Chapter 4 – Stormwater Management Standards and Performance Criteria

Introduction

This chapter presents stormwater management standards and performance criteria for land development projects in Connecticut. The standards and performance criteria apply to all new development, redevelopment, retrofits, and other land disturbance activities, whether considered individually or collectively as part of a larger common plan, which are subject to local, state, or federal regulatory requirements to address post-construction stormwater management.

What's New in this Chapter?

- Updated stormwater management standards and performance criteria
- Consistency with stormwater retention and treatment requirements in the CT DEEP stormwater general permits
- Updated design storm precipitation for stormwater quality and quantity control
- Use of EPA stormwater BMP performance curves and pollutant-specific load reduction targets

Project proponents are required to meet and demonstrate compliance with the management standards and performance criteria using non-structural Low Impact Development (LID) site planning and design techniques and structural stormwater Best Management Practices (BMPs), in addition to operational source controls and pollution prevention. The management standards and performance criteria are intended to help preserve pre-development site hydrology and pollutant loads to the maximum extent possible to protect water quality, maintain groundwater recharge, and prevent flooding.

The performance criteria address the full spectrum of storm flows and their associated water quality and quantity impacts. These range from smaller more frequent storms that are responsible for a majority of the annual runoff volume and pollutant loads, to larger less frequent events that can cause flooding. Given the observed and anticipated future increases in precipitation as a result of climate change, the performance criteria include updated design storm precipitation amounts and intensities for more resilient stormwater management designs.

The management standards and performance criteria presented in this Manual are intended to be consistent with the post-construction stormwater management requirements of the CT DEEP stormwater general permits, as well as local requirements within municipal planning, zoning, and stormwater ordinances and regulations. Some differences may exist between the standards and performance criteria in this Manual and local requirements. For example a local Inland Wetlands and Watercourses authority may require to maintain certain flow levels with respect to a downstream wetland, shallow water body, vernal pool, or small watercourse, etc. Where local requirements are less stringent than noted in this Manual, the intent of this Manual is to provide recommended guidance based on the most relevant science at the time of its publication.

Table 4-1 summarizes the stormwater management standards and performance criteria, which are described in more detail in the following sections.

KEY TERM:

Maximum Extent Achievable (MEA)

This term is meant to indicate the site design has incorporated that element as completely as possible for the given site parameters. The justification and documentation of achieving this extent is described further in each of the sub sections below.

Maximum Extent Achievable (MEA) - LID Site Planning and Design

Maximum Extent Achievable (MEA) – Stormwater Treatment

Maximum Extent Achievable (MEA) – Stormwater Retention

***Note:** The term MEA is used, but not specifically defined, in the current MS4 General Permit. The concepts described here are synonymous with the term Maximum Extent Practicable (MEP) of the MS4 General Permit.

Table 4-1. Stormwater Management Standards and Performance Criteria Summary

Stormwater Management Standard	Performance Criteria
Standard 1 – Runoff Volume and Pollutant Reduction Preserve pre-development hydrology and pollutant loads to protect water quality and maintain groundwater recharge.	**LID Site Planning and Design (non-structural)** Consider the use of non-structural LID site planning and design strategies, to the maximum extent achievable, prior to the consideration of other practices, including structural stormwater BMPs. Refer to Chapter 5 - Low Impact Development Site Planning and Design Strategies for impervious surface disconnection and other non-structural LID Site Planning and Design techniques that can reduce post-development impervious area and stormwater runoff volumes. **Stormwater Retention and Treatment (structural)** After application of non-structural LID site planning and design techniques, use structural stormwater BMPs to retain and/or treat the remaining post-development stormwater runoff volume: ➢ Retention: Retain on-site the following post-development stormwater runoff volume for the site (Required Retention Volume) to the Maximum Extent Achievable using structural stormwater BMPs: Required Retention Volume (RRV): ○ 100% of the site's Water Quality Volume (WQV) ▪ All new development ▪ Redevelopment or retrofit of sites that are currently developed with existing DCIA[42] of less than 40% ▪ Any new stormwater discharges located within 500 feet of tidal wetlands ○ 50% of the site's WQV ▪ Redevelopment or retrofit of sites that are currently developed with existing DCIA of 40% or more ➢ Additional Treatment without Retention: If the post-development stormwater runoff volume retained on-site does not meet the Required Retention Volume for the site, provide stormwater treatment without retention to the Maximum Extent Achievable for the volume above that which can be retained, up to 100% of the site's WQV. The additional stormwater treatment should be provided using structural stormwater BMPs to achieve annual average pollutant load reduction targets for sediment, floatables, and nutrients, per Table 4-3. Refer to Chapters 7 through 13 for selection and design of structural stormwater BMPs for meeting the Stormwater Retention and Treatment requirements.

[42] Note DCIA is not equivalent to the impervious area, see the distinction noted in Chapter 2.

Stormwater Management Standard	Performance Criteria
Standard 2 – Stormwater Runoff Quantity Control[43] Do not exceed pre-development peak flow rates and manage the volume and timing of runoff to prevent downstream flooding, channel erosion, and other adverse impacts, and safely convey flows into, through, and from structural stormwater BMPs.	**Peak Runoff Attenuation for Site Development / Redevelopment** Control the 2-year, 24-hour post-development peak flow rate to 50% of the 2-year, 24-hour pre-development peak flow rate for each point at which stormwater discharges from a site using structural stormwater BMPs. Control the 10-year, 24-hour post-development peak flow rate to the 10-year, 24-hour pre-development peak flow rate for each point at which stormwater discharges from a site using structural stormwater BMPs. Potentially control the 100-year, 24-hour post-development peak flow rate to the 100-year, 24-hour pre-development peak flow rate for each point at which stormwater discharges from a site using structural stormwater BMPs, as required by the review authority. Demonstrate that any increased volume or change in timing of stormwater runoff will not result in adverse effects such as increased flooding downstream of the site or at other off-site locations, as required by the review authority. **Conveyance Protection** Design the conveyance system leading to, from, and through structural stormwater BMPs based on the post-development peak flow rate associated with the 10-year, 24-hour or larger magnitude design storm. **Emergency Outlet Sizing** Size the emergency outlet of stormwater quantity control structures to safely pass the post-development peak runoff from the 100-year, 24-hour or larger magnitude design storm in a controlled manner without eroding the outlet and downstream drainage systems. Refer to Chapters 7 through 13 for selection and design of structural stormwater BMPs for meeting the Stormwater Runoff Quantity Control requirements.

[43] Per the CTDOT MS4 Permit, linear projects have alternative standards and may take an alternative approach to address constraints that are different than those that affect traditional parcel development projects. These alternative linear project standards can be found in the CTDOT drainage manual, the CTDOT MS4 General Permit, the General Construction Permit and in the supporting materials that CTDOT has developed.

Stormwater Management Standard	Performance Criteria
Standard 3 – Construction Soil Erosion and Sediment Control Design, install, and maintain effective soil erosion and sedimentation control measures during construction and land disturbance activities. Consideration for final site stabilization should also be included during the development of a SESC Plan.	Develop and implement a Soil Erosion and Sediment Control (SESC) Plan in accordance with local and/or state regulatory requirements, the Connecticut Guidelines for Soil Erosion and Sediment Control Guidelines (as amended), and the requirements of the CT DEEP Construction Stormwater General Permit.
Standard 4 – Post-Construction Operation and Maintenance Perform long-term maintenance of structural stormwater management systems to ensure that they continue to function as designed and implement operational source control and pollution prevention measures.	Develop and implement a long-term Operation and Maintenance (O&M) Plan, which identifies required inspection and maintenance activities for structural stormwater BMPs. Operational source control and pollution prevention practices (see Chapter 6 - Source Control Practices and Pollution Prevention) should be included in the O&M Plan. Refer to Chapter 7 – Overview of Structural Stormwater Best Management Practices for general maintenance guidelines for stormwater BMPs, Chapter 13 – Structural Stormwater BMP Design Guidance for recommended maintenance for specific stormwater BMPs, and Appendix B for BMP-specific maintenance inspection checklists.

Stormwater Management Standard	Performance Criteria
Standard 5 – Stormwater Management Plan Document how the proposed stormwater management measures meet the stormwater management standards, performance standards, performance criteria, and design guidelines.	Prepare a Stormwater Management Plan (see Chapter 12 – Stormwater Management Plan) to document how the proposed stormwater management measures for a specific land development project or activity meet the stormwater management standards, performance criteria, and design guidelines contained in the Connecticut Stormwater Quality Manual, as well as other local, state, and federal stormwater requirements.

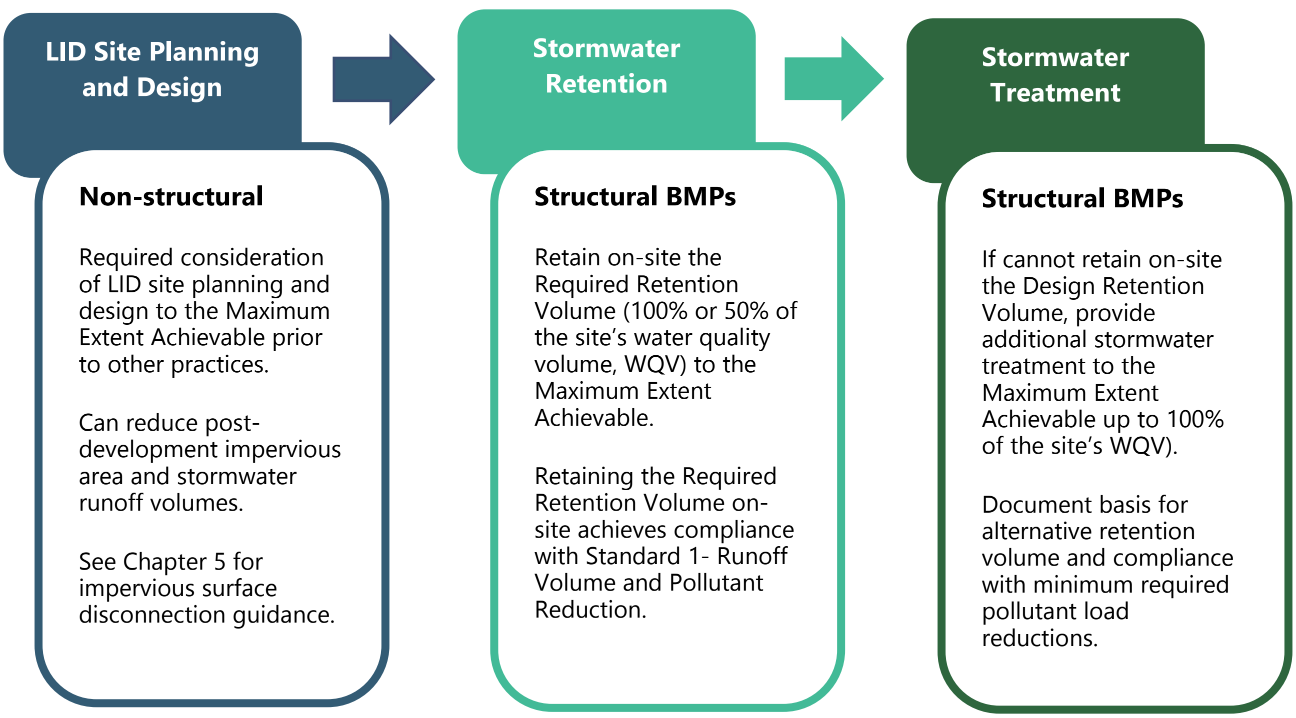
Note: Consult local and state regulations for additional stormwater management requirements. The above standards and criteria are recommended where local or state regulations are less stringent.

Standard 1 – Runoff Volume and Pollutant Reduction

Standard 1 (Runoff Volume and Pollutant Reduction) is intended to preserve pre-development hydrology (runoff duration, rate, and volume) and pollutant loads to protect water quality and maintain groundwater recharge by retaining and/or treating stormwater runoff from smaller, more frequent storms.

Standard 1 requires consideration of non-structural LID site planning and design techniques to reduce and disconnect post-development impervious areas on a site prior to consideration of structural stormwater BMPs. Once LID site planning and design techniques have been applied, structural stormwater BMPs should be used to retain on-site the required post-development stormwater runoff volume (i.e., retention volume) primarily through stormwater infiltration or reuse. If the retention volume for the site cannot be fully retained on-site, additional stormwater BMPs should be used to treat the volume above that which can be retained. Figure 4-1 illustrates schematically the major elements of and general process for complying with Standard 1.

Figure 4-1. Runoff Volume and Pollutant Reduction (Standard 1) Elements and Process



LID Site Planning and Design (non-structural)

Consider the use of non-structural LID site planning and design strategies, to the **MEA** (see the text box below for the definition) prior to the consideration of other practices, including structural stormwater BMPs, consistent with the CT DEEP stormwater general permits. The objective of this is to ensure that non-structural LID site planning and design techniques are considered at an early stage in the planning process and integrated into the project design.

Refer to Chapter 5 - Low Impact Development Site Planning and Design Strategies for performance criteria and design guidance for impervious area disconnection and other non-structural LID site planning and design strategies that can reduce post-development impervious area and stormwater runoff volumes.

Maximum Extent Achievable (MEA) – LID

For demonstrating "maximum extent achievable" regarding the LID Site Planning and Design requirement, a project proponent should demonstrate the following:

1. All reasonable efforts have been made to incorporate the use of LID site planning and design strategies in accordance with current local, state, and federal regulations,
2. A complete evaluation of all possible LID site planning and design strategies has been performed based on consideration of site characteristic, water quality, and other factors, and
3. The highest practicable use of LID site planning and design strategies is incorporated into the project.

The Stormwater Management Plan (Chapter 12 – Stormwater Management Plan) should include:

- LID Site Planning and Design Opportunities and Constraints Plan
- Completed LID Site Planning and Design Checklist documenting the non-structural LID strategies selected for the project and why other non-structural LID strategies could not be incorporated into the project.

Note: These LID principles are requirements of the CT DEEP Construction General Permit and are highly recommended for other categories of stormwater management.

Stormwater Retention and Treatment (structural)

After application of non-structural LID site planning and design strategies to the MEA, select and design structural stormwater BMPs in accordance with this Manual to manage the remaining post-development stormwater runoff volume from the site through on-site retention and treatment.

Stormwater Retention

Retain on-site the applicable post-development stormwater runoff volume **for the site**, referred to as the "Required Retention Volume," using structural stormwater BMPs. The Required Retention Volume is equal to 100% or 50% of the site's Water Quality Volume (WQV) depending on the type of project or activity (new development, redevelopment, or retrofit) and the existing Directly Connected Impervious Area (DCIA) of the site, consistent with the post-construction stormwater management provisions of the CT DEEP stormwater general permits. Refer to Table 4-2 for determining the appropriate Required Retention Volume for a given land development project or activity.

