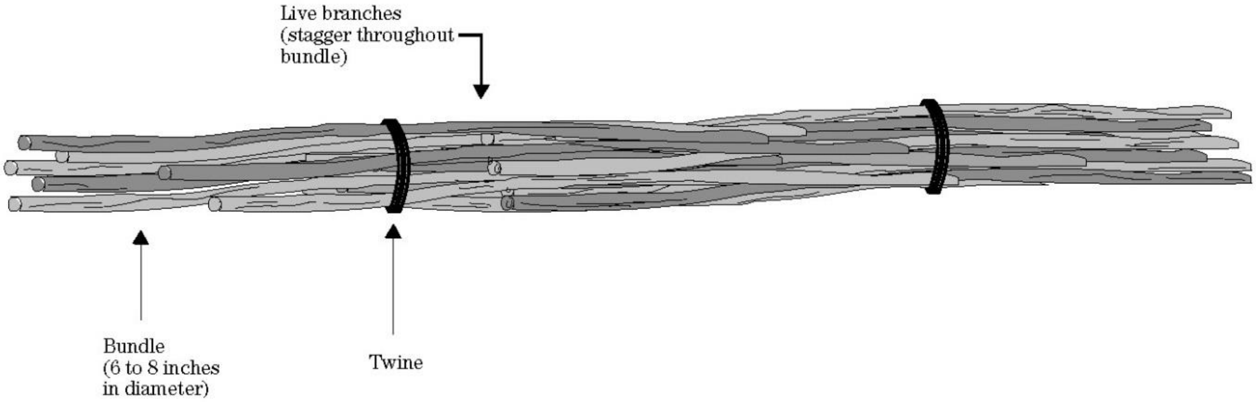
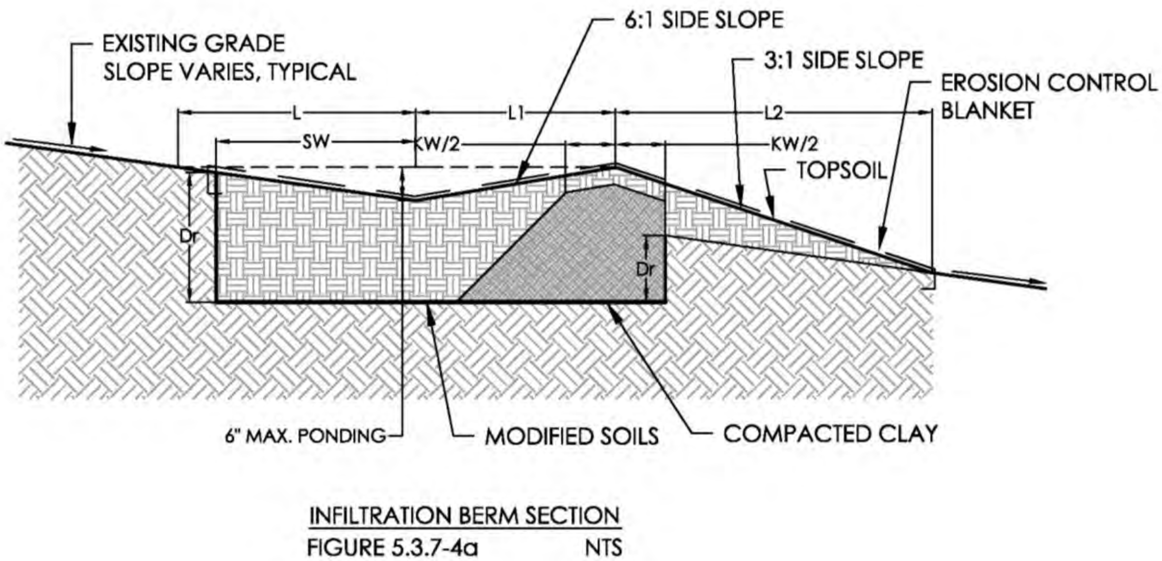


Figure 5.3.7-3. Typical Live Fascine Bundle (*USDA & NRCS Engineering Field Handbook).*

Applicable Protocols and Specifications

The following Protocols and Specifications (see Appendices A through F) are applicable to infiltration berms and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 2 Coordination with Other Utilities
- Protocol 3 Site Evaluation and Infiltration Testing
- Protocol 4 Infiltration System Guidelines
- Protocol 5 Planting and Mulching Guidelines
- Appendix F
  - Stormwater System Specifications
  - Bioretention Soil Specifications
  - Aggregates and Drainage Layers
  - Pipes
  - Control Structures
  - Geotextiles



Drainage Area	Existing Slope, %	Berm Length	Sideslope, L1	Sideslope, L2	Ponding Depth, PD	L	Ponding Width	Top Soil Depth, TSD	Soil Depth at left, Dl	Soil Depth at right, Dr	Key Width, KW	Soil Width, SW
		(ft)	ft	ft	(in)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
1	13.0%	232	3	4.40	6	3.82	6.82	0.25	1.99	1	1.5	3.00
2	10.0%	82	3	3.44	6	4.98	7.98	0.25	1.88	1	1.5	5.74
3	5.2%	77	3	2.33	6	9.61	12.61	0.25	1.70	1	1.5	6.00

Figure 5.3.7-4. An infiltration berm's dimensions are determined by the surface slope. For proper construction and quantification of volume management, the berm dimensions must be specified as indicated in the example table.

Design Considerations for Infiltration Berms

If designed to meet the specific needs of the site, an infiltration berm is an effective BMP that typically accompanies other BMPs in a larger stormwater management system.

1. **Location and Capture Area**

- Infiltration berms should be located on gentle to moderate slopes (15 percent or less).
- Infiltration berms should be located to prevent vegetation damage and soil compaction due to pedestrian traffic or unintended vehicle compaction.
- Optimum infiltration berm locations are often areas that are generally “unused” along slopes of woodlands and meadows, parks, public playgrounds, school yards, plazas, and courtyards, and in place of traditional landscape planting areas around buildings and structures.

2. **Entrance/Flow Conditions**

It is important for flow to enter an infiltration berm in a distributed flow or as sheet flow. Generally, runoff flows to infiltration berms through dispersed surface sheet flow along a depressed curb, lawn area, or edge of pavement, or down a hillside. Careful grading is essential to prevent a concentrated flow point and potential erosion. Concentrated flows of runoff should always be avoided to prevent erosion, gully formation, and preferential flow paths. When runoff travels across a surface for long distances, flows can begin to concentrate. For pervious contributing areas, flow path lengths greater than 150 feet should be avoided. For impervious contributing areas, flow path lengths greater than 100 feet should be avoided.

3. **Management of Sediment, Trash, and Debris**

In areas of high sediment load, infiltration berms should include measures to prevent the movement of material toward the berm and infiltration area.

During the establishment of vegetation, temporary erosion control blankets (ECBs) should be placed over the berm and infiltration area. If infiltration berms are placed in areas with relatively high runoff velocities where channelization is evident or where soils are currently eroding, it may be appropriate to use permanent turf reinforcement mats.

Any trash or debris that collects behind the berm should be removed regularly.

4. **Storage and Stay-on-Volume**

An infiltration berm may be designed to capture SOV, but very often it may only be able to capture a portion of the SOV. In this situation, the remaining SOV and water quality volume must be managed by downstream BMPs.

An infiltration berm provides volume management within the surface ponding area and the modified soil area.

Storage Volume (ft^3) = Surface Water Volume + Soil Storage Volume

Surface Water Volume: Available surface water storage behind the berm (always equal to or less than 6 inches deep). The designer should consider the bed side slopes when estimating volume.

Soil Storage Volume: The bioretention soil volume x void space ratio of 0.20. Again, slopes will affect the berm geometry and corresponding volume.

5. Area and Dimensions

In addition to reducing runoff velocities, the goal of infiltration berms is to detain stormwater volume upgrade, or "behind," the berm. This can be achieved by ponding water on the surface, by modifying the soils to increase their absorptive capacities, and/or by constructing an infiltration trench. The dimensions of ponding depth, modified soil depth and width, and infiltration trench depth and width behind the berm are a function of the quantity and velocity of the stormwater it is intended to receive, as well as other site conditions such as slope and soil type.

In general, infiltration berms should meet the following guidelines:

- Infiltration berms should be no higher than 6 inches to encourage infiltration and prevent excessive ponding behind the berm.
- Topsoil or planting soil should be placed over the compacted portion of the berm with a depth (at least 3 inches) sufficient for plant establishment.
- Individual berm length will depend on functional need and site size.
- Modified soil dimensions along the uphill side of the berm will vary based on runoff volume. Generally, modified soils are between 1 and 2 feet deep and can vary in width from 1 to 10 feet. It is recommended that excavated onsite soil be modified with compost and sand if necessary to limit the need to import soils.
- If an infiltration trench is used for stormwater volume storage, it should be designed using the guidelines in Section 5.3.3, Infiltration Trenches. Soil testing is not required for berms located within existing woodland, but soil maps/data should be consulted when siting the berms.
- Infiltration testing must be performed in accordance with Protocol 3 (see Appendix C) when infiltration is proposed for reduction of SOV.
- In all cases, the soils in the infiltration footprint should be protected from compaction.
- If a berm is to be mowed, the slope should not exceed a 4:1 ratio (horizontal to vertical) in order to prevent "scalping" by mower blades. If trees are to be planted on berms, the slope should not exceed a 5:1 to 7:1 ratio. Other herbaceous plants, which do not require mowing, can tolerate slopes of up to 3:1.

6. Overflow and Peak Rate

All infiltration berms must provide a safe way for water to overflow or bypass the system when large storms generate more stormwater runoff than the berm can hold. Overflow must be routed across undisturbed areas.

In the event that an infiltration berm is not sized to fully capture the first 1.0 inch (or 1.6 inch) of rainfall volume from its drainage area, it should overflow to a complementary BMP downstream. In all cases, infiltration berms should be designed so that water overflows uniformly across the crest of the berm and so that no points of concentrated flow are formed along the top or at the edges of the berm.

Infiltration berms do not usually have sufficient capacity for significant detention storage/mitigation, but may be credited for site peak rate control as described below.

Peak Rate Control and Infiltration Credit

For the purposes of site peak rate control, the designer may adjust the Curve Number value based on the volume managed by both the SOV and the infiltration volume that occurs during a portion of a 24-hour storm event. This will allow the designer to account for runoff that was captured by applying low-impact development and to formulate a representative lower Curve Number. This is described in Chapter 7.

When adjusting the Curve Number, the infiltration volume can be estimated as the infiltration that occurs during 12 hours of a 24-hour design storm. The infiltration area is the bottom area of the modified soils and does not include the berm itself.

7. Infiltration Berm Soils

There are three soil considerations for infiltration berms:

- The conditions of the native subsoil in the infiltration footprint
- The modified soils used for stormwater volume storage
- The soil used in berm construction

When excavating for infiltration berm construction, it is essential that the native subsoil within the infiltration footprint is not compacted with construction equipment. If the native soil is compromised during construction, the soils should be restored using the guidelines in Section 5.4.3, Restore and Amend Disturbed Soils.

If soil behind the berm is intended to store stormwater, it should be modified in accordance with Appendix F – Bioretention Soil Specification. If an inadequate soil specification is used, or if the modified soils are prepared, installed, or maintained poorly, runoff may infiltrate either too quickly or not quickly enough. If the soil infiltration rate is too low, the result is runoff overtopping the berm and exiting without treatment or detention. If the soil infiltration rate is too high, runoff will not have enough contact with the soil media to provide adequate water quality treatment, and there may be difficulty maintaining healthy vegetation.

8. Water Quality/Total Suspended Solids

Infiltration berms that can capture and manage the required SOV through infiltration are considered to meet all water quality requirements. See Chapter 7 for additional discussion about water quality improvement.

Construction Considerations

For the best success, infiltration berms should not be installed until site construction is complete and site stabilization has occurred. Infiltration berms completed before site stabilization **must** be protected from receiving sediment-laden runoff. Direct runoff around completed infiltration berms until site stabilization has occurred. Do not allow sediment-laden water to flow into berm infiltration footprints.

Construction Sequence Example

The following construction sequence is for an infiltration berm without a subsurface stone infiltration trench. If a stone infiltration trench is desired, the sequence should be modified to incorporate the guidelines in Section 5.3.3, Infiltration Trenches.

Step 1 Excavate Berms

a. Do **not** compact or subject existing subgrade in the infiltration footprint to excessive construction equipment traffic. Protect areas from vehicle traffic during construction with construction fence, silt fence, or compost sock.
b. Rough grade the infiltration berm area, avoiding compaction in the infiltration footprint behind the berm.
c. Remove fine materials and/or surface ponding in the infiltration footprint, caused by erosion, with light equipment and scarify underlying soils to a minimum depth of 6 inches with a York rake or equivalent by light tractor.

d. Halt excavation and notify the engineer immediately if evidence of sinkhole activity, unanticipated bedrock or groundwater conditions, or other site conditions are encountered that may affect infiltration bed design or performance.

Step 2 Install Infiltration Berms

a. Construct and fine grade berms to line, grade, and elevations indicated. Accurate grading is essential for infiltration berms. **Even the smallest nonconformities may compromise flow conditions.** Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction.
b. Place the modified bioretention soils uphill behind the berm to the dimensions indicated. Lightly scarify the soil before placing modified bioretention soil.
c. Place planting soil immediately after approval of berms and bioretention soils. Any accumulation of debris or sediment that takes place after approval of subgrade shall be removed prior to installation of planting soil.
d. Install planting soil and lightly compact (tamp with backhoe bucket). Keep equipment movement over planting soil to a minimum – do not over compact. Install planting soil to grades indicated on the drawings.
e. Complete final grading of the berm after the top layer of soil is added. Lightly tamp down soil and smooth sides of the berm. The crest and base of the berm should be level along the contour.
f. Seed and vegetate according to plans, and stabilize topsoil. Plant the infiltration berm areas at a time of the year when successful establishment without irrigation is most likely. Temporary irrigation may be needed in periods of little rain or drought. Vegetation should be established as soon as possible to prevent erosion and scour.
g. Stabilize freshly seeded berms with appropriate temporary or permanent soil stabilization methods, such as erosion control matting or blankets. Erosion control for seeded swales shall be required for at least the first 75 days following the first storm event of the season. If runoff velocities are high, consider sodding the swale or diverting runoff until vegetation is fully established.
h. Mulch planted and disturbed areas with compost mulch to prevent erosion while plants become established.
i. Protect infiltration berms from sediment at all times during construction. Silt fences, diversion berms, and/or other appropriate measures shall be used at the toe of slopes adjacent to infiltration berms to prevent sediment from washing into these areas during site development.
j. When the site is fully vegetated and the soil mantle stabilized, notify the engineer. The engineer shall inspect the infiltration berm drainage area at his/her discretion before the area is brought online and sediment control devices removed.

Operations and Maintenance

Infiltration berms require relatively low maintenance. However, if localized erosion develops, it must be addressed immediately.

- Inspect for uniformity in cross-section and longitudinal slope, especially along the top and at the edges of the berm, and correct irregularities causing concentrated flow conditions as needed.
- While vegetation is being established, pruning and weeding may be required.
- Detritus may need to be removed approximately twice per year. Perennial grasses can also be cut down or mowed at the end of the growing season.
- Infiltration berms should be inspected annually for sediment buildup, erosion, vegetative conditions, etc.
- Mow and trim vegetation to ensure safety, aesthetics, and proper berm operation, or to suppress weeds and invasive species; dispose of cuttings in a local composting facility; mow only when the berm is dry to avoid rutting.

5.3.8 Green Roofs

Description

A green roof (also referred to as a vegetated roof or living roof) consists of vegetated roof cover used to mimic the hydrologic performance of surface vegetation rather than the impervious surface cover of a flat or pitched roof. Green roofs are effective in reducing the volume of runoff from a roof as well as the rate at which runoff leaves a rooftop. Green roofs help to minimize thermal impacts to downstream receiving waters. Green roofs may be designed to accommodate functions ranging from simple rainfall management to more complex systems that integrate rainfall management with livable/usable space.

Green roofs may be designed to meet a variety of goals and conditions. Green roofs may be **extensive** systems, designed to be very simple, light systems with a relatively thin (2- to 4-inch) layer of engineered media installed with a variety of drought-resistant vegetative species. Extensive green roofs are lightweight, low cost, and low maintenance. More complex green roof designs, referred to as **intensive** systems, incorporate deeper soils to promote and sustain larger planting structures and integrate human occupancy of roof space (see Figures 5.8-1and 5.8-2). Regardless of the complexity of the system, green roofs may be designed and constructed to meet stormwater management requirements.

Green roof plant species, especially for extensive green roofs, generally have shallow root systems, good regenerative qualities, and resistance to direct solar radiation, drought, frost, and wind.

Green roofs always include one or more drainage layers, separation fabrics (which may include a root barrier), and a waterproofing system, which is one of the more important components of a green roof. Designs and specifics vary with different manufacturers and designers.

In addition to stormwater benefits, green roofs provide direct benefits in terms of increased longevity of the roofing system (by protecting the roof from temperature extremes) and insulation benefits that may reduce heating or air-conditioning energy costs.

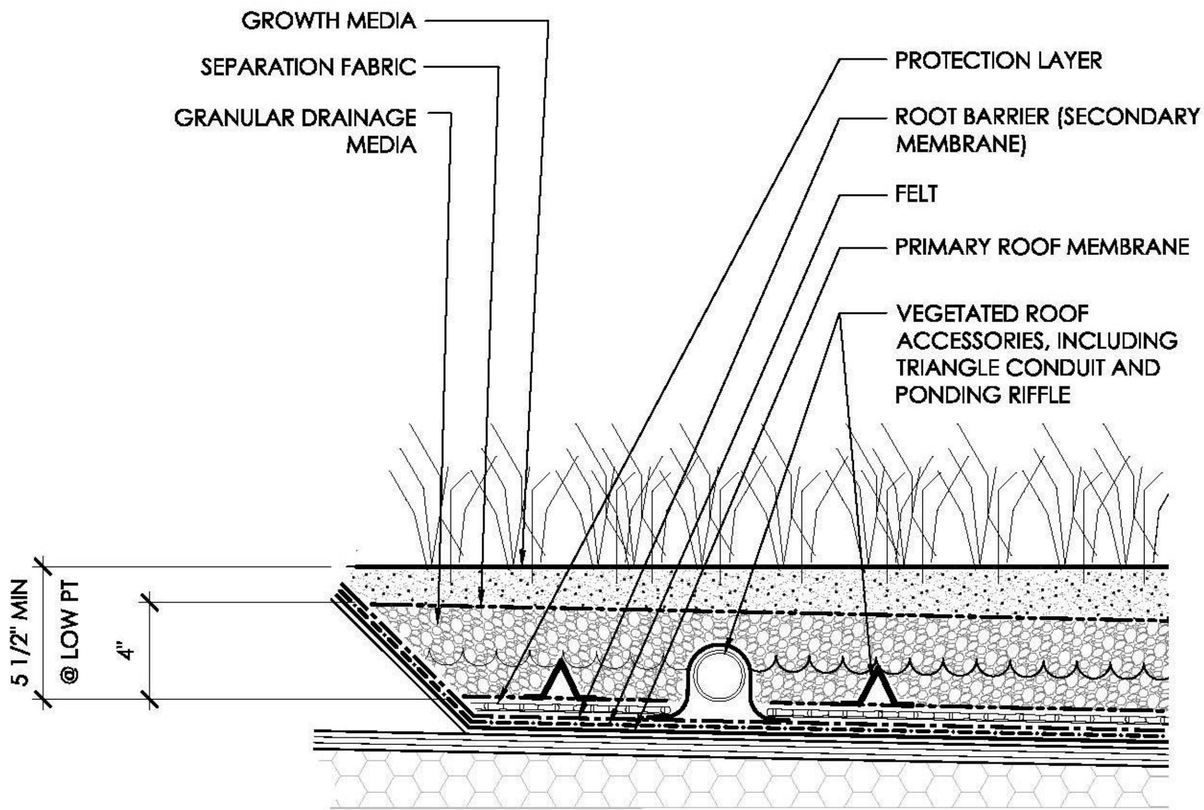


Figure 5.3.8-1. Example of extensive green roof cross-section.

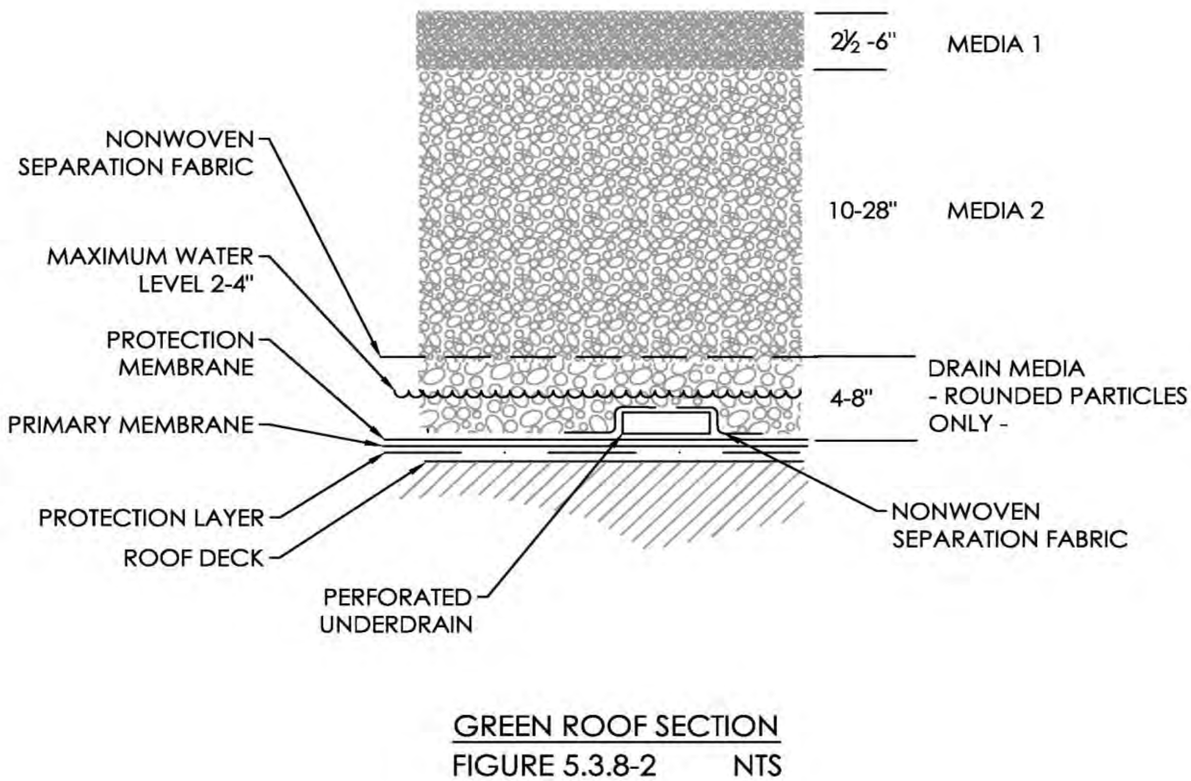


Figure 5.3.8-2. Example of intensive green roof cross-section.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden*	Cost**
Green Roof	U/S/R	M	H	H	L	H	H	M	L/M	M/H

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Maintenance burden depends on design.

**Initial cost may be relatively high, but low over the long-term.

Key Design Features

- 2 to 6 inches of engineered growing media with high mineral content; assemblies that are 4 inches and deeper may include more than one type of engineered media.
- One or more drainage layers.
- Engineered media for extensive vegetated roof covers is typically 85 percent to 97 percent non-organic (wet combustion or loss on ignition methods).
- Vegetated roof covers intended to achieve water quality benefits should not be fertilized.
- Internal building drainage, including provisions to cover and protect deck drains or scuppers, must anticipate the need to manage large rainfall events without inundating the cover.
- Assemblies planned for roofs with pitches steeper than 2:12 must incorporate supplemental measures to ensure stability against sliding.
- May include a wind erosion stabilization system.

Applications

- Residential
- Institutional
- Commercial
- Industrial
- Roadside (i.e., atop bus shelter)

Advantages

- Appropriately designed green roofs can manage quantity, improve quality, and reduce the rate of stormwater runoff.
- Green roofs provide energy savings by providing an insulating layer to buildings, which also provides sound-absorbing benefits to the building and surroundings.
- Green roofs mitigate urban heat island effects and reduce atmospheric levels of greenhouse gases.
- Green roofs provide habitat for birds, butterflies, and other animals that may be displaced due to building development.

Disadvantages

- Green roofs are not recommended in areas where groundwater recharge is desired.
- Green roofs may be more expensive to design and construct than other BMPs, particularly when retrofitting an existing building if structural modifications are required for the additional roof load.

- Maintenance for green roofs may require weeding and watering to be done by hand, especially during establishment.

Figure 5.3.8-3. Green roof at the Kresge Foundation in Troy, Michigan.

Roadside Green Roof

Figure 5.3.8-4. Green roof on a bus shelter (http://inhabitat.com/philadelphia-plants-its-very-first-bus-stop-green-roof/philly-bus-green-roof-7/?extend=1).

Hotel Green Roofs

Figure 5.3.8-5. Chattanooga green roof at the Crash Pad.

Institutional Green Roofs

Figure 5.3.8-6. Extensive green roof plaza atop a parking garage at UNC Chapel Hill.

Commercial Green Roofs

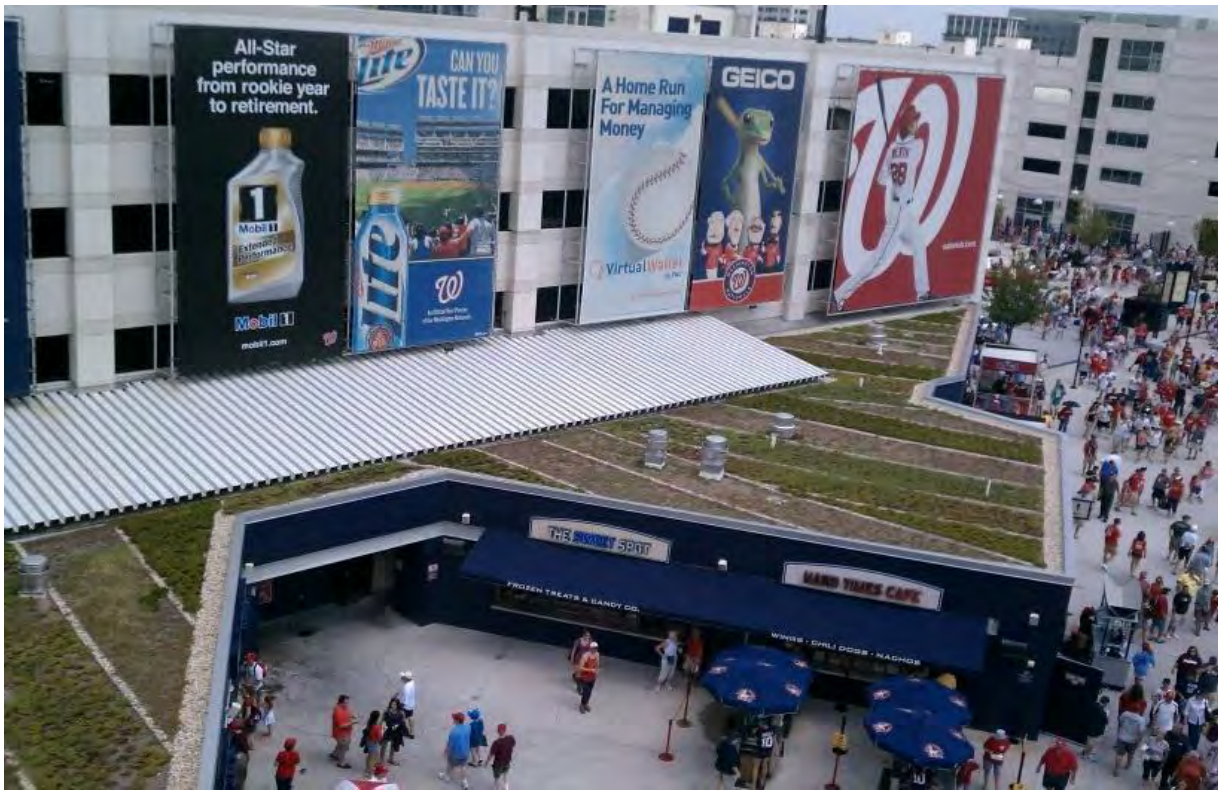


Figure 5.3.8-7. Green roof at a Washington Nationals Stadium.

Applicable Protocols and Specifications

The following protocols and specifications (see Appendices A through F) are applicable to green roofs and must be addressed:

- Protocol 5 Planting and Mulching
- Stormwater System Specifications
  - Impervious Liners and Waterproofing

Manufacturer specifications and design criteria must also be addressed.

Design Considerations for Green Roofs

All green roofs are designed with four primary component layers (from bottom to top): a waterproofing layer, an insulating layer, a stormwater storage layer, and a growth (vegetated) layer. Green roofs may be designed to meet a variety of stormwater and development program goals, when carefully designed using the following considerations:

1. Location and Capture Area

Green roofs are typically designed to manage the rainfall that falls onto the vegetated area. They also may be sized to manage runoff from other roof areas where vegetation may not be established (e.g., areas of steeply pitched roofs, air conditioning units).

2. Entrance/Flow Conditions

For green roofs situated atop roofs with slopes greater than 1.5 percent, battens should be incorporated to hold drainage layers in place and temporary erosion control measures should be implemented to minimize erosion while vegetation is established.

Green roofs that receive drainage from more steeply sloped roof areas should include an area for velocity dissipation (i.e., cobbles) prior to runoff flowing onto the vegetated area.

3. Management of Sediment, Trash, and Debris

Green roofs designed to integrate human occupancy of roof space should have a maintenance program that includes frequent inspection and removal of accumulated trash and debris.

4. Storage and Stay-on-Volume

Green roofs may be designed to manage SOV or a portion of SOV. To be excluded from the SOV area, the green roof must be designed with a minimum media depth of 2½ inches.

For green roofs intended to manage runoff from non-vegetated roof areas, supporting calculations must be provided showing that the roof design has capacity to receive additional runoff.

5. Surface Area and Dimensions

The size and surface area of a green roof are a function of the building program and architectural preferences. Depth of growing media, drainage media, and other components vary based on manufacturer or design criteria.

6. Overflow and Peak Rate

All green roofs must provide a safe way for water to exit the system when large storms generate more stormwater runoff than the media can hold. The inclusion of a positive overflow route ensures that flooding risks, which can cause overloading of the structural capacity of the building and related property damage, are minimized.

The positive overflow route is most often via the downspouts and roof gutters normally provided in the building design.

Careful consideration must be provided to maintenance of downspouts and roof gutters, particularly with regard to accumulation of debris from plants during seasonal changes.

Figure 5.3.8-8. Green roof drainage box (image courtesy of Roofmeadow).

Peak Rate Control Credit

For the purposes of site peak rate control, the designer may use a Curve Number of 75 for green roof areas.

7. Underdrain

Green roofs that include additional storage capacity (i.e., those managing other non-vegetated areas) may be designed with an underdrain to allow for positive outflow of larger design storms. Underdrains may be designed as perforated pipes connected to roof gutters or manufactured products that promote positive drainage.

Non-vegetated areas managed by underdrained green roof systems may not be excluded from SOV area calculations.

Figure 5.3.8-9. Installation of drainage layer beneath intensive green roof.

8. Waterproofing

All vegetated roof covers require a premium waterproofing system. Depending on the waterproofing materials selected, a supplemental root-fast layer may be required to protect the primary waterproofing membrane from plant roots.

Insulation, if included in the roof covering system, may be installed either above or below the primary waterproofing membrane. Most vegetated roof cover systems can be adapted to either roofing configuration.

Figure 5.3.8-10. Geotextile and root protection.

Construction Considerations

- Install waterproof membranes carefully to ensure that the structural integrity of the roof and building are maintained.
- It is strongly recommended to test for water tightness prior to installation beyond the waterproof layer.
- Implement temporary erosion controls, including control measures for dust suppression, during construction until vegetation has been suitably established.
- Follow specific manufacturer or designer construction requirements.

Operations and Maintenance

All green roofs require regular maintenance to ensure proper function.

- Green roof area should be weeded at least twice per year.
- Detritus and other debris should be removed regularly from gutters, downspouts, and other screens and filters to prevent system clogging.
- Waterproof layers (and roof substructure) should be inspected regularly for signs of water below the vegetated cover.

5.3.9 Runoff Capture and Reuse

Description

Rainwater can be used as a resource when it is captured from rooftops and other impervious surfaces, stored in rain barrels or cisterns, and reused as non-potable water (see Figure 5.3.9-1). Captured rainwater can be used for landscape irrigation, fire needs, toilet flushing, or other greywater uses. Roof runoff is generally cleaner and more suitable than runoff from parking lots and roads, which require additional treatment and maintenance to address sediment. Air conditioning condensate (although not part of runoff) can also be captured for reuse instead of being discharged to the storm sewer. Runoff capture and reuse reduces the volume and peak flows associated with stormwater runoff.

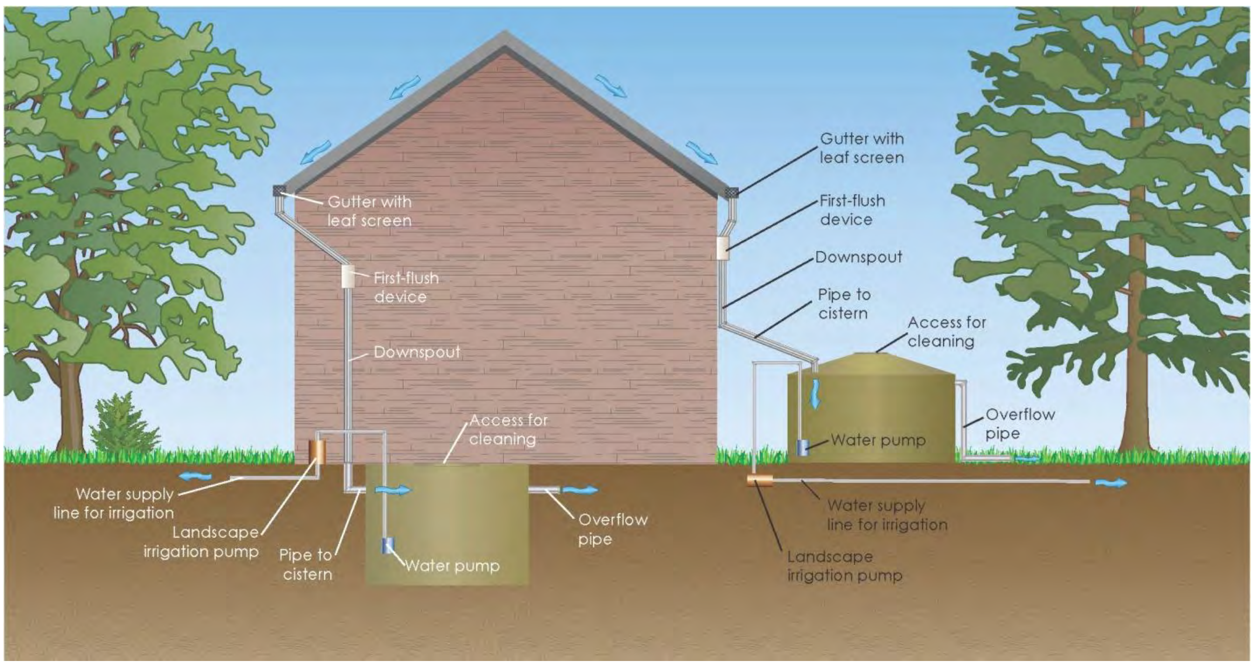


Figure 5.3.9-1. Roof runoff can be captured in cisterns above or below grade and used for irrigation or non-potable water needs.

BMP Functions Table

BMP	Applicability*	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden*	Cost*
Runoff Capture and Reuse	U/S/R	H	H	H	L	H	L	L	M/H	M/H

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Rating varies based on design considerations.

Key Design Features
(see Figure 5.3.9-2)

- Cisterns may be above- or below-ground tanks made from a variety of materials including wood, concrete, plastic, stone, or modular storage units.
- The volume of runoff generated from the contributing area must be considered.
- Contributing areas must be evaluated for potential pollutants including metals, fungicides, and herbicides. Roofs should not include copper or be treated with fungicides or herbicides.
- Storage devices should be sized to store the appropriate runoff volume from the contributing capture area and reuse needs should be adequate to drain the cistern within 96 hours to ensure that sufficient storage is available for subsequent rainfall events.
- When used for greywater reuse (such as toilet flushing), a backup water supply is required to supplement the system during dry periods.
- Collection and reuse systems must include an emergency overflow for large storm events.
- Cisterns must be watertight, vented, completely covered or screened, composed of non-reactive materials, and be approved for potable water storage, although runoff cannot be used for potable needs without treatment. This includes irrigation water that has any human contact (i.e., sprinklers).
- Distribution lines and other system appurtenances must be clearly labeled as non-potable water.
- If the storage device is open to the air, a screen or other cover is necessary to prevent mosquito breeding.
- Spigots or hose bibs at above-grade cisterns should be labeled “NON-POTABLE” and be equipped with an atmospheric vacuum breaker.
- Safety labels should be placed on cisterns stating “NON-POTABLE” and “DROWNING HAZARD.”
- Backflow preventers must be installed on water service lines from cisterns.

- Storage tanks should be placed in cool, shaded areas to help prevent the growth of algae.
- All collection and redistribution of stormwater runoff have the potential to cause human pathogenic issues. All capture and reuse BMPs that involve human contact must include disinfection components to prevent human health and safety issues arising from any potential contact with the collected water. Both ultraviolet (UV) and ozone disinfection systems are available for this purpose.

Applications

- Residential
- Commercial
- Institutional: schools, universities, libraries, etc.
- Brownfields
- Uses: irrigation, toilet flushing, fire storage
- Toilet flushing in high-use buildings (i.e., schools, visitor centers) is one of the most effective reuse methods.

Advantages

- Provides volume reduction.
- Contributes to peak rate reduction.
- Reduces potable water needed for irrigation, toilet flushing, or other applications.
- Visible cisterns increase public awareness.

Disadvantages

- Water held within a cistern must be emptied between storms to provide volume reduction for the next storm.
- Treatment of water for reuse may be necessary depending on the contaminants in the contributing drainage area. Reusing runoff for potable uses is not recommended in the U.S., unless water is treated to all required water quality standards.
- Pumps may be required. Note: there are proprietary systems that automate the emptying before the next storm event.

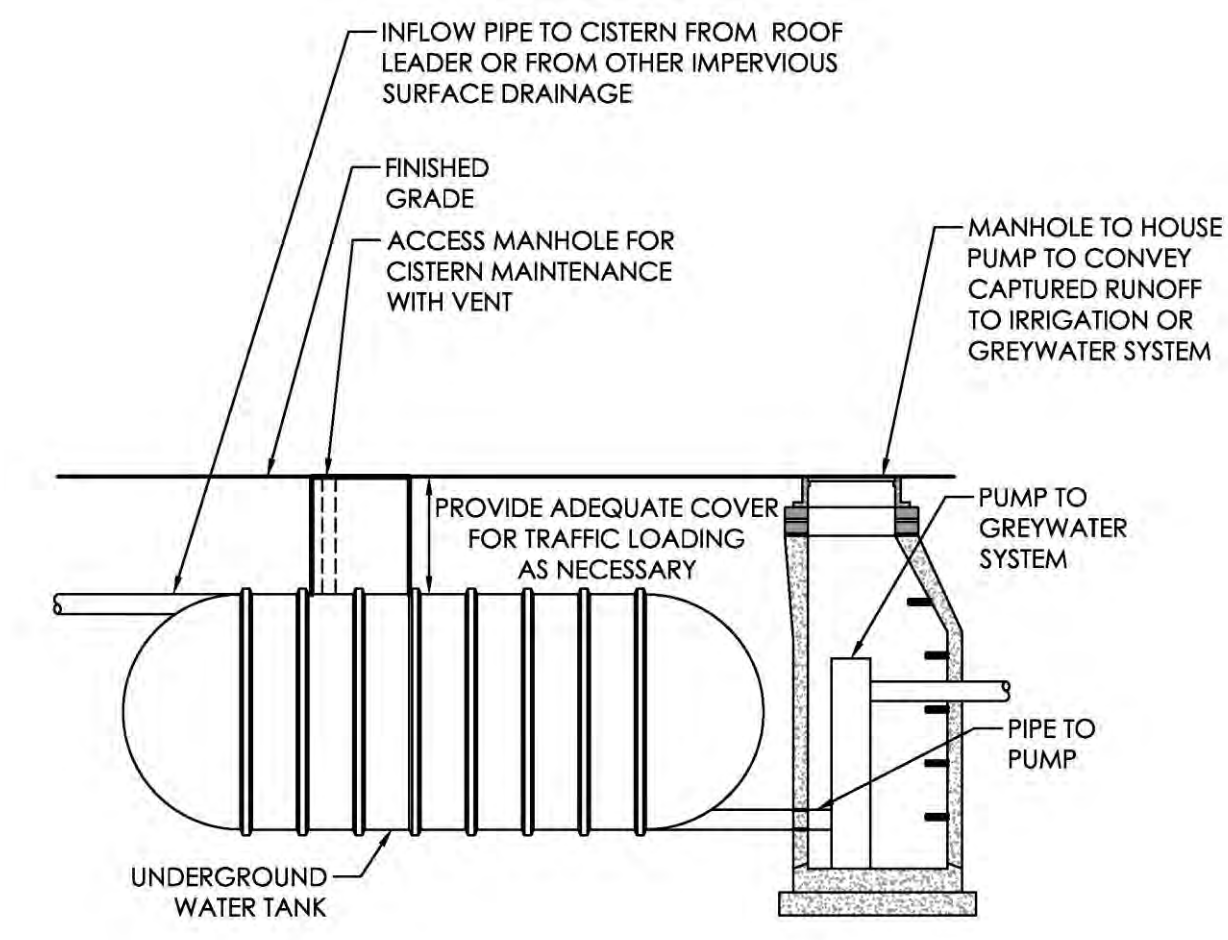


Figure 5.3.9-2. Cross-section of an underground cistern.

Applications

Runoff capture and reuse may be implemented on a variety of sites in urban and suburban environments, on residential, institutional, and commercial properties. Potential applications include office buildings, schools, libraries, multi-family residential buildings, and mixed-use areas for irrigation, fire suppression systems, toilet flushing, or other greywater uses.

Residential Rain Barrel

Figure 5.3.9-3. Rain barrels generally do not capture very large amounts of runoff, but are useful for increasing public awareness of stormwater issues.

Decorative Cistern Capture and Reuse

Figure 5.3.9-4. Cisterns can be decorative as well as functional, as is this cistern capturing runoff from a library roof. The cistern, located outside the children's library, is essentially a rain barrel with a slow-release discharge to the landscape.

Capture and Reuse for Toilet Flushing

Figure 5.3.9-5. This wooden cistern captures roof runoff at a research facility. The water is used for both toilet flushing and research needs. The captured runoff was more suitable and required less treatment for research use than the available potable water supply.

Indoor Cistern Capture and Reuse

Figure 5.3.9-6. This cistern is located indoors. Roof runoff is captured for toilet flushing within the building.

__Applicable Protocols and Specifications__

The following Specifications (see Appendix F) are applicable to runoff capture and reuse and must be addressed:

- Stormwater System Specifications
  - Aggregates and Drainage Layers
  - Pipes
  - Control Structures
  - Geotextiles
  - Impervious Liners and Waterproofing

__Design Considerations for Runoff Capture and Reuse__

The key design components for runoff capture and reuse are discussed below.

1. Location and Capture Area

- Contributing drainage areas must be considered to determine if sufficient runoff will enter cisterns to provide the necessary water demands.
- Often, contributing drainage areas are rooftops. Consideration of roof pitch, roofing materials, and large overhanging trees must be made when evaluating capture and reuse.
- Roofs made of copper or that are treated with fungicides or herbicides should not be used for rainwater capture and reuse.
- Pavement areas, such as parking lots, sidewalks, or roadways, may also be captured for irrigation reuse but may require more treatment.

2. Entrance/Flow Conditions

- When runoff enters a rain barrel or cistern through roof leaders, it should pass through a first-flush diverter that is self-draining with a cleanout (see Figure 5.3.9-7).
- Runoff captured from paved surfaces may enter a subsurface cistern through stormwater structures and piping, or after first passing through a water quality, pretreatment BMP. A first-flush diverter with a cleanout should be a part of the piping system conveying runoff to the cistern (see Figure 5.3.9-7).

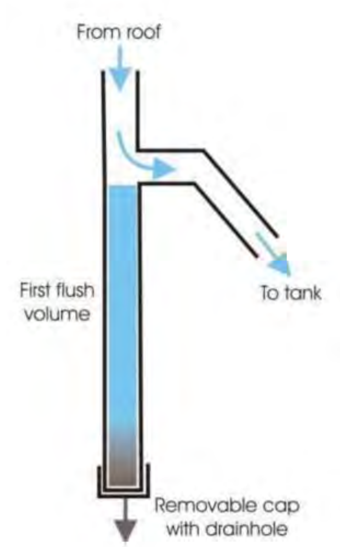


Figure 5.3.9-7. Simple first-flush diverter
(http://cehi.org.lc/Rain/Rainwater%20Harvesting%20Toolbox/Media/Print/RWHCEHI.pdf).

3. Management of Sediment, Trash, and Debris

- Screens should be used on gutters, inlets, and outlets to limit debris entering the system.
- A first-flush diverter may be used to prevent leaf litter and other debris from rooftops from entering cisterns.
- Captured runoff has the potential to collect sediment, metals, dust, bird waste, and other foreign components that may contribute to pathogenic growth, discolor collected water, or add an odor to reused water. These concerns may be minimized by avoiding collection of water from areas with large overhanging trees and installing gutter guards to prevent leaf litter and other large debris from entering the cistern from roofs.
- Regular inspection and cleaning of both the distribution system and the cistern tank itself will prevent contamination of reuse systems from sediment, trash, and debris.

4. Storage and Stay-on-Volume

A rain barrel or cistern provides volume management within the storage device only. The size of the storage device is dependent on the contributing drainage area.

The **SOV** is a function of the storage volume available within the storage device for the 1.0-inch or 1.6-inch storm. The portion of the project roof that is tributary to the storage device would be **considered to meet 100 percent of the SOV only if the collected volume of water is completely used by the intended reuse application within 72 hours of a rainfall event.**

5. Area and Dimensions

- The number of rain barrels or the size of the cistern required will be determined by the drainage area, the intended capture goal, and the usage needs of the reuse application (see Figure 5.3.9-8).
- The designer must select a pump of adequate capacity to meet the flow requirements for the reuse system.

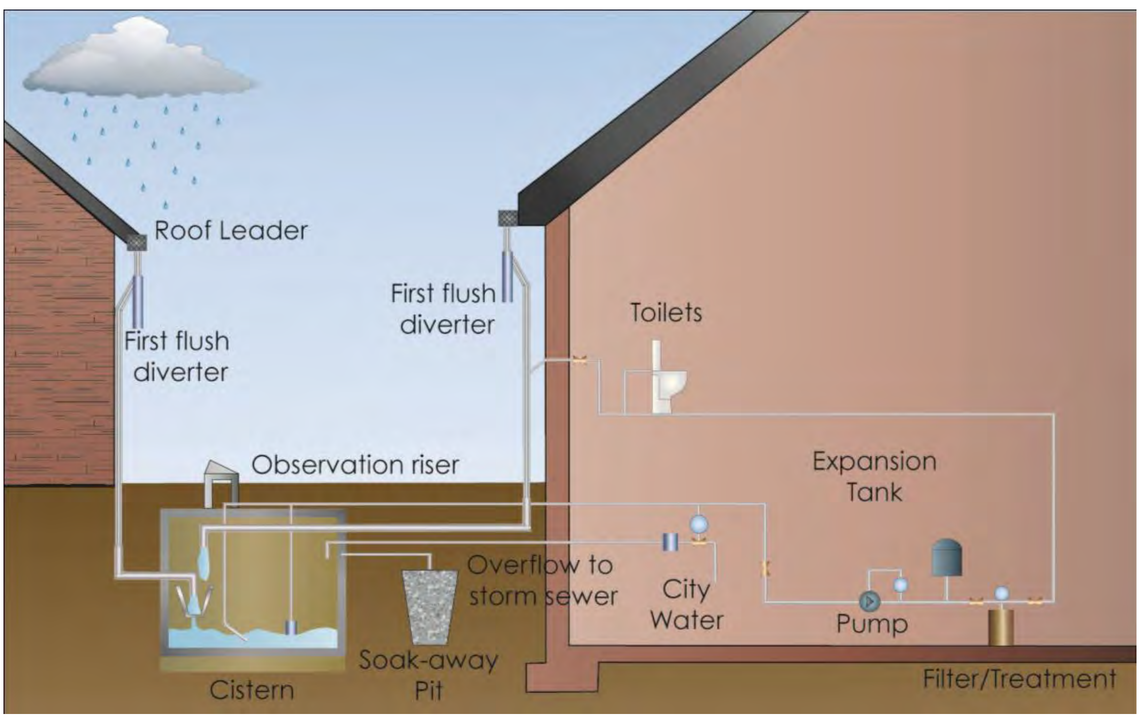


Figure 5.3.9-8. Runoff from residential buildings can be reused for irrigation, toilet flushing, or other greywater uses, such as washing machines.

6. Overflow and Peak Rate

- All rain barrels and cisterns must provide a safe way for water to exit the system when large storms generate more stormwater runoff than the storage device can hold, or bypass the system when it is full. The cistern can be designed to slowly drain to the landscape between storm events to provide capacity if it is not completely used. The overflow should convey runoff to an approved discharge point.
- The size of the overflow device or orifice should be equal in area to the total of all inlet orifices.

Peak Rate Control Credit

- For the purposes of site peak rate control, the designer may adjust the Curve Number value based on the volume managed by the SOV during a portion of a 24-hour storm event. This is described in Chapter 7.

7. Waterproofing

- Cisterns must be watertight and seams should be checked regularly for leaks.

8. Water Quality / Total Suspended Solids

- All capture and reuse BMPs must include disinfection components to prevent human health and safety issues arising from any potential contact with the collected water.
- All cisterns should be shaded to the maximum extent possible to help prevent algal growth.

Sizing Calculations Worksheet for Runoff Capture and Reuse

(Link to worksheet)

Construction Considerations

- Prior to installing a rain barrel or cistern, clean roofs, gutters, and downspouts and install effective leaf screens.
- Install rain barrels and cisterns on level surfaces.
- For elevated cisterns, consider head required to provide necessary pressure for the designed reuse.
- Follow the manufacturer’s instructions for rain barrel or cistern installation.

Operations and Maintenance

All runoff capture and reuse systems require regular maintenance to ensure proper functioning.

- All parts of rain barrels and cisterns should be inspected twice annually to make sure they are operable and that there are no leaks.
- Detritus and other debris should be removed regularly from gutters, downspouts, and other screens and filters to prevent system clogging.
- Tanks should be cleaned once per year with a non-toxic cleanser.
- Backflow preventers should be checked annually for proper functioning.
- Complex systems may require pumps, valves, and other appurtenances that may require increased maintenance to ensure functionality.

5.3.10 Disconnection of Impervious Areas

Description

The disconnection of impervious areas can be achieved by directing runoff from roof leaders, roads, driveways, and other paved surfaces toward vegetated areas rather than conveying runoff to conventional stormwater management measures (see Figure 5.3.10-1). Disconnecting impervious areas allows for the filtering and possibly infiltration of runoff onsite, reduces burdens on conventional storm sewer systems, can be a low-cost retrofit or reduce piping costs on new construction projects, and can reduce downstream erosion by dispersing runoff near the source. This section describes the management of impervious areas directed to a vegetated surface that is **not** covered under another BMP section of the manual (i.e., rooftops managed by bioretention areas are covered elsewhere).

Figure 5.3.10-1. Roof leaders from a residence sheet flow across turf and, eventually, to a meadow area, which filters and absorbs stormwater runoff.

Disconnection of impervious areas differs from vegetated filter strips (Section 5.3.6) in the application of the BMP. Vegetated filter strips are designed to treat runoff from planned impervious areas in accordance with the specifications in Section 5.3.6. Disconnection of impervious areas, while achieving similar stormwater management goals, is applied with different location and capture area limitations. Disconnection of impervious areas is typically implemented as a retrofit on existing projects to promote disconnection from municipal infrastructure.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Disconnection of Impervious Area	U/S/R	H	L	H	H	H	H	L	L	M

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Features

Figure 5.3.10-2. An energy dissipating splash block receives downspout runoff.

- Roof leaders, roads, driveways, and other paved surfaces are disconnected from traditional storm sewer systems by dispersing runoff at the source onto a sufficiently sized vegetated area.
- The vegetated area receiving stormwater flows must be graded to promote overland sheet flow. Grading should move water away from all structures. Disconnection of impervious surfaces must never cause basement seepage or compromise building foundations.
- Dispersing stormwater flows limits pollutant mobility and maximizes onsite infiltration.
- Roof leaders usually are discharged to an energy dissipating measure, such as a splash block, before sheet flowing onto a pervious area (see Figure 5.3.10-2).
- Roads, driveways, paths, or other paved surfaces may be dispersed into the landscape through sheet flow by eliminating curbs or through cuts in the curb. If curb cuts are used, an energy dissipating device, such as a cobble splash block, may be necessary.
- Disconnections are encouraged on relatively permeable soils (Hydrologic Soil Groups A and B).

Applications

- Residential
- Commercial
- Industrial
- Institutional
- Urban and suburban settings
- Especially applicable for roof leaders, paved pathways, and limited areas of impervious surfaces such as parking lots

Advantages

- Reduces the volume of runoff and allows for increased infiltration and filtration of stormwater runoff through vegetation.
- Peak runoff rates are reduced.
- Pollutants are captured and retained by filtering through plants and soil.
- Increased time of concentration, reduced runoff volume, and slowing of the rapid conveyance of pollutants.
- Reduces flows to traditional storm sewer systems.
- A low-cost retrofit or can provide cost savings on new projects.
- Can reduce downstream erosion by dispersing runoff near the source.

Disadvantages

- Improper design has the potential to cause basement seepage, yard ponding, or erosion.
- Specific site characteristics including land use, soil, and topography influence implementation.
- Requires nearby areas to be designed to receive stormwater runoff.
- Not as applicable in densely developed areas.

Applications

Disconnection of impervious area can be applied to any impervious area, within a certain size limit of drainage area, adjacent to a pervious area with an adequate size and slope.

Disconnection of Roof Leaders

Figure 5.3.10-3. Roof runoff may be disconnected to a receiving vegetated area.

Disconnection of Paths

Figures 5.3.10-4a and b. Paths can be disconnected by sheet flowing onto a vegetated area of an adequate size and slope.

Disconnection of Parking Lots

Figure 5.3.10-5. A parking lot is disconnected by directing flow through curb cuts to a vegetated area that includes a filter strip.

Applicable Protocols and Specifications

While disconnection of impervious areas may not specifically require these considerations, the heavy reliance on runoff storage, infiltration, and BMPs indicates that the following Protocols and Specifications (see Appendices A and F) apply and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 5 Planting Guidelines

Design Considerations for Disconnection of Impervious Areas

The key design components for disconnection of impervious areas discussed below allow design flexibility to ensure maximum performance from this versatile BMP.

1. **Location and Capture Area**

For a roof area to be considered disconnected, the following must be met:

- Roof area cannot be considered a designated hot area (this may be applicable to industrial roofs with material deposition concerns, etc.).
- The drainage area to each disconnected discharge must be 500 square feet or less.
- The roof leader must have an energy dissipating device, such as a splash block, at the point of discharge.
- The vegetated surface receiving the discharge must provide a continuous flow path of 75 feet or greater.
- The vegetated surface receiving the discharge must have an average slope of 5 percent or less.
- Roof leaders must be at a distance of at least 10 feet from impervious surfaces to discourage "reconnection."

For other impervious surfaces to be considered disconnected, the following must be met:

- Runoff cannot come from a designated hot area.
- The contributing impervious drainage area must be 1,000 square feet or less.
- The contributing impervious drainage area must not have a flow path exceeding 75 feet in length.
- The vegetated surface receiving the discharge must be equal to or greater than the contributing impervious drainage area length.
- The vegetated surface receiving the discharge must be continuous.

2. **Entrance/Flow Conditions**

Runoff from disconnected impervious surfaces will be directed to the receiving vegetated area, through roof leaders, curb cuts, sheet flow, or a level-spreading device. All discharge points must be designed to produce flow that will not cause scour or erosion at the soil surface. Splash blocks, cobble strips, or another energy dissipater should be used where runoff is discharged on the receiving vegetated area to minimize entrance velocities. A gravel level spreader as described in BMP 5.3.6, Vegetated Filter Strips may be applicable.

3. **Management of Sediment, Trash, and Debris**

- Roof leaders, curb cuts, and other points of discharge onto receiving vegetated areas should be checked regularly and cleared of accumulated debris to ensure positive flow onto vegetated surface.

- Discharge points and receiving vegetated areas should be inspected regularly for signs of scour, erosion, or ponding. If improper grading is discovered, it must be repaired to promote positive sheet flow across the receiving vegetated area.
- Caution should be used when disconnecting impervious areas with high sediment loads. Such areas should include an initial measure to trap and remove sediment. A filter strip may address this concern.
- All entry points and structural components should be inspected and maintained in accordance with Chapter 8 of this manual.

4. Storage and Stay-on-Volume

Only impervious areas and receiving vegetated areas that meet all of the requirements listed in the Location and Capture Area section above will be considered as meeting 100 percent of the SOV using the disconnected impervious BMP.

Disconnected impervious areas that meet all of the requirements listed in the Location and Capture Area section above may be <u>removed from the impervious area for calculation of the SOV.</u> Runoff from these areas must still be considered for storm conveyance and peak rate mitigation purposes (see item 6, Overflow and Peak Rate below).

5. Area and Dimensions

See item 1, Location and Capture Area above.

6. Overflow and Peak Rate

The disconnection of impervious surfaces to a vegetated surface meeting the requirements listed above in item 1, Location and Capture Area can be excluded from volume management calculations for SOV but must be considered for peak rate control.

For the purposes of peak rate calculations, these areas can be considered to have a Curve Number value equivalent to "Lawn in Good Condition" for the soil type that receives the disconnected runoff. There is no additional adjustment to the weighted Curve Number value.

Construction Considerations

Existing sites can achieve the disconnection of impervious surfaces by modifying roof leaders, introducing curb cuts in existing curbs, removing curbs, or modifying existing storm sewer systems to discharge to vegetated areas that meet the minimum requirements listed in the Location and Capture Area section above.

For new construction, the design process should emphasize the disconnection of impervious surfaces wherever possible, since it is a low-cost stormwater management technique that limits the need for relatively expensive structures and piping.

Operations and Maintenance

Managing runoff by disconnecting impervious surfaces is a low-maintenance stormwater management technique. Roof gutters, downspouts, splash blocks, curb cuts, and other discharge points onto vegetated surfaces must be checked regularly for debris and be cleaned. The receiving vegetated surface should be checked for erosion and scour and for the health of the vegetation, and it should be regraded and replanted as necessary.

5.3.11 Stormwater Planter Box

Description

Planter boxes are structures, either elevated or at ground level, which are filled with bioretention soils and plants to capture, detain, and filter stormwater runoff through physical, biological, and chemical processes. Planter boxes are commonly constructed of concrete, concrete masonry units, or brick. Planter boxes can be placed adjacent to the external downspouts of a building to receive rooftop runoff, as shown on Figure 5.3.11-1, or along streets to receive runoff from impervious surfaces such as sidewalks or roadways. Planter boxes are similar to bioretention in function, but tend to be more structural in design and appearance.

Figure 5.3.11-1. A downspout from an existing building is disconnected to a stormwater planter box.

Planter boxes may be designed with open bottoms to infiltrate water (infiltration planter box). Planter boxes may also be designed with an impervious bottom to discharge directly to the storm sewer system after temporarily detaining and treating runoff (flow-through planter box). All planter boxes must be designed with a positive drainage overflow connection to a secondary stormwater management system or storm sewer.

Planter boxes often are designed to provide temporary surface ponding prior to runoff filtering through the soils. Planter boxes may also include an underlying stone stormwater bed to increase stormwater capacity.

BMP Functions Table

BMP	Applicability*	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden*	Cost*
Stormwater Planter Box	U/S	L	M	H	M	H	M	L	M/H	L/M

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Rating varies based on design considerations.

Key Design Features
(see Figure 5.3.11-2)

- Use a combination of surface ponding, soil storage, vegetation, and potentially, stone storage and infiltration to treat stormwater runoff.
- Capture the runoff from the small (1.6 inches and less) rainfalls events, and the first portion of larger rainfall events.
- The surface area and size are directly correlated to the contributing drainage area size and land use, especially impervious surfaces. A planter box may not always be able to capture the full SOV.
- Should be level at the bottom.
- Inflow velocities at downspouts or curb cuts may require energy dissipation, such as a stone or concrete splash block, or other velocity control measures to prevent erosion.
- May be designed for infiltration by placing with an open bottom on uncompacted subgrade.
- Planter boxes adjacent to buildings to receive roof runoff should not be designed for infiltration to protect building foundations and basements.
- Planter boxes that cannot infiltrate **must** include a low-flow slow-release system. Lined and slow-release systems may be constructed on compacted fill material.
- Always include an overflow control structure or design to allow large storm events to bypass or discharge at a controlled flow rate without passing through the soils.

Applications

Planter boxes may be installed on virtually any site, but are most useful at providing stormwater management in highly urbanized areas where space is limited:

- Along roadways, sidewalks, and parking stalls
- Rooftop runoff – adjacent to or near buildings
- Treatment of stormwater runoff in urban, high-density residential and commercial sites

Advantages

- Allows for treatment of stormwater runoff in areas where space for larger BMPs is limited.
- Provides water quality treatment within a small footprint.
- Can be incorporated into a larger stormwater management system or "treatment train."
- Excellent option to provide partial SOV capture and improve water quality.
- Well suited for retrofit projects.
- Applicable to small drainage areas.

Disadvantages

- May not provide full management of SOV. However, can be combined with other BMPs to meet SOV.
- May be maintenance intensive.
- May be subject to vandalism and/or accumulated trash/debris, requiring additional maintenance.
- Highly structural nature may be cost-prohibitive in certain applications.

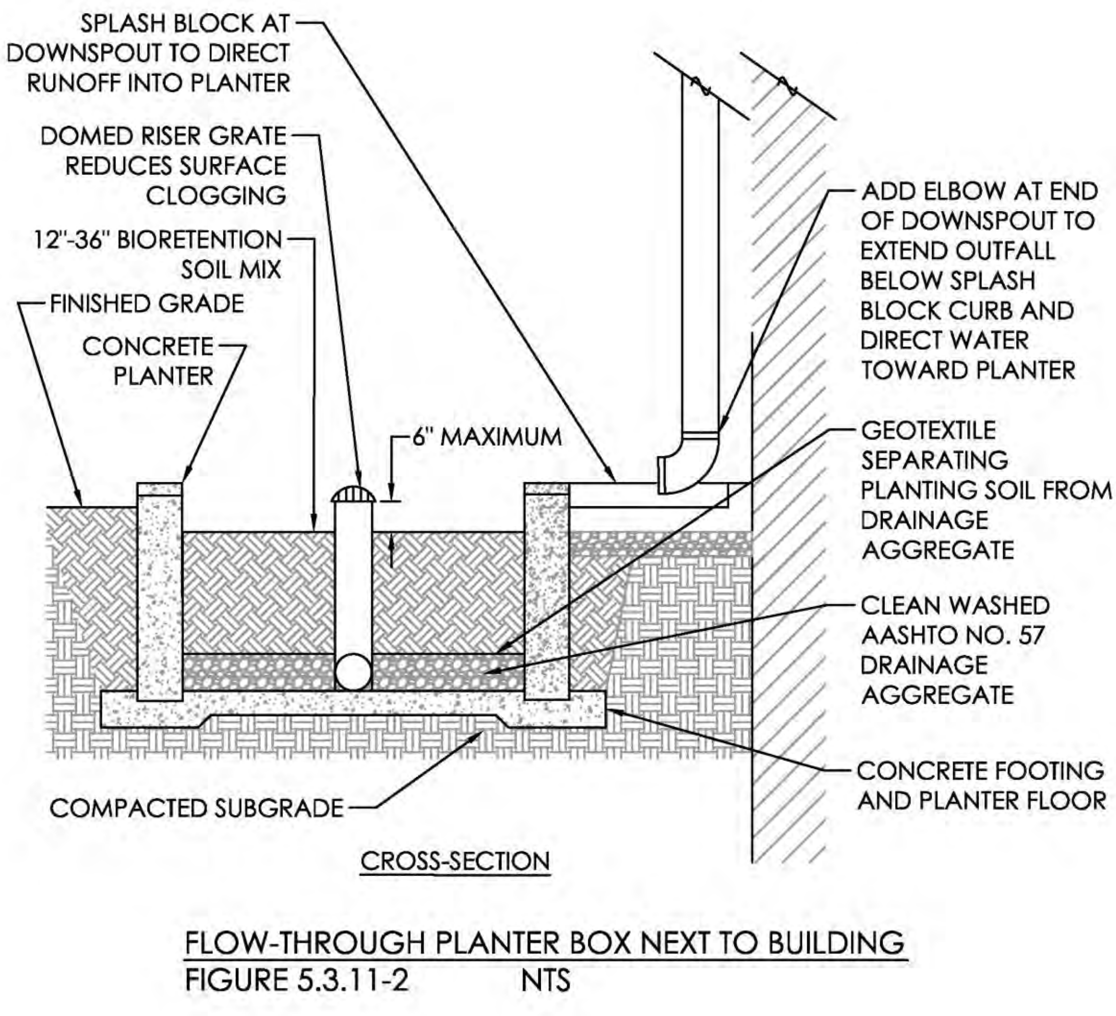


Figure 5.3.11-2. A typical cross-section for a flow-through planter box.

Applications

Planter boxes may be used in myriad ways in the urban and suburban environments, on residential, institutional, and commercial properties and within the public right-of-way. Potential applications include capturing roof runoff directly adjacent to buildings, within or along parking lots, adjacent to parking stalls on roadways, sidewalks and paths, plazas, playgrounds, and athletic fields and courts.

Streetside Planter Box

Figures 5.3.11-3a and b. This street was retrofitted to incorporate infiltration planter boxes within the right-of-way. Runoff enters the planter boxes through curb cuts.

Parking Lot Planter Box

Figure 5.3.11-4. Infiltration planter box within a parking lot, during construction. Water will enter through curb cuts, which are closed during construction. Note that the asphalt around the planter box was milled and repaved, allowing it to drain to the curb cuts following construction.

Institutional Planter Box

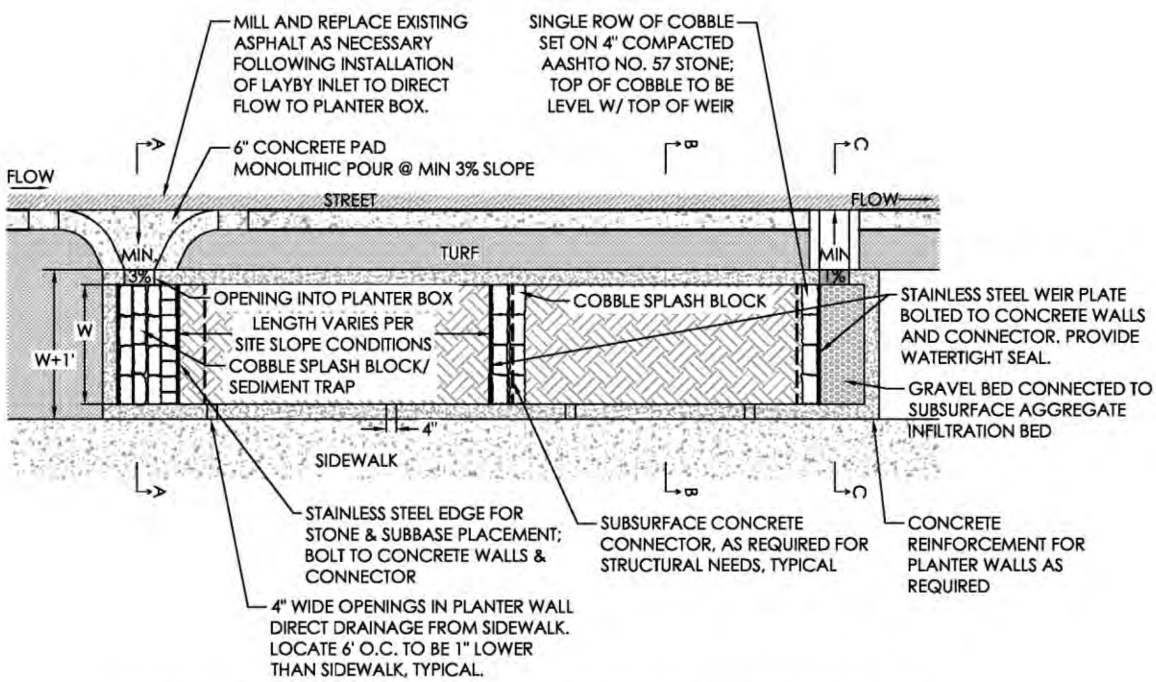
Figure 5.3.11-5. Flow-through stormwater planter boxes adjacent to this library receive roof runoff and provide plantings within the hardscape seating area. Overflow from these planter boxes is directed to a bioretention area (right side of photo). River cobbles (not shown) were added to eliminate any tripping hazard in a high-use area by reducing the depth of the planter box edge to the finished surface.

Variations

Curb Extensions/Curb Bump-Out

Large planter boxes constructed within and along a street are also referred to as "curb extensions" or "curb bump-outs." These are sometimes constructed within over-wide drive aisles to capture stormwater as well as to provide traffic calming. Curb extensions function in the same way as planter boxes in that they are curbed vegetated areas with soil and potentially stone for stormwater storage. Curb cuts allow the entry of roadway and sidewalk runoff to sheet flow into the system.

Curb bump-outs and curb extensions must be structurally designed with consideration of the traffic loads both during and after construction. Examples of curb extension planter box design details are shown on Figures 5.3.11-6 through 5.3.11-9.



STREETSIDE PLANTER BOX EXAMPLE (SLOPES ≤ 5%) WITH INFILTRATION BED PLAN VIEW
FIGURE 5.3.11-6 NTS

Figure 5.3.11-6. Example of streetside planter box (plan view). Weirs are used to "step" the sections of the planter box down the slope.

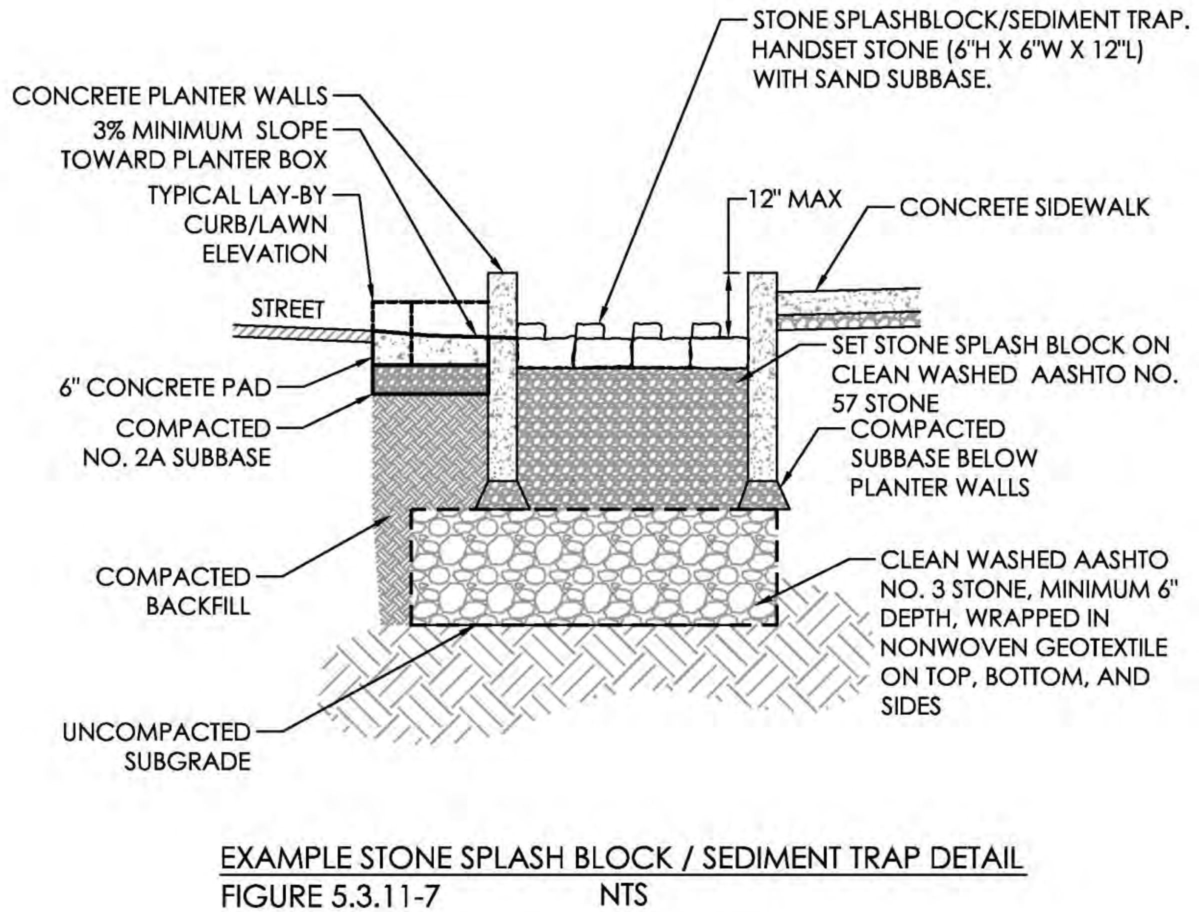


Figure 5.3.11-7. Example of the entrance conditions into a streetside planter box (cross-section A-A').

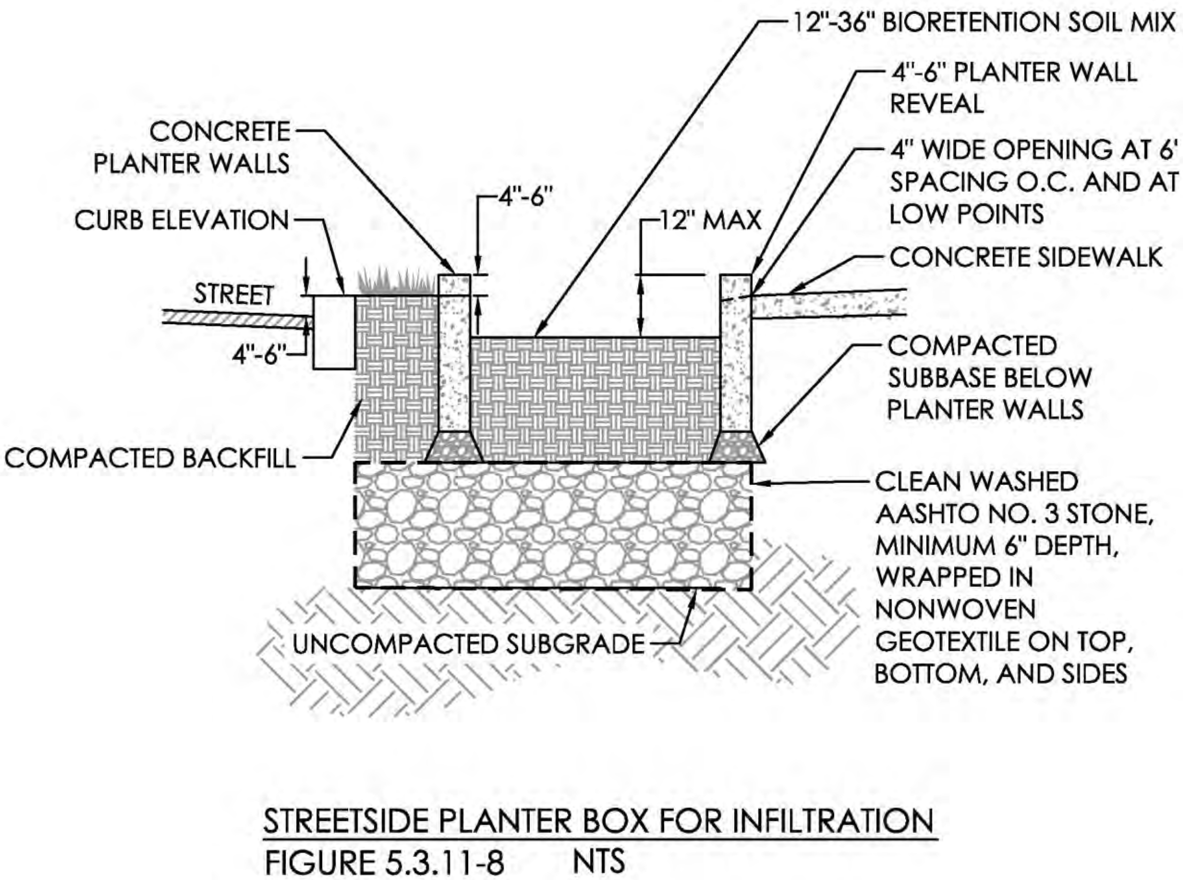


Figure 5.3.11-8. Example cross-section streetside planter box (cross-section B-B'). This planter box includes an underlying stone storage bed to increase storage capacity.

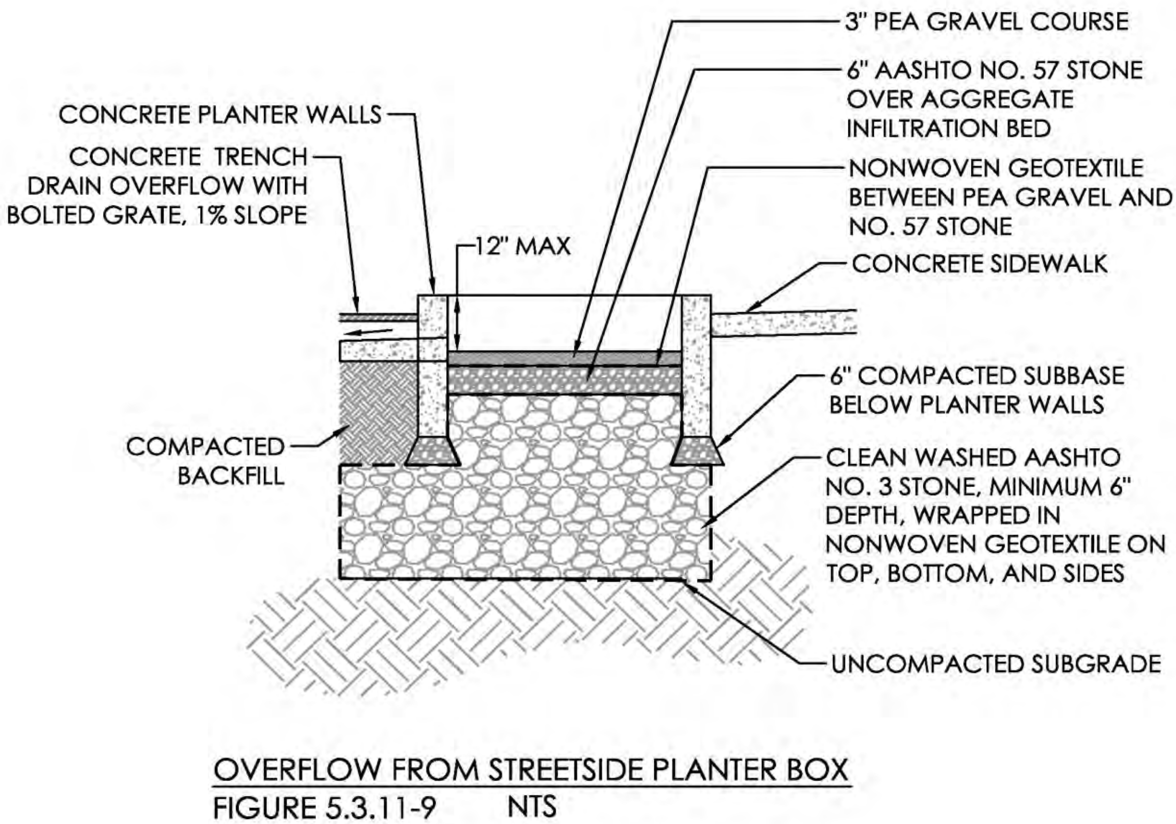


Figure 5.3.11-9. Example of the overflow (exit) from a streetside planter box (cross-section C-C'). In this application, a gravel connection to the underlying stone bed is provided.

Applicable Protocols and Specifications

The following Protocols and Specifications (see Appendices A through F) are applicable to planter boxes and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 2 Coordination with Other Utilities
- Protocol 3 Site Evaluation and Infiltration Testing
- Protocol 4 Infiltration System Design and Construction Guidelines
- Protocol 5 Planting and Mulching Guidelines

- Appendix F
  - Aggregates and Drainage Layers
  - Stormwater System Specifications
  - Bioretention Soil Specifications
  - Pipes
  - Control Structures
  - Geotextiles
  - Impervious Liners and Waterproofing

Design Considerations for Planter Boxes

The key design components for planter boxes discussed below allow design flexibility to ensure maximum performance from this BMP.

1. Location and Capture Area

- When possible, the planter box should be located directly downstream of the existing stormwater source to maximize runoff capture.
- Planter boxes shall be constructed a minimum of 2 feet behind the curb if they are located adjacent to on-street parking. If planters are constructed in an area where there is no parking or loading, they may be constructed directly behind the curb.
- Planter boxes may intrude into the walking zone a maximum of 1 foot. A minimum walkway width of 4 feet must be maintained, 5 feet is preferred, and even greater may be required on high-volume pedestrian streets. ADA requirements must be followed.
- Planter boxes may not be placed adjacent to a designated handicapped parking space.
- Planter boxes are best suited to capture smaller drainage areas and may only capture a portion of the SOV.
- If applicable, consider linking subsurface storage beds to complementary BMPs as part of a larger system, or “treatment train,” to achieve additional stormwater and streetscaping benefit.

2. Entrance/Flow Conditions

Runoff can enter a planter box from roof leaders or through stormwater pipes, sheet flow, or curb cuts. All planter boxes must be designed to receive flow that will not cause scour or erosion at the soil surface. Roof drains and concentrated flows should be directed onto a stabilized surface within the planter box, such as a splash block or cobbles, to minimize entrance velocities.

Curb cuts or trench drains are sometimes used to convey runoff from the street to stormwater planters. Curb cuts are used when planter boxes are constructed directly behind the curb (see Figure 5.3.11-10). Trench drains are used when the planter is set back from the curb and water must be conveyed under an area with pedestrian access. Concrete aprons can be placed on the street side of curb cuts or trench drains to facilitate capture. Splash blocks or another energy dissipater should be placed on the planter side of the trench drain to prevent erosion (see Figure 5.3.11-11). To capture sidewalk runoff, notches may be cut in planter walls every few feet, depending on grade and the size of contributing drainage areas.

Figure 5.3.11-10. Curb cuts convey street runoff into and out of this streetside planter box. Overflow from the planter box is captured by the downstream storm sewer inlet.

Figure 5.3.11-11. A concrete splash block at a downspout to a flow-through planter box prevents erosive conditions at the soil surface.

3. Management of Sediment, Trash, and Debris

Planter boxes may often collect sediment, leaf litter, trash, and other debris, so they may require frequent inspection and maintenance for removal of accumulated trash and debris. In areas of high trash or with specific concerns such as plastic shopping bags (a common concern in commercial areas), the entrance conditions may include a screen to prevent material from entering the planter box. Plant selection should consider the amount and type of trash that may enter the planter box. Items such as windblown plastic shopping bags that adhere to vegetation should be considered when selecting plants.

All plants, entry points, and structural components should be inspected and maintained in accordance with Chapter 8 of this manual.

4. Storage and Stay-on-Volume

A planter box provides volume management within the surface ponding area, the bioretention soil area, and the stone storage bed (if applicable). Because water must move **through** the bioretention soils, the entire volume is storage. This is different from non-vegetated BMPs, such as pervious pavement wherein the pavement section is excluded.

The **SOV** is a function of the storage volume available for the 1.0-inch or 1.6-inch storm.

Storage Volume (ft^3) =

Surface Water Volume + Soil Storage Volume + Stone Storage Volume

Surface Water Volume: Available surface water storage between soil surface and overflow structure (always equal to or less than 6 inches).

Soil Storage Volume: This is the bioretention soil volume x 0.20 void space ratio.

Soil Storage Volume (ft^3) = Soil Area (ft^2) x Soil Depth (ft) Below Overflow x Void Ratio

Stone Storage Volume: This is the stone storage volume x 0.40 void space ratio.

Stone Storage Volume (ft^3) = Stone Area (ft^2) x Stone Depth (ft) Below Overflow x Void Ratio

Void ratios are generally:

- 0.20 for bioretention soils
- 0.40 for clean-washed aggregate such as AASHTO No. 3
- 0.85 to 0.95 for manufactured storage units depending on manufacturer

5. Area and Dimensions

One of the benefits of planter boxes is that they can be adjusted to fit the dimensions of very small spaces such as narrow spaces adjacent to buildings, along walkways and streets, and adjacent to parking areas. Planter box surface depth and curb requirements should always be considered to avoid creating trip hazards for pedestrians. The bottom of each planter box should be level.

Planter boxes are typically designed to have some surface ponding and soil storage, and they sometimes are designed with stone storage below the planting soil. By constructing the planter box without a liner or concrete bottom, a planter box may be designed for infiltration.

A basic guideline is to plan for a planter box with a surface area that does not exceed a rule-of-thumb ratio of the impervious and compacted pervious areas draining to it. The amount of rainfall volume must also be considered. The following ratios based on design rainfall depth can be used to estimate a planter box area:

1-inch Rainfall
1:10 ratio of surface area to impervious drainage area

1.6-inch Rainfall
1:8 ratio of surface area to impervious drainage area

The dimensions of ponding depth, planting soil depth and width, and stone depth and width within a planter box are a function of the quantity and velocity of stormwater it is intended to receive, and the available space for construction. The designer should estimate the depth of water, soil, and stone storage using the Sizing Calculations Worksheet.

As a general rule-of-thumb, planter boxes should meet the following guidelines:

- Surface ponding depths should not be greater than 6 inches, especially when constructed in pedestrian areas.
- Planting soils should be a minimum of 12 inches in depth and should be adequate to support the vegetation types selected for planting.
- The internal dimensions of a planter box will vary based on site conditions and the desired stormwater capture.
- If stone storage is required, the footprint of the stone may extend outside of the limits of the planter box if it is constructed without a bottom.

The recommended depths for surface water storage, soil storage, and stone storage are:

Surface Water Storage Depth: 6 inches maximum in high-use areas (along streets, at schools, in public landscapes, etc.)

Bioretention Soil Depth: Between 12 and 36 inches

Stone Storage Depth: Minimum 6 inches

6. Overflow and Peak Rate

All planter boxes must provide a safe way for water to exit the system when large storms generate more stormwater runoff than the planter box can hold. The inclusion of a positive overflow route ensures that flooding risks and related property damage are minimized.

The positive overflow route is often in the form of a domed riser or grated pipe that is placed within a planter box at the maximum ponding depth elevation (see Figure 5.3.11-12). The domed riser or grated pipe may create a direct connection of the planter box surface to the subsurface soil or stone, and it may also serve as a positive overflow connection designed to allow high flows to be conveyed through the device to an approved discharge point. **The minimum allowable diameter of an overflow pipe for small**

planter boxes (such as adjacent to buildings) is 4 inches. All overflows must safely convey the 10-year peak rate. Designs should also ensure that in the event that an overflow pipe becomes clogged or a rain event larger than a 10-year event occurs, then overflows will have a safe emergency escape route rather than being allowed to flood buildings or other structures.

Figure 5.3.11-12. A grated pipe in a stormwater planter box provides overflow to existing storm sewer when ponding above the designed water level occurs on the surface (similar to Figure 5.3.11-2).

Planter boxes designed with surface entry points, such as through curb cuts or trench drains, may be graded such that, once full, they do not receive any more water and flow back onto the contributing surface to a complementary BMP or other approved discharge point.

Peak Rate Control and Infiltration Credit

For the purposes of site peak rate control, the designer may adjust the curve number value based on the volume managed by both the SOV and the infiltration volume that occurs during a portion of a 24-hour storm event. This will allow the designer to account for runoff that was captured by applying LID, and develop a representative lower curve number. This is described in Chapter 7.

When adjusting the curve number, the infiltration volume can be estimated as the infiltration that occurs during 12 hours of a 24-hour design storm. This will ensure that estimated infiltration volumes are not greater than the actual volume captured within the BMP.

Infiltration Volume (ft^3) = Planter Box Bottom Area (ft^2) x Infiltration Rate (in/hr) x 1/12 x 12 hours

7. Freeboard

It is recommended that planter boxes include a **minimum of 4 inches of freeboard** above the overflow route. Higher freeboard may create a deeper planter box surface, which may be undesirable in pedestrian areas. The designer should consider the potential for flooding onto sidewalks or other areas and provide control measures.

8. Underdrain

When a planter box is not designed for infiltration but is constructed with a liner or an impermeable box structure, an underdrain is required. The underdrain is used to ensure that water moves through the system so water does not pond for excessive time periods on the surface or become stagnant below grade. **Underdrain systems must be included in the design if the native soil infiltration is less than 0.1 inch per hour or if the system is lined with an impervious liner** and intended for slow release only. Underdrains must be located at the intended bottom of the planter box system (i.e., below soils and stone if applicable). See Protocol 3 for the infiltration testing procedure and Protocol 4 for infiltration system guidelines.

Planter boxes require very low discharge rates when managing the water quality volume. However, planter boxes are generally small in area and it may be difficult to construct an underdrain that can extend the discharge rate over more than 48 hours. Planter boxes that capture less than 1,000 square feet of impervious drainage are assumed to provide water quality volume with a discharge of the water quality storm between 24 and 48 hours.

9. Waterproofing

Planter boxes are uniquely able to fit into spaces where space limits the use of other BMPs, such as adjacent to structures and roadways. When planter boxes are designed near existing infrastructure or buildings, they should be designed with a liner or impermeable box structure to prevent water from causing damage to foundations and other infrastructure components (see Figure 5.3.11-13). The liner, if applied, must meet the guidelines provided in the Stormwater Specification. It is recommended that planter boxes adjacent to buildings be fully lined. Other planter boxes, such as along streets and parking lots, may be designed to discharge through the bottom of the planter box provided that the requirements of Protocol 1, Setbacks from Structures, and Protocol 2, Coordination with Other Utilities are met.

Figure 5.3.11-13. A waterproof liner is placed in the stormwater planter box to protect the adjacent building.

10. Bioretention Soils

Planter boxes should have soils adequate to support vegetation and stormwater absorption, and should meet the intent of the soils specified in Appendix F – Bioretention Soil Specification. If the planter box is intended to infiltrate, it is essential that the native subsoil within the infiltration footprint is not compacted with construction equipment.

Planter box bioretention soils must never be placed when wet or during wet weather. Soils should be protected from saturation until plant installation, and from sediment deposition into the planter box.

11. Vegetation

The type of plant and planting plan for planter boxes must comply with Protocol 5 (Appendix E) of this guide. Plants appropriate to the aesthetic and visibility needs of planter boxes should be specified. When located along streets, plant material selection must consider visibility for traffic needs. Plants cannot grow to block signs or obstruct views.

12. Water Quality/Total Suspended Solids

Planter boxes that can capture and manage the required SOV through infiltration are considered to meet all water quality requirements. Planter boxes that are underdrained must be sized to provide water quality treatment. See Chapter 7 for additional discussion.

Sizing Calculations Worksheet for Planter Boxes

(Link to worksheet)

Construction Considerations

Planter boxes should be built in the final phase of construction to prevent damage.

No sediment-laden waters should enter the planter box at any time. The planting of vegetation should coincide with the plant's growth cycle to promote successful establishment, and the planter box should be protected from runoff entering until the vegetation is adequately established.

Construction Sequence Example

Step 1 Excavate Planter Box

a. Protect planter box area from sediment and stormwater runoff during construction.
b. Excavate to the bottom elevation of the system, either the bottom of soil, the bottom of the stone, or the bottom of the structural box. If the planter box is designed for infiltration, care should be taken not to compact the existing subsoil.

Step 2 Install Planter Box

a. Construct planter box sides (and bottom) as required (see Figure 5.3.11-14).
b. Place geotextile at the bottom elevation of the excavated area for an infiltration planter box. For a flow-through planter box, place liner or waterproof constructed box (see Figure 5.3.11-15).
c. Install underdrain system if required.
d. Install stormwater piping and structures at specified elevations. Ensure that all stormwater structures are protected from sediment.
e. Fill planter box with planting soil and/or stone at elevations specified in the design (see Figure 5.3.11-15). Complete final grading of the planter box after the top layer of soil is added. Lightly tamp down soil.
f. Construct splash blocks at entry points to the planter box.
g. Construct curb cuts and/or trench drains into the system if applicable.
h. Seed and vegetate according to plans. Plant the planter box at a time of the year when successful establishment without irrigation is most likely. Temporary irrigation may be needed in periods of little rain or drought.
i. Mulch planted area with compost mulch to prevent erosion while plants become established.
j. Protect planter boxes from sediment at all times during construction.
k. Before erosion and sediment control measures are removed or downspouts are disconnected in a planter box, verify that vegetation is sufficiently established.

Figure 5.3.11-14. A stormwater planter box during construction. The sidewalls of the planter box are constructed once the final surface grade outside the box is met.

Figure 5.3.11-15. A stormwater planter box that includes a stone bed during construction with geotextile to separate the soil and stone.

Operations and Maintenance

Both the structural components and vegetation within planter boxes require routine inspection and maintenance. Plants may require additional water during extremely dry periods and care should be exercised to ensure that appropriate measures are taken to protect plantings during periods of frost and other damaging weather events.

All inflow and outflow structures must be inspected and maintained to ensure removal of accumulated sediment and debris. See Chapter 8 for additional guidance.

5.3.12 Manufactured Devices (Proprietary Devices)

Description

Manufactured devices are pre-fabricated devices that implement technologies ranging from filtration and adsorption to vortex separation and settling to treat stormwater prior to discharge from a site.

There are many manufactured devices marketed by proprietary vendors to treat stormwater runoff. Common types of manufactured devices include hydrodynamic devices, catch basin inserts, cartridge filters, and biotreatment devices. Manufactured devices provide stormwater treatment with varying degrees of effectiveness.

Manufactured devices are effective as a water quality treatment component of a stormwater treatment system, or treatment train, which includes volume-reducing BMPs.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Manufactured Devices*	U/S/R	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H	L/M/H

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Ratings vary between manufactured products and their application in design.

Key Design Features

- Hydraulic flow capacity of each manufactured device must match that of design storm event flows to achieve desired performance.
- Incorporate into a stormwater system or treatment train for optimal performance.
- Manufacturer installation, operation, and maintenance instructions must be followed to ensure performance.

Applications

- Roadways, walkways, and parking stalls
- Parking lots

- Playgrounds, plazas, and basketball and tennis courts
- As part of multifamily housing and commercial office areas
- Institutional: schools and university campuses

Advantages

- Can be used in areas with restricted space.
- Can be used in areas with limited infiltration capacity.
- May be engineered to target specific pollutants.

Disadvantages

- Performance is highly dependent on matching hydraulic flow capacity to that of design storm event flow rates.
- Devices are not typically visible and may be "forgotten."
- More frequent maintenance may be required as compared to traditional technologies.
- Review time may be longer for evaluation of projected performance (third-party verified pollutant removal rates).

Applications

Manufactured devices may be used in urban and suburban environments, on residential, institutional, and commercial properties, and within the public right-of-way. Potential applications include roadways, alleys, sidewalks and paths, plazas, playgrounds, and athletic fields and courts. Manufactured devices may be implemented on virtually any project site if they are designed and constructed to meet the manufacturer's specifications.

Applicable Protocols and Specifications

The following must be submitted to the City at the time of application: manufacturer specifications; engineering drawings of the assembled device; manufacturer's installation, operation, repair, and maintenance instructions and recommended schedule; and any other information relevant to the application of the specific manufactured device from the manufacturer. Third-party verification of device performance must also be submitted to the City for review and consideration prior to approval.

Design Considerations for Manufactured Devices

Vendors are continually expanding and updating manufactured devices; design guidance from each applicable vendor should be consulted prior to design. At a minimum, manufactured devices must meet the following criteria:

- Selected manufactured devices must have 80 percent minimum treatment effectiveness for the removal of total suspended solids.
- Selected manufactured devices must not pond water for more than 72 hours following a storm event.
- Selected manufactured devices must not degrade water quality by resuspending floatable debris, or total suspended solids, or by leaching pollutants during subsequent storm events.
- Selected manufactured devices must not be constructed at a depth that is inaccessible by a vacuum truck/hose for cleaning and maintenance.
- Selected manufactured devices must provide a mechanism to bypass flows during storm events that exceed the water quality design peak flow rate for the device.
- Selected manufactured devices must provide a mechanism by which flows may be diverted for isolation of the device during maintenance and repair.

1. Location and Capture Area

Designed properly, manufactured devices may be incorporated on a variety of sites. With regard to hydrodynamic devices, it is important to control inflow rates. To do this, it is crucial to understand the hydraulic capacity of the device and the flow rates from contributing drainage areas.

2. Entrance/Flow Conditions

The primary design consideration for most manufactured devices is the peak rate of runoff entering the device. Devices that rely on vortex separation and/or filtration must be designed with careful consideration of peak rates of inflow into the device.

All manufactured hydrodynamic devices must be located such that inflow velocities do not exceed the maximum treatment flow rate specified by the vendor.

Upstream conveyance structures (pipes, swales, etc.) should be designed to discharge into manufactured devices at velocities no greater than the vendor-recommended maximum flow rate.

3. Freeboard

All manufactured devices must meet vendor construction specifications, including sump and freeboard requirements.

4. Management of Sediment, Trash, and Debris

Manufactured devices must not degrade water quality by resuspending floatable debris or total suspended solids or by leaching pollutants during subsequent storm events. Careful hydraulic design and diligent maintenance are required for ensured performance of manufactured devices.

5. Storage and Stay-on-Volume

Manufactured devices designed to treat runoff through filtration and/or settlement must carefully consider storage capacity and discharge velocity to ensure water is retained in the device for an appropriate length of time to allow for pollutant removal.

6. Overflow

All manufactured devices must be capable of conveying larger storms without resuspending floatable debris and/or accumulated sediment.

7. Water Quality/Total Suspended Solids

Manufactured devices must have an 80 percent minimum treatment effectiveness for total suspended solids (at the flow rate specified, when applicable), and be certified by an independent, third-party testing laboratory prior to consideration by the City. All manufactured devices should be field tested (laboratory testing of field-collected samples) and monitored after installation to ensure achievement of 80 percent total suspended solids removal.

Construction Considerations

All manufactured devices must be constructed in accordance with vendor-recommended construction specifications.

Operations and Maintenance

Operation and maintenance of manufactured devices must be performed in accordance with vendor-recommended construction specifications.

Specifications

A copy of all relevant vendor specifications must be submitted to the City prior to stormwater management plan approval.

5.3.13 Naturalized Basins and Retrofitting Existing Detention Basins

Description

A naturalized basin is a flat-bottomed, vegetated, and shallow basin that collects and filters runoff, allowing pollutants to settle out as water infiltrates or is retained in planting soils. A naturalized infiltration basin is designed to retain the SOV or required stormwater volume with no surface discharge. The basin and outlet structure are also designed to provide peak flow rate control. A naturalized detention basin can provide peak rate mitigation while also reducing runoff volume, improving water quality, and providing temperature mitigation. Habitat creation and reduced maintenance (mowing) may be additional benefits.

Retrofitting an existing traditional detention basin into a naturalized basin can be a very cost-effective retrofit method, especially in developed areas where existing basins only provide large storm peak rate mitigation.

A naturalized basin includes:

- A level bottom that allows runoff (in small rainfall events) to disperse across the basin bottom, increasing contact with soils and vegetation.
- Soils and vegetation that retain some portion of the initial runoff, improve water quality, and mitigate temperature impacts.
- A “lengthened” and often meandering flow path through the basin that prevents flows from shortcutting rapidly through the basin.
- A sediment forebay or stabilized discharge location for flows entering the basin to slow velocity, prevent erosion, and allow initial settling and sediment removal in an area that is easily maintained.
- A modified outlet structure designed to retain some volume of initial runoff within the basin, with no surface discharge. The basin may be designed to infiltrate, or for the soils to hold and evapotranspire small amounts of runoff in the same manner as a green roof.

Figures 5.3.13 -1a and b. This detention basin in a residential neighborhood was retrofit to become a naturalized detention basin.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Naturalizing Detention Basins	U/S/R	H	H	H	H	H	H	H	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Features

- A level or nearly level (0.5 percent slope) bed bottom across the basin that allows water to disperse over a large planted area. The bottom may be graded to include small, isolated pools of shallow additional depth (2 to 4 inches) if desired.
- A meandering flow path to increase the travel length and time of small storms through the basin. This may include berms or other grading measures.
- A sediment forebay or other measures to trap coarse sediment at entrance locations into the basin.
- Modified soils that absorb and potentially infiltrate runoff.
- A modified outlet structure that retains the SOV portion of runoff.
- Capacity to mitigate peak flow rates, but with limited high water depth (in new basins) to avoid excessive inundation of plantings.
- Limited side slopes with 3:1 maximum recommended in new naturalized basins and 4:1 preferred.
- Naturalized plantings that can tolerate frequent shallow wet conditions and occasional inundation. Plantings, especially deep-rooted vegetation systems that maintain soil porosity, are critical to the success of a naturalized basin.
- Lawn is not acceptable for a naturalized basin. Typical lawn grass has a shallow root system and requires frequent mowing, both of which contribute to limited soil porosity.
- Grasses and vegetation should not be mowed to less than 4 inches in height.
- A design and maintenance plan that allows for mowing and removal of vegetation at the end of the growing season. Access for mowing and sediment removal must be provided.
- Limited depth of basin to ensure sufficient light conditions to support vegetation.
- If appropriate, a maintained edge that provides a transition from manicured landscapes to naturalized landscapes.

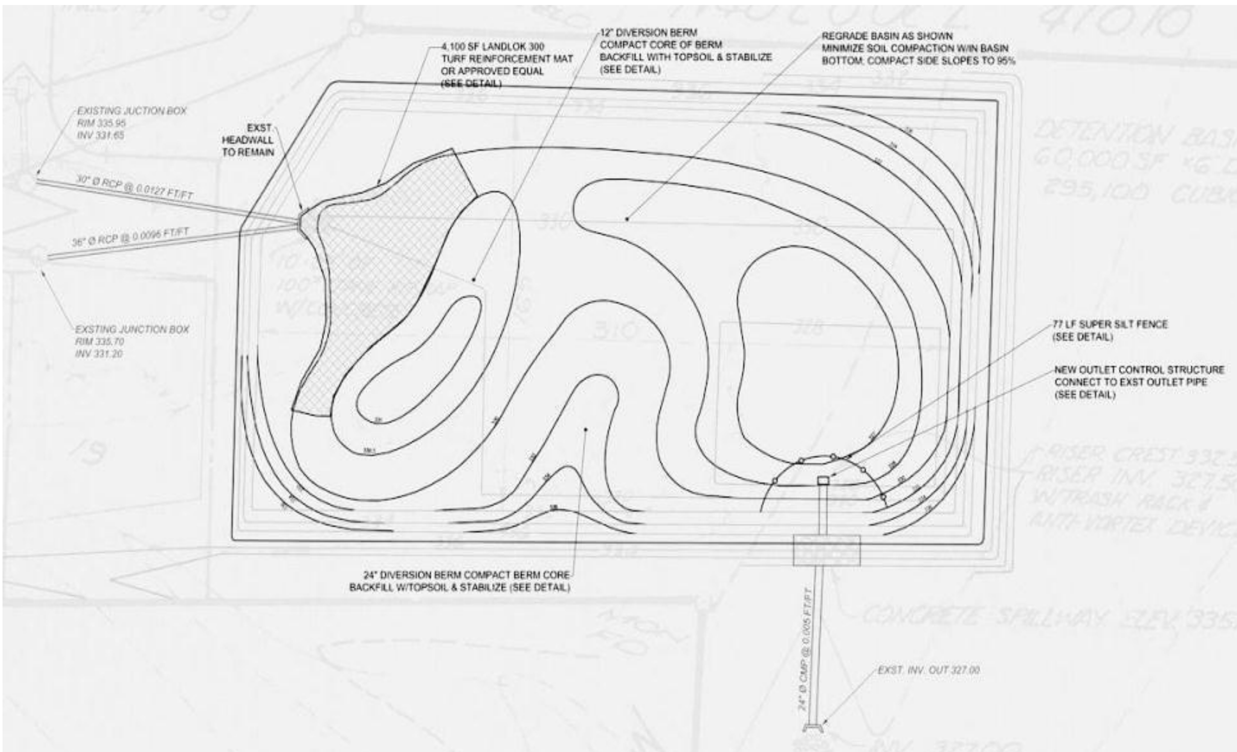


Figure 5.3.13 -2. Example of design components for retrofitting an existing detention basin into a naturalized basin. Key structural components include a more level bottom with berms to divert flow through the basin, a stabilized entrance and berm to disperse erosive flows, and a modified outlet structure to retain small storms.

Applications

- May be implemented in residential, commercial, institutional, and public facilities
- Well suited for linear basins, such as alongside roads and highways
- Excellent option for retrofitting existing dry detention basins (high value)

Advantages

- Provides volume reduction through retention of small storms.
- Provides peak rate attenuation for large and small storms.
- Improves water quality by allowing sediments to settle and nutrient uptake by vegetation.
- May provide habitat for wildlife. Plantings can be designed to increase bird habitat.
- Low maintenance burden after vegetation is established. May reduce mowing and maintenance requirements as compared to a mowed basin.

- Cost-effective, especially as a retrofit option.
- Retention of small rainfall events may reduce erosive stream conditions downstream of existing detention basins.

Disadvantages

- For newly constructed basins, may require a larger footprint to maintain a limited high water depth and still provide peak rate control.
- Requires an alternate maintenance regime.
- Maintenance personnel must be made aware of specific maintenance requirements that are different than conventional mowing.
- Cannot be “forgotten” as maintenance is required for basin performance.
- Vegetation must be harvested to prevent release of captured nutrients.
- Signage may be required to inform the public of intended naturalized conditions. Perceptions that basin is “not maintained” must be addressed with education.

Figure 5.3.13 -3. Concept rendering showing how berms can be used to increase the flow path through a naturalized basin.

Applications

New Commercial Naturalized Basin

Figure 5.3.13 -4. This naturalized basin captures runoff from a high traffic roadway. The basin is broad and shallow to limit the maximum water depth in extreme events.

Public Basin Retrofit

Figures 5.3.13-5a and b. The existing detention basin in this community park was modified to capture ½-inch rainfall events and to eliminate an erosive flow path condition.

Applicable Protocols and Specifications

The following protocols and specifications (see Appendices A through F) are applicable to naturalized basins and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 2 Coordination with Other Utilities

- Protocol 3 Site Evaluation and Infiltration Testing (for swales intended to infiltrate)
- Protocol 4 Infiltration System Design and Construction Guidelines (for swales intended to infiltrate)
- Protocol 5 Planting and Mulching Guidelines
- Appendix F Specifications
  - Stormwater System Specifications
  - Bioretention Soil Specifications
  - Aggregates and Drainage Layers
  - Pipes
  - Control Structures
  - Geotextiles
  - Impervious Liners and Waterproofing

Design Considerations for Naturalized Basins and Retrofitting Existing Detention Basins

The key design components for naturalized basins are provided below. When retrofitting an existing detention basin, it is not always possible to adhere to all design criteria.

1. Location and Capture Area

Locate a new naturalized basin:

- At a lower drainage point on a site to capture portions of the site that have not been addressed by other BMPs.
- To receive discharge from other BMPs, and to meet any remaining SOV and peak rate needs.
- To receive runoff from high sediment areas such as roads and high-use parking lots.
- At locations where a naturalized landscape is appropriate to the land use type and will not create concerns.
- Outside of floodplains and riparian buffers.

Existing detention basins that are good candidates for retrofits (based on location) are basins that:

- Receive direct runoff from roads and parking lots, and can be modified to reduce sediment and temperature impacts from these areas.
- Basins that discharge directly into a stream or waterway. These basins generally were designed to allow the small frequent runoff events to quickly pass through the basin. Capturing and retaining any portion of these frequent events will improve water quality.
- Basins that have a large, relatively flat bottom, or can be regraded to create one.

Slopes

- Naturalized basins require a level and expansive bottom area, and are not well suited to construction on steep (15 percent) and very steep slopes (>25 percent).
- Naturalized basins should not discharge onto steep or very steep slopes, and should not discharge at flow rates that will create erosive conditions. Naturalized basins should be set back a minimum of 100 feet from downstream slopes greater than 10 percent.
- Naturalized basins can receive runoff from drainage areas that are steep or very steep, but entrance velocities into the basin cannot be erosive, and a larger sediment forebay is recommended.

2. Entrance Conditions: Sediment Forebay

Both naturalized basins and existing detention basins that are being retrofitted must include a sediment forebay at each inflow location. A sediment forebay is a settling pool or plunge pool at the inflow location that allows coarse-grained sediment to settle out before runoff is distributed throughout the basin. A sediment forebay can prolong the life of a naturalized basin and allow for easier maintenance by trapping sediment and debris within a confined area. The sediment forebay should be visible and accessible for maintenance.

A sediment forebay is constructed by excavation to create a berm from native material, or by constructing earthen berms, gabions, rock check dams, or rip-rap berms. These structures allow overflow into the larger basin. Key design criteria for a sediment forebay include:

- Capacity to capture between 0.1 inches and 0.25 inches of drainage area runoff volume within the forebay. Areas of high sediment should capture 0.25 inches within the forebay. For retrofit basins, forebay capacity is often a function of what can be achieved within the constraints of an existing basin's drainage area and dimensions but a general rule the forebay volume should be approximately 25% of the total basin volume.
- Wet or dry conditions between storms, or a mixture of both. A sediment forebay may have portion that is dry between storm events to facilitate cleaning and maintenance. A sediment forebay should be designed with a pool near the discharge point that remains wet between storms.
- Designed for non-erosive entrance flows. This may include hardscape measures (rip-rap, cobbles) to disperse flow through the vegetated forebay area, berms to disperse flow, or the use of TRMs.
- Earthen berms must be non-erosive when overtopped in large storm events. Berms can be evaluated as low-head weirs. Earthen berms should be stabilized with erosion control fabrics if necessary.
- Limited in average depth (not greater than 18 inches). Pool areas may be deeper.
- Slightly higher in elevation (1 to 2 feet) than the remaining naturalized basin. This is not always feasible in a retrofit basin.

- Constructed with a permanent stake or marking indicating depth to where sediment should be removed from forebay during maintenance.

3. Flow Conditions: Flow Path Through Basin

Traditional detention basins do not provide any consideration for management of the small frequent rainfall events, or the initial runoff from larger events. Basins are often designed to intentionally discharge small storms with little or no rate control (to maximize detention capacity during large events). As a result, small rainfalls pass through the basin quickly with limited opportunity for pollutant removal.

Figure 5.3.13-6. The concrete low-flow channel in this existing basin was removed as part of a retrofit. A meandering, vegetated flow path was created in its place.

Naturalized basins are designed to capture the small storm runoff volume, and maximize the ability of runoff to contact vegetation and soils. In addition to a sediment forebay, the basin can be designed to extend the flow path through the basin. This can be done with slight grading and planting berms to force the runoff to disperse widely through the basin bottom area.

Grading to create an extended flow path through a basin is especially useful when retrofitting an existing basin, especially if the basin was designed with inlet and outlet conditions that “shortcut” the flow through the basin.

In retrofitting basins, existing concrete or other low-flow channels should be removed.

4. Naturalized Basin Soil Media

Existing soils can be modified with sand and compost for use in naturalized basins. It is generally impractical to replace existing soils for large basins, but the soils can be modified as necessary. The growing media can be a blend of existing soils, sand, and compost that is 30 to 40 percent compost by weight. The following gradation is recommended:

Sieve Size	Percent Passing
1”	100
No. 4	75 – 100
No. 10	40 – 100
No. 40	15 – 50
No. 100	5 – 25
No. 200	5 – 15

The blend shall have a Coefficient of Uniformity (D60/D10) equal to or greater than 6 to ensure that it is well graded (has a broad range of particle sizes).

The modified soil depth should be between 12 and 18 inches.

5. Dimensions and Area

To support healthy vegetation, naturalized basins must have a limited depth of water during frequent rainfall events, and this water must infiltrate, evaporate, or slow release between rainfall events. During the infrequent large storm events, the water depth and duration cannot cause damage to the existing vegetation. The vegetation and alternating wet and dry conditions are required to maintain soil porosity. The following dimension ranges are recommended:

- Sediment Forebay Depth:
  - 12 to 18 inches, wet pools may be deeper
- SOV Surface Water Depth at Outfall from Basin:
  - 6 to 12 inches (depths of 8 inches or less preferred)
- Maximum High Water Depth During Large Events (for new basins):
  - 3 to 4 feet (2- and 5-year events); 5 feet (10-year and larger events)
- Side Slopes:
  - 3:1 maximum (existing basin side slopes should not be modified)
- Freeboard:
  - 1 foot
- Basin Bottom Slope:
  - Not greater than 0.5 percent
- Length to Width Ratio:
  - 3:1 or greater as measured from inflow to outflow

Retrofit detention basins cannot always be modified to meet the recommended dimensions for new naturalized basins. This should not preclude retrofitting the basin, as volume and water quality improvements will still be achieved.

Naturalized basins are often the most "downstream" BMP applied on a site, providing both SOV and peak rate control. The size and surface area of a newly constructed naturalized basin are a function of the SOV from the drainage area that will discharge to the naturalized basin, less any SOV that has been captured by other BMPs within the drainage area. Dimensions are also determined by the required storage for peak rate mitigation. Because the maximum surface water depths are limited so as not to damage vegetation, and because sufficient bottom area must be provided to meet SOV requirements, a naturalized basin may have a larger area than a traditional deep detention basin. Designers are encouraged to implement upstream BMPs and reduce the size of any new naturalized basins.

Naturalized basins are likely to receive runoff from a mix of land uses. A naturalized basin should be designed with a bottom surface area that does not exceed a recommended ratio of the impervious and compacted pervious areas draining to it. The amount of rainfall volume must also be considered. The following "rule of thumb" ratios based on design rainfall depth can be used to estimate a naturalized basin bottom surface area:

<u>1-inch Rainfall</u>
1:10 ratio of surface area to impervious drainage area

<u>1.6-inch Rainfall</u>
1:8 ratio of surface area to impervious drainage area

<u>Retrofit Basin:</u> When retrofitting an existing basin, the bed bottom area is limited by existing conditions within the basin. Most detention basins are designed with a slope toward the outfall structure. To increase the bed bottom area of an existing detention basin, and to create capacity for volume capture (without impacting peak rate detention capacity), the basin can be excavated and graded to create a new and level bottom.

Figure 5.3.13-7. In addition to modifying the basin itself, the outflow structure can be modified to retain volume. A simple weir plate at an existing headwall is often a cost-effective outlet modification. This basin was modified to retain a 4-inch water depth below the weir.

The SOV for a retrofit basin is usually determined by the existing drainage area and the extent to which the existing basin can be regraded and/or excavated to capture volume. Many retrofit basins will not be able to achieve the prescribed SOV, but even a partial SOV capture of ½ inch or less can have significant benefits.

6. Storage and Stay-on-Volume

The **storage** capacity of a naturalized basin is a function of the volume **below** the lowest overflow structure invert. This includes the surface water storage plus the storage within the modified soils:

Storage Volume (ft^3) = Surface Water Volume + Soil Storage Volume

Surface Water Volume: Available surface water storage beneath the lowest overflow structure invert.

Soil Storage Volume: The available storage in modified soils and planting areas. This is estimated based on the depth and area of modified soils and a void space ratio of 0.20.

For new naturalized basins, designers are strongly encouraged to implement an LID approach and incorporate additional BMPs to achieve the required SOV.

7. Peak Rate Control

New naturalized basins must meet the design requirements indicated above while also meeting the City requirements for detention basin performance and construction. Retrofit naturalized detention basins must retain their peak rate control capacity as originally intended and designed. For this reason, increased basin capacity is sometimes achieved by slightly excavating and regrading the basin bottom to provide for increased capacity below the existing maximum detention storage elevation of the basin.

8. Freeboard

Naturalized basins that are designed to provide peak rate control must provide the required freeboard in accordance with City requirements. Retrofit basins may be modified to allow a smaller freeboard (not less than 6 inches) if the City determines that conditions allow a smaller freeboard.

9. Underdrain

Underdrain systems must be included in the design if the native soil infiltration is less than 0.1 inch per hour or if the system is lined with an impervious liner and intended for slow release only. Underdrains must be located at the intended bottom of the naturalized basin (i.e., below modified soils). See Protocol 3 for the infiltration testing procedure and Protocol 4 for infiltration system guidelines.

Naturalized basins and retrofitted systems may require very low discharge rates to achieve infiltration and/or manage the water quality volume. Constructing a very small orifice will often achieve this, but a small orifice is easily subject to clogging.

One method for achieving a low discharge rate is to install a perforated pipe at the bottom elevation of the basin area. If the pipe is located in the modified soils, it must be set in clean-washed gravel and wrapped in non-woven geotextile to prevent soil movement. A perforated low-flow pipe can be set directly in a stone stormwater bed. The perforated pipe connects to a stormwater structure (such as a catch basin) with a transition coupling for a very small orifice. Various products are available for this purpose.

If infiltration is limited, the naturalized basin may allow for up to 1 inch of surface water storage depth without an underdrain if the top 12 inches of soil have been modified and the ponding area is fully vegetated. This area can be assumed to evapotranspirate or perform as a green roof system.

10. Management of Sediment, Trash, and Debris

In areas of high sediment load, basins should include measures to prevent the movement of material toward the berm and infiltration area.

To prevent erosion during the establishment of vegetation, temporary ECBs should be placed over the basin slopes and infiltration area. If basins are constructed in areas with relatively high runoff velocities where channelization is evident or where soils are currently eroding, it may be appropriate to use permanent TRMs.

Any trash or debris that collects behind berms should be removed regularly.

Woodchip or bark mulch should not be used in a naturalized basin because such material is inclined to float or move during large storm events.

11. Water Quality/Total Suspended Solids

Naturalized basins that can capture and manage the required SOV through capture and infiltration are considered to meet all water quality requirements. Naturalized basins that are underdrained but can capture and treat the required water quality volume as defined in Chapter 7 are also considered to provide water quality treatment. The underdrain must be designed for slow release in accordance with the requirements of Chapter 7.

12. Public Awareness and Signage

Naturalized basins may appear unmaintained to a public that is accustomed to basins that are mowed, especially for a retrofit basin when there is a change in appearance. This should be addressed by:

- Signage that informs the public of the functions and intention of the basin, including the landscape.

- A mowed edge of 4 to 6 feet in width at the edge of the naturalized portion of the landscape to create a transition between "natural" and manicured landscapes. For retrofit basins, the top berm of the basin can serve this purpose.

Figure 5.3.13-8. Signage can help the community understand the importance of the naturalized basin and the intent of the "natural" landscape.


Figure 5.3.13-9. A mowed edge can create a transition between a "natural area" and a manicured landscape.

Construction Considerations

For the best success, naturalized basin areas should not be installed and planted until site construction is complete and site stabilization has occurred. Naturalized and/or existing basin areas completed before site stabilization **must** be protected from receiving sediment-laden runoff. Runoff should be directed around completed basin areas until site stabilization has occurred. Sediment-laden water should not be allowed to enter modified soils.

The excavated capacity of a basin may be used as a temporary sediment trap area during construction. The bottom elevation during use as a sediment trapping and storage measure should be a minimum of 1 foot higher than the final bed bottom elevation. At the time of conversion from a sediment measure to a basin bed, any sediment and the remaining 1 foot of material should be removed for construction of the infiltration bed.

Construction Sequence Example

Step 1 Excavate and Prepare Subgrade

a. The bottom of a naturalized basin shall not be compacted or subject to excessive construction equipment traffic. Protect areas from vehicle traffic during construction with construction fence, silt fence, or compost sock.
b. The naturalized basin should not receive runoff from any disturbed areas in the drainage area until these areas have been stabilized.
c. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding in the graded bottom, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent by light tractor.

d. A naturalized basin may be used as a sediment trap during construction, provided that the basin is not excavated to the final bottom elevation until the site is stabilized.

Step 2 Install or Modify Outlet Structure, Berms, and Stabilization Measures at Inflow Locations

a. If possible, close and secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering the naturalized basin before completion and site stabilization.
b. While the basin is closed during construction, maintain drainage overflow pathways to provide for drainage during storm events.
c. Modify existing soils if required. Construct modified flow paths.
d. Modify or install the outlet structure, berms, inlet structures, soil stabilization measures, etc. Complete fine grading.
e. The design engineer should observe the basin conditions following excavation and grading and prior to placement of vegetation to confirm that construction requirements have been met. Documentation of engineering observation must be provided to the City (see Appendix I).

Step 3 Install Vegetation

a. Install vegetation in such a manner as to prevent soil compaction or alteration of grades.

Figure 5.3.13-10. It is important to avoid soil compaction during planting. Retrofit naturalized basins are often good opportunities for volunteer planting efforts if the grading and structural modifications are completed by trained professionals.

Operations and Maintenance

Maintenance is most important during the vegetation establishment period for a naturalized basin, and all basins should include a clear three-year plan for maintenance and removal of invasive vegetation during establishment. After the establishment period:

- Inspect and clean the outlet structure biannually.
- Inspect and remove sediment at all entrance conditions biannually.
- Pruning and weeding may be required.
- Detritus must be removed approximately twice per year. Perennial grasses should be cut down or mowed at the end of the growing season, and all material removed.

5.4.1 Recreate Natural Flow Patterns

Description

Each site has an inherent geometry that reflects the natural, historic water patterns within a regional system. In many urban and suburban areas, these flow paths have been constricted, rerouted, buried, paved, or built over until the original drainage patterns were obscured and the stormwater management benefits lost. Natural flow patterns are comprised of a number of familiar components that, when combined, create a dispersed, multi-scale drainage network. Such a network includes conveyance and detention as well as other components.

Figure 5.4.1-1. Lawn area that used to be a wet meadow with ephemeral pond and swale. Notice remnant swale in middle ground of picture.

Where possible, natural drainage functions should be reestablished as site constraints allow. Retrofitting sites with small, varied, and connected stormwater management measures following historic patterns provides greater security from flooding and can create redundancy within natural and structural systems.

Figure 5.4.1-2. Lawn area during construction of restoration.

Some diverse, multi-scale, hydrologic features include:

- Bioswales
- Intermittent/ephemeral and perennial water courses
- Check dams, weirs, and baffles
- Depressions
- Basins, wetlands, or pools
- Floodplain terraces
- Wet meadows

Restoration of these features may include:

- Changing channel (cross-sectional) configuration by:
  - Widening buffers and/or creating benches that mimic floodplains.
  - Reestablishing the natural meander of a channel.

Figure 5.4.1-3. Restoration of wet meadow with ephemeral pond and swale complete.

Figure 5.4.1-4. Hickory Valley CC (now "First Tee") restored stream channel (before and after).

- Regrading the site.
- Day-lighting drainage flow from pipes.
- Enhancing vegetated cover with flood- and drought-tolerant, densely planted, deep-rooted species.
- Optimizing opportunities for infiltration and storage at points along the original flow path through the creation of depressions and bioswales. (This conversion may include the reuse of storm sewers for storage and/or overflow.)

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Recreate Flow Patterns	U/S/R	M	M/H	M	M	M	L	H	M	L/M/H

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Guidelines

- Identify drainage patterns in site context.
- Identify and map historic natural drainage features (swales, channels, ephemeral streams, depressions, etc.).
- Minimize filling, clearing, or other disturbance of existing drainage features.

- Utilize natural drainage features instead of engineered systems whenever possible.
- Provide erosion protection or energy dissipation measures if the flow into the channel or swale can reach an erosive velocity.
- Plant native vegetative buffers around drainage features.

Advantages

- Dispersed, small-scale storage.
- Increased flood storage.
- Reduced water velocity.
- Reduced suspended sediment load.
- Increased pollutant and nutrient removal.
- Aeration/oxygenation of water depending on channel morphology.
- Surficial drainage pathways and devices can replace or adapt existing structural drainage measures as storage and/or overflow.
- Drainage can become a site-organizing feature and/or a site amenity.

Disadvantages

- May require other smaller BMPs over a larger portion of the site.
- Requires interconnected design of BMPs and may be subject to site program constraints.

Applications

- Strategies can be applied at multiple scales and with varying levels of formality.
- Restoration of natural flow patterns is particularly suited to large development properties such as residential, institutional, and corporate campuses in less urban areas. However, restoration can be useful at multiple scales.
- In denser urban areas, natural drainage functions can be mimicked with varying levels of formal, constructed (but vegetated) channels, basins, etc. This is referred to as reinterpreting the natural drainage patterns.

Applicable Protocols and Specifications

Protocol 2 Coordination with Other Site Utilities
Protocol 3 Soil Testing

Protocol 5 Planting and Mulching Guidelines
Protocol 6 Bioretention Soil Specifications

Design Considerations

This BMP is eligible for SOV credits as defined in Chapter 7. A Criteria Checklist is provided at the end of this section as a summary of design and establishment considerations.

Site Analysis

Where possible, identify and use the site's existing and historic hydrologic patterns in the proposed design. Look for opportunities to reconnect to remnants of the existing natural drainage features and reestablish natural drainage functions that serve to slow and/or retain runoff, maximize recharge, remove sediment and pollutants, oxygenate water, etc.

- Understand the site context—its location within the watershed and its hydrologic connectivity.
  - Identify and map existing, and where possible, historic drainage features. Note: USGS has an online Historical Topographic Map Collection showing the drainage and landforms of Chattanooga from 1936 to 1969 (http://nationalmap.gov/historical/index.html). Use the smallest map scale possible for the best detail, typically 1:24,000.
    - Historic aerial photographs can also provide other important information.
    - Storm sewers can provide clues to historic hydrologic patterns.
  - Identify the site's location within the larger watershed.
    - Placement in the watershed provides insight to hydrologic performance. For example, areas located within drainage areas close to headwaters or zero order streams will perform differently than sites along the banks of the Tennessee River. Stormwater systems should correspond to the inherent demands of the site. In headwater areas, infiltration should usually be maximized, whereas in broad floodplain areas, the focus should be on cleaning and dispersing stormwater.
    - Headwater stream drainage areas are critical to overall watershed health and should be given special consideration.
  - Identify healthy, stable references for channel/basin configurations appropriate to the site's position in the watershed, slope, and geology. For example, a drainage channel on a steep slope in eastern Tennessee will, most likely, look like a mountain stream. This is very different from the sluggish, braided watercourse with many meanders found on flat areas and in the valleys.
- Identify and map stormwater flow into and out of the site, including overland flow as well as underground flow (where possible). Use current topographic maps to calculate the size and location of drainage areas tributary to and within the project site.
  - Calculate current volume and velocity from the drainage areas for the given design storm.

- Current stormwater volumes will differ from historic volumes due to urbanization and must be accounted for when sizing new stormwater features that mimic historic patterns.
- Identify any existing storm sewers or other structural conveyances (paved ditches, culverts, etc.).
- Reassess stormwater management plan as the site plan develops.

Design Strategies

Compare the historical drainage configuration with present drainage along with site program requirements and determine what is feasible given spatial and budget constraints. What can be reused? What will provide the best performance in terms of water quality or volume reduction?

Create a dispersed, multi-scale drainage network with many varied and **connected** stormwater management measures based on historic drainage patterns. In denser urban areas, mimic natural drainage functions with varying levels of formal, constructed (but vegetated) channels, basins, etc. This is referred to as “reinterpreting” the natural drainage patterns. The following are several strategies for accomplishing this:

- Repair Structural Damage
  Although preserving or restoring healthy soils and vegetation is a key component in restoring site stormwater management performance, it may be critical to first address structural damage to the site. This includes restoring site topography and drainage damaged by previous grading, slumping, or erosion.
  - Remove, where feasible, historic fill and reshape leveled ground to direct water toward the drainage feature to be preserved as appropriate.
  - Reestablish stormwater management components such as bioswales, intermittent/ephemeral and perennial water courses, depressions, basins, pools, wetlands, floodplain terraces, and wet meadows in a choreographed, connected system.
  - Flow Path − Channel Design
    Conventional trapezoidal swale channels with 3:1 side slopes and flat bottoms are primarily to convey water. While these conventional designs are easier to calculate and engineer, they do not mimic natural conditions. Additional stormwater management benefits can be achieved with adjustments to the design. See Section 5.4.1.1, Naturalize Swales and Drainage Ditches in this manual for more detailed information.

    While modifying the channel design typically requires more space, it incorporates the following benefits: infiltration and filtration, pollutant removal, and increased storage opportunities. Other BMPs such as check dams or ponds can be used to supplement the functions of revised channel design. In addition, these areas can provide amenities if incorporated into the site design.

- Create a meandering channel with adjacent flood storage. Where appropriate, recreate natural stream meanders. Use rocks and logs or other materials to create deflectors to manipulate flow.
- Design the two sides of the channel so that they are different in section—one side steep and terraced and the other graded into a bowl-shaped floodplain.

Figure 5.4.1-5. Recreating a meander within a channel, note boulders and curves, and that the right side is higher than the left, which has area for overflow if the water "jumps" the channel banks.

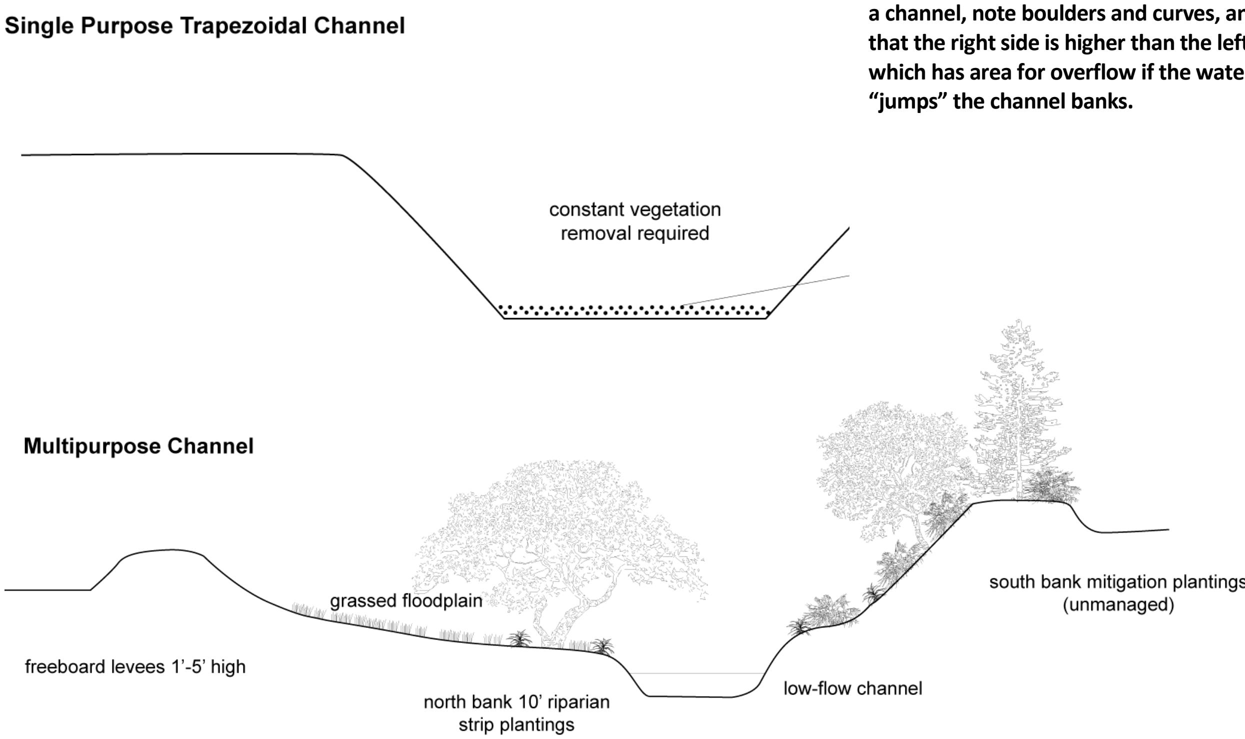


Figure 5.4.1-6. Two channel sections – Engineered vs. Naturalistic.

- Plan for Increased Volume – Sizing
  If the historic drainage patterns are being used as the basis for the current stormwater management plan, present stormwater volumes must be taken into consideration. Development/redevelopment on the site as well as within the areas draining to the site will most likely increase stormwater volumes.
  - Where the velocity and volume are high:
    - Create extra storage/infiltration capacity where applicable.
    - Stabilize swale slopes with bioengineering techniques.

- Use check dams with low weirs and small pools. Check dams are recommended for any vegetated swales with longitudinal slopes greater than 3 percent.

Figure 5.4.1-7. Log check dam installed.

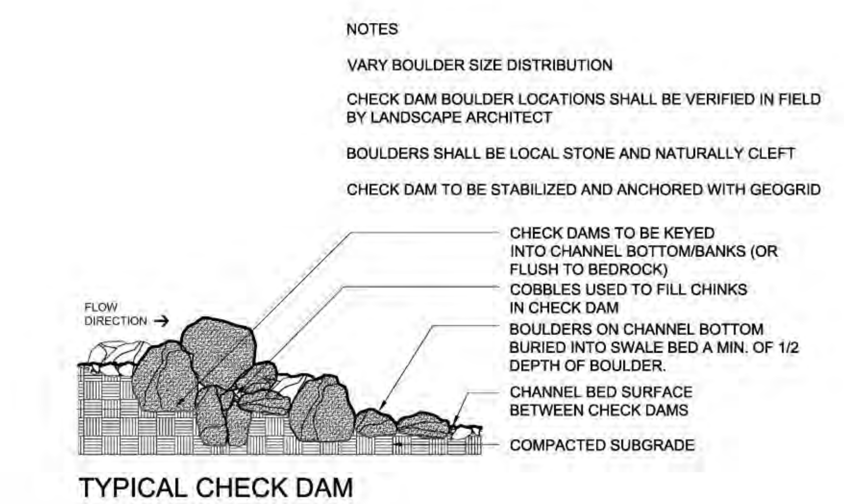


Figure 5.4.1-8. Stone check dam installed.