Table 4-2. Required Retention Volume Determination

Type of Project or Activity	Required Retention Volume (RRV)[1]	Additional Treatment Volume Required[1]	
		If Volume Retained Meets or Exceeds RRV	If Volume Retained Does Not Meet RRV
➢ New development[2] ➢ Redevelopment[3] or retrofit of sites that are currently developed with existing DCIA[4] of less than 40% ➢ Any new stormwater discharges located within 500 feet of tidal wetlands, which are not fresh-tidal wetlands, to avoid dilution of the high marsh salinity and encouragement of the invasion of brackish or upland wetland species	100% of site's WQV	None	(100% of site's WQV) – (Volume Retained)
➢ Redevelopment or retrofit of sites that are currently developed with existing DCIA[4] of 40% or more	50% of site's WQV	None	(100% of site's WQV) – (Volume Retained)

[1] Provide stormwater retention or additional treatment without retention to the Maximum Extent Achievable as defined in the CT DEEP stormwater general permits and described in this section.

[2] "New Development" means any construction or disturbance of a parcel of land that is currently in a natural vegetated state and does not contain alteration by man-made activities.

[3] "Redevelopment" means any construction activity (including, but not limited to, clearing and grubbing, grading, excavation, and dewatering) within existing drainage infrastructure or at an existing site to modify, expand, or add onto existing buildings, structures, grounds, or infrastructure.

[4] For the purpose of determining the Required Retention Volume, existing DCIA should be calculated based on the existing (pre-development) conditions of the overall project site.

- "Retention" means to hold post-development runoff on-site using structural stormwater BMPs or non-structural LID site planning and design strategies. In addition, it means there shall be no subsequent point source discharge to the drainage system or surface waters, including bypass of the stormwater BMP through inlet or outlet controls, **of any portion of** the Required Retention Volume. Retention practices reduce post-development runoff volumes and therefore are also called "runoff reduction" practices.

- Table 8-1. Stormwater Management Suitability in Chapter 8 identifies stormwater BMPs and their suitability for meeting the stormwater retention performance criterion. In general, Infiltration BMPs and Stormwater Reuse BMPs are considered suitable retention practices. Infiltration BMPs are preferred for meeting the stormwater retention performance criteria because they also recharge groundwater. Filtering BMPs (bioretention systems, tree filters, and surface sand filters) can provide retention of stormwater when designed specifically for infiltration. Dry water quality swales and green roofs are also suitable for providing stormwater retention.

- Retention practices should be sized to meet or exceed the applicable Required Retention Volume and should be designed, installed, and maintained consistent with the guidelines contained in this Manual to preserve pre-development hydrology and to achieve minimum average annual pollutant load reductions for sediment, floatables, and nutrients.

- In cases where the Required Retention Volume cannot be fully[44] retained on-site, retain stormwater runoff on-site to the "Maximum Extent Achievable" (see text box for demonstrating this) and provide additional stormwater treatment without retention as summarized in Table 4-2. Required Retention Volume Determination and described in the following section.

The Standard 1 stormwater retention requirements can be met at each individual discharge point along the boundary of the development site or internal to the site (i.e., design point) such as abutting properties, roadways, wetlands and watercourses, and receiving storm drainage systems.[45] I Or the Standard 1 retention requirement may also be demonstrated sitewide or for multiple design points.

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[44] Fully means for the site. This can be address through multiple LID strategies, and structural BMPs in series or separately at several discharge points. The element that is important here is the RRV for the entire site.

[45] Per the CTDOT MS4 Permit, linear projects have alternative standards and may take an alternative approach to address constraints that are different than those that affect traditional parcel development projects. These alternative linear project standards can be found in the CTDOT drainage manual, the CTDOT MS4 General Permit, the General Construction Permit and in the supporting materials that CTDOT has developed.

- Appendix C presents calculation methods for designing retention and treatment stormwater BMPs and demonstrating compliance with the Standard 1 retention requirements by demonstrating individual BMPs.

- Pretreatment is necessary for most BMPs and should be provided as necessary (see Table 8-1. Stormwater Management Suitability) guidelines in Chapter 13 – Structural Stormwater BMP Design Guidance.

Maximum Extent Achievable (MEA) – Stormwater Retention*

For the Stormwater Retention requirement, MEA means maximum extent achievable using control measures that are technologically available and economically practicable and achievable considering best industry practice. To demonstrate compliance with the MEA standard for stormwater retention, a project proponent should:

- **Documentation:** Submit documentation for review and approval by the review authority describing site constraints (e.g., brownfields, capped landfills, bedrock, elevated groundwater, etc.) that would prevent on-site retention of the full Design Retention Volume. The documentation should include:
    - An explanation of site limitations
    - A description of the stormwater retention practices implemented
    - An explanation of why this constitutes the Maximum Extent Achievable
    - An alternative retention volume (i.e., the volume that can be retained on-site when the Required Retention Volume cannot be fully retained)
    - A description of the measures used to provide additional stormwater treatment without retention for sediment, floatables, and nutrients above the alternative volume up to the site's WQV
    - Analysis demonstrating that the average annual pollutant load reductions achieved by the proposed stormwater treatment measures meet or exceed minimum required reductions for sediment, floatables, and nutrients. The analysis should use the EPA stormwater BMP performance curves.

AND

- **Offsite Retention Mitigation:** Propose a stormwater retrofit project on another site within the same CT DEEP Subregional Basin or USGS HUC12 watershed (and preferably the same municipality) as the project site, provided the municipality has an offsite mitigation program in place. The proposed retrofit project can be funded directly by the project proponent, or the project proponent can propose a fee to be paid by the project proponent to be deposited into a dedicated account of the municipality for use by the municipality to fund in whole or in part the stormwater retrofit. The fee should be based on an estimate of the cost necessary to implement the retrofit to achieve a similar amount of retention to the amount by which the actual amount of retention fails to achieve the required retention volume for the site. Offsite mitigation is allowed for new development and redevelopment.

***Note:** The term MEA is used, but not specifically defined, in the current MS4 General Permit. The concepts described here are synonymous with the term Maximum Extent Practicable (MEP) of the MS4 General Permit.

- In the case of linear projects that do not involve impervious surfaces (e.g., electrical transmission rights-of-way or natural gas pipelines), stormwater retention is not required if the post-development runoff characteristics do not differ significantly from pre-development conditions.

- In the case of linear redevelopment projects (e.g., roadway reconstruction or widening) for the developed portion of the right of way:

    - For projects that may be unable to retain the Required Retention Volume (50% of the site's WQV), the alternate retention volume and additional treatment measures (see below) may also be applied, OR
    - For projects that will not increase the DCIA within a given CT DEEP Local Basin, the project proponent should implement the additional stormwater treatment measures (see below) but is not required to retain the Required Retention Volume (50% of the site's WQV).
    - For projects that are adding DCIA but unable to meet the retention requirements, the project proponent should prioritize the removal of the pollutant of concern if discharging to an impaired waterbody. If the project is not discharging to an impaired waterbody, the project proponent should prioritize the removal of TSS.

Stormwater Treatment

If the post-development stormwater runoff volume retained on-site does not meet the Required Retention Volume (100% or 50% of the site's WQV) for the site, provide stormwater treatment without retention for the post-development runoff volume above that which can be retained (the "alternate retention volume") up to 100% of the site's WQV (refer to Table 4-2. Required Retention Volume Determination).

Table 8-1. Stormwater Management Suitability identifies stormwater BMPs that can be used to provide stormwater treatment without retention. Treatment practices should be sized for the appropriate WQV or Water Quality Flow (WQF) and should be designed, installed, and maintained consistent with the guidelines contained in this Manual to achieve minimum average annual pollutant load reductions for sediment, floatables, and nutrients.

- Pretreatment is required for most stormwater BMPs and should be provided, as necessary (Table 8-1. Stormwater Management Suitability), in accordance with the design guidelines in Chapter 13 - Structural Stormwater BMP Design Guidance.

- When necessary, meeting Standard 1 through a combination of stormwater retention and treatment may require a treatment train approach – the use of multiple stormwater BMPs in series (e.g., an infiltration BMP sized for a portion of the required retention volume, followed by a treatment BMP to treat the remaining volume **up to** the site's full WQV).

- In cases where the stormwater treatment requirement cannot be fully achieved on-site, provide stormwater treatment to the "Maximum Extent Achievable" (see text box for definition).

Maximum Extent Achievable (MEA) – Stormwater Treatment*

For the Stormwater Treatment requirement, "MEA" means maximum extent achievable using control measures that are technologically available and economically practicable and achievable considering best industry practice. To demonstrate compliance with the MEA standard for stormwater treatment, a project proponent should:

- **Documentation:** Submit documentation for review and approval by the review authority describing site constraints that would prevent on-site treatment of the required treatment volume. The documentation should include:
  - An explanation of site limitations
  - A description of the stormwater treatment practices implemented and an alternative treatment volume (i.e., the volume that can be treated on-site when the required treatment volume cannot be achieved)

AND

- **Offsite Treatment Mitigation:** Propose a stormwater retrofit project on another site within the same CT DEEP Subregional Basin or USGS HUC12 watershed (and preferably the same municipality) as the project site, provided the municipality has an offsite mitigation program in place. The proposed retrofit project can be funded directly by the project proponent, or the project proponent can propose a fee to be paid by the project proponent to be deposited into a dedicated account of the municipality for use by the municipality to fund in whole or in part the stormwater retrofit. The fee should be based on an estimate of the cost necessary to implement the retrofit to achieve a similar amount of treatment to the amount by which the actual amount of treatment fails to achieve the required treatment volume for the site. Offsite mitigation is allowed for new development and redevelopment.

***Note:** The term MEA is used, but not specifically defined, in the current MS4 General Permit. The concepts described here are synonymous with the term Maximum Extent Practicable (MEP) of the MS4 General Permit.

Water Quality Volume

Updated Water Quality Volume

The Water Quality Volume (WQV) concept is based on the “first flush” principle, which assumes that most pollutants in stormwater runoff are conveyed in the initial portion of a storm event. As such, the WQV is the volume of runoff generated by the water quality storm. The water quality storm is defined as the 90th percentile rainfall event (accounting for 90 percent of all 24-hour storms on an average annual basis). The runoff volume associated with the 90th percentile rainfall depth roughly corresponds to the volume of runoff that is infiltrated in a natural condition and thus should be managed on-site to restore and maintain pre-development hydrology for duration, rate, and volume of stormwater flows.[46]

Prior to this update, the water quality storm was defined as the 1-inch storm. This version of the Manual replaces the previous 1-inch water quality storm with an updated 90th percentile rainfall depth of 1.3 inches. Specifically, this represents the average of 90th percentile rainfall depths calculated for several locations throughout Connecticut using daily precipitation observations over an approximately 40-year period of record (1980-2021) and the procedure cited in EPA technical guidance (see Appendix G for further information).

Water Quality Volume Calculation

As described above, the WQV is a key factor in determining the Required Retention Volume and any additional treatment requirements. The WQV is the volume of stormwater runoff from a given storm event that must be retained and/or treated to remove most of the post-development stormwater pollutant load on an average annual basis and to help maintain pre-development site hydrology in terms of duration, rate, and volume of stormwater flows including groundwater recharge. The WQV is calculated using the following equation:

$$WQV = \frac{(P)(R)(A)}{12}$$

where:

WQV = water quality volume (cubic feet)
P = 1.3 inches (90^{th} percentile rainfall event)
R = volumetric runoff coefficient = 0.05+0.009(I)
I = post- development impervious area (percent) after application of non-structural LID site planning and design strategies and before application of structural stormwater BMPs
A = post-development total drainage area of site or design point (square feet)

[46] USEPA. Section 438 Technical Guidance December 2009. Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act. EPA 841-B-09-001. December 2009. www.epa.gov/owow/nps/lid/section438.

- For the WQV calculation, impervious area (*I*) should be measured from the post-development site plan and includes all directly connected impervious surfaces (DCIA as defined in this Manual) within boundaries of the site or for the drainage area of the each design point.

- Impervious areas that drain as sheet flow onto and over an adjacent pervious area that, due to its size, slope, vegetation, and underlying soil characteristics, meets the criteria for "simple disconnection criteria for "impervious area (simple) disconnection" can be subtracted from the post development impervious area term in the WQV equation. This provides further incentive to use simple disconnection and other non-structural LID site planning and design strategies to reduce the need for and size of structural stormwater BMPs to meet the retention and treatment performance criterion.

Water Quality Flow

The Water Quality Flow (WQF) is the peak flow rate associated with the water quality storm or WQV, as described above. Although most of the structural stormwater BMPs in this Manual should be sized based on a design volume (Required Retention Volume and any additional treatment volume), some BMPs such as grass channels and proprietary treatment/pretreatment BMPs should be designed based on peak flow rate. In this approach, the stormwater BMP (including inlet structure) must have a flow rate capacity equal to or greater than the design WQF in order to prevent bypass and treat the associated design WQV for the site. Flow diversion structures (also called flow splitters) are typically used to bypass flows in excess of the design WQF for off-line stormwater BMPs.

The design WQF is calculated based on the design WQV for the site using a modified NRCS Runoff Curve Number for small storm events. The procedure is based on the approach described in Claytor and Schueler, 1996.[47] The Inlet and Outlet Controls section of Chapter 13 - Structural Stormwater BMP Design Guidance provides design guidance for flow diversion structures.

Demonstrating Compliance with Standard 1

Stormwater management systems should be designed to achieve the average annual pollutant load reductions from directly connected impervious area for sediment (Total Suspended Solids) and nutrients (Total Phosphorus and Total Nitrogen) shown in Table 4. 3.

Achieving these minimum required load reductions for sediment and nutrients is assumed to provide adequate reductions of other stormwater pollutants including floatable materials. However, it is important to note that if the full retention goal (i.e., Required Retention Volume) is

[47] Claytor, R.A. and T. R. Schueler. 1996. Design of Stormwater Filtering Systems. Center for Watershed Protection. Silver Spring, Maryland.

met, then it is assumed pollutant reduction is also achieved and individual pollutant calculations are not necessary.

Table 4. 3 Minimum Average Annual Pollutant Load Reductions When Evaluating BMP Selection and Sizing (Only needed when additional stormwater treatment is needed[1])

Water Quality Parameter	New Development	Redevelopment/Retrofits
Total Suspended Solids (TSS)	90%	80%
Total Phosphorus (TP)	60%	50%
Total Nitrogen (TN)	40%	30%

[1] Pollutant load reduction percentages are calculated based on average annual loading and not based on any individual storm event. Load reductions based on post-construction stormwater management standards contained in the EPA Massachusetts MS4 General Permit.

- A proposed stormwater management system meets or exceeds these average annual pollutant load reductions when the Required Retention Volume is retained on-site using suitable stormwater retention practices (refer to Figure 8- 1).[48]

- If the stormwater runoff volume retained on-site does not meet the Required Retention Volume (100% or 50% of the site's WQV), and therefore additional stormwater treatment is required, the project proponent should document that the proposed stormwater management system meets or exceeds the minimum required average annual pollutant load reductions through the use of EPA Region 1 stormwater BMP performance curves (see the following section).