- Swales with check dams more effectively reduce runoff quantity and quality than those without. Check dams create a series of small pools along the length of the swale. The frequency/number of small-dammed pools depends on the length and slope of the swale, as well as the desired amount of storage/treatment volume. These pools help to decrease energy in the water and enhance aeration, decrease runoff volume and velocity, and promote additional filtering and settling of nutrients and other pollutants. Care must be taken to avoid erosion around the ends of the check dams.
- Pools must drain within a maximum of 72 hours to prevent mosquito breeding.

– Design small wetlands as storage basins adjacent to the channel to store floodwaters and promote groundwater recharge where appropriate.
– Plant vegetative buffers around recreated drainage features and re-vegetate all cleared or disturbed areas to trap sediment. Use deep-rooted plants suitable to alternating flood and drought conditions (i.e., floodplain vegetation). Selected vegetation must be able to thrive at the specific site and should be chosen carefully. No invasive plant species may be used. See Protocol 5 Planting and Mulching Guidelines.

Figure 5.4.1-9. Avoid straight, uniform cross-section grass swales where possible.

Figure 5.4.1-10. Vegetated swale – note meanders, rocks, grasses, etc. More pleasing to the eye than a straight swale, but still conveys stormwater and has more water quality functions.

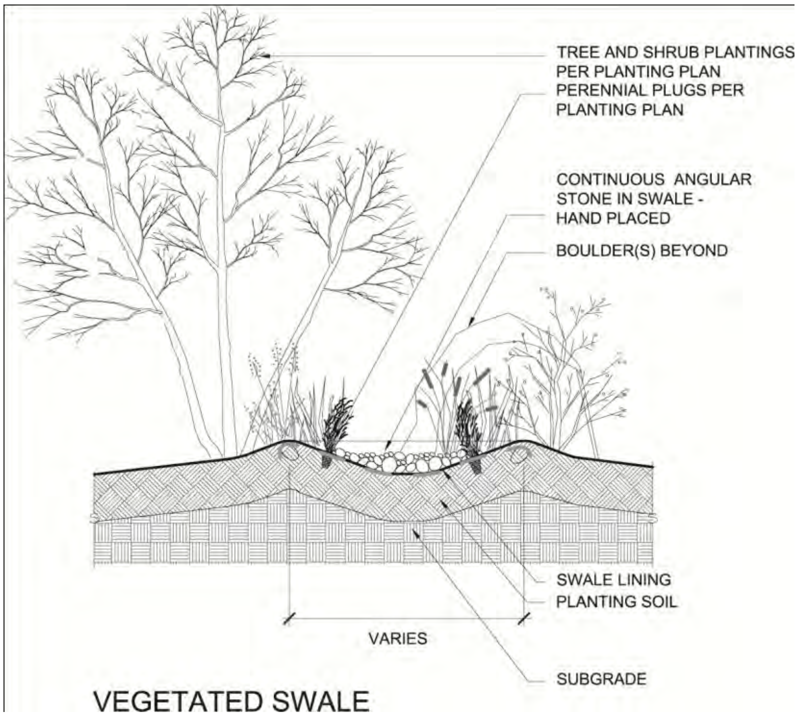


Figure 5.4.1-11. Vegetated swale detail.

Construction Sequence

- Identify proposed natural drainage features on the construction drawings and stake out these features in the field at the start of construction.
- Strictly delineate and enforce protection areas and minimal disturbance areas.
- Protect recreated drainage features from sediment and stormwater loads during construction.
- Use smaller machinery in these areas and avoid working soil when wet to protect soil structure and infiltration rates.

Operations and Maintenance

Naturalized drainage features that are protected and integrated as part of a site's development require monitoring and targeted maintenance and inspections, especially after large rain events. Inspections can assess variables such as erosion, bank stability, sediment/debris accumulation, plant condition, and the presence of invasive species. Problems should be corrected in as timely a manner as possible to avoid compounding effects.

When vegetation is being established, efforts such as watering, weeding, mulching, replanting, etc. may be required regularly during the first few years. Undesirable species should be removed and desirable replacements planted if necessary.

Protected drainage features on private property should consider an easement, deed restriction, or other legal measure to discourage future disturbance or neglect. These measures can be tailored to protect not only the channel but also associated basins. In some cases, depending on the location, the City may require these legal measures.

References

Adams, Michele and Donald Watson. 2011. *Design for Flooding: Architecture, Landscape, and Urban Design for Resilience to Climate Change*, Wiley & Sons.

Dunne, Thomas and Luna B. Leopold. 1978. *Water in Environmental Planning*, W.H. Freeman and Company.

Riley, Ann L. 1998. *Restoring Streams in Cities: A Guide for Planners, Policymakers and Citizens*, Island Press.

USDA, NRCS*. Engineering Field Handbook*, Website:http://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21429.

Criteria Checklist BMP 5.4.1

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance for the owner/applicant for successful implementation.		
• Identify existing remnant and historic natural flow pathways on the site inventory plan.	☐	☐
• Delineate and label historic flow patterns on the existing conditions and site protection plan.	☐	☐
• Identify and map stormwater flow into and out of the site, including overland flow as well as underground flow (where possible). Use current topographic maps to calculate the size and location of drainage area flowing to and within the project site.	☐	☐
• Delineate and label current conceptual design on the appropriate plans as outlined in Chapter 4, General Design and Review Process for New Development and Redevelopment. Note relationship to historic flow patterns.	☐	☐
• Where possible, identify and use the site's existing and historic hydrologic patterns in the proposed design. Look for opportunities to reconnect to remnants of the existing natural drainage features and reestablish natural drainage functions.	☐	☐
• Highlight recreated/reinterpreted natural flow pathways that are integrated into stormwater management.	☐	☐
• Have measures been taken to guarantee that natural pathways will not be negatively impacted by stormwater flows? Have they been sized appropriately?	☐	☐
• Proposed natural drainage features should be identified on the construction drawings and staked out in the field at the start of construction. Protection and minimal disturbance areas should be delineated and enforced.	☐	☐
• Provide written description of any work that may need to be performed within the protected areas and areas of minimal disturbance.	☐	☐
• Utilize natural drainage features instead of engineered systems whenever possible.	☐	☐
• Plant native vegetative buffers around drainage features.	☐	☐

5.4.1.1 Naturalize Swales and Drainage Channels

Description

Chattanooga neighborhoods have an abundance of open swales and drainage channels. These conveyance channels are generally remnants from agricultural landscapes and Works Progress Administration (WPA) projects designed only to convey stormwater. Constructed swales and open drainage channels are designed primarily for unimpeded conveyance with 3:1 slopes and flat bottoms. Depending on the amount and speed of flow, these channels are traditionally constructed of earth or concrete. Earth banks are frequently stabilized with turf or farm grasses, which are easily eroded as stormwater volume and velocity increase as a result of adjacent development. Traditional maintenance required to maintain flow capacity removes vegetation growing in the channel and returns the ditch to a trapezoidal section to maintain the flow function of the channel. Some remnant channels are allowed to return to forest rather than being reused as a part of new development.

Figure 5.4.1.1-1. Typical farm channel.

Figure 5.4.1.1-2. Concrete channel under construction.

There is considerable opportunity to reshape and naturalize these flow paths to increase their stormwater management performance. This practice reconfigures traditional turf swales and drainage channels to create more naturalistic and effective channel designs to slow stormwater velocity, expand stormwater storage, and provide bank stabilization through reshaping and appropriate plantings. Naturalized channels improve water quality by increasing the removal of nutrients and reducing erosion and sediments.

BMP Functions Table

Grasses and other deep-rooted vegetation established within a drainage channel can filter runoff. Living and decomposing plants with their associated microorganisms trap sediments, take up excess nutrients, and break down chemical compounds. In the southeastern United States, vegetated drainage channels have been particularly successful in reducing sediment, nitrogen, and phosphorous from fertilizers and pesticide concentrations, especially water-soluble pesticides. In addition, modifying the length of a straight ditch by creating meanders, reestablishing a floodplain, and planting with a variety of flood- and drought-tolerant deep-rooted native vegetation provides other important stormwater management functions.

Figure 5.4.1.1-3. Concrete drainage channel in Chattanooga.

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Naturalize Swales and Drainage Channels	S/R	H	H	M	M	H	H	M	M	L/M/H

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

Key Design Guidelines

- Define site hydrologic context.
- Identify and map natural drainage features (swales, channels, ephemeral streams, depressions, etc.) and any “traditional” drainage channels onsite.
- Evaluate possibilities for improvement, e.g., amount of space available, site context, etc.
- Use local, healthy, intact natural drainage features as a guide for the redesign of existing channels.
- Minimize filling, clearing, or other disturbance of drainage features.

- Use “natural” drainage features instead of heavily structured solutions.
- Where peak flow in large storms is fast and heavy, provide mechanisms within and along the channel to slow water, reduce volume, and reinforce channel sides.
- Design vegetative buffers as well as planting to stabilize the channel.

Advantages

- Improved drainage and ecological function.
- Increased slope stability and channel stability.
- Greater area for flood control.
- Vegetated swales are a first component of a “treatment train” for stormwater runoff before it enters streams and wetlands.
- Vegetated swales can replace more expensive structural drainage systems.
- Naturalized channels can become an aesthetic feature and wildlife habitat.

Figure 5.4.1.1-4. Highly urbanized, vegetated drainage swale.

Disadvantages

- May require additional space.
- Regrading and planting are an additional cost.
- Periodic maintenance of plants.
- Special city and state regulations for some existing drainage channels.

Applications

- Any size or type of property, from residential to commercial (including highly urbanized sites), containing formal or channel ditches that could be reconfigured and/or replanted

Figure 5.4.1.1-5. Drainage channel at Hamilton Place Mall that could easily become an amenity.

Naturalizing existing drainage channels to increase stormwater management performance is appropriate for a wide variety of settings. These opportunities include large-scale commercial and industrial properties (shopping centers and manufacturing sites) as well as residential developments and institutional or corporate campuses. Drainage channels often form boundaries between properties and are opportunities for preservation of right-of-way and for joint improvement projects. Many drainage channels are city owned and located in a public right-of-way or utility easement.

Figure 5.4.1.1-6. Vegetated swale with check dams in a residential neighborhood.

Applicable Protocols and Specifications

- Protocol 2 Coordination with Other Utilities
- Protocol 3 Soil Testing
- Protocol 5 Planting Guidelines

Figure 5.4.1.1-7. Vegetated swale retrofit with meadow seeding and check dams along roadside.

Design Considerations

This BMP is eligible for SOV credits as defined in Chapter 7. A Criteria Checklist is provided at the end of this section as summary of design and establishment considerations.

<u>Overview</u>

Underground pipes have been the dominant method of conveyance in most development and redevelopment projects. However, open drainage channels still exist within much of Chattanooga. Concern regarding healthy water and the effective and multipurpose management of stormwater has returned open channels to the status of a cutting-edge BMP. For example, formalized planted open channels are now important components of "complete streets."

Figure 5.4.1.1-8. Drainage channel running behind a residential area in Chattanooga, Tennessee.

The stormwater management goal in naturalizing existing drainage channels is not only to slow flow but also to remove pollutants, encourage infiltration and filtration, and increase storage opportunities. Other BMPs such as check dams or ponds can be used to supplement the functions of naturalized drainage channels. These areas can also provide site amenity if incorporated into the site design.

Design Strategies

- If retrofitting an existing swale or drainage channel that is part of a larger system, safe conveyance for larger storms must be a priority.
  - Evaluate existing swales or structured drainage features to determine their volume requirements within the larger system's hydrologic engineering (i.e., provide adequate cross-sectional area to pass design storms through the site).
  - Avoid obstructions or constrictions that will cause flooding or create erosion problems.
  - Note: Agreements must be made between the owner and the City before naturalization of existing swales can be incorporated into the stormwater management plan for a site and before volume or water quality credits can be received. Some existing conveyances might also require an Aquatic Resource Alteration Permit (ARAP) from TDEC or possible permitting from the U.S. Army Corps of Engineers before work can be performed.
- Where space allows, redesign the sides of trapezoidal channels to create a meandering swale with a broad floodplain on one side. A linear depression adjacent to one side of the channel bank will store water from larger storms, reducing peak flows.
  - Remove any fill and regrade channel to meander if there is space to increase the length or width of the channel.

Figure 5.4.1.1-9. Drainage channel street side in residential area in Chattanooga, Tennessee.

Figure 5.4.1.1-10. Vegetated swale in apartment complex in Portland, Oregon.

Figure 5.4.1.1-11. Meandering vegetated swale in subdivision, street side, in Philadelphia, Pennsylvania.

- Use natural drainage patterns in the area surrounding the site as a model.
- Plant both sides of the bank with occasional trees and shrubs and a ground layer of deep-rooted, low-maintenance, flood- and drought-tolerant plants. Native grasses are particularly well suited to this regimen. If applicable, plants can be selected to remove specific pollutants.

• Check dams located within the channel are recommended for vegetated swales with longitudinal slopes greater than 3 percent. Check dams create a series of small, temporary pools along the length of the swale to:
  - Enhance infiltration capacity;
  - Decrease runoff volume, rate, and velocity; and,
  - Provide filtering of nutrients and pollutants, and settling of sediments in the pools.

  The frequency of check dams within the swale will depend on swale length and degree of slope as well as on the desired amount of storage volume.
  - Care must be taken to avoid erosion around the ends of the check dams.
  - Check dam pools should be designed to prevent mosquito breeding.
  - River-rock should be used in lieu of rip-rap.

Figure 5.4.1.1-12. Naturalized swale with check dams and river-rock reinforced channel.

• Energy Dissipation

  Provide erosion protection or energy dissipation measures if the flow into the channel or swale can reach an erosive velocity.
  - The higher the design velocity of the flow, the greater the need to stabilize the banks. Consider stabilization of naturalized channels with bioengineering techniques.
  - Design the channel with carefully placed obstructions to slow flow and to provide additional habitat. In general, use local materials such as boulders and preserve tree trunks to help manage, convey, and dissipate the energy of runoff during high flows.
  - Stabilize the entire swale with jute netting as necessary to establish vegetation and prevent erosion.
  - When possible, allow seeds to establish (germinate) before allowing water into the swale. Sods (of both wetland grasses and wildflowers) will establish more reliably.

Figure 5.4.1.1-13. Energy dissipation at outfall structure.

Construction Issues

- At the start of construction, identify drainage features on the site plans and construction drawings and stake existing and proposed channel configuration in the field.
- Protect newly created or modified drainage features from excessive sediment and stormwater loads during reestablishment and while they remain in a disturbed state.
- Be careful that site designs do not burden recreated drainage features from upstream stormwater loads. Key strategies for protecting the site's drainage ways during construction include:
  - Control stormwater discharged into the drainage way under construction.
  - Dissipate energy in swales with check dams, boulders, and channel configuration.
  - Restrict construction access, especially on steep slopes.
  - Use small machines to work in tight spaces and minimize damage to the soil by keeping machines on already compacted areas (e.g., small cranes operated from a nearby roadway can deliver materials to the construction area).
  - Do not drive construction vehicles across a swale unless a stabilized crossing is provided.

Operations and Maintenance

Natural drainage features that are properly protected and integrated as part of a site's development should require minimal maintenance after establishment. Periodic inspections and targeted maintenance actions are critical. Evaluate erosion, bank stability, sediment/debris accumulation, and the presence of invasive species. Problems should be corrected in as timely a manner as possible to avoid compounding effects.

During establishment of vegetation, watering, weeding, mulching, replanting, etc. are required. Undesirable species should be removed and desirable replacements planted.

Consider an easement, deed restriction, or other legal measures to protect swales from future disturbance or neglect. In some cases, depending on the location, the City may require these legal measures.

References

Brown, Larry C. 2004. *Demonstration of Drainage Channel Restoration to Improve Stream Integrity and Maintain Flow Capacity*, Final Narrative Report to the Great Lakes Protection Fund. http://web.epa.ohio.gov/dsw/nps/NPSMP/docs/LbrownGLPFproject.pdf.

Goldman, S.J., K. Jackson, and T.A. Bursetynsky, P.E. 1986. *Erosion and Sediment Control Handbook,* McGraw Hill Book Company.

U.S. Department of Agriculture, Natural Resources Conservation Service. 2007. *National Engineering Handbook*, Part 654 Stream Restoration Design, Chapter 10, Two-Stage Channel Design. http://policy.nrcs.usda.gov/OpenNonWebContent.aspx?content=17770.wba.

Criteria Checklist BMP 5.4.1.1

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance for the owner/applicant for successful implementation.		
• Identify existing “traditional” ditches on the Existing Conditions and Site Protection Plan.	☐	☐
• Identify and map stormwater flow into and out of the site, including overland flow as well as underground flow (where possible). Use current topographic maps to calculate the size and location of drainage area flowing to and within the project site.	☐	☐
• Delineate and label current conceptual design on the appropriate plans as outlined in Chapter 4, General Design and Review Process for New Development and Redevelopment. Note how they relate to known historic flow patterns.	☐	☐
• Evaluate possibilities for improvement. Where possible, identify and use the site’s existing and historic hydrologic patterns in the proposed design.	☐	☐
• Minimize filling, clearing, or other drainage feature disturbance.	☐	☐
• Provide mechanisms to reduce velocity and volume, and reinforce channel sides where peak flow may be erosive.	☐	☐
• Avoid obstructions or constrictions that will cause flooding or create erosion problems.	☐	☐
• Where space allows, redesign the sides of trapezoidal channels to create a meandering swale with a broad floodplain on one side.	☐	☐
• Plant both sides of the bank with occasional trees and shrubs and a ground layer of deep-rooted, low-maintenance flood- and drought-tolerant plants.	☐	☐
• Check dams located within the channel are recommended for vegetated swales with longitudinal slopes greater than 3 percent.	☐	☐
• Protect newly created or modified drainage features from excessive sediment and stormwater loads during reestablishment and while they remain in a disturbed state.	☐	☐

5.4.2 Improve Native Landscape Cover Types

Description

In an integrated stormwater management plan, the “natural” landscape is an important tool to reduce stormwater runoff volume and velocity and to improve water quality. This BMP requires that the site have a remnant native plant community (forest, field, hedgerow, etc.), which can be an important contributing part of the stormwater management system.

Remnants of native plant communities found on development sites are frequently degraded, damaged, transformed, or partially destroyed. In some cases, impacts to ecosystems are caused or aggravated by natural processes such as wildfires, floods, storms, or hurricanes. In most cases however, degradation is the direct or indirect result of human activities. The objective of this BMP is to initiate or accelerate the recovery of ecosystem health for water quality function.

“Restoration” implies returning a landscape to a former, more pristine state. In reality, historic conditions cannot be replicated. For most development and redevelopment projects, a realistic goal is to remove or mitigate destructive impacts and reintroduce significant missing processes and components, where possible. The intent of these actions is to allow natural processes to bring about gradual recovery. Interventions can include:

- Reintroduction of a characteristic assemblage of species.
- Reintroduction of “keystone” species, where missing. (Keystone species are plants or animals that play a critical role in maintaining the structure and function of an ecological community.)
- Improvement of soil structure, chemistry, and biology.
- Reintroduction of basic natural processes by a controlled burn.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Improve Native Landscape Cover Types	U/S/R	H	H	M	M	H	H	H	L	L

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

While there are many benefits to improving existing native cover types, the primary purpose of this BMP is to increase the potential for effective stormwater management on a site and to provide the developer with another means of stormwater management. This BMP functions by reestablishing a healthy plant community with thick, spongy soil layers that:

- Generates less runoff.
- Absorbs a greater volume of water through infiltration, evaporation, and evapotranspiration.
- Improves soil conditions through the addition of organic material, which increases soil pore space.
- Reduces the need for maintenance by fertilizers, herbicides, and pesticides.
- Reduces the force of precipitation by leaf interception.

Key Design Guidelines

- Shift conventions and practices and revise plans to favor preservation and reuse of remnant natural areas to allow nature to do some of the work of stormwater management.
- Identify key remnant landscape cover types on the site to be protected or enhanced, such as meadows, woodlands, and forests.
- Evaluate the condition of these areas, and establish strategies for increased stormwater management functions.
- Where possible, use or create these areas as site amenities.

Advantages

- Improving and sustaining remnant natural areas can provide additional stormwater management capacity.
- Native cover types require less maintenance than manicured, ornamental landscapes.
- A native landscape can be an attractive alternative.
- These areas can be used to structure the site, screen unsightly views, and provide visual interest and recreational opportunities.

Disadvantages

- Enhancement efforts have a level uncertainty, as it is difficult to guarantee a specific condition, appearance, or functionality.

- Acceptance of an evolving landscape (adjusted by management interventions over time) requires a willingness to employ unfamiliar management techniques.
- Native landscapes have an aesthetic that not all may find attractive.

Applications

- Any development or redevelopment site where native vegetation already exists
- Even an extremely small area can contribute to stormwater quality; however, the larger the area, the greater the contribution

Where there are remnant native plant communities onsite, this BMP can be used in a wide range of contexts—from urban to rural—and at very different sizes, from hedgerows between vacant lots to forests of several acres and larger.

Figure 5.4.2-1. Replanting understory layer in existing forest.

Figure 5.4.2-2. Aerial with kudzu infestation indicated.

Figure 5.4.2-3. Highly disturbed woodland. Note the presence of invasive vines (English ivy and Multiflora rose) but also healthy ground cover (May Apples – *Podophyllum peltatum).*

Figure 5.4.2-4. Reforestation with whips in tube guards.

Applicable Protocols and Specifications

Protocol 5 Planting Guidelines

Design Considerations

Restoration is an incremental process that proceeds in phases. It is almost impossible to amend a natural landscape in a single, large effort. Instead, smaller interventions, at regular intervals, should be planned and management techniques adjusted according to what is working.

To minimize cost, intervene minimally. Take only those actions that are necessary to counteract disturbance. Take no actions that will inhibit important natural processes onsite.

Guidance for successful implementation is as follows:

Priorities for Enhancement

Identify remnant natural areas that can contribute to the proposed stormwater management system or can provide volume reduction or water quality improvement for other impervious area onsite. Soil infiltration capacity is measured along a gradient of absorption and varies from poor performance (soil under well-maintained turf grasses) to good performance (spongy, absorbent soils under a mature forest). To choose which natural plant community remnant should be preserved, use the following list to help prioritize. In general, number 1 provides the least stormwater management benefits and number 4 provides the greatest benefits.

1. Annual, Biennial, and Perennial Meadows (primarily herbaceous, agricultural crops to native grasses, wildflowers, ferns, etc.)

2. Old Fields and Savannahs (woody vegetation within the matrix of a meadow)

Figure 5.4.2-5. Wildflower meadow.

Figure 5.4.2-6. Sassafras savannah.

3. Young Woodlands and Mature Woodlands (woodlands generally have a few tree species growing densely together with only tree trunks and ground layer)

4. Mature Forest, Old Growth Forest (closed tree canopy, shade-tolerant plants, mixed species, mixed ages and many layers; Old Growth Forest returns to few tree species and two major layers: canopy and ground layer)

Figure 5.4.2-7. Young woodland – pole stage – approximately 10 years.

Figure 5.4.2-8. Mature forest.

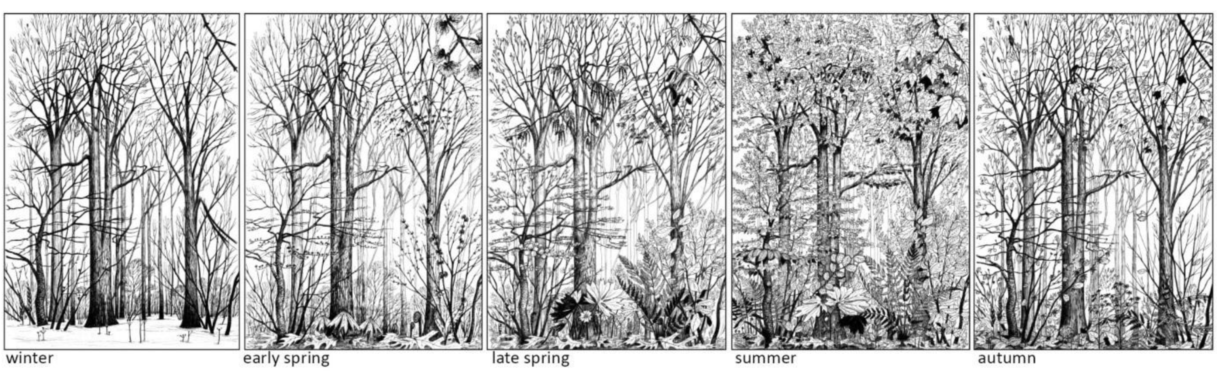


Figure 5.4.2-9. Mature forest layers through the seasons.

This BMP is eligible for SOV credits as defined in Chapter 7. A Criteria Checklist is provided at the end of this section as a summary of design and establishment considerations.

Restoration Steps

- Assess vegetation onsite and delineate areas to be preserved. Note landscape cover type, size, condition, and age.
- Integrate areas selected for protection into site and stormwater plans to meet multiple objectives and create environmental and social connections (trail systems, hedgerows, etc.)
- Identify glaring problems within the selected enhancement area, e.g., fill and soil pushed over the slope into the valley, extreme cut, exposed subsoil or bedrock, bare and eroded soil, invasive exotic plants, trash, and toxic materials. Particularly note erosion and sedimentation problems such as gullies and bare soil. Also note influences beyond the site that may undermine enhancement efforts.
- Identify and address factors that suppress regeneration of native plants or contribute to overall plant community decline before replanting or amending the soil. If these factors are not addressed, efforts spent on enhancement will be wasted.
- Where relevant, identify major cyclical processes that shape the site, e.g., floods, fire, etc. These recurring natural events may help to sustain the native plant community and prevent colonization by invasive exotics.
- Search for a healthy model in the neighborhood to serve as a design reference:
  - Plant community structure and pattern—Use the model to determine the arrangement, types, and density of plants.
  - Identify and protect desirable and sensitive species and any rare, threatened, or endangered plant (or animal) species. Particularly identify “keystone” species. If absent, replace these species where possible.

Figure 5.4.2-10. Illegal dumping.

Figure 5.4.2-11. Prescribed forest burn for species management *(*Note: Controlled burns require proper safety precautions and may not be permitted).

- An unusual amount of dead or dying plants requires a determination of cause.

- Where necessary, remove masses of aggressive, invasive exotic species to expose the potential of the area.
  - Invasive exotic species often occur as dense shrub thickets or extensive, heaping vine cover. Vines in trees and climbing over shrubs suppress reproduction on the ground and shade older trees and shrubs, eliminating seed sources. Privet, Japanese honeysuckle, kudzu, mimosa trees, and tree of heaven are the most prevalent invasive exotics in Chattanooga.
  - Remove large tangles of aggressive exotic species to allow an accurate evaluation of the site and suggest appropriate repair strategies.
- General considerations:
  - Effective control treatments vary by species. In some cases, non-chemical options exist.
    - Emphasize techniques that minimize soil disturbance and that remove the exotic plants by the roots where possible, while leaving adjacent, desirable plants undamaged. When removing existing invasive plants, either pull up by the roots or eliminate re-sprouts later.
  - Some invasive exotics are more troublesome than others. For example, highly aggressive species such as kudzu and privet are particularly difficult to eradicate and should be removed as early as possible, before they are well established.
  - Phase removal of exotic canopy trees to keep a shady forest cover.
- Specific removal methods:
  - Hand pulling: Suggested for restricted areas of herbaceous weeds or small seedlings of woody plants.

Figure 5.4.2-12. Removing invasive exotics.

Figure 5.4.2-13. Forest edge before kudzu removal (photo credit V&V, LLC).

Figure 5.4.2-14. Forest edge after kudzu removal, ready for new plantings (photo credit V&V, LLC).

- Tools: A weed wrench allows the user to pull up young tree seedlings (too large to pull by hand) by the roots. This tool disturbs the adjacent areas only minimally.
- Mowing: In general, broadleaved herbaceous plants will diminish with regular mowing. Broadleaved herbaceous plants include both weeds and wildflowers, and a meadow mown more than three times a year will become predominantly grasses. Note: Kudzu has been removed successfully in some steep slope areas of Chattanooga through the use of goats that graze on the weed.

Figure 5.4.2-15. Weed wrench.

- Controlled burning: This technique can be used to manage any landscape cover type. However, in meadow management, fire is used to reduce the number of trees and increase the amount of grasses and wildflowers.
    - Burning can be used in two major ways: 1) If the remnant natural area is small, or only a small portion of it requires treatment, a single person, with a backpack propane torch, can burn small areas (approximately 10 feet by 10 feet). Generally, small-scale burns are done as a patchwork of squares, with unburned vegetation between burned patches. Extreme caution must be used to prevent wildfire; 2) Where a relatively large-scale burn is considered (approximately 1 acre or more), property managers should coordinate with the local fire department and state conservation agencies. Permits are required from the City of Chattanooga.
    - Caution: Some undesirable species, such as black locust, are "fire increasers." If these species are already present, burning may encourage them. Conversely, successful regeneration of oak forests in the eastern United States has historically required fire.
    - The local branch of the (nonprofit) Nature Conservancy will burn a designated area for a small fee:

      The Nature Conservancy
      East Tennessee Program Office
      625 Market Street, Suite 1201
      Knoxville, TN 37902
      (865) 546-5001

- Tilling: For large areas of infestation, tilling can uproot and kill undesirable species. However, tilling can also kill native species and encourage invasive plants that spread by underground rhizomes or stolons, such as kudzu (*Pueraria lobata)*.

- Application of herbicides: This is a method of last resort, but necessary in some cases. Herbicide treatments should be applied **only** to a specific plant and **never broadcast,** especially near water bodies. Use a colored dye in the herbicide mix to identify areas that have been sprayed. Use the least persistent pesticide available to accomplish the job.

  There are different improvement techniques for every landscape cover type. Consult the Society for Ecological Restoration International at http://www.ser.org/ for specific directions for your site:

  SER Southeast Chapter
  c/o SER International
  1017 O Street NW
  Washington, D.C. 20001
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- General Recommendations
  - In healthier systems with minimal disturbance, native seeds may be present in the soil. Areas adjacent to other healthy natural areas can benefit from seeds transported by wind, water, and animals. If time is not a factor, and rapid cover is not critical, these areas can be left to regenerate on their own.
  - Plant tough, vigorous, generalist species, which will create immediate cover and discourage invasive species.
  - Stabilize edges. Where a remnant natural area meets a manmade landscape, the design should create a graceful, smooth transition. Construction often leaves these transition areas highly disturbed. Repair of these newly exposed edges is critical.
  - Regrade where necessary, stabilize the soil, and replant with fast-growing, tough, native edge species. Repair of damaged edges will protect the health of the natural landscape and enhance its stormwater benefits.
  - Newly exposed, existing trees are often vulnerable to wind throw. Replant a strip along newly formed edges (where a portion of the natural landscape has been cut away) to buffer the remaining native landscape from increased wind, light, noise, and other impacts.

Figure 5.4.2-16. Tree planting at edges and lawn conversion to meadow.

Figure 5.4.2-17. Invasive exotic vines (kudzu) cover the forest edge.

Figure 5.4.2-18. Forest edge planted with flowering understory and shrubs.

Operations and Maintenance

A number of different techniques may be needed to sustain a healthy native cover.

Watering

Watering or irrigation may be required during the period of establishment and during severe droughts.

Erosion Control

Erosion should be monitored before, during, and after enhancement efforts, until the site is stabilized.

Control of Invasive Plant and Animal Species

Look for signs of takeover by aggressive, exotic plants. Also look for (usually very obvious signs of) a population explosion of herbivores.

- Monitor the property regularly for invasive plant species. When they do appear, remove them as soon as possible, before they have a chance to become established and spread. Rapid removal will prevent formation of extensive root systems, which make eradication of invasive species difficult, if not impossible.
- Long-term invasive species monitoring and management should be considered part of a holistic landscape management program that is coordinated with herbivore control and follow-up planting. Key areas to monitor:
  - Look for regeneration of native plants specifically on the ground layer. If there are no seedlings or the seedlings are predominantly non-native, reevaluate the problem and repair.
  - If invasive exotic plants do not diminish significantly, reevaluate the problem and change management techniques.
  - Monitor newly stabilized edges to ensure that invasive species are under control, planted material is surviving and thriving, and there is evidence of natural regeneration.
- Herbivore control:
  - Ongoing control of extra abundant herbivores (white-tailed deer, rabbits, geese, etc.) is an important adjunct to landscape enhancement, preventing plant damage from browsing, rubbing, and grazing.
  - Eastern Tennessee has experienced slow growth in deer population due to less productive habitat and other factors. If deer predation becomes a problem, consider the following strategies:
    - Plant large caliper trees with branches above 6 feet.
    - Protect trunks of young trees with plastic tubes.
    - Protect shrub and herbaceous plant material, as hungry deer will eat everything and prefer wildflowers.

Figure 5.4.2-19. Seedling regeneration on forest floor.

Figure 5.4.2-20. Deer-fenced protected area to the right – unprotected area to the left (photo credit Nature Conservancy).

- Fence enhancement areas with effective deer fencing. A strong plastic mesh is adequate. Fencing must be tall enough to keep deer out, 12 to 18 feet high.
- Organize an official "cull" with private bow hunters or professional sharp shooters, with the Tennessee Wildlife Resource Agency (TWRA).

Fertilization

Over-fertilization increases weeds and nutrient loads in runoff. Test the soil before fertilizing. Organic compost is preferred over chemical fertilizers.

Integrated Pest Management

To reduce the environmental impact of herbicides, pesticides, and fungicides, use a pest management program, also referred to as an integrated pest management (IPM) program. IPM strategies combine a number of techniques including knowledge of the lifecycle of targeted pests (e.g., disrupting breeding cycles), known predators, and microorganisms that are pathogens to the pest species; selection of the best local growing conditions; mechanical controls such as quarantine; physical removal of diseased plants and traps; establishment of an acceptable level of pests; and responsible herbicide and pesticide use.

Monitoring

To evaluate the success of enhancement efforts, look for:

- Health of planted plants
- Regeneration/recruitment of native seedlings
- An increase in the abundance and diversity of native plants
- More visibly ordered structure in forests: ground layer, shrub layer, understory trees, canopy
- Fewer invasive exotics
- No bare soil patches

References

Society for Ecological Restoration International Science & Policy Working Group. 2004. *The SER International Primer on Ecological Restoration.* www.ser.org.

Criteria Checklist BMP 5.4.2

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance for the owner/applicant for successful implementation.		
• Assess vegetation onsite and delineate areas to be preserved. Note landscape cover type, size, condition, and age.	☐	☐
• Integrate areas selected for protection into site and stormwater plans to meet multiple objectives and create environmental and social connections (trail systems, parks, etc.).	☐	☐
• Identify glaring problems within the selected enhancement area, for example, fill and soil pushed over the slope into the valley; extreme cut, exposing subsoil or bedrock fill; bare and eroded soil; invasive exotic plants; trash; toxic materials, etc. Particularly note erosion and sedimentation problems such as gullies and bare soil.	☐	☐
• Identify and address factors that suppress regeneration of native plants or contribute to overall plant community decline before replanting or amending the soil.	☐	☐
• Where relevant, identify major cyclical processes that shape the site, for example, floods, fire, etc.	☐	☐
• Plant Community Structure and Pattern—Use a healthy neighborhood model to determine the arrangement, types, and density of plants.	☐	☐
• Identify and protect desirable and sensitive species and any rare, threatened or endangered plant (or animal) species. Particularly identify “keystone” species. If absent, replace these species where possible.	☐	☐
• Where necessary, remove masses of aggressive, invasive exotics.	☐	☐
− Remove large tangles of aggressive exotic species to allow a clear evaluation of the site and suggest appropriate repair strategies.	☐	☐
− Hand pulling: Suggested for restricted areas of herbaceous weeds or small seedlings of woody plants.	☐	☐
− Tools: “Weed Wrench,” allows user to pull up young tree seedlings (too large to pull by hand) by the roots.	☐	☐
− Mowing: In general, broadleaved herbaceous plants will diminish with regular mowing.	☐	☐
− Controlled burning: This technique can be used to manage any landscape cover type.	☐	☐
– Tilling: For large areas of infestation, tilling can uproot and kill undesirable species.	☐	☐

– Application of herbicides is a method of last resort, but necessary in some cases. Herbicide treatments should be applied only to a specific plant and never broadcast, especially near water bodies.	☐	☐
• Stabilize edges where a remnant natural area meets a manmade landscape for a smooth transition. Construction often leaves these transition areas highly disturbed. Repair of these newly exposed edges is critical.	☐	☐
• Newly exposed, existing trees are often vulnerable to wind throw. Replant a strip along newly formed edges (where a portion of the natural landscape has been cut away) to buffer the remaining native landscape from increased wind, light, noise, and other	☐	☐
• Water or irrigate during the period of establishment and during severe droughts.	☐	☐
• Erosion should be monitored before, during and after enhancement efforts, until the site is stabilized.	☐	☐
• Monitor property regularly for invasive plant species. Remove them before they become established and spread.	☐	☐
• If deer browsing is an issue:	☐	☐
– Plant large caliper trees with branches above 6 feet.	☐	☐
– Protect trunks of young trees with plastic tubes.	☐	☐
– Protect shrub and herbaceous plant material, as hungry deer will eat everything and prefer wildflowers.	☐	☐
– Fence enhancement areas with effective deer fencing. A strong plastic mesh is adequate. Fencing must be tall enough to keep deer out, 12 – 18 feet high	☐	☐
– Organize an official “cull” with private bow hunters, or with professional sharp shooters, with the State Fish and Wildlife agency and in coordination with the USDA.	☐	☐
• Test the soil before fertilizing. Use organic compost before using chemical fertilizers.	☐	☐

• To reduce the environmental impact of herbicides, pesticides and fungicides, use a pest management program.	☐	☐
• Monitor success of enhancements by determining the health of plants, the apparent regeneration/recruitment of native seedlings, an increase in the abundance and diversity of native plants, a more visibly ordered structure in forests (ground layer, shrub layer, understory, canopy), if there are fewer invasive exotics, and if there are no bare soil patches.	☐	☐

5.4.2.1 Change Cover Type

Description

A change in cover type to enhance stormwater management involves replacing surfaces that have a high coefficient of runoff with an absorbent, more permeable ground layer. Changing the surface cover of the ground can significantly reduce the volume and velocity of stormwater runoff and improve water quality. This BMP focuses specifically on improving the permeability and retention of stormwater with the use of high-performance vegetative cover.

Figure 5.4.2.1-1. Lawn.

Natural vegetation in the Tennessee Valley can be grouped into several, readily identifiable landscape types ranging from turf grasses to mature forest:

- Lawn (with European turf grasses)
- Annual, Biennial, and Perennial Meadows (primarily herbaceous—agricultural crops to native grasses, wildflowers, ferns, etc.)
- Old Fields and Savannahs (woody vegetation within the matrix of a meadow)
- Young Woodlands and Mature Woodlands (woodlands generally have a few tree species growing densely together with only tree trunks and ground layer)
- Mature Forest and Old Growth Forest (mature forests have closed tree canopy, shade-tolerant plants, mixed species, mixed ages, and many layers, while old growth forests revert to only a few dominant canopy tree species with two major layers—canopy and ground layer)

Figure 5.4.2.1-2. Meadow.

Figure 5.4.2.1-3. Savannah.

Figure 5.4.2.1-4. Mature woodland.

Figure 5.4.2.1-5. Forest.

These landscapes represent a natural succession of development over time. Stormwater management benefits are related to soil infiltration capacity and vary from worst performance (soil under turf grasses) to best performance (spongy, absorbent soil under a mature forest).

The changes that make up this gradual succession show themselves in many ways, with different species, structure, and appearance. A typical succession or change of landscape type follows a progressive pattern from field to forest—from young, open, sunny landscapes with one or two major layers to old, closed, shady landscapes with multiple layers and sometimes a wide variety of species and plant ages.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Change Cover Type	U/S/R	H	H	M	H	H	H	M	M	L*

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Initial cost may be high, but low in the long-term.

Key Requirements

- Identify areas that, after fitting the program onto the site, are appropriate for cover conversion during site assessment.
- Define which landscape type complements the proposed development, reduces maintenance costs, and increases stormwater management functions.
- Determine where cover can be converted.
- Design for a strong, simple image.
- Monitor and repair where necessary.

Advantages

- Substitutes high-maintenance areas with lower maintenance ones after establishment period.
- Provides greater permeability of soils and plant roots.
- Increases water-absorbing capacities of the soil.
- Lifecycle cost is less expensive than structural BMPs.

Disadvantages

- May not complement desired site character; site program must be compatible.
- Unfamiliar maintenance may be perceived as cumbersome and difficult.
- Lack of trained maintenance professionals.
- Establishment costs can be significant.
- May require extra time and expertise to design.

Applications

This BMP can be applied to any land development that has the land area and the program to allow for substitution of a meadow, old field, woodland, or forest for less permeable cover (i.e., lawn) or pavement.

- Lawn Conversion to Meadow − Steep slopes, edges between landscape types (such as between forest and lawn), property edges, and leftover spaces (between roads, service access areas, etc.) are particularly suitable locations for meadow conversion.
- Lawn Conversion to “No Mow” Lawn − High-visibility areas near walkways and buildings are particularly suitable locations for “no mow” lawn conversion.

- Lawn Conversion to Planting Beds (Trees/Ground Cover/Low Shrubs/Grasses) − Open areas around buildings, parking lots, and other facilities are suitable locations for this conversion.
- Conversion to Young Woodland or Forest – Road edges and property edges to screen views, to create or reinforce riparian corridors, and to screen problematic views or provide a boundary at major site divisions are suggested suitable locations for this conversion.
- Conversion of Construction-Staging Sites and Transition Areas − Sites that require stabilization for erosion control may be good candidates for conversion from lawn to meadow or lawn to woodland.

Figure 5.4.2.1-6. No mow lawn, with meadow in background.

Figure 5.4.2.1-7. Old field plantings along road edge.

Figure 5.4.2.1-8. Lawn conversion to meadow bordering property boundary.

Applicable Protocols and Specifications

- Protocol 3 Soil Testing
- Protocol 5 Planting Guidelines

Design Considerations

During site assessment, the design team should identify areas that, after fitting the program onto the site, could be converted from pavement or turf to a later successional vegetation type. Some conversions may be more feasible than others but may not offer the same water management benefit. The designer should balance these considerations.

This BMP is eligible for SOV credits as defined in Chapter 7. A Criteria Checklist is provided at the end of this section as a summary of design and establishment considerations.

The following considerations are provided as guidance:

- Determine the size and location of the area for cover change.
- Determine the choice of landscape type (meadow, forest, woodland, etc.) and individual species based on site conditions (soil type, soil moisture, sun/shade, exposure/protection, etc.) combined with program requirements and the owner's wishes.
- Choose suitable landscape type and determine its character:
  - For any proposed area that is relatively small and close to people and activities, consider the following:
    - Design a strong structure for the landscape. Often these landscapes are perceived to be messy and unkempt. However, if framed well, people are more likely to understand that the design was intentional.

- Create visible transitions. Maintenance of the edges of natural landscape cover types is especially important so that these landscapes look orderly and attractive. An adjacent lawn needs to be healthy and well-mown. The grades from one landscape cover type to another should meet gracefully and without abrupt changes in elevation. Edges between meadow and lawn can be cut with a flail mower to create a shorter grass height as a transition. Maintain a strip of mowed lawn between walkways and meadow.
- Establish a miniature of the landscape type chosen with young plants, replicating the most evocative elements of the type being emulated.

Figure 5.4.2.1-9. Mown path through meadow with strategically placed flowering tree.

- Choose species that are more ornamental, that are pleasing in all seasons, and that will thrive under the site conditions. For example, if meadow is substituted for lawn near a building, use a lot of flowers that bloom all summer.

Figure 5.4.2.1-10. Ornamental meadow planting.

- When establishing a more complex landscape, such as a woodland or forest, create the appropriate number of layers. With forest, structure the landscape with a few larger trees, use flowering understory, and provide a rich ground layer of ferns and wildflowers. With woodlands, structure the landscape as a “two-layer” forest consisting of closely spaced, even-aged young trees above, and shade-tolerant meadow below.
- Shady conditions and dense trees will help limit invasive exotics.

– For any proposed area with a cover type change that is primarily for stormwater management and will not be seen regularly, consider the following:
- Plugs or young plants can be used for forests, woodlands, and meadows. They should be planted closely together. The goal is not to create an illusion of a finished cover type, but rather to set in motion the natural processes that will gradually create a finished cover type over time. A well-established ground layer is critical to the success of this approach. This also helps to control invasive plants and weeds.

Figure 5.4.2.1-11. Meadow plugs being installed.

- For creating meadows in larger areas, seeding is a more cost-effective planting method.
  - The creation of a meadow need not be restricted to native grasses and wildflowers. Meadows can also be made of low shrubs and/or low woody ground covers, or even of ferns.

Figure 5.4.2.1-12. Fern meadow.

- Hayfields are another possible meadow presentation. These meadows are made of typical agricultural species (cereal crops, etc.). Although this solution is quick and easy and looks established shortly after planting, the stormwater benefits are not as significant. Agricultural meadows also require mowing and periodic over-seeding. This type of meadow is most viable where growing food or raising animals is part of the site program, or where there is a nearby farmer willing to cultivate the land.
- When considering transition to forest or woodland, consider creating a connection between other natural landscapes.

Conversion Methods

- Lawn Conversion to “No Mow” Lawn

  “No mow” lawn is a special mix of fescues and/or woodland sedges selected to grow no more than 4 to 6 inches tall and that requires no mowing. There are many proprietary blends on the market, many of which are drought tolerant and some that will grow taller than 4 to 6 inches. To convert typical lawn to “no mow,” do the following:

Figure 5.4.2.1-13. No mow lawn.

  – Lift and remove all existing grass with roots and rototill soil to a depth of 6 inches.
  – Allow land to lay fallow and let weeds sprout but not produce seeds. The time frame will depend on the type of weed species and climate conditions; monitoring is required. Smother or apply herbicide to weeds and leave area fallow for a month.
  – Rototill dead plants and any remaining weeds into the soil.
  – Amend soil mixture with organic matter and nutrients specific to soil test results.
  – Seed with “no mow” lawn.
  – Plant critical areas with plugs for an instant effect.
  – Mulch (see Protocol 5, Planting and Mulching, in this manual).

- Lawn Conversion to Planting Beds (Trees/Ground Cover/Low Shrubs/Grasses)

  – Remove turf (see options below).
  – Add organic matter and other soil amendments (per soil tests).
  – Rototill into the soil to a depth of 12 inches prior to planting.

- Lawn Conversion Meadow

  There are different approaches to converting lawn to meadow:

  - Reduce Mowing Frequency Gradually

    A reduction in mowing frequency can gradually convert a lawn, especially a lawn in poor condition, into a tall-grass and/or wildflower meadow. Reduced mowing works well if cost is an issue and appearance is not of great importance. This method is viable where native soils are relatively intact and where field observations suggest that natural regeneration of native meadow plants will occur from the existing seed bank. This conversion has the advantage of exposing no bare soil and maintaining meadow plants from the start. It may be summarized as follows:

    - Change the mowing timing and height to favor the growth of native warm-season grasses over turf grasses.
    - Monitor the native meadow species that emerge.
    - Promptly remove weed species and invasive exotics before they can spread.
    - Plant specific wildflowers or grasses, if desired, into the meadow as plugs (use this method only after finding some evidence of existing native grasses and wildflowers).
    - The establishment of meadow can be advanced by over-seeding or plugging.
    - Establish a mowing regimen for this conversion technique; the recommended regimen is to mow five times during the first year, four times the second year, three times the third year, two times the fourth year, and once in the fifth year.

Figure 5.4.2.1-14. Conversion area at the State University of New York – Buffalo.

Figure 5.4.2.1-15. Seeded meadow starting to germinate.

– Meadow Seeding

This method is appropriate for newly graded areas and other sites with bare soil. The advantage of this method is that it allows the designer to plant a specific species mix with a relatively high degree of control. The downside is that the existing plant cover must be killed first and the early meadow takes several years to establish.

- Remove lawn or pavement and prepare soil as discussed below under soil preparation.
- Seeding is generally the preferred and least expensive planting method in areas greater than 1 acre.
- Drill seeding is most effective because it ensures good seed-to-soil contact. For drill seeding, use a drill with a specialized seed box containing "picker wheels" to facilitate the handling of fluffy native grass seed through the seed chute. Drill seeders are available through state wildlife agencies, soil conservation districts, the Natural Resources Conservation Service, and some local chapters of Quail Unlimited (University of Tennessee Extension Service 2004).
- Seed can also be broadcast by hand or by mechanical seeder. When using a mechanical seeder, use one with "picker wheels" that allows fluffy seeds to pass. Alternatively, mix fluffy seed with a carrier (cracked corn, cottonseed hulls, clean sand, or perlite). After planting, use a "cultipack" to make sure there is firm seed-to-soil contact. Do not seed in winds exceeding 5 miles per hour.
- Seeded meadows take two to five years to fully establish and can look weedy during this period, but will develop structure over time.

Figure 5.4.2.1-16. Drill seeder.

Figure 5.4.2.1-17. Cultipack.

– Ornamental Meadows/Plugging

- Remove lawn or pavement and prepare soil as discussed below under soil preparation.
- If planting a tall grass and wildflower meadow and an immediate effect is required, consider using grass or wildflower "plugs." Plugs are small herbaceous plants grown in trays, with root systems already started. They are more expensive than seed and require more labor to plant

(this planting method is similar to planting ground cover, such as ivy slips), but provide an immediate impact.
    - Plant spacing is species specific, but it is more effective to plant densely to reduce weeds (maximum 12 to 18 inches apart).
    - Consider supplementing seeded meadows with plugs in visible areas for immediate effect.

- Conversion to Young Woodland/Forest

  There are several approaches to creating forest on a cleared site. All of these methods require careful monitoring of invasive species, especially in the first couple of years.

  Stabilize soil with erosion control consisting of a leaf litter to a depth of 1 inch. Place open weave burlap on top of leaf litter and cover burlap with thin layer (no more than 1 inch) of leaf litter. Use additional leaf litter to fill any holes.

  Approaches include:

  – Planting four to five distinct layers in a matrix of species of varied ages (canopy, understory, high shrub, low shrub, and ground layer). Different plant sizes will help differentiate the layers. Use additional leaf litter between the plants and to fill any holes. Plant small woody plants and containers of herbaceous woodland plants through the burlap and leaf litter to establish a ground layer.
  – Sow by hand fast-growing forest tree seeds, such as cherry and tulip poplar.
  – Plant a meadow and intersperse with canopy trees that will act as seed sources and allow for succession.
  – Plant dense cover of tree seedlings with volunteers.
  – Many sites still have a seed bank in the soil containing native species. Eliminating disturbance to the system (mowing, etc.) may result in desired native woodland over time with minimal inputs.

Construction Considerations

- Identify areas designated for cover change and stake in the field.
- Protect these areas during construction (see Section 5.2.1, Protect Undisturbed and Healthy Soils, of this manual).
- Removal of Pavement or Lawn
  – Pavement
    - Pavements, including the gravel sub-base, should be dug up and removed. Remove concrete pieces, cement, large stones, and soils contaminated by oil, gas, and other extraneous materials that are harmful to plant growth. All turf grasses should be removed with particular care given to removing grasses with strong stolon/rhizome roots (i.e., Bermuda grass, Zoysia

grass) and tall fescues; this grass species is highly competitive and can crowd out new herbaceous plantings quickly if roots are left behind.

Figure 5.4.2.1-18. Pavement removal.

- Lawn (several removal options are effective)
  - Smother: Cover ground completely with plywood, layers of newspaper, or thick organic mulch (leaves, etc.; do not use any type of plastic sheeting because it will deteriorate in the sun and break up into many tiny shards). Leave area covered for two months.

Figure 5.4.2.1-19. Smothering lawn with newspapers and mulch.

  - Cultivate: Remove existing sod with cutter, then rototill or plow soil. Repeat two to three times at one-week intervals. Rhizomatous grasses may require a longer tilling period.

- Herbicide: A method of last resort, but necessary in some cases. Use with caution around water bodies due to the susceptible nature of aquatic organisms. Use the least persistent pesticide available to accomplish the job. Note that some have the ability to change the structure of the soil. Apply herbicide according to the manufacturer's written instructions.

- Soil Preparation
  Consider consulting with a soil scientist. Soil conditions and the needs of landscape types can vary greatly. Generalized suggestions are as follows:
  - Soil preparation for areas formerly under pavement:
    - For previously paved areas, replace topsoil (for forest, woodland, and no mow grasses), till soil to a minimum depth of 8 inches, and remove stones larger than 1 inch. Apply a 1-inch layer of organic compost and rototill into the top 4 inches of soil. Fertilizers are not required since the organic matter supplies the necessary nutrients without creating a nutrient-rich soil.
    - For meadows, harrow to break up clods (lumps of soil) and to provide a finer finish, good tilth, and suitable soil structure for seedbed.
    - Soils may also need to be amended with specific nutrients depending on soil tests. **Please note: Native meadows grow best in nutrient-poor conditions.**

Figure 5.4.2.1-20. Harrowing.

  - Soil preparation for areas formerly under lawn:
    - For drill seeding, remove thick thatch, stones, construction debris, etc., greater than 1 inch.
    - For broadcast seeding, loosen soil to a depth of 3 inches, and remove stones, construction debris, etc., greater than 1 inch.
    - For meadows, harrow to break up clods (lumps of soil) and to provide a finer finish, a good tilth, and suitable soil structure for seedbed.
    - In both cases, amend soils with organic matter and specific nutrients, depending on recommendations from soil tests. **Please note: Native meadows grow best in nutrient-poor conditions.**

- Plant Sources
  - Meadows
    - For tall grass and/or wildflower meadows, select quality seeds and/or plugs from reliable sources. Many vendors supply pre-mixed blends of native grasses and wildflower for various conditions and purposes. Vendors may also prepare a custom mix.
  - Woody and Herbaceous Plants
    - Tennessee is a major nursery state; therefore, sourcing of appropriate plants should not be an issue. Contract growing or use of plants rescued from construction sites are options if lead time permits.

- Post Planting Protection
  - Meadows
    - Protect seeded areas from hot, dry weather or drying winds by spreading straw or hay mulch 1 inch thick. Crimp mulch or apply a tackifier to protect seed.
    - Mulch plugged areas with hay or straw.
  - Woody and Herbaceous Plants
    - The leaf litter and open weave burlap covering the bare soil should protect the newly planted plants. For additional protection measures, see Section 5.4.2, *Improve Native Landscape Cover Types*, in this manual.

Operations and Maintenance

- Initial Establishment
  - After initial planting, water new cover type with a fine spray at a minimum rate of ½ inch per week for eight weeks after planting, unless rainfall is adequate.
  - Mow meadows during the first growing season to a height of 6 inches. Annual and biennial weeds grow more quickly than perennial grasses and wildflowers. If weeds exceed 9 inches in height, remove flowering heads with a weed whacker.
  - Control of weeds and invasive plants is critical, especially prior to cover type planting and during the establishment period.

Figure 5.4.2.1-21. Meadow mowing.

- Long-term Management
  - For highly visible landscapes of all cover types, regular monitoring and maintenance are critical to a tidy and pleasing appearance. Maintenance includes watering during droughts, weeding, removing invasive species, and replanting where plants are damaged.
  - For landscapes where the primary purposes of the cover type are erosion control and increased soil permeability, and the landscape is not regularly seen, maintenance can be reduced to an inspection twice a year for problems and immediate repair and mowing once or twice yearly for meadows: late winter/early spring and once in mid-summer.
  - Maintenance of the edges of natural landscape cover types is especially important so that these landscapes look orderly and attractive. An adjacent lawn needs to be healthy and well-mown. The grades from one landscape cover type to another should meet gracefully and without abrupt changes in elevation. Edges between meadow and lawn can be cut with a flail mower to create a shorter grass height as a transition.

- Controlling Invasive Plants
  - Regardless of cover type, removal of invasive species is critical to the success of this BMP. As soon as detected and when these pest plants are large enough, pull (mechanically or by hand), mow, spray with spot chemical applications, burn, or use a combination of techniques. Remove invasive species before seed formation to prevent reseeding. A link to a list of invasive species can be found in Protocol 5, Planting Guidelines, in this manual.

Figure 5.4.2.1-22. Hand removal of invasives.

  - Mowing
    - For all herbaceous cover types (including old fields and savannahs where woody plants are set in a matrix of meadow), mow once or twice a year to prevent takeover by woody species and to maintain a tight and attractive appearance. Mowing is the most often used, most familiar, and most widely accepted technique. Mow in late winter/early spring and again in mid-summer.
    - Some native grasses grow in individual clumps. Avoid damaging the base of these grasses when mowing by setting the mower blade at a height of 4 to 6 inches.
    - In ornamental meadows or if numbers of volunteers are available, it may be feasible to remove small woody plants by hand. Since mowing can disturb the soil, removal by hand reduces disturbance and discourages weeds.
    - Mowing can be scheduled to favor particularly desirable species. For specific directions, consult the University of Tennessee (various departments of biological sciences, etc.), the USDA Agricultural Extension Service, and the Tennessee Department of Environment and Conservation (TDEC).
    - For herbaceous landscapes, or old fields and savannahs (meadow matrix with woody shrubs and small trees), a yearly inspection and twice yearly mowing are adequate.
  - Controlled Burns
    - Controlled burning is mainly used in grasslands but can also be used in woodlands.
    - Where possible for every cover type, consider a controlled winter (early February) burn. Burning is often the most cost-effective management option and yields the most visually attractive results.

Figure 5.4.2.1-23. Controlled burn on green roof meadow.

This management technique is particularly easy and effective with meadows and will create a tighter and more attractive landscape. It can also be used successfully with woodlands and forest to control invasive species and foster a rich ground layer.

- Note that controlled burning as a management method should be done in coordination with the local fire department and requires a permit issued by the Hamilton County Air Pollution Control Bureau (http://www.apcb.org/Open_Burning/Burning_Permits_copy.aspx). Burning is allowed October through April.
- If the meadow or other landscape types are extensive, the Nature Conservancy can be asked (for a fee) to bring trained staff to burn the area professionally.
- Benefits of Burning
  - Deposits nutrients, in a readily available form, into the soil
  - Stimulates plant growth
  - Provides a lush and neater appearance
  - Exposes the soil to the sun, by eliminating plant litter, allowing space for new seeds to germinate
  - Favors warm native grasses over cool-season European turf grasses

– Herbicides and Pesticides
  - Use of integrated pest management practices to minimize use of herbicides and pesticides.

References

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Criteria Checklist BMP 5.4.2.1

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance for the owner/applicant for successful implementation.		
• Identify size and location of areas where cover can be converted.	☐	☐
• Cover conversion areas shall be clearly identified on the site plan.	☐	☐
• Define which landscape type complements the proposed development and increases stormwater management functions.	☐	☐
• Determine the choice of landscape type (meadow, forest, woodland, etc.) and individual species based on site conditions (soil type, soil moisture, sun/shade, exposure/protection, etc.), program requirements, and owner's wishes.	☐	☐
• For areas close to people and activities:	☐	☐
○ Design a strong structure for the landscape.	☐	☐
○ Create visible transitions between cover types.	☐	☐
○ Choose species that are more ornamental, that are pleasing in all seasons, and that will thrive under the site conditions.	☐	☐
○ When establishing a more complex landscape, such as a woodland or forest, create the appropriate number of layers.	☐	☐
○ Use shady conditions and dense trees to help limit invasive exotics.	☐	☐
• For less visible areas primarily intended for stormwater management:	☐	☐
○ Plugs or young plants can be used for forests, woodlands, and meadows and should be planted closely together to set in motion natural processes that will create a cover type over time.	☐	☐
• When considering transition to forest or woodland, consider creating a connection between other natural landscapes.	☐	☐
• Use appropriate conversion methods outlined in in this BMP at 5.4.2.1.7 to achieve desired specific landscape conversion results.	☐	☐
• Identify areas designated for cover change and stake in the field and protect these areas during construction.	☐	☐
• Dig up and remove pavement including the gravel sub-base and other extraneous materials or pollutants harmful to plant growth.	☐	☐

• Remove lawn (removal options include smothering, cultivating, or, as a last resort, herbicide).	☐	☐
• Consider consulting with a soil scientist when preparing soil. Soil conditions and the needs of landscape types can vary greatly.	☐	☐
• Follow the soil preparation guidelines outlined in this BMP and Section 5.4.3 for areas formerly under pavement and areas formerly under lawn.	☐	☐
• For tall grass and/or wildflower meadows, select quality seeds and/or plugs from reliable sources.	☐	☐
• Protect seeded areas from hot, dry weather or drying winds by spreading straw or hay mulch.	☐	☐

5.4.3 Amend and Restore Disturbed Soils

Description

Soils are an important component of effective stormwater management. A healthy soil (defined as a living natural system consisting of a mixture of weathered minerals, decomposing organic matter, and biological organisms, that contains adequate air and water for the support of plants) permits water infiltration for groundwater recharge and provides water-holding capacity to support vegetation, both contributing to reduction in stormwater runoff.

This BMP provides guidance for the amendment and restoration of project site soils to improve their performance as a stormwater volume management media. This is also important for the effective performance of the engineered BMPs described in Section 5.3.

Disturbed soils may have been degraded by a number of factors, both natural and manmade. These factors include:

- Contamination and/or soil mixed with trash and construction debris.
- Mixed/imported fill soils with intermingled soil layers.
- Soil that has been compacted by foot traffic, vehicles, or equipment, and the pore spaces necessary to a healthy, functioning soil have been compressed. Silts and clays (with finer grain sizes) are more prone to compaction.
- Erosion has reduced soil to a thin covering, lacking nutrients, microorganisms, organic matter, soil depth, and water-holding capacity.

Indicators of disturbed soils may include one or more of the following:

- Soil horizons that differ significantly in depth, texture, or physical or chemical properties from a healthy reference soil in a neighboring undisturbed area.
- High bulk density readings by soil type at which growth limitations can be expected.
- Organic matter content lower than that of the reference soil.
- Soil chemical characteristics (parameters such as pH, salinity, cation exchange capacity, and nutrient profiles) different from that of healthy reference soil in a neighboring undisturbed area.
- Presence of toxic compounds.
- Presence of weedy, opportunistic, or invasive plant species.
- Presence of construction debris.

Restoring degraded soil involves de-compaction; restoration of soil porosity; reintroduction (amendment) of soil microorganisms, organic matter, and nutrients to support healthy rooting environments for plants; and reestablishment of the soil's long-term capacity for infiltration, storage, and pollutant removal.

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden	Cost
Amend and Restore Disturbed Soils	U/S/R	H	H	M	H	M	M	H	L	L*

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Initial cost may be high, but low in the long term.

Key Design Guidelines

- If possible, avoid importing topsoil from another location.
- Existing soil conditions should be evaluated before creating a restoration strategy.
- Test for bulk density, organic matter, soil texture, nutrient deficiencies, and the presence/absence of microorganisms, fungi, and bacteria.
- Where necessary, recreate an ideal soil profile.
- Physical loosening of the soils can mitigate compaction.
- Compost amendments and teas can increase biological communities and water-holding capacities and mitigate compaction over time.

Applications

Soil restoration is appropriate and useful where the soil has been badly damaged, especially where the soil's long-term capacity for infiltration, water storage, and pollutant removal is necessary for BMP function and for planting (either a vegetative cover or ornamentals).

Advantages

- Uses the landscape soils as a stormwater BMP, decreasing the need for structural measures to manage site stormwater.
- Healthy soils support healthy plant growth, providing cost savings on plant maintenance (labor, pesticides, fertilizers, and irrigation).

Disadvantages

- Initial upfront development costs.
- The value of soil improvement and/or repair is not well understood and often value engineered out of the project.
- A soil specialist is required to evaluate existing impaired soils and provide a formula for remediation.
- Careful oversight is required during the creation and installation of new soils. Contractors frequently do not study the specifications carefully or follow directions.

Applications

Soil restoration is appropriate and useful anywhere the soil has been degraded, especially where the soil's long-term capacity for infiltration, water storage, and pollutant removal is necessary for BMP function and for planting (either a vegetative cover or ornamentals).

Figure 5.4.3-1. Debris in wooded lot.

Figure 5.4.3-2. Highly compacted lawn.

Figure 5.4.3-3. Brownfield.

Applicable Protocols and Specifications

Protocol 3 Soil Testing

Design Considerations

This BMP is eligible for SOV credits as defined in Chapter 7. A Criteria Checklist is provided at the end of this section as a summary of design and establishment considerations.

<u>Soil Design Options</u>

Three options are typically available when designing soil restoration or amendment strategies. Note that material availability must be taken into consideration.

- Import topsoil from another location.
  - Topsoil should not be stripped from agricultural fields, swamps, or bogs. The soil must be analyzed to make sure it meets the necessities of the site, specifications, and the plant palette.
- Modify existing soil material with amendments.
- Design the topsoil or an entire soil profile.
  - It is strongly recommended that the soil be designed for the Chattanooga climatic zone along with the corresponding plant palette.
  - Create specifications for the following soil horizon layers: O, A, B, and C. See Section 5.2.1, Protect Undisturbed and Healthy Soils, in this manual for a discussion of soil horizons. Other horizons omitted from the above list are generally not necessary and site design factors may limit their inclusion.

Figure 5.4.3-4. Soil being delivered to an elevated planting site.

Figure 5.4.3-5. Applying liquid biological amendment (compost tea) in situ.

- The primary function of each of these layers is as follows:
  - Compost imitates the organic horizons in the “O” layer.
  - Horizon “A” is the primary rooting medium.
  - A subsoil (B layer) provides added volume for rooting, plant stability, and nutrient and water storage.
  - In deeper urban profiles, a drainage layer serves in place of the parent material (C layer).

Figure 5.4.3-6. Designed soil layers being installed.

Figure 5.4.3-7. Close-up of designed soil layers.

Restoring Soil Structure

When natural soil is disturbed, it loses its structure. Loss of healthy soil structure affects the soil's ability to support plant life, move water, support microorganisms, etc. Soil horizons altered by compaction, grading, or other disturbances can lead to unhealthy vegetation, unstable soils, and poor stormwater management capacity.

Figure 5.4.3-8. Urban soils being salvaged/sorted and debris being removed.

Spreading topsoil or any material as a layer over an unknown sub-base material is **not** an effective strategy. Rather, a disturbed soil profile should be redesigned to reflect healthy existing conditions and the BMPs chosen for the site. The possibility of reusing existing site materials as components of the new soils and/or of using recycled materials should be explored.

Figure 5.4.3-9. Urban soils being salvaged and mixed onsite.

Most natural soils have gradual transitions between layers that are important to the movement of water, roots, and nutrients. In contrast, sharp interfaces between horizons can impede or even stop water movement.

Strategies for Soil De-compaction

What is soil compaction?

Soil compaction reduces porosity. Soils become compacted by the simple application of pressure from foot traffic, vehicles, settling, and even rain on unprotected or fragile soils. As soil particles are compacted, their pore space shrinks, creating soils that are largely impervious. Plant roots and soil organisms are negatively impacted by compaction. Biological activity is greatly reduced, decreasing the ability of living organisms to breathe, eat, and move. Compaction of soil can occur naturally and is called a "hard pan." In nature, hard pans usually result from special chemical or physical properties of the soil, which cement the particles together and create a barrier layer that is generally impenetrable.

There are two notable types of mechanical compaction:

- Minor Compaction – surface compaction within 8 to 12 inches
  - An axle load greater than 10 tons can compact through the root zone, up to 1 foot deep.
- Major Compaction – deep compaction, 1 foot or greater
  - An axle load greater than 20 tons can compact up to 2 feet deep.
  - Large areas are usually compacted to increase strength and stability for paving and foundations. As a result, lawns adjacent to these areas often have major compaction issues.

Compacted soil is determined in part by its bulk density, which is calculated as the dry weight of soil divided by its volume. Bulk density reflects the soil's ability to function as structural support, and to allow water and nutrient movement and the exchange of atmospheric gases. In general, the higher the bulk density of a soil, the lower the infiltration rate and the higher the stormwater runoff volume.

Remediation

Once the bulk density and depth of compaction have been determined for the soils, there are several possible strategies that can be used to mitigate the effects of soil compaction.

- Potential strategies for minor soil compaction (compaction that occurs in the top 8 to 12 inches of soil):
  - Core aeration.

Figure 5.4.3-10. Core aerator.

  - The effect of core aeration is temporary, requiring at least annual treatment depending on the use of the site.
  - Organic matter amendment.

Figure 5.4.3-11. Top dressing with compost.

- Native planting.
- Tilling/scarifying is an option as long as it is done deep enough (at least 12 inches) and the right equipment is used. Other site work, such as utility installation and paving, should be completed before commencing preparation of soils.

• Potential strategies for major soil compaction (compaction that extends to 20 inches or more):
  - Ripping/Sub-soiling: Sub-soiling chisels (a type of plow) can be pulled through the soil to break up deep compacted layers. The preferred depth is 24 to 30 inches. A series of passes in two perpendicular directions will improve effectiveness.

Figure 5.4.3-12. Chisel plow.

- Some variations of these plows should not be allowed because they are too shallow (e.g., various disks, chisel plows), can compact the soil just beneath the depth of tillage (e.g., disks), or are not built to pull through densely compacted layers (e.g., spring-loaded equipment).

- If deep sub-soiling is planned, consider the location of utility lines, tree roots, and potential archaeological artifacts. Utility conflicts are the most common reason why sub-soiling may not be appropriate.

- Mitigating compaction in areas with existing vegetation:
  - For soil amendment within 3 feet of the drip zone of trees, compost should be worked into the upper 3- to 4-inch depth of the soils, just short of the transport roots, with a hand-tiller or similar tool. Because of the reduced depth of incorporation, amendment quantity will need to be reduced proportionately.

Figure 5.4.3-13. Hand tiller.

  - Restoration of appropriate soil chemical characteristics for plant growth requires matching the pH, cation exchange capacity, and nutrient profiles of the original undisturbed soil or the site's reference soil. Choose soil amendments (and fertilizers if needed) that minimize nutrient loading to waterways or groundwater.
  - Amendments to the soil should extend to a minimum depth of 12 inches.

Figure 5.4.3-14. Tree being injected with compost tea.

- De-compacting soils around trees:
  - Air Spading: First delineate the major framework roots. When roots are located, push the air into the ground to a depth of 1 foot. Ensure that the soil moisture is between 5 and 15 percent.

Figure 5.4.3-15. Air spading.

- Raised Root Soil Fill: Raised root systems above the soil surface need to be covered with soil to provide root plate weight and more accessible rooting volume. After the existing soil has been de-compacted, the filling soil should be placed no more than 3 inches thick per year. The soil used should be approved additional specified planting soil. Ensure that the soil moisture is between 5 and 15 percent before any soil remediation is performed.
- Vertical Mulching: Vertical mulching can be used in situations where there are several trees with overlapping roots that are difficult to identify and locate. Core the soil to a depth of 12 to 18 inches using a 4- to 6-inch-diameter auger in a grid pattern with holes approximately 3 feet apart on center. Take care to not excessively damage many large framework roots. The area to be cored shall be the entire area, excluding a 3- to 5-foot radius away from the tree trunk to the limits of the tree crown's drip edge. Scratch the walls of the core hole before filling the hole with a soil using approved additional planting soil. Ensure that the soil moisture is between 5 and 15 percent before any soil remediation is performed.

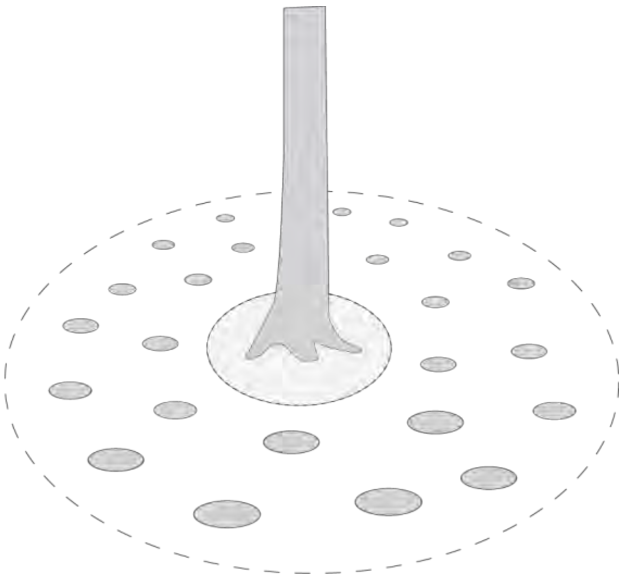

Figure 5.4.3-16. Vertical mulching.

- Radial Trenching: Radial trenching should be used when soil compaction is severe in and around single trees or when structural framework roots are easily identified and located. First delineate the major framework roots. Ensure that the soil moisture is between 5 and 15 percent prior to accomplishing any soil work. Starting 3 to 5 feet away from the trunk, dig a trench between the framework roots using a 10-inch-wide bucket or air spade down to a depth of 10 to 15 inches, just beyond the drip edge of the tree crown. Scarify the edges of the trench to remove any soil smearing. Fill the trench with soil using the approved additional planting soil.

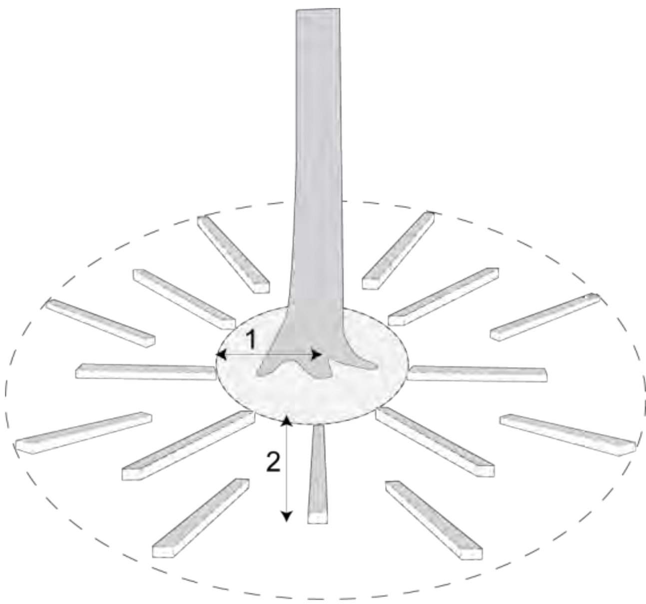

Figure 5.4.3-17. Radial trenching – 1) 3 to 5 feet away from the trunk, 2) trenches 10 inches wide, 10 to 15 inches deep to the edge of the drip line of the tree as indicated.

<u>Soil Amendments</u>

Soils should be amended, as suggested by the soil test analysis.

There are several possible organic amendments:

- Compost: Composted leaves, sewage sludge, and animal waste, if permitted.
  - Compost should be well-decomposed so as not to “burn” the plants with heavy doses of raw nutrients.
  - Well-decomposed compost is an excellent source of slow-release nutrients, promoting plant growth, feeding beneficial soil microorganisms, and reducing water stress.
  - Wood derivatives: Shredded and composted, nitrogen-treated sawdust, ground bark, or woodchips.
  - Manure: Well-rotted, stable cattle manure.
- Fertilizers: Use organic compost or slow-release fertilizers. Base rates on recommendations provided by the soil test report. (Note: Fertilizers may not be needed for meadow conditions because meadows thrive in poor mineral soils and disturbed richer soils can encourage the growth of weeds and invasive plants.)

- Biological Amendments: Mycorrhizal inoculants and compost teas (a dissolved solution of compost made by steeping compost in water for three to seven days) are the most recently recommended amendments.
- Mulch and erosion control materials (type depends on vegetative cover):
  - Straw mulch with tackifier
  - Compost mulch
  - Woodchip mulch
  - Fiber mulch

Figure 5.4.3-18. Soil injected with mycorrhizal inoculants before planting.

Decontamination

Contaminated sites are often extremely complex and primarily the result of former and present land use. Land development at brownfield sites normally occurs in three phases:

1. Site assessment
2. Site remediation
3. Redevelopment

Mapping contaminated soils and the resulting cleanup can be time consuming and expensive. An expert team of contamination specialists (geologists, hydrologists, industrial chemists), as well as special geographic information system (GIS) and computer modeling skills, may be required if the problem is extensive and if the proposed redevelopment covers most of the site.

Management of stormwater on brownfield sites depends largely on the remediation strategies. Imaginative remediation schemes can be integrated with site development plans to reduce costs.

Figure 5.4.3-19. Compost tea brewer.

On contaminated sites, the aim of soil remediation is to reduce contaminants to a level suitable for the use proposed, allowing the site to be developed with minimal environmental risks.

Bioremediation is the most economical remedial technique available for severely contaminated sites. This technique uses specific plants with their associated microorganisms to treat organic fuel-based contaminants such as hydrocarbons. The microorganisms living on the plants, including bacteria and fungi, use the pollutants as food, transforming them into more benign chemical compounds. This method of treating severe contamination is not fully explored herein. It is akin to the removal of pollutants and sediments by vegetation discussed in other protective and restorative BMPs.

For more information on soil remediation, see TDEC Division of Remediation online at http://www.tn.gov/environment/dor/.

Urban Soils

Urban soils are those soils that are disturbed in profile (one or more layers) and may consist primarily of fill materials or construction debris. In natural soils, wind, water, ice, gravity, and heat are the active agents in soil-forming processes. Mixing, filling, and contamination create a soil very different in characteristic and function from a similar healthy natural soil.
General characteristics of urban soils are:

- Horizon layers mixed
- Compaction
- Presence of a surface crust on bare soil; usually hydrophobic
- Restricted aeration and water drainage
- Interrupted nutrient cycling and modified soil organism activity
- Presence of manmade materials and other contaminants
- Extreme soil temperature regimes (hot/cold)

Figure 5.4.3-20. Urban soils.

Mixed Soils

Mixed soils may change abruptly at one or more levels within the profile, meaning the rooting environment may be drastically different from one area to the next or the whole profile may be homogenized, with elements from previously distinct profiles intermixing in a variety of proportions throughout the site. This all depends on the type and extent of the processes having previously affected the soil on the site (stripping, filling, mixing, compaction, addition, etc.). Thorough analysis of the entire soil profile and its properties is needed to ensure proper design and planning for landscape, hardscape, and architectural elements on the site.

Construction Considerations

Preconstruction Soil Testing: See Protocol 3 – Soil Testing

Soils should be amended, based on information on texture, organic matter content, nutrient deficiencies, and pH, as determined by recommended USDA Extension Service soil tests.

Management of Disturbance and Soil Erosion

Minimize the length of time that soil is left bare and unprotected. Avoid leaving soil bare during rainy or windy periods. Provide special protections for critical areas, such as steep slopes and the borders of streams. Note: Chattanooga requires a Land Disturbing Permit for most land disturbing activity. Please refer to Chapter 3 for applicability.

- Clear only those areas where construction is to begin and avoid creating large expanses of cleared areas.
- Plant temporary vegetation or cover crops to hold soil in place.
- Use compost berms and erosion blankets to prevent soil movement. Use silt fences to mitigate overland flow of stormwater.
- Use mulch for temporary erosion control and as part of the final landscaping plan.

Soil Characteristics: The following soil characteristics are difficult or generally unsuitable for reuse in Chattanooga (USDA Forest Service 1979):

- Salinity (millimoles per cubic meter): greater than 6
- Alkalinity (exchangeable sodium percentage [ESP]): greater than 8
- Concentration of toxic or undesirable elements: Moderate and higher
- Soil pH: less than 5 and greater than 8

Infiltration Rates: See Protocol 3, Soil Testing, in this manual.

Amendments: The addition of organic compost is probably the most critical amendment for soil deficiencies on most sites to prepare the site for planting. To apply amendments, loosen the soil to a depth of 3 inches and incorporate the organic materials by rototilling or disk harrowing to mix the soil and compost again to a depth of at least 3 inches. Inoculate the site with compost tea (commercially available). Fertilization with nutrients the soil needs in the recommended quantities will make up for inherent nutrient deficiencies.

Placing Soils on Steep Slopes

On steep slopes, increasing soil moisture can potentially cause soil instability. Soil should be placed in these areas during dry weather and in early fall to allow the roots of the plants to establish before the onset of frost. On slopes steeper than 4:1, protect seeded areas with erosion-control blankets and/or erosion-control fiber mulch.

Designed Soils

- The various components of a designed soil must be mixed. A variety of methods exist for mixing.
- The soil profile is best installed by layers (soil horizons) to ensure horizontal continuity of the material. Use natural soil profiles typical of the area to suggest appropriate thickness of each layer. Wide variations in thickness within a layer are not acceptable.
- Place soil in 4- to 6-inch “lifts” to ensure uniform thickness. Mix each lift between horizons.
- Conduct recommended tests; see Protocol 3, Soil Testing, in this manual.

Stockpiling Topsoil

- Stockpiles must be protected from wind and water erosion. Cover with an impermeable material to slow down drying, reduce dust, and exclude windblown weed seeds. On large projects, piles can be planted with a fast-growing cover crop to provide protection.
- Keep piles moderately damp to avoid drying out, blowing away, and creating dust.
- Where possible, create several smaller piles, rather than one large pile, to keep the soil from compacting under its own weight. The depth of each pile should be no more than 6 feet for sandy soils and 4 feet for clay soils.
- Living organisms in stockpiles will die from lack of oxygen, excessive drying, or other factors. It is difficult to prevent this loss during storage. Remediate soil, when replaced, with compost teas and living organisms to restore the biotic component.
- Handle the soil in these stockpiles as little as possible to prevent compaction.
- Store soil for as short a time period as possible.
- If stockpiling areas are to be counted as permeable, when the soil pile has been removed and the project is complete, reinvigoration of soil remaining under the pile location (with compost teas and other amendments) will be required.

Placing Stockpiled or Imported Topsoil

- Test the topsoil before placing on prepared subsoil to identify deficient or missing nutrients, organic matter, texture, etc. as noted above.
- Amend soil with missing components. Note plant requirements for an adequate depth of topsoil:
  - A minimum of 4 inches for turf, no mow mix, and ornamental herbaceous plants.
  - 6 to 8 inches for woody vegetation.
  - 5 percent minimum organic content.
  - Compact each lift to 75 to 82 percent of maximum Standard Proctor density according to ASTM D 698 or a maximum of 100 pounds per square inch within the top 6 inches of the soil profile, measured using a cone penetrometer with a ¾-inch diameter head.
  - Note: Topsoil may not be required where planting meadow vegetation.
- To allow water to pass from one layer to the other, topsoil must be "bonded" to the subsoil when it is reapplied to disturbed areas. This bonding can be accomplished by applying 2 to 3 inches of topsoil, tilling it into the underlying soil, and then applying the remaining topsoil.

Operations and Maintenance

- After the restoration and amendment process, soil may settle. In these instances, the area(s) in question should be backfilled with additional approved material and compacted to specified rates. Any newly disturbed areas should be restored to an acceptable condition.
- Planting areas should be amended for any critical deficiencies as shown by the soil tests.
- Drainage swales and other BMPs with vegetation must be periodically cleared of sediment to ensure that soil layers drain properly and do not get clogged. Maintain a buffer of vegetation at the edges of each vegetated BMP to reduce erosion and sediment deposition.
- To ensure the long-term health of designed soil and BMP vegetation:
  - Collect initial soil samples in each soil area after construction is complete and submit them for laboratory testing for additional amendments needed.
  - Each "type" of soil must be sampled separately and not mixed together. Tailor amendments to each area to reduce the possibility of over-fertilization and contamination of groundwater.
  - Repeat soil sampling every two years after the initial sampling and amend soils to follow test recommendations.

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Criteria Checklist BMP 5.4.3

ITEM DESCRIPTION	YES	N/A
The following checklist provides a summary of design guidance for the owner/applicant for successful implementation.		
• Evaluate existing soil conditions, including bulk density, organic matter, soil texture, and existing vegetation, before forming a restoration strategy.	☐	☐
• Perform soil restoration where appropriate and useful, anywhere the soil has been disturbed or badly damaged, especially where there will be new planting.	☐	☐
• Determine which of the following options for amending or restoring soil is appropriate: importing topsoil from another location; modifying existing soil with amendments; designing the topsoil or soil profile.	☐	☐
• Do not spread topsoil or any material as a layer over unknown sub-base material.	☐	☐
• Utilize the appropriate soil de-compaction strategy depending on depth of compaction and proximity to areas of existing vegetation.	☐	☐
• Utilize the appropriate soil de-compaction strategy for soil around trees. Strategies include air spading, raised root soil fill, vertical mulching, and radial trenching.	☐	☐
• Amend soil, based on the deficiencies made apparent by soil test analysis.	☐	☐
• For mixed or urban soils, thoroughly analyze the entire soil profile and its properties to ensure proper design and planning for landscape, hardscape, and architectural elements on the site.	☐	☐
• Minimize the length of time that soil is left bare and unprotected.	☐	☐
• Provide special protection to critical areas such as steep slopes and stream borders.	☐	☐
• Control soil moisture on steep slopes to prevent soil instability. Installation should be performed during dry weather, and early enough in the year to permit the establishment of vegetation before the onset of winter.	☐	☐
• Utilize the appropriate soil stockpiling strategies.	☐	☐
• Provide language in specifications for imported topsoil to be “bonded” to the subsoil when it is reapplied to disturbed areas.	☐	☐
• Provide language in specifications if soil settling occurs, the area(s) in question should be backfilled with additional approved material, compacted to specified rates.	☐	☐

5.5.1 Street Sweeping

Description

Street sweeping is the preventive practice of removing large debris and small particulate matter from street surfaces. Regular street sweeping prevents buildup of sediments in the stormwater distribution system and the contamination of receiving waters.

Figure 5.5.1-1. This regenerative air street sweeping unit removes both large debris and fine particulates (http://www.tymco.com/sweepers/model-dst-6/index.htm, accessed August 2012).

BMP Functions Table

BMP	Applicability	Volume Reduction	Water Quality	Peak Rate Reduction	Recharge	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden*	Cost
Street Sweeping	U/S	L	M	L	L	L	L	L	M/H	L/M

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Maintenance burden varies depending on equipment manufacturer and pollutant loading from contributing land use.

Key Design Features

- Street sweeping programs must be designed in accordance with specific site characteristics, including traffic volume, land use around the area to be swept, and proximity to receiving waters.
- Street sweeping frequency must be increased in areas where sediment and debris accumulation is observed.
- Street sweeping programs must include a mechanism to record the amount of waste collected in order to reevaluate program needs and adjust frequency of street sweeping operations in areas that generate larger amounts of sediment and debris.

Variations

There are several types of commercial street sweeping units. The three most common include vacuum sweepers, regenerative air sweepers, and mechanical sweepers.

Vacuum sweepers use rotating brooms that feed into a high-powered vacuum to remove brush, sediment, and debris from paved surfaces. Some models spray the area to be vacuumed with a small amount of water to control dust while others operate on dry surfaces and incorporate a filter system for dust control. Vacuum sweepers are the only type of sweeping unit permissible on porous pavements.

Regenerative air sweepers also use rotating brooms that feed into high-powered vacuums, but include direct application of forced air to dislodge any residual sediment particles that may not be captured with brooms alone. Regenerative sweepers provide the highest water quality benefits as they remove fine particulates. Regenerative air sweepers and any sweepers that use forced air are not permitted for use on porous pavements.

Mechanical sweepers use rotating brooms to direct debris onto a conveyor system for collection into the sweeper unit. Most mechanical sweepers include water for dust suppression. These sweepers are not efficient for removal of fine particles and are not recommended for use in areas adjacent to receiving waters.

Applications

- Residential
- Commercial
- Industrial/institutional
- Urban and suburban areas

Advantages

- Improves water quality of stormwater runoff from impervious surfaces.
- Implemented correctly, street sweeping may be an effective pretreatment practice for highways, parking lots, and other large paved areas.

Disadvantages

- Street sweeping programs must be tailored to the needs of the City and consider the surrounding land uses and their potential for pollutant contribution.
- Requires flexibility in scheduling to avoid street sweeping during inclement weather and high traffic periods.

Applicable Protocols and Specifications

Street sweeping must be performed in accordance with the equipment manufacturer's instructions. Programs for street sweeping must be designed to consider the frequency of sweeping operations necessary to remove accumulated sediment at an effective rate.

Design Considerations

Street sweeping programs can vary in terms of water quality improvement depending on the frequency of street sweeping operation, the frequency of rainfall events in the area to be swept, and the pollutant contributions from upgradient land uses.

1. Frequency of Street Sweeping

The frequency of street sweeping is dependent on the traffic volume of the roadway or parking area to be swept and the anticipated pollutant load from the volume of traffic; higher traffic volume areas generate higher pollutant loadings. Pollutant reduction efficiency also depends on the frequency of rainfall events. A study performed in Portland, Oregon, found very high pollutant load reductions with minimum weekly street sweeping operations in an area with relatively frequent rainfall events. This study found that regenerative air street sweepers collected 30 percent to 70 percent of particles less than 63 microns in size and 94 percent to 96 percent of particles of greater size (Sutherland and Jelen 1997).

Table 5.5.1-1. Pollutant Contributions from Residential Source Areas, Bellevue, WA

Sweeping Operation	Frequency of Sweeping			
	Monthly	Twice Monthly	Sweeping Weekly	Twice Weekly
Schwarze EV	51	63	79	87
Elgin Regenerative	43	53	65	71
Tandem (M+V)	33	41	49	53
Mobil Mechanical	17	23	29	33
NURP Era	0	0	0	0

Source: Pitt 1985 (adapted from: *http://www.pacificwr.com/Publications/Newsletter_Vol4_No4.pdf,* accessed August 2012).

2. Upgradient Pollutant Contributions

Street sweeping efficiency must also take into consideration the pollutant contributions from upgradient surfaces that wash onto pavements scheduled for sweeping operations. This is less a concern for largely urban areas with a high percentage of imperviousness. And, if pollutants are only carried to paved areas during storm events, street sweeping will be significantly less effective. It is important to know the drainage area and the potential for pollutants to be carried to street sweeping areas in order to develop an appropriately frequent street sweeping program.

Table 5.5.1-2. Pollutant Contributions from Residential Source Areas, Bellevue, WA

	Percent Outfall Contributions from Source Areas					
Source Area	Total Solids	COD	Phosphate	TKN	Pb	Zn
Streets	9%	45%	32%	31%	60%	44%
Driveways and parking lots	6	27	21	20	37	28
Rooftops	<1	3	5	10	<1	24
Front yards	44	13	22	19	<1	2
Back yards	39	12	20	20	<1	2
Vacant lots and parks	2	<1	<1	<1	<1	<1

Source: Pitt 1985 (adapted from: *http://rpitt.eng.ua.edu/Publications/StormwaterTreatability/Street%20Cleaning%20Pitt%20et%20al%20SLC%202004.pdf*, accessed August 2012).

3. Type of Street Sweeping Unit

As discussed in the variations section, there are three general types of street sweeping units available. The sediment particle removal efficiencies vary by type of street sweeper used and the size of the particles collected on the pavement surface.

Table 5.5.1-3. Model-Based Removal Efficiencies for a Range of Particle Size Classes and Technology

Particle Size	NURP-Era Mechanical	Newer Mechanical	Regenerative Air	Vacuum
µm	% removal			
<63	44	100	32	70
63 > 125	52	100	71	77
125 >250	47	92	94	84
250 > 600	50	57	100	88
600 >1000	55	48	100	90
1000 > 2000	60	59	100	91
>2000 µm	51	76	82	82

Source: Sutherland and Jelen 1997 (adapted from Center for Watershed Protection, Technical Memorandum 1, October 2006).

4. Water Quality/Total Suspended Solids

Street sweeping programs may be included as part of a larger stormwater management system to ensure that 80 percent TSS removal is achieved. Any areas subject to street sweeping may also be managed for water quality with additional BMPs such as grass filter strips or grass swales.

In general, the greater the traffic volume on a paved surface (roadway or parking lot), the greater the pollutant loads. The greater the pollutant loads, the greater the potential effectiveness of street sweeping.

Operations and Maintenance

Street sweeping operations must be carefully planned and monitored to achieve the desired performance. Observations of accumulated sediment and/or debris will require increased sweeping frequency. Street sweeping programs must include a mechanism to record the amount of waste collected in order to reevaluate program needs and adjust frequency of street sweeping operations in areas that generate larger amounts of sediment and debris than anticipated in previous program design.

Equipment operation must be performed in accordance with manufacturer instructions. Maintenance of equipment must be performed in accordance with manufacturer specifications.

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Chapter 6 Technical Guidelines for Areas of Special Considerations

For the City of Chattanooga's stormwater program to achieve success in restoring the health of the City's streams and water resources, it is imperative that better stormwater management techniques be widely implemented. Certain areas represent challenges to the stormwater management approach defined and described in this manual as a result of higher than normal pollutant concentrations in runoff, the possibility of material spills that could contaminate groundwater or surface water, or past contamination issues that could become more dispersed in stormwater.

These areas may include:

- Hot areas and/or brownfield sites
- Highways and roads
- Urban redevelopment sites and CSO districts

In many instances, better stormwater management can be achieved in these areas through careful consideration in design, with the simplest approach often being to prevent runoff from the areas of special consideration from "mixing" with cleaner runoff. Other techniques, such as housekeeping and spill prevention and control, are essential and will improve opportunities for better stormwater management.

6.1 Hot Areas/Brownfields

The City's MS4 Permit defines "hot area" to mean an area where land use or activities have the potential to generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater. Applicants must clearly identify all potential hot areas on project concept and plan drawings. A typical example is the fueling area at a gas station. Other examples include loading dock areas (depending on the nature and amount of material handled) and outdoor material storage areas (again, depending on the nature of the stored material). Areas with a high potential for material spills should also be considered hot areas.

It is important to identify hot areas when developing a stormwater plan because the runoff may require a higher level of treatment, or the runoff may not be suitable for infiltration or reuse. It may be possible or desirable to keep the runoff from these hot areas from mixing with other site runoff, or to implement systems that can prevent stormwater mixing in the event of a spill. Stormwater runoff from other portions of the site should **never** be directed to, through, or across a hot area.

Many hot areas have higher than average pollutant levels, but are suitable for pretreatment measures or housekeeping practices that will address the pollutant levels such that the hot area may be suitable for inclusion in the SOV measures incorporated at the site. Waste containment dumpsters are one example (see Figure 6-1). Certain areas that are subject to spills of hazardous material may be addressed by spill containment practices (see Figure 6-2). Potential recommendations for hot areas and areas with higher pollutant loads are indicated in Table 6-1.

Figure 6-1. Dumpsters and outdoor storage of materials are examples of hot areas that can be addressed through better housekeeping practices.

Figure 6-2. Incorporation of a debris and spill containment program at a truck stop "hot area" located atop karst topography with a subsurface infiltration bed. Incorporation of these measures allowed for successful stormwater management, including infiltration on karst.

Table 6-1. Pretreatment Options for Stormwater Hot Areas

Minimum Pre-Treatment Options	Stormwater Hotspots: Vehicle Fueling Areas	Dumpsters/ Outdoor Material Storage, Loading Docks	Vehicle Maintenance	Outdoor Storage of Liquids	Other Uses or Activities Designated by Appropriate Autority	High use Areas, i.e. Fast Food restaurants, convenience stores, etc.
Oil/ Water Separators/ Hydrodynamic Separators	X		X		X	
Sediment Traps/ Catch Basin Sumps		X			X	X
Trash/ Debris Collectors in Catch Basins		X			X	X
Water Quality Inserts for Inlets	X	X	X	X	X	X
Use of Drip Pans and/or Dry Sweep Material under Vehicles/ Equipment	X		X			
Use of Absorbent Devices to Reduce Liquid Releases	X		X	X		
Spill Prevention and Response Program	X	X	X	X	X	
Diversion of Stormwater away from Potential Contamination Areas	X	X	X	X	X	X
Vegetated Swales/ Filter Strips		X			X	X
Stormwater Filters (Sand, Peat, Compost, etc)					X	X
BMPs that are a part of Stormwater Pollution Prevention Plan (SWPPP) under a NPDES Permit	X		X	X	X	

One specific type of hot area found in the City is a brownfield. The term brownfield is defined by the City's NPDES MS4 Permit to mean real property, the expansion, redevelopment, or reuse of which may be complicated by the presence of a hazardous substance, pollutant, or contaminant. Urban areas such as the City of Chattanooga may apply smart growth principles by working with TDEC to promote brownfield remediation and redevelopment to encourage the reuse of infill sites with pedestrian and public-transit access instead of increasing urban sprawl. TDEC maintains a database of properties identified as brownfields and oversees the remediation and redevelopment of those areas through the TDEC

Brownfields Program. More information about TDEC's Brownfields Program may be obtained at: (http://www.tn.gov/environment/dor/voap/).

Figure 6-3. This Salvation Army facility is located on a brownfield site and applied better storwmwater management practices.

Stormwater management options for brownfield redevelopment projects vary depending on the level of remediation a brownfield site has undergone prior to redevelopment (see Figure 6-3). Therefore, it is important to understand the extent and specific location of contamination to the greatest extent possible. Brownfield sites where contaminated soils have been completely removed may apply all stormwater management BMPs presented in this manual. Redevelopment of completely remediated brownfields should prioritize minimizing land disturbance and soil compaction, minimizing new impervious surfaces, and maximizing infiltration, evaporation/evapotranspiration, and reuse as an integrated measure throughout the site design. Brownfields that have not had contaminated soils completely removed during remediation may still be redeveloped, on the condition that certain precautionary protection measures are taken to avoid infiltration on or disturbance of "hot areas" where contaminated soils remain. Brownfields with remaining contaminated soils may not be suitable for structural stormwater infiltration measures, but may include nonstructural measures, such as disconnection of impervious surfaces, to promote evaporation, evapotranspiration, and infiltration.

The following recommendations may be applied when designing better stormwater practices for brownfield sites:

- **Understand the location and types of contaminants of concern at a site.** The pollutant concern areas may be localized or dispersed.
- **Avoid infiltration practices in contaminated areas.** This will prevent the further dispersement of pollutants. However, further testing may also demonstrate that the residual pollutants will not leach from the percolation of rainfall through the contaminated soils. It may not be necessary or desired to keep natural water movement from continuing through the soils.

- **Prevent runoff from "clean" areas from discharging on or through the area of contamination.** Never "mix" stormwater from contaminated areas with cleaner runoff, and avoid designs that could spread contamination from brownfield sites.
- **Retain existing vegetation and trees, and revegetate.** This will increase evapotranspiration as well as reduce the overall volume of runoff, while also restoring biological function to the soils.
- **Use impervious surfaces to prevent water movement through contaminated areas.** Impervious areas can be strategically placed over existing contamination areas.
- **Implement BMPs that reuse and evaporate rainfall**. Greenroofs and capture/reuse systems are especially important on brownfield sites.

In the event that a hot area, contaminated soils, or other hazardous materials are uncovered in the site investigation or construction, the designer or contractor should immediately contact TDEC at (423) 634-5755 for direction.

6.2 Highways and Roads

Highways and roadways present specific challenges for stormwater management. These include:

- Balancing stormwater management with safe traveling conditions
- Drainage areas comprised of up to 100 percent imperviousness
- Pollutant loads, especially high thermal pollution impacts
- Increased potential for hazardous material spills
- The use of chemical pollutants in construction materials
- Deicing and antiskid applications
- The linear nature of roadways, with limited right-of-way in many situations
- Visibility concerns associated with vegetation types and locations
- Areas of extensive cut and fill, especially in highway construction

These are only some of the issues to be considered when designing stormwater management BMPs for highway and road projects.

Water quality is perhaps the most important consideration in stormwater management measures for highway and roadway projects, as these areas tend to have higher levels of sediment and suspended solids. The Federal Highway Administration summarized the sources and concentrations of typical pollutant constituents in a 1999 study of highway and roadway drainage in ultra-urban areas. These summaries are shown in Table 6-2.

Table 6-2. Sources of Pollutants in Highway Runoff and Associated Concentrations (FHWA 1999)

Constituent	Source	Concentration (mg/L)
Particulates	Pavement wear, vehicles, atmospheric deposition, maintenance activities - Total Suspended Solids (TSS) - Volatile Suspended Solids (VSS) - Total Organic Carbon (TOC) - Chemical Oxygen Demand (COD) - Biochemical Oxygen Demand (BOD) - Fecal coliform (organisms/ 100 ml)	 TSS - 45-798 VSS - 4.3-79 TOC - 24-77 COD - 14.7-272 BOD - 12.7-37 50-590
Nitrogen, Phosphorus	Atmosperic deposition and fertilizer application - Total Kjeldahl Nitrogen (TKN) - Total Phosphorus as P - Nitrate & Nitrite (NO_3+NO_2)	TKN - 0.335-55.0 P - 0.113-0.998
Lead	Leaded gasoline from auto exhausts and tire wear	0.073-1.78
Zinc	Tire wear, motor oil, and grease	0.056-0.929
Iron	Autobody rust, steel highway structures such as bridges and guardrails, and moving engine parts	
Copper	Metal plating, bearing and brushing wear, moving engine parts, brake lining wear, fungicides and insecticides	0.022-7.033
Cadmium	Tire wear and insecticide application	
Chromium	Metal plating, moving engine parts, and brake lining wear	
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, brushing wear, brake lining wear, and asphalt paving.	
Manganese	Moving engine parts	
Cyanide	Anti-caking compounds used to keep deicing salts granular	
Sodium, Calcium, Chloride	Deicing salts	
Sulphates	Roadway beds, fuel, and deicing salts	
Petroleum	Spill, leaks, antifreeze and hydraulic fluids, and asphalt surface leachate	

An additional pollutant of concern for roadways is thermal pollution, as the initial runoff from roadways is often significantly warmer or colder than the receiving stream temperatures, and roadway runoff is often diverted directly to water bodies.

Stormwater runoff volume and pollutant concentrations may be minimized by incorporating filtration and infiltration BMPs to the maximum extent practicable. Vegetated swales, vegetated filter strips, and bioretention systems have excellent potential for improving water quality, reducing temperature impacts, and managing SOV for highway and roadway projects. Chapter 5 of this manual provides more detailed information on the BMPs mentioned above.

The following recommendations may be applied when designing better stormwater practices for roads and highways:

- **Integrate environmental protection issues early in the planning process.** This is an emerging trend in federal transportation projects, and should be applied to all roadway improvement or construction projects. Designers should be familiar with this manual, and the site protection BMPs described in Chapter 5 should be applied to roadway projects.
- **Minimize clearing and grubbing, and implement vegetative BMPs.** Both existing vegetation and restored vegetation can slow the velocity of runoff, reduce temperature impacts, and allow for infiltration and pollutant reduction. The rhizosphere (plant rooting zone) is the landscape area where the most significant water quality benefits are achieved, and should be retained to the greatest extent possible by limiting any unnecessary clearing. The type of road and level of traffic will influence the extent of density of vegetation that may safely be retained. Local roads, with lower volumes and speeds, should always be evaluated to minimize site clearing to the greatest extent possible. Often, areas are disturbed because clear direction on limiting disturbance was not provided.
- **Limit compaction to load-bearing areas.** Highways tend to have a significant amount of cut and fill, and a large footprint of disturbance. Local roadways are often constructed or repaired with little consideration of the effects of compaction. Compaction beyond 85 percent bulk density can inhibit root growth, and compaction requirements for non-load-bearing areas should not exceed 85 percent. Much of the compaction in non-load-bearing areas may occur inadvertently during construction, and therefore, it is especially important on roadway projects that the site protection BMPs described in Chapter 5 be defined and implemented (see Figure 6-4).

Figure 6-4. Unnecessary material storage and equipment movement can compact soils, resulting in more runoff after construction. Clearly limiting vehicle access to unpaved areas can improve soil conditions adjacent to roadways.

- **Consider the issue of spills.** Spills may occur on any roadway, although the likelihood of spills at many locations is low and should not preclude the use of a full range of BMPs, including infiltration. However, certain areas may have a greater likelihood of spills, such as the portion of rest stop areas where trucks are parked and stored, certain industrial area roads, and road maintenance/material storage areas. These areas should incorporate spill prevention and control measures.
- **Reduce impervious surfaces.** Where feasible and safe, reductions in road and shoulder width will reduce both stormwater impacts and project costs. Especially on new roads and low-speed/low-volume residential roads, reducing impervious area can save construction costs and also serve as one of the most cost-effective retrofit options (see Figure 6-5). Alternatively, pervious pavements may be used in parking lanes and spaces

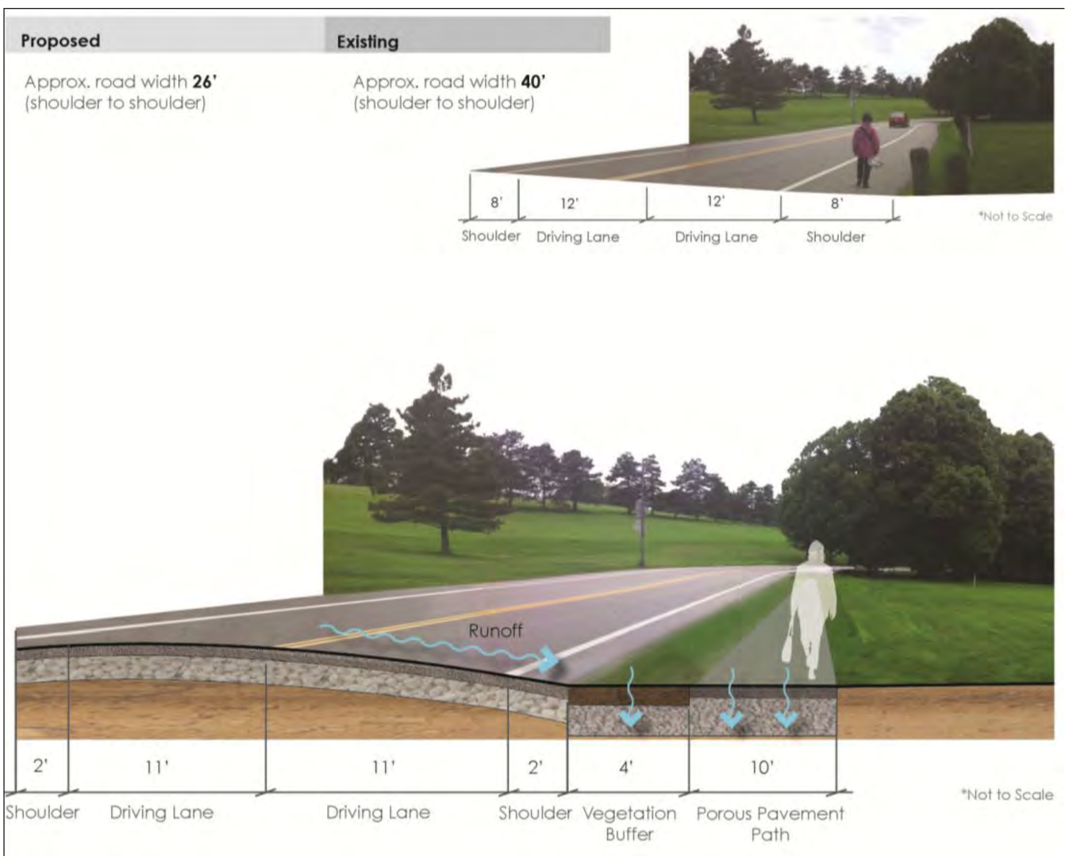

Figure 6-5. A green "skinny" street can manage runoff generated by the road and accommodate multiple users.

- **Limit the use of curb and gutter systems and the practice of conveying runoff in storm sewers wherever possible.** Where runoff from highways can be dispersed via sheet flow over a vegetated area, water quality can be improved. Level spreaders are an effective BMP for this practice. On local roads, curbs may be needed at certain locations to prevent traffic from straying from the pavement, such as entrances, intersections, etc. However, these curbs can be eliminated or depressed along portions of the road where curbs are not needed for traffic control.

Figure 6-6. A stormwater pipe discharging roadway runoff directly into an urban stream during a rainfall event.

- **Avoid discharging directly into water bodies.** In addition to spill concerns, the water quality and temperature impacts from roadways can decimate aquatic life. Temperature impacts alone can alter the entire microbial community and food chain in an otherwise healthy stream system. Roadway runoff should never be directed to any water body, including natural wetlands, without measures to reduce pollutants and temperature impacts (see Figure 6-6). Properly vegetated swales, filter strips, and dispersed flow over planted areas can serve this purpose.
- **Implement green infrastructure.** To achieve many of the recommendations above, the use of green infrastructure, such as tree trenches, vegetated swales, and bioretention systems, can and should be implemented following the guidelines provided in Chapter 5 of this manual.
- **Provide training and guidance for roadway maintenance staff, and require maintenance plan documentation in a format that can be easily used by maintenance staff.** In many roadway situations, little or no guidance or training is provided to the maintenance staff after construction is completed. It is imperative that maintenance staff be provided with specific guidance on the types of systems that have been installed, their required maintenance needs and schedules, and the appropriate practices. For example, many areas may require a reduced or altered mowing regime, but if guidance is not provided, this will not be put into practice. Every project should include a laminated 11-inch by 17-inch maintenance plan for guidance after designers and contractors have completed construction.

- **Reevaluate roadside ditch cleaning and maintenance practices.** Proper maintenance of ditches is important to both flood control and water quality, however, there may be opportunities to improve or maintain vegetation. The Washington State Department of Transportation assessed maintenance practices for highway ditches and bioswales and found significant water quality benefits when the lower portion of vegetation (approximately one-quarter) was retained. The specific findings and recommendations can be found at http://www.wsdot.wa.gov/Research/Reports/400/495.1.htm.

Additionally, all stormwater management measures associated with highway and roadway projects within the public right-of-way of a City or Tennessee Department of Transportation (TDOT) roadway shall be, at a minimum, designed, constructed, and maintained in a manner consistent with the City's Code and Engineering Standards and TDOT's current General NPDES Permit for Discharges of Storm Water Associated with Construction Activities (Construction General Permit or CGP) issued by TDEC, as appropriate. Additional information on TDOT's Construction General Permit and Statewide Storm Water Management Plan may be found at http://www.tdot.state.tn.us/sswmp/.

6.3 Urban Redevelopment and Combined Sewer Overflows

Two additional areas requiring special consideration for stormwater management within the City of Chattanooga are urban redevelopment areas and combined sewer overflows. Urban areas have often been subjected to significant soil compaction activities, which result in nearly impervious soil conditions. These areas may also be underlain by a maze of maintained and/or abandoned utilities and infrastructure with the potential to limit the implementation of infiltration BMPs. When redevelopment is proposed on an urban infill site, applicants may need to consider alternate stormwater management measures to achieve required SOV and meet water quality objectives. Redevelopment projects can improve stormwater conditions in a number of ways, including modifying soil to promote vegetated filters and swales, reducing the existing impervious surface area, and incorporating a green roof into building designs.

Reduction of impervious surface areas and installation of green roofs are also effective at managing stormwater in areas that are tributary to a CSO. CSOs may also benefit from the application of extended detention BMPs to allow for the slow release of site captured water; this allows for a reduction in synchronous peak flows, which are typical of the characteristic flashiness of small urban watersheds.

In both urban redevelopment and CSO areas, applicants must be diligent in the site assessment phase to document potential conflicts, such as underground utilities and other infrastructure, as well as current and past land use, to ensure appropriate BMP selection.

Potential urban redevelopment and CSO area design constraints:

- Limited space and zero lot line properties
- Underground utilities (both in use and abandoned)
- Unknown fill material, or fill consisting primarily of urban rubble
- Lack of remaining soil, and the need to recreate healthy soils
- Highly compacted soil conditions
- High density of use and the durability of materials, especially vegetative systems
- Need to maintain safe traffic and Americans with Disabilities Act (ADA) requirements

6.4 References

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Chapter 7 Stormwater Management Calculations and Methodology

7.1 Overview

There are five primary components of better stormwater management that the designer must document for stormwater permitting requirements:

1. **Reduction of runoff quantities and pollutant loads** through source control and other non-structural practices (site protection and restoration BMPs).
2. **Capture and retention of the SOV** (in cubic feet of runoff).
3. Implementation of **water quality management** to achieve 80 percent reduction in TSS (in percent reduction).
4. Sufficient **conveyance capacity** of all stormwater structures to safely convey or direct peak flow rates (in cubic feet per second or feet per second as appropriate).
5. Mitigation of the **peak flow rate** (in cubic feet per second).

Several methodologies are available to estimate total runoff volume and peak runoff rate, as well as different approaches for estimating water quality improvement. This chapter describes the calculation methodologies required to comply with stormwater management regulations in the City of Chattanooga. Certain project types and sites may not be required to meet all stormwater calculation components as described in Chapter 3 and later sections of this chapter.

7.2 Step 1 − Runoff Reduction through Site Protection and Restoration

Rethinking the site design to reduce the hydrologic impacts of development is one of the most important and effective stormwater practices. Implementing better stormwater management begins by reducing unnecessary site disturbance, protecting important natural features and functions (protective BMPs), and employing practices that restore or recreate the functions of natural features (restorative BMPs).

<u>Damage Prevention and Site Protection BMP Credits (Protective BMPs)</u>

Protective BMPs are practices that protect and maintain areas of water quality and ecological benefit, and protect areas that are more susceptible to erosion and pollutant generation when disturbed. For the purpose of calculations and methodologies for specific protective BMPs, **the project area that incorporates protective BMPs is excluded from the project area used to calculate the SOV and water quality**. In other words, if a site area is protected and undisturbed as described in the protective BMPs, it is assumed that the protective BMPs provide water quality benefits and reduce runoff volumes. The area protected by the following "protective BMPs" in this manual may be excluded from SOV calculations:

5.2.1 Protect Undisturbed and Healthy Soils
- 5.2.1.1 Preserving Landforms
- 5.2.1.2 Protect Highly Erodible Soils on Steep Slopes

5.2.2 Protect and Incorporate Natural Flow Paths
5.2.3 Protect and Preserve Riparian Corridors
5.2.4 Protect and Preserve Natural Vegetation
- 5.2.4.1 Protect Historic or Specimen Trees

In order for these BMPs to be credited, they must be properly documented and implemented during construction. Chapter 5 provides specific guidance for each BMP, along with a checklist for compliance for each protective BMP. Essentially, for a project intended to protect a portion of a site both during and after construction, certain practices and measures must be implemented and documented on the plan sheets.

For example, tree protection fencing must be installed and maintained during construction, but if the area under a canopy tree is protected, it may be subtracted from the SOV and water quality area. The Protect Undisturbed and Healthy Soils BMP (Section 5.2.1) may be widely applied to new and redevelopment projects to reduce SOV. Portions of the site that can be protected from disturbance and from the movement of equipment and vehicles during and after construction can be considered undisturbed and excluded from the SOV and water quality requirements.

Excluding the area of protective BMPs in the SOV and water quality calculations is intended as an incentive to applicants/owners to reduce site disturbance and maintain the water quality benefits of important natural features. Reducing the site disturbance footprint will directly reduce the SOV. It should be noted that the drainage area of protective BMPs is **not** excluded from peak flow rate and safe conveyance calculations. This includes safe conveyance of flows originating offsite. These areas will contribute stormwater runoff in larger storm events, and this runoff must be safely managed to prevent localized or regional flooding conditions.

Additionally, the protective BMPs include BMP 5.2.4.2, Soil and Plant Salvage. This BMP will not reduce SOV, but the reuse of soils and plants can maintain ecological function and may reduce construction costs for the applicant/owner.

Protective practices allow a developer to exclude areas needing SOV management by implementing protective practices that maintain a site's ability to self-manage stormwater. By preventing the possibility for damage to a site's natural features, a developer is able to avoid building stormwater infrastructure for protected areas in a good, natural condition.

Restorative Practices and BMP Credits (Restorative BMPs)

A number of BMPs are presented in Chapter 5 that improve water quality by restoring the health and function of natural systems, and correspondingly reduce runoff volumes and pollutant loads. These are referred to as restorative BMPs and include:

5.4.1 Recreate Natural Flow Patterns
  5.4.1.1 Naturalize Swales and Drainage Channels
5.4.2 Improve Native Landscape Cover Types
  5.4.2.1 Change Cover Type
5.4.3 Amend and Restore Disturbed Soils

For the purpose of calculations and methodologies, **each of these restorative BMPs provides a specific volume credit (based on size/extent of BMP). These credits can be used to directly reduce the project SOV.**

Specific guidance for each restorative BMP, along with a checklist for compliance for each restorative BMP, is provided in Chapter 5. Section 7.7 provides "Credit Calculations and Worksheets."

Inclusion of these restorative practices allows for a credit to be applied to the SOV that a developer is required to manage. By implementing these practices, up to 25 percent of the required SOV can be excluded from management, thus decreasing the size of BMPs needed to manage a disturbed area's SOV. This credit can help a developer save time, effort, and capital on the implementation of stormwater BMPs because the necessary SOV to be managed is reduced. The developer receives value from the implementation of restorative practices while stormwater runoff volumes are reduced as a result of improved site management.

Green Roofs, Pervious Pavement, and Tree Planting Incentives

In addition to protective BMPs and restorative BMPs, certain practices also serve to reduce runoff, and correspondingly, can be excluded from the area used to quantify the required SOV:

- Pervious Pavement that Is Exclusively "Self-Managing"

  Pervious pavement is described in BMP 5.3.1. A pervious pavement area that **only** receives direct rainfall (that lands on the pavement or drains onto the pavement) can be excluded from the area used to calculate SOV. That is, the footprint of self-managing pervious pavement can be excluded from the area used to calculate SOV. Typical areas that may be eligible for this incentive include pervious paths, plazas, sidewalks, and parking areas.

In many applications, a pervious pavement area may be constructed over a stormwater bed that is intended to receive and manage runoff from other areas. (For example, the designer may elect to convey additional runoff from other areas into the stormwater bed, as discussed in Chapter 5.) In this situation, where the pervious pavement area is managing a larger project area, the pervious pavement is **not** eligible for exclusion from the area used to calculate SOV. Instead, the storage capacity of the stormwater bed is used to meet site SOV requirements, and the pavement is considered to have the same runoff coefficients as impervious pavement (since all rainfall will directly enter the stormwater bed and must be accounted for).

- Green Roofs

  Green roofs can be used to manage SOV onsite. Designs and supporting calculations should be submitted to the City for approval during the concept level of the application process. Guidance on green roof design can be found in BMP 5.3.6.

  Tree canopy serves to intercept and slow rainfall, and tree root systems help to maintain a more permeable ground surface. New trees planted with the center of the trunk within 10 feet of connected impervious surfaces may be eligible for SOV reduction credit. Deciduous trees may qualify for 10 cubic feet of SOV credit, and coniferous trees may qualify for 6 cubic feet of SOV credit. All trees must be planted in accordance with the City's ordinances, including landscape requirements.

The Non-Structural BMP Credits Worksheet (see Section 7.7) can be used to quantify the stormwater benefits of protective BMPs, restorative BMPs, and incentives. Current worksheets can be accessed at *(http://www.chattanooga.gov/public-works/city-engineering-a-water-quality-program)*.

7.3 Step 2 – Manage Stay-on-Volume

The City's NPDES MS4 Permit requires applicants/owners to manage the first inch of rainfall with no discharge to surface waters. This volume of stormwater is defined as the SOV in Chapter 3 and is determined based on the runoff potential from the land uses within the project area. Calculation of the SOV is performed using the Small Storm Hydrology Method.

Project Area for SOV

As described above, the SOV is calculated based on the disturbed area of a project site. Areas that are undisturbed in accordance with the protective BMPs, as well as offsite drainage areas that are beyond the project property boundary, may be excluded from the SOV. This is shown diagrammatically on Figure 7-1. The applicant/owner is responsible for the SOV associated with the footprint of disturbance for a project site.

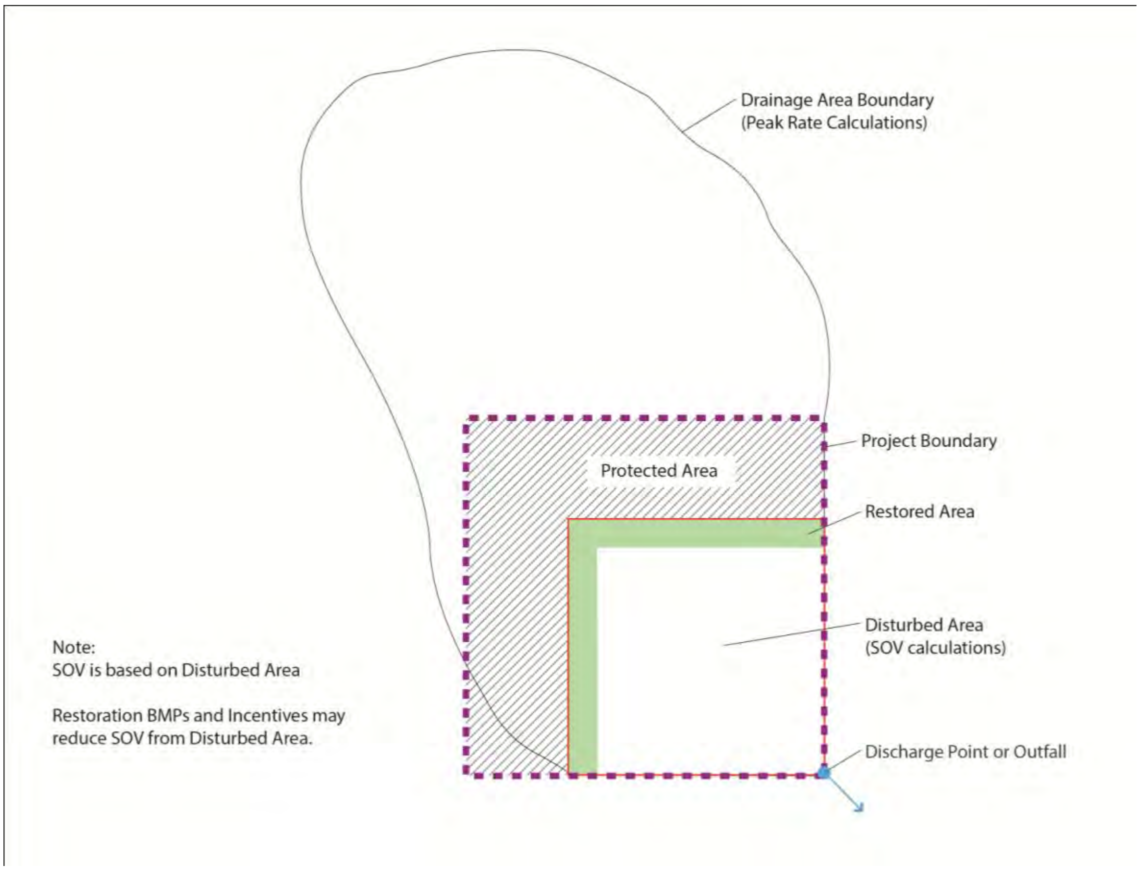


Figure 7-1. The SOV is calculated based on the disturbed area of a project. Protective BMPs and incentives may further reduce the SOV.

Small Storm Hydrology

The Small Storm Hydrology Method (SSHM) was developed to estimate the runoff volume from urban and suburban land uses for relatively small storm events (generally no more than 1.6 inches). Other common procedures, such as the runoff curve number method, are less accurate for small storms. The CN methodology can significantly underestimate the runoff generated from smaller storm events (Claytor and Schueler 1996 and Pitt 2003). The SSHM is a straightforward procedure in which runoff is calculated using volumetric runoff coefficients based on both land use type and rainfall. The runoff coefficients (Rv) are based on extensive field research from the Midwest and the southeastern United States, and Ontario, Canada, over a wide range of land uses and storm events. The coefficients have also been tested and verified for numerous other U.S. locations. Runoff coefficients for individual land uses generally vary with the rainfall amount – larger storms have higher coefficients. The runoff coefficients (Rv) for seven urban land use scenarios for the ½-inch, 1.0-inch, and 1.6-inch storms are provided in Table 7-1.

Table 7-1. Small Storm Hydrology Coefficients (Rv)

Small Storm Hydrology Coefficients (Rv) for Urban Land Uses

	Rv for 0.5"	Rv for1.0"	Rv for 1.6"	Rv for 2.1"
Flat Roof	0.79	0.85	0.88	0.90
Pitched Roof	0.95	0.97	0.99	0.99
Large Impervious Areas	0.97	0.98	0.99	0.99
Small Impervious Areas	0.64	0.70	0.79	0.85
Sandy Soils	0.02	0.03	0.05	0.08
Typical Urban Soils	0.10	0.12	0.15	0.18
Clayey Soils	0.19	0.21	0.24	0.27

Source: Pitt. 2003

Note:
- Soils mapped as "Urban" must use Rv values for urban soils.
- Soils mapped as Hydrologic Group A may use Rv values for sandy soils if soil group is described as sand. Otherwise, urban Rv values apply.
- Soils mapped as Hydrologic Group B must use Rv values for typical urban soils.
- Soils mapped as Hydrologic Group C or D must use Rv values for clayey soils.

See below for definitions.

The SSHM uses only those seven land area categories shown in Table 7.1. Based on field observation and detailed monitoring of specific source area runoff, several of these categories may be further defined as follows (Pitt 2003):

- ***Flat Roofs*** – This category also includes large unpaved parking areas located on typical urban soils. Large unpaved parking areas on sandy soils may apply the sandy soil runoff coefficients. In this context, "large" means an area of unpaved parking with an average dimension greater than 24 feet in any direction.

- ***Large Impervious Area*** – This category describes impervious areas with an average dimension greater than 24 feet in any direction. Examples of large impervious areas include parking lots with curbs, roads with curbs, highways, etc.

- ***Small impervious Areas*** – This category describes impervious areas with an average dimension no greater than 24 feet in any direction. Examples of small impervious areas include roads without curbs, small parking lots without curbs, and sidewalks.

For each land use type, SOV is calculated based on land use area, land use coefficient, and rainfall volume using the following equation:

SOV = P/12 * Rv * Area, where:

SOV = Stay-on-Volume (ft^3)
P = Rainfall depth (in)
Rv = Small Storm Hydrology Method runoff coefficient (Table 7-1)
A = area of land use (ft^2)

The Rainfall Depth P is based on project watershed location and type, and can be found in Table 3-2.

For a site with multiple land uses, SOV is calculated as follows:

$$SOV = \sum_{i=1}^{n} \left[\left(\frac{P}{12} * Rv_i * A_i\right) + \left(\frac{P}{12} * Rv_{i+1} * A_{i+1}\right) + \cdots + \left(\frac{P}{12} * Rv_n * A_n\right)\right]$$

For example, a small commercial building project that includes a single building structure with a pitched roof approximately 2,131 ft^2 in area, a large driveway/parking area approximately 12,258 ft^2 in size, and lawn areas (clayey soils) approximately 17,141 ft^2 in size would typically require management of 1,473 ft^3 SOV for a 1.0-inch rainfall depth, as calculated below:

$$SOV = \left[\left(\frac{1.0}{12} * 0.98 * 12{,}258\right) + \left(\frac{1.0}{12} * 0.21 * 17{,}141\right) + \left(\frac{1.0}{12} * 0.97 * 2{,}131\right)\right]$$
$$SOV = [1001 + 300 + 172]$$
$$SOV = 1473\ ft^3$$

A similar project located within the South Chickamauga watershed would require management of 2,448 ft^3 SOV for a 1.6-inch rainfall depth, per the calculations below:

$$SOV = \left[\left(\frac{1.6}{12} * 0.99 * 12{,}258\right) + \left(\frac{1.6}{12} * 0.24 * 17{,}141\right) + \left(\frac{1.6}{12} * 0.99 * 2{,}131\right)\right]$$
$$SOV = [1618 + 549 + 281]$$
$$SOV = 2{,}448\ ft^3$$

Managing SOV may be accomplished using one or a combination of BMPs, including restorative BMPs. As discussed previously, SOV may also be decreased by reducing site disturbance and implementing protective BMPs.

BMPs that infiltrate or capture and reuse runoff can be used to manage SOV. Many BMPs will also manage SOV via evapotranspiration (ET). ET is addressed in the BMP design by the volume credit assigned to soil storage (generally 20 percent of soil volume).

In practice, ET is a complex process by which plants, soils, and climatological processes interact. ET is a viable and important component for achieving SOV, but is difficult to quantify on a single rainfall event basis since ET occurs primarily during non-storm periods. Modeling ET involves dynamic simulation of multiple parameters over extended periods of time, including soil type, soil porosity, field moisture capacity, plant type, root depth, cover condition, and wilting point, as well as rainfall data, rainfall timing, and ambient temperature. Because of the complexity of determining ET quantities, applicants/owners wishing to take volume credit for ET must submit a detailed model analysis, such as WinSLAMM or similar model approved by the City of Chattanooga, that supports any additional reduction in SOV attained through ET.

SOV Rainfall Depth and Credits

The rainfall depth requirements for the calculation of SOV are described in Chapter 3, Table 3.2. These values (P = 1.6 inches for new development projects in the South Chickamauga watershed and 1 inch for all other new development; P = 1 inch for all redevelopment projects) are applied to calculated SOVs.

As described in Chapter 3, the City's NPDES MS4 Permit allows incentive standards for redeveloped sites. The City may allow a 10 percent reduction in the volume of rainfall to be managed (SOV) for the following types of development:

- Redevelopment in specific areas identified by the City
- Brownfield redevelopment
- High density (>7 units per acre)
- Vertical density (floor to area ratio of 2 or >18 units per acre)
- Mixed-use and transit-oriented development (within ½ mile of transit)

The 10 percent volume management reduction may be cumulative up to 50 percent for sites that meet multiple incentives. The project must meet the development type definition as defined by the City. The additional 10 percent reduction for redevelopment applies only to redevelopment locations or types specifically identified by the City as being eligible for the additional credit (i.e., redevelopment incentive areas).

The approval of any incentive reduction is at the discretion of the City to determine if the site meets the intent of the incentives. The applicant/owner must demonstrate that the proposed project meets the intent of the incentives.

For example, a commercial project located in the South Chickamauga watershed that meets City-defined criteria for both vertical density and transit-oriented development, and includes a 30,000-ft^2 building with a pitched roof and a 30,000-ft^2 parking garage with a flat roof (no parking on roof), would require management of 5,984 ft^3 of SOV, as calculated below:

$$SOV = \left[\left(\frac{1.6}{12} * 0.99 * 30{,}000\right) + \left(\frac{1.6}{12} * 0.88 * 30{,}000\right)\right] * (1.0 - 0.10 - 0.10)$$

$$SOV = [3{,}960 + 3{,}520] * 0.80$$

$$SOV = 5{,}984\ ft^3$$

SOV and Multiple BMPs for LID Design

Low-impact development is the practice of managing stormwater volume through soil and vegetative practices **close to the source of runoff**. This means that a site may include multiple BMPs, each located close to a source of runoff and managing a “sub-area” of a larger drainage area. This is shown diagrammatically on Figure 7-2 – Scenario 1. **The disturbed drainage area tributary to each structural BMP must be delineated, and each BMP sized to capture the SOV from the sub-drainage area.** If a BMP cannot manage the required SOV, it may discharge to a downstream area and BMP designed to accommodate the additional, unmanaged volume. This is shown diagrammatically on Figure 7-2 – Scenario 3. Designers may use Worksheet 3 of the LID Calculation Tool to appropriately size each BMP. **The sub-drainage areas used to calculate SOV may not necessarily correspond to areas required for peak rate calculations. Flow rate capacity calculations for structures such as inlets, pipes, etc. must consider all drainage to that structure, including offsite contributions.**

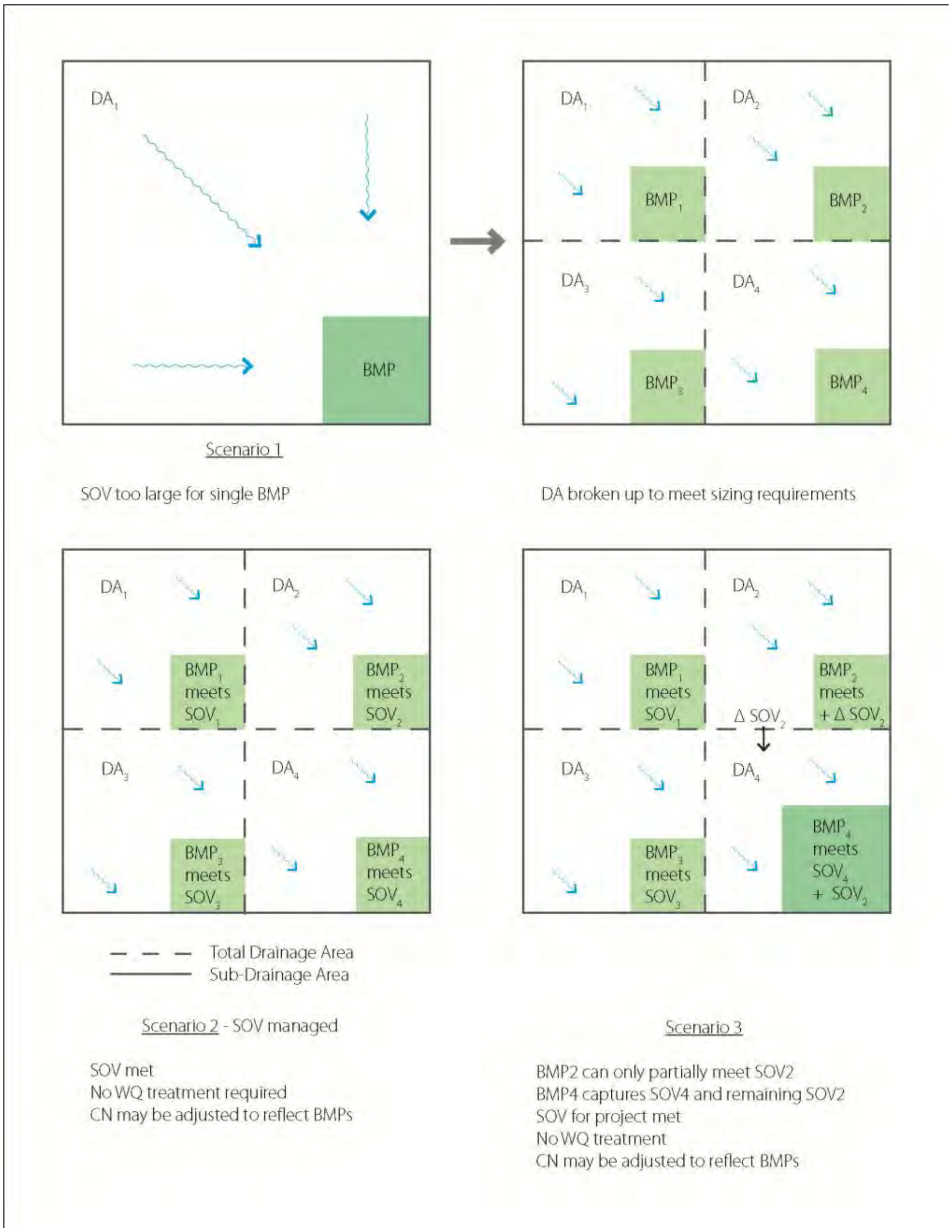


Figure 7-2. SOV and multiple BMPs for LID design.