Stormwater BMP Performance Curves

EPA Region 1 developed performance curves to help quantify the pollutant reduction benefits of structural stormwater BMPs. The curves provide estimates of the long-term cumulative pollutant removal performance of a BMP as a function of the BMP size (physical storage capacity). The curves were developed using EPA's Stormwater Management Model and long-term rainfall data from Boston, Massachusetts to simulate rainfall-runoff and pollutant loading and removal during rain events in New England. The models were calibrated and tested with performance data from stormwater controls evaluated by the University of New Hampshire Stormwater Center. The curves relate the depth of runoff treated from the impervious area to average annual pollutant reduction for various types of structural stormwater BMPs and stormwater pollutants. Curves have been developed for TSS, TP, TN, Zinc, fecal indicator bacteria (*E. coli* and Enterococcus), and runoff reduction. Multiple curves have been developed for stormwater

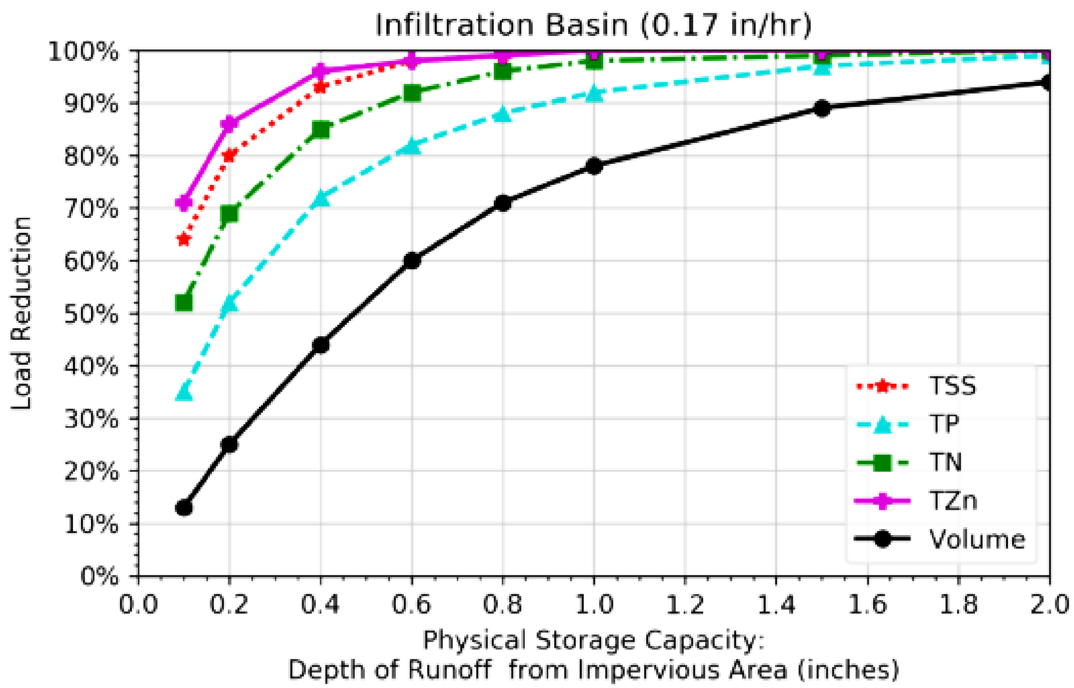
[48] On-site retention of the Required Retention Volume (100% or 50% of the site's WQV) using stormwater BMPs designed in accordance with the guidelines in this Manual is assumed to achieve average annual pollutant load reductions that exceed the minimum required values in Table 4-3 based on EPA Region 1 stormwater BMP performance curves.

infiltration BMPs to represent various soil conditions, land uses and infiltration rates. The curves can be used to size stormwater BMPs and to quantify the pollutant removal benefit (i.e., credit) for a range of sizes and types of BMPs.

Figure 4- 2 shows a typical set of BMP performance curves for an infiltration basin in Type B soils. In this example, an infiltration basin designed with a physical storage volume equivalent to the runoff volume created by the first 1 inch of runoff of precipitation over the contributing impervious area will result in average annual load reductions of approximately 100% for TSS, 92% for TP, and 98% for TN. The curves also demonstrate that:

- Structural stormwater BMPs sized to store less than 1 inch of runoff from the impervious area can still achieve substantial pollutant load reductions, which allows for the use of smaller structural controls for retrofit applications and on sites with limited space and other physical constraints, while still meeting pollutant removal goals.
- Structural stormwater BMPs provide diminishing pollutant reduction benefits above a certain size (the "knee" in the curve), although on-site retention of stormwater volumes **up to** the Required Retention Volume (100% or 50% of the site's WQV) is important to maintain pre-development hydrology (i.e., volume, rate, and temperature of runoff) and groundwater recharge.

Figure 4- 2 Example Stormwater BMP Performance Curves for Infiltration Basin in Type B Soils



Source: University of New Hampshire Stormwater Center

Use of Performance Curves to Demonstrate Compliance with Minimum Required Pollutant Load Reductions for Individual BMPs

When the Required Retention Volume cannot be retained on-site, and therefore additional stormwater treatment is required, the stormwater BMP performance curves should be used to document that the proposed stormwater management system meets or exceeds the minimum required pollutant load reductions listed in Table 4. 3. The following procedure should be used:

1. Calculate the runoff depth from the impervious area BMP can statically store the following equation:

$$Depth\ of\ Runoff\ from\ Impervious\ Area\ (inches) = \frac{V}{DCIA} * 12\frac{inches}{foot}$$

   where:

   V = BMP static storage volume (cubic feet)
   $DCIA$ = post-development Directly Connected Impervious Area (square feet) draining to the BMP after application of non-structural LID site planning and design strategies

   - The static storage volume is the volume of stormwater a structural stormwater BMP can physically hold. It includes the BMP's permanent storage volume (ponding above the surface, voids in subsurface engineered media, and subsurface structures such as chambers or tanks) but does not include the volume associated with peak rate attenuation control (volume above the primary outlet). It also doesn't include the additional treatment volume as a result of the water that infiltrates into the underlying soil while the system is filling or stormwater that bypasses the system through inlet or outlet controls.

   - Appendix C provides the corresponding EPA stormwater BMP performance curves and equations for calculating the static storage volume for each type of structural stormwater BMP presented in this Manual.

2. With the calculated Depth of Runoff from Impervious Area, use the appropriate stormwater BMP performance curves in Appendix C to obtain the average annual pollutant load reduction percentages of the BMP for TSS, TP, and TN.

3. If the pollutant load reduction percentages provided by the BMP meet or exceed the minimum required pollutant load reductions in Table 4. 3 (for all three pollutants), then the proposed stormwater management system meets the pollutant reduction performance criteria.
4. If the pollutant load reduction percentages provided by the BMP are less than the minimum required pollutant load reductions in Table 4. 3 (for any of the three pollutants), then the proposed stormwater management system does not meet the

pollutant reduction performance criteria, and the system should be increased in size to achieve the minimum required pollutant load reduction(s) or another BMP should be selected. In this situation, the curves should be used in “reverse” to determine the required Depth of Runoff from Impervious Area and required static storage volume to achieve the target pollutant load reduction.

5. When multiple stormwater BMPs are used in series to provide treatment or a combination of retention and treatment, the BMP performance curves should be used to calculate the individual average annual pollutant load reduction percentages for each BMP in the treatment train. The overall average annual pollutant load reductions for the entire treatment train should be calculated using one of the following approaches:

   - Use the equation below for two treatment BMPs in series when both BMPs treat the same water as it flows from one BMP to the next:

     $$R = (A + B) - \frac{(A \times B)}{100}$$

     where:

     R = total pollutant load reduction (%)
     A = pollutant load reduction of first or upstream BMP (%)
     B = pollutant load reduction of second or downstream BMP (%)

   - For more BMPs in series when all of the BMPs treat the same water as it flows from one BMP to the next, calculate the total pollutant load reduction percentage by successively applying the pollutant load reductions of each individual BMP to the load entering from the upstream BMP. For example:

     - Initial TSS Load Upstream of BMP 1 = 1.0
     - TSS Load Removed by BMP 1 = 1.0 x 60% Removal Rate = 0.6
     - Remaining TSS Load Downstream of BMP 1 = 1.0 – 0.6 = 0.4
     - TSS Load Removed by BMP 2 = 0.4 x 50% Removal Rate = 0.2
     - Final TSS Load Downstream of BMP 2 = 0.4 – 0.2 = 0.2
     - Total TSS Removal Rate = 1.0 – 0.2 = 0.8 or 80%

   - When the upstream BMP bypasses without treatment a portion of the Required Retention Volume to a downstream BMP (i.e., the two BMPs do not treat the same water), obtain the pollutant load reductions for each individual BMP from the performance curves based on their respective static storage volumes. Then calculate the overall pollutant load reduction efficiency of the treatment train as the weighted average of the load reductions of the individual BMPs, weighted by the respective static storage volumes.

Standard 2 – Stormwater Runoff Quantity Control

The objective of Standard 2 (Stormwater Runoff Quantity Control) is to maintain pre-development peak runoff rates and manage the volume and timing of runoff to prevent downstream flooding, channel erosion, and other adverse impacts resulting from development. The associated performance criteria address relatively frequent events that cause channel erosion and larger events that result in bankfull and overbank flooding. The stormwater runoff quantity control standard also addresses the design of stormwater conveyance systems associated with stormwater BMPs to safely manage flows during larger storms. Figure 4- 3 illustrates schematically the major elements of Standard 2.

Figure 4- 3 Stormwater Runoff Quantity Control (Standard 2) Elements

Peak Runoff Attenuation for Site Development\ Redevelopment

2,10,100-yr, 24-hr Storms

Control the 2-yr post development peak flow rate to 50% of predevelopment rate.

Control the 10-yr post development peak flow rate to pre-development rate.

Potentially Control the 100-year post development peak flow rate to pre-development rate, as required by review authority.

Conveyance Protection

10-yr, 24-hr Storm

For on-line structural stormwater BMPs, design the conveyance system leading to, from, and through the stormwater BMPs based on the 10-yr or larger storm event.

Design conveyance system based on peak flow rate of the largest storm for which peak runoff attenuation is provided (i.e., 10-yr storm or larger up to 100-year storm).

Emergency Outlet Sizing

100-yr, 24-hr Storm

For on-line stormwater quantity control BMPs, size the emergency outlet of stormwater quantity control structures to safely pass the post-development peak flow rate from the 100-year storm event or larger storm (at the discretion of the review authority) in a controlled manner without eroding the outlet and downstream drainage systems.

Note: The storms for peak runoff attenuation control should be verified with the appropriate review authority. The examples provided above represent the storms storm events most often required by municipalities. However, some review authorities may have different requirements. In addition, please note that CT DEEP's Construction Stormwater General Permit only requires peak run off attenuation evaluation and control only for large-scale solar project with regards to the 2, 25, 50 and 100-year 24-hour storms.

The Standard 2 stormwater quantity control criteria should be met at each individual discharge point along the boundary of the development site or internal to the site (i.e., design point) such as abutting properties, roadways, wetlands and watercourses, and receiving storm drainage systems.

Linear projects have alternative standards and may take an alternative approach to address constraints that are different than those that affect traditional parcel development projects. These alternative linear project standards can be found in the CTDOT drainage manual, the

CTDOT MS4 General Permit, the General Construction Permit and in the supporting materials that CTDOT has developed.

Stormwater Quantity Control Design Storms

Stormwater quantity controls are designed to manage peak rates of runoff from storm events of various sizes, which are also called “design storms.” Stormwater quantity control design storms are defined in terms of rainfall depth and duration, recurrence interval (i.e., the likelihood or probability of the occurrence of a certain size storm event), and rainfall distribution (i.e., how rain falls during a storm event).

Updated Stormwater Quantity Control Design Storm Rainfall

NOAA Atlas 14 (and subsequent generations of NOAA precipitation-frequency products) replaces Technical Paper No. 40 (TP-40) as the definitive source of design rainfall in Connecticut. The version of NOAA Atlas 14 for the northeastern United States, including Connecticut, was released in 2015 and revised in 2019. NOAA Atlas 14 contains precipitation frequency estimates for selected durations and frequencies with associated lower and upper bounds of the 90% confidence interval (5% lower and 95% upper confidence limits). NOAA Atlas 14 is a significant improvement over the TP-40 precipitation estimates since it includes more observation locations, more sophisticated statistical analysis methods, a much longer period of record, and more recent precipitation data, thereby accounting for observed increases in extreme precipitation as the climate has become warmer and wetter. NOAA Atlas 14 has also been adopted by CT DEEP as the source of design storm precipitation in the Construction Stormwater General Permit and in the CTDOT Transportation MS4 Permit. CTDOT has incorporated the use of NOAA Atlas 14 precipitation frequency estimates in the CTDOT Drainage Manual. The NOAA Atlas 14 results are published online through the Precipitation Frequency Data Server.

Stormwater runoff quantity control design storms in Connecticut should be based on:

- **Rainfall Depth and Duration:** 24-hour precipitation depth with a specified recurrence interval as defined by the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 (or latest generation of this product at the time of the site planning) precipitation frequency estimates,[49] or equivalent regional or state rainfall probability information developed from NOAA Atlas 14. Designs should be based on, at a minimum, the 50th percentile (median) NOAA Atlas 14 precipitation depth, which is the primary value reported by the online Precipitation Frequency Data Server (PFDS). The review authority

[49] NOAA Atlas 14 Volume 10 Version 3, Precipitation-Frequency Atlas of the United States, Northeastern States. NOAA, National Weather Service, 2015, revised 2019. https://www.weather.gov/media/owp/oh/hdsc/docs/Atlas14_Volume10.pdf

may require at their discretion the use of greater 24-hour precipitation depths such as the upper bound of the 90% confidence interval (also reported by the PFDS) to account for larger and more intense observed storm events.

- NOAA Atlas 14 (or latest generation of this product at the time of the site planning) precipitation frequency estimates should be selected for the project site based on the site address, latitude/longitude coordinates, or by clicking on the approximate center of the site.
- "Precipitation depth" and "Partial duration" time series type should be selected from the dropdown menus.
- Select precipitation depths from the storm duration row labeled "24-hour" (see Figure 4- 4).
- County-wide average 24-hour precipitation depths derived from NOAA Atlas 14 (or latest generation of this product at the time of the site planning) may also be used, provided that the county-wide average values are representative of the project site and the values are based on the latest version of NOAA Atlas 14. Such values have been incorporated as standard options in hydrologic analysis software such as HydroCAD. However, site-specific precipitation estimates obtained from the NOAA Atlas 14 Precipitation Frequency Data Server are preferred.

- **Rainfall Distribution:** Natural Resources Conservation Service (NRCS) Type D regional rainfall distribution, which is derived from the NOAA Atlas 14 rainfall data (referred to as "NOAA_D" rainfall distribution). Other equivalent regional rainfall distributions specifically developed for use in Connecticut, or a site-specific rainfall distribution based on NOAA Atlas 14 data, may be used for design purposes at the discretion of the review authority.[50]

[50] USDA Natural Resources Conservation Service. 2018. Connecticut Instruction 210-397 – Using NOAA Atlas 14, Volume 10 Extreme Precipitation Data with WinTR-55 in Connecticut, January 24, 2018. file:///F:/P2020/0636/A11/Background%20Documents/Climate%20Change%20and%20Precipitation/Win%20TR-20%20Rainfall%20Distributions/CT_INSTRUCTION_210-397-WinTR-55_NOAA.pdf

Updated Rainfall Distribution

The NOAA_D rainfall distribution replaces the NRCS Type III regional distribution, which has historically been used in Connecticut and other Atlantic coastal areas, as well as the Northeast Regional Climate Center (NRCC) regional rainfall distributions developed in 2015. In 2018, Connecticut NRCS began recommending the use of the NOAA_D regional rainfall distribution throughout Connecticut. The NRCS NOAA_D rainfall distribution is available as a standard rainfall distribution in hydrologic analysis software such as WinTR-55. In HydroCAD, the NRCC_D distribution is available as a pre-defined rainfall distribution for Connecticut, while NOAA_D is not. NOAA_D may be created as a user-defined rainfall distribution in HydroCAD. The NOAA_D rainfall distribution is available online in text format.