Partial SOV Capture and “Swap” Areas

In certain instances, a project site may achieve only partial SOV capture. In such instances, the applicant/owner has several options:

1. The applicant/owner may elect to apply the water quality requirement. However, the water quality treatment volume requirements are based on a higher rainfall amount than the SOV rainfall amounts, as described in Section 7.3, and generally require volume capture, treatment, and, depending on the BMP, extended release over not less than 48 hours. The water quality rainfall may be reduced by the portion of the SOV rainfall managed as follows:

   Water Quality Rainfall − SOV Rainfall Managed = Adjusted Water Quality Rainfall

   For example, if the rainfall depth for calculation of the water quality volume is 2.1 inches, and the project has successfully achieved the SOV for a ½-inch rainfall, the adjusted water quality rainfall is:

   2.1 inches − 0.5 inches = 1.6 inches rainfall for water quality calculations

2. Alternatively, the applicant/owner may elect to manage an existing developed portion of the site (that currently does not have stormwater management), in lieu of managing the stormwater from the new construction. In other words, existing developed areas may be “swapped” to meet SOV requirements for the new development. The managed area must be part of the same property/location and under the control of the same applicant/owner. For example, the applicant/owner may elect to capture runoff from an existing building in lieu of managing an area of new construction. This is often a very cost-effective approach, especially in dense urban situations, brownfield sites, CSO areas, etc. The “swapping” of management areas must be approved by the City, and should be identified during the concept permit phase.

7.4 Step 3 – Water Quality Improvement

For projects that cannot manage 100 percent of the SOV, the City’s MS4 Permit requires that “….the remainder of the stipulated amount of rainfall must be treated prior to discharge with a technology documented to remove 80% total suspended solids (TSS). The treatment technology must be designed, installed and maintained to continue to meet this performance standard” (3.2.5.2.3 of the permit). Applicants/owners must demonstrate reduction of TSS by implementing treatment BMPs that are designed, installed, and maintained to continuously meet this water quality standard.

Water quality in stormwater runoff can vary greatly, affected primarily by land use and geographic location. For meeting stormwater management requirements, applicants/owners can demonstrate water quality improvement with one of the following approaches:

1. Capture, treatment, and slow release of the defined water quality volume of the runoff from the water quality rainfall. WQv is defined as the runoff resulting from the 1-year, 24-hour type II rainfall event for BMPs that treat flow rates and 2.1-inch rainfall for BMPs that treat volumes. Runoff must be captured by appropriately designed BMPs and remove 80 percent of the TSS. BMPs (e.g., 5.3.4, 5.3.11, etc.) that function by treating volume must slow release between 48 and 72 hours to allow adequate settling and treatment time and not dry out.

   or

2. Demonstration of the percent reduction of TSS achieved on an annual basis using a continuous simulation model, such as WinSLAMM or a previously approved equal.

   or

3. Percent reduction of TSS by BMP type based on the International BMP Database (http://www.bmpdatabase.org). (Note: The database indicates a range of effectiveness for various BMPs; the 96 percent confidence level is to be applied). The applicant/owner will be responsible for demonstrating to the City that the BMPs are designed to achieve the proposed percent reductions for TSS, based on estimated pollutant loadings from land use types and designed performance of BMPs.

Option 1: Capture, Treatment, and Slow Release of the Water Quality Volume

Project sites that are unable to manage 100 percent of the SOV must design, install, and maintain BMPs to improve the quality of stormwater runoff discharge in accordance with the City's MS4 Permit. Based on analysis of the City's existing land uses, the chart on Figure 7-3 shows that most of the accumulative (total) solids are associated with runoff resulting from rainfall depths of approximately 2.1 inches. As a baseline, project sites that are unable to manage 100 percent of the SOV must design, install, and maintain water quality BMPs to treat the first 2.1 inches of rainfall, less any partial SOV achieved, prior to discharging from the site.

For other than flow rate controlled manufactured BMPs, to provide sufficient time for water quality treatment to occur and to reduce the impacts of hydro-modification from unmitigated volume increases, the water quality runoff volume must be detained and slowly released between 48 and 72 hours. In other words, the water quality volume should be released at a low flow rate such that full (100 percent of stored volume) release does not occur until between 48 and 72 hours after the beginning of rainfall.

For project sites that must meet peak rate controls, this requirement may increase the size of detention storage. Therefore, applicants/owners are encouraged to achieve as high a SOV as feasible.

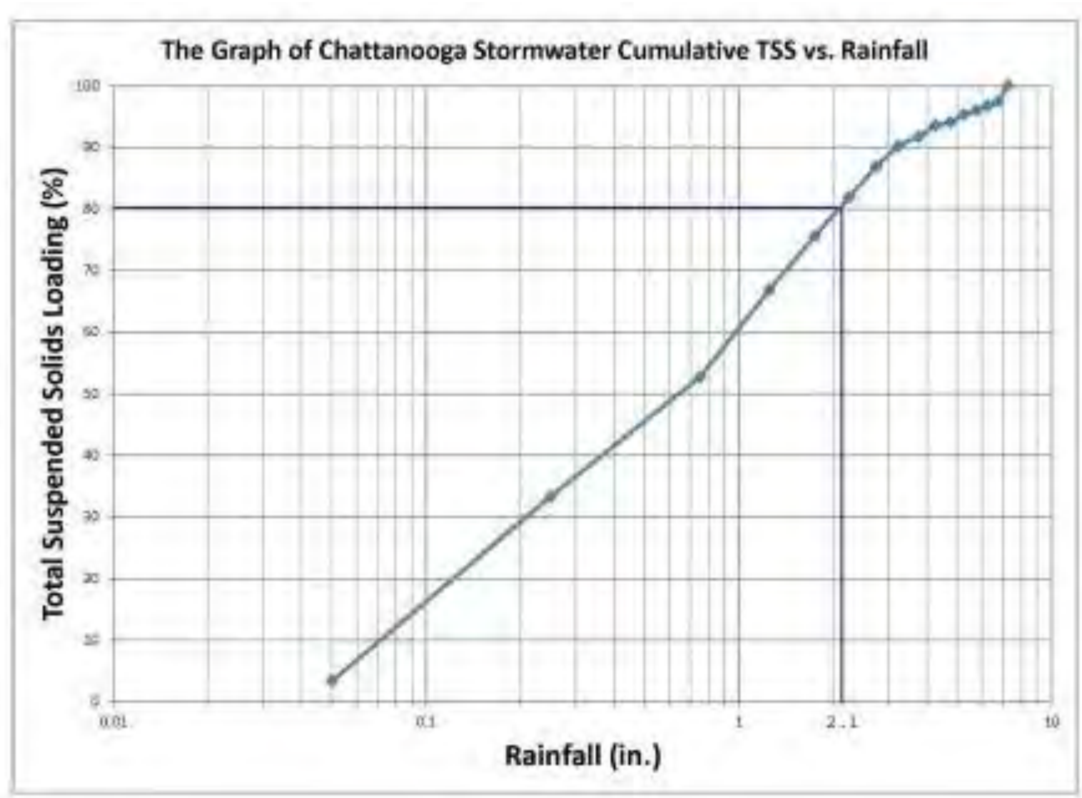


Figure 7-3. Rainfall capture and treatment for 80 percent TSS.

Option 2: Calculate the Percent TSS Reduction on an Annual Basis Using a Continuous Simulation Model that Incorporates Water Quality, such as WinSLAMM or Previously Approved Equal

Applicants/owners may provide a detailed model analysis, such as WinSLAMM, demonstrating achievement of an 80 percent reduction in TSS for different design storm depths. Submission of a WinSLAMM model does not in any way constitute approval from the City to manage a lesser storm. The City reserves the right to require management of runoff from the first 2.1 inches of rainfall regardless of submitted modeling.

Option 3: Percent Reduction of TSS by BMP Type Based on the International BMP Database (http://www.bmpdatabase.org/)

Alternatively, the City may allow the applicant to rely on assumed percent reduction values as provided in the International BMP Database. Many BMPs do not achieve 80 percent TSS reduction, and therefore, several BMPs may be required to achieve the targeted pollutant reduction. This approach does not consider different pollutant land use loadings, and therefore may result in areas where water quality BMPs are "over-applied" or "under-applied." To avoid this, the applicant is required to estimate pollutant loadings from land use types based on event mean concentration (EMC) values as provided in the International BMP Database or other documented sources. Providing the estimated effluent concentration and TSS loading for a specific rainfall event will allow the City to evaluate the performance of the proposed BMPs. The applicant should evaluate pollutant loadings and reductions based on the water quality rain event of 2.1 inches.

While the use of assumed percent reduction is widely accepted in other stormwater management programs, there is little supporting scientific evidence to substantiate performance in accordance with the assumed values. The applicant/owner should be prepared to support and substantiate any claimed TSS reduction values to the satisfaction of the City. Submission of documentation supporting an assumed percent reduction does not in any way constitute approval from the City. The City reserves the right to require additional management to meet water quality goals based on project location, type, and proposed BMP design.

One example where percent reduction may apply is when an applicant/owner proposes a hydrodynamic separation device from a certain manufacturer to treat runoff from a 10,000-square-foot parking area to achieve 80 percent TSS reduction.

First, the design runoff rate from the parking area must be computed, using the Rational Method for a 1-year design storm, as described below.

$$Qp = C * i * A$$

$$Qp = 0.98\ cfs$$

where:

- Qp = peak rate of runoff (ft^3/sec)
- C = 0.95, for impervious asphalt
- i = 4.5 (in/hr), for a 1-year design storm assuming a 5-minute time of concentration across the parking area
- A = 0.23 (ac)

A manufactured device is selected that has a design treatment capacity capable of handling an inflow velocity of 0.98 cubic feet per second (cfs). In this example, a manufactured device with a capacity range of 0.1 to 2 cfs was selected. See Section 5.3.12 for additional information regarding manufactured devices, including long-term operational monitoring requirements.

BMP Treatment Trains

A stormwater management BMP treatment train is a system of interconnected stormwater management BMPs constructed in series and designed to treat stormwater management to meet volume and rate reduction and water quality requirements. Studies have shown that incorporating treatment trains into traditionally developed projects significantly reduces pollutant loadings and volumetric runoff, and slows the rate at which stormwater leaves the project site. Treatment trains, however, rely primarily on appropriately sized source controls to achieve these benefits. While treatment trains promote green infrastructure and more closely mimic natural, undeveloped hydrologic conditions, it is important to realize the challenges and limitations when incorporating stormwater management BMP treatment trains into any site design. In particular, treatment trains rely on highly variable, assumed percent reductions to demonstrate compliance with intended water quality goals without considering the pollutant loading from contributing drainage areas. As such, stormwater management BMP treatment trains must provide a detailed model analysis, such as WinSLAMM or other City approved model, to document achievement of water quality goals prior to City approval.

Water quality BMPs, such as filter strips, and restorative BMPs, such as riparian buffers and restored soils, are important components of a treatment train approach. These practices reduce pollutants and also slow and reduce runoff. Designers are encouraged to incorporate such practices when SOV cannot be met, rather than relying on a single BMP to improve water quality.

Other Pollutants of Concern

The City of Chattanooga's NPDES MS4 Permit requires the City to reduce TSS concentrations from all new and redevelopment sites. However, TSS is not necessarily the only pollutant of concern; phosphorous, nitrogen, bacteria, and even temperature are pollutants commonly attributed to the various land uses found in Chattanooga.

Phosphorous is a chemical nutrient that can find its way into stormwater runoff from fertilized lawn areas, pet waste, road salts, and accumulated sediments. Increased levels of phosphorous in stormwater runoff may cause eutrophication and other water quality impairments that impact potability and recreational uses of affected water bodies (phosphorus is often the limiting nutrient in freshwater systems). Phosphorus is often bound to sediment such that TSS reduction can also reduce phosphorus loads.

Nitrogen is a chemical nutrient that may occur in several forms. Its primary contributing land use is agricultural sources, such as manure, and other natural sources; however, overuse of landscape fertilizers can impact nitrogen loads. Atmospheric deposition onto impervious surfaces can also contribute to nitrogen loads. Increased levels of nitrogen may cause algae and bacteria blooms that rapidly degrade water quality. Nitrogen is generally found in stormwater in a dissolved form that is not easily treated or removed. Vegetative BMPs must be maintained (i.e., vegetation removed at the end of the growing season) to prevent the release of nitrogen.

Bacteria, including E. coli, may be transported into stormwater runoff from pet waste or sanitary overflows during wet weather events. Livestock, wildlife, and septic systems can also affect bacteria levels. Bacteria and other pathogenic microorganisms create potentially devastating effects on human health and safety, not just from drinking contaminated water, but often merely from physical contact.

Finally, temperature plays a key role in the overall health and quality of waters receiving stormwater runoff. Any increase or decrease in temperature in a receiving water body, such as a stream, river, or lake, impacts the ability of that water body to sustain an environment suitable for its native species. For example, trout are primarily a cold water species; significant variations above the temperatures they can normally withstand may result in large-scale fish kills that impact both the health and recreational use of the affected water body. More commonly, alterations in stream temperature ranges will alter the microbial community in a water body, initiating species changes throughout the food chain.

Although the City's current NPDES MS4 Permit does not specifically require compliance with reduction requirements for any other pollutants of concern, Table 7-2 may be used as a general guide in determining which BMPs may improve water quality being degraded by the pollutants (other than TSS) described above.

Table 7-2. BMP Applicability Matrix for Water Quality Improvement for Specific Pollutants of Concern

BMP POLLUTANT REDUCTION POTENTIAL								
	Total Suspended Solids (TSS)		Total Phosphorus (TP)		Total Nitrogen (TN)		Bacteria E. Coli	
BMP	% Reduction	Performance Rating	% Reduction	Performance Rating	% Reduction	Performance Rating	% Reduction	Performance Rating
Pervious Pavement 5.3.1	80	H	40	L	18	L	--	--
Infiltration Bed 5.3.2	--	--	--	--	--	--	--	--
Infiltration Trench 5.3.3	--	--	--	--	--	--	--	--
Bioretention 5.3.4	78	H	18	L	36	L	71	H
Vegetated Swales 5.3.5	37	L	N/A	N/A	14	L	--	--
Vegetated Filter Strips 5.3.6	36	M	N/A	N/A	16	L	--	--
Infiltration Berms 5.3.7	--	--	--	--	--	--	--	--
Green Roofs 5.3.8	72	H	N/A	N/A	N/A	N/A	93	H
Runoff Capture and Reuse 5.3.9	--	--	--	--	--	--	--	--
Disconnection of Impervious Area 5.3.10	--	--	--	--	--	--	--	--
Stormwater Planter Box 5.3.11	--	--	--	--	--	--	--	--
Manufactured Devices 5.3.12	47	L	84	L	17	L	--	--

Key: H = High M = Medium L = Low N/A = Not Applicable

Pollutant reduction potential was adapted from performance summaries published in July 2012 by the International Stormwater BMP Database.

Notes:

1. Values for manufactured devices were taken as an average across the types specified in the IBD 2012 report.
2. Any device that returned a negative % reduction (increase) in any pollutant was marked with N/A.
3. Any % reduction over 70% was rated “H,” over 50% was rated “M,” below 50% was rated “L.”
4. Blank values indicate no data available.
5. Naturalized basin data (BMP 5.3.13) are not available and subject to design variables. Values can approximate bioretention.

7.5 Step 4 – Capacity Calculations

As defined in Chapter 3, stormwater designs must control peak discharge rates and demonstrate that all pipes, inlets, swales, trenches, and other stormwater conveyance structures have the capacity for the 10-year storm event. The designer should also consider conditions during large storm events onsite so as not to flood roads, buildings, etc.

Conveyance structures, such as pipes, swales, and inlets, that are designed only to transport runoff from project sites less than 25 acres may be sized for capacity using the Rational Method. Rational Method coefficients are provided in Table 7-3.The Rational Method has been used extensively to estimate peak runoff rates from relatively small (25 acres or less), highly impervious drainage areas using the following equation:

$$Qp = C * i * A$$

where:

Qp	=	peak rate of runoff (ft^3/sec)
C	=	rational method runoff coefficient
i	=	average rainfall intensity (in/hr) for a storm with duration equal to the time of concentration of the area
A	=	drainage area (ac)

The Rational Method may **not** be used to calculate water quality, infiltration, or SOV. The Rational Method may not be used to analyze peak rate mitigation in accordance with Section 7.6 below nor may it be used to calculate detention pond volumes.

Table 7-3. Rational Method Coefficients (C)

Rational Runoff Coefficients			
Land Cover	Rational Runoff Coefficient, C		
	slope <2%	slope 2%-7%	slope >7%
Flat Roofs	0.90	0.90	0.90
Pitched Roofs	1.00	1.00	1.00
Asphalt	0.95	0.95	0.95
Concrete	0.95	0.95	0.95
Brick	0.85	0.85	0.85
Unimproved Areas	0.35	0.35	0.35
Lawns, sandy soils	0.10	0.15	0.20
Lawns, urban and clayey soils	0.15	0.20	0.30
Meadow Areas	0.30	0.30	0.30
Wooded Areas	0.15	0.15	0.15

Adapted from Viessman, W. and M. Hammer, 1993

Average rainfall intensity in inches per hour (for the duration equal to the time of concentration) can be obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 interactive application at: http://dipper.nws.noaa.gov/hdsc/pfds/.

7.6 Step 5 – Peak Rate

The City requires applicants/owners to manage the peak flow rate at which all stormwater runoff leaving a project site is discharged. The post-development peak rate must not exceed the pre-developed peak rate of discharge for the 2-, 5-, 10, and 25-year storm events and check for the safe passage of the 100-year storm event.

Table 7-4. 24-hour Design Storm Rainfall Events for Chattanooga (reference: http://www.nws.noaa.gov/oh/hdsc)

24-HR Design Storm Rainfall Events for Chattanooga	
Rainfall Return Period (yr)	24-HR Rainfall Amount (in)
1	3.1
2	3.7
5	4.5
10	5.1
25	6.0
100	7.4

NRCS Unit Hydrograph Method for Peak Rate Calculation (Cover Complex Method)

NRCS developed a system to estimate peak runoff rates and runoff hydrographs using a dimensionless unit hydrograph derived from many natural unit hydrographs from diverse watersheds throughout the country (NRCS Chapter 16, 1972). As discussed below, the NRCS methodologies are available in several public domain computer models, including the TR-55 (WinTR-55) computer model (2003).

Runoff is calculated using this method with only a curve number (based on land cover type and hydrologic soil group) and rainfall depth. Curve numbers and additional information on the development of the method may be found in "Urban Hydrology for Small Watersheds" published by the Soil Conservation Service, now NRCS, in 1986. Recommended CN values for use in Chattanooga are provided in Table 7-5. Additionally, the recommended CN for pervious pavement is 75; green roofs may apply a CN of 72. **This methodology is commonly referred to as the "Cover Complex Method" and is the accepted methodology for peak rate calculation in Chattanooga.**

Table 7-5. Recommended NRCS Cover Complex Curve Numbers for Chattanooga Land Uses

Runoff curve numbers for urban areas [1]					
Cover Description		**Curve numbers for hydrologic soil group**			
Cover Type and hydrologic condition	Hydrologic condition	A	B	C	D
Impervious Areas:					
Paved parking lots, roof, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and Roads					
Paved: curbs and storm sewers (exclude right-of-way)		98	98	98	98
Paved, open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Meadow - continuous grass, protected from grazing and generally mowed for hay		30	58	71	78
Dirt (including right-of-way)		72	82	87	89
Pasture, grassland, or range - continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Brush - brush -weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Open Spaces (parks, golf courses, cemeteries, etc.)[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Woods-grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77

[1] Average runoff condition, and $I_a = 0.2S$.
[2] Poor: <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed
[3] Poor: < 50% ground cover
Fair: 50 to 75% ground cover
Good: > 75% ground cover
[4] Actual curve number is less than 30; use CN=30 for runoff computations
[5] CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods for pasture
[6] Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning
Fair: Woods are grazed but not burned, and some forest litter covers the soil
Good: Woods are protected from grazing , and litter and brush adequately cover the soil.

Technical Release 55 (TR-55) was originally published in 1975 as a simple procedure to estimate runoff volume, peak rate, hydrographs, and storage volumes required for peak rate control (NRCS 2002). TR-55 was released as a computer program in 1986 and work began on a modernized Windows version in 1998.

WinTR-55 generates hydrographs from urban and agricultural areas and routes them downstream through channels and/or reservoirs. WinTR-55 uses the TR-55 model for all of its hydrograph procedures and is an acceptable method to determine peak flow rate (NRCS 2002). WinTR-55 Version 1 was officially released in 2002 and can be downloaded at:
http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/quality/?&cid=stelprdb1042901.

WinTR-55 or other tools (e.g., HEC-HMS, HydroCAD) based on the Cover Complex Method may be used to estimate pre-development and post-development peak flow rates. There are also a number of proprietary software modeling tools that use the Cover Complex Method to calculate peak flow rates and may be used for stormwater calculation purposes.

Peak Rate and Simplified Method

Chapter 3, Section 3.3, Determining Applicability, specifies criteria based on impervious area and disturbed area that qualify projects for the Simplified Method and exemption from peak rate control. All projects in the CSO area regardless of size require peak rate attenuation coordinated with facility fixtures. SOV and water quality treatment requirements apply to all projects with 5,000 square feet or more of disturbed area. All projects seeking to use the Simplified Method must demonstrate safe conveyance of the 10-year event.

Peak Rate and Discharge Location or Outfall

A large project site may have multiple subareas and discharge points. The drainage areas of these subareas may be different between the pre- and post-development conditions. Projects have traditionally been evaluated for peak rate control "as a whole" such that the combined discharge rate at all discharge locations from the project site is not greater than the combined discharge rate before development.

The use of a "project discharge rate" is still acceptable with the following caveats:

- If a project site straddles two or more stream channel watersheds, the discharge rates must be evaluated on a sub-watershed basis. This is to discourage designs that alter the hydrology between two stream systems. This is especially important in headwater (first and second order) streams.

- The peak discharge to any specific site discharge location (to a discharge point from the property, to a surface discharge location, or to waters of the United States as defined at 40 CFR 122.2) cannot be greater after development than before development. This is to prevent localized stream channel erosion and alteration.

The Ten-Percent Rule

While retention of the SOV onsite reduces downstream volume, post-development discharges can nonetheless increase the total volume of runoff. This increased volume combined with other downstream tributaries may increase the peak flows. The “ten-percent” rule criterion has been adopted to improve the effectiveness of onsite detention in maintaining pre-development peak flows in the downstream system.

The ten-percent rule recognizes that onsite detention has a “zone of influence” downstream where its effectiveness can be felt. Beyond the zone of influence, the detention control becomes insignificant compared to the runoff from the total drainage area at that point. That zone of influence is considered to be the point where the drainage area controlled by onsite detention comprises 10 percent of the total drainage area. For example, if the site facility controls 10 acres, the zone of influence ends at the point where the total drainage area is 100 acres or greater.

Application of the ten-percent rule requires the design professional to:

- Determine the target peak flow for the site for pre-development conditions.
- Determine the lower limit of the zone of influence (10 percent point).
- Determine the pre-development peak flows and timing of those peaks at each tributary junction beginning at the pond outlet and ending at the next tributary junction beyond the 10 percent point.
- Change the land use on the site to post-development and rerun the model.
- Designed the onsite control facility such that the discharge from the site for the 25-year post-development storm event does not increase the peak flows at the outlet and the determined tributary junctions.

If downstream peak flow cannot be attenuated, one of the following options may be considered:

- Control of downstream impacts of the 25-year storm event volume may be waived by the City, saving the developer the cost of sizing a detention basin for downstream peak flow control. In this case, the City may require a mitigation fee from the developer for alleviating downstream flooding or making conveyance improvements.
- Work with the local government to reduce the flow elevation through the channel or flow conveyance structure improvements downstream.

- Obtain a flow easement from downstream property owners to the 10 percent point.

  Example:

  Site A is a development of 10 acres, all draining to an extended detention stormwater pond. The overbank flooding and extreme flood portions of the design are going to incorporate the ten-percent rule. Looking downstream at each tributary in turn, it is determined that the analysis should end at the tributary marked “80 acres.” The 100-acre (10 percent) point is between the 80-acre and 120-acre tributary junction points.

  The assumption is that if there is no peak flow increase at the 80-acre point, there will be no increase through the next stream reach downstream through the 10 percent point (100 acres) to the 120-acre point. The designer constructs a simple HEC-1 model of the 80-acre areas using single existing condition sub-watersheds for each tributary. Key detention structures existing in other tributaries must be modeled. An approximate curve number is used since the *actual* peak flow is not key for initial analysis; only the increase or decrease is important. The accuracy in curve number determination is not as significant as an accurate estimate of the time of concentration. Since flooding is an issue downstream, the pond is designed (through several iterations) until the peak flow does not increase at junction points downstream to the 80-acre point.

  Site B is located downstream at the point where the total drainage area is 190 acres. The site itself is only 6 acres. The first tributary junction downstream from the 10 percent point is the junction of the site outlet with the stream. The total 190 acres is modeled as one basin with care taken to estimate the time of concentration for input into the model of the watershed. The model shows that a detention facility at site B, in this case, will actually increase the peak flow in the stream.

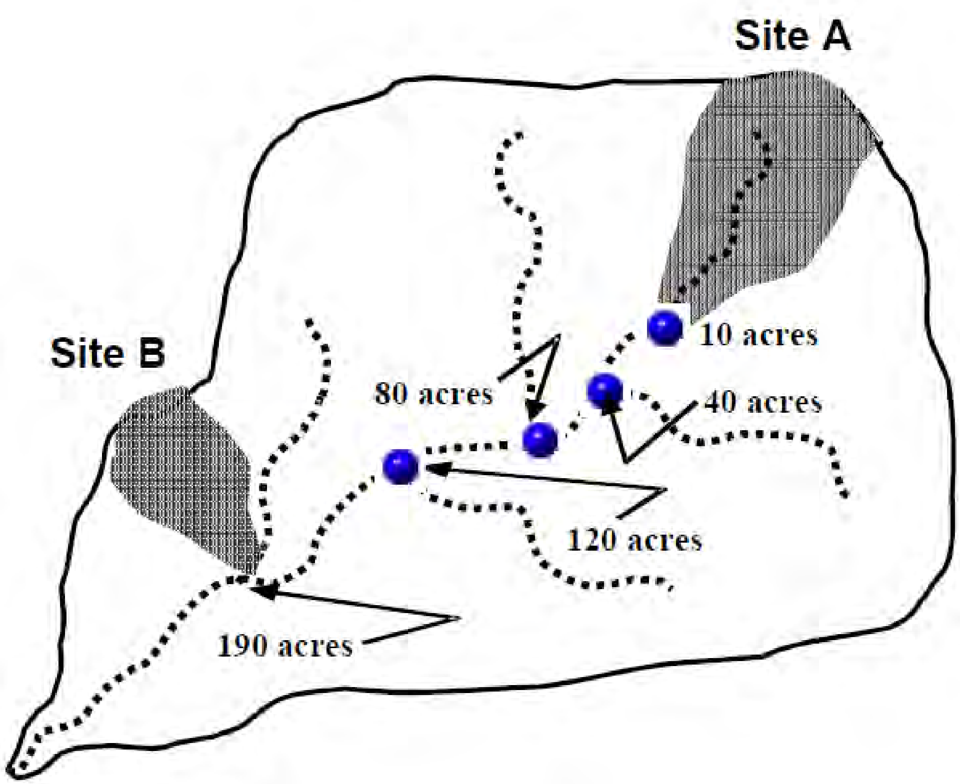


Figure 7-4. Example of Application of 10-Percent Rule (Source: Knox County, TN Stormwater Management Manual, Volume 2, 2008)

The 50-Acre Rule

Because of the potential flood hazard on property adjacent to an unmapped watercourse draining 50 acres or more above a property under construction, the City of Chattanooga may require that each unmapped watercourse draining 50 or more acres be investigated by a professional engineer and the elevation of adjacent structures with setbacks from the centerline of the unmapped watercourse marked on the design drawings and/or subdivision plat. The minimum elevation of the proposed structure shall be determined on the basis of a 100-year flood level on framed floor systems. The engineer shall use an accepted national method of calculation (e.g., USDA Technical Release No. 55 "Urban Hydrology for Small Watersheds"; American Society of Civil Engineers [ASCE] Manual of Practice No. 37 "Design and Construction of Sanitary and Storm Sewers"). The minimum setback shall be determined by an elevation of the unmapped watercourse based on the erosion potential of the watercourse and lot elevation as determined by the engineer. All projects adjacent to an unmapped watercourse draining 50 or more acres and for which 100-

year storm elevation calculations are required shall have a certification by a professional engineer that reads as follows:

I have made a flood hazard study of the project shown hereon and the drainage area above it and all affected proposed structures and/or lots within this project area are marked with a minimum building elevation. An elevation benchmark of public record for reference is noted on the drawings and/or plat, and established on the project with a minimum building elevation. Any unmarked proposed buildings and/or lots have been determined be above the required elevation and do not require a minimum building elevation due to their location and the existing drainage structure design.

SEAL

Name ________________________

*P.E. #*_______________

Such certification will be provided on the final plan submittal

Peak Rate and CN Adjustment to Reflect SOV Capture

To account for the impacts on peak rate reduction through the application of LID measures on a project site, an adjustment may be made to the CN assigned to disturbed areas managed by a BMP. The CN value is adjusted to reflect both the volume captured in various BMPs (SOV) as well as any infiltration that occurs over a defined time period during a large storm.

CN adjustment, part of the Runoff Reduction Method (Battiata et al. 2010), combines the NRCS runoff equations 2-1 through 2-4 in “Urban Hydrology for Small Watersheds” (USDA 1986) to develop an adjusted CN that accounts for the reduced runoff volume from implementing volume reduction BMPs. This modification of the standard computational procedure starts with a combination of TR-55 Runoff Equations 2-1 and 2-2 in order to show runoff depth in terms of rainfall and potential retention, producing Equation 2-3. In addition, the potential retention, S, is related to soil and cover conditions of the watershed through the designation of a runoff CN as shown in Equation 2-4.

TR-55 Eqn. 2-1:

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S}$$

TR-55 Eqn. 2-2

$$Ia = 0.2S$$

TR-55 Eqn. 2-3:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

TR-55 Eqn. 2-4:

$$S = \frac{1000}{CN} - 10$$

where:
- Q = Runoff volume (inches)
- P = rainfall depth (inches)
- Ia = Initial abstraction (inches)
- S = potential maximum retention after runoff begins (inches)
- CN = Runoff curve number
- R = Retention storage in inches (SOV provided by structural runoff reduction practices + allowable infiltration, see below)

In the CN adjustment method, the runoff depth (Q) is reduced to reflect the volume captured or infiltrated. The retention storage depth retained onsite (equivalent to the storage provided on the site through various structural BMPs and infiltration) is reflected in terms of R and is subtracted from the total runoff depth, Q in inches. A new modified S value (S_{mod}) is then calculated using Modified Eqn. 2-3. The S_{mod} value can be determined by reorganizing the modified Eqn. 2-3 to solve directly for S_{mod}.

Modified Eqn. 2-3:

$$Q - R = \frac{(P - 0.2S_{mod})^2}{(P + 0.8S_{mod})}$$

S_{mod} = potential maximum retention after runoff begins (inches) reflecting volume captured or infiltrated

For example, if Q = 4.19 inches, R = 1.01 inches, and P = 5.1 inches, modified equation 2-3 above can be solved for S_{mod} using the Quadratic Formula.

Standard Quadratic Equation:

$$ax^2 + bx + c = 0$$

Substituting values for Q, R, and P yields and combining like terms yields:

$$4.19 - 1.01 = (5.1 - 0.2S_{mod})^2 \div (5.1 - 0.2S_{mod})$$

Converting the equation to the standard Quadratic Equation form:

$$3.18 \text{ x } (5.1 + 0.8S_{mod}) = (5.1 - 0.2S_{mod}) \text{ x } (5.1 - 0.2S_{mod})$$

Completing the multiplication yields:

$$16.218 + 2.544S_{mod} = 26.01 - 2.04S_{mod} + 0.04\ (S_{mod})^2$$

Then combining and collecting like terms:

$$0.04 \text{ x } S_{mod}^2 - 4.584 \text{ x } S_{mod} + 9.792 = 0$$

This is now in the standard Quadratic Equation form where:

a = 0.04, b = 4.584, and c = 9.792

Solving the Quadratic Formula:

$$x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

$$S_{mod} = \frac{-(-4.584) \pm \sqrt{[(-4.584)^2 - 4(0.04)(9.792)]}}{2(0.04)}$$

Therefore, S_{mod} = 2.186 inches or 112 inches. Use S_{mod} = 2.186 inches.

Using the value found by solving for S_{mod}, a new adjusted CN may be calculated after rearranging Equation 2-4 as shown below (Battiata et al. 2010).

$$CN_{adj} = \frac{1000}{S_{mod} + 10}$$

For the purposes of site peak rate control, designers may adjust the CN value based on the volume managed by the SOV as well as the infiltration volume that occurs during a portion of the 24-hour design storm event. Designers may also adjust the CN value based solely on the water quality volume when proposing slow-release LID BMPs for water quality treatment. This will allow designers to account for runoff captured by applying LID and to develop a lower CN as described above.

When adjusting the CN, the infiltration volume may be estimated as the infiltration that occurs during 12 hours of a 14-hour design storm to ensure that credited infiltration volumes are not greater than the actual volume captured within each BMP. Infiltration volume may be estimated using the following equation:

Infiltration Volume (ft^3) = Infiltration BMP Bottom Area (ft^2) x Infiltration Rate (in/hr) x 1/12 x 12 hours

Retention storage (R) in inches may be calculated by adding the SOV captured (by all BMPs) plus the infiltration volume (provided by all BMPs) and dividing by the drainage area managed as follows:

R (inches) = (SOV + Infiltration Volume) (ft^3) / Drainage Area Managed (ft^2) x 1/12

For example, if a BMP is sized to capture a SOV of 1,260 ft^3, infiltrate 1,400 ft^3, and has a managed drainage area of 31,530 ft^2, the retention storage (R) is calculated as follows:

$$R\ (inches) = \left(\frac{1260 + 1400}{31{,}530}\right) \times \frac{12\ in.}{1\ ft.}$$

$$R = 1.01\ in.$$

Implementing this process for CN adjustment allows applicants/owners to illustrate the effect of LID components on the ability to attenuate peak rate increases seen as a result of traditional development. It is important to note, however, that the values for P are unique to each design storm. As such, a unique adjusted CN must be calculated for each design storm required.

Depending on conditions and the extent of LID, the adjusted post-development CN may be lower than the pre-development CN. However, the designer must confirm that the time of concentration (Tc in hours) is not shorter after development than before, assuming that peak rates have not been altered.

The CN value should **only** be adjusted for the disturbed area (or area managed by a volume managing BMP). If the outfall for peak flow rates includes other drainage areas (such as protected areas and/or any applicable offsite areas), the adjusted CN value should **not** include those areas. Protected areas and offsite areas should be evaluated as separate sub-areas for peak rate evaluation.

Worksheet 4 of the LID Calculation Tool includes the Quadratic Formula and may be used to adjust the CN value.

7.7 Credit Calculations and Worksheets

Restorative BMPs may qualify for up to a 25 percent SOV volume credit, whereas areas served by protective BMPs are not excluded from runoff determination.

Design and volume credits are available for the following non-structural BMPs:

Non-Structural BMP Credits Worksheet

<u>Protective Practices Credits</u>

5.2.1 Protect Undisturbed and Healthy Soils
- 5.2.1.1 Preserving Landforms
- 5.2.1.2 Protect Highly Erodible Soils on Steep Slopes

5.2.2 Protect and Incorporate Natural Flow Paths
5.2.3 Protect and Preserve Riparian Corridors
5.2.4 Protect and Preserve Natural Vegetation
- 5.2.4.1 Protect Historic or Specimen Trees
- 5.2.4.2 Soil and Plant Salvage

<u>Restorative Practices Credits (Volume Credits)</u>

5.4.1 Recreate Natural Flow Patterns
- 5.4.1.1 Naturalize Swales and Drainage Channels

5.4.2 Improve Native Landscape Cover Types
- 5.4.2.1 Change Cover Type

5.4.3 Amend and Restore Disturbed Soils

Non-Structural BMP Credits Worksheet

Protective Practices Credits

5.2.1 Area of Protected Undisturbed and Healthy Soils	________	ac.
5.2.1.1 Area of Minimized Land Disturbance	________	ac.
5.2.1.2 Area of Protected Soils/Steep Slopes	________	ac.
5.2.2 Area of Protected Natural Flow Paths	________	ac.
5.2.3 Area of Protected/Enhanced Riparian Corridors	________	ac.
5.2.4 Area of Protected/Preserved Vegetation	________	ac.
Total Protected Area	________	ac.

$$Site\ Area - Protected\ Area = Stormwater\ Management\ Area$$

[ ] - [ ] = [ ]

Restorative Practices Credits (**Maximum 25% of SOV**)

Volume Credits*

5.4.1 Recreate Natural Flow Patterns									
Vegetated Area of Natural Flow Path	________	ft^2	x	$^1/_4$"	x	$^1/_{12}$	=	________	ft^3
5.4.1.1 Naturalize Swales and Drainage Channels									
Vegetated Area of Naturalized Swale/Ditch	________	ft^2	x	$^1/_4$"	x	$^1/_{12}$	=	________	ft^3
5.4.2 Enhance Native Cover Types									
Area of Enhanced Native Cover Type	________	ft^2	x	$^1/_4$"	x	$^1/_{12}$	=	________	ft^3
5.4.2.1 Change Cover Type									
Area of Cover Changed to Meadow or other cover type (per BMP 5.4.2.1)	________	ft^2	x	$^1/_4$"	x	$^1/_{12}$	=		ft^3
Area of Cover Changed to Forest	________	ft^2	x	$^1/_2$"	x	$^1/_{12}$	=	________	ft^3
5.4.3 Amend and Restore Disturbed Soils									
Area of Amended/Restored Soils	________	ft^2	x	$^1/_4$"	x	$^1/_{12}$	=	________	ft^3
Tree Planting (2-inch caliper minimum)									
Deciduous	________	trees	x	10	ft^3	/tree	=	________	ft^3
Evergreen	________	trees	x	6	ft^3	/tree	=	________	ft^3
						Total Non-Structural Volume Reduction:		________	ft^3

7.8 Calculation Submittal Requirements

Applicants/owners must submit the following to the City prior to approval of any stormwater management plan:

1. All applicable worksheets in electronic format
2. All applicable Excel tools in electronic format
3. All modeling packages (TR-55, WinSLAMM) in original electronic format, including all applicable input/output files, land use files, rain files, and parameter files
4. Any hand calculations in paper format, to include the preparer and reviewer's initials and the date of calculation. All submissions must be legible.

Chapter 8 Maintenance and Performance

8.1 Introduction

Maintenance and operational inspection are critical to continued performance of all BMPs. Owners must check their facilities regularly to determine maintenance needs. An Operations and Maintenance Plan must be prepared and submitted to the City for any BMP that is implemented on a project. The Operations and Maintenance Plan must include a detailed schedule of maintenance activities, including a specific schedule of inspection frequency.

The primary goals of any Operations and Maintenance Plan are to:

- Establish legal and fiscal responsibility for operational inspection and maintenance activities.
- Establish grounds for physical access by the City to BMPs requiring inspection and maintenance.
- Provide a detailed schedule for the applicant/owner, who is legally responsible for performing all inspection and maintenance activities, including regulation inspection, routine maintenance, and regular operational activities required to maintain BMP function.
- Identify all facilities, runoff sources, and discharge points that require maintenance.
- Provide short-term and long-term guidance on operations and maintenance to prevent system deterioration and failure.
- Provide logs to be filled out by persons physically performing inspection and maintenance activities.

8.2 Operations and Maintenance Plan Requirements

Each project site must develop a site-specific Operations and Maintenance Plan that addresses all of the primary goals described above. At a minimum, a site-specific Operations and Maintenance Plan must include the following:

1. Map – A laminated copy of the Stormwater Management Plan drawing or map, drawn to a legible scale (maximum 1” = 100’) that accurately identifies the location, type, and associated infrastructure components for each BMP installed on the project site.
2. Inspection and Maintenance Agreement – A legal document (legal form provided by the City) identifying the owner(s) as the individual(s) responsible for ensuring that inspection, operations, and maintenance activities are completed.
3. Schedule – A detailed schedule of inspection frequency and maintenance/repair actions required at the time of inspection and a schedule of regular maintenance activities required for continued BMP performance.
4. Procedures – Detailed procedures outlining the specific actions necessary, including material replacement/repair procedures, to perform all scheduled maintenance tasks.

5. As-built Drawings – A laminated 11-inch by 17-inch copy of as-built construction plans showing all components of each BMP including inflow/outfall structures and monitoring areas and material certifications to ensure that repairs are completed in a manner consistent with intended design.
6. Inspection and Maintenance Logs – Forms by which persons performing inspections, operations, and maintenance activities can log their activities to document compliance with the Inspection and Maintenance Agreement.

8.3 Inspection and Maintenance Agreements

Necessary Inspection and Maintenance Agreements must be filed for each project as directed by the City and submitted to the Land Development Office with the Final Plans submittal

8.4 Inspection Checklists

The following inspection checklists may be amended to specific BMP designs when necessary to ensure compliance with a site-specific Operations and Maintenance Plan. These checklists should be submitted to the City as part of annual reporting requirements to the Water Quality Department.

Checklists follow for each major category of BMP:

5.2 Damage Prevention and Protection Practices

5.3 Structural BMPS

5.4 Restoration Practices

5.2.1	Protect Undisturbed and Healthy Soils Inspection Checklist	FORM

Inspected by: ____________ **BMP ID#:** ____________ **Property Owner:** ____________

Date of Inspection: ____________ **Weather:** ____________

Location Description: ____________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present.**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION				
	Is protective fencing still in place where designated by Site Protection Plan?		• Relocate/add fence per Site Protection Plan.	
	Are individual protection measures still in place, such as tree trunk protection and erosion control measures?		• Reinstall protections as shown in details.	
	Are stockpiles properly located?		• Relocate stockpiles to designated locations per design plans.	
	Are sensitive areas either extremely wet or dry?		• Avoid working in these areas. • Implement wet weather restrictions • Perform work only when soil is friable.	
	Are topsoil stockpiles protected from erosion and wind?		• Cover stockpile with breathable material or seed with fast-growing cover crop.	
AFTER CONSTRUCTION				
	Is regraded terrain protected from erosive surface water flows?		• New individual protections may be needed to intercept and control surface water flow.	
	Is planted vegetation protecting steep slopes intact and flourishing?		• Irrigate as needed. Replant dead plants or replace with stronger/more aggressive species.	
	Are erosion control measures still in place and functioning as designed?		• Reinstall damaged erosion control measures. Consult engineer if measures are not sufficient for site conditions.	
	Are construction disturbances encroaching on riparian corridors or other sensitive areas?		• Relocate fencing to protect sensitive areas.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.2.1.1	# Preserving Land Forms Inspection Checklist	FORM

Inspected by: ______________ **BMP ID#** ______________ **Property Owner:** ______________
Date of Inspection ______________ **Weather** ______________
Location Description: ______________

Inspection Category	**Inspector Verification** (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION					
		Are sedimentation and stormwater accumulating onsite?		• Areas designated as "Protected" or "Areas of Minimal Disturbance" must be protected from sediment and stormwater loads (from disturbed, upgradient parts of the site), as well as from construction traffic.	
		Do new grades meet existing grades after construction?		• Monitor to ensure these areas do not erode.	
		Is soil intact and undisturbed by foot traffic, especially on slopes?		• Fence off "Protected" and "Minimal Disturbance Areas" with chain link fencing as identified on the Site Protection Plan.	
		Are protection fences knocked down or damaged?		• If broken, fences need to be immediately repaired, and if knocked down, set up again.	
		Are sensitive areas either extremely wet or dry?		• Avoid working in these areas. • Implement wet weather restrictions • Perform work only when soil is friable.	
		Are construction disturbances encroaching on riparian corridors or other sensitive areas?		• Relocate fencing to protect sensitive areas.	
AFTER CONSTRUCTION					
		Do new grades meet existing grades after construction?		• Monitor to ensure these areas do not erode.	
		Is slope integrity suspect due to grading during site construction?		• Regraded terrain requires monitoring of surface water flow to ensure that slope integrity is maintained.	
		Are plants are dying on slope sides?		• Where plants are dying, replace with stronger, more aggressive species.	
		Is slope stabilization is suspect after site grading operations?		• Irrigate to establish new vegetation.	

5.2.1.1	Preserving Land Forms Inspection Checklist	FORM

Inspection Category	Inspector Verification (initial)	Maintenance Issue	Is this Issue Present? (Y/N)	Required Actions To Address Issues Present	Comments (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
		Are erosion control measures still in place and functioning as designed?		• Reinstall damaged erosion control measures. Consult engineer if measures are not sufficient for site conditions.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.2.1.2	Protect Highly Erodible Soils on Steep Slopes Inspection Checklist	FORM

Inspected by: ______________________ **BMP ID#** ______________________ **Property Owner:** ______________________
Date of Inspection ______________________ **Weather** ______________________
Location Description: ______________________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION				
	Are highly erodible soils and/or steep slopes present onsite?		• Mark limits of soil disturbance on the ground. Put protection measures in place – slope stability, erosion and sediment controls, site protection fencing, tree protection fencing.	
	How to ensure site fencing will hold up to be most effective?		• Ensure that fencing remains standing and without holes. Ensure that erosion control strategies are in place and functional.	
	Is runoff being directed toward the slope?		• Redirect construction runoff.	
AFTER CONSTRUCTION				
	How to ensure slopes will not erode after construction?		• Stabilize all disturbed slopes greater than 5% as soon as the work is finished. Stabilize all existing or newly installed swales and/or channels, especially on steep slopes with highly erodible soils.	
	What to do with site fencing after construction?		• Remove protective fencing unless requested otherwise by owner.	
	Is there any damage to protected areas?		• Repair any accidental damage to protected areas.	
	How will slope integrity be maintained?		• Steep terrain requires monitoring to ensure that slope integrity is maintained after adjacent lands have been modified. Locations where new grades meet steep slopes also require monitoring to ensure that the transition remains seamless.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.2.2	Protect and Incorporate Natural Flow Paths Inspection Checklist	FORM

Inspected by: ______________________ **BMP ID#** ______________________ **Property Owner:** ______________________

Date of Inspection ______________________ **Weather** ______________________

Location Description: ______________________

Inspector Verification (initial)	Maintenance Issue	Is this Issue Present? (Y/N)	Required Actions To Address Issues Present.	Comments (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION				
	Are the natural drainage features located and protected onsite?		• At the start of construction, natural drainage features to be protected should be identified, flagged, and fenced. These features must be included on both the site plan and the construction protection plan drawings.	
	Is there erosion, bank stability, sediment/debris accumulation, infested or dying plants or the presence of invasive species (both plant and animal) onsite?		• These problems should be corrected in a timely manner to avoid compounding these effects.	
	Is there proper overflow for each stormwater component?		• Provide for overflow mechanism if system is missing or deficient.	
	Do stormwater flows to drainage pathway inlets have energy dispersal mechanisms in place?		• Install splash block, level spreaders, energy dissipaters, etc.	
	Is existing healthy vegetation preserved along flow paths?		• Preserve existing plant material within and at the edge of these flow paths, or replace if damaged.	
AFTER CONSTRUCTION				
	Is there erosion, bank stability, sediment/debris accumulation, infested or dying plants or the presence of invasive species (both plant and animal) on site?		• These problems should be corrected in a timely manner to avoid compounding these effects.	
	Are new plantings being maintained?		• For new planting, watering, weeding, mulching, replanting, etc. may be required especially during the first year after planting.	
	Are there signs of drought?		• If the region is suffering from a prolonged drought, fragile areas with important stormwater functions should be watered to ensure that the vegetation lives.	

5.2.2	Protect and Incorporate Natural Flow Paths Inspection Checklist	FORM

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present.**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Are invasive exotics present?		• Invasive exotics should be removed and the flow path replanted with desirable replacements.	
	Are overflow inlets clogged?		• Remove debris from inlets after substantial rain events.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.2.3	Protect and Preserve Riparian Corridors Inspection Checklist	FORM

Inspected by: ______________________ **BMP ID#** ______________________ **Property Owner:** ______________________

Date of Inspection ______________________ **Weather** ______________________

Location Description: ______________________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION				
	Is there evidence of gully formation, denuded areas, bare soil or other damage after a large storm?		• Gullies should be filled and regraded, and bare spots replanted and protected.	
	Is dead wood present in stream corridor?		• Do not harvest trees in zone #1, dead wood in the streams provides important food for microorganisms in a healthy aquatic system.	
	Was a level spreading device used to concentrate flow into sheet flow?		• Check for any channelization or standing pools of water below the level spreader. Sediment and debris should be removed semiannually.	
	Are white tail deer present?		• Provide 18-foot open, wire or plastic deer fencing, or organize "culls" or private bow-hunting permits.	
	Is there a threat of damage (loss of vegetation and compaction) by vehicular traffic or pedestrians on larger campuses, parks, subdivisions, etc.?		• Farm or ranch fencing may be desirable around perimeter of zone #3.	
	Is there runoff channeled by swales in zones #1 and #2?		• Use a level spreader, or similar tool, in the meadow (zone #3) to convert concentrated flow to sheet flow. Any level spreader or similar tool used should be inspected periodically to repair any developing rills or standing pools of water. Sediment and debris should be removed from below the level spreader semiannually.	
	Is there exotic, invasive vegetation present in zones #2 and #3?		• Locate and suppress exotic, invasive vegetation (especially smothering vines) or a single, aggressive native species.	

5.2.3	Protect and Preserve Riparian Corridors Inspection Checklist	FORM

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
AFTER CONSTRUCTION				
	Are there new plantings in riparian corridor?		• Watering during the establishment period will be necessary if there are new plantings.	
	Is the design a corporate or residential community (including retirement complexes)?		• Consider having the tenants manage for wildlife.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.2.4	Protect and Preserve Natural Vegetation Especially on Steep Slopes and Along Flow Paths Inspection Checklist	FORM

Protect and Preserve Natural Vegetation
Especially on Steep Slopes and Along Flow Paths
Inspection Checklist

Inspected by: ____________________ **BMP ID#** ____________________ **Property Owner:** ____________________

Date of Inspection ____________________ **Weather** ____________________

Location Description: ____________________

Inspection Category	**Inspector Verification** (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION					
		Has protective fencing been placed around Protected Areas or Areas of Minimal Disturbance?		• Add protective fencing per Site Protection Plan.	
		Are exposed natural/forest edges being repaired?		• Begin repair process.	
		Is work being performed within the Protected Areas or Areas of Minimal Disturbance?		• Cross-check work being performed with written description of anticipated work within these areas. • Verify that work has been approved by landscape architect or owner's representative.	
		Is regular monitoring being performed?		• Monitor before and during construction for any signs of erosion, disease or invasive species and take corrective action.	
AFTER CONSTRUCTION					
		Are protected areas (especially around disturbed edges) being protected during drought conditions?		• Initiate temporary irrigation during drought periods for at least a 2-year recovery period.	
		Is regular monitoring being performed and corrective actions being taken?		• Monitor after construction for any signs of erosion, disease or invasive species and take corrective action.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.2.4.1	Protect Historic or Specimen Trees Inspection Checklist	FORM

Inspected by: ____________________ **BMP ID#** ____________________ **Property Owner:** ____________________
Date of Inspection ____________________ **Weather** ____________________
Location Description: ____________________

Inspection Category	**Inspector Verification** (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION					
		Has protective fencing been placed around trees?		• Relocate/add protective fencing per Tree Protection Plan.	
		Have initial protection measures been started prior to construction (one growing season prior)?		• Consult an arborist. • Begin protection measures immediately. • Typical measures include treatment with plant growth regulators, root pruning, fertilization, and canopy pruning.	
		Has construction activity been restricted within tree protection zones?		• Enforce construction activity limitations within protection zones. This includes no parking, vehicular use, stockpiling, storage, or staging within the designated root zones.	
		Have root zones been protected from compaction?		• Install measures to protect soil from compaction and disturbance if access routes are required through tree protection zones. • Avoid using large equipment near protected trees. • Route construction traffic where permanent hardscape is to be located that will not include BMPs.	
AFTER CONSTRUCTION					
		Are trees being protected from "drought stress" post construction?		• Initiate proactive irrigation during drought periods. • Be careful not to alter the hydrology of the soil.	
		Have trees been pruned?		• Prune dead wood and crossing branches for tree health and safety.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.2.4.2	**Soil and Plant Salvage Inspection Checklist**	FORM

Inspected by: ____________ **BMP ID#** ____________ **Property Owner:** ____________
Date of Inspection ____________ **Weather** ____________
Location Description: ____________

Inspection Category	**Inspector Verification** (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION					
		Has protective fencing been placed around salvage areas?		• Relocate/add protective fencing per Site Protection Plan.	
		Has tree protection fencing been placed around trees to be salvaged that are outside salvage areas?		• Add protective fencing per Site Protection Plan.	
		Has protective fencing been placed around placement areas?		• Relocate/add protective fencing around placement areas. • Avoid activities within placement areas that will result in increased soil compaction or erosion.	
		Have staging areas been delineated and supplied with temporary irrigation (if necessary)?		• Delineate staging areas. • Add protective fencing. • Supply area with temporary irrigation if required to sustain salvaged materials.	
AFTER CONSTRUCTION					
		Is supplemental water being supplied to salvaged material during the establishment period (I year minimum)?		• Supply area with temporary irrigation during the establishment period. • Provide contractor agreement for watering services.	
		Is the salvaged material being monitored regularly to ensure health?		• Monitor salvaged material.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.1	# Pervious Pavement Inspection Checklist	FORM

Inspected by: ______________________ **BMP ID#:** ______________________ **Property Owner:** ______________________

Date of Inspection: ______________________ **Weather:** ______________________

Location Description: ______________________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions to Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there standing or pooling water, especially on pervious surfaces?		• Check perforated pipe outlet for obstruction or damage.* • Flush perforated pipe to remove obstructions/sediment.* • Repair or replace perforated pipe, replace with new soil and regrade. • Subsurface layers may need cleaning and/or replacing. • In dry weather, use a mechanical sweeper or a vactor truck to vacuum clean surface area. • In wet weather, use a vactor truck to vacuum clean surface area.	
	Is there visible water flowing over the surface of the pervious concrete/pavers during a low-intensity storm?		• Check perforated pipe outlet for obstruction or damage.* • Flush perforated pipe to remove obstructions/sediment.* • Repair or replace perforated pipe, replace with new soil and regrade. • Subsurface layers may need cleaning and/or replacing. • In dry weather, use a mechanical sweeper or a vactor truck to vacuum clean surface area. • In wet weather, use a vactor truck to vacuum clean surface area.	
	Is there sediment visible on the surface of the pervious concrete?		• In dry weather, use a mechanical sweeper or a vactor truck to vacuum clean surface area.	

*If perforated pipe is present.

5.3.1	# Pervious Pavement Inspection Checklist	FORM

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there under cutting or washout along the sidewalks and/or curbs abutting a planter strip?		• Fill in eroded areas and regrade.	
	Are there cracks, uplifts, slumps, missing pavers, and/or potholes present?		• Check perforated pipe outlet for damage. • Repair or replace perforated pipe, replace with new soil and regrade. • Subsurface layers may need cleaning and/or replacing. • Replace or repair damaged areas.	
	Is there sediment present in the catch basin and in the overflow pipe?		• Check perforated pipe outlet for damage. • Repair or replace perforated pipe, replace with new soil and regrade. • Subsurface layers may need cleaning and/or replacing. • Replace or repair damaged areas.	
	Is vegetation clogging the inlet flow areas?		• Trim and/or remove the excess vegetation.	
	Is there vegetation growing in the cracks, stress lines, and/or abutment areas?		• Remove vegetation. • In dry weather, use a mechanical sweeper or a vactor truck to vacuum clean surface area. • In wet weather, use a vactor truck to vacuum clean surface area.	
	Is algae present?		• In dry weather, use a mechanical sweeper or a vactor truck to vacuum clean surface area. • In wet weather, use a vactor truck to vacuum clean surface area.	
	Is there trash/debris in the area?		• Remove all trash and debris.	

5.3.1	# Pervious Pavement Inspection Checklist	FORM

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there gummy material or other substances stuck to the pervious surface?		• In dry weather, use a mechanical sweeper or a vactor truck to vacuum clean surface area. • In wet weather, use a vactor truck to vacuum clean surface area.	
	Check for damaged sidewalk, curb, gutter, and catch basin including uplift and/or settling.		• Remove and replace damaged areas.	
	From the inspection port or inlets, is there evidence of water remaining in the bed after 3 days of dry weather?		• Further evaluate. Restoration may be required.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.2/5.3.4	Infiltration/Bioretention Inspection Checklist	FORM

Inspected by: ____________ **BMP ID#:** ____________ **Property Owner:** ____________

Date of Inspection: ____________ **Weather:** ____________

Location Description: ____________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there accumulation of sediment (sand, dirt, mud) at the infiltration bed entrance or overflow locations?		• Remove sediment and check the grading.	
	Is there evidence of animal activity such as holes or dirt mounds from digging or burrowing?		• Repair and fill in damaged areas. • Implement rodent control activities where warranted. Activities must be in accordance with applicable laws.	
	From the inspection port or inlets, is there evidence of water remaining in the bed after 3 days of dry weather?		• Further evaluate. Restoration may be required.	
	Is there trash/debris in the area?		• Remove all trash and debris.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.3	# Infiltration Trench Inspection Checklist	FORM

Inspected by: ____________________ **BMP ID#:** ____________________ **Property Owner:** ____________________

Date of Inspection: ____________________ **Weather:** ____

Location Description: ____

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there standing or pooling of water?		• Remove top layer of pea gravel. • If ponded water remains, further grading and replacement may be necessary.	
	Is water bypassing the trench opening?		• Clean and/or remove any obstructions in and around the inlet. • Check high-flow inlet for damage.	
	Is there evidence of under cutting or washouts around the inlet splash blocks?		• Reposition the inlet splash block(s) or dissipater(s). • Fill in eroded areas and regrade.	
	Is there accumulation of sediment (sand, dirt, mud) around the trench, especially at inlets?		• Remove sediment and check the grading.	
	From the inspection port or inlets, is there evidence of water remaining in the bed after 3 days of dry weather?		• Further evaluate. Restoration may be required.	
	Is there trash/debris in the trench area?		• Remove all trash and debris	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.5	Vegetated Swale Inspection Checklist	FORM

Inspected by: ____________________ **BMP ID#:** ____________________ **Property Owner:** ____________________

Date of Inspection: ____________________ **Weather:** ____

Location Description: ____

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there standing or pooling of water after 3 days of dry weather?		• Remove any obstruction in the swale and/or regrade to restore positive drainage.	
	Is there poor drainage during a high-intensity storm event (i.e., overtopping)?		• Clean the high-flow bypass inlet. • Check pipe for damage and/or blockage. Repair if required.	
	Is the flow into the vegetated swale even and uniform?		• Remove any obstruction preventing a uniform flow into the vegetated swale.	
	Is there evidence of under cutting or washouts along the impervious surfaces abutting the vegetated swale?		• Fill in eroded areas and regrade. • Erosion control materials must be used.	
	Is there channelization (gully) forming along the length of the vegetated swale area?		• Fill in eroded areas and regrade. • Additional repairs, such as the use of turf reinforcement material (TRM), may be necessary.	
	Is there accumulation of sediment (sand, dirt, mud) in the vegetative swale or at entrance?		• Remove sediment and check the grading. Add replacement soil and/or mulch.	
	Are there voids and/or holes around the high-flow bypass inlet?		• Inspect the high-flow bypass inlet for damage. Replace or repair as necessary. • Fill in eroded areas and regrade.	

5.3.5	Vegetated Swale Inspection Checklist	FORM

Inspector Verification (initial)	Maintenance Issue	Is this Issue Present? (Y/N)	Required Actions To Address Issues Present	Comments (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there evidence of animal activity such as holes or dirt mounds from digging or burrowing?		• Repair and fill in damaged areas. • Implement rodent control activities where warranted. Activities must be in accordance with applicable laws.	
	Is vegetation clogging the inlet/outlet flow areas?		• Trim and/or remove the excess vegetation.	
	Are there dead or dry plants/weeds? Is the vegetation overgrown?		• Remove dead and/or dry vegetation. Replace as needed. • Remove or trim any vegetation that is causing a visual barrier, trip, and/or obstruction hazard. • Mow grass as needed.	
	Is there trash/debris in the area?		• Remove all trash and debris.	
	Are there missing or disturbed aesthetics features?		• Replace and/or reposition aesthetic features to original placement. • Placement should not disrupt flow characteristics/design.	
	Are the aesthetic features firmly secured in place?		• Repair and/or replace loose or damaged features.	
	Check for damaged sidewalk, curb, gutter, and catch basin including uplift and settling.		• Remove and replace damaged areas.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.6	Vegetated Filter Strip Inspection Checklist	FORM

Inspected by: ______________________ **BMP ID#:** ______________________ **Property Owner:** ______________________

Date of Inspection: ______________________ **Weather:** ____

Location Description: ____

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there standing or pooling of water after 3 days of dry weather?		• Remove any obstruction in the buffer strip and/or regrade to restore positive drainage. • Clean and/or remove any obstructions in and around the storm drain inlet.	
	Is there poor drainage during a high-intensity storm event?		• Clean and/or remove any obstructions in and around the storm drain inlet.	
	Is the flow into the filter strip even and uniform?		• Remove any obstruction preventing a uniform flow into the filter strip.	
	Is there evidence of under cutting or washouts along the impervious surfaces of the filter strip?		• Fill in eroded areas and regrade.	
	Is there channelization (gully) forming along the length of the filter strip area?		• Fill in eroded areas and regrade.	
	Is there accumulation of sediment (sand, dirt, mud) in the filter strip?		• Remove sediment and check the grading. Add replacement soil and/or mulch.	
	Are there voids and/or holes around the storm drain inlets?		• Inspect the storm drain inlet for damage. Replace or repair as necessary. • Fill in eroded areas and regrade.	
	Has planting successfully established?		• Restore soils and planting. • Evaluation of selected species and soil conditions should be made to ensure successful restoration.	

Vegetated Filter Strip Inspection Checklist

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there evidence of animal activity such as holes or dirt mounds from digging or burrowing?		• Repair and fill in damaged areas. • Implement rodent control activities where warranted. Activities must be in accordance with applicable laws.	
	Is vegetation clogging the inlet/outlet flow areas?		• Trim and/or remove the excess vegetation.	
	Has planting successfully established?		• Restore soils and planting. • Evaluation of selected species and soil conditions should be made to ensure successful restoration.	
	Are there dead or dry plants/weeds? Is the vegetation overgrown?		• Remove dead and/or dry vegetation. Replace as needed. • Remove or trim any vegetation that is causing a visual barrier, trip, and/or obstruction hazard. • Mow grass as needed.	
	Is there trash/debris in the area?		• Remove all trash and debris.	
	Check for damaged sidewalk, curb, gutter, and catch basin including uplift and settling.		• Remove and replace damaged areas.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.7	Infiltration Berm Inspection Checklist	FORM

Inspected by: ______________________ **BMP ID#:** ______________________ **Property Owner:** ______________________

Date of Inspection: ______________________ **Weather:** ____

Location Description: ____

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there standing or pooling of water after 3 days of dry weather?		• Remove any obstruction in the berms and/or regrade to restore positive drainage.	
	Is there poor drainage during a high-intensity storm event?		• Clean structural components. • Check inlet structures for damage and/or blockage. Repair if required.	
	Is there channelization (gully) forming along the length of the infiltration berms?		• Fill in eroded areas and regrade.	
	Is vegetation clogging the inlet/outlet flow areas?		• Trim and/or remove the excess vegetation.	
	Is the vegetation overgrown?		• Mow grass as needed.	
	Is there trash/debris in the area?		• Remove all trash and debris.	
	Is the mulch distributed evenly throughout infiltration berm?		• Redistribute and add additional mulch if needed.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.8	# Green Roof Inspection Checklist	FORM

Inspected by: ____________________ **BMP ID#:** ____________________ **Property Owner:** ____________________

Date of Inspection: ____________________ **Weather:** ____

Location Description: ____

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there standing or pooling of water?		• Check outlet(s)/downspouts for obstruction or damage. • If ponded water remains, further grading and replacement may be necessary.	
	Is there channelization (gully) forming along the length of the green roof area?		• Fill in eroded areas and regrade.	
	Is vegetation clogging the outlet flow areas?		• Trim and/or remove the excess vegetation around the outlet areas.	
	Are there dead or dry plants/weeds?		• Remove dead and/or dry vegetation. Replace as needed.	
	Check for broken or damaged drain outlets, splash blocks, and grates.		• Replace or repair all damaged features.	
	Is the vegetation irrigation functional (if present)?		• Repair broken/missing spray emitters. Reposition to eliminate over spray and/or over watering.	
	Is there trash/debris on the green roof area?		• Remove all trash and debris.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.9	# Runoff Capture and Reuse Inspection Checklist	FORM

Inspected by: ____________ **BMP ID#:** ____________ **Property Owner:** ____________

Date of Inspection: ____________ **Weather:** ____________

Location Description: ____________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there standing or pooling of water after 3 days of dry weather around the storage tanks?		• Regrade overflow drainage area. • Reposition splash block/dissipater. • Check for leaks from storage tanks.	
	Is there excessive splashing/spray from the overflow outlet?		• Reposition splash block or dissipater to reduce or eliminate splash/spray.	
	Are the house/building gutters overflowing during a rain event?		• Check gutter downspout and gutter for obstructions. • Check storage tank(s) inlet screens for blockage. • Check storage tank(s) outlet(s) for blockage.	
	Are the storage tank(s) overflowing?		• Check storage tank(s) outlet(s) blockage.	
	Is there evidence of under cutting or washouts around the storage tank(s)?		• Reposition splash block(s)/dissipater(s). • Fill in eroded areas and regrade. • Repair any leaks or overflows from storage tank(s).	
	Is there accumulation of sediment/debris in the storage tank(s)?		• Remove sediment and check inlet/gutter screens. • Verify that the lid of the storage tank is secure.	
	Is there undercutting or washouts around the outlet splash block(s)?		• Reposition splash block(s) or dissipater(s). • Fill in eroded areas and regrade.	
	Is water freezing in the storage tank(s)?		• Remove water from tank(s) before winter. • Divert inflow away from tank during freezing conditions.	

5.3.9	# Runoff Capture and Reuse Inspection Checklist	FORM

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is vegetation clogging the outlet flow areas?		• Trim and/or remove the excess vegetation around the outlet flow area.	
	Is the mulch/gravel distributed evenly throughout the storage tank area?		• Redistribute and add additional mulch if needed. • Regrade vegetated swale area.	
	Are there dead or dry plants/weeds?		• Remove dead and/or dry vegetation. Replace as needed. • Remove or trim any vegetation that is causing a visual barrier, trip, and/or obstruction hazard.	
	Is there trash/debris in the area?		• Remove all trash and debris.	
	Are there missing or disturbed aesthetic features?		• Replace and/or reposition aesthetic features to original placement. • Placement should not disrupt flow characteristics/design.	
	Are the vector control/prevention devices in place and functional?		• Replace or repair all damaged components. • Contact vector control if problem persists.	
	Is the irrigation system functional?		• Repair broken/missing spray emitters.	
	Are the aesthetic features firmly secured in place?		• Repair and/or replace loose or damaged features.	
	Is the backflow operation/maintenance log current? (If installed)?		• Test all backflow prevention assemblies annually by the system owner using an approved certified tester.	
	Is there algae or other growth in the storage containers?		• Clean tank(s) with non-toxic cleaners.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.10	# Disconnected Impervious Area Inspection Checklist	FORM

Inspected by: ____________ **BMP ID#:** ____________ **Property Owner:** ____________

Date of Inspection: ____________ **Weather:** ____________

Location Description: ____________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there standing or pooling of water after 3 days of dry weather?		• Remove any obstruction in the area to which disconnected impervious area drains and/or regrade to restore positive drainage. • Clean and/or remove any obstructions in and around points of discharge into vegetated area.	
	Is there poor drainage during a high-intensity storm event?		• Clean and/or remove any obstructions in and around the storm drain inlet.	
	Is the flow into the filter strip even and uniform?		• Remove any obstruction preventing a uniform flow into the vegetated disconnection area.	
	Is there evidence of under cutting or washouts along the impervious surfaces draining to vegetated disconnection area?		• Fill in eroded areas and regrade.	
	Is there channelization (gully) forming along the length of the vegetated disconnection area?		• Fill in eroded areas and regrade.	
	Is there accumulation of sediment (sand, dirt, mud) in the vegetated disconnection area?		• Remove sediment and check the grading. • Add replacement soil and/or mulch.	
	Has planting successfully established?		• Restore soils and planting.	

5.3.10	Disconnected Impervious Area Inspection Checklist	FORM

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is accumulated vegetation inhibiting inflow to vegetated disconnection area?		• Trim and/or remove excess vegetation.	
	Has planting successfully established?		• Restore soils and planting. • Evaluation of selected species and soil conditions should be made to ensure successful restoration.	
	Is there trash/debris in the vegetated disconnection area?		• Remove all trash and debris.	
	Check for damaged sidewalk, curb, gutter, and catch basin including uplift and settling.		• Remove and replace damaged areas.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.11	Stormwater Planter Box Inspection Checklist	FORM

Inspected by: ____________________ **BMP ID#:** ____________________ **Property Owner:** ____________________

Date of Inspection: ____________________ **Weather:** ____

Location Description: ____

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there standing or pooling of water after 3 days of dry weather?		• Check perforated pipe outlet for obstruction or damage.* • Flush perforated pipe to remove obstructions. • Remove and replace the first few inches of topsoil. • Remove all the soil and inspect perforated pipe. Repair or replace perforated pipe, replace with new soil and regrade.	
	Is there overflow due to excessive splashing/spraying?		• Reposition splash block or dissipater to reduce or eliminate splash/spray overflow.	
	Is water overflowing the sides of the planter unit during a high-intensity storm event?		• Clean and/or remove any obstructions in and around the outlet. • Check high-flow bypass inlet pipe for obstruction or damage.	
	Is there evidence of under cutting or washouts around the inlet splash blocks?		• Reposition the inlet splash block(s) or dissipater(s). • Fill in eroded areas and regrade.	
	Is there channelization (gully) forming along the length of the planter area?		• Reposition the inlet splash block(s) or dissipater(s). • Fill in eroded areas and regrade.	
	Is there accumulation of sediment (sand, dirt, mud) in the planter?		• Remove sediment and check the grading. Add replacement soil and/or mulch.	
	Is the mulch unevenly distributed in the planter area?		• Redistribute and add more mulch if needed. • Regrade filter strip area.	

*If perforated pipe is present.

5.3.11	# Stormwater Planter Box Inspection Checklist	FORM

Inspector Verification (initial)	Maintenance Issue	Is this Issue Present? (Y/N)	Required Actions To Address Issues Present	Comments (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is vegetation clogging the inlet/outlet flow areas?		• Trim and/or remove the excess vegetation around the inlet/outlet areas.	
	Are there dead or dry plants/weeds? Is the vegetation overgrown?		• Remove dead and/or dry vegetation. Replace as needed. • Remove or trim any vegetation that is causing a visual barrier, trip, and/or obstruction hazard.	
	Is there trash/debris in the planter area?		• Remove all trash and debris.	
	Is the planter and/or surrounding area marked with graffiti?		• Remove all graffiti from the area.	
	Are there missing or disturbed aesthetic features?		• Replace and/or reposition aesthetic features to original placement.	
	Check for broken or damaged drain inlets/outlets, splash blocks, and grates.		• Replace or repair all damaged features.	
	Are there cracks, holes, and/or damaged sides, or top of the planter unit?		• Repair or replace unit. Repairs must be watertight.	
	Are the aesthetic features firmly secured in place?		• Repair and/or replace loose or damaged features.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.12	Manufactured Devices Inspection Checklist	FORM

Manufactured Devices Inspection Checklist

Inspected by: ______________________ **BMP ID#:** ______________________ **Property Owner:** ______________________

Date of Inspection: ______________________ **Weather:** ______________________

Location Description: ______________________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	If vegetated, are there dead or dry plants/weeds?		• Remove dead and/or dry vegetation. Replace with appropriate plants as needed.	
	If vegetated, is vegetation overgrown?		• Trim and/or remove excess vegetation.	
	Is there trash/debris clogging the inlet structure?		• Remove all trash and debris from inlet areas.	
	Is there trash/debris near the outlet structure?		• Remove all trash and debris from outlet areas.	
	Is the device clogged with debris/sediment?		• Remove accumulated debris and sediment.	
	Is there any evidence of cracking, subsidence, spalling, erosion, or other deterioration of structural components?		• Repair or replace structural components as needed.	
	Are oil absorption booms/devices clogged or saturated?		• Replace oil absorption booms/devices as needed.	
	Is oily residue on weir, overflow?		• Remove and safely dispose of accumulated residues. • Replace all oil absorption and/or oil separation appurtenances as needed.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.3.13	# Naturalized Basin Inspection Checklist	FORM

Inspected by: ______________ **BMP ID#:** ______________ **Property Owner:** ______________

Date of Inspection: ______________ **Weather:** ______________

Location Description: ______________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is there a high drawdown of water level over a short period?		• Check outlet control valves and height of outlet/overflow channel. Repair and/or replace components as necessary. • Review operational manual.	
	Check the operation of the drainage system (valves, weirs, pipes, etc.)		• Cycle the drainage system to verify operation.	
	Is water overflowing the sides of the basin during a high-intensity storm event?		• Clean and/or remove any obstructions in and around the inlet. • Check high-flow bypass inlet pipe for obstruction or damage.	
	Is there evidence of undercutting or washouts around the inlet/outlet of the basin?		• Reposition the inlet splash block(s) or dissipaters. • Fill in eroded areas and regrade.	
	Is there channelization (gully) forming along the banks of the pond?		• Fill in eroded areas, regrade banks, and replant area. • Remove excess sediment from the pond.	
	Is there accumulation of sediment (sand, dirt, mud) in the basin?		• Remove sediment from the basin and regrade.	
	Is there evidence of animal activity such as holes or dirt mounds from digging or burrowing?		• Repair and fill in damaged areas. Regrade if needed. • Implement rodent control activities where warranted. Activities must be in accordance with applicable laws.	

5.3.13	Naturalized Basin Inspection Checklist	FORM

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Is vegetation clogging the inlet/outlet flow areas?		• Trim and/or remove excess vegetation around the inlet/outlet areas.	
	Are there dead or dry plants/weeds?		• Remove dead and/or dry vegetation. Replace as needed. • Remove or trim any vegetation that is causing a visual barrier, trip, and/or obstruction hazard. • Remove any nuisance, dangerous plant species. • Remove, trim, or mow all vegetation that may present a fire hazard.	
	Is the vegetation overgrown or in excess?		• Remove the excess vegetation and biomass. • Regrade pond bottom if needed.	
	Is there trash/debris in the basin?		• Remove all trash and debris.	
	Are mosquitoes present?		• Contact vector control.	
	Are the signage and fencing in place and in good condition?		• Repair or replace signage and fencing. • Add additional barrier signage to block access to hazardous areas.	

This checklist is to be used in conjunction with the maintenance plan developed by a certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.4.1	Recreate Natural Flow Patterns Inspection Checklist	FORM

Inspected by: ______________ **BMP ID#** ______________ **Property Owner:** ______________

Date of Inspection ______________ **Weather** ______________

Location Description: ______________

Inspector Verification (initial)	**Maintenance Issue**	**Is This Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION				
	Are natural drainage features being utilized instead of engineered systems?		• Verify that implemented drainage systems correspond with site plan.	
	Are proposed natural drainage features being staked out on the site and protected with adequate site protection measures?		• Stake out features in the field and delineate minimal disturbance areas.	
	Are recreated drainage features being protected from sediment and stormwater loads during construction?		• Install protection measures to prevent sedimentation and negative impacts from stormwater loads.	
	Are erosion protection or energy dissipation measures being installed if the channel or swale can reach erosive velocity?		• Verify whether erosive velocity can be reached in channels or swales.	
	Are native vegetation buffers being installed around drainage features?		• Consult planting plan and verify.	
	Is the installation of stormwater features being monitored to ensure proper sizing?		• Monitor before and during construction for signs of under or oversized systems and take corrective action.	
	Is large machinery being used in minimal disturbance areas?		• Smaller machinery should be used in these areas and work should be avoided on wet soil to protect sol structure and infiltration rates.	
AFTER CONSTRUCTION				
	Is maintenance being performed once naturalized drainage features are established?		• Twice yearly maintenance is required. Periodic inspections as well as targeted maintenance actions may also be important.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.4.1.1	Naturalize Swales and Drainage Ditches Inspection Checklist	FORM

Inspected by: ____________ **BMP ID#** ____________ **Property Owner:** ____________
Date of Inspection ____________ **Weather** ____________
Location Description: ____________

Inspection Category	Inspector Verification (initial)	Maintenance Issue	Is this Issue Present? (Y/N)	Required Actions To Address Issues Present	Comments (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION					
		Are natural drainage features being utilized instead of engineered systems?		• Verify that implemented drainage systems correspond with site plan.	
		Are proposed drainage features and channel configurations being staked out on the site and protected with adequate site protection measures?		• Stake out features and configurations in the field and delineate minimal disturbance areas.	
		Are drainage features being protected from sediment and stormwater loads during construction?		• Install protection measures to prevent sedimentation and negative impacts from stormwater loads.	
		Are erosion protection or energy dissipation measures being installed if the channel or swale can reach erosive velocity?		• Verify whether erosive velocity can be reached in channels or swales and install protection measures where necessary.	
		Are native vegetation buffers being installed around drainage features?		• Consult planting plan and verify. Install vegetated buffers to stabilize the channel.	
		Is small machinery being used to minimize soil damage?		• Use small machinery and protect soil from construction traffic. Work should be avoided on wet soil to protect sol structure and infiltration rates.	
		Are construction vehicles being driven across swales?		• Do not drive construction vehicles across a swale unless a stabilized crossing is provided.	
		Are check dams being installed in swales with slopes greater than 3%?		• Verify swale slope and install check dams at a frequency appropriate for swale length, slope, and desired storage volume.	
		Are check dam pools draining adequately?		• Check dam pools should drain in 72 hours to prevent mosquito breeding.	

5.4.1.1	Naturalize Swales and Drainage Ditches Inspection Checklist	FORM

AFTER CONSTRUCTION					
		Is maintenance being performed during establishment?		• Perform watering, weeding, mulching, replanting, etc. Remove undesirable species and replace.	
		Is maintenance being performed once naturalized drainage features are established?		• Perform periodic inspections as well as targeted maintenance. Evaluate erosion, bank stability, sediment/debris accumulation, and invasive species presence. Correct problems in a timely manner.	
		Are check dam pools draining adequately?		• Check dam pools should drain in 72 hours to prevent mosquito breeding.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.4.2	**Improve Native Cover Types Inspection Checklist**	FORM

Inspected by: ____________________ **BMP ID#** ____________________ **Property Owner:** ____________________

Date of Inspection ____________________ **Weather** ____________________

Location Description: ____________________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION				
	Has vegetation onsite been preserved and have preservation areas been delineated?		• Delineate preservation areas.	
	Have problems within the enhancement area been identified and if so, are they being addressed?		• Problems such as fill, bare or eroded soil, invasive species, trash, etc. need to be addressed in the restoration process.	
	Are outside influences present beyond the site that may undermine enhancement efforts? If so, are they being addressed?		• Develop a plan to address negative offsite influences.	
	Have factors that suppress regeneration of native plants been identified and addressed?		• Address these factors or efforts spent on enhancement will be wasted.	
	Have desirable and sensitive species been protected?		• Protect accordingly, paying particular attention to "keystone" species, replacing them where possible if they are absent.	
	If present, have masses of aggressive exotics been removed?		• Remove large tangles of aggressive exotic species to allow a clear evaluation of the site.	
	Are improvement techniques being used that are appropriate to the landscape cover type?		• Consult the Society for Ecological Restoration (www.ser.org) for specific directions for your site.	
AFTER CONSTRUCTION				
	Is irrigation being utilized during the period of establishment and during severe droughts?		• Monitor improvement areas and employ irrigation where needed.	
	Is erosion being monitored?		• Monitor erosion until the site has stabilized.	
	Is the site being monitored for invasive species?		• Monitor site regularly for invasive species.	

5.4.2	Improve Native Cover Types Inspection Checklist	FORM

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
			• Consider long-term monitoring/ management.	
	Are extra abundant herbivores being controlled (white-tailed deer, rabbits, geese, etc.)?		• Reference 5.4.2 Improve Native Cover Types for appropriate management strategies.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.4.2.1	Change Cover Type Inspection Checklist	FORM

Inspected by: ____________________ **BMP ID#** ____________________ **Property Owner:** ____________________

Date of Inspection ____________________ **Weather** ____________________

Location Description: ____________________

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION				
	Are visible transitions being created between cover types?		• Maintain the edge of natural landscape cover so it looks orderly and attractive.	
	Are invasive species being monitored?		• Monitor and manage invasive species, especially for the first two years.	
	Have areas identified for cover change been staked in the field?		• Stake conversion areas.	
	Has a soil scientist been consulted?		• Soil conditions and the needs of different landscape types can vary greatly. Consult a soil scientist to assist in determining the correct course of action.	
	Is post-planting protection installed?		• Use the appropriate protection measures depending on cover type.	
	Is initial planting being watered?		• Water new cover types at a minimum rate of ½ inch per week for eight weeks after planting, unless there is adequate rainfall.	
AFTER CONSTRUCTION				
	Are meadows being mowed?		• Mow meadows during the first growing season to a height of 6 inches. If weeds exceed 9 inches, remove flowering heads.	
	Are weeds and invasives under control?		• As soon as detected and when these pest plants are large enough, pull (mechanically or by hand), mow, spray with spot chemical applications, burn or use a combination of techniques. • Remove invasive species before seed formation to prevent reseeding.	
	Is regular monitoring and maintenance taking place on highly visible landscapes?		• Maintain all cover types. Maintenance includes watering, weeding, removing invasives, and replanting damages plants.	

5.4.2.1	Change Cover Type Inspection Checklist	FORM

Inspector Verification (initial)	**Maintenance Issue**	**Is this Issue Present?** (Y/N)	**Required Actions To Address Issues Present**	**Comments** (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
	Are regular monitoring and maintenance taking place on less visible landscapes?		• For less visible landscapes where the primary purpose of the cover type is erosion control and increased permeability, maintenance can be reduced to twice a year inspection for problems and immediate repair and once or twice yearly mowing for meadows.	
	Are regular monitoring and maintenance taking place at the edges of natural landscapes?		• Maintain the edges of natural landscape cover types so that these landscapes look orderly and attractive.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

5.4.3	Amend and Restore Disturbed Soils Inspection Checklist	FORM

Inspected by: ____________ **BMP ID#** ____________ **Property Owner:** ____________

Date of Inspection ____________ **Weather** ____________

Location Description: ____________

Inspection Category	Inspector Verification (initial)	Maintenance Issue	Is this Issue Present? (Y/N)	Required Actions To Address Issues Present	Comments (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
DURING CONSTRUCTION					
		Has site work such as utility installation and paving been completed prior to commencing soil preparation?		• Complete site work.	
		If deep subsoiling is planned, are utility locations clearly marked?		• Mark utility locations. Utility conflicts are the most common reason why methods such as subsoiling may not be appropriate.	
		If decompacting soil around tree root, is care being taken to protect tree roots?		• Use proper techniques to avoid root damage as outline in 5.4.3, Amend and Restore Disturbed Soils.	
		Has a preconstruction soil test been performed?		• Test soil texture, porosity, and water retention and perform a chemical analysis to determine what is needed to create a viable soil.	
		If contaminants were/are present, has the site been remediated?		• Assess and remediate contaminated land.	
		Is soil being left bare and unprotected?		• Minimize the length of time that soil is left bare and unprotected. Avoid bare soil during periods of seasonally high precipitation or wind. Provide special protection to critical areas such as steep slopes and stream borders.	
		Are soil amendments being applied properly?		• Follow guidelines noted in 5.4.3.	
		Is installation occurring on steep slopes?		• Installation should be performed during dry weather, and early enough in the year to permit the establishment of vegetation before the onset of winter. • Protect seeded areas with slopes exceeding 1:4 with erosion-control blankets and/or erosion-control fiber mulch.	
		Are designed soils being installed?		• Ensure proper mixing. • Install soil by horizon. • Achieve greater uniformity by placing soil in 4- to 6-inch lifts, mixing lifts between horizons.	

5.4.3	Amend and Restore Disturbed Soils Inspection Checklist	FORM

Inspection Category	Inspector Verification (initial)	Maintenance Issue	Is this Issue Present? (Y/N)	Required Actions To Address Issues Present	Comments (Describe maintenance completed and, if needed maintenance was not conducted, note when it will be done.)
				• Test soil after installation.	
		Is soil being stockpiled?		• Follow stockpiling guidelines noted in 5.4.3.	
AFTER CONSTRUCTION					
		Is soil settling taking place?		• Backfill the areas in question with additional approved material, compacted to specified rates and restore any disturbed areas to an acceptable condition.	
		Are drainage swales present on the site?		• Clean drainage swales periodically to remove sediment, trash, and invasive plants and to sustain functionality. • Maintain surrounding filter vegetation to reduce sediment deposition within the swales.	
		Is monitoring taking place?		• After one year, collect soil samples in each of the various soil areas and submit them for laboratory testing for fertilizer and liming recommendations. • Sample each "type" of soil and planting area separately (similar areas can be grouped). Tailor fertilization and amendment needs to each area for maximum effect while reducing over fertilizing and possible contamination of groundwater and runoff. • Repeat soil sampling for these areas every two years after first sampling and fertilize and amend to test recommendations.	

This checklist is to be used in conjunction with the maintenance plan developed by the certified professional and in accordance with the Operations and Maintenance Agreement on file with the City of Chattanooga. Please review those documents prior to performing field inspections.

Protocol 1 Infiltration BMP Setbacks from Structures

A. Purpose of this Protocol

This protocol (Protocol 1) provides the designer with guidance regarding BMP setback distances from structures, including buildings, pavements, utilities, and other existing or proposed structures.

B. Infiltration and Setback Considerations

Infiltration systems infiltrate both laterally (through the bed sides) and vertically (through the bed bottoms). When designing infiltration systems, it is important to maintain an adequate horizontal setback distance from structures to avoid potential damage to those structures from water migration.

As a general guideline, BMPs should be set back at least 5 feet horizontally from a structure to allow for protection of the BMP and structure during construction. However, this may not always be feasible or desirable. Infiltration BMPs may be located immediately adjacent to a structure if the design addresses details such as waterproofing of the structure, protection of pavement subbase, etc. The proximity of adjacent structures, the nature and condition of specific site conditions, and the soil conditions should be considered when determining the appropriate setback.

The following additional factors should be considered when locating infiltration BMPs near structures:

- The age and type of structure. If a building has a foundation or slab underdrain system and this system intercepts the infiltrated water, the intercepted flow will quickly discharge to the sewer system and reduce the effectiveness of the BMP.
- Older buildings with stone foundations or poor foundations are more likely to be adversely impacted by altered conditions.
- Utilities that are in poor condition may be damaged by infiltrated runoff.

Unless a structure has appropriate waterproofing, infiltration BMPs should be located such that the infiltrated water moves below the subgrade of the structure, or below the invert of a utility and bedding material.

C. Estimating Required Horizontal Setback Distance

Appropriate horizontal setbacks from structures that are both upgrade and downgrade from the infiltration BMP can be estimated by the following approach. The top water surface elevation of the BMP is compared to the elevation of interest at the structure, which is assumed to be 2 feet below the basement or lowest slab elevation of a building, or 1 foot below the invert of a utility. This approach assumes that water moves laterally out of the infiltration bed at an angle of 45 degrees and that there are no site-specific conditions that would direct the flow of water laterally toward the structure. Such site-specific conditions include, but are not limited to:

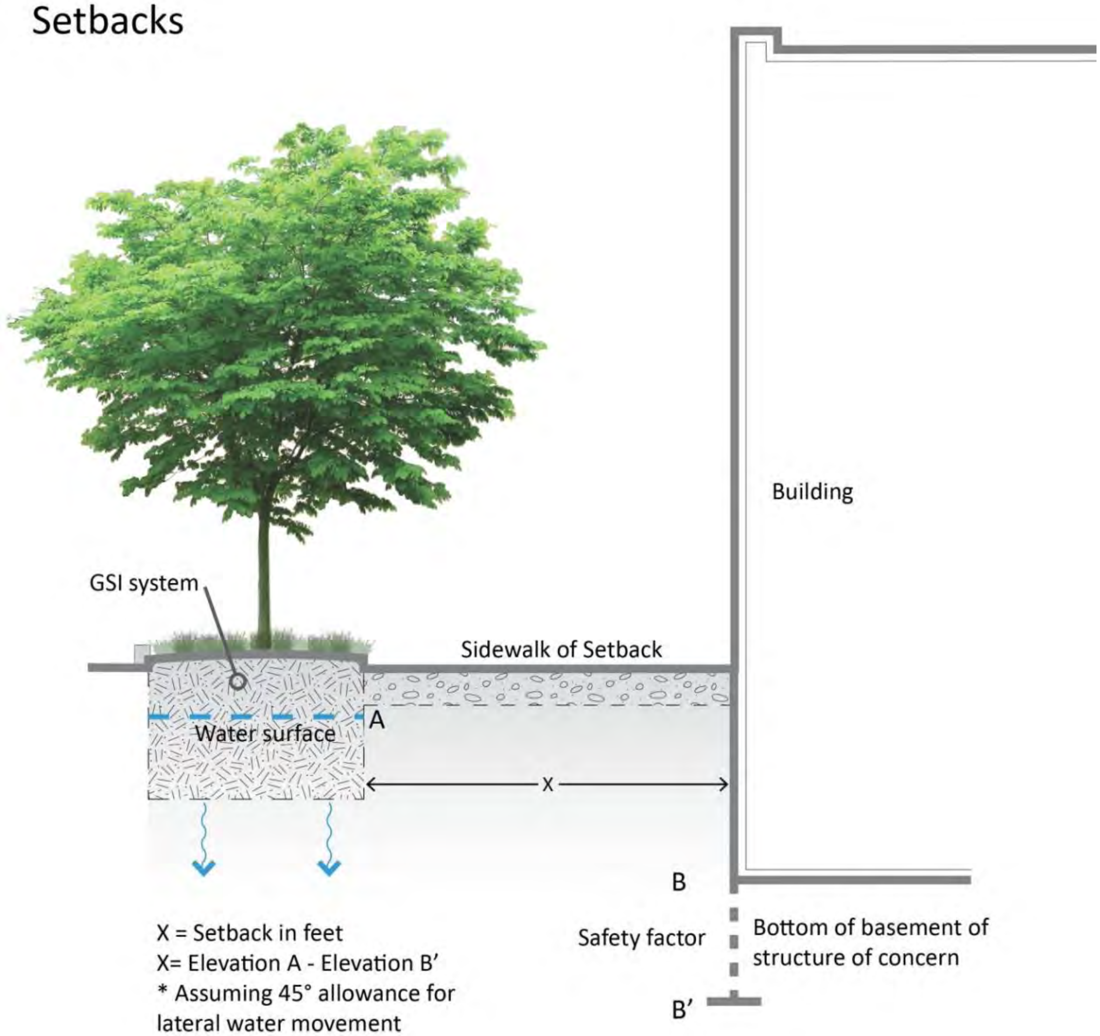
- Pipes or laterals that could unintentionally direct water flow toward the structure
- Confined layers in the soil (such as clay horizons, historic buried impervious areas, etc.) that could intercept the vertical flow of water and direct water toward the structure

The difference between the water surface elevation of the top of storage and the elevation of the bottom of the structure along with a safety factor to determine setback is shown on Figure A-1.

If an infiltration bed is closer than the calculated setback, an impermeable geo-membrane liner should be used along the vertical side of the storage bed and along the bottom of the storage bed to a distance that is at least the calculated setback distance from the building. Using a geo-membrane liner in this way may reduce the infiltration footprint of the system and increase the loading ratio, which must be factored into the design.

The designer should always consider potential impacts when locating infiltration BMPs and may adjust the location and size of the BMP accordingly. For example, a BMP may be set back from a downhill structure a sufficient distance to avoid water movement toward the structure. However, other factors such as existing soil conditions, amount of infiltrated water, etc. should be considered by the designer.

Setbacks



<u>Example:</u>

Top water Surface Elevation	= A = 750’ elev
Basement slab elevation	= B = 740’ elev
2’ “safety factor”	B’ = 738’ elev

X = A - B’ = 750’ - 738’ = 12’ Setback

Figure A-1

Protocol 2 BMP Coordination with Other Utilities

A. Purpose of this Protocol

This protocol (Protocol 2) provides the designer with guidance regarding BMP selection and location in coordination with other existing or proposed utilities.

B. Types of Utilities To Be Considered

In designing BMPs, it is almost certain that there will be other existing or proposed utilities that must be considered in the design of the stormwater management system. This is especially true in redevelopment or retrofit sites served by existing utilities. Common utilities encountered include:

- Water lines and laterals
- Combined sanitary/storm sewers, sanitary sewers and separate stormwater sewers, and sewer laterals
- Gas lines
- Fiber optic and telecommunication cables
- Steam lines
- Valves and vaults associated with the utilities listed above
- Utility boxes
- Underground electric lines
- Aboveground utility lines and utility poles
- Others

C. Setbacks of Utilities from BMPs

For construction purposes and to avoid utility disturbance, a minimum horizontal setback of at least 5 feet should be maintained from the edge of a BMP to the outer edge of a utility. In certain situations, this may not be feasible, as discussed below. For utilities that are adjacent to an infiltration BMP, setbacks should follow Protocol 1, Infiltration BMP Setbacks from Structures.

D. Design Considerations for Existing and Proposed Utilities

The designer should confirm that the existing conditions plan or site survey indicates the location, and if available, depth of all existing underground utilities. To the greatest extent possible, BMPs should not be located above existing or proposed underground utilities for several reasons:

- The need for future repair of the utility may result in disturbance or damage to the BMP.
- The utility may be damaged during construction of the BMP.
- For infiltration BMPs located above a utility, the possibility exists that infiltrated water may travel along the pipe bedding material or damage an older utility.
- For buried utilities that pass through the BMP, the possibility exists that water may travel laterally along the utility line, possibly to an undesirable location such as a basement. This situation should be avoided if possible. If it cannot be avoided, water stops must be used to prevent lateral movement of water. Water stops must be used for all pipe crossings into and out of BMPs where the utility will be located in saturated conditions. In new development projects, such as laterals to homes, defined utility corridors will reduce the need for utilities to "pass through" a BMP.

The potential for utility damage must be considered both during and after site construction. Older pipe systems, such as unlined corrugated metal pipes greater than 25 years in age, may be more susceptible to damage. Potential damage of a utility below a BMP system may be reduced by the use of a geo-grid; however, each utility location should be evaluated by the designer on a case-by-case basis.

E. Construction Considerations

Mapped information may be inaccurate or incomplete. During construction, the actual utility locations and dimensions must be confirmed by the contractor, and field changes may be required by the designer to address unanticipated utility locations. The construction plans should provide direction to the contractor to stop work and contact the designer when unanticipated utility locations or conditions are encountered.

F. Protection of Trees and Utilities

The types and locations of existing and proposed trees should be considered in the BMP design process. Trees are a valuable tool for reducing stormwater runoff, and existing trees are often damaged by the placement of new utilities. At a minimum, new utilities should be set outside the existing tree canopy.

Conversely, new trees planted as part of site design and stormwater management should be located to minimize future utility damage from tree roots.

G. Overhead Utilities and Future Vegetation Maintenance Needs

Overhead wires may limit the type and selection of planting material in a BMP. If trees are planted, the impact on overhead wires should be considered in both species selection and provisions for tree trimming and maintenance.

Protocol 3 Soil Testing

Section 1. General Description

A. Purpose of this Protocol

The soil testing protocol (Protocol 3) describes the necessary field testing procedures to:

1. Help determine what BMPs are suitable at a site and at what locations.
2. Obtain the required data for infiltration BMP design.
3. Understand and evaluate site soil conditions: soil compaction (soil porosity), missing soil components (including microorganisms and organic matter) needed to reestablish the soil's long-term capacity for infiltration, storage, and pollutant removal.

B. When to Conduct Onsite Soil Testing

Soil evaluation is a four-step process, described on page C-3. Step 1, Desktop Analysis, should be conducted early in the Concept Stormwater Management Plan phase of the project (and prior to concept stormwater management plan submission to the City) as discussed in Chapter 4. Information developed in the desktop analysis will focus information gathering during site visits and inform the Concept Stormwater Management Plan.

Following Concept Stormwater Management Plan approval by the City, the design team should have a preliminary understanding of potential BMP locations prior to detailed soil testing. The design team should conduct detailed testing as early as possible during the Preliminary Stormwater Management Plan phase.

Detailed infiltration testing is described in steps 2 through 4 in Section II. If indicated by the testing results, adjustments to the design should be made. The designer may need to adjust the site layout and grading to incorporate the results of detailed soil testing and to achieve necessary infiltration results. Detailed soil testing for compaction and soil fertility is described in Section III, after infiltration testing.

C. Who Should Conduct Testing

Qualified professionals who can substantiate by qualifications/experience their ability to carry out the evaluation should evaluate the soil test pits and soil samples. A professional experienced in observing and evaluating soil conditions is necessary to ascertain conditions that might affect BMP performance (e.g., clay layers, groundwater movement, etc.). Soil scientists, agronomists, civil engineers with appropriate experience, geotechnical engineers, and trained technicians are examples of suitable professionals.

D. Importance of Stormwater BMP Areas

Sites are often traditionally defined as unsuitable for infiltration BMPs and soil-based BMPs due to proposed grade changes (excessive cut or fill) or lack of suitable areas. Many sites will be constrained and unsuitable for infiltration BMPs. However, if suitable areas exist, these areas must be identified early in the Concept Stormwater Management Plan phase and should not be subject to a building program that precludes infiltration BMPs. An exemption should not be provided for “full build-outs” where suitable soils otherwise exist for infiltration.

E. Safety

As with all field work and testing, attention should be given to all applicable Occupational Safety and Health Administration (OSHA) regulations and local guidelines related to earthwork and excavation. Digging and excavation should never be conducted without adequate notification through the Tennessee One Call system. Excavations should never be left unsecured and unmarked, and all applicable authorities should be notified prior to any work.

Section II. Infiltration Testing: A Four-Step Process

Infiltration testing is a four-step process to obtain the necessary data for the design of the Stormwater Management Plan. The four steps include:

1. Desktop analysis – conducted prior to Concept Stormwater Management Plan Submission
    - Based on available published and site-specific data
    - Includes consideration of proposed development plan
    - Used to identify potential BMP locations and testing locations
    - Prior to field work (desktop)
    - Onsite screening test may be conducted (visual observation of site conditions)
2. Test pit (deep hole) observation or soil boring
    - Includes multiple testing locations
    - Provides an understanding of subsurface conditions
    - Identifies limiting conditions
3. Infiltration testing
    - Must be conducted onsite
    - Different testing methods available
    - Alternate methods for additional screening and verification testing
4. Consideration of infiltration rate in design and modeling application
    - Determination of a suitable infiltration rate for design calculations
    - Consideration of BMP drawdown
    - Consideration of peak rate attenuation

Step 1. Desktop Analysis

Prior to performing testing and developing a detailed site plan, existing conditions at the site should be inventoried and mapped including, but not limited to:

- Existing mapped individual soils and USDA hydrologic soil group classifications.
- Existing geology, including the locations of any dikes, faults, fracture traces, solution cavities, landslide prone strata, or other features of note.

- Existing streams (perennial and intermittent, including intermittent swales), water bodies, wetlands, hydric soils, floodplains, alluvial soils, stream classifications, headwaters, and first-order streams.
- Existing topography, slope, and drainage patterns.
- Existing and previous land uses.
- Other natural or manmade features or conditions that may impact design, such as past uses of site, existing nearby structures (buildings, walls), etc.

A Concept Site Layout Plan for development should be evaluated, including:

- The concept grading plan and areas of cut and fill.
- The locations of other features of note such as utility rights-of-way, water and sewer lines, etc.
- Existing data such as structural borings, drillings, and geophysical testing.
- The proposed locations of development features (buildings, roads, utilities, walls, etc.).

In step 1, the designer should determine the potential locations of infiltration BMPs. The approximate locations of these BMPs should be indicated on the proposed development plan and should serve as the basis for the location and number of tests to be performed onsite following Concept Stormwater Management Plan approval.

Important: If the proposed development program is located in areas that may otherwise be suitable for BMP location, or if the proposed grading plan is such that potential BMP locations are eliminated, the designer is strongly encouraged to revisit the proposed layout and grading plan and adjust the development plan as necessary. Full build-out of areas suitable for infiltration BMPs should not preclude the use of BMPs for volume reduction and groundwater recharge.

Step 2. Test Pits (Deep Holes)

A test pit (deep hole) allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically in that portion of the site. A large number of test pit observations can be made across a site at a relatively low cost and in a short time period. The use of soil borings as a substitute for test pits may be necessary in areas where existing pavement or structure precludes a test pit excavation. Visual observation is narrowly limited in a soil boring and the soil horizons cannot be observed in-situ, but must be observed from the extracted borings. Borings and other procedures, however, may be substituted for test pits if necessary because of site constraints.

A test pit consists of a backhoe-excavated trench, 2½ to 3 feet wide, to a depth of between 72 inches and 90 inches, or until bedrock or fully saturated conditions are encountered. The trench should be benched at a depth of 2 to 3 feet for access and/or infiltration testing.

At each test pit or boring, the following conditions shall be noted and described. Depth measurements should be described as depth below the ground surface:

- Identification and depth of soil horizons (upper and lower boundary)
- Soil texture and color for each horizon
- Color patterns (mottling) and observed depth
- Depth to water table
- Depth to bedrock
- Observance of pores or roots (size, depth)
- Estimated type and percentage of coarse fragments
- Hardpan or limiting layers
- Strike and dip of horizons (especially lateral direction of flow at limiting layers)
- Additional comments or observations

Figure C-1. Soil test pit.

The sample soil log form at the end of this protocol may be used for documentation of each test pit.

At the designer's discretion, soil samples may be collected at various horizons for additional laboratory analysis. Following testing, the test pits should be refilled with the original soil and the surface replaced with the original topsoil. A test pit should never be accessed if soil conditions are unsuitable for safe entry, or if site constraints preclude entry. OSHA regulations must always be observed.

It is important that the test pit or boring provide information related to conditions at or near the bottom of the proposed infiltration BMP. If the BMP depth will be greater than 90 inches below existing grade, deeper excavation will be required. However, such depths are discouraged, as infiltration rates tend to decrease with depth until weathered bedrock is encountered. Except for surface discharge BMPs (filter strips, etc.), the designer is cautioned regarding the proposal of systems that are significantly lower than the existing topography. The suitability for infiltration may decrease, and risk factors are likely to increase. The designer should reduce grading and earthwork as needed to reduce site disturbance and compaction.

The number of test pits varies depending on site conditions and the proposed development plan. General guidelines are as follows:

- For single-family residential subdivisions with on-lot BMPs, one test pit per lot is recommended, preferably within 25 feet of the proposed BMP area. Verification testing should take place when BMPs are sited at greater distances.

- For multi-family and high-density residential developments, one test pit per BMP area or acre is recommended.
- For large infiltration areas (basins, commercial, institutional, industrial, and other proposed land uses), multiple test pits should be evenly distributed at the rate of four to six tests per acre of BMP area.

The recommendations above are guidelines. Additional tests should be conducted if local conditions indicate significant variability in soil types, geology, water table levels, bedrock, topography, etc. Similarly, uniform site conditions may indicate that fewer test pits are required. Excessive testing and disturbance of the site prior to construction are not recommended.

Step 3. Infiltration Tests/Permeability Tests

A variety of field tests exist for determining the infiltration capacity of soil. Laboratory tests are **strongly** discouraged, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests should be conducted in the field. Tests should not be conducted in the rain or within 24 hours following significant rainfall events (greater than 0.5 inches), or when the temperature is below freezing.

At least one infiltration test should be conducted at the proposed bottom elevation of an infiltration BMP, and a minimum of two tests per test pit are recommended. The designer may elect to test two different elevations to allow flexibility in BMP design.

Based on observed field conditions, the designer may elect to modify the proposed bottom elevation of a BMP. Personnel conducting infiltration tests should be prepared to adjust test locations and depths depending on observed conditions.

Methodologies discussed in this protocol include:

- Double-ring infiltrometer tests
- Percolation tests

There are differences between the two methods. A double-ring infiltrometer test estimates the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil. A percolation test allows water movement through both the bottom and sides of the test area.

For infiltration basins, it is strongly advised that an infiltration test be carried out with a double-ring infiltrometer (not percolation test) to determine the saturated hydraulic conductivity rate. This precaution is taken to account for the fact that only the surface of the basin functions to infiltrate, as measured by the test.

Other testing methodologies and standards that are available but not discussed in detail in this protocol include (but are not limited to):

- Constant head double-ring infiltrometer
- Testing as described in the Maryland Stormwater Manual Appendix D.1 using 5-inch diameter casing
- ASTM 2009 Volume 04.08, Soil and Rock (I): Designation D 3385-09, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer
- ASTM 2002 Volume 04.08, Soil and Rock (II): Designation D 5093-02(2008), Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring
- Guelph permeameter
- Constant head permeameter (amoozemeter)

a. Methodology for Double-Ring Infiltrometer Field Test

A double-ring infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is determined as the amount of water per surface area and time unit that penetrates the soils. The diameter of the inner ring should be approximately 50 percent to 70 percent of the diameter of the outer ring, with a minimum inner ring size of 4 inches, preferably much larger. Double-ring infiltrometer testing equipment that is designed specifically for that purpose may be purchased. However, field testing for stormwater BMP design may also be conducted with readily available materials.

Figure C-2. Double-ring infiltrometer test.

Equipment for double-ring infiltrometer test

- Two concentric cylinder rings 6 inches or greater in height. Inner-ring diameter equal to 50 percent to 70 percent of outer-ring diameter (i.e., an 8-inch ring and a 12-inch ring). Material typically available at a hardware store may be acceptable.
- Water supply.
- Stopwatch or timer.
- Ruler or metal measuring tape.
- Flat wooden board for driving cylinders uniformly into soil.

- Rubber mallet.
- Log sheets for recording data.

Procedure for double-ring infiltrometer test

- Prepare level testing area. This should be at or close to the proposed BMP location bed bottom.
- Place outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of 2 inches.
- Place inner ring in center of outer ring; place flat board on ring and drive ring into soil a minimum of 2 inches. The bottom rim of both rings should be at the same level.
- The test area should be presoaked immediately prior to testing. Fill both rings with water to water level indicator mark or rim at 30-minute intervals for 1 hour. The minimum water depth should be 4 inches. The drop in the water level during the last 30 minutes of the presoaking period should be applied to the following standard to determine the time interval between readings:
  - If water level drop is 2 inches or more, use 10-minute measurement intervals.
  - If water level drop is less than 2 inches, use 30-minute measurement intervals.
- Obtain a reading of the drop in water level in the center ring at appropriate time intervals. After each reading, refill both rings to water level indicator mark or rim. Measurement to the water level in the center ring shall be made from a fixed reference point and shall continue at the interval determined until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼ inch or less of drop between the highest and lowest readings of four consecutive readings.
- The drop that occurs in the center ring during the final period or the average stabilized rate, expressed as inches per hour, shall represent the infiltration rate for that test location.

b. Methodology for Percolation Test

Equipment for percolation test

- Post hole digger or auger
- Water supply
- Stopwatch or timer
- Ruler or metal measuring tape
- Log sheets for recording data
- Knife blade or sharp-pointed instrument (for soil scarification)
- Course sand or fine gravel
- Object for fixed-reference point during measurement (nail, toothpick, etc.)

Procedure for percolation test

This percolation test methodology is based largely on traditional onsite sewage investigation of soils:

Figure C-3. Percolation test.

- Prepare level testing area.
- Prepare hole having a uniform diameter of 6 to 10 inches and a depth of 8 to 12 inches. The bottom and sides of the hole should be scarified with a knife blade or sharp-pointed instrument to completely remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Loose material should be removed from the hole.
- (*Optional*) Two inches of coarse sand or fine gravel may be placed in the bottom of the hole to protect the soil from scouring and clogging of the pores.
- Test holes should be presoaked immediately prior to testing. Water should be placed in the hole to a minimum depth of 6 inches over the bottom and readjusted every 30 minutes for 1 hour. Between June 1 and December 31, the presoak should be conducted for 2 hours to simulate saturated spring conditions.
- The drop in the water level during the last 30 minutes of the final presoaking period should be applied to the following standard to determine the time interval between readings for each percolation hole:
  - If water remains in the hole, the interval for readings during the percolation test should be 30 minutes.
  - If no water remains in the hole, the interval for readings during the percolation test may be reduced to 10 minutes.
- After the final presoaking period, water in the hole should again be adjusted to a minimum depth of 6 inches and readjusted when necessary after each reading. A nail or marker should be placed at a fixed reference point to indicate the water refill level. The water level depth and hole diameter should be recorded.
- Measurement to the water level in the individual percolation holes should be made from a fixed reference point and should continue at the interval determined from the previous step for each individual percolation hole until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼ inch or less of drop between the highest and lowest readings of four consecutive readings.
- The drop that occurs in the percolation hole during the final period, expressed as inches per hour, shall represent the percolation rate for that test location.

Step 4. Consideration of Infiltration Rate in Design and Modeling Application

As discussed in Chapter 7 of this manual, infiltration systems can be modeled similarly to traditional detention basins. The marked difference with modeling infiltration systems is the inclusion of the infiltration rate, which can be considered as another outlet. For modeling purposes, it is convenient to develop infiltration rates that vary (based on the infiltration area provided as the system fills with runoff) for inclusion in the Stage-Storage-Discharge table.

Alternate tests or investigations can be used for verification. For instance, if the final BMPs are not located precisely over the test locations, alternate testing or investigations can be used to verify that the soils are the same as the soils that yielded the earlier results. However, the design team should document these verification test results or investigations. Other testing methods are acceptable to assess a soil's suitability for infiltration for early screening and occasionally for verification. Only professionals with substantiated qualifications may carry out verification procedures.

Section III. Other Soil Tests

Other soil tests are extremely useful when the design team needs to identify the better soils on a site—both for BMPs (structural, preventive, and restorative) and for landscape plantings. Tests for bulk density, contamination, texture class, organic matter content, and pH should be conducted before designing BMPs with vegetation or before specifying plants in restorative BMPs such as cover change, and before designing and planting ornamental landscapes.

A. Soil Compaction—Bulk Density Tests

1. Purpose of Bulk Density Tests

Bulk density tests can help determine the relative compaction of soils before and after site disturbance and/or restoration. These tests measure the level of compaction of a soil as an indicator of a soil's ability to absorb water. Disturbed and urbanized sites often have very high bulk densities. These soils have limited ability to absorb rainfall and therefore have high rates of stormwater runoff. Restorative techniques are described in Section 5.4.3, Amend and Restore Disturbed Soils, in this manual. Both the use of deep-rooted vegetation and the restoration of soil structure, missing chemical components, and living soil organisms can lower soil bulk density and improve the site's ability to absorb rainfall and reduce runoff.

Macropores occur primarily in the upper soil horizons and are formed by plant roots (both living and decaying), soil animals, bacteria and fungi, weathering processes caused by the movement of water, the freeze-thaw cycle, soil shrinkage due to desiccation of clays, chemical processes, and other mechanisms. These macropores are a critical method to infiltrate water and exchange atmospheric gases, both oxygen and carbon dioxide, under natural conditions. Good engineering and design should maintain or restore these macropores during construction of site BMPs.

2. Relationship of Soil Type to Bulk Density

A major indicator for compacted soil is bulk density, which is calculated as the dry weight of soil divided by its volume. Bulk density is important because it reflects the soil's ability to function for structural support, water and solute movement, and soil aeration. In general, higher bulk density of a soil correlates to a lower infiltration rate and a higher stormwater runoff volume.

Different soil types have different bulk densities:

- Maximum allowable bulk densities for sustainable soil management are based on 95 percent of the bulk density value at which growth limitations are expected for an average range of plant material, as described by Daddow and Warrington (1983).
- While these requirements are expressed as maximum allowable bulk densities, it is important to note that densities that are too low can also cause problems, especially for lawn areas or steep slopes.

To calculate the maximum allowable bulk density for a soil:

- Obtain a laboratory analysis of the sand, silt, and clay percentages as well as existing bulk density.
- Refer to Chart A to determine the ideal bulk density for a determined soil texture.

Chart A – Soil Textures and Bulk Densities

Soil texture	Ideal bulk densities (g/cm3)	Bulk densities that may affect root growth (g/cm3)	Bulk densities that restrict root growth (g/ cm3)
Sands, loamy sands	<1.60	1.69	>1.80
Sandy loams, loams	<1.40	1.63	>1.80
Sandy clay loams, loams, clay loams	<1.40	1.60	>1.75
Silts, silt loams	<1.30	1.60	>1.75
Silt loams, silty clay loams	<1.10	1.55	>1.65
Sandy clays, silty clays, some clay loams (35-45% clay)	<1.10	1.49	>1.58
Clays (>45% clay)	<1.10	1.39	>1.47

3. Procedures for Bulk Density Tests

Various procedures are available to conduct bulk density tests, including a procedure developed by the USDA (http://soils.usda.gov/sqi/assessment/files/chpt4.pdf). The density measurements should be carried out in conjunction with a soil texture analysis. Sandy soils infiltrate well, but tend to have a somewhat higher bulk density than finer soils. Experienced personnel can perform the texture analysis manually onsite.

B. Soil Contamination

Contaminated sites have a wide range of complexity, primarily dependent on previous, existing, and proposed land use. Land development at brownfield sites normally occurs in three stages:

1. Site assessment

2. Site remediation

3. Redevelopment

Step 1 − Site Assessment:

a. Develop a preliminary survey to determine the presence of contaminants.
b. Develop a plan to sample, measure, and monitor the site.
c. Conduct special tests to determine the type and degree of contamination.
d. Specialists such as soil scientists, geologists, chemists, hydrologists, and engineers should be consulted. The design team with expert help can then develop a Site Remediation Plan.

Step 2 − Site Remediation:

Typical site remediation uses earth-moving solutions to address soil and groundwater contamination. How stormwater is managed depends largely on how the site was remediated. Contaminated soil can be completely removed from the site, isolated and capped, or blended with clean soil so that it meets state standards for public health and safety. Assessment and cleanup of properties must conform to the requirements of both U.S. Environmental Protection Agency (USEPA) and Tennessee state requirements.

For more information on site remediation, go to TDEC Division of Remediation:

http://www.tn.gov/environment/dor/

Step 3 − Redevelopment:

After the environmental concerns are addressed through cleanup or institutional controls, assessment is complete, and the appropriate actions taken, plans must be developed for resolving unacceptable environmental risks and integrating solutions into the development plans.

Contact economic development staff of local, state, and federal agencies to determine possible financial and technical resources available to help with planning and financing brownfield redevelopment.

C. Soil Texture, Organic Matter Content, Nutrient Levels, and pH

Soils should be amended based on information provided by the results of soil tests for the following parameters: texture class, organic matter content, nutrient deficiencies, and pH

- Take soil samples from representative areas on the site.
- Do not mix these soils together.
- Test each individual sample for texture class, organic matter content, nutrient levels, and pH.
- Send samples to the University of Tennessee Extension for analysis (Hamilton County, 6183 Adamson Circle, Chattanooga, TN 37416-3648), Website: https://utextension.tennessee.edu/hamilton/Pages/Soil-Testing.aspx.
- Results should be interpreted by a professional soil scientist or USDA Extension Service expert. (Laboratory tests often include professional interpretation of results and recommendations.)

Please note: Sands and soils based off of limestone parent material are calcareous and therefore basic. You cannot permanently amend limestone-based soils with sulfur to drive down the pH. Some soils are amendable, but calcareous soils are not. Elemental sulfur, with the help of bacteria, will work to decrease the pH for a little while (+/-5 years), but the pH will increase again and plants will turn yellow, suffer, and die, unless more sulfur is added in perpetuity. Helpful hint: know if local soils are limestone based and make sure plant material can handle the high pH. This is easier than playing soil alchemy.

D. Highly Erodible Soils

- Highly Erodible Soil Map Units

  A soil map unit with an erodibility index of 8 or greater is considered to be highly erodible land (HEL) USDA Regulation 7 CFR 610, Subpart (Source: National Food Security Act Manual Part 511—Highly Erodible Land Determinations).

- Calculating Potential Erodibility (PE) of a soil map unit:

  1. Sheet and Rill Erosion (using USLE): PE = R x K x LS where:

     R = rainfall and runoff, K = susceptibility of the soil to water erosion
     LS = the combined effects of slope length and steepness

2. Wind Erosion (using WEQ): PE = C x I, where:

   C = climatic characterization of wind speed and surface soil moisture expressed as a percentage, I = the susceptibility of the soil to wind erosion

Erosion Equation	**Calculation**
Sheet and Rill Erosion (USLE)	R x K x LS = EI T
Wind Erosion (WEQ)	C x I = EI T

Note: The factor values for the equations used in the soil-loss equations are those in effect as of January 1, 1990 in the USDA NRCS Field Office Technical Guide (FOTG).

- Calculating the Erodibility Index (EI)

  The EI for a soil map unit is determined by dividing the potential erodibility for the soil map unit by the soil loss tolerance (T) value established for the soil in the FOTG as of January 1, 1990.

  Please note: The Highly Erodible Map Unit List contained in the FOTG as of January 1, 1990, is used for all EI calculations.

References

ASTSWMO, Idaho State Response and Brownfields Program Operations Task Force. 2007. *Toolbox for Cleanup*: *Redevelopment of Contaminated Sites in Small Cities and Rural Communities.* http://www.deq.idaho.gov/media/533454-toolbox.pdf.

Daddow and Warrington. 1983. *Growth-limiting Soil Bulk Densities as influenced by Soil Texture*, USDA Forest Service, Fort Collins, Colorado.

University of Tennessee, Extension Service, Hamilton County, Soil Testing. https://utextension.tennessee.edu/hamilton/Pages/Soil-Testing.aspx.

	# Sample Soil Log	FORM

Tested by: ____________

Test Pit: ____________ *Date:* ____________ *Elevation:* ____________ *Equipment Used:* ____________

Geology: ____________ *Soil Type:* ____________ *Land Use:* ____________ *Weather:* ____________

Additional comments:

Horizon	Upper Boundary	Lower Boundary	Soil Textural Class	Type, Size, Coarse Fragments, etc.	Soil Color	Color Patterns	Pores, Roots, Rock Structure	Depth to Bedrock	Depth to Water	Comments

Protocol 4 Infiltration System Design and Construction Guidelines

A. Purpose of this Protocol

This protocol (Protocol 4) provides technical information and design guidance common to all infiltration BMPs.

This protocol provides the designer with specific guidelines for the design, construction, and long-term performance of infiltration BMPs. These guidelines fall into three categories:

1. Site conditions and constraints
2. Design considerations
3. Construction requirements

Successful BMP implementation is dependent on careful consideration of site conditions, thoughtful design, and quality construction. These guidelines provide important information and instruction.

B. Infiltration BMPs and Their Purpose

The phrase "infiltration BMPs" describes a wide range of stormwater management practices aimed at infiltrating some fraction of stormwater runoff from developed surfaces into the soil horizon and potentially into deeper groundwater. The major infiltration strategies are:

- Pervious Pavement (Chapter 5.3.1)
- Infiltration Bed (Chapter 5.3.2)
- Infiltration Trench (Chapter 5.3.3)
- Bioretention (Bioinfiltration, Rain Garden) (Chapter 5.3.4)
- Vegetated Swales (Biofilters-Grass Swales) (Chapter 5.3.5)
- Vegetated Filter Strips (Biofilters, Grass Strips) (Chapter 5.3.6)
- Infiltration Berms (Chapter 5.3.7)
- Other BMPs that support infiltration not covered in this guide

Infiltration BMPs are one of the most beneficial approaches to stormwater management for a variety of reasons, including:

- Reduction of the peak rate of runoff
- Reduction of the volume of runoff

- Removal of a significant portion of the particulate-associated pollutants and some portion of the solute pollutants
- Recharge of groundwater and maintenance of stream base flow

Infiltration BMPs attempt to replicate the natural hydrologic regime. During periods of rainfall, infiltration BMPs reduce the volume of runoff and help to mitigate potential flooding events. During periods of reduced rainfall, this recharged water serves to provide base flow to streams and maintain in-stream water quality. Qualitatively, infiltration BMPs are known to remove nonpoint source pollutants from runoff through a complex mix of physical, chemical, and biological removal processes. Infiltration promotes maintenance of the natural temperature regimes of stream systems (cooler in summer, warmer in winter), which can be critical to the aquatic ecology. Because of the ability of infiltration BMPs to reduce the volume of runoff, there is a corresponding reduction in erosive “bank full” conditions and downstream erosion and channel morphology changes.

Infiltration BMPs are designed to infiltrate some portion of runoff during every runoff event. During small storm events, a large percentage of the runoff may infiltrate, whereas during large storm events, the volume that infiltrates may be only a small portion of the total runoff. However, because most of the rainfall in Tennessee occurs in small (less than 1-inch) rainfalls, the annual benefits of an infiltration system may be significant.

C. Infiltration System Guidelines

1. Site Conditions and Constraints

a) It is desirable to **maintain a 2-foot clearance above the regularly occurring seasonally high water table**. This reduces the likelihood that temporary groundwater mounding will affect the system, and provides sufficient distance for water movement through the soil to allow adequate pollutant removal. Some minor exceptions may be allowed for very shallow systems and on-grade systems, filter strips, buffers, etc.

b) **A minimum depth to bedrock (including weathered bedrock) of 2 feet should be maintained to ensure adequate pollutant removal**. In special circumstances, filter media may be employed to remove pollutants if adequate soil mantle does not exist. Generally, the bottom of an infiltration system should provide at least 2 feet of soil mantle.

c) **Soils underlying infiltration BMPs should have measured infiltration rates between 0.1 and 10 inches per hour**. In most development programs, this will result in reasonably sized infiltration systems. Where soil permeability is extremely low, infiltration may still be possible, but the surface area required could be large and therefore other volume reduction methods may be warranted. Soils with rates in excess of 6 inches per hour may be excessively well-drained and require an additional soil buffer (such as an organic layer over the bed bottom). Such situations should be evaluated on a case-by-case basis.

d) **Infiltration BMPs should be sited so that risk to groundwater quality is minimized**. Systems should be located at least 50 feet from individual water supply wells and 100 feet from community or municipal water supply wells. Horizontal separation distances or buffers from special geologic features, such as fractures, traces, and faults, may also be appropriate depending on water supply sources and should be evaluated on a case-by-case basis.

e) **Infiltration at hot areas should include consideration of site conditions**. Where there is a likelihood of spills of hazardous substances, such as fueling stations, infiltration systems should not be employed. However, the entire project site should not be excluded from infiltration, only those areas subject to spills or storage of hazardous substances. If structural spill containment procedures, such as containment areas, are employed, infiltration may be feasible. Each site should be evaluated on a case-by-case basis.

f) **Brownfield sites must be evaluated on a case-by-case basis.** In many situations, depending on the nature of past uses and potential contamination, infiltration will not adversely affect site conditions or water quality. However, sites with known soil contamination issues may not be suitable for infiltration. The designer should coordinate with the City and TDEC requirements on a case-by-case basis.

g) **Infiltration BMPs should be sited so that they present no threat to subsurface structures**. These include building foundations and basements, certain utilities, existing subsurface structures, etc. (See Protocol 1, Infiltration BMP Setbacks from Structures, and Protocol 2, BMP Coordination with Other Utilities, for additional information.)

In general, soils of hydrologic soil group D will not be suitable for infiltration. Similarly, areas of floodplains and areas in proximity to wetlands and streams generally will not be suitable for infiltration (due to a high water table and/or proximity to underlying rock formations). For developing areas previously used for agricultural purposes, the designer should consider the past patterns of land use. Areas that were suitable for cultivation will likely be suitable for some level of infiltration. Areas that were excluded from cultivation often indicate locations that are too wet or too rocky, and will likely not be suitable for infiltration.

2. <u>Design Considerations</u>

a) **Do not infiltrate in compacted fill**. Infiltration in native soil without prior fill or disturbance is preferred but not always possible. Areas that have experienced historic disturbance or fill are suitable for infiltration provided that sufficient time has elapsed and soil testing indicates infiltration is feasible. Fill that was placed more than 10 years ago and that has been subject to rainfall and weathering may be suitable for infiltration. In disturbed areas, it may be necessary to infiltrate at a depth beneath soils that have previously been compacted by construction methods or long periods of mowing, i.e., 12 to 18 inches below the existing surface grade.

b) **A level infiltration area is preferred**. Bed bottoms should always be graded into the existing soil mantle, with terracing as required to construct flat-bottom structures. Sloped bottoms tend to pool and concentrate water in small areas, reducing the overall rate of infiltration and longevity of the BMP. Infiltration areas should be flat, or nearly so (less than a 1 percent slope). Orienting infiltration BMPs along the existing contours will facilitate level bottoms and reduce the amount of cut/fill required for construction.

c) **Preserve the soil mantle to the maximum extent possible and minimize excavation**. Soils that do not need to be disturbed for the building program should be left undisturbed and protected (Chapter 5.2.1). Macropores can provide a significant mechanism for water movement in infiltration systems, and the extent of macropores often decreases with depth. Maximizing the soil mantle increases pollutant removal capacity and reduces concerns about groundwater mounding. Therefore, excessive excavation for the construction of infiltration systems is strongly discouraged.

d) **Isolate "hot areas."** Site plans that include "hot areas" must be considered in BMP design. Hot areas are most often associated with industrial uses, past contamination, and high traffic, such as gasoline stations and vehicle maintenance areas. These areas may be suitable for infiltration BMPs if designed with management measures to address potential contamination issues. This may include structural spill containment measures prior to infiltration BMPs, oil water separators, etc. Hot areas must be evaluated on a case-by-case basis.

   Additionally, certain land uses may have unusually high levels of sediment and other pollutants. Examples include high-intensity commercial uses (fast-food restaurants, convenience stores, etc.), especially areas around dumpsters and material handling areas and loading docks. The potentially high pollutant loadings warrant consideration in BMP design, and pretreatment may be required. Pretreatment devices that operate effectively in conjunction with infiltration BMPs include grass swales, vegetated filter strips, settling chambers, oil/grit separators, sediment sumps and traps, and water quality inserts. The pollutants of greatest concern, site by site, should guide selection of pretreatment options depending upon the nature and extent of the land development under consideration. Selection of pretreatment techniques will vary depending upon whether pollutants are of a particulate (sediment, phosphorus, metals, etc.) versus soluble (nitrogen and others) nature. Types of pretreatment (i.e., filters) should be matched with the nature of the pollutants expected to be generated.

e) **Consider the loading ratio of impervious area to bed bottom area**. One of the more common reasons for infiltration system failure is the design of a system that attempts to infiltrate a substantial volume of water in a very small area. Infiltration systems work best when the water is “spread out.” The loading ratio describes the ratio of impervious drainage area to infiltration area, or the ratio of total drainage area to infiltration area. In general, the following loading ratio guidelines are recommended:

For 1-inch rainfall or less:

- A maximum impervious loading ratio of 10:1 relating impervious drainage area to infiltration area
- A maximum total loading ratio of 20:1 relating total drainage area to infiltration area

For storms greater than 1 inch and less than or equal to1.6 inches:

- A maximum impervious loading ratio of 8:1 relating impervious drainage area to infiltration area
- A maximum total loading ratio of 16:1 relating total drainage area to infiltration area

The above loading ratios are **guidelines** intended to assist the designer in achieving successful BMP implementation. Loading ratios rarely fit neatly into these exact ratios, as the BMP location will be a function of location opportunities (based on topography, soils, etc.) and land use. However, exceeding the loading ratios for impervious area should be done in coordination with input from the City and with careful consideration of the nature of the runoff. For example, BMPs that receive “clean” roof runoff may be less susceptible to clogging than BMPs that receive sediment-laden road runoff, and a higher loading ratio may be warranted if soil conditions are suitable.

f) **Limit the depth of water**. The total depth of standing surface water generally should not be greater than 2 feet above an infiltration area to avoid excessive pressure and potential sealing of the bed bottom. Typically, water depth is limited by the loading ratio and drawdown time and is not an issue.

g) **Consider drawdown time**. In general, infiltration BMPs must be designed so that the system is completely drained within 72 hours. Table D-1 provides a summary of volume infiltration potential within the required 72-hour drawdown time for a range of infiltration rates.

Table D-1. Summary of Volume Infiltration Potential

Infiltration Rate ($^{in.}/_{hr.}$)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Volume Infiltrated in 72 hours (in.)	7.2	14.4	21.6	28.8	36.0	43.2	50.4	57.6	64.8	72.0
Drawdown Time at 1.0 inch (hr.)	10.0	5.0	3.3	2.5	2.0	1.7	1.4	1.3	1.1	1.0
Drawdown Time at 10.0 inches (hr.)	100.0	50.0	33.3	25.0	20.0	16.7	14.3	12.5	11.1	10.0
Drawdown Time at 1.6 inches (hr.)	16.0	8.0	5.3	4.0	3.2	2.7	2.3	2.0	1.8	1.6
Drawdown Time at 12.8 inches (hr.)	128.0	64.0	42.7	32.0	25.6	21.3	18.3	16.0	14.2	12.8

h) **Design infiltration BMPs with a positive overflow** that discharges excess volume in a non-erosive manner, and allows for controlled discharge during extreme rainfall events or frozen bed conditions. Infiltration BMPs should never be closed systems dependent entirely upon infiltration. Large storm events must be able to "overflow." Overflow systems should have the capacity to convey the flow from the 25-year, 5-minute rainfall intensity.

i) **Incorporate geotextiles into the design as necessary in certain infiltration BMPs**. Infiltration BMPs that are subject to soil movement and deposition must be constructed with suitably well-draining non-woven geotextiles to prevent movement of fines and sediment into the infiltration system. The designer is encouraged to exercise caution and use geotextiles as necessary at the soil/BMP interface.

tile

j) **Avoid severe slopes (>20 percent) and toes of slopes**, where possible. Specific onsite investigations by experienced personnel need to be made to determine acceptability of each case.

3. <u>Construction Requirements</u>

a) **Do not compact soil infiltration beds during construction**. Prohibit heavy equipment from the infiltration area and minimize other traffic. Equipment should be limited to vehicles that will cause the least compaction, such as tracked vehicles.

b) **Protect the infiltration area from sediment until the surrounding site is <u>completely</u> stabilized**. Methods to prevent sediment from washing into BMPs should be clearly shown on plans. Geotextile used as a bed bottom liner should be extended several feet beyond the bed and folded over the edge to protect from sediment wash into the bed during construction, and then trimmed. Runoff from construction areas should never be allowed to drain to infiltration BMPs. This can usually be accomplished by diversion berms and immediate vegetative stabilization. The infiltration area may be used as a temporary sediment trap or basin during earlier stages of construction. However, if an infiltration area is also to be used as a temporary sediment basin, excavation should be limited to within 1 foot of the final bottom invert of the infiltration BMP to prevent clogging and compacting of the soil horizon, and final grade should be removed when the contributing site is fully stabilized. All infiltration BMPs should be finalized at the end of the construction process, when upstream soil areas have a dense vegetative cover (at least 70 percent).

c) **Provide thorough construction oversight**. Long-term performance of infiltration BMPs is dependent on the care taken during construction. Plans and specifications must be followed precisely. The designer is encouraged to meet with the contractor to review the plans and construction sequence prior to construction, and to inspect the construction at regular intervals and prior to final acceptance of the BMP.

d) **Provide quality control of materials**. As with all BMPs, the final product is only as good as the materials and workmanship that went into it. The designer is encouraged to review and approve materials and workmanship, especially as related to aggregates, geotextiles, soil and topsoil, and vegetative materials.

D. Common Causes of Infiltration BMP "Failures"

The concept of failure is simple – a design no longer provides the benefit or performance anticipated. With respect to stormwater infiltration BMPs, the term requires some qualification, since the net result of "failure" may be a reduction in the volume of runoff anticipated or the discharge of stormwater with excessive levels of pollutants. Where the system includes built structures, such as porous pavements, failure may include loss of structural integrity for the wearing surface, whereas the infiltration function may continue uncompromised. For infiltration systems with vegetated surfaces, such as play fields or rain gardens, failure may include the inability to support surface vegetation, caused by too much or too little water.

The primary causes of reduced performance appear to be:

a) Poor construction techniques, especially soil compaction/smearing, which result in significantly reduced infiltration rates

b) A lack of site soil stabilization prior to the BMP receiving runoff, which greatly increases the potential for sediment clogging from contiguous land surfaces

c) Inadequate pretreatment, especially of sediment-laden runoff, which can cause a gradual reduction of infiltration rates

d) Lack of proper maintenance (erosion repair, revegetation, removal of detritus, catch basin cleaning, vacuuming of pervious pavement, etc.), which can reduce the longevity of infiltration BMPs

e) Inadequate design

Infiltration systems should be designed such that failure of the infiltration component does not completely eliminate the peak rate attenuation capability of the BMP. Because infiltration BMPs are designed to infiltrate small, frequent storms, the loss or reduction of this capability may not significantly impact the storage and peak rate mitigation of the BMP during extreme events.

Protocol 5 Planting Guidelines

A. Purpose of this Protocol

The purpose of the Planting Guidelines (Protocol 5) is to help the designer identify appropriate plant choices for site-specific BMPs (both restorative and structural), and to provide guidance on less familiar planting methods and plant establishment techniques.

B. Vegetated Systems in Stormwater Management

Plants, soils, microorganisms, and water should be understood together as a living system, used to harness natural processes to mitigate stormwater impacts and other benefits. Plants and their relationship to microorganisms and soil structure are an integral component of vegetated BMPs. Choosing the right plants and keeping them healthy will help to ensure that a vegetated BMP performs most effectively. Whether the BMP is protective, restorative, or structural, the major stormwater functions of vegetation are to reduce stormwater volume and velocity by:

- Evapotranspiration primarily from plant leaves
- Infiltration by root channels in the soil
- Slowing and filtering of sediment by aboveground plant mass

C. General Design Strategies

The following are general considerations and design strategies that are now commonly used. Plant selection criteria are detailed in Section 2 below.