Figure 4- 4 24-hour Design Storm Rainfall Depths from NOAA Atlas 14 Precipitation Frequency Data Server

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 10, Version 3

PF tabular | PF graphical | Supplementary information

Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.332 (0.259-0.415)	0.405 (0.315-0.506)	0.523 (0.406-0.656)	0.621 (0.479-0.784)	0.756 (0.565-1.00)	0.858 (0.629-1.16)	0.965 (0.686-1.36)	1.08 (0.730-1.57)	1.25 (0.813-1.88)	1.39 (0.881-2.13)
10-min	0.471 (0.367-0.588)	0.573 (0.447-0.717)	0.740 (0.574-0.929)	0.879 (0.679-1.11)	1.07 (0.800-1.42)	1.22 (0.890-1.65)	1.37 (0.971-1.93)	1.54 (1.03-2.22)	1.78 (1.15-2.67)	1.97 (1.25-3.02)
15-min	0.554 (0.432-0.692)	0.675 (0.525-0.843)	0.872 (0.677-1.09)	1.04 (0.800-1.31)	1.26 (0.942-1.67)	1.43 (1.05-1.94)	1.61 (1.14-2.26)	1.81 (1.22-2.61)	2.09 (1.35-3.13)	2.32 (1.47-3.56)
30-min	0.761 (0.593-0.950)	0.922 (0.718-1.15)	1.19 (0.921-1.49)	1.41 (1.09-1.78)	1.71 (1.27-2.26)	1.93 (1.42-2.62)	2.17 (1.54-3.06)	2.44 (1.64-3.52)	2.82 (1.83-4.23)	3.14 (1.99-4.81)
60-min	0.968 (0.755-1.21)	1.17 (0.912-1.46)	1.50 (1.17-1.88)	1.78 (1.37-2.24)	2.15 (1.61-2.85)	2.44 (1.79-3.30)	2.74 (1.95-3.86)	3.07 (2.07-4.44)	3.56 (2.30-5.33)	3.95 (2.50-6.06)
2-hr	1.28 (1.00-1.59)	1.53 (1.20-1.90)	1.95 (1.52-2.42)	2.29 (1.78-2.87)	2.76 (2.08-3.64)	3.11 (2.30-4.20)	3.49 (2.51-4.92)	3.93 (2.66-5.65)	4.59 (2.99-6.85)	5.15 (3.27-7.84)
3-hr	1.49 (1.18-1.84)	1.78 (1.40-2.20)	2.25 (1.77-2.80)	2.65 (2.07-3.31)	3.19 (2.42-4.19)	3.60 (2.67-4.84)	4.03 (2.92-5.67)	4.55 (3.09-6.51)	5.34 (3.48-7.93)	6.01 (3.82-9.11)
6-hr	1.89 (1.50-2.31)	2.26 (1.80-2.77)	2.87 (2.28-3.54)	3.38 (2.67-4.19)	4.09 (3.12-5.33)	4.60 (3.45-6.17)	5.17 (3.77-7.24)	5.85 (3.98-8.32)	6.89 (4.51-10.2)	7.79 (4.97-11.7)
12-hr	2.32 (1.86-2.82)	2.81 (2.25-3.42)	3.61 (2.89-4.41)	4.27 (3.40-5.26)	5.19 (3.99-6.73)	5.87 (4.42-7.81)	6.60 (4.84-9.19)	7.49 (5.13-10.6)	8.86 (5.81-13.0)	10.0 (6.42-15.0)
24-hr	2.72 (2.21-3.28)	3.35 (2.71-4.05)	4.38 (3.53-5.32)	5.23 (4.20-6.39)	6.41 (4.98-8.28)	7.28 (5.54-9.65)	8.23 (6.09-11.4)	9.41 (6.46-13.2)	11.3 (7.41-16.4)	12.9 (8.25-19.1)

While precipitation frequency estimates published in NOAA Atlas 14 reflect observed increases in extreme precipitation over the last several decades, NOAA Atlas 14 does not account for anticipated future increases in extreme precipitation due to projected climate change. The NOAA Atlas 14 analysis methods assume stationarity in both the historical data used in making the estimates and in future conditions. This assumption may not be appropriate under changing (i.e., non-stationary) climatic conditions. NOAA is working with several research universities to develop precipitation frequency estimates that account for non-stationary climate assumptions and factor in climate projections; however, that product was not available as of the revision date of this Manual and is therefore not specifically addressed in this Manual. To account for the best science, including current and projected future rainfall, this Manual recommends the inclusion of the most recent generation of NOAA Atlas precipitation frequency products at the time of the site planning.

Peak Runoff Attenuation for Site Development and Redevelopment

Select and design stormwater BMPs (structural or non-structural measures) in accordance with the appropriate permits and the guidance contained in this Manual to control stormwater runoff quantity impacts, including flooding and erosive flows. The peak runoff attenuation criterion is intended to address increases in peak flow rates associated with a range of design storms, including events that result in bankfull flow conditions (typically the 2-year storm, which controls the form of the stream channel) and larger storms that cause overbank flooding.

- Through hydrologic and hydraulic analysis, calculate pre-development and post-development peak flow rates for the 2-year, 10-year, and potentially the 100-year 24-hour storms for each point at which stormwater discharges from a site (i.e., design point).

The following criteria should be met for each design point using structural stormwater BMPs:

- Control the 2-year, 24-hour post-development peak flow rate to 50% of the 2-year, 24-hour pre-development peak flow rate.

- Control the 10-year, 24-hour post-development peak flow rate to the 10-year, 24-hour pre-development peak flow rate.

The following criteria may be required at the discretion of the review authority:

- Potentially control the 100-year, 24-hour post-development peak flow rate to the 100-year, 24-hour pre-development peak flow rate.

- Demonstrate that any increase in volume or change in timing of stormwater runoff (for any design storm event) will not result in adverse effects such as increased flooding downstream of the site or at other off-site locations. Delaying the release of stormwater using detention/storage BMPs to attenuate peak flow rates, combined with upstream peak discharge (i.e., coincident peak flows), can also result in increases in peak flows at critical downstream locations such as road culverts and areas prone to flooding and is most pronounced for detention structures in the middle to lower third of a watershed.

The review authority may waive compliance with one or more of the peak runoff attenuation requirements under the following circumstances:

- Peak runoff attenuation may be waived for the 2-year, 24-hour storm event for sites having less than 1 acre of DCIA because the size of the orifice or weir required for extended detention becomes too small (approximately 1 inch in diameter) to effectively operate without clogging.
- Peak runoff attenuation may be waived for the 2-year, 10-year, and 100-year 24-hour storm events for sites that discharge stormwater directly into a large river (fourth order or greater), lake, or tidal waters where the development area is less than 5 percent of the watershed area upstream of the development site. If the stormwater runoff from a site will flow over or past another property, or discharge to a storm sewer or other conveyance, before reaching any of the above waterbodies, the project proponent should demonstrate compliance with the peak runoff attenuation performance criterion.
- When a downstream analysis indicates that peak discharge control would not be beneficial or would exacerbate peak flows in downstream areas through coincident peak flows.

The review authority, at its discretion, may require the project proponent to evaluate pre- and post-development peak runoff rates and provide peak runoff attenuation for other design storms including more intense, shorter-duration storms to reflect potential changes in rainfall characteristics due to climate change or other factors.

Stormwater Retention and Adjusted Runoff Curve Number

Retention or infiltration of the water quality design storm to meet the runoff volume and pollutant reduction requirements of Standard 1 may also reduce the peak rate of runoff for stormwater runoff quantity control design storms. A reduced NRCS runoff curve number (CN) may be used in peak flow rate calculations when stormwater is retained on-site through infiltration or reuse, either using impervious area (simple) disconnection (see Chapter 5 - Low Impact Development Site Planning and Design Strategies) or a stormwater infiltration system designed to fully infiltrate the Required Retention Volume (100% or 50% of the site's WQV).

For impervious area disconnection, the disconnected impervious area should be assigned a CN corresponding to the type of vegetation used for the qualifying pervious area (e.g., grass/lawn, brush or forest) in fair condition.

For stormwater infiltration systems, an adjusted CN for the area draining to the infiltration system should be determined for each design storm using the following method:

- Calculate the volume of stormwater retained by the infiltration system (see Chapter 10 - General Design Guidance for Stormwater Infiltration Systems and BMP-specific design guidance in Chapter 13).

- Calculate the stormwater runoff volume for the water quality storm and the 2-, 10-, and 100-year, 24-hour storms as described in this chapter.
- Subtract the volume of stormwater retained by the infiltration system from the stormwater runoff volume for the various storm events. The result is the runoff volume that will be discharged from the infiltration system during each storm event.
- Convert the volume of stormwater discharged from the infiltration system to an equivalent discharge depth (in inches) by dividing the volume discharged by the area draining to the infiltration system.
- Using the calculated discharge depth described above and the precipitation for each design storm event, calculate the adjusted CN values using the equation or graphical solution (Figure 2-1 from TR-55) presented in Appendix D of this Manual (i.e., Graphical Peak Discharge Method).

Once the adjusted CN values are determined, also calculate the time of concentration and either follow the remaining steps in the Graphical Peak Discharge Method in Appendix D or use a stormwater hydrologic/hydraulic routing model based on the NRCS Curve Number method (e.g., HydroCAD or similar software) to calculate peak discharge rates for each design storm event.

Downstream Analysis for Site Development and Redevelopment

A downstream hydrologic and hydraulic analysis may be required, at the discretion of the review authority, to demonstrate that increased volume or change in timing of stormwater runoff (for any design storm event) will not increase flooding downstream of the site or at other off-site locations. A downstream analysis may also be required when existing conditions are already causing known drainage or flooding conditions or existing channel erosion at or downstream of the project site or at other off-site locations.

The downstream analysis should include the following elements:

- Routing calculations should proceed downstream to a confluence point where the site drainage area represents 10 percent of the total drainage area above the point (i.e., the "10 percent rule").
- Calculation of peak flows, velocities, and hydraulic effects at critical downstream locations (stream confluences, culverts, other channel constrictions, and flood-prone areas) to the confluence point where the 10 percent rule applies.
- The analysis should use an appropriate hydrograph routing method, such as routing employed by TR-20, to route the pre- and post-development runoff hydrographs from the project site to the downstream critical locations.

- The analysis should include the analysis of impacts of existing land uses and projected land uses assuming full development under existing zoning and land use ordinances in the drainage area.

- A downstream analysis is not required if a project proponent can demonstrate through hydrologic and hydraulic analysis that, for stormwater leaving the site, the post-development runoff hydrograph does not exceed the pre-development hydrograph at any point in time for the same design storm event. This typically requires on-site retention/infiltration of stormwater to maintain or reduce pre-development runoff volumes and peak flow rates.

If flow rates and velocities at critical downstream locations increase by less than 5% from the pre-developed condition, and no existing structures are adversely impacted including exceedance of freeboard clearances and allowable flow velocities, then no additional analysis is necessary. Otherwise, the project proponent should redesign the stormwater quantity controls on the site and/or propose corrective actions to the impacted downstream areas.

Conveyance Protection

For structural stormwater BMPs designed in an "on-line" configuration, design the conveyance system leading to, from, and through structural stormwater BMPs based on the 10-year, 24-hour. At a minimum. On-line stormwater BMPs should be designed based on the peak flow rate of the largest storm for which peak runoff attenuation is provided (i.e., 10-yr, 24-hour storm event or larger up to the 100-year, 24-hour storm). This criterion is designed to prevent erosive flows within internal and external conveyance systems associated with stormwater BMPs such as channels, ditches, berms, overflow channels, and outfalls.

The review authority may also require the use of larger magnitude design storms for conveyance systems associated with stormwater BMPs, including stormwater drainage systems upstream or downstream of the BMPs. Such drainage systems should be designed in accordance with the Connecticut Department of Transportation Drainage Manual as well as applicable local and state design and permitting requirements.

Off-line stormwater BMPs (i.e., designed to manage and convey peak flows up to the water quality storm and bypass higher flows) should be designed with a bypass or overflow for flows larger than the water quality storm.

Emergency Outlet Sizing

Size the emergency outlet of stormwater quantity control BMPs to safely pass the post-development peak flow from the 100-year, 24-hour storm event (or larger storm events at the discretion of the review authority) in a controlled manner without eroding the outlet and downstream drainage systems. Emergency outlets constructed in natural ground are generally preferable to constructed embankments. This requirement is only applicable to stormwater management facilities that are designed in an "on-line" configuration and for the purpose of providing stormwater quantity control.

Standard 3 – Construction of Soil Erosion and Sediment Control

Effective soil erosion and sedimentation control measures should be designed, installed, and maintained during construction and land disturbance activities. Project proponents must develop and implement a Soil Erosion and Sediment Control (SESC) Plan in accordance with local and/or state regulatory requirements, the Connecticut Guidelines for Soil Erosion and Sediment Control, as amended (Guidelines), and the requirements of the CTDEEP General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities. The SESC Plan documents how the proposed activities are consistent with the performance criteria in the Guidelines. The SESC Plan should be included as part of the Stormwater Management Plan (see Chapter 12).

Standard 4 – Post-Construction Operation and Maintenance

Ongoing maintenance is critical to ensure that structural stormwater BMPs continue to function as designed. Project proponents must develop and implement a long-term Operation and Maintenance (O&M) Plan, which identifies required inspection and maintenance activities for structural stormwater BMPs.

The O&M Plan should include, at a minimum, detailed inspection and maintenance tasks, schedules, responsible parties, and financing provisions. Operational source control and pollution prevention measures for the site (see Chapter 6 - Source Control Practices and Pollution Prevention) should also be described in the O&M Plan. The O&M Plan should be included as part of the Stormwater Management Plan (see Standard 5).

Standard 5 – Stormwater Management Plan

A Stormwater Management Plan is required to document how the proposed stormwater management measures for a specific land development project or activity meet the stormwater management standards, performance criteria, and design guidelines contained in the Connecticut Stormwater Quality Manual, as well as other local, state, and federal stormwater requirements. Refer to Chapter 12 for more information on developing a Stormwater Management Plan.

Chapter 5 – Low Impact Development Site Planning and Design Strategies

Introduction

What's New in this Chapter?

- Replaces and integrates the 2011 Low Impact Development Appendix into the revised Manual
- Streamlines content to focus on non-structural LID site planning and design strategies (Chapters 7 through 13 address structural LID measures)
- Provides design guidance for impervious area (simple) disconnection
- Incorporates LID credits to help quantify the benefits and incentivize the use of certain non-structural site planning and design techniques for meeting the runoff volume and pollutant reduction standard in Chapter 4 - Stormwater Management Standards and Performance Criteria

This chapter addresses the use of Low Impact Development (LID) site planning and design strategies to reduce stormwater runoff volumes and pollutant discharges. LID site planning and design is a non-structural approach for avoiding or reducing the impacts of development on natural site hydrology, which can minimize the need for structural stormwater Best Management Practices (BMPs).

Stormwater Management Standard 1, as described in Chapter 4 - Stormwater Management Standards and Performance Criteria of this Manual, requires project proponents to consider the use of LID site planning and design strategies, to the Maximum Extent Practicable, to reduce and disconnect post-development impervious areas on a site prior to consideration of structural stormwater BMPs. Once LID site planning and design techniques have been considered and applied appropriately, structural stormwater BMPs should be used to retain on-site or treat the remaining required post-development stormwater runoff volume. This approach incorporates LID as the industry standard for all sites and encourages the integration of non-structural LID techniques early in the site planning and design process, consistent with the CT DEEP stormwater general permits.

This chapter provides guidance on the use of LID site planning and design strategies, including LID credits for common impervious area reduction and disconnection techniques, to help project proponents use these measures to meet the runoff volume and pollutant reduction requirements of Standard 1. Local development regulations and ordinances often dictate the extent to which these strategies can be applied for a particular project. Therefore, communities may need to revise their local land use regulations and ordinances to allow the use of these strategies. This chapter also provides guidance to communities for revising local land use regulations to enable and encourage the use of LID site planning and design strategies.

What is LID?

Low Impact Development (LID) is a site design and stormwater management strategy that maintains, mimics, or replicates pre-development hydrology through the use of numerous site design principles and small-scale structural stormwater practices distributed throughout a site to manage runoff volume and water quality at the source. LID includes the use of both non-structural site planning and design techniques, which are addressed in this chapter, and the use of distributed, small-scale structural stormwater BMPs, which are addressed in Chapter 13 - Structural Stormwater BMP Design Guidance and other sections of this Manual.

The fundamental objective of LID is to *avoid*, *reduce*, and *manage* the adverse impacts of development or redevelopment sites while still enabling the intended use of the site and enhancing the development relative to conventional development. The over-arching goals of LID and associated principles for achieving these goals are as follows:[51]

1. **Avoid Impacts**
    a. Protect as much undisturbed open space as possible to maintain pre-development hydrology and allow precipitation to naturally infiltrate into the ground.
    b. Maximize the protection of natural drainage areas, streams, surface waters, wetlands, and jurisdictional wetland buffers.
    c. Minimize land disturbance, including clearing and grading, and avoid areas susceptible to erosion and sediment loss.
    d. Minimize soil compaction and restore soils that were compacted due to construction activities or prior development
    e. Preserve the natural water cycle.
2. **Reduce Impacts**
    a. Provide low-maintenance, native vegetation that encourages water retention and minimizes the use of lawns, fertilizers, and pesticides.
    b. Minimize new impervious surfaces.
    c. Match as closely as possible the pre-development or natural site runoff characteristics in terms of volume and timing of runoff (mimic the natural water cycle).
3. **Manage Impacts at the Source**
    a. Break up or disconnect the flow of runoff from impervious surfaces by directing it to adjacent pervious, vegetated surfaces (disconnect).
    b. Infiltrate precipitation as close as possible to the point it reaches the ground using multiple, small-scale structural stormwater BMPs distributed throughout a site (decentralize and distribute).

[51] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

c. Utilize less complex, non-structural methods for stormwater management that are lower cost and lower maintenance than conventional structural controls.
d. Provide source controls to prevent or minimize the use or exposure of pollutants into stormwater runoff at the site in order to prevent or minimize the release of those pollutants into stormwater runoff.

Benefits of LID

LID provides a number of benefits and advantages over traditional development and stormwater management approaches. Some of these benefits and advantages include:

Reduced consumption of land for stormwater management. LID practices rely upon the natural capacity of undisturbed land to absorb precipitation thus reducing the need for structural stormwater controls that often require significant land area. When structural controls are still needed, they are typically small, close to the source of runoff, and can be integrated into the areas of the site that are typically not used for stormwater management.

Reduced development costs. Traditional stormwater management can require substantial land clearing, earthwork, structural drainage systems, and structural stormwater controls. LID approaches involve more compact design with less land clearing and earthwork, less impervious area, and the use of natural flow paths and vegetated conveyances instead of catch basins and pipes. This results in reduced reliance on drainage infrastructure, smaller stormwater controls, and reduced need for excavation and construction materials, which translates into cost savings to developers.

Increased property values. In addition to reduced development costs, sites that employ LID can have increased property values by improving the quality of building lots and increasing their marketability (e.g., greater sense of community cohesion and character, more attractive landscape, and more open space for conservation and recreation).

More aesthetically pleasing development. Traditional stormwater management tends to incorporate the use of large, unnatural looking practices such as detention ponds that take up valuable space on a site. When neglected, these practices may present safety and mosquito concerns. LID can result in a more aesthetically pleasing and naturally attractive landscape.

Reduced maintenance. Most LID site planning and design techniques require little or no maintenance. LID structural practices generally require less maintenance and similar or lower maintenance costs that traditional drainage systems. Much of the maintenance that is required can be accomplished by the average landowner or contracted landscape maintenance companies.

Preserved site hydrology. LID management mimics natural site hydrology and relies on the ability of undisturbed land to retain and absorb runoff from impervious surface. Runoff that is absorbed recharges groundwater and stream baseflow and does not need to be managed or controlled by a structural stormwater practice.

Reduced pollutant loads and improved water quality. LID approaches reduce the loading of sediments, nutrients, and pathogens to streams and other waterbodies because. Landscapes that utilize LID practices minimize discharge and often retain all runoff from events smaller than the 2-year, 24-hour design storm. The runoff volume reduction benefits of LID result in significantly reduced pollutants loadings compared to structural stormwater BMPs that rely on pollutant removal through treatment alone.

Preservation of natural systems. LID preserves large portions of contiguous land in an undisturbed, natural state, which preserves the chemical, biological, and ecological integrity of natural systems.

Enhanced climate and community resilience. Improved land use strategies contribute to community resiliency and can help mitigate impacts from climate change. For example, LID can help avoid or reduce increases in runoff volumes and peak flows to existing urban infrastructure that is, in many cases, already undersized due to past development and vulnerable to more intense and frequent storms. Maintaining existing site vegetation, minimizing and disconnecting impervious surfaces, and using small-scale controls that rely on vegetation can also provide shading and cooling of runoff from impervious surfaces, mitigating increased temperatures.

LID Site Planning and Design Techniques

The remainder of this chapter focuses on non-structural LID site planning and design techniques, which should be applied to the MEA (see Standard 1 in Chapter 4 - Stormwater Management Standards and Performance Criteria) prior to consideration of structural stormwater BMPs. Once LID site planning and design techniques have been considered and applied appropriately, structural stormwater BMPs should be used to manage the remaining required post-development stormwater runoff volume (see Chapter 13 - Structural Stormwater BMP Design Guidance and other sections of this Manual).

Table 5- 1 summarizes and categorizes LID site planning and design techniques according to the three broad objectives described previously – avoiding, reducing, and managing impacts. The following sections describe each technique. Applications of these techniques and related LID site planning and design credits are described in later sections of this chapter.

Table 5- 1 LID Site Planning and Design Techniques

<table>
<tr><th>LID Objective</th><th>Site Planning and Design Technique</th></tr>
<tr><td>Avoid Impacts</td><td>Minimizing Soil Compaction
Minimizing Site Disturbance
Protecting Sensitive Natural Areas
Preserving Vegetated Buffers
Avoiding Disturbance of Steep Slopes
Siting on Permeable and Erodible Soils
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<tr><td>Reduce Impacts</td><td>Reducing Impervious Surfaces
Local Roads
Cul-de-sacs
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<tr><td>Manage Impacts at the Source</td><td>Disconnecting Impervious Surfaces (DCIA reduction)
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Disconnection Using Structural Stormwater BMPs
Conversion of Impervious Areas to Pervious Areas
Source Controls</td></tr>
</table>

Avoid Impacts

Minimizing Soil Compaction

Healthy soils, which have not been compacted, perform numerous valuable stormwater functions, including:

- Effectively cycling nutrients
- Minimizing runoff and erosion
- Maximizing infiltration of stormwater and water-holding capacity

- Absorbing and filtering excess nutrients, sediments, and pollutants to protect surface and groundwater
- Providing a healthy root environment
- Creating habitat for microbes, plants, and animals
- Reducing the resources needed to care for turf and landscape plantings.

When soils are overly compacted, the soil pores are destroyed and permeability is drastically reduced. In fact, the runoff response of vegetated areas with highly compacted soils closely resembles that of impervious areas, especially during large storm events.[52]

Minimizing soil compaction is the practice of protecting and minimizing damage to existing soil quality caused by the land development process. Minimizing soil compaction is not only important for drainage of a site and the successful use of other LID site planning and design techniques and structural stormwater BMPs, but also for minimizing impacts to established vegetation. Heavy equipment used within the drip line of a tree can cause soil compaction, resulting in the death of tree roots. Damage done to a tree's root system may take 3 to 4 years after construction to become evident in a tree's canopy. Maintaining healthy soil can significantly reduce the cost of landscaping vegetation (higher survival rate, less replanting) and landscaping maintenance.

Specific techniques to minimize soil compaction include:

- Fencing off an area during construction ("no disturbance areas") to minimize unnecessary soil disturbance and compaction. Vehicle movement, storage, or equipment/material lay-down are not to be permitted in such areas.

- Use of the smallest (lightest) equipment possible and minimizing travel over areas that will be revegetated (e.g., lawn areas) or used for infiltration of stormwater runoff from impervious surfaces such as adjacent pervious areas.

- Prohibiting the use of excavation equipment within the limits of infiltration-based structural stormwater BMPs to avoid compaction of the bottom of the infiltration system. A hydraulic excavator or backhoe loader, operating outside the limits of the infiltration system, should be used to excavate and place materials in the excavation, which should then be raked by hand.

- Restoring soils compacted as a result of construction activities or prior development. This typically requires modification of the underlying soils to restore the pre-development infiltration rate and soil porosity and improve soil quality to support vegetation. The soil should be treated by scarification, ripping (tilling), or use of a shatter-type soil aerator to a depth of 9 to 12 inches or more depending on site and soil conditions. Amendment with 2

[52] Schueler, T.R. 1995. *Site Planning for Urban Stream Protection*. Metropolitan Washington Council of Governments, Washington, D.C

to 4 inches of topsoil or organic material may be required to improve plant establishment based on soil testing results.

Minimizing Site Disturbance

Land disturbance, including clearing and grading, can dramatically alter the pre-development hydrology of a site, exposing soils to erosion, compacting the soils by heavy equipment, and altering the natural terrain and drainage patterns. The limits of clearing and grading refer to the part of the site where development will occur. This includes impervious areas such as roads, sidewalks, and buildings, as well as pervious areas such as lawn and open drainage systems. Limiting the land area disturbed by development (i.e., development footprint) is most effectively addressed at the site planning level.

Specific techniques for minimizing site disturbance include:

- Land disturbance activities should be limited to only those areas absolutely necessary for construction purposes. The disturbance limits should reflect reasonable construction techniques and equipment needs together with the physical constraints of the development site such as slopes, soils, and natural features to be avoided (including avoiding disturbing topsoil).

- At a minimum, the 100-year floodplain, wetlands and associated buffers, areas with erodible soils, forested areas and other natural open space to be protected, and areas designated for stormwater practices should be protected from disturbance and/or compaction.

- Limits of disturbance may vary by type of development, size of lot or site, and by the specific development feature involved. For example, for sites not previously developed or graded, limit site disturbance with the following recommendations:[53]

    - 40 feet beyond the building perimeter and parking garages

    - 10 feet beyond surface walkways, patios, surface parking and utilities less than 12 inches in diameter

    - 15 feet beyond primary roadway curbs and main utility branch trenches

    - 25 feet beyond constructed areas with permeable surfaces (such as permeable paving areas, infiltration-based stormwater BMPs, and playing fields) that require additional staging areas to limit compaction in the constructed area.

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[53] U.S. Green Building Council (USGBC). 2018. LEED Version 4 for Neighborhood Development. Updated July 2, 2018.

- Use of “site fingerprinting” to minimize land clearing and grading by establishing a limit on the percentage of a parcel that can be developed, ensuring that a minimum percentage of the parcel remains in a natural undisturbed state. This technique reduces clearing to the minimum area required for building and roadway footprints, construction access, and safety setbacks.
    - For example, on previously developed or graded sites, restore or protect a minimum of 50% of the site area (excluding the building footprint) or 20% of the total site area (including building footprint), whichever is greater, with native or adapted vegetation.[53]
- The limits of land disturbance (and no disturbance) should be depicted on the approved site plans and should be delineated in the field with tape, signs, or orange construction fence prior to commencing land disturbance activities. These limits should be reviewed and modified as necessary during a mandatory on-site preconstruction meeting.
- Maintain the area outside the limits of disturbance at natural grade and retain existing, mature vegetated cover.
- As described in the Connecticut Soil Erosion and Sediment Control Guidelines, implement proper construction sequencing to reduce the duration of soil exposure. Construction sequencing is a site-specific work schedule that coordinates the timing of site development related land-disturbance activities and the implementation of temporary and permanent erosion and sediment control measures during any particular phase to minimize soil erosion and sedimentation. Wherever practicable, site construction activities should be phased, with each phase having its own construction sequence and erosion and sediment control measures, to avoid the disturbance of over 5 acres at one time or 3 acres for sites that discharge directly to impaired waters consistent with the requirements of the CT DEEP Construction Stormwater General Permit.
- Existing topsoil should be stored on-site and reused during final grading to the maximum extent practicable. Stockpile areas should be clearly identified on the site plan.
- As-built topographic surveys should be required for site compliance to prevent more cut and/or fill than shown on an approved site plan.
- Existing stands of forest should be identified and protected before construction activity begins to the maximum extent possible.
- Individual large trees (i.e., trees with a Diameter at Breast Height or DBH of 24 inches or greater measured 4.5 ft from the ground surface) should be retained whenever feasible; the area within the drip line, or crown of the tree, should be fenced or roped off to protect trees and their roots from construction equipment.

- Performance bonds should be required to ensure that sites are cleared and graded according to the approved site plan and to cover the replacement cost of trees and other vegetation earmarked for preservation when damaged by construction activities (up to two years after completion of construction).

- Developments that are designed to “fit the terrain” of the site require significantly less grading and soil disturbance than those that are designed without regard for the existing topography. Road patterns should match the landform by placing roadways parallel to contour lines where possible. In doing so, natural drainageways can be constructed along street rights-of-way, thereby reducing the need for storm pipes.

Protecting Sensitive Natural Areas

Sensitive natural areas include woodlands, significant tree species, wetlands and watercourses, floodplains, and other hydrologically sensitive and naturally vegetated areas. Preserving and avoiding land disturbance activities in close proximity to these resources are important strategies for preserving predevelopment hydrology, water quality, important ecological functions, and the natural character and aesthetic value of a site.

Protecting sensitive natural areas involves delineating and defining sensitive natural areas before performing site layout and design. Once sensitive natural areas on a site are delineated, ensure that these areas and native vegetation are protected in an undisturbed state throughout the design, construction, and occupancy stages of a project.

If an area is permanently protected under a conservation easement or other legally enforceable deed restriction that ensures perpetual protection of the proposed area, the project proponent can subtract the conservation area from the total site area when calculating the applicable Water Quality Volume. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked. Managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management. Credits for protecting sensitive natural areas are described in the Section titled LID Site Planning and Design Credits.

Preserving Vegetated Buffers

Vegetated buffers are naturally vegetated areas between developed land and surface waterbodies and wetlands. Vegetated buffers protect water quality by providing shade for cooling, stabilizing banks, mitigating flow rates, and providing for pollutant removal by filtering runoff and promoting infiltration. Vegetated buffers also provide flood storage and wildlife habitat.

Preservation of vegetated buffers involves delineating and preserving naturally vegetated buffers and implementing measures to ensure that buffers and native vegetation are protected throughout planning, design, construction, and occupancy. General guidelines and standards for vegetated buffers include:

- A minimum buffer width of 100 feet as measured from the edge of a resource (wetland, top bank elevation of a stream, etc.) is recommended to preserve most buffer functions. Larger buffer widths (up to 300 feet or more) may be necessary for critical resources such as public drinking water supplies or based on site characteristics such as slope, soils, land use, vegetation type, and other factors.

- The minimum recommended buffer width may not be achievable on existing developed sites. The greatest buffer width that is practical should be maintained and restored and should not be reduced to less than 25 feet or below local or state regulatory requirements.

- Other environmental features important to water quality preservation and enhancement should be included within the buffer, such as the 100-year floodplain and steep slopes.

- Vegetated buffers should be protected during construction. Buffer zones and limits of disturbance should be shown on every drawing within every set of construction plans including, but not limited to, clearing and grading plans and sediment control plans. Buffer limits should be staked out in the field prior to any construction activity. Limits of disturbance should be marked with orange construction fence barriers with accompanying signs.

- The vegetative species should reflect the predevelopment, natural vegetative community present in the area. This can be achieved by either preserving the existing vegetation or managing a disturbed buffer. Disturbed areas should be either planted with native species or allowed to revert to the natural vegetation over time, with an invasive species management plan. Some selective clearing may be allowed in the outer portion of a buffer to allow for removal of dead or diseased trees, especially those that pose a safety hazard.

- Although buffers should remain in a natural vegetated state, certain uses and activity restrictions are appropriate in different zones within the buffer depending on the width and density of vegetation. The inner half of the buffer along the shoreline or bordering wetland should remain as a “no touch” zone, with uses limited to passive recreation such as limited access paths for walking and canoe launches. The outer zone may be managed for heavier foot and bicycle traffic and may be acceptable for stormwater BMPs. Specific uses or activities within the upland review area associated with state jurisdictional wetlands also may be dictated by local inland wetlands and watercourses regulations.

- Design site runoff to enter the buffer as sheet flow. Where necessary, incorporate stormwater BMPs to retain and treat concentrated stormwater inflow to the buffer.

Avoiding Disturbance of Steep Slopes

The potential for soil erosion is significantly increased on slopes of 25% (4H:1V slope) or greater. Development on steep slopes also results in a larger disturbance footprint than development on flatter slopes. Development (clearing, grading, or other soil disturbance) on slopes of 25% or greater should be avoided.

Siting on Permeable and Erodible Soils

Whenever possible, highly erodible soils should be left undisturbed and protected from disturbance during site construction. Gravel soils tend to be the least erodible. As clay and organic matter increase, soil erodibility tends to decrease. Infiltration-based structural stormwater BMPs and pervious areas used for infiltration of runoff from adjacent impervious surfaces should be located on those portions of the site with the most permeable soils.

Protecting Natural Flow Pathways

Natural drainage features such as vegetated swales and channels and natural micro-pools or depressions should be preserved or incorporated into the design of a site to take advantage of their ability to infiltrate and attenuate flows and filter pollutants. Site designs should use and/or improve natural drainage pathways whenever possible to reduce or eliminate the need for stormwater pipe networks. Natural drainage pathways should be protected from significantly increased runoff volumes and flow rates through the use of upstream stormwater BMPs that control runoff volume and flow rate. Level spreaders, erosion control matting, revegetation, outlet stabilization, and check dams can also be used to protect natural drainage features.

Conservation and Compact Development

Compact development is a site development strategy that incorporates smaller lot sizes to reduce overall impervious cover while providing more undisturbed open space and protection of water resources. The strategy relies on mixed-use development patterns, which generate less stormwater than the typical single-use suburban model. In addition to stormwater and water quality benefits, compact development also promotes livability, walkability, and transportation efficiency, including a reduction in greenhouse gas emissions. This approach is also consistent with State of Connecticut policies to promote compact, transit accessible, pedestrian-oriented, mixed use development patterns and land use.

In a residential setting, compact development is referred to as “conservation” or “open space” development. Conservation development concentrates density in one portion of the site while preserving a large percentage of the site as open space. The similar concept of “cluster zoning” was adopted by many communities in the 1980s but did not include clear rationale or objective analysis to determine what open space or natural resources were most important to protect on a site. Conservation development promotes the use of existing opportunities and constraints to shape the final site design.[54] Conservation development is most effective for reducing impervious cover when used in conjunction other LID site design strategies that reduce the impacts of development such as narrower streets and reduced parking. Conservation subdivisions have also been shown to have marketing and sales advantages, as buyers prefer

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[54] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

lots close to or facing protected open space. Conservation subdivisions have also been shown to appreciate faster than counterparts in conventional developments.[55]

Municipal land use regulations dictate the extent to which compact development strategies are allowed. Although many communities in Connecticut allow various forms of compact development, communities may need to re-evaluate local zoning and subdivision regulations to effectively promote the use of compact development strategies. The information sources listed at the end of this chapter provide additional information on how communities can modify local land use regulations to promote the use of compact development and related LID site planning and design techniques.

Reduce Impacts

Once a site development strategy has been selected, sensitive resource areas have been identified and preserved, and other site constraints have been avoided, the next objective of the LID site planning and design process is to reduce the impacts of land alteration. This includes minimizing the creation of new impervious surfaces, preserving the timing of site runoff to approximate pre-development conditions (i.e., slowing the flow), and the use of low maintenance LID landscaping.

Similar to avoidance of impacts, the extent to which impacts can be reduced on a site is also often dictated by local land use regulations, which have the potential to facilitate or hinder the implementation of LID site planning and design strategies. Communities should review and update their local land use regulations to reduce unnecessary creation of new impervious surfaces, remove barriers to the use of LID practices, and promote the use of low maintenance landscaping. The following sections provide strategies for communities to modify local land use regulations to reduce development impacts. Additional information on these topics can be found in the information sources listed at the end of this chapter

Reducing Impervious Surfaces

Reducing impervious surfaces includes minimizing areas associated with roads, sidewalks, driveways, buildings, and parking lots. By reducing the amount of impervious cover on a site, increases in post-development stormwater runoff are reduced while infiltration and evapotranspiration are increased. Reducing the area covered by impervious surfaces also provides greater opportunity for conservation of natural features and more space for vegetated swales, bioretention systems, and other structural stormwater BMPs.

Local Roads. Many local roads are wider than necessary. Reducing the length and width of roads can reduce the creation of new impervious surfaces. Other benefits of narrower roads

[55] Nonpoint Education for Municipal Officials (NEMO). 1999. "Conservation Subdivisions: A Better Way to Protect Water Quality, Retain Wildlife, and Preserve Rural Character". NEMO Fact Sheet #9.

include reduced clearing and grading impacts, reduced vehicle speeds (i.e., "traffic calming"), lower maintenance costs, and enhanced neighborhood character.

- Design local roads for the minimum required pavement width needed to support travel lanes; on-street parking; and emergency, maintenance, and service vehicle access. These widths should be based on future traffic volumes without compromising safety. Table 5- 2 provides recommended minimum road width standards for local roads.

Table 5- 2 Recommended Minimum Road Widths for Local Roads

Rural Local Roads (1)			
Annual Average Daily Traffic (AADT)	Type of Roadside Development		
	Open (Rural)	Moderate Density	High Density
<400	22	N/A	N/A
400 – 1,500	24	24	N/A
1,500 – 2,000	26	26	26
>2,000	28	28	28
Urban Local Roads			
On-Street Parking	Type of Area		
	Suburban	Intermediate	Built-Up
None (2)	24	24	24
One Side (3)	29	29	29
Both Sides (4)	34	34	34

Source: Adapted from CTDOT Highway Design Manual (2003 Edition including Revisions to February 2013)

Notes:

(1) Includes two travel lanes (9 to 12 feet in width) and two 2-foot shoulders.
(2) Includes two 10-foot travel lanes and two 2-foot shoulders.
(3) Includes two 10-foot travel lanes, one 2-foot shoulder, and one 7-foot parking lane.
(4) Includes two 10-foot travel lanes and two 7-foot parking lanes.
(5) Table excludes bicycle facilities, which are typically 5 feet wide.

- Consider site and road layouts that reduce overall street length. Reduce total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length. Conservation (open space) development and other compact forms of development can reduce overall street length.

- Consider elimination of curbs and the use of roadside vegetated open channels or swales as an alternative to traditional curb and gutter drainage (i.e., curbing, catch basins, and pipes), especially in low or medium density developments and slopes where roadside erosion is not a concern (typically slopes of less than 8 percent). Open vegetated channels provide the potential for infiltration and filtering runoff from impervious surfaces, as well as groundwater recharge and reduced runoff volume. In addition to the water quality benefits that open vegetated channels provide, these systems are also significantly less expensive to construct than conventional storm drain systems. The use of vegetated drainage swales in lieu of conventional storm sewers may be limited by soils, slope, and development density.

- Use curb extensions or "bumpouts" at roadway intersections or mid-block locations to reduce impervious area, manage stormwater through bioretention or other structural stormwater BMPs, provide traffic calming, and improve pedestrian safety. These practices are most applicable in medium or high-density developments.

- Use permeable pavement for on-street parking stalls, sidewalks, and crosswalks.

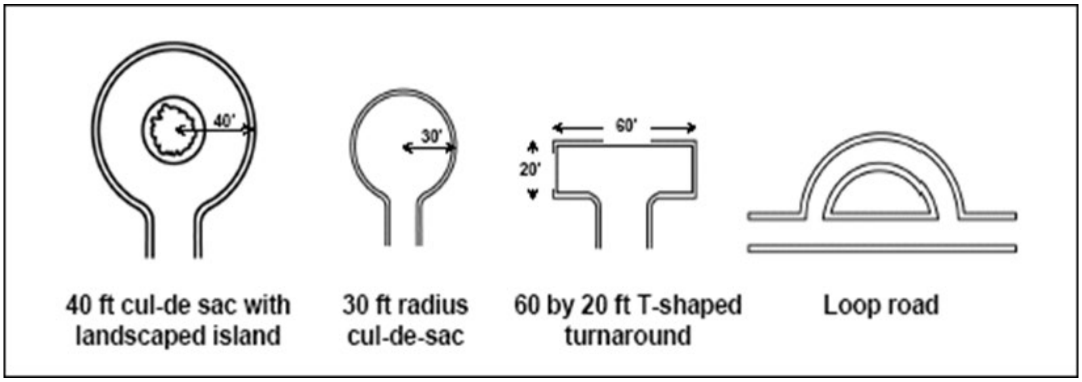
Cul-de-sacs. Cul-de-sacs are residential streets that are open at one end and have a dead-end at the other. Cul-de-sacs have a large "bulb" located at the closed end of the street to enable emergency and service vehicles to turn around without having to back up. Traditional cul-de-sacs utilize a large radius (50 to 60 feet or more), paved turnaround that can dramatically increase the imperviousness of a residential subdivision. Alternatives to this traditional design include turnaround bulbs with smaller radii and the use of a landscaped island (i.e., rain garden or bioretention area) in the center of the cul-de-sac to collect rainwater from the end of the roadway (Figure 5-1). The amount of pavement at cul-de-sac turnarounds can be reduced through the following techniques:

- Reduce the radius (and size) of the turnaround to the minimum required to accommodate emergency and maintenance vehicles, which is typically 30 to 40 feet. Consider the types of vehicles that may need to access a street. Fire trucks, service vehicles, and school buses are often cited as needing large turning radii. However, some fire trucks are designed for smaller turning radii. In addition, many newer large service vehicles are designed with a tri-axle (requiring a smaller turning radius) and school buses usually do not enter individual cul-de-sacs.

- Use a pervious center island (i.e., native vegetation or structural stormwater BMP such as an infiltration basin or bioretention system). If a cul-de-sac island is used, the cul-de-sac radius should allow for a minimum 20-foot-wide road.

- Minimize the number of cul-de-sacs and consider alternative turnaround designs such as hammerheads (T-shaped turnaround) and loop roads (jug handles).

Figure 5-1. Reduced Cul-de-Sac Radius and Alternative Turnaround Designs



Source: Adapted from Atlanta Regional Commission, 2001.[56]

Sidewalks. Subdivision codes often require sidewalks on both sides of the street, as well as a minimum sidewalk width and distance from the street, which can create excess impervious cover and stormwater runoff.

- Adopt flexible design standards that are based on safe pedestrian movement and limiting impervious cover.
- Limit sidewalks to one side of the street. A sidewalk on one side of the street may suffice in low traffic areas where safety and pedestrian access would not be significantly affected.
- Reduce sidewalk widths (3 to 4 feet), separate them from the street with a vegetated area, and grade sidewalks to drain into front lawns and away from rather than towards the street.
- Consider alternative surfaces such as permeable pavement or gravel where appropriate. Consider removing sidewalks from the roadway right-of-way and provide access to natural features or connect other destinations, such as a playground, park, or adjacent development.

Driveways. Driveways account for significant amounts of impervious cover in suburban residential development. Generally, local subdivision regulations do not contain explicit driveway design standards regarding dimensions and surface materials. Subdivision regulations also indirectly influence the length of the driveway when excessive front yard setbacks, which dictate how far houses must be from the street, are required. Overall lot imperviousness can be reduced by minimizing driveway lengths, encouraging alternative pervious surfaces, and allowing shared driveways wherever possible.

- Consider the use of shared driveways that connect two or more homes together.
- Consider minimum driveway widths of 9 feet or less (one lane) and 18 feet or less (two lanes).

[56] https://atlantaregional.org/natural-resources/water/georgia-stormwater-management-manual/

- Reduce front yard setbacks (20 to 30 feet), resulting in shorter driveways and reduced driveway imperviousness. A 20- to 30-foot-long driveway is generally adequate to meet parking needs.
- Use alternative permeable driveway surfaces (e.g., grass, gravel, permeable pavement) or the use of “two track” design for residential driveways (i.e., hard surface for vehicle tires to drive on, with grass or other permeable surface in-between and outside the tracks).

Buildings. Reducing the footprints of buildings can reduce the impervious cover in certain residential and commercial settings. Residential and commercial building footprint area can be reduced by using alternate or taller buildings while maintaining the same floor-to-area ratio.

- Minimize building footprint area and building setbacks.
- Consider the use of green roofs and the use of rain barrels and cisterns for stormwater harvesting and reuse.
- Direct roof runoff to vegetated pervious areas and structural stormwater BMPs such as rain gardens/bioretention systems, dry wells, and other infiltration or filtering systems.

Parking Lots. Parking lots account for a large percentage of impervious cover in commercial, industrial, and institutional settings. The amount of parking and associated impervious area is dictated by local land use regulations. Reducing parking ratio requirements, allowing the use of shared parking and off-site parking allowances, providing compact car spaces, minimizing stall dimensions, incorporating efficient parking aisles, use of structured parking, and using pervious materials in spillover parking areas can serve to minimize the total impervious areas associated with parking lots.

- **Parking Ratios.** The number of parking spaces at a site is determined by local parking ratios which dictate the minimum number of spaces per square foot of building space, number of dwelling units, persons, or building occupancy. Parking ratios are typically set as minimums, not maximums, thereby allowing for excess parking. Parking ratios also typically represent the minimum number of spaces needed to accommodate the highest hourly parking at the site.

    - Establish both minimum and maximum parking ratios to provide adequate parking while reducing excess impervious cover. Parking demand ratios should be based upon project-specific parking studies, where feasible. Allow additional spaces above the maximum ratio only if project-specific parking studies indicate a need for additional capacity.

    - Incorporate mechanisms into local zoning regulations that tailor parking requirements to specific development projects. Allow flexibility within the regulations and require the developer to demonstrate the appropriate amount of parking needed.[57]

- Strategies for eliminating or reducing excess parking through parking demand ratios include but are not limited to: 1) setting minimum and maximum parking ratios (providing a range of values) based on a local parking study, 2) starting with industry standard values such as those developed by the Institute of Transportation Engineers (ITE) and the Urban Land Institute (ULI) and adjusting those values to reflect local characteristics, 3) consider using current minimum parking ratios as the new maximum requirements, and 4) eliminating minimum parking requirements for non-residential properties.

- **Shared Parking.** Shared parking is a strategy that reduces the number of parking spaces needed by allowing a parking facility to serve multiple users or destinations. This approach is most successful when the participating facilities are in close proximity to each other and have peak parking demands that occur at different times during the day or week or if they share patrons that can park at one facility and walk to multiple destinations. Parking ratios can be reduced if shared parking arrangements are in place, when multi-modal transit (e.g., mass transit, bike share, or car share programs) is provided, or when nearby on-street parking is available. Shared parking generally requires contractual agreements between two adjacent users or the use of parking management districts with multiple property owners.[58]

  A related strategy is to reserve sufficient land on the project site for projected future parking requirements (e.g., future buildout or redevelopment), but only construct a portion of the parking area at the outset of the project, maintaining the additional parking as green space and converting to parking on an as-needed basis.

- **Off-Site Parking Allowances.** Current land use regulations in many communities require new development and redevelopment projects to provide all parking on-site and do not allow off-site parking availability to be counted. Communities should increase the flexibility of parking requirements and include off-site parking allowances for certain types of development such as redevelopment sites and compact mixed-use centers given the difficulty of complying with conventional on-site parking demands in such settings. Design standards should specify a maximum distance (typical walking distance of 400-800 feet)

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[57] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

[58] Capitol Region Council of Governments (CRCOG). 2002. Livable Communities Toolkit: A Best Practices Manual for Metropolitan Regions, Shared Parking Fact Sheet.

and requirements for well-marked safe pedestrian travel between the site and off-site parking lot.[59]

- **Structured Parking.** Vertical parking structures can reduce impervious cover by reducing the parking footprint. In urban areas or areas where land availability is limited or land costs are high, parking garages are generally more economical to build than purchasing additional land. In such areas, communities should consider using incentives (e.g., tax credits; stormwater waivers; or density, floor area, or height bonuses) to encourage the use of multi-level, underground, and under the building parking garages.[60]

- **Parking Stall and Aisle Geometry.** Local parking codes often require standard parking stall dimensions to accommodate larger vehicles. Reducing parking stall size and incorporating alternative internal geometry or traffic patterns through the use of one-way aisles and angled parking stalls can reduce parking lot size and impervious cover.

    - Reduce parking stall dimensions to 9 feet wide and 18 feet long.
    - Encourage one-way aisles used in conjunction with angled parking to reduce the amount of aisle space needed to access each stall, depending on the geometry of the parking lot.
    - Allow for a portion of parking lots to be comprised of compact car spaces (e.g., 8-foot by 16-foot stalls or smaller) including signage clearly designating compact car spaces.

- **Alternative Paving Materials.** Impervious cover can also be reduced through the use of alternative paving materials (e.g., permeable pavement) for parking stalls, parking aisles, and overflow parking. Local land use regulations should allow for the use of permeable pavement and promote the use of such materials in low traffic areas such as overflow parking areas. Chapter 13 - Permeable Pavement contains design guidance for permeable pavement systems including porous asphalt, pervious concrete, permeable interlocking concrete pavers, and other open course paver systems (plastic turf reinforcing grids, concrete grass pavers, etc.).

- **Parking Lot Landscaping.** Landscaped areas within and around parking lots can reduce the amount of impervious cover, allow for retention and treatment of parking lot runoff, provide tree canopy and shading, and enhance the appearance of a parking lot and associated development. Small-scale infiltration and treatment stormwater BMPs (e.g., bioretention, tree filters, vegetated filter strips, water quality swales, etc.) can be incorporated into parking islands and around the perimeter of parking lots.

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[59] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

[60] Center for Watershed Protection (CWP). 2017. Better Site Design Code and Ordinance Worksheet. December 2017.

- Require a minimum percentage of a parking lot to be landscaped.
- Allow the use of structural stormwater BMPs and open section drainage (via sheet flow and flush curbs or curb cuts) within landscaped areas, setbacks, or parking areas.
- Require landscaping within parking areas that "breaks up" pavement at fixed intervals and allow vegetated stormwater management areas to count toward required landscape minimums.
- Consider requiring a minimum amount of tree canopy coverage over on-site parking lots. A minimum landscape area width of 6 feet is recommended to support large, mature trees.

Preserving Pre-development Time of Concentration

The peak discharge rate and volume of stormwater runoff from a site are influenced by the runoff travel time and hydrologic characteristics of the site. Runoff travel time can be expressed in terms of "time of concentration" which is the time it takes for runoff to travel from the most distant point of the site or watershed to the downstream outlet or design point. Runoff flow paths, ground surface slope and roughness, and channel characteristics affect the time of concentration. Increasing the post-development time of concentration to match the time of concentration for pre-development conditions can substantially reduce development impacts in terms of peak rates of runoff and runoff volumes. Site design techniques that can modify or increase the runoff travel time and time of concentration include:

- Maximizing overland sheet flow.
- Maintaining pre-development flow paths on vegetated surfaces.
- Increasing the number of and lengthening flow paths on vegetated surfaces.
- Minimizing the number and length of flow paths on impervious surfaces.
- Maintaining overland flow across vegetated surfaces and areas with permeable soils.
- Maintaining pre-development infiltration rates by preserving those areas of the site. with high-permeability soils.
- Maximizing use of vegetated swales for the conveyance of stormwater instead of traditional curb/gutter and piped drainage systems.
- Maintaining or augmenting existing vegetation on the site.

Use of Low Maintenance Landscaping

As described in Chapter 6 - Source Control Practices and Pollution Prevention, lawns and other landscaped areas can contribute stormwater runoff pollution, resulting in adverse impacts to surface waters and groundwater, due to overfertilization, overwatering, overapplication of pesticides, and direct disposal of lawn clippings, leaves, and trimmings.

To reduce these potential impacts, low-maintenance, native vegetation should be used along with other LID landscaping techniques to minimize lawn area, irrigation needs, fertilizers, and pesticides. This approach can also help conserve water by reducing irrigation water demand and increase resilience of surface and groundwater resources during periods of drought. Chapter 6 -

Source Control Practices and Pollution Prevention contains links to additional sources of information on low maintenance and LID landscaping practices.

Communities should also develop or update their local land use regulations to reflect low maintenance or LID landscaping approaches that specifically address the link between a functional landscape and protection of water quality, water conservation, and resilience. LID landscape regulations should also be tailored to different land uses, densities, and locations.[61]

Manage Impacts at the Source

After all reasonable efforts to avoid and reduce impacts are exhausted, the final objective of the LID site planning and design process is to manage any remaining stormwater impacts including increases in runoff volume, pollutant loads, and peak flows. Techniques for managing stormwater impacts include disconnecting impervious surfaces by directing runoff to adjacent vegetated pervious areas (simple disconnection) or to structural stormwater BMPs located close to the source of runoff, conversion of impervious to pervious areas, and the use of source controls and pollution prevention.

Disconnecting Impervious Surfaces

As described in Chapter 2 - Stormwater Impacts, impervious surfaces with a direct hydraulic connection to a storm drainage system or a waterbody are considered “Directly Connected Impervious Area (DCIA).” Impervious surfaces that are separated from drainage systems or a waterbody by pervious surfaces or structural stormwater BMPs designed to retain the appropriate portion of the site’s Water Quality Volume (WQV) are considered “disconnected” and contribute less runoff and reduced pollutant loading. Disconnecting impervious surfaces promotes infiltration and filtration of stormwater runoff and the reduction of DCIA. The two primary strategies for disconnecting impervious surfaces are described below.

Simple Disconnection. Impervious area disconnection, also called “simple disconnection,” is a non-structural technique that involves directing stormwater runoff from impervious surfaces as sheet flow onto adjacent vegetated pervious surfaces where it has the opportunity for infiltration and treatment. Simple disconnection can be used to direct runoff from roofs, driveways, roads, parking lots, and solar arrays to vegetated pervious areas that meet specific characteristics (also called “Qualifying Pervious Areas”) such that the appropriate portion of the site’s WQV is dispersed and retained/infiltrated on-site without causing erosion or basement seepage. Key characteristics of the receiving pervious area include slope, soil infiltration capacity, dimensions and flow path length, size relative to the contributing area, and density of vegetation. Sites with flatter slopes, pervious soils, and a dense stand of vegetation are better

[61] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

suited for maintaining dispersed flow. Flows for larger storm events should bypass or exit the pervious area in a controlled manner.

Credits for the use of simple disconnection to meet the runoff volume and pollutant reduction requirements of Standard 1 (refer to Chapter 4 - Stormwater Management Standards and Performance Criteria) are described in LID Site Planning and Design Credits, including minimum criteria for receiving credit and restrictions on the use of simple disconnection.

Disconnection Using Structural Stormwater BMPs. Impervious areas that discharge runoff to structural stormwater BMPs designed to retain the appropriate portion of the Water Quality Volume (i.e., Infiltration BMPs or Stormwater Reuse BMPs) are also considered disconnected. Small-scale structural stormwater BMPs located close to the impervious areas where runoff is generated are generally preferred over large end-of-pipe controls. Chapters 8-13 of this Manual provide guidance on the selection, design, construction, and maintenance of structural stormwater BMPs to meet the stormwater management standards and performance criteria outlined in Chapter 4.

Conversion of Impervious to Pervious Areas

Impervious area conversion involves removing and replacing existing excess impervious surfaces (pavement, buildings, etc.) with pervious vegetated surfaces (lawn, meadow, woods) and restoring the pre-development infiltration rate and storage capacity (i.e., porosity) of the underlying soils. Conversion of the impervious surface to a vegetated pervious surface results in a reduction in runoff volume and pollutant loads and an increase in infiltration and groundwater recharge. This technique is applicable to redevelopment and retrofit situations. Credits for the use of impervious area conversion on redevelopment sites are described in LID Site Planning and Design Credits. Chapter 9 - Stormwater Retrofits provides additional guidance on impervious area conversion.

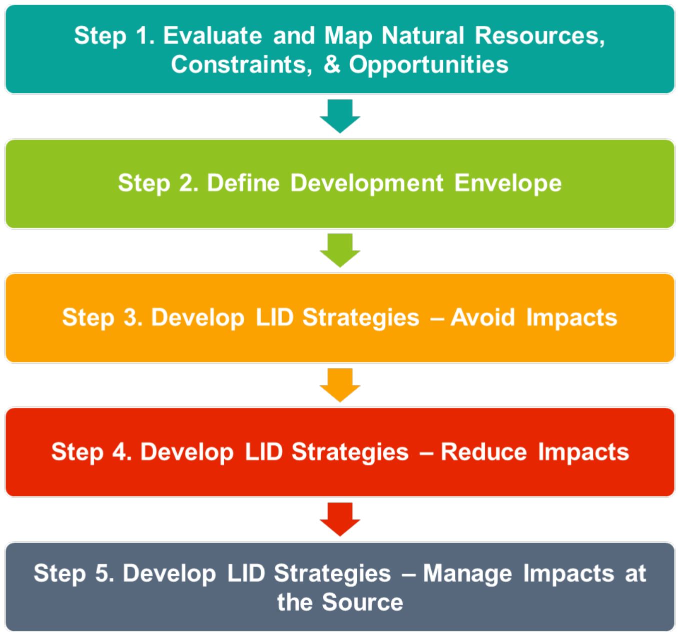
Source Controls and Pollution Prevention

Utilizing the source controls and pollution prevention measures described in Chapter 6 - Source Control Practices and Pollution Prevention can help minimize or prevent the discharge of pollutants in stormwater runoff. Source control practices and pollution prevention are operational practices (e.g., street and parking lot sweeping, catch basin cleaning and drainage system maintenance, and lawn and landscape management) that limit the generation of stormwater pollutants at their source and should be incorporated, to the maximum extent practicable, into the site design and operational aspects of all land development projects.

LID Site Planning and Design Process

Using LID successfully requires consideration of LID site planning and design strategies from the project's inception through final design. The LID site planning and design process focuses on the basic LID principles of preserving natural site characteristics and pre-development hydrology.

Figure 5-2. LID Site Planning and Design



The recommended LID site planning and design process is shown schematically in Figure 5-2. LID Site Planning and Design Process. This process is most applicable to new development, although the same principles and strategies can be applied to redevelopment projects and retrofits.

Once the local, state, and federal regulatory requirements and relevant stormwater management standards for a project are determined, the LID site planning and design process begins by evaluating and mapping existing natural resources as well as site constraints and opportunities for the use of LID techniques. The areas identified to be preserved in a natural state help define the remaining developable area or "development envelope" for the site. LID strategies are then applied within the development envelope to further avoid impacts, reduce impacts, and manage impacts at the source, in that order of priority, as described in the previous sections.

Appendix E contains a checklist for use by project proponents, designers, and reviewers to help document the consideration and use of LID site planning and design techniques to the "Maximum Extent Practicable," as described in Chapter 4 - Stormwater Management Standards and Performance Criteria.

Step 1. Evaluate and Map Natural Resources, Constraints, & Opportunities

The following natural resources, potential site development constraints, and opportunities for the use of LID techniques should be evaluated and shown on an existing conditions base map of the project site (also referred to as a "LID Site Planning and Design Opportunities and Constraints Plan").

Soils. Determine and map the major soil type(s) on the site and associated infiltration rates, erodibility, and other characteristics. General soils information can be obtained from the online USDA NRCS Web Soil Survey.

Wetlands, Rivers, and Streams. Show the boundaries of inland wetlands and watercourses (intermittent and perennial) on the site as delineated in the field by a Certified Soil Scientist or Professional Wetland Scientist. Assess the quality of each wetland system (functions and values) on the site using methodologies established by the U.S. Army Corp of Engineers. Field-verify upland soil types on the site during the field delineation. Show regulatory buffers such as upland review areas and applicable stream or riparian buffer requirements. Since regulatory buffers vary by municipality, it is important to consult with the municipal wetland staff early in the development of the site plan. Also, field-delineate and show unique or significant wetland types such as vernal pools and associated upland protection buffer areas.

Natural Drainage Patterns and Hydrologic Features. Map prominent hydrologic features such as seeps, springs, drainage swales, and isolated depression storage areas. Show existing drainage patterns on the base map, as verified in the field.

Vegetation. Identify and show the existing vegetation types (deciduous forest, coniferous forest, meadow, etc.) and patterns on the site including tree lines. Features such as tree clusters, grassy areas, tidal and/or inland wetlands vegetation, and unique vegetation should be shown. Include all significant tree species with a Diameter at Breast Height (DBH) of 24 inches and greater measured at 4.5' above ground surface.

Flood Hazard Zones. Delineate the limits of the 1 percent annual chance (100-year) flood on the site based on surveyed site topography and the base flood elevation shown on available flood insurance mapping and flood studies by the Federal Emergency Management Agency (FEMA).

Bedrock. Identify areas of shallow bedrock or ledge based on soils mapping, test pits or soil borings, and visible rock outcrops.

Topography and Steep Slopes. Show site topography at 2-foot contour intervals obtained from traditional field survey or aerial survey methods by a licensed land surveyor. For sites with slopes less than 2%, include spot elevations and 1-foot contours. Determine and show areas of steep slopes, which are defined as slopes of 25% (4H:1V slope) or greater as measured over a minimum distance of 50 feet.

Coastal Resources. Identify and show coastal resources on or adjacent to the site including tidal wetlands, beach soils, dunes, bluffs, escarpments, coastal flood hazard areas, coastal waters, estuarine embayments, intertidal flats, submerged aquatic vegetation, and shellfish concentration areas. If applicable, identify and show the location of the Connecticut Coastal Jurisdiction Line (CJL), which is the jurisdictional limit for tidal, coastal, and navigable waters.

Other Sensitive Areas. Identify and map other sensitive areas on or near the project site including but not limited to watercourses supporting cold water fisheries, waters with identified water quality impairments or approved Total Maximum Daily Loads (TMDLs), state and federal listed species and significant natural communities identified by the CT DEEP Natural Diversity

Database, terrace escarpments located in the Connecticut River valley, agricultural land (prime farmland, unique farmland, and farmland of statewide or local importance), and stone walls.

Step 2. Define Development Envelope

Determine the development envelope in which buildings, roads and other constructed features may be sited with minimal impacts to natural resources and site hydrology. Setting the development envelope should also consider construction techniques, and make efforts to retain and protect mature trees, minimize clearing and grading for buildings, access and fire prevention, and other construction activities, including stockpiles and storage areas. The envelope should also be confined to areas to be permanently altered. Limiting the development envelope also reduces the amount of site disturbance and impervious cover, thereby generating less runoff and requiring smaller stormwater management systems.

In general, the following steps should be followed to define the development envelope:

1. Determine those environmentally sensitive areas to be protected from development such as wetlands, watercourses, vernal pools, and their associated buffer areas (see Step 1).
2. Delineate the different vegetative cover types on the site. Highlight those areas of special characteristics or environmental sensitivities. Areas with concentrations of trees with a diameter at breast height (DBH) of 24 inches or greater should be noted on the plan.
3. Determine and delineate steep slopes (slopes greater than 25% or 4H:1V slope as measured over a minimum distance of 50 feet).
4. Determine and delineate those soil areas which have moderate to high infiltration rates (A and B soils). These areas should be reserved for impervious area disconnection or infiltration systems.
5. Once the above areas have been clearly delineated on the base plan, the remaining areas generally define the development envelope. Determine and define the pre-development runoff patterns on the site in order to provide a preliminary understanding of the sites' drainage patterns and the ultimate discharge points.

Step 3. Develop LID Strategies – Avoid Impacts

Once the development envelope is defined, utilize other LID strategies to further avoid impacts including minimizing soil compaction, minimizing site disturbance, and conservation or other compact development approaches, as described in the section titled Avoid Impacts.

Step 4. Develop LID Strategies – Reduce Impacts

Implement LID strategies to further reduce development impacts, such as minimizing the creation of new impervious surfaces, preserving the timing of site runoff to approximate pre-development conditions, and using low maintenance LID landscaping, as described in the section titled Reduce Impacts.

Step 5. Develop LID Strategies – Manage Impacts at the Source

Finally, after all reasonable efforts to avoid and reduce impacts are exhausted, manage any remaining stormwater impacts by disconnecting impervious surfaces (direct runoff to adjacent vegetated pervious areas or to structural stormwater BMPs), converting impervious areas to pervious surfaces, and implementing source controls and pollution prevention measures, as described in the section titled Manage Impacts at the Source.

LID Site Planning and Design Applications

LID site planning and design strategies can be applied in a variety of land use settings for new development and redevelopment projects. The following sections provide common applications of LID site planning and design techniques for residential development and commercial/industrial/institutional development. The use of LID site planning and design strategies for retrofits, including parcel-based and roadway or right-of-way retrofit applications, are addressed in Chapter 9 - Stormwater Retrofits.

Residential Development

Compact Development

For new development, implement conservation or open space design strategies as much as possible to avoid impacts as described in the Section titled Avoid Impacts (e.g., minimize soil compaction and site disturbance; protect sensitive natural areas, vegetated buffers, and flow paths; and permanently set aside open space for multiple objectives including stormwater management).

House Lots

- Orient lots and buildings to maximize opportunities for simple disconnection, use of infiltration-based structural stormwater BMPs, and conveyance of stormwater through the use of vegetated open channels including linear bioretention and water quality swales.
- Convey stormwater from lots not adjacent to pervious vegetated areas using swales or dispersed as low velocity sheet flow to areas more conducive to infiltration.
- Locate lots adjacent to preserved open space to improve aesthetics and privacy.
- Orient lots to use shared driveways to access houses along common lot lines.

Roads

- Lay out roads and lots to minimize grading. Road alignments should follow existing grades to the extent possible.
- Consider reduced driveway widths and reduced front yard setbacks to limit driveway lengths.

- Use roadside vegetated open channels or swales as an alternative to traditional curb and gutter drainage (i.e., curbing, catch basins, and pipes) in low or medium density developments and where roadside erosion is not a concern (typically slopes of less than 8 percent).
- Use swales on one side of the road where roads with a cross slope are allowed. Otherwise, use a crowned road cross section and swales on both sides of the road.
- Completely eliminate curbing to promote sheet flow to roadside swales or use curb openings to convey gutter flow to roadside swales.
- For roads with grades generally greater than 8%, use catch basins and curb/gutter drainage, with catch basin outlets connected to roadside swales or other structural stormwater BMPs within the road right-of-way.

Driveways

- Grade driveways to adjacent open space and lawn areas (simple disconnection), rain gardens, or water quality swales to retain and infiltrate runoff on the lot and prevent driveway runoff from reaching the road.
- Consider use of driveway infiltration trenches, which are stone-filled trenches along the edge of a driveway to collect water from the driveway, allowing it to soak into the ground and reducing erosion along the edge of the driveway.
- Consider use of permeable surfaces such as porous asphalt, porous concrete, permeable concrete pavers, grass pavers, plastic turf reinforcing grids, and geocells (cellular confinement systems).

Roofs

- Direct roof downspouts to pervious vegetated areas (simple disconnection), dry wells or other small-scale infiltration systems (i.e., rain gardens), or to rain barrels for non-potable reuse such as lawn, landscape, or garden watering.

Lawns

- Use low-maintenance LID landscaping techniques to minimize lawn area and maintenance needs (e.g., irrigation, fertilizers, and pesticides).
- Use diverse selection of native vegetation species.
- Create shade by maintaining existing tree canopy and preserving natural/wild areas.
- Maintain pre-development flow path lengths in natural drainage patterns.

Commercial, Industrial, and Institutional Development

This section addresses LID site planning and design strategies for new development and redevelopment sites in commercial (office buildings, small commercial buildings, and big box retail), industrial, and institutional settings. These sites typically have larger building footprints and parking facilities, which can result in greater impervious cover and stormwater impacts. Such sites also present opportunities to reduce and manage stormwater impacts by minimizing and disconnecting impervious surfaces.

Compact Development

- For new development, implement conservation or open space design strategies as much as possible to avoid impacts as described in the Section titled Avoid Impacts (e.g., minimize soil compaction and site disturbance; protect sensitive natural areas, vegetated buffers, and flow paths; and permanently set aside open space for multiple objectives including stormwater management).

Parking Lots

- Lay out and grade parking lots to direct runoff to structural stormwater BMPs (e.g., bioretention, tree filters, and water quality swales) in parking islands and around the perimeter of parking facilities to retain and infiltrate stormwater and convey it to other structural stormwater BMPs if necessary. Eliminate curbing or use curb cuts to direct sheet flow runoff into these features.

- Consider use of impervious area disconnection (simple disconnection) to direct runoff to adjacent vegetated areas if there is sufficient land area on the site.

- Where surface area is limited, use underground infiltration systems and underground detention below parking lots.

- Use permeable pavement for parking stalls, parking aisles, and overflow parking.

- Provide compact car spaces, minimize parking stall dimensions, and incorporating efficient parking aisles such as diagonal parking spaces with one-way aisles.

- Consider shared parking agreements with adjacent or nearby properties.

- Consider use of structured parking.

- Pretreatment is required for runoff from parking lots prior to entering a structural stormwater BMP (see Chapter 13 - Structural Stormwater BMP Design Guidance) or prior to discharge to adjacent vegetated areas through the use of impervious area disconnection (simple disconnection).

- Infiltration of stormwater from industrial and commercial facilities is restricted for certain Land Uses with Higher Potential Pollutant Loads (LUHPPLs) (see Chapter 10 - General

Design Guidance for Stormwater Infiltration Systems), in locations where contaminated soils exist, where the required vertical separation to SHGT cannot be met, or in locations with unacceptable horizontal setbacks for infiltration.

Roofs

- Direct roof downspouts to pervious vegetated areas (simple disconnection), dry wells or other infiltration systems, or to cisterns for non-potable reuse such as lawn or landscape irrigation.
- Consider use of green roofs to manage runoff from building roof areas.

Lawn and Landscaped Areas

- Use low-maintenance LID landscaping techniques to minimize lawn area and maintenance needs (e.g., irrigation, fertilizers, and pesticides).
- Use diverse selection of native vegetation species.
- Incorporate trees in bioretention systems within parking lot islands and around the perimeter of parking lots to provide shade and cooling of impervious surfaces and stormwater runoff during the summer.
- Maintain pre-development flow path lengths in natural drainage patterns.

LID Site Planning and Design Credits

Credits are a way of quantifying the benefits of LID site planning and design techniques, providing additional incentive to use non-structural approaches for meeting the runoff volume and pollutant reduction requirements of Standard 1, as described in Chapter 4 - Stormwater Management Standards and Performance Criteria. LID site planning and design credits may be used to reduce the required Water Quality Volume and Required Retention Volume, provided that the proposed measures meet specific minimum criteria. Implementing such LID site planning and design measures (i.e., those that meet the criteria to receive credits) can reduce or eliminate the need for structural stormwater BMPs.

This section presents credits for the following non-structural LID site planning and design techniques for managing impacts at the source:

- Impervious area conversion
- Impervious area (simple) disconnection
    - Roof runoff
    - Driveways, roads, and parking lot runoff
    - Stormwater runoff from solar arrays.

These techniques provide quantifiable runoff volume and pollutant reduction benefits. For each LID site planning and design technique, a description of the credit is provided along with the minimum criteria for receiving credit.

Credits are not provided for the LID site planning and design techniques described in this chapter that are designed to avoid or reduce impacts. Such techniques involve minimizing land disturbance and impervious area and conserving natural site features, all of which contribute to a reduction in runoff volume and pollutant loads. Standard 1 requires project proponents to consider the use of LID site planning and design strategies, to the MEA, prior to consideration of structural stormwater BMPs. Therefore, all of the LID strategies presented in this chapter should be considered for use, regardless of whether LID credits are available.

Impervious Area Conversion

Converting impervious surfaces (pavement, buildings, etc.) to pervious vegetated surfaces (lawn, meadow, woods) and restoring the pre-development infiltration rate and storage capacity (i.e., porosity) of the underlying soils can be an effective strategy for reducing existing impervious cover on redevelopment sites. Conversion of the impervious surface to a pervious vegetated surface results in a reduction in runoff volume and pollutant loads and an increase in infiltration and groundwater recharge.

The subgrade below pavement is often highly compacted, with low infiltration and water storage capacity, and lacking organic material in the soil structure to support vegetative growth. An important aspect of converting impervious surfaces to pervious vegetated surfaces is to ensure that the converted area has similar hydrologic functions and characteristics as a natural, undeveloped area in terms of runoff and infiltration. This typically requires modification of the underlying soils to restore the pre-development infiltration rate and soil porosity and improve soil quality to support vegetation.

Credit Description

An impervious area conversion credit is available when an existing impervious surface is converted to a pervious vegetated surface and the pre-development infiltration rate and storage capacity of the underlying soils is restored.

If the impervious area conversion meets the minimum criteria presented below, the converted area can be deducted from the total impervious area, reducing the required Water Quality Volume and Required Retention Volume and the size of the structural stormwater BMPs needed to meet the static storage volume and pollutant reduction requirements of Standard 1.

Minimum Criteria for Credit

The impervious area conversion credit is subject to the following minimum criteria and restrictions:

- The existing impervious surface must be replaced with a pervious vegetated surface (lawn, meadow, woods) to provide natural or enhanced hydrologic functioning.
- The soils beneath the previously paved surface, which are typically highly compacted, must be modified to restore the pre-development infiltration rate and porosity (similar to that of the native underlying soils) and improve the soil quality to support vegetation. The subgrade must be treated by scarification, ripping (tilling), or use of a shatter-type soil aerator to a depth of 9 to 12 inches or more depending on site and soil conditions.
- Soil testing is required (by the University of Connecticut Soil Testing Laboratory, another university soil testing laboratory, or a commercial soil testing laboratory) to determine the suitability of the soils for plant growth and to classify the permeability (in terms of Hydrologic Soil Group) of the restored pervious area. Amendment with 2 to 4 inches of topsoil or organic material may be required to improve plant establishment or restore soil permeability.
- Impervious area conversion should not be used where subsurface contamination is present from prior land use due to the increased threat of pollutant migration associated with increased hydraulic loading from stormwater infiltration, unless the contaminated soil is removed and the site is remediated, or if approved by CT DEEP on a case-by-case basis.

Impervious Area