1. Native or Non-Native—but Never Invasive Exotic

   a. Although the term "native plant" has become part of the botanical, horticultural, and even the public vocabulary, there is little agreement on its definition. In this manual, native plants are defined as those plants that have evolved with other plants and animals in response to specific conditions of climate, geology, landforms, soils, and water, and that are not genetically altered by human beings.

   b. “Exotic” plants are defined as plant species has been brought from their native habitats and planted during and since settlement of the region. Exotic plants are still being carried away from their native habitats and introduced to new places, by intention or by accident. There is a general consensus in the scientific community that an “exotic” plant, which does not spread aggressively in the landscape or significantly alter existing environmental conditions, is relatively harmless and can be planted.

c. “Invasive exotic,” also known as “invasive” or “noxious weeds,” are defined as introduced species (also called "non-indigenous, non-native or pest” species). These species are potentially poisonous to livestock, multiply prolifically, and gradually alter or displace the native landscape. They can disrupt and even obliterate native plant communities and significantly change local habitats. Invasive exotic species often are so successful because human beings have reworked and damaged local conditions.

   There is also scientific evidence that a non-native “invasive plant,” which multiplies and spreads aggressively and has the potential to take over and to eliminate a complex, dynamic eco-system, is problematic. Because of the economic and environmental damage created by these plants, they are not to be used on any project site or for any BMP.
   Invasive exotic plants frequently found in eastern Tennessee are listed at: http://www.tneppc.org/invasive_plants.

   The USDA Federal and State Lists of Invasive and Noxious Weeds can be found at: http://plants.usda.gov/java/noxiousDriver#state.

   ***Both of these lists are continually updated, so they are not included in this appendix. The project owner and the design team should check proposed plants against these lists to be sure no problematic plants are included in the design.**

d. “Cultivars” and “ornamentals” are non-native plants. Cultivars are plant varieties produced in cultivation by selective breeding. These plants are generally selected for a particular characteristic or combination of characteristics, and when propagated, retain these characteristics. An ornamental plant is a cultivar, grown for decorative purposes and used most frequently in garden and landscape designs for display.

   Non-native plants that have originated in environmental conditions that are similar to local environmental circumstances and that are tolerant of local conditions can be particularly useful, both to fulfill the specific demands of certain BMPs and to provide a wider and showier plant palette; however, they are not suited to ecological restoration projects.

2. General Species Selection/Specific Site Variables

Selecting species that are a “good fit” with specific site conditions is a key factor in determining the success of vegetated BMPs of all kinds. Plants that are well-adapted to the unique constraints of a project site and to the specific BMP will thrive and contribute significantly to the repair of the hydrologic system.

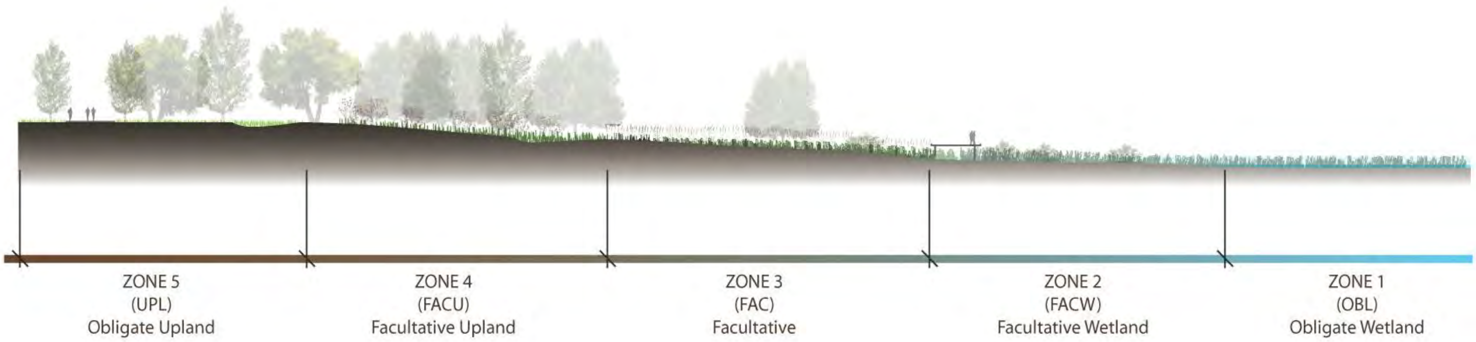
Understanding the specific soils, landforms, exposure, hydrology, and existing natural vegetation is crucial to determining which species will quickly form stable, self-supporting communities and sustain a high-performance landscape. Appropriate species selection should also decrease long-term costs by reducing energy and nutrient inputs.

Refer to the appropriate plant database for the following information:

a. Soil Moisture
   Structural BMPs can create large fluctuations in soil moisture. Plants in these engineered facilities need to be able to withstand both temporary inundation and extended drought once established.

   Moisture conditions can be described by gradient, described and shown below as a series of zones. As moisture conditions fluctuate, plants can change zones. These zones range from 1, constant standing water to 5, well-drained uplands:

   - ZONE 1 – Obligate Wetland (OBL): plants that grow in standing water more than 99 percent of the time. These plants are also called hydrophytes, floating leaved plant communities, and emergent plant communities.
   - ZONE 2 − Facultative Wetland (FACW): plants that usually occur in water (67 to 99 percent of the time); occasionally found in non-wetland environments.
     USDA: Usually is a hydrophyte but occasionally found in uplands emergent zone.
   - ZONE 3 − Facultative (FAC): plants that are equally likely to occur in wetland or non-wetland environments (34 to 66 percent of the time).
     USDA: Commonly occurs as either a hydrophyte or non-hydrophyte.
   - ZONE 4 − Facultative Upland (FACU): plants usually found in uplands (67 to 99 percent of the time); occasionally found in wetland environments.
     USDA: Occasionally is a hydrophyte but usually occurs in uplands.
   - ZONE 5 – Obligate Upland (UPL): rarely is a hydrophyte, almost always in uplands (99 percent of the time or more).



b. Flood Tolerance/Drought Tolerance

The ability of a plant to tolerate occasional submersion is an important consideration in the selection of plants for wetlands, stormwater basins, and floodplains. The depth of water and the duration of submersion affect the plants need for air exchange through leaves. Submersion for extended periods of time will kill plants intolerant of low oxygen conditions.

The USDA plant database provides a description of a particular plant's tolerance to drought as well as anaerobic conditions (flood). http://plants.usda.gov/adv_search.html

c. Soil pH and Type

For many bioretention facilities, soil specifications call for sand. Most sand from Chattanooga area sources is typically limestone based manufactured sand which result in alkaline soil mixes and cannot be modified to lower its pH by amendments (i.e., sulfur). Additives will drive down pH for a year or two, but eventually the soil reverts back to a higher pH. Neutral or low pH sand will need to be provided from nearby mountain or river sources, or plant choices will need to be tolerant of higher pH. The *USDA plant database provides minimum and maximum pH tolerances for plants*. *http://plants.usda.gov/adv_search.html*

d. Light

All plants require some light to produce food, but not all plants require the same amount of light. Select plants based on need for sunlight and/or shade tolerance. The USDA website above *and TVA website at (http://www.tva.com/river/landandshore/stabilization/plantsearch.htm)* provide assistance in the selection of plants based on light requirements.

e. Microclimate

The climate of a specific place within a larger area needs to be considered as well as plant zone, general winds, etc. Local variations may result in colder, frost-prone environments. Some areas may experience more consistent winds than typical for the larger area. It can be something as simple as a consistently shady spot on an otherwise sunny site. Careful observation and input from local residents will be helpful.

f. Salt Tolerance

Plants adjacent to roads (especially highways) and pedestrian pathways that receive snow-melt salts should be selected for greater salt tolerance. Salting is infrequent and is generally limited to major arteries, roads at higher elevations, and routes to emergency facilities (fire and police stations, hospitals, etc. Plants have a range of tolerance to salt. *The USDA Plant database provides a description of a particular plant's tolerance to salt.* *http://plants.usda.gov/adv_search.html*

g. Height and Spread of Plant and Width and Depth of Root System

h. Consider height, spread, and type/extent of roots at maturity when selecting canopy, understory trees, and large shrubs. Avoid under-drains and other utilities. Shallow rooted trees are more likely to heave pavements and out-compete smaller plants for soil moisture and nutrients. Planting Time

   i. Optimum planting time for turf grasses is spring, between March to May, and fall, from September to November, depending on the weather.
   ii. Optimum planting time for canopy trees, understory trees, shrubs, and woody ground covers is fall-winter, November 15 through February 15, before the first frost, when woody plants are dormant.
   iii. Bare root material should not be planted from April 15 through October 15, due to summer heat and drought stress.
   iv. Containerized stock can be planted at any time soil is workable, but must be watered in hot, dry periods.

i. Establishment Period – Warranty Period

   i. In general, the nursery contractor should match its guarantee period to the establishment period. The length of this establishment period varies with plant type.
      - Turf grasses − 60 days
      - Native (warm season) meadow grasses − 2 to 3 years
      - Perennials − 3 months
      - Trees − 2 years
      - shrubs − 1 year
      - Live stakes − 1 to 2 years
   ii. The warranty period is usually the same as the length of the establishment period. During this time, the contractor may be responsible for watering, etc., and is generally responsible for replacing dead and dying plants.

iii. The period immediately following planting is critical for survival. “Balled and Burlapped” plants have lost roots. Immediately after planting, plants typically require approximately 1 inch of water per week if there is no rain.
iv. Weeding during the establishment period prevents competition from undesirable plants. For minimum disturbance, remove unwanted plants manually. Mowing will keep weeds in check, more frequent mowing will favor grasses. Meadows can be mown at specific times to favor specific species.

j. Plant Stock and Availability
   i. Plants should conform to the standards of the American Standard for Nursery Stock, as approved by the American National Standard Institute (ANSI). Note that these standards establish only the minimum requirements for nursery-grown plants, i.e., relation of size of crown of plant to root ball dimension, or minimum number of stems for shrubs based on size. Higher-quality plants may be preferred by the client and provided by a reputable nursery.
   ii. Using smaller plants is often more effective since they are less expensive, easier to handle, experience less transplant shock, require less initial irrigation, and adapt more quickly to the site.
   iii. An extensive list of appropriate species typically available from commercial nurseries in and around Tennessee can be found at the end of this Appendix. Where not readily available, plants can be contract grown.

k. Seed Stock and Availability
   i. The addition of a companion or “nurse” crop (quick-growing annual or weak perennial added to permanent mixtures) is a good practice on difficult sites, for late seeding, or in situations where the development of permanent cover is likely to be slow. The companion crop germinates and grows rapidly, holding the soil until the perennial species becomes established. The seeding rate of the companion crop must be limited to avoid crowding, especially under optimum growing conditions.

Nurse Crop/Companion Crop Suggestions:

Name	Scientific Name	Planting Dates	Broadcast Pure Live Seed	Notes
Barley	*Horduem vulgare*	August – November	144 lbs. per acre* 3.3 lbs. per 1000 sq. ft.*	14,000 seeds per pound. Winter hardy. Use on productive soils.
Weeping Love	*Eragrostis*	March – June	4 lbs. per acre*	1,500,000 seeds per pound. May last for

Grass	*curvula*		0.1 lbs. per 1000 sq. ft.*	several years. Nice addition to a meadow mixture.
Common Oats	*Avena sativa*	September – November	128 lbs. per acre* 2.9 lbs. per 1000 sq. ft.*	13,000 seeds per pound. Use on productive soils. Not as winter hardy as barley or rye.
Rye	*Secale cereal*	July – November	168 lbs. per acre* 3.9 lbs. per 1000 sq. ft.*	18,000 seeds per pound. Drought tolerant and winter hardy.
Annual Rye	*Lolium multiflorum*	August – April	40 lbs. per acre* 0.9 lbs. per 1000 sq. ft.*	227,000 seeds per pound.
Wheat	*Triticum Aestivum*	September – December	180 lbs. per acre* 4.0 lbs. per 1000 sq. ft.*	15,000 seeds per pound.
Virginia Wild Rye	*Elymus virginicus*	September – December	20 lbs. per acre* 0.5 lbs. per 1000 sq. ft.*	80,000 seeds per pound. Likes moist sites.

*Planting rates shown above are for a single species cover crop. Adjust seeding rates for mixtures of seeds accordingly. Reduce seeding rates by 50 percent for drill seeding applications.

ii. For both turf and meadow, seed mixes with a diversity of species are preferable to a single species mix. Mixtures provide greater adaptability to different growing conditions and better tolerance to disease and pests.
iii. Meadow Grasses: Sources include specialized wildflower seed companies, as well as some traditional turf grass or agricultural seed producers. Selection for meadow seed should be based on local conditions and may include a nurse crop to stabilize the soil ahead of slower germinating grasses and wildflowers as part of erosion and sediment controls. Meadows do best on nutrient-poor soils.
iv. Turf Grasses: USDA certifies and regulates turf grass purity, germination rate, crop content, and weed content. The label should indicate the producer state, the seed distributor, and mix or blend according to the test methods and procedures of the Association of Official Seed Certifying Agencies.
v. Quality seed should be acquired from reliable sources.

l. Disease Risk

Consider Emerging Disease Risk when Choosing Plant Species:
Careful attention to tree health is especially important in places where people will frequently be passing through or visiting. Ultimately, trees should need little help in surviving, but during construction activities, it is possible that undesirable environmental conditions can stress trees and make them more susceptible to pests and diseases. It is suggested to proactively manage an urban forest to protect noteworthy trees from emerging diseases and insects. The following tree species are subject to severe insects/diseases and, at present, may require annual inspections and/or treatments to support their long-term health:

i. American elm – Dutch elm disease. Without annual preventive treatment, American elms have an uncertain lifespan. There are, however, new disease-resistant cultivars such as "Valley Forge", "Princeton" and "New Harmony."
ii. Ash – emerald ash borer. The emerald ash borer has been found in Tennessee. Containment of the emerald ash borer is a difficult task and the long-term outlook for ash species is uncertain. Annual preventive treatments are available for individual trees. Planting new ash trees is not recommended.
iii. Red oak group (e.g., red oak, pin oak, scarlet oak) and to a lesser extent sycamores, maples, elms – bacterial leaf scorch (BLS). This chronic disease causes infected trees to chronically decline and die. While there is neither prevention nor a cure for BLS, watering during drought periods may reduce disease symptoms and help extend the lifespan of infected trees. Prompt removal of infected wood may help slow the progress of the disease; however, this management technique has not been scientifically validated. Trees at risk for BLS, especially the red oak group, should be protected from environmental stresses such as drought, salt, and root damage. Successful tree protection during design and construction can help extend the lifespan of trees susceptible to BLS.
iv. Hemlock - woolly adelgid (HWA). The woolly adelgid is a pest from East Asia that attacks the eastern hemlock (*Tsuga Canadensis*) and the Carolina hemlock (*Tsuga caroliniana*), sucking the sap and injecting a toxin while feeding. Like the ash tree, containment has been difficult and few options are available to control the pest. While advancements are being made in producing a resistant cultivar, planting new hemlocks is not recommended at this time.

3. General Planting Methods

a. Seeding Grasses and Wildflowers
The method employed will depend on the scale of work, budget, terrain, etc.
Seeding methods include:
i. Broadcasting (spreading seed on the surface of the ground)
    - Broadcast seeding is the cheapest and fastest method.
ii. Drill seeding
    - Drill seeding provides the best soil/seed contact.
iii. Hydro-seeding

- Hydro-seeding is used on more difficult terrain and large areas. Seed and mulch can be applied separately in two steps, or in combination. It is a two-step process, which provides better soil/seed contact for higher germination rates.

b. Planting Trees, Shrubs, and Small Plants
   Plants should be planted in prepared planting soil of sufficient width and depth to support the long-term growth of the plant.
   i. Balled and Burlapped, and Container-Grown Trees and Shrubs:
      - Excavate soil approximately three times as wide as the root ball diameter and to depth of root ball.
      - Check for evidence of unexpected water seepage or retention in planting pit before planting.
      - Examine root balls and remove stem girdling roots and kinked roots.
      - Remove containers and burlap, rope, and wire baskets from tops and sides of root ball.
      - Set root ball in center of planting pit with plant plumb and with root flare at adjacent grade.
      - REMOVE all plastic wrapping; where wrapped in burlap, cut off the top one-third. If ball has a wire basket, REMOVE the entire basket.
      - Backfill pit with mix of equal parts original excavated soil and planting soil.
      - Apply mycorrhizal inoculants into backfill according to manufacturer's instructions.
      - Backfill around root ball in layers and tamp to settle soil and eliminate air spaces.
      - When pit is half full, water thoroughly. Continue backfilling with planting soil.

c. Bare-Root Stock
   Woody plant seedlings lifted from the nursery soil and delivered with their roots bare of soil.
   i. Roots of bare-rooted stock shall be kept moist and protected from freezing during planting operations by placing in a water-soil (mud) slurry, peat moss, sphagnum moss, superabsorbent (e.g., polyacrylamide) slurry or other equivalent material. (Note: Do not soak trees in water for more than 8 hours.)
   ii. The planting trench or hole must be deep and wide enough to permit roots to spread out and down without doubling, J-rooting, or L-rooting.
   iii. If the roots are too long for the planting equipment, minimal pruning of small end roots may be needed. Do not prune back into the main root system or more than 25 percent of the total root length.
   iv. Prune out any diseased root branches. Pack soil around each plant firmly to eliminate air pockets after planting.

d. Ground Cover and Small Plants
   i. Use planting soil for backfill. Dig holes of sufficient size to allow for spreading of roots.
   ii. Cut pot-bound roots and dip in solution of root dip and mycorrhizal inoculants complying with manufacturer's written instructions.

iii. Plant root ball by working soil around roots to eliminate air spaces, and leave a slight saucer indentation around plants.
iv. Plant top of root ball flush with adjacent grades.
v. Water soil thoroughly and apply 2 to 3 inches of mulch on surface.

e. A less conventional, but effective way to preserve soil structure, small plants, microorganisms, seed reservoirs, etc. is to cut and stockpile the upper soil layers as a “sod” *(*see 5.2.4.2, Soil and Plant Salvage, in this manual).

f. Live Staking of Floodplain and Wetland Woody Plants (See Detail)
Live stakes are cuttings taken from living plants capable of rooting quickly when placed in soil.
i. The cut stems develop root systems holding the soil in place.
ii. Native floodplain and wetland species are good candidates for live stake planting. Species include willow, shrub dogwood, box elder, sycamore, and elderberry.
iii. Also used, but with less success, are alder, sycamore, and viburnum. Willow is often used in combination with other species as it seems to stimulate root development in the other species. The ability to establish themselves quickly makes the plants especially suited for bank and slope stabilization. The ease of transport is an added benefit.
iv. Planting timing: February to early March when plants are completely dormant (before bud swelling), and when ground is not frozen. Keep stems moist. Plant the same day if possible.
v. Live stake description: Dormant, healthy green wood with a minimum of two bud scars near the upper part of the stem, 2 to 4 feet long. Cut the top end of the stem square and the bottom end of the stem at a 45-degree angle to identify which end to insert in the ground.
vi. Insert bottom end of cuttings into soil at a 45-degree angle and tamp soil around the stem. To avoid splitting the stake, use a dead blow hammer that has sand or shot in the hammerhead. In hard soil, use an iron bar or steel pipe to create a hole for planting. Discard split stakes and replace with new live stakes.
vii. Additional techniques including whips, fascines, and wattles. See: http://www.fs.fed.us/publications/soil-bio-guide/guide/chapter5.pdf.

D. Mulch and Compost

1. Mulch is defined as a material applied as a layer over the soil. Mulch typically includes organic materials, but also could include stone aggregates.
2. Compost is decomposed organic matter used as a **soil amendment** to improve the tilth of the soil.

E. Mulch for Vegetated Stormwater Systems

As a part of a vegetated BMP system, mulch provides a number of critical functions:
1. Acting as a sponge, soaking up stormwater and allowing water to infiltrate soil slowly and also maintaining soil moisture for plants.

2. Inhibiting evaporation from soil.
3. Discouraging the establishment of weeds.
4. Mitigating wind and water erosion. Where this is a primary function, degree of slope and soil type should help determine effective mulch types.
5. Hardwood mulch can absorb heavy metals from stormwater.
6. Moderating soil temperatures.

F. Mulch Selection

As a general rule, use mulch that complements the types of plantings being established. Use straw (or similar) mulch for meadows, leaf litter (or similar) mulch for woodland plantings, etc. Compost grass clippings and sods separately from the leaves of woody plants. These two types of organic material develop different micro-biota (specific to grass or to woody plants) in the process of decomposing. This recommendation does not necessarily apply to ornamental plantings.

1. Mulch for Seeding
   Mulch used to cover seed is typically fine in texture and lightweight, to protect seeds from drying out. This mulch should generally be straw or fiber with tackifiers.

   a. Straw mulches include salt hay or threshed straw of agricultural crops (wheat, rye, oats, barley, etc.) and must be air-dried, clean, and mildew and weed-seed free. Hay from native, warm-season grasses can also be used and does not need to be seed-free. Straw may be spread by hand or blower to form a uniform layer ¾ inches in loose thickness. It can be anchored by crimping with a disk, or by spraying with a bonding agent/tackifier.

   b. Fiber is a biodegradable, dyed-wood, cellulose-fiber mulch. It is nontoxic and free of germination inhibitors or living plants. It has a pH range of 4.5 to 6.5 (slightly acid to relatively neutral). Fiber mulch is typically applied by hydro-spray according to the manufacturer's written instructions. Seed and fiber mulch can be applied together in a single-step process, or separately for better soil/seed contact.

2. Mulch for Planted Meadows
   Wildflowers and grasses grown in containers should be straw and can include salt hay or threshed straw of agricultural grasses (wheat, rye, oats, barley, etc.) and must be air-dried, clean, and be mildew and weed-seed free. Hay from native, warm-season grasses can also be used. Straw mulch may be spread by hand or blower to form a uniform layer ¾ inches in loose thickness.

3. Mulch for Woody Plants
   Mulch for woody plants can be thicker and denser than mulch for seeding, and is resistant to erosion by wind and water.

a. Materials can include shredded hardwood, ground or shredded bark, salt hay or threshed straw, pine needles, and peanut, pecan, and cocoa-bean shells. Individual particle sizes should range from ½ inch to 3 inches in circumference.
b. Mulch should be no more than 3 inches thick to allow exchange of gases from soil to atmosphere.

4. Mulch for Structural BMPs
   Mulches that float when wet should be avoided in structural BMPs.
   a. Mulch that floats can be lost and will clog stormwater inlets. Non-composted mulches tend to float and should not be used.
   b. Hardwood bark that is double or triple shredded and well-composted will remain in place.

5. Do Not Use:
   a. Shredded pine bark in structural BMPs.
   b. Un-composted bark mulch, fresh clippings, and immature composted materials, which rob soil of oxygen and nitrogen.
   c. Rubber mulch or Crumb Rubber.
   d. Plastic sheeting of any kind, as it disintegrates from exposure.

G. Types of BMPs and Their Specific Issues

In this manual, BMPs are divided into three categories two of which are discussed below:

1. Restorative BMPs
2. Structural BMPs

For these BMP types, there are significant differences in the approach to plant selection and the use of alternate planting methods.

1. Restorative BMPs

Ecological restoration is an intentional activity used to initiate or accelerate the recovery of a degraded, damaged, or destroyed ecosystem (regardless of how minor the interventions). Restoration should be understood as a gradient of different approaches ranging from strict, historical restoration (for instance, returning an ecosystem to a documented historical condition using accurate, scientifically based parameters) to simple repair and enhancement of an existing landscape, where the goal is only a healthier, more functional ecosystem. These practices focus on creating healthier, more functional ecosystems for stormwater management.

a. Protection or Restoration?

First determine if a landscape requires restoration as opposed to protection. If native plant communities with specific dominant species are present (NatureServe provides plant community examples, see link below or xl lists provided), evidence of human disturbance is minima and exotic invasive plants make up less than 25 percent of the total area than the area may be preserved rather than restored.

b. Landscape Selection – Cover type

To determine the landscape category most suited for a restorative BMP on a specific project, identify nearby natural areas with environmental conditions similar to the site. The Chattanooga Arboretum and Nature Center is situated in a very large block of forested area at the edge of Chattanooga to the west of Look Out Mountain. Prentice Cooper State Forest and Wildlife Management area is in proximity to Chattanooga as is Cahutta National Forest. These areas will contain landscape communities that could be used as reference models, depending on the project circumstances. Match growth requirements (soil, light, moisture) to the conditions on the site. A parallel, but less disturbed site can illustrate a range of local landscape types that complement the proposed budget, program, and building footprint. Additionally NatureServe write ups have been provided with specific dominant species for your convenience.

For specific plant community types for the Level III Ecoregion *Ridge and Valley Provence* designated by USEPA, use the NatureServe website:
http://www.tn.gov/environment/na/pdf/tn_eco_systems.pdf
Or the Nature Serve Data Explorer:
http://www.natureserve.org/explorer/servlet/NatureServe?init=Ecol
Or refer to the accompanying plant database for suggestions.

c. Plant Selection for Restorative BMPs

Appropriate species selection depends on the specific requirements of the BMP; on project goals, schedule, and budget; and on the visibility and accessibility of a given stormwater management measure.

i. Plant selection is focused primarily on functional improvements (i.e., plants whose roots increase soil porosity).
ii. Plants are chosen for their ability to survive and thrive in difficult, existing conditions, with minimal long-term management.

iii. Species selected for restorative BMPs are typically native. Plants chosen are not usually nursery specimens, cultivars, hybrids, or ornamental species (with the exception of some plants bred to survive particular, difficult conditions or to remove pollutants).
iv. For greater “fidelity” to local ecosystems, plants can be collected or grown from seed harvested from Level IV Ecoregions - *Southern Limestone/Dolomite Valleys and Low Rolling Hills,* designated by USEPA.

d. Planting Methods for Restorative BMPs

Appropriate planting methods also depend on the specific requirements of the BMP; on project goals, schedule, and budget; and on the visibility and accessibility of a given stormwater management measure.

i. Typically, planting strategies for restorative BMPs differ from those chosen for structural BMPs, but this is not an ironclad rule. Restorative BMPs are frequently located within a large site, in underused or less visible areas, where smaller plant sizes and lower-cost strategies can be used.
ii. Canopy trees and understory can be planted in smaller, even very small sizes, as “whips” or “seedlings,” or less than 1-inch caliper trees. Shrubs can also be smaller (less than 2 to 3 feet in height) and often grown in containers or flats. Woody groundcovers are in flats or in mats. Herbaceous plants are either seeded in, over extensive areas, or planted as plugs for smaller, difficult areas that require immediate cover.
iii. Density of plants is generally greater to stabilize soil. In restoration landscapes, loss of plants is part of the process, and there is no need to leave space for a plant to develop to maximum size and shape, as in ornamental landscapes.
iv. The typical goal of a restorative BMP is to reproduce the plant-to-plant and plant-to-site relationships found in similar (but less disturbed) local environments, in more or less the same numbers and patterns.
v. Also consider collecting seeds and plants from USDA plant hardiness zone 7b to 8a to accommodate global warming.
vi. A less conventional but effective way to preserve soil structure, small plants, microorganisms, and seed reservoirs, etc. is to cut and stockpile the upper soil layers as “sod.” See 5.2.4.2 Soil and Plant Salvage.

e. Mulches for Restorative BMPs

Mulches are often simple native materials such as straw or hay for meadows and leaves for woodlands and forests.

f. Management for Restorative BMPs
    i. Restorative landscapes are generally "managed" rather than "maintained." Plants are allowed to organize themselves by natural mechanisms such as "colonization, competition and reproduction." Individual species are not pampered—those that die are no longer part of the system, and are not replaced.
    ii. Measures to protect plants from an overabundance of grazers (i.e., deer and rabbits) can be critical to the survival of a restorative BMP.
    iii. Non-chemical Management of invasive plant species is critical to BMP success.

2. Structural BMPs

a. Planting Strategies for Structural BMPs
    i. BMPs that are visible are generally required to have "people-pleasing" qualities (showy flowers, dramatic forms, fall color, and winter interest).
    ii. Planting design frequently leaves greater space between plants, to allow each plant to grow and mature, without being crowded by others.
    iii. While these landscape plantings will grow and mature, they are not expected to change into a different landscape (for example, from a meadow to a forest) over time. They are generally understood to be "stage sets," which are relatively static and only grow older and larger.

b. Species Selection for Structural BMPs
    i. Plant species used can be natives, but cultivars are more frequently chosen—since they are often developed for aesthetic qualities.
    ii. Plant species chosen for structural BMPs generally require a higher performance in a more concentrated space.
    iii. Plants are often larger, more mature, "specimens," chosen to create an immediate effect. Tag individual plants at the selected nursery to ensure the stock is healthy and has an appropriate form based on the design requirements.
    iv. Minimum size for canopy must be 2 inches in caliper or greater. Minimum size for understory trees is 6 feet or greater. Where possible, use multiple stem species.
    v. Minimum size shrubs are 3 to 4 feet high or greater.
    vi. Minimum size for herbaceous plugs is 5 inches deep (deep roots ensure a fast start). Shallow rooted herbaceous plants, such as ferns and sedges, can be broader and shallower.

c. Mulches for Structural BMPs
    i. Where possible, all space on the ground should be filled with plants and the use of mulches kept to a minimum.
    ii. Consider imaginative alternatives to traditional mulches, i.e., boulders, river rock, pebbles and crushed glass, choose mulches that complement site textures and colors.

d. Management for Structural BMPs
   i. See specific structural BMP for operations and maintenance guidance.
   ii. Anti-herbivore measures can be important on corporate headquarters, institutional campuses, and other large properties. These measures may include control of Canadian geese on lawn. Replacing vast extents of lawn with other cover types should greatly reduce the Canadian geese problem.

References

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Price, John C., and Robert Karesh. 2012. *Tennessee Erosion and Sedimentation Control Handbook: A Stormwater Planning and Design Manual for Construction Activities.* TDEC. http://www.tnepsc.org/handbook.asp.

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STORMWATER SYSTEM SPECIFICATIONS

AGGREGATES

__**Infiltration Beds**__

1. All aggregates within infiltration beds shall be clean and thoroughly washed and shall meet the following:

   a) Maximum wash loss of 0.5% (ASTM C117)

   b) Minimum durability index of 35 (ASTM D3744)

   c) Los Angeles Test Machine (L.A). abrasion loss, 30% maximum (ASTM C131 and C535)

   d) Aggregate shall be 100% crushed material

   e) Fractured faces, 1 side 98% minimum, 2 sides 90% minimum (ASTM D5821)

2. Unless otherwise approved by the Engineer, coarse aggregate for the infiltration beds shall be uniformly graded with the following gradation (AASHTO size no. 3)

U.S. Standard Sieve Size	Percent Passing
2 ½” (63 mm)	100
2” (50 mm)	90-100
1½” (37.5 mm)	35-70
1” (25 mm)	0-15
½” (12.5 mm)	0-5

3. Choker base coarse aggregate for infiltration beds shall have the following gradation (AASHTO size no. 57):

U.S. Standard Sieve Size	Percent Passing
1½” (37.5 mm)	100
1” (25 mm)	95-100
½” (12.5 mm)	25-60
4” (4.75 mm)	0-10
8” (2.36mm)	0-5

4. Bedding coarse aggregate for permeable pavers shall be washed, crusher run, free of fines, organics, and soluble salts, and have the following gradation (ASTM size no. 89):

U.S. Standard Sieve Size	Percent Passing
1½" (37.5 mm)	100
3/8"(0.945 mm)	90-100
4" (4.75 mm)	20-55
8" (2.36 mm)	5-30
16"	0-10
50"	0-5

BIORETENTION SOILS SPECIFICATION

BIORETENTION SOIL

General

Bioretention soil shall be a well-blended mixture of mineral aggregate and compost measured on a volume basis.

Landscape Bioretention Soil

Landscape bioretention soil shall consist of two parts compost (approximately 35 to 40 percent) by volume and three parts mineral aggregate (approximately 60 to 65 percent), by volume. The mixture shall be well blended to produce a homogeneous mix. Organic matter content shall be 8 to 10 percent, with the final mix to be determined by the Engineer based on samples and test results submitted.

Turf Bioretention Soil

Turf bioretention soil shall consist of one part compost by volume (approximately 30 to 35 percent), and two parts mineral aggregate (approximately 65 to 70 percent) by volume. The mixture shall be well blended to produce a homogeneous mix. Organic matter content shall be 4 to 6 percent, with the final mix to be determined by the Engineer based on samples and test results submitted.

Composted Material

Compost products shall be the result of the biological degradation and transformation of Type I or III feed stocks under controlled conditions designed to promote aerobic decomposition. Compost shall be stable with regard to oxygen consumption and carbon dioxide generation. Compost shall be mature with regard to its suitability for serving as a soil amendment or an erosion control BMP as defined below. The compost shall have a moisture content that has no visible free water or dust produced when handling the material.

Compost production and quality shall meet the following physical criteria:

1. Compost material shall be tested in accordance with Testing Methods for the Examination of Compost and Composting (TMECC) Test Method 02.02-B, "Sample Sieving for Aggregate Size Classification."

Compost shall meet the following:

	Minimum	Maximum
Percent passing 1”	99%	100%
Percent passing 5/8”	90%	100%
Percent passing 1/4”	40%	90%

2. The pH shall be between 5.5 and 8.0 when tested in accordance with TMECC 04.11-A, “1:5 Slurry pH.”

3. Manufactured inert material (plastic, concrete, ceramics, metal, etc.) shall be less than 1.0 percent by weight as determined by TMECC 03.08-A, "Percent Dry Weight Basis."

4. Organic matter content should be between 45 and 65 percent dry weight basis as determined by TMECC 05.07A, “Loss-On-Ignition Organic Matter Method.”

5. Soluble salt contents shall be less than 6.0 mmhos/cm tested in accordance with TMECC 04.10-A, “1:5 Slurry Method, Mass Basis.”

6. Maturity shall be greater than 80 percent in accordance with TMECC 05.05-A, “Germination and Vigor.”

7. Stability shall be 7 or below in accordance with TMECC 05.08-B, “Carbon Dioxide Evolution Rate.”

8. The compost product must originate a minimum of 65 percent by volume from recycled plant waste. A maximum of 35 percent by volume of other approved organic waste, not including biosolids, may be substituted for recycled plant waste. The supplier shall provide written verification of feedstock sources.

9. The carbon to nitrogen ratio shall be less than 25:1 as determined using TMECC 04.01, “Total Carbon” and TMECC 04.02D, “Total Kjeldhal Nitrogen.” The Engineer may specify a C:N ratio up to 35:1 for projects where the plants are entirely native species.

10. The Engineer may also evaluate compost for maturity using the Solvita Compost Maturity Test at time of delivery. Compost shall score a number 6 or above on the Solvita Compost Maturity Test.

The compost supplier shall test all compost products within 90 calendar days prior to application. Samples shall be collected using the Seal of Testing Assurance (STA) sample collection protocol. The sample collection protocol can be obtained from the U.S. Composting Council, 4250 Veterans Memorial Highway, Suite 275, Holbrook, NY 11741 Phone: 631-737-4931, www.compostingcouncil.org. The sample shall be sent to an independent STA Program approved laboratory. The compost supplier shall pay for the test. A copy of the approved independent STA Program laboratory test report shall be submitted to the Engineer prior to initial application of the compost. Seven days prior to application, the Contractor shall submit a sample of each type of compost to be used on the project to the Engineer.

Compost not conforming to the above requirements or taken from a source other than those tested and accepted shall be immediately removed from the project and replaced at no cost to the Owner.

The Contractor shall submit the following information to the Engineer for approval:

1. Written verification from the supplier and laboratory analyses that the materials comply with the processes, testing, and standards specified in these Specifications. An independent STA Program certified laboratory shall perform the analysis.

2. A list of the feedstock by percentage present in the final compost product.

3. A copy of the producer's STA certification as issued by the U.S. Composting Council.

Acceptance shall be based upon a satisfactory Test Report from an independent STA Program certified laboratory and the sample(s) submitted to the Engineer.

STORMWATER SYSTEM SPECIFICATIONS

CONTROL STRUCTURES

Manufacturers

1. Nyloplast
2. Other Engineer Approved Manufacturers

Properties

1. Storm Drain Inlets, Trench Drains, and Structures: Concrete Construction: Concrete construction shall be in accordance with latest edition of TDOT Standard Specifications for Road and Bridge Construction.

   a) Precast and Cast-in-Place Concrete Inlets and Trench Drains: Precast concrete inlets may be substituted for cast-in-place structures and shall be constructed as specified for cast-in-place. Precast structures may be used only in those areas where there is no conflict with existing underground structures that may necessitate revision of inverts. Concrete structures shall be placed on a 6- or 8-inch bed of compacted coarse aggregate Size No. 2A as indicated on the plans and details. Reinforcement steel, if required for handling, shall have a minimum of 2-inch cover. Handling devices, if used, shall be removable and the holes filled with concrete. Concrete structures will be modified to provide 18 inches of sediment storage and bottom leaching basins, open to gravel sumps in subgrade.

   b) All polyvinyl chloride (PVC) inline drains shall be as manufactured by Nyloplast or other approved manufacturer and as noted on site detail drawings or approved equals.

   c) Inline drains shall be sized as shown on the plans or as required for necessary pipe connections and have standard grates. All PVC inline drains shall be manufactured with black colored PVC.

   d) Trench drain grates/covers and frames shall be sized as shown on the plans. Trench drain grates and covers shall be bolted to the frame.

2. Compression Joints

   a) All ductile iron pipes and fittings used in the construction of sewers, including bends and wye branches, shall have gasket joints. Unless otherwise noted in the Special Specifications, the pipe and fittings shall have push-on joints. The gaskets shall be manufactured and tested in accordance with the American National Standard for Rubber-Gasket Joints for Cast Iron and Ductile Iron

Pressure Pipes and Fittings, ANSI A21.11 (AWWA C11 1).

b) The outside edges of field cut pipes and fittings shall be beveled back 1/8 inch from the cut edges on a 30-degree angle in order to avoid damaging the gasket.

3. Trash Screens

Trash screens shall be stainless steel with 0.05- to 2.5-centimeter (0.19- to 1-inch) openings.

4. Weir Plates

a) Stainless Steel Weir Plates

(1) Weirs shall be as specified herein and have the characteristics and dimensions shown in the Contract Drawings.
(2) Stainless steel weir plates shall be fabricated of stainless steel having a minimum thickness of ¼ inch and shall have adequate strength to prevent distortion during normal handling, during installation, and while in service.

b) Anchor bolts shall be used for mounting the weir plates. Anchor bolts shall have a minimum diameter of ¼ inch.

5. Epoxy Mortar

a) The following products may be acceptable epoxy mortar gel, provided they meet all material requirements:

(1) Meta Bond HM Gel, as manufactured by American Meta Seal Company, 509 Washington Avenue, Carlstadt, NJ 07072
(2) Sikadur 31 Hi-Mod Gel, as manufactured by Sika Corporation, Box 297, Lyndhurst, NJ 07071
(3) Thermal-Chem Mortar Resin Gel (Product No. 304), as manufactured by Thermal-Chem, Inc., 1400 Louis Avenue, Elkgrove, IL 60007

b) The following products may be acceptable epoxy bonding agents, provided they meet all material requirements:

(1) Meta Bond HM, or Meta Bond HM Gel, as manufactured by American Meta Seal Company
(2) Sikastix 370, Sikadur Hi-Mod, or Sikadur 31 Hi-Mod Gel, as manufactured by Sika Corporation
(3) Thermal-Chem Mortar Resin (Product No. 3), or Thermal-Chem Mortar Resin Gel (Product No. 304), as manufactured by Thermal-Chem, Inc.

c) The shrink epoxy mortar gel and bonding agent shall meet the following requirements:

(1) 100 percent solids formulation
(2) Tensile strength no less than 3000 psi after 7 days and 73°F, per ASTM D 638
(3) Tensile elongation no greater than 7 percent per ASTM D 638
(4) Compressive strength no less than 3000 psi after 24 hours at 73°F, and no less than 6000 psi after 7 days at 73°F per ASTM D 695

d) Sand shall be oven-dry silica sand and meet the following gradations:

(1) At least 70 percent by weight passing #20 sieve
(2) No more than 35 percent by weight passing #40 sieve

e) Epoxy mortar shall be composed of epoxy mortar gel and sand mixed at a 1:1 ratio by loose volume, or according to the manufacturer's instructions.

STORMWATER SYSTEM SPECIFICATIONS

GEOTEXTILES

Geotextile Filter Fabric − Geotextile (drainage filter fabric) shall be nonwoven needle-punched material and shall conform to the following:

Manufacturers

1. TenCate Mirafi 160N
2. Other Engineer Approved Manufacturers

Properties

1. Grab Tensile Strength – ASTM D4632 – minimum 150 lbs
2. Grab Tensile Elongation – ASTM D4632 – 50%
3. Puncture Strength – ASTM D6241 – minimum 90 lbs
4. Trapezoid Tear – ASTM D4533 – 60 lbs
5. Apparent Opening Size – ASTM D4751 – 60 to 70 U.S. Sieve
6. Flow Rate – ASTM D4491 –110 gal/min/ft^2
7. UV Resistance – ASTM D4355 – 70%
8. Permittivity – ASTM D4491 – 1.5/sec

STORMWATER SYSTEM SPECIFICATIONS

IMPERVIOUS LINERS

Manufacturers

1. Solmax 230 (30 mil)

2. Other Engineer Approved Manufacturers

Properties

1. Thickness – ASTM D5199 or D5994 − 30 mils

2. Break Stress – ASTM D6693 – 77 lbs/in

3. Break Elongation – ASTM D6933 – 350%

4. Puncture Resistance – ASTM D6241 – 90 or 410 lbs

5. Tear Resistance – ASTM D1004 – 80 lbs

6. Dimensional Stability – ASTM D1204 – 3%

7. Density – ASTM D1505

Miscellaneous

Adhesives: Provide types of adhesive primers, compounds, solvents, and tapes recommended in writing by impervious liner manufacturer for binding, for sealing of seams in liner, and for sealing penetrations through the impervious liner.

Fabrication

1. Fabricate impervious membrane liner panels from sheets in sizes as large as possible with factory-sealed seams, consistent with limitations of weight and installation procedures. Minimize field seaming.

2. Factory-fabricated seams shall be made with 2-inch overlap plus or minus ¼ inch by an automated thermal high-pressure process.

	CONCEPT STORMWATER MANAGEMENT PLAN REVIEW MEETING APPLICATION	

Project Name and Address:	Project Number (for City Use Only):
Applicant Information	
Name of applicant / agent:	
Street address of applicant / agent:	
City / State / Zip Code of applicant / agent:	
Telephone number of applicant / agent:	Fax number of applicant / agent:
Email address of applicant / agent:	Mobile phone number of applicant / agent:
Applicant's interest in subject property:	

PLEASE PROVIDE THE REQUESTED INFORMATION IN EACH OF THE SECTIONS BELOW WITHIN THE SPACE PROVIDED. IF ADDITIONAL SPACE IS REQUIRED, PLEASE ATTACH ADDITIONAL PAGES AS NECESSARY.
ITEM DESCRIPTION
Existing Site Characteristics and Location
Briefly describe the existing zoning and land uses on this property.
Identify the Chattanooga watershed(s) within which the site is located and attach a location map (USGS Quad Map).

CONCEPT STORMWATER MANAGEMENT PLAN REVIEW MEETING APPLICATION

ITEM DESCRIPTION	YES	NO
Proposed Site Characteristics		
Will the proposed project require any zoning changes? Please describe the size, type, and character of project in the space below.	☐	☐
Will the proposed project require any other city, state or federal permits? Please identify. .	☐	☐

Other Information / Comments
Please indicate the expected start of construction date and anticipated completion date. Please provide any other information or comments that may assist the City in evaluating the project in the space provided. Attach additional sheets as may be needed.

CONCEPT STORMWATER MANAGEMENT PLAN REVIEW MEETING APPLICATION

Applicant Acknowledgements	
I understand that approval of the attached Concept Stormwater Management Plan does not constitute fulfillment of all requirements necessary to begin construction. I further acknowledge that I am responsible for meeting all regulatory obligations and obtaining all necessary permits from all city, state, and federal agencies with jurisdiction over the project prior to beginning construction.	
I understand that the City of Chattanooga Land Development Office, in cooperation with the Water Quality Office, requires a licensed Landscape Architect to design and seal the planting plans for projects implementing low-impact development and green infrastructure such as rain gardens, bioretention, and constructed wetlands, etc.	
Applicant Signature	**Date**

Lead Design Professional Information	
Name/ Title of design professional / affiliated company:	
Street address:	
City / State / Zip Code:	
Telephone number:	Tennessee registration number:
Email address :	
Signature	**Date**

CITY USE ONLY IN THIS SECTION

Department/Office	Reviewer Initials	Attend Concept Review Meeting	
		YES	NO
Land Development Office (required)		☐	☐
Landscape Architect (required)		☐	☐
Water Quality Office		☐	☐
City Engineering Office		☐	☐
Chattanooga-Hamilton County Regional Planning Agency		☐	☐

CONCEPT STORMWATER MANAGEMENT PLAN CHECKLIST

Project: Name and Address ____

Owner: Name, Address, Phone No.____
____

Design Professional: Name, Address, Phone No.____
____

PROJECT TRACKING INFORMATION (FOR CITY USE ONLY)		
MARK THE APPROPRIATE BOX TO THE RIGHT OF THE QUESTION.		
GENERAL PROJECT INFORMATION		
Is the proposed project New Development or Redevelopment?	**NEW DEVELOPMENT** ☐	**REDEVELOPMENT** ☐

Can the proposed project be described as meeting any of the following development type definitions in accordance with the City's MS4 Permit? (check all that apply):	**YES**	**NO**
Is this a redevelopment project?	☐	☐
Is this a brownfield redevelopment project?	☐	☐
Is this a high-density (>7 units per acre) project?	☐	☐
Is this a vertical density (Floor to Area Ratio [FAR] of 2 of >18 units per acre) project?	☐	☐
Is this a mixed-use and transit-oriented development (within ½ mile of transit) project?	☐	☐

REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE CONCEPT PLAN SUBMISSION OR IF IT IS N/A.

ITEM DESCRIPTION	YES	N/A
Title Sheet and Title Block	☐	☐
a. Name, address, email, and telephone number of the owner/applicant.	☐	☐
b. Project site address. Address must include street address and state.	☐	☐
c. Property is currently zoned ______. Proposed zoning is ________ per Zoning Case __________.	☐	☐
	☐	☐
d. Approval blocks to be signed by the appropriate agencies.	☐	☐
e. Graphic scale and north arrow on all maps.	☐	☐
f. Total and disturbed area of the project site.	☐	☐
g. Vicinity map at 1"=500' scale maximum, showing the following:	☐	☐
1. Project site location (use Hamilton County GIS)	☐	☐
2. Receiving stream (ref: http://tnmap.tn.gov/wpc/) for TDEC Exceptional Waters	☐	☐
3. Location in HUC 12		

	CONCEPT STORMWATER MANAGEMENT PLAN CHECKLIST

ITEM DESCRIPTION	YES	N/A
Existing Site Conditions Assessment Plan – 1"=100' scale maximum, showing the following:	☐	☐
a. Property owners b. Easements c. Existing zoning of adjoining parcels (ref: Hamilton County GIS Zoning Layer) d. Contours, 2' intervals (http://www.chattanooga.gov/searchresults?q=gis+maps) e. Site Drainage 1. Water bodies (perennial and intermittent creeks, streams, springs, lakes, and ponds) 2. Riparian corridors 3. Mapped floodplains 4. Wetlands (including vegetation condition – wet meadow, shrub/scrub, and/or swamp) f. Vegetation and its Condition (annotate drawing) 1. Tree canopy lines 2. Individual trees (above 6" in caliper, identify specimens) g. Soil Types (http://websoilsurvey.nrcs.usda.gov) 1. List all soil types with descriptions 2. Indicate alluvial soils 3. Description table to include, at a minimum: i. Permeable soils based on hydrologic soil groups ii. Soil structure based on soil maps (% sand, silt, and clay) h. Geologic Features 1. Karst areas/sinkholes 2. Rock outcrops i. Manmade features including, but not limited to, buildings, parking areas, utilities, rights-of-way, cemeteries, and burial grounds j. Other (describe below)	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Proposed Site Layout Plan – 1"=100' scale maximum, showing the following items overlain on the project parcel map and site inventory map:	☐	☐
a. Layouts and width of the right-of-way and paving of proposed streets, alleys, and easements b. Layout of lots showing approximate dimensions, lot numbers, and approximate area of each lot c. Parcels of land intended to be dedicated or reserved for schools, parks, playgrounds, parking areas, common open space, or other public, semi-public or community purposes d. Any identified floodplain area or district, including limits of the 100-year flood defined by FEMA e. Proposed limits of clearing and grading f. All proposed new impervious areas g. Proposed locations and types of all stormwater management BMPs h. Proposed stormwater infrastructure conveyance facilities i. Constructed slopes j. Buffers	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

	CONCEPT STORMWATER MANAGEMENT PLAN CHECKLIST

ITEM DESCRIPTION	YES	N/A
Diagrammatic Landscape Concept Plan (required as part of site plan) – 1”=100’ scale maximum, showing the following items overlain on the proposed site layout plan:	☐	☐
a. Diagrammatic locations of proposed open space including:	☐	☐
1. Primary conservation areas – sensitive lands including water bodies and their buffers (creeks, streams, springs, lakes, and ponds), wetlands, 100-year floodplains, slopes exceeding 15%, soils prone to erosion and slumping	☐	☐
2. Secondary conservation area – mature woodlands, existing hedgerows, meadows, aquifer recharge areas, highly permeable soils, significant wildlife habitat areas, prime farmland, historic archaeological or cultural features, prominent hilltops or ridges, and scenic views	☐	☐
3. Potential public access – areas intended to be dedicated for common open space, schools, parks, playgrounds, or other public, semi-public or community purposes (Primary and secondary conservation areas are encouraged to be used for these purposes and to be connected to an internally linked open space system. This open space connects to other open spaces areas beyond the site boundaries.)	☐	☐
b. Diagrammatic pedestrian and vehicular circulation routes and parking areas, with zoning parking requirements	☐	☐
Design Professional Signature:______________________________________Date:____________________________	☐	☐
Owner Signature: _______________________________________Date:___________________________	☐	☐

	PRELIMINARY STORMWATER MANAGEMENT PLAN CHECKLIST

Project: Name and Address ____

Owner: Name, Address, Phone No.____

____

Design Professional: Name, Address, Phone No.____

____

PROJECT TRACKING INFORMATION (FOR CITY USE ONLY)		
REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE PRELIMINARY PLAN SUBMISSION OR IF IT IS N/A.		
ITEM DESCRIPTION	**YES**	**N/A**
Concept Plan and Checklist (appended)	☐	☐
Title Sheet	☐	☐
a. Applicant name and phone number.	☐	☐
b. Project site address. Address must include street address and latitude/longitude coordinates.	☐	☐
c. Graphic scale and north arrow on all maps.	☐	☐
d. Total and disturbed area of the project site.	☐	☐
e. Vicinity map at 1”=500’ scale maximum, showing the following:		
1. Project site location within surrounding areas	☐	☐
2. All Community Waters	☐	☐
3. Location in HUC 12	☐	☐
Title Block on all Plans	☐	☐
a. Name, address, email, and telephone number of the owner/applicant	☐	☐
b. Name, address, email, telephone number, and seal of the professional engineer certifying engineering aspects, professional land surveyor certifying accuracy of plan survey, and professional landscape architect certifying landscape and vegetation aspects	☐	☐
c. Approval blocks to be signed by the appropriate agencies	☐	☐
d. Certification of title showing the applicant is the owner of land, agent of the landowner or tenant with permission of the landowner	☐	☐
e. Copy of the deed	☐	☐
***Existing Conditions Assessment and Site Protection Plan** – 1”=100’ scale maximum*	☐	☐
Natural features and proposed setbacks and protected areas of no disturbance for:		
a. Watercourses and drainage ways	☐	☐
b. Marshes and wetlands	☐	☐
c. Rock outcrops or significant geologic features (i.e., sinkholes)	☐	☐
d. Wooded areas, trees, and vegetation	☐	☐
e. Soils and areas of soil protection	☐	☐
f. Contours at vertical intervals of 2 feet or less	☐	☐

	PRELIMINARY STORMWATER MANAGEMENT PLAN CHECKLIST

Manmade features, including:		
a. Buildings	☐	☐
b. Sanitary/storm sewers	☐	☐
c. Water mains	☐	☐
d. Culverts	☐	☐
e. Fire hydrants	☐	☐
f. Other significant manmade features on or adjacent to the tract or any approved recorded plans	☐	☐
g. Easements and rights-of-way for drainage facilities and utilities	☐	☐
h. Cemeteries and/or burial grounds	☐	☐
REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE PRELIMINARY PLAN SUBMISSION OR IF IT IS N/A.		
ITEM DESCRIPTION	**YES**	**N/A**
Site Layout Plan *– 1"=100' scale maximum*	☐	☐
a. Proposed lot dimensions	☐	☐
b. Proposed lot numbers and/or names	☐	☐
c. Widths of the proposed right-of-way	☐	☐
d. Pedestrian and vehicular circulation systems (use minimum widths, where possible)		
1. Proposed parking areas	☐	☐
2. Zoning parking requirements, layout including regular and ADA stalls, bays, and drive lanes	☐	☐
3. Proposed streets	☐	☐
4. Proposed alleys	☐	☐
e. Existing buildings to remain	☐	☐
f. Proposed building	☐	☐
g. Proposed permanent outdoor storage areas	☐	☐
h. Proposed lighting and signage (including pylon and monument signage at right-of-way)	☐	☐
i. Proposed easements and rights-of-way for drainage facilities and utilities and locations for utility boxes	☐	☐
j. Other proposed parcels; land intended to be dedicated or reserved for:		
1. Schools	☐	☐
2. Parks	☐	☐
3. Playgrounds	☐	☐
4. Parking areas	☐	☐
5. Common or open space	☐	☐
6. Other public or community purposes	☐	☐
k. Where the subdivision and/or land development lies partially or completely within any identified floodplain area or district, or where such activities border any identified floodplain area or district, the preliminary plan shall include the following information:	☐	☐
a. Location and elevation of benchmark, proposed roads, utilities, building sites, fills, flood or erosion protection facilities	☐	☐
b. The 100-year flood elevations and floodway limits	☐	☐
c. Areas subject to special deed restrictions	☐	☐
d. All required landscaped areas including edges of existing woodlands, perennial stream buffers, street yard extents, utility easements, and screening buffer extents with dimensions called out	☐	☐
e. Location and elevation of benchmark, proposed roads, utilities, building sites, fills, flood or erosion protection facilities	☐	☐
f. Areas subject to special deed restrictions	☐	☐

g. All required landscaped areas including edges of existing woodlands, perennial stream buffers, street yard extents, utility easements, and screening buffer extents with dimensions called out	☐	☐
h. Limits of clearing, grading, and construction with estimate of existing vegetation and trees to be removed	☐	☐
i. Details and specifications	☐	☐

REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE PRELIMINARY PLAN SUBMISSION OR IF IT IS N/A.

ITEM DESCRIPTION	YES	N/A
Utility Plan *– 1”=100’ scale maximum*	☐	☐
Profiles of the following:		
a. Each street, including centerline grades	☐	☐
b. Proposed sanitary and storm sewers and water lines, with invert elevations and connections to existing systems	☐	☐
Locations of existing and proposed:		
a. Utility mains Areas where stormwater is proposed to connect to combined sewers must be clearly identified	☐	☐
b. Street lighting facilities	☐	☐
Proposed Open Space System (both hardscape and softscape):		
a. Proposed protected areas	☐	☐
b. Proposed stormwater system, showing conveyance and potential BMP areas	☐	☐
c. Proposed planting areas, including lawn areas, planting beds, areas to be restored, etc.	☐	☐
d. Proposed hardscape areas, including patios, terraces, plazas, etc.	☐	☐
Existing and Proposed Stormwater Plan *– 1”=100’ scale maximum* *(See Chapter 7 for standards and calculations)*	☐	☐
Land use and drainage information, including:		
a. Limits of land disturbance (including area summary)	☐	☐
b. Existing and proposed impervious cover (including area summary)	☐	☐
c. Existing and proposed drainage facilities (including size and invert elevations for all conveyance, collection, and treatment facilities and BMPs)	☐	☐
d. Locations of infiltration tests, soils borings, and fill areas	☐	☐
Drainage areas, including:		
a. Existing conditions drainage areas	☐	☐
b. Proposed post-construction drainage areas	☐	☐
c. Time of concentration lines	☐	☐
d. Drainage areas to existing and proposed drainage facilities (including all conveyance, collection, and treatment facilities and each proposed BMP)	☐	☐

	PRELIMINARY STORMWATER MANAGEMENT PLAN CHECKLIST	

REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE PRELIMNARY PLAN SUBMISSION OR IF IT IS N/A.

ITEM DESCRIPTION	YES	N/A
Other Stormwater Information		
Stormwater management information, including:		
a. The mapping of the watershed area or areas in which the proposed subdivision or land development is located.	☐	☐
b. Existing and proposed contours as per the requirements for preliminary or final plans.	☐	☐
c. Existing water bodies within the project area including streams, lakes, ponds, field-delineated wetlands, or other bodies of water.	☐	☐
d. Other physical features including flood hazard boundaries, sinkholes, streams, existing drainage courses, areas of natural vegetation to be preserved, and the total extent of the upstream area draining through the site.	☐	☐
e. The locations of all existing and proposed utilities, sanitary sewers, and water lines within 50 feet of property lines.	☐	☐
f. Soil names and boundaries. Additionally, the Hydrologic Soil Group of the soils should be identified.	☐	☐
g. Proposed changes to the land surface and vegetative cover including the type and amount of impervious area to be added.	☐	☐
h. Proposed structures, roads, paved areas, and buildings.	☐	☐
i. Horizontal alignment and vertical profiles of all open channels, including velocities and any required matting.	☐	☐
j. Overland drainage paths.	☐	☐
k. Appropriate access easements around all stormwater management and conveyance facilities, located outside the City right-of-way, that would provide ingress to and egress from a public right-of-way.	☐	☐
l. Design details for stormwater infiltration, water quality, and detention/retention facilities including operation and maintenance plan with clear identification of the nature of permanent stormwater BMPs.	☐	☐
m. The complete drainage system for the subdivision or land development including the identification of drainage features that will be incorporated into the design.	☐	☐
n. An overall stormwater management plan for the entire site. If the subdivision or land development is to be developed in phases, the plan shall be submitted with the first phase and appropriate future development phases for the drainage system shall be indicated.	☐	☐

	PRELIMINARY STORMWATER MANAGEMENT PLAN CHECKLIST		

REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE PRELIMINARY PLAN SUBMISSION OR IF IT IS N/A.

ITEM DESCRIPTION	YES	N/A
Preliminary Grading. Planting and Soils Plan - *scale no less than 1”=50’*	☐	☐
Preliminary Development Plan (as base with items from Schematic Landscape Plan) including:		
a. Proposed hardscape, including sidewalks, plaza, building footprints, structural BMPs, etc.	☐	☐
b. Limit of grading line/limit of disturbance line and features to be preserved (for example, boundaries of perennial stream buffers)	☐	☐
c. Existing and proposed grading for hardscape and softscape (Show existing contours in dashed line – screened back, annotated with elevation on the uphill side of existing grades. Show proposed 1-foot contours as solid lines, annotated with elevation on the uphill side of contour or with break in contour line.)	☐	☐
d. Existing trees to remain and their root protection zones	☐	☐
e. Swale centerlines with flow direction indicated	☐	☐
f. Important spot elevations	☐	☐
g. Areas of amended soils including engineered planting mixes for lawns, seeded areas, BMPs, and planting beds, etc.	☐	☐
h. Details as required	☐	☐
i. The location and clear identification of the nature of permanent stormwater BMPs	☐	☐
j. Property lines, rights-of-way, alleys, required setbacks, street yard requirements, buffer requirements, screening requirements, and easements	☐	☐
k. The 100-year flood elevations and floodway limits	☐	☐
l. Zoning of subject property and of adjacent properties	☐	☐
m. Limits of clearing and grading	☐	☐
n. Sight triangles for intersections	☐	☐
o. Proposed protected areas	☐	☐
p. Proposed areas to be restored	☐	☐
q. Vegetation used as a permanent stormwater BMP or associated with bioretention areas	☐	☐
r. Location , species, and spacing of proposed planting, keyed to the plant schedule	☐	☐
1. Proposed seeded area and seed mix name, keyed to plant schedule	☐	☐
2. Proposed location, species, and spacing of required street yard, buffer, and parking lot plantings , keyed to the plant schedule	☐	☐
3. Plant schedule containing quantity, scientific name, common name, installation size, spacing, condition (container, B&B, etc.), and any applicable notes including ideal plant installation time and any planting hazards. Seed mixes should be included in schedule and provide scientific name, common name, and pure live seed amount by percentage of total weight required. (This does not include seeding for E&S measures unless it is permanent.)	☐	☐

	PRELIMINARY STORMWATER MANAGEMENT PLAN CHECKLIST	
REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE CONCEPT PLAN SUBMISSION OR IF IT IS N/A.		
ITEM DESCRIPTION	**YES**	**N/A**
***Preliminary plan package will be accompanied by the following data and supporting documentation/narrative**:*		
Stormwater plan narrative including the following items:		
a. General statement of the scope of the project	☐	☐
b. General description of permanent stormwater management techniques, including:		
1. Construction specifications of the materials to be used for stormwater management facilities	☐	☐
2. How the permanent stormwater management techniques will meet the required SOV	☐	☐
3. How each permanent stormwater BMP will address water quality	☐	☐
4. How each permanent stormwater BMP will be operated and maintained	☐	☐
5. The identity of the person(s) responsible for operations and maintenance	☐	☐
c. Discussion of ownership and maintenance of all drainage and stormwater management facilities	☐	☐
Any other reports deemed necessary and identified by the City during the Concept Stormwater Management Plan approval.	☐	☐
Design Professional Signature:______________________________________Date:___________________________	☐	☐
Owner Signature: _______________________________________Date:__________________________	☐	☐

FINAL STORMWATER MANAGEMENT PLAN CHECKLIST

Project: Name and Address ____

Owner: Name, Address, Phone No.____
____

Design Professional: Name, Address, Phone No.____
____

PROJECT TRACKING INFORMATION (FOR CITY USE ONLY)

REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE PRELIMINARY PLAN SUBMISSION AND ANY CHANGE IS NOTED AND APPROVED.

ITEM DESCRIPTION	YES	NO
Preliminary Plan and Checklist (appended)	☐	☐
Title Sheet Approved and Complete	☐	☐
Reviewer Comments		
Title Block on all Plans Approved and Complete	☐	☐
Reviewer Comments		
Existing Conditions Assessment and Site Protection Plan Approved and Complete	☐	☐
Reviewer Comments		

	FINAL STORMWATER MANAGEMENT PLAN CHECKLIST		
Project Name and Address:			
REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE PRELIMINARY PLAN SUBMISSION AND ANY CHANGE IS NOTED AND APPROVED.			
ITEM DESCRIPTION		**YES**	**NO**
Site Layout Plan Approved and Complete		☐	☐
Reviewer Comments			
Utility Plan Approved and Complete		☐	☐
Reviewer Comments			
Stormwater Plan Approved and Complete		☐	☐
Reviewer Comments			

FINAL STORMWATER MANAGEMENT PLAN CHECKLIST

Project Name and Address:

REVIEWER TO MARK THE APPROPRIATE BOX TO THE RIGHT OF EACH ITEM DESCRIPTION INDICATING WHETHER IT HAS BEEN INCLUDED WITH THE PRELIMINARY PLAN SUBMISSION AND ANY CHANGE IS NOTED AND APPROVED.

ITEM DESCRIPTION	YES	NO
Final Grading, Planting, and Soils Plan Approved and Complete	☐	☐
Reviewer Comments		
Erosion and Sediment Control Plan Approved and Complete	☐	☐
Reviewer Comments		
Inspection and Maintenance Agreement - signed, executed copy	☐	☐
Reviewer Comments		

Reviewer Signature: ____Date: ____________________________

Design Professional Signature:____Date:_____________________________

Owner Signature: ____Date:____________________________

Construction Oversight Certification for Stormwater Management BMPs

FORM

Project Name and Address:	Project Number(for City Use Only):

Construction Oversight for Subsurface Stormwater Management BMPs

The City of Chattanooga requires the licensed professional responsible for the design of stormwater management BMPs to oversee the construction of subsurface stormwater management BMPs. Construction oversight includes observation of bed conditions following excavation and grading and prior to the placement of material to confirm that all construction requirements have been met.

This form must be completed and submitted to the City prior to building occupancy.

Professional Certification

I, ____________________________________, hereby certify to the best of my knowledge, information, and belief, that I observed the soil bed conditions following excavation and grading and prior to the placement of BMP media material. I further certify that all construction requirements outlined in the design drawings and specifications have been met for the BMPs listed below.

BMP	***Date of Observation***

	Professional Seal
Signature	
Printed Name	
License #	**Date**

Post-Construction Inspection and Certification for Stormwater Management BMPs

FORM

Project Name and Address:	Project Number(for City Use Only):

The City of Chattanooga will conduct a Final Inspection of the Stormwater Management Practices associated with all projects required to comply with the City's stormwater management regulations. The Final Inspection will include inspection of all surface BMPs to ensure consistency with the City approved plans and details.

Additionally, as-built drawings and construction certification, as outlined below, must be provided to the City prior to permit closeout/issuance of a building occupancy permit.

Construction Certification and As-Built Drawing Submission Requirements for Stormwater Management BMPs

General Requirements

1. The certified professional shall mark up the plan drawings as necessary to indicate all project conditions, location configurations, and any other changes or deviations that vary from the original City approved drawings. The as-built information added to the drawings may be supplemented by detailed sketches, if necessary, clearly indicating the work as constructed.
2. These as-built drawings are actual representations of as-built conditions, including all revisions made necessary by change orders, design modifications, requests for information, and field orders.
3. As-built drawings shall be made available and accessible to City inspectors at all times during the construction period.

Drawing Requirements

1. All as-built information added to the plan drawings shall be shown in RED.
2. Each sheet shall be labeled "AS-BUILT DRAWING" in large printed letters.

Plan Requirements

All red-lined as-built plans must include the following information:

1. Clear location of all stormwater management BMPs in plan view.
2. Labeled distances from structures and other utilities from stormwater management BMPs.
3. Labeled delineated drainage areas to each stormwater management BMP.
4. Signature and seal of registered Professional Engineer responsible for preparation of as-built drawings.

Supporting Documentation

1. All available construction photo documentation and material receipts obtained relevant to stormwater management BMP installation for City verification purposes.
2. A completed, signed, and sealed copy of the Professional Certification statement below.

	# Post-Construction Inspection and Certification for Stormwater Management BMPs	FORM

Project Name and Address:	Project Number(for City Use Only):

Professional Certification

I, ____________________________________, hereby certify to the best of my knowledge, information, and belief, that the accompanying as-built drawings, as defined below, accurately reflect the as-built conditions, are true and correct, and are in conformance with the City of Chattanooga's stormwater management regulations and that the project site was constructed in accordance with the approved construction plans and accepted construction practices.

Item	***Description***	***Dated***

	Professional Seal
Signature	
Printed Name	
License #	**Date**

Appendix K

Introduction

This appendix includes two examples of a typical site design to help guide a manual user through the design process. The examples were created to utilize the manual as a reference for more detailed guidance and information by indicating manual locations where additional information can be found. The **BMP Excel Workbook** referenced within these examples was developed as a guide to help make concept and preliminary design easier on the applicant by automating repetitive calculations of a typical submission within a calculation tool. There may be design instances that do not fit within the typical submission and will need supporting calculations documented outside of the **BMP Excel Workbook**.

K.1. Detailed Calculations Example and LID Calculation Tool (BMP Excel Workbook) – New Office Campus Project

Example 1: New Office Campus Designed for Volume Management (SOV Requirements)
Location: South Chickamauga Watershed
Combined sewer area: No
Parcel size: 8 acres

An owner is proposing to construct a new office complex that includes two new buildings on an 8.0-acre parcel in the South Chickamauga Creek watershed. Development will include construction of two new buildings, parking, and walkway areas on the southern portion of the site.

Step 1 Determine Stormwater Applicability

The site will result in more than 1 acre of land disturbance. As indicated in **Chapter 3, Section 3.3.1, Table 3-1**, the following permits and documentation are required:

- Land Disturbance Permit
- Stormwater Pollution Prevention Plan (SWPPP)
- Performance Method: detailed stormwater calculations must be submitted to the City to demonstrate compliance with requirements for volume management, water quality, safe conveyance of flows, and peak rate mitigation
- Tennessee NPDES Stormwater Construction Permit

The proposed project will be located on a previously undeveloped parcel in the South Chickamauga Creek watershed. Watershed maps to determine a project's location can be found on the City's website (***http://www.chattanooga.gov***) under Public Works, City Engineering and Water Quality Program, Public

Education. According to **Chapter 3, Section 3.3.3, Table 3-2**, the rainfall depth that must be managed for new development projects in the South Chickamauga Creek watershed is 1.6 inches, with no discharge to surface waters.

As indicated on the flow chart of **Chapter 3, Section 3.4, Figure 3-1**, if the project design can meet the 1.6-inch SOV requirement for volume management, the water quality requirements will also be assumed to be satisfied. The project design must also meet peak runoff rate control requirements. As described in **Chapter 3, Section 3.4, Item 3**, post-development peak runoff rates must be no greater than pre-development peak runoff rates for the 2-, 5-, 10-, and 25-year, 24-hour storm events. Additionally, the peak runoff rate and maximum water surface elevation must be indicated for peak rate mitigation devices or facilities.

This project does not meet the requirements for any of the incentives listed in **Chapter 3, Section 3.7**. Therefore, the full volume of runoff from the 1.6-inch rainfall must be managed.

CONCEPT PLAN DEVELOPMENT, SUBMISSION, AND REVIEW (Steps 2 through 5)

Step 2 Evaluate the Site

All projects subject to the City of Chattanooga's stormwater management requirements must prepare and submit a concept plan for City review and approval prior to preliminary and final plan submissions. The process for developing a concept plan is indicated in **Chapter 4, Figure 4-1**. The Concept Stormwater Management Plan Review Meeting Application can be found in **Appendix G (Concept Stormwater Management Plan Review Meeting Application)**. The applicant can use the Concept Stormwater Management Plan Checklist found in **Appendix H (Concept, Preliminary, and Final Stormwater Management Plan Checklist)** to assist in the development of the concept plan.

The site is gently sloping (5% to 8%) to the north and is currently in a meadow condition. There are no water bodies, riparian corridors, mapped floodplains, or wetlands. There is no existing tree canopy and there are no existing trees over 6 inches in caliper. There are no existing manmade structures. Review of the soil types (***http://websoilsurvey.nrcs.usda.gov***) indicates that the underlying soils are hydrologic group C, primarily Lobelville cherty silt loam (Lo), and there is no indication of shallow groundwater in the area of proposed development. For concept plan purposes, it is assumed that infiltration BMPs may be employed.

Step 3 Develop Site Layout Plan and Incorporate Protective BMPs

This project will include two new one-story office buildings with a total of 33,250 square feet of office space, and will provide 133 parking spaces. All land development requirements (i.e., setbacks, building heights, etc.) must be met in accordance with the City of Chattanooga Chapter 38 – Chattanooga Zoning Ordinance.

Figure K-1. Concept Project Site Layout Sketch

By orienting the buildings, entrance driveway, and parking lots along the contours of the site, the amount of site disturbance can be reduced. There is opportunity to protect existing soils (**Chapter 5, BMP 5.2.1**) and preserve landforms (**Chapter 5, BMP 5.2.1.1.**). Areas that will be protected and undisturbed during construction, as described in **Chapter 5.2, Damage Prevention and Protection Practices**, may be excluded from stormwater management requirements <u>for volume control</u> as described in **Chapter 7, Section 7.2**. Stormwater from all impervious surfaces and all disturbed portions of the site must be managed for SOV. The **BMP Excel Workbook, Worksheet 1** can be used to estimate the project area protected in accordance with **Chapter 5.2, Damage Prevention and Protection Practices,** and therefore exempt from SOV requirements. This is shown on Figure K-2. Peak rate conveyance requirements must include all drainage areas, including areas addressed by Damage Prevention and Protection Practices, and offsite areas that drain onto a site.

To establish the area of land disturbing activity from which SOV may be calculated, the following steps were taken:

a. Determine the size of the parcel on which the project is to be constructed.
b. Determine the area, if any, of the overall project parcel that will remain undeveloped and where protective BMPs will be applied.

As depicted on Figure K-1, construction will occur within a 3.90-acre project area on the southern portion of the property only. The construction area will be clearly marked with construction fence to ensure that the 4.10 acres to remain undeveloped in the northern portion of the property are not impacted by activities during construction. Soils will be protected in accordance with **Chapter 5, BMP 5.2.1**. A total of 4.10 acres may be omitted from the project area for SOV calculation. This information can be documented using the **BMP Excel Workbook, Worksheet 1** as seen on Figure K-2 and following the formula:

Disturbed Area Requiring Stormwater Management = Total Parcel Area – Total Protected Area
= 8.00 – 4.10
= 3.90 acres

SOV DESIGN RAINFALL =	1.6	in.

TARGET LOADING RATIO =	8	(See Ch. 5 for details)

Concept Design

Total Parcel Area =	348,480	ft.^{2}	or	8.00 ac
Total Proposed Impervious Area =	99,844	ft.^{2}	or	2.29 ac
Protected Areas				0.00 ac
5.2.1 Area of Protected Undisturbed and Healthy Soils	178,596	ft.^{2}	or	4.10 ac
5.2.1.1 Area of Minimized Land Disturbance	0	ft.^{2}	or	0.00 ac
5.2.1.2 Area of Protected Soils/Steep Slopes	0	ft.^{2}	or	0.00 ac
5.2.2 Area of Protected Natural Flow Paths	0	ft.^{2}	or	0.00 ac
5.2.3 Area of Protected/Enhanced Riparian Corridors	0	ft.^{2}	or	0.00 ac
5.2.4 Area of Protected/Preserved Vegetation	0	ft.^{2}	or	0.00 ac
Total Protected Area	178,596	ft.^{2}	or	4.10 ac
Total Disturbed Area	169,884	ft.^{2}	or	3.90 ac
				0.00 ac
Total Impervious Area	99,844	ft.^{2}	or	2.29 ac
Total Pervious Area	70040	ft.^{2}	or	1.61 ac
Concept Level BMP Area	12,481	ft.^{2}	or	0.29 ac
(Based on Proposed Impervious Area)				

Disturbed Area Requiring Stormwater Management =	169,884	ft^2	**(A)**
=	3.90	ac	

Figure K-2. Determination of Stormwater Management Area after Implementing Damage Prevention and Protection Practices, BMP Excel Workbook, Worksheet 1

Step 4 Develop Concept Stormwater Management Plan

Project site and development program; determine target area for BMP sizing.

The design professional has a number of options for stormwater management. For this example, the existing information on site conditions indicates that infiltration BMPs may be feasible. The design professional may elect to take all of the runoff to one large BMP, such as a large infiltration bed beneath a pervious parking lot. For concept plan purposes, the design professional is required to demonstrate that enough project area will be available to incorporate the required amount of BMPs, and to indicate the types and sizes of BMPs being considered. BMPs can be adjusted and modified in the detailed design phase when additional project information is available.

The minimum BMP area is a function of:

- The amount of impervious area draining to the BMP. This is referred to as the Loading Ratio.
- The rainfall depth to be managed.

The recommended Loading Ratios as a function of rainfall depth are indicated in **Chapter 5, Section 5.3** in the individual Structural Design Measure sections**.** For a rainfall depth of 1.6 inches, the recommended loading ratio is:

- 8:1 impervious area to BMP area

From Figure K-2, the total impervious area is 2.29 acres, or 99,844 square feet. At an 8:1 Loading Ratio, the minimum BMP area is: 99,844 square feet / 8 = 12,481 square feet Minimum BMP Area.

Therefore, the concept plan must indicate that at least 12,481 square feet of BMP area is available to meet the SOV, and that drainage can be directed to the BMP(s). The location of each BMP, as well as the approximate area of each BMP, must be indicated on the concept plan.

However, the guiding principle of Low-Impact Development is to manage runoff as close as possible to the existing source, and to use soils and vegetation to reduce the volume of runoff. The design professional may elect to add a number of different BMP types, and in different locations, to reduce construction costs or achieve other goals. Efficient LID design professionals will incorporate measures such as landscape restoration and "self-managing" BMPs such as porous pavers to reduce the size and cost of larger BMPs whenever possible. For example, the design professional may decide to limit the depth of stone storage/infiltration beds beneath the parking areas, and instead manage some portion of the runoff in a bioretention area **(Chapter 5, BMP 5.3.4)** to take advantage of cost-effectively using this landscape area for stormwater management. Similarly, construction costs could be reduced by using pervious pavers for the patio and sidewalk that are "self-managing" **(Chapter 5, BMP 5.3.1),** or by "disconnecting" these areas in accordance with **Chapter 5, BMP 5.3.10** so that they are not considered impervious.

For the purposes of this example, a number of additional BMPs are implemented in the detailed design. While a smaller number of BMPs, with greater capacity to receive more runoff, could have been used, more BMPs are shown here for information purposes. These include sidewalks and a patio constructed of pervious pavement (**Chapter 5, BMP 5.3.1**) that will only receive direct rainfall. Two bioretention areas (**Chapter 5, BMP 5.3.4**) will also be included in the stormwater management plan.

Step 5 Concept Plan Submission and Review

Concept Stormwater Management Plan Submission

In accordance with **Chapter 4, Section 4.2.1**, the owner will provide the City with one electronic copy of concept stormwater management plan drawings, as well as one electronic copy of all applicable supporting data and plans for review and comment, and a Stormwater Management Plan Review Meeting Application, found in **Appendix G (Concept Stormwater Management Plan Review Meeting Application)**. Concept stormwater management plans will be prepared using the Concept Stormwater Management Plan Checklist in **Appendix H (Concept, Preliminary, and Final Stormwater Management Plan Checklist)**, ensuring all items listed are shown.

Concept Review Meeting

A concept review meeting with City personnel, attended by the owner and the owner's design professional, is required to discuss the concept stormwater management plan, overall project design, and any other concerns to work toward resolution of potential conflicts. Approval of the concept stormwater management plan is a required prerequisite for preliminary and final approval prior to permitting. **Chapter 4, Section 4.2.1.4** discusses the concept review meeting in further detail.

If the design professional can indicate that consideration has been provided as to the proposed location of SOV-managing BMPs, and that sufficient area will be provided to manage the SOV at the recommended impervious area loading ratio for the depth of SOV rainfall, the concept plan can be considered adequate. The final BMP locations, sizes, and types can be determined in the detailed design for preliminary and final stormwater management plan approval.

PRELIMINARY PLAN DEVELOPMENT, SUBMISSION, AND REVIEW (Steps 6 and 7)

Step 6 Detailed Site Investigation and Testing

Upon receiving approval of the concept stormwater management plan from the City, detailed design of stormwater management measures may proceed. The first step in preliminary stormwater management plan development is to locate the proposed BMPs in accordance with **Appendix A (Protocol 1 Infiltration BMP Setbacks from Structures)** and **Appendix B (Protocol 2 BMP Coordination with Other Utilities)**, and to conduct site testing in accordance with **Appendix C (Protocol 3 Soil Testing)**. For this example, test pits were excavated in the area of each proposed infiltration BMP and infiltration testing was performed at the proposed bottom elevation of each infiltration BMP. Soil testing produced an infiltration rate of 0.4 inches per hour at all locations, confirming the assumptions made during concept stormwater management plan development. In the event that infiltration was not suitable at the proposed locations, but was feasible in other portions of the site, the design professional could adjust the site plan and BMP locations accordingly.

Step 7 Calculation of SOV To Be Managed by Each BMP

In keeping with LID principles, the project BMPs will manage runoff close to where it is generated. Each BMP must be sized to capture the required SOV from the area draining to it. If a BMP can only capture a portion of the required SOV from the area draining to it, a second, downstream BMP must provide the remaining SOV capture. A system of interconnected stormwater management BMPs, or “treatment train,” constructed in series must be designed to meet volume reduction, rate reduction, and water quality requirements for all tributary sub-drainage areas. Proper design includes sizing calculations and analysis demonstrating the capture area, SOV for each individual BMP, and capacity of each BMP, as well as the capture area, SOV and capacity of the entire treatment train, and conveyance calculations between BMPs. **Chapter 7, Section 7.4** discusses treatment trains in more detail.

Delineate sub-drainage areas to each BMP and calculate SOV to be managed by each BMP.

For this example, six structural BMPs are being considered and therefore six sub-drainage areas of disturbed area have been delineated, as shown on Figure K-3**.** These sub-areas and land uses are as follows:

Figure K-3. Delineated Sub-areas

- Sub-area 1 includes lawn and an impervious parking lot. For this example, an unlined bioretention area **(Chapter 5, BMP 5.3.4)** within the landscape plantings is being proposed. Other alternatives, such as directing this runoff to a bed beneath one of the porous parking lots, could also meet requirements. The design professional may select the appropriate BMPs for the site.
- Sub-area 2 includes lawn, two sections of 24-foot-wide driveway, a flat-roofed building, and a pervious parking lot. For this sub-area, an unlined infiltration bed **(Chapter 5, BMP 5.3.2)** beneath the pervious parking lot is proposed.
- Sub-area 3 includes a pervious asphalt sidewalk **(Chapter 5, BMP 5.3.1)**. This pervious pavement will be "self-managing." That is, the pervious pavement will absorb the rainfall that falls directly onto it without generating runoff for the small rainfall events (up to 1.6 inches based on manual design guidance for pervious sidewalks in **Chapter 5, BMP 5.3.1**) that must be managed for SOV or water quality.
- Sub-area 4 includes lawn, a 24-foot-wide driveway, a flat-roofed building, and a pervious parking lot. For this sub-area, an infiltration bed **(Chapter 5, BMP 5.3.2)** beneath the pervious parking lot is also proposed.
- Sub-area 5 includes a building's pitched roof and lawn, which will be managed by a bioretention area **(Chapter 5, BMP 5.3.4)**.
- Sub-area 6 includes a building's outdoor patio. This will be constructed of pervious pavers **(Chapter 5, BMP 5.3.1)**, and like Sub-area 3, will be "self-managing."
- For each sub-area to a BMP, the land use types, surface areas, and associated SOV can be estimated using the **BMP Excel Workbook, Worksheet 1**, as shown on Figure K-4.

Preliminary Design

INITIAL TARGET BMP AREA =	12,481 ft^2

Sub-Drainage ID per BMP (numbers and lowercase letters only)	Land Use Type	Surface Condition	Disturbed Land Area (ft^2)	Disturbed Land Area (ac)	Rv Value, from Table	Stay on Volume (ft^3)
1a	Typical Urban Soils	Pervious	17,710	0.41	0.15	354
1b	Large Impervious	Impervious	10,000	0.23	0.99	1,320
2a	Small Impervious	Impervious	10,204	0.23	0.79	1,075
2b	Typical Urban Soils	Pervious	15,800	0.36	0.15	316
2c	Flat Roof	Impervious	11,000	0.25	0.88	1,291
2d	Large Impervious	Impervious	10,000	0.23	0.99	1,320
2e	Small Impervious	Impervious	15,190	0.35	0.79	1,600
3	Small Impervious	Impervious	4,000	0.09	0.79	421
4a	Flat Roof	Impervious	20,000	0.46	0.88	2,347
4b	Large Impervious	Impervious	10,000	0.23	0.99	1,320
4c	Typical Urban Soils	Pervious	9,080	0.21	0.15	182
4d	Small Impervious	Impervious	5,200	0.12	0.79	548
5a	Typical Urban Soils	Pervious	27,450	0.63	0.15	549
5b	Pitched Roof	Impervious	2,250	0.05	0.99	297
6	Small Impervious	Impervious	2,000	0.05	0.79	211

Figure K-4. Calculation of SOV by Sub-drainage Area with SSHM Runoff Coefficients, BMP Excel Workbook, Worksheet 1

The required SOV is calculated using the Small Storm Hydrology Method, as described in **Chapter 7, Section 7.3**. Rv values utilized by the Small Storm Hydrology Method are automatically populated within the table based on the user-defined rainfall depth and land use types. These values can be found in the **BMP Excel Workbook, Worksheet 1** or in **Chapter 7, Section 7.3, Table 7-1**, of the manual. The total SOV by sub-area for this example is summarized on Figure K-5 for informational purposes. If using the **BMP Excel Workbook**, it will tabulate the SOV for each sub-area automatically as the design professional adjusts drainage areas and BMP sizes. This information can be found in the **BMP Excel Workbook, Summary Table.**

Sub-Drainage ID	Total Disturbed Area (ft^2)	Total Disturbed Impervious Area (ft^2)	Sub-Drainage Area SOV (ft^3)
1	27,710	10,000	1,674
2	62,194	46,394	5,602
3	4,000	4,000	421
4	44,280	35,200	4,396
5	29,700	2,250	846
6	2,000	2,000	211

Figure K-5. Summary of SOV by Sub-drainage Area, BMP Excel Workbook, Summary Table

<u>Reduce SOV by implementing restorative BMPs.</u>

The design professional may choose to reduce the size of structural BMPs by using landscape restorative measures that reduce runoff volume and provide SOV credit. These include **Chapter 5, BMPs 5.4.1 through 5.4.3**. For each of these restorative BMPs as defined in the **Non-Structural BMP Credits Worksheet, Chapter 7, Section 7.7**, the restorative BMP can be translated into an SOV volume "credit."

The first step is to consider areas within each sub-area where restorative practices may be implemented. For this example, in accordance with the tree planting credits in **Chapter 7, Section 7.2**, this project will include planting 10 evergreen and 15 deciduous trees to reduce the SOV in sub-areas 1 and 2, respectively. The project also proposes to include a 2,000-square-foot area of meadow in sub-area 5 (in lieu of lawn) as part of a required landscape plan. In accordance with **Chapter 5, BMP 5.4.2.1**, this cover type change can also reduce the SOV to be managed by structural BMPs. Additionally, the project will include 5,000 square feet in sub-area 4 where soils disturbed during construction will be restored and amended in accordance with **Chapter 5, BMP 5.4.3**. The SOV volume "credit" of these restorative BMPs can be calculated in accordance with **Non-Structural BMP Credits Worksheet, Chapter 7, Section 7.7**. These credits, and the adjusted SOV as a result of these credits, can also be estimated using the **BMP Excel Workbook, Worksheet 2**, as indicated on Figure K-6. This worksheet provides the adjusted SOV volume by sub-area. As described **in Chapter 7, Section 7.7,** the use of restorative BMPs can only reduce the SOV by a maximum of 25% for each sub-area. **BMP Excel Workbook, Worksheet 2** will not allow the design professional to decrease SOV by more than 25% within each sub-area. Note that the restorative credits are applied to the appropriate BMP sub-areas. In this example, the total SOV volume credit of 336 cubic feet has been achieved through tree planting, meadow planting, and soil restoration done in accordance with the requirements of **Chapter 5, BMPs 5.4.1 through 5.4.3.**

Restorative Volume Credit Worksheet							
Sub-Drainage ID	Sub-Drainage SOV (ft^3)	Restorative Practice Credit Type	Area (ft^2)	# of Trees	Volume Credit (ft^3)	Total Volume Credit (limit to maximum of 25% of SOV) (ft^3)	Net Drainage Area SOV (ft^3)
1	1,674	Tree Planting - Evergreen		10	100	100	1,574
		None			0		
		None			0		
2	5,602	Tree Planting - Deciduous		15	90	90	5,512
		None			0		
		None			0		
3	421	None			0	0	421
		None			0		
		None			0		
4	4,396	Amend and Restore Disturbed Soils	5,000		104	104	4,292
		None			0		
		None			0		
5	846	Change Cover Type to Meadow	2,000		42	42	804
		None			0		
		None			0		
6	211	None			0	0	211
		None			0		
		None			0		

Figure K-6. Restorative Credits for Tree Plantings and Cover Type Changes, BMP Excel Workbook, Worksheet 2

Determine the BMP area and storage capacity necessary for each sub-drainage area.

The SOV remaining after restorative credits are applied will be managed by six infiltrating structural BMPs, one in each sub-drainage area. Using the recommended loading ratio for a 1.6-inch rainfall depth, BMPs were located on the site plan. Locations of proposed BMPs with regard to setbacks from structures were considered in accordance with **Appendix A (Protocol 1 Infiltration BMP Setbacks from Structures)**, to avoid potential damage due to water migration. Also, coordination with other utilities, in accordance with **Appendix B (Protocol 2 BMP Coordination with Other Utilities)**, determined that the locations of the proposed BMPs would not conflict with existing or proposed utilities.

A summary of the BMP areas, calculated capture volumes, and impervious to BMP area loading ratios is shown on Figure K-7. The BMPs may be dimensioned using the **BMP Excel Workbook, Worksheet 3**.

The process of sizing and selection of BMPs needs to incorporate site and design knowledge that may not be found in this manual. Site conditions and design requirements need to be considered to determine which BMPs are the most appropriate given specific site conditions and what BMP dimensions will best fit within a site. Dimensioning a BMP can become an iterative process, so utilizing the **BMP Excel Workbook, Worksheet 3** may be helpful.

The **BMP Excel Workbook** provides a designer with the necessary SOV that is required to be captured per sub-drainage area in **BMP Excel Workbook, Worksheet 3** under the column titled, "Net Drainage Area

SOV." This column is the net value of SOV after SOV volume credit has been subtracted for all restorative practices tabulated in **BMP Excel Workbook,Worksheet 2**. In general, a designer will need to know at this point in the design process which areas are available onsite within each sub-drainage area for each BMP and also what volume is needed to be captured in each BMP (**BMP Excel Workbook, Worksheet 3**). Most often this will be indicated by a parking area that may be able to contain an infiltration bed or a landscaped area that could be used for bioretention. These available areas will be the starting point for sizing the necessary BMPs per sub-drainage area.

BMP Excel Workbook, Worksheet 3 can then be used to iteratively adjust which BMPs will be applied to each sub-drainage area and their dimensions. For example, if sub-drainage area 2 has a large parking lot required by City code where an infiltration bed is feasible, a designer might start with the area of the parking lot and adjust the depth of stone storage until the BMP capture volume is greater than the net drainage area SOV. If it appears the entire area of parking is not needed for use as an infiltration bed, the designer can scale down the footprint of the infiltration bed. These design iterations should consider pipe elevations entering and exiting a BMP, pipe cover requirements, and any other site conditions that could influence BMP dimensions. Additional information specific to BMP selection and sizing can be found in **Chapter 5.** Another example might be a situation where a landscape feature such as a bioretention area is desired by the property owner but a maximum amount of ponding is not appropriate. The designer would then have to minimize surface storage in **BMP Excel Workbook, Worksheet 3** for that particular sub-drainage area and provide additional subsurface storage in the form of soil or stone. Using guidance provided in **Chapter 5,** each chosen BMP can be tailored to site requirements using **BMP Excel Workbook, Worksheet 3** to vary BMP area, storage media, and storage media depths per design requirements.

Sub-Drainage ID	BMP Type	Infiltration Rate (in./hr)	Runoff Storage Type	Mid-height Area (ft^2)	Depth of Storage (ft)	Storage Capacity (%)	Storage Volume (ft^3)	BMP Surface Area (ft^2)	BMP Capture Volume (ft^3)	Net Drainage Area SOV (ft^3)	Drawdown Time (hrs)	Loading Ratio
1	**Bioretention**	0.40	Surface	1,200	1	100%	1,200	1,200	1,680	1574	42	8
			Soil	1,200	2	20%	480					
			Stone			0%	0					
2	**Infiltration Bed**	0.40	Surface			0%	0	10,000	6,000	5512	18	5
			Soil			0%	0					
			Stone	10,000	1.5	40%	6,000					
3	**Self-Managing Pervious Pavement**	0.40	Surface			0%	0	4,000	533	421	4	1
			Soil			0%	0					
			Stone	4,000	0.333	40%	533					
4	**Infiltration Bed**	0.40	Surface			0%	0	10,000	5,000	4292	15	4
			Soil			0%	0					
			Stone	10,000	1.25	40%	5,000					
5	**Bioretention**	0.40	Surface	800	0.66	100%	528	800	848	804	32	3
			Soil	800	2	20%	320					
			Stone			0%	0					
6	**Self-Managing Pervious Pavement**	0.40	Surface			0%	0	2,000	266	211	4	1
			Soil			0%	0					
			Stone	2,000	0.333	40%	266					

Figure K-7. Summary of BMP Sizing, BMP Workbook, Worksheet 3

Calculate the total volume managed and confirm that SOV is met.

After sizing the BMPs, the spreadsheet will compute the total SOV managed (using both structural BMPs and restorative practices) and compare the BMP capture volume to the required sub-drainage area SOV. When the total volume managed is equal to the required sub-drainage area SOV, 100% of the SOV has been achieved. As shown on Figure K-8, the structural BMPs combined with the restorative credits in each sub-drainage area have achieved slightly more than 100% of the SOV. Figure K-8 was generated from the **BMP Excel Workbook, Summary Table**.

Project Summary								
Sub-Drainage ID	Total Disturbed Area (ft^2)	Total Disturbed Impervious Area (ft^2)	Sub-Drainage Area SOV (ft^3)	Volume Credit (ft^3)	Net Sub-Drainage Area SOV (ft^3)	Loading Ratio	BMP Capture Volume (ft^3)	Capture > SOV?
1	27,710	10,000	1,674	100	1,574	8	1,680	YES
2	62,194	46,394	5,602	90	5,512	5	6,000	YES
3	4,000	4,000	421	0	421	1	533	YES
4	44,280	35,200	4,396	104	4,292	4	5,000	YES
5	29,700	2,250	846	42	804	3	848	YES
6	2,000	2,000	211	0	211	1	266	YES
Totals	169,884	99,844	13,150	336	12,814		14,327	YES

Figure K-8. Calculate required total volume managed onsite.
If the total volume managed (BMP capture volume) is equal to or greater than the net sub-drainage area SOV, 100% of the SOV has been achieved. BMP Excel Workbook, Summary Table

Develop preliminary infiltration system design.

Proposed infiltration BMP design was evaluated within the guidelines established in **Appendix D (Protocol 4 Infiltration System Design and Construction Guidelines)**, including consideration of drawdown time. Drawdown time was calculated by determining the effective depth of water within the BMP by considering the depth and type of storage that make up the BMP. The effective depth of water is then divided by the infiltration rate to yield the hours of drawdown time. Figure K-9 shows the drawdown times for each BMP summarized from **BMP Excel Workbook, Worksheet 3**. In this case, drawdown times are less than the maximum 72 hours as stipulated by City Code, Chapter 31, Article VIII.

$$Drawdown = \left(\frac{Ponding\ Depth\ (in.) * 1.0 + Soil\ Depth\ (in.) * 0.2 +\ Stone\ Depth\ (in.)\ \ * 0.4}{Infiltration\ Rate\ (\frac{in}{hr})}\right)$$

Drainage Area / BMP	Drawdown Time (hrs.)
1 - Bioretention	42
2 - Infiltration Bed	18
3 - Self-Managing Pervious Pavement	4
4 - Infiltration Bed	15
5 - Bioretention	32
6 - Self-Managing Pervious Pavement	4

Figure K-9. Summary of Drawdown Times for Infiltration BMPs

Adjust Curve Number (CN) for the project site and evaluate peak rate.

After acquiring infiltration rates and completing preliminary infiltration system design to manage 100% of SOV, the design professional is required to evaluate the project for peak rates of runoff. To account for the impacts on peak rate reduction through the application of LID measures on a project site, an adjustment may be made to the CN values assigned to disturbed areas managed by an LID BMP. The method for adjusting CN values is provided in **Chapter 7, Section 7.6**. The modified CN value gives the design professional credit for the volume stored in the BMPs and for the volume that is infiltrated from the BMPs. The infiltration volume is limited to the amount infiltrated during 12 hours of the 24-hour storm.

The first step is to determine a weighted CN for both the pre-development and post-development conditions. Because the predevelopment condition is a single land cover throughout, the weighted CN value for this area will be 71, since the area consists of meadow with “C” soils as the existing condition. A weighted CN value will be necessary to determine peak rates from both the pre-development and post-development conditions but only the post-development weighted CN will be adjusted since volume capture will only take place within the post-development BMPs. The CN weighting procedure is equivalent to dividing the total sum of each land use area times its corresponding CN value by the total area. The calculation method would be the same for determining the pre-development CN if multiple land covers were present in the pre-development condition. A summary of area, land cover descriptions, and associated CNs is shown on Figure K-10. See **Chapter 7, Section 7.6, Table 7-5** for recommended CN values.

Land Cover Description	Area (ft.^{2})	CN
Lawn	70,040	74
Buildings and Driveways	63,844	98
Pervious Parking, Patio, and Sidewalk	26,000	75
Impervious Parking	10,000	98

Total Area = 169,884 ft.^{2}

Figure K-10. Summary of Area, Land Cover, and Corresponding CN for Use in Weighted CN Calculation

$$Weighted\ CN = \frac{\sum(Land\ cover\ area\ x\ CN)}{Total\ land\ cover\ area} = \frac{14{,}369{,}672}{169{,}884} = 84.59\ (rounded\ to\ 85)$$

After determining the post-development weighted CN, calculate the potential retention, *S*, for the project site using the weighted CN value and TR-55 Eqn. 2-4 from **Chapter 7, Section 7.6**.

$$S = \frac{1000}{CN} - 10 = \frac{1000}{85} - 10 = 1.76\ \ inches$$

Once the potential retention is determined, use that value to calculate the runoff volume, *Q*, for the 2-year, 5-year, 10-year, 25-year, and 100-year storms using equation TR-55 2-3 from **Chapter 7, Section 7.6** and the design rainfall depths, *P*, for each storm shown in **Chapter 7, Section 7.5, Table 7-4**.

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

$$For\ the\ 10year\ storm, Q_{10} = \frac{(5.1 - 0.2 \times 1.76)^2}{(5.1 + 0.8 \times 1.76)} = 3.46\ inches$$

Similarly, using the same equation, Q_2 = 2.19 inches, Q_5 = 2.91 inches, Q_{25} = 4.30 inches, and Q_{100} = 5.64 inches.

The reduction volume, *R*, is the sum of all volumes stored (SOV) and infiltrated by the BMPs on the project site over 12 hours of the 24-hour storm. Soils testing in the vicinity of each proposed BMP showed the in-situ soils were capable of infiltrating at a rate of 0.4 inches per hour. Infiltration volume can be determined by multiplying the BMP bottom area (ft^2) by the infiltration rate (in/hr), which takes into account unit conversion and amount of infiltration allowed. SOV and infiltration volumes for each BMP are summarized on Figure K-11.

Drainage Area / BMP	SOV (ft.^{3})	Infiltration Volume (ft.^{3})
1 - Bioretention	1,680	480
2 - Infiltration Bed	6,000	4000
3 - Self-Managing Pervious Pavement	533	1600
4 - Infiltration Bed	5,000	4000
5 - Bioretention	848	320
6 - Self-Managing Pervious Pavement	266	800
Total =	14,327	11,200

Figure K-11. Summary of SOV and Infiltration Volumes Provided by Each BMP

$$R = \frac{\sum_{n=1}^{i}\left[(SOV + Infiltration\,Volume)_n\,(in\,cubic\,feet)\right]}{Total\,land\,cover\,area\,(in\,square\,feet)} \times \frac{12inches}{1foot}$$

$$R = \left(\frac{14{,}327ft^3 + 11{,}200ft^3}{169{,}884ft^2}\right) \times \frac{12inches}{1foot} = 1.80\,inches$$

Using the runoff volume, *Q*, minus the reduction, *R*, recalculate the potential retention, *S*, for each storm (2-, 5-, 10-, 25-, and 100-year), using modified equation 2-3 from **Chapter 7, Section 7.6**.

$$Q - R = \frac{(P - 0.2S_{mod})^2}{(P + 0.8S_{mod})}$$

$$For\ the\ 10year\ storm, Q_{10} - R = (3.46 - 1.80) = 1.66\ inches = \frac{(5.1 - 0.2S_{mod})^2}{(5.1 + 0.8S_{mod})}$$

Solve for S to obtain $S_{10,mod}$ = 5.59 (calculated within the background of BMP Excel Workbook, Worksheet 4)

Similarly, using the same equation, $S_{2,mod}$ = 8.43 inches, $S_{5,mod}$ = 6.28 inches, $S_{25,mod}$ = 5.00 inches, and $S_{100,mod}$ = 4.52 inches.

After the potential retention is determined for each storm, these values are used in rearranged equation 2-4 from **Chapter 7, Section 7.6** to calculate the adjusted CN for each storm.

$$CN_{adj} = \frac{1000}{S_{mod} + 10}$$

$$For\ the\ 10year\ Storm, CN_{10,adj} = \frac{1000}{S_{10,mod} + 10} = \frac{1000}{(5.59 + 10)} = 64$$

Similarly, using the same equation, $CN_{2,adj}$ = 54, $CN_{5,adj}$ = 61, $CN_{25,adj}$ = 67, and $CN_{100,adj}$ = 69.

The adjusted CNs were used in WinTR-55, along with the calculated time of concentration (Tc), to evaluate the peak rate of runoff from the developed site with the designed BMPs and compared to the peak rate of runoff from the pre-developed site. The adjusted CN for the 2-, 5-, 10-, 25-, and 100-year design storms are shown on Figure K-12. The peak rates of runoff for these design storms in the pre-developed, developed/unmanaged, and developed/managed conditions are shown on Figure K-13.

Weighted CN	Storm Frequency	Rainfall (in)	S	Q (in)	BMP Capture Volume (ft^3)	Infiltration Volume (12 hrs) (ft^3)	Total BMP Volume Reduction (ft^3)	Q minus Total Volume Reduction (in)	Adjusted CN
85	2	3.70		2.19				0.39	54
	5	4.50		2.91				1.11	61
	10	5.10	1.76	3.46	14,327	11,200	25,527	1.66	64
	25	6.00		4.30				2.50	67
	100	7.40		5.64				3.83	69

Figure K-12. Adjusted Curve Numbers for the 2-, 5-, 10-, 25-, and 100-Year Design Rainfall Events, BMP Excel Workbook, Worksheet 4

Condition	CN	Tc (hr)	2-Yr Peak Rate (cfs)	5-Yr Peak Rate (cfs)	10-Yr Peak Rate (cfs)	25-Yr Peak Rate (cfs)	100-Yr Peak Rate (cfs)
Predeveloped	71	0.32	5.06	7.93	9.62	12.8	18.04
Developed/Unmanaged (No BMPs)	85	0.29	10.12	13.76	15.8	19.49	25.24
Developed/Managed	69	0.29	4.69	7.55	9.29	12.52	17.81

Figure K-13. Peak Rates of Runoff in the Pre-Developed, Developed/Unmanaged, and Developed/Managed Conditions. Implementation of appropriate volume management BMPs (structural and restorative) may result in a design that does not require additional detention measures.

Depending on conditions and the extent of LID, the adjusted post-development CN may be lower than the pre-development CN, negating the requirement for additional peak rate attenuation structures. It is important to note that the designer must confirm that the time of concentration (Tc in hours) is not shorter after development before assuming that peak rates have not been altered. This case can be seen in the example. Peak rates for all storms in the Developed/Managed condition with LID BMPs are lower than the pre-development peak rates. The SOV abstracted from the runoff by these BMPs is accounted for so that additional peak rate mitigation is not necessary. This limits the construction and maintenance of stormwater facilities that are oversized by ignoring the value of SOV capture and infiltration.

If peak rate mitigation was not achieved during the initial BMP design, this would be the point to modify BMP dimensions or add additional facilities to the system for peak rate control. Note that from previous sections of this example, some BMPs have a lower loading ratio than the 8:1 guideline, meaning that these BMPs may have capacity for additional stormwater management. At this point, the design professional may elect to use the BMPs for peak rate control as well as SOV, eliminating other detention BMP requirements if peak rate requirements are not met with the initial BMP sizing. This decision will depend on proposed BMP dimensions, site conditions, and BMP guidance found in **Chapter 5** of this manual. If current BMP dimensions are optimized for site conditions and can only be used for SOV capture, other facilities may be needed to manage peak rates if calculations show peak rate mitigation is necessary. An alternative to separate facilities would be to increase the dimensions of the BMP to accommodate peak rate control within the system as long as SOV storage and retention are maintained along with BMP design guidance found in **Chapter 5.** Porous parking lots are an example of a BMP well-suited to providing both volume and rate management.

<u>Complete a stormwater management plan narrative.</u>

A stormwater plan narrative must be prepared and submitted with preliminary stormwater management plans for approval by the City. The stormwater management plan narrative must include documentation of the calculations performed above, as well as construction specifications of materials to be used in the proposed stormwater management measures.

<u>Prepare an Operations and Maintenance Plan.</u>

An Operations and Maintenance Plan must be prepared in accordance with **Chapter 8, Section 8.2**.

<u>Submit preliminary stormwater management plan.</u>

In accordance with **Chapter 4, Section 4.2.2**, the owner will provide the City with one hard copy and one electronic copy of preliminary stormwater management plan drawings, as well as of all applicable supporting data, plans, and calculations (i.e., soil testing reports, stormwater calculations, etc.) for the City's review and comment.

The Preliminary Stormwater Management Plan Checklist in **Appendix H (Concept, Preliminary, and Final Stormwater Management Plan Checklist)** provides additional details on the required components of a preliminary stormwater management plan submission, including both stormwater management plan narrative and drawings.

FINAL PLAN DEVELOPMENT, SUBMISSION AND REVIEW (Steps 8 and 9)

Step 8 Submit Final Plan Documents and Obtain Permits

Following approval of preliminary stormwater management plans, final plans may be submitted to the City. In accordance with **Chapter 4, Section 4.2.3**, the owner will provide the City with three hard copies of the final stormwater management plan drawings, and one hard copy of all applicable supporting data, plans, and calculations (i.e., soil testing reports, stormwater calculations, etc.) for review and approval. An electronic submission of all materials is also required.

Inspection and Maintenance Agreements, prepared in accordance with **Chapter 8, Section 8.3**, must also be filed for each project, as directed by the City and submitted to the Land Development Office, with the final plan submission.

No final plan will be approved by the City until all applicable state and federal permits have been obtained and all applicable bonds have been posted.

Step 9 Construct and Inspect

<u>Construction Oversight</u>

During construction, the licensed professional responsible for the design of stormwater management BMPs must oversee the construction of subsurface stormwater management BMPs. The Construction Oversight Certification for Stormwater Management BMPs in **Appendix I (Construction Oversight Certification for Stormwater Management BMPs)** must be completed and submitted to the City prior to building or site occupancy.

<u>Inspection and Certification</u>

The City of Chattanooga will conduct a Final Inspection of the stormwater management practices associated with this project. The Final Inspection will include inspection of all surface BMPs to ensure consistency with the City approved plans and details. The Post-Construction Inspection and Certification for Stormwater Management BMPs, outlined in **Appendix J (Post-Construction Inspection and Certification for Stormwater Management BMPS),** must be included with as-built drawings, as required.

As Built Drawings

As stated in **Chapter 4, Section 4.2.3.4**, the City's current procedures, requirements, and content regarding as-built drawings are applicable as identified on the City's webpage at http://www.chattanooga.gov/public-works/land-development-office/forms-and-permits.

Annual Reporting

The inspection checklists provided in **Chapter 8, Section 8.4** will be submitted to the City's Water Quality Department annually.

END OF EXAMPLE 1

K.2. Detailed Calculations Example and LID Calculation Tool (BMP Excel Workbook) – New Office Campus Project

Example 2: New Office Campus Designed for Water Quality Management (WQ Requirements)
Location: South Chickamauga Watershed
Combined sewer area: No
Parcel size: 8 acres

This example is identical to the first example for the concept phase. However, during the site testing of the detailed design, excavation of test pits revealed that the onsite soils have an infiltration rate of 0.05 inches/hour, which is less than the minimum infiltration rate of 0.2 inches/hour required for BMPs without underdrainage, thus rendering infiltration infeasible. Other volume-reducing BMPs, such as cisterns for reuse **(Chapter 5, BMP 5.3.9)** or green roofs **(Chapter 5, BMP 5.3.8)**, cannot provide enough SOV capacity on this site to meet project needs. Therefore, the BMPs are sized for the Water Quality Volume (WQv) of 2.1 inches. This means that the BMPs must have the capacity to store and slowly release, in accordance with the requirements of **Chapter 7, Section 7.4**, the total volume of runoff from the 2.1-inch rainfall event.

STEPS 1 THROUGH 5 – SAME AS EXAMPLE 1

PRELIMINARY PLAN DEVELOPMENT, SUBMISSION, AND REVIEW (Steps 6 and 7)

Step 6 Detailed Site Investigation and Testing

Upon receiving approval of the concept stormwater management plan from the City, detailed design of stormwater management measures may proceed. The first step in preliminary stormwater management plan development is to locate the proposed BMPs in accordance with **Appendix A (Protocol 1 Infiltration BMP Setbacks from Structures)** and **Appendix B (Protocol 2 BMP Coordination with Other Utilities)**, and to conduct site testing in accordance with **Appendix C (Protocol 3 Soil Testing)**. For this example, test pits were excavated in the area of each proposed infiltration BMP. During the excavation of the test pits, it was discovered that infiltration would not be feasible on the site. In the event that infiltration was not suitable at the proposed locations, but was feasible in other portions of the site, the design professional could adjust the site plan and BMP locations accordingly.

In keeping with LID principles, the project includes BMPs that will manage runoff close to the source. Each BMP must be sized to capture the required WQv from the area draining to it. If a BMP can only capture a portion of the required WQv from the area draining to it, a second, downstream BMP must provide the remaining WQv capture.

<u>Delineate sub-drainage areas to each BMP and calculate WQv required for each sub-area.</u>

For this example, four structural BMPs are being considered for five sub-drainage areas of disturbed area delineated, as referenced to Figure K-3. These sub-areas and land uses are as follows:

- Sub-area 1 includes lawn and an impervious parking lot. For this example, an underdrained bioretention area **(Chapter 5, BMP 5.3.4)** within the landscape plantings is being proposed. Other alternatives, such as directing this runoff to a bed beneath one of the porous parking lots, could also meet requirements. The design professional may select the appropriate BMPs for the site.
- Sub-area 2 includes lawn, two sections of 24-foot-wide driveway, a flat-roofed building, and a pervious parking lot. For this sub-area, an underdrained infiltration bed **(Chapter 5, BMP 5.3.2)** beneath the pervious parking lot is proposed.
- Sub-area 3 includes an impervious sidewalk that will directly discharge to the outfall shown on Figure 3. WQv for the entire site, however, will be met by capturing an equivalent volume in sub-area 2.
- Sub-area 4 includes lawn, a 24-foot-wide driveway, a flat-roofed building, and a pervious parking lot. For this sub-area, an underdrained infiltration bed **(Chapter 5, BMP 5.3.2)** beneath the pervious parking lot is also proposed.
- Sub-area 5 includes a building's pitched roof and lawn, and outdoor patio (sub-area 6 on Figure K-3 and in Example 1), which will be managed by an underdrained bioretention area **(Chapter 5, BMP 5.3.4)**.

For each sub-area to a BMP, the land use types, surface areas, and associated SOV can be estimated using the **BMP Excel Workbook, Worksheet 1**, as shown on Figure K-14.

Preliminary Design

INITIAL TARGET BMP AREA = 12,481 ft^2

Sub-Drainage ID per BMP (numbers and lowercase letters only)	Land Use Type	Surface Condition	Disturbed Land Area (ft^2)	Disturbed Land Area (ac)	Rv Value, from Table	Stay on Volume (ft^3)
1a	Typical Urban Soils	Pervious	17,710	0.41	0.18	558
1b	Large Impervious	Impervious	10,000	0.23	0.99	1,733
2a	Small Impervious	Impervious	10,204	0.23	0.85	1,518
2b	Typical Urban Soils	Pervious	15,800	0.36	0.18	498
2c	Flat Roof	Impervious	11,000	0.25	0.90	1,733
2d	Large Impervious	Impervious	10,000	0.23	0.99	1,733
2e	Small Impervious	Impervious	15,190	0.35	0.85	2,260
3	Small Impervious	Impervious	4,000	0.09	0.85	595
4a	Flat Roof	Impervious	20,000	0.46	0.90	3,150
4b	Large Impervious	Impervious	10,000	0.23	0.99	1,733
4c	Typical Urban Soils	Pervious	9,080	0.21	0.18	286
4d	Small Impervious	Impervious	5,200	0.12	0.85	774
5a	Typical Urban Soils	Pervious	27,450	0.63	0.18	865
5b	Pitched Roof	Impervious	2,250	0.05	0.99	390
5c	Small Impervious	Impervious	2,000	0.05	0.85	298

Figure K-14. Calculation of WQv by Sub-drainage Area with SSHM Runoff Coefficients, BMP Workbook, Worksheet 1

The required WQv is calculated using the Small Storm Hydrology Method, as described in **Chapter 7, Section 7.3**. Rv values utilized by the Small Storm Hydrology Method are automatically populated within the table based on the user-defined rainfall depth and land use types. These values can be found in the **BMP Excel Workbook, Worksheet 1** or in **Chapter 7, Section 7.3, Table 7-1**, of the manual. The total SOV by sub-area for this example is summarized on Figure K-15 for informational purposes. If using the **BMP Excel Workbook**, it will tabulate the SOV for each sub-area automatically as the design professional adjusts drainage areas and BMP sizes. This information can be found in the **BMP Excel Workbook, Summary Table**. In this case where the 2.1 volume is required, the designer may select this value from the dropdown menu of the **BMP Excel Workbook, Worksheet 1**. Rv values appropriate for the 2.1 volume are updated by the spreadsheet as well.

Sub-Drainage ID	Total Disturbed Area (ft^2)	Total Disturbed Impervious Area (ft^2)	Sub-Drainage Area SOV (ft^3)
1	27,710	10,000	2,290
2	62,194	46,394	7,740
3	4,000	4,000	595
4	44,280	35,200	5,942
5	31,700	4,250	1,552

Figure K-15. Summary of WQv by Sub-drainage Area, BMP Excel Workbook, Summary Table

Reduce WQv by implementing restorative BMPs.

The design professional may choose to reduce the size of structural BMPs by using landscape restorative measures that reduce runoff volume and provide WQv credit. These include **Chapter 5, BMPs 5.4.1 through 5.4.3**. For each of these restorative BMPs as defined in the **Non-Structural BMP Credits Worksheet, Chapter 7, Section 7.7**, the restorative BMP can be translated into a WQv "credit" volume. The first step is to consider areas within each sub-area where restorative practices may be implemented. For this example, in accordance with the tree planting credits in **Chapter 7, Section 7.2**, this project will include planting 10 evergreen and 15 deciduous trees to reduce the WQv in sub-areas 1 and 2, respectively. The project also proposes to include a 2,000-square-foot area of meadow in sub-area 5 (in lieu of lawn) as part of a required landscape plan. In accordance with **Chapter 5, BMP 5.4.2.1**, this cover type change can also reduce the SOV to be managed by structural BMPs. Additionally, the project will include 5,000 square feet in sub-area 4 where soils disturbed during construction will be restored and amended in accordance with **Chapter 5, BMP 5.4.3**. The WQv "value" of these restorative BMPs can be calculated in accordance with **Non-Structural BMP Credits Worksheet, Chapter 7, Section 7.7**. These credits, and the adjusted WQv as a result of these credits, can also be estimated using the **BMP Excel Workbook, Worksheet 2**, as indicated on Figure K-16. This worksheet provides the adjusted WQv by sub-area. As described **in Chapter 7, Section 7.7,** the use of restorative BMPs can only reduce the WQv by a maximum of 25%. **BMP Excel Workbook, Worksheet 2** will not allow the design professional to decrease WQv by more than 25%. Note that the restorative credits are applied to the appropriate BMP sub-areas. In this example, the total SOV volume credit of 336 cubic feet has been achieved through tree planting, meadow planting, and soil restoration done in accordance with the requirements of **Chapter 5, BMPs 5.4.1 through 5.4.3**.

Restorative Volume Credit Worksheet							
Sub-Drainage ID	Sub-Drainage SOV (ft^3)	Restorative Practice Credit Type	Area (ft^2)	# of Trees	Volume Credit (ft^3)	Total Volume Credit (limit to maximum of 25% of SOV) (ft^3)	Net Drainage Area SOV (ft^3)
1	2,290	Tree Planting - Evergreen		10	100	100	2,190
		None			0		
		None			0		
2	7,740	Tree Planting - Deciduous		15	90	90	7,650
		None			0		
		None			0		
3	595	None			0	0	595
		None			0		
		None			0		
4	5,942	Amend and Restore Disturbed Soils	5,000		104	104	5,838
		None			0		
		None			0		
5	1,254	Change Cover Type to Meadow	2,000		42	42	1,213
		None			0		
		None			0		

Figure K-16. Restorative Credits for Tree Plantings and Cover Type Changes, BMP Excel Workbook, Worksheet 2

Determine the BMP area and storage capacity necessary for each sub-drainage area.

The WQv remaining after restorative credits are applied will be managed by six structural BMPs designed to capture and slow-release the WQv, one in each sub-drainage area. Using the recommended loading ratio of 8:1 for a 2.1-inch rainfall depth, BMPs were located on the site plan. Locations of proposed BMPs with regard to setbacks from structures were considered in accordance with **Appendix A (Protocol 1 Infiltration BMP Setbacks from Structures)**, to avoid potential damage due to water migration. Also, coordination with other utilities, in accordance with **Appendix B (Protocol 2 BMP Coordination with Other Utilities)**, determined that the locations of the proposed BMPs would not conflict with existing or proposed utilities. Even though the proposed BMPs will not be designed for infiltration, the design guidance provided in these appendices should be considered to ensure appropriate safety in design.

A summary of the BMP areas, calculated capture volumes, and impervious to BMP area loading ratios is shown on Figure K-17. The BMPs may be dimensioned using the **BMP Excel Workbook, Worksheet 3**.

The process of sizing and selection of BMPs needs to incorporate site and design knowledge that may not be found in this manual. Site conditions and design requirements need to be considered to determine which BMPs are the most appropriate given specific site conditions and what BMP dimensions will best fit within a site. Dimensioning a BMP can become an iterative process, so utilizing the **BMP Excel Workbook, Worksheet 3** may be helpful.

The **BMP Excel Workbook** provides a designer with the necessary SOV that is required to be captured per sub-drainage area in **BMP Excel Workbook, Worksheet 3** under the column titled, "Net Drainage Area

SOV." This column is the net value of SOV after SOV volume credit has been subtracted for all restorative practices tabulated in **BMP Excel Workbook,Worksheet 2**. In general, a designer will need to know at this point in the design process which areas are available onsite within each sub-drainage area for each BMP and also what volume is needed to be captured in each BMP (**BMP Excel Workbook, Worksheet 3**). Most often this will be indicated by a parking area that may be able to contain an infiltration bed or a landscaped area that could be used for bioretention. These available areas will be the starting point for sizing the necessary BMPs per sub-drainage area.

BMP Excel Workbook, Worksheet 3 can then be used to iteratively adjust which BMPs will be applied to each sub-drainage area and their dimensions. For example, if sub-drainage area 2 has a large parking lot required by City code where an infiltration bed is feasible, a designer might start with the area of the parking lot and adjust the depth of stone storage until the BMP capture Volume is greater than the net drainage area SOV. If it appears the entire area of parking is not needed for use as an infiltration bed, the designer can scale down the footprint of the infiltration bed. These design iterations should consider pipe elevations entering and exiting a BMP, pipe cover requirements, and any other site conditions that could influence BMP dimensions. Additional information specific to BMP selection and sizing can be found in **Chapter 5.** Another example might be a situation where a landscape feature such as a bioretention area is desired by the property owner but a maximum amount of ponding is not appropriate. The designer would then have to minimize surface storage in **BMP Excel Workbook, Worksheet 3** for that particular sub-drainage area and provide additional subsurface storage in the form of soil or stone. Using guidance provided in **Chapter 5,** each chosen BMP can be tailored to site requirements using **BMP Excel Workbook, Worksheet 3** to vary BMP area, storage media, and storage media depths per design requirements.

Sub-Drainage ID	BMP Type	Infiltration Rate (in./hr)	Runoff Storage Type	Mid-height Area (ft^2)	Depth of Storage (ft)	Storage Capacity (%)	Storage Volume (ft^3)	BMP Surface Area (ft^2)	BMP Capture Volume (ft^3)	Net Drainage Area SOV (ft^3)	Drawdown Time (hrs)	Loading Ratio
1	**Bioretention**		Surface	1,200	1	100%	1,200	1,200	2,280	2190	-	8
			Soil	1,200	3	20%	720					
			Stone	1,200	0.75	40%	360					
2	**Infiltration Bed**		Surface			0%	0	10,000	8,000	7650	-	5
			Soil			0%	0					
			Stone	10,000	2	40%	8,000					
3	**NONE**		Surface			0%	0	0	0	595	-	N/A
			Soil			0%	0					
			Stone			0%	0					
4	**Infiltration Bed**		Surface			0%	0	10,000	7,000	5838	-	4
			Soil			0%	0					
			Stone	10,000	1.75	40%	7,000					
5	**Bioretention**		Surface	800	1	100%	800	800	1,600	1510	-	5
			Soil	800	3	20%	480					
			Stone	800	1	40%	320					

Figure K-17. Summary of BMP Sizing, BMP Workbook, Worksheet 3

Calculate the total volume managed and confirm that WQv is met.

After sizing the BMPs, the spreadsheet can compute the total WQv managed (using both structural BMPs and restorative practices) and compare the BMP capture volume (WQv) to the required sub-drainage area WQv. As shown on Figure K-18, the structural BMPs combined with the restorative credits have achieved slightly more than 100% of the WQv for the entire project area, even though the impervious sidewalk in sub-drainage area 3 is not managed. The BMPs across the rest of the project area have been sized to capture 18,800 feet^3, which is slightly more than the 17,783 feet^3 required after subtracting the restorative credits. Figure K-18 was generated from the **BMP Excel Workbook, Summary Table**.

Project Summary								
Sub-Drainage ID	Total Disturbed Area (ft^2)	Total Disturbed Impervious Area (ft^2)	Sub-Drainage Area SOV (ft^3)	Volume Credit (ft^3)	Net Sub-Drainage Area SOV (ft^3)	Loading Ratio	BMP Capture Volume (ft^3)	Capture > SOV?
1	27,710	10,000	2,290	100	2,190	8	2,280	YES
2	62,194	46,394	7,740	90	7,650	5	8,000	YES
3	4,000	4,000	595	0	595	N/A	0	NO
4	44,280	35,200	5,942	104	5,838	4	7,000	YES
5	31,700	4,250	1,552	42	1,510	5	1,600	YES
Totals	169,884	99,844	18,119	336	17,784		18,880	YES

Figure K-18. Calculate required total volume managed onsite. If the total volume managed (BMP capture volume) is equal to or greater than the net sub-drainage area SOV (WQv), 100% of the WQv has been achieved. BMP Excel Workbook, Summary Table

Step 7 Prepare a Preliminary Stormwater Management Plan

Develop preliminary slow-release system design.

Proposed BMP design for water quality volume includes engineering design and calculation of a slow-release structure (i.e., weir plate, orifice, etc.) to ensure the BMP drains down within 48 and 72 hours in accordance with **Chapter 7, Section 7.4**.

Adjust Curve Number for the project site and evaluate peak rate.

After completing preliminary slow-release system design to manage 100% of WQv, the design professional is required to evaluate the project for peak rates of runoff. To account for the impacts on peak rate reduction through the application of LID measures on a project site, an adjustment may be made to the CN values assigned to disturbed areas managed by an LID BMP. The method for adjusting CN values is provided in **Chapter 7, Section 7.6**. The modified CN value gives the design professional credit for the volume stored in and slow-released from the BMPs.

The first step in CN adjustment is to determine a weighted CN for both the pre-development and post-development conditions. Because the CN adjustment for this section of the example requires only the post-development conditions to be considered, the figures and text only address the post-development weighted CN. The method is the same for determining the pre-development CN. A weighted CN value will be necessary to determine peak rates from both the pre-development and post-development conditions, but only the post-development weighted CN will be adjusted since volume capture will only take place because of the post-development BMPs. The CN weighting procedure is equivalent to dividing the total sum of each land use area multiplied by its corresponding CN value by the total area. A summary of area, land cover descriptions, and associated CNs is shown on Figure K-19. See **Chapter 7, Section 7.6, Table 7-5** for recommended CN values.

Land Cover Description	Area (ft.^{2})	CN
Lawn	70,040	74
Buildings and Driveways	67,844	98
Pervious Parking, Patio, and Sidewalk	22,000	75
Impervious Parking	10,000	98
Total Area =	169,884	ft.^{2}

Figure K-19. Summary of Area, Land Cover, and Corresponding CN for Use in Weighted CN Calculation

$$Weighted\ CN = \frac{\sum(Land\ cover\ area\ x\ CN)}{Total\ land\ cover\ area} = \frac{14{,}369{,}672}{169{,}884} = 85.12\ (rounded\ to\ 85)$$

After determining the weighted CN, calculate the potential retention, *S*, for the project site using the weighted CN value and TR-55 Eqn. 2-4 from **Chapter 7, Section 7.6**.

$$S = \frac{1000}{CN} - 10 = \frac{1000}{85} - 10 = 1.76\ inches$$

Once the potential retention is determined, use that value to calculate the runoff volume, *Q*, for the 2-, 5-, 10-, 25-, and 100-year storms using equation TR-55 2-3 from **Chapter 7, Section 7.6** and the design rainfall depths, P, for each storm shown in **Chapter 7, Section 7.5, Table 7-4.**

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

$$For\ the\ 10-year\ storm, Q_{10} = \frac{(5.1 - 0.2 \times 1.76)^2}{(5.1 + 0.8 \times 1.76)} = 3.46\ inches$$

Using the same equation, Q_2 = 2.19 inches, Q_5 = 2.91 inches, Q_{25} = 4.30 inches, and Q_{100} = 5.64 inches.

The reduction volume, *R*, is the sum of all volumes stored (WQv) and slow-released by the BMPs on the project site. WQv volumes for each BMP are summarized on Figure K-20.

Drainage Area / BMP	SOV ($ft.^3$)	Infiltration Volume ($ft.^3$)
1 - Bioretention	2,280	0
2 - Infiltration Bed	8,000	0
3 - Self-Managing Pervious Pavement	0	0
4 - Infiltration Bed	7,000	0
5 - Bioretention	1,600	0
Total =	18,880	0

Figure K-20. Summary of WQv Volumes Provided by Each BMP

$$R = \frac{\sum_{n=1}^{i}\left[(SOV + Infiltration\ Volume)_n\ (in\ cubic\ feet)\right]}{Total\ land\ cover\ area\ (in\ square\ feet)} \times \frac{12 inches}{1 foot}$$

$$R = \left(\frac{18{,}880 ft^3 + 0 ft^3}{169{,}884 ft^2}\right) \times \frac{12 inches}{1 foot} = 1.33\ inch$$

Using the runoff volume, *Q*, minus the reduction, *R*, recalculate the potential retention, *S*, for each storm (2-, 5-, 10-, 25-, and 100-year), using modified equation 2-3 from **Chapter 7, Section 7.6**.

$$Q - R = \frac{(P - 0.2S_{mod})^2}{(P + 0.8S_{mod})}$$

$$For\ the\ 10-year\ storm, Q_{10} - R = (3.46 - 1.33) = 2.13\ inches = \frac{(5.1 - 0.2S_{mod})^2}{(5.1 + 0.8S_{mod})}$$

Solve for S to obtain $S_{10,mod}$ = 4.24 (BMP Excel Workbook, Worksheet 4)

Similarly, using the same equation, $S_{2,mod}$ = 5.39, $S_{5,mod}$ = 4.57, $S_{25,mod}$ = 3.94 inches, and $S_{100,mod}$ = 3.66 inches.

Once the potential retention is determined for each storm, these values are used in rearranged equation 2-4 to calculate the adjusted CN for each storm.

$$CN_{adj} = \frac{1000}{S_{mod} + 10}$$

$$For\ the\ 10 - year\ Storm, CN_{10,adj} = \frac{1000}{S_{10,mod} + 10} = \frac{1000}{(4.24 + 10)} = 70$$

Using the same equation, $CN_{2,adj}$ = 65, $CN_{5,adj}$ = 69, $CN_{25,adj}$ = 72, and $CN_{100,adj}$ = 73.

The adjusted CNs were used in WinTR-55, along with the calculated time of concentration (Tc), to evaluate the peak rate of runoff from the developed site with the designed BMPs and compared to the peak rate of runoff from the pre-developed site. The adjusted CNs for the 2-, 5-, 10-, 25- ,and 100-year design storms are shown on Figure K-21. The peak rates of runoff for the 2-, 5-, 10-, 25-, and 100-year design storm in the pre-developed, developed/unmanaged, and developed/managed conditions are shown on Figure K-22.

Weighted CN	Storm Frequency	Rainfall (in)	S	Q (in)	BMP Capture Volume (ft^3)	Infiltration Volume (12 hrs) (ft^3)	Total BMP Volume Reduction (ft^3)	Q minus Total Volume Reduction (in)	Adjusted CN
85	2	3.70	1.76	2.19	18,880		18,880	0.86	65
	5	4.50		2.91				1.58	69
	10	5.10		3.46				2.13	70
	25	6.00		4.30				2.97	72
	100	7.40		5.64				4.30	73

Figure K-21. Adjusted Curve Numbers for the 2-, 5-, 10-, 25-, and 100-Year Design Rainfall Events, BMP Excel Workbook, Worksheet 4

Condition	CN	Tc (hr)	2-Yr Peak Rate (cfs)	5-Yr Peak Rate (cfs)	10-Yr Peak Rate (cfs)	25-Yr Peak Rate (cfs)	100-Yr Peak Rate (cfs)
Predeveloped	78	0.32	7.27	10.52	12.38	15.86	21.27
Developed/Unmanaged (No BMPs)	85	0.3	10.12	13.76	15.8	19.49	25.24
Developed/Managed	73	0.3	5.93	9.06	10.9	14.29	19.8

Figure K-22. Peak rates of Runoff in the Pre-developed, Developed/Unmanaged, and Developed/Managed Conditions. Implementation of appropriate volume management BMPs (structural and restorative) may result in a design that does not require additional detention measures.

Depending on conditions and the extent of LID, the adjusted post-development CN may be lower than the pre-development CN, negating the requirement for additional peak rate attenuation structures. This case can be seen in the example. Peak rates for all storms in the Developed/Managed condition with LID BMPs are lower than the pre-development peak rates. The WQv abstracted from the runoff by these BMPs is accounted for so that additional peak rate mitigation is not necessary. This limits the construction and maintenance of stormwater facilities that are oversized by ignoring the value of WQv capture and slow-release.

If peak rate mitigation was not achieved during the initial BMP design, this would be the point to modify BMP dimensions or add additional facilities to the system for peak rate control. Note that from previous sections of this example, some BMPs have a lower loading ratio than the 8:1 guideline, meaning that these BMPs may have capacity for additional stormwater management. At this point, the design professional may elect to use the BMPs for peak rate control as well as WQv, eliminating other detention BMP requirements if peak rate requirements are not met with the initial BMP sizing. This decision will depend on proposed BMP dimensions, site conditions, and BMP guidance found in **Chapter 5** of this manual. If current BMP dimensions are optimized for site conditions and can only be used for WQv slow-release, other facilities may be needed to manage peak rates if calculations show peak rate mitigation is necessary. An alternative to separate facilities would be to increase the dimensions of the BMP to accommodate peak rate control within the system as long as WQv slow-release is maintained along with BMP design guidance found in **Chapter 5**. Porous parking lots are an example of a BMP well-suited to providing both volume and rate management.

<u>Complete a stormwater management plan narrative.</u>

A stormwater plan narrative must be prepared and submitted with preliminary stormwater management plans for approval by the City. The stormwater management plan narrative must include documentation of the calculations performed above, as well as construction specifications of materials to be used in the proposed stormwater management measures.

<u>Prepare an Operations and Maintenance Plan.</u>

An Operations and Maintenance Plan must be prepared in accordance with **Chapter 8, Section 8.2**.

<u>Submit preliminary stormwater management plan.</u>

In accordance with **Chapter 4, Section 4.2.2**, the owner will provide the City with one hard copy and one electronic copy of preliminary stormwater management plan drawings, as well as of all applicable supporting data, plans, and calculations (i.e., soil testing reports, stormwater calculations, etc.) for the City's review and comment.

The Preliminary Stormwater Management Plan Checklist in **Appendix H (Concept, Preliminary, and Final Stormwater Management Plan Checklist)** provides additional details on the required components of a preliminary stormwater management plan submission, including both stormwater management plan narrative and drawings.

FINAL PLAN DEVELOPMENT, SUBMISSION, AND REVIEW (Steps 8 and 9)

Step 8 Submit Final Plan Documents and Obtain Permits

Following approval of preliminary stormwater management plans, final plans may be submitted to the City. In accordance with **Chapter 4, Section 4.2.3**, the owner will provide the City with three hard copies of the final stormwater management plan drawings, as well as one copy of all applicable supporting data, plans, and calculations (i.e., soil testing reports, stormwater calculations, etc.) for review and approval. An electronic submission of all materials is also required.

Inspection and Maintenance Agreements, prepared in accordance with **Chapter 8, Section 8.3**, must also be filed for each project, as directed by the City and submitted to the Land Development Office, with the final plan submission.

No final plan will be approved by the City until all applicable state and federal permits have been obtained and all applicable bonds have been posted.

Step 9 Construct and Inspect

<u>Construction Oversight</u>

During construction, the licensed professional responsible for the design of stormwater management BMPs must oversee the construction of subsurface stormwater management BMPs. The Construction Oversight Certification for Stormwater Management BMPs in **Appendix I (Construction Oversight Certification for Stormwater Management BMPs)** must be completed and submitted to the City prior to building occupancy.

<u>Inspection and Certification</u>

The City of Chattanooga will conduct a Final Inspection of the stormwater management practices associated with this project. The Final Inspection will include inspection of all surface BMPs to ensure consistency with the City approved plans and details. The Post-Construction Inspection and Certification for Stormwater Management BMPs, outlined in **Appendix J (Post-Construction Inspection and Certification for Stormwater Management BMPS),** must be included with as-built drawings, as required.

As-Built Drawings

As stated in **Chapter 4, Section 4.2.3.4**, the City's current procedures, requirements, and content regarding as-built drawings are applicable as identified on the City's webpage at http://www.chattanooga.gov/public-works/land-developmentoffice/forms-and-permits.

Annual Reporting

The inspection checklists provided in **Chapter 8, Section 8.4** will be submitted to the City's Water Quality Department annually.

END OF EXAMPLE 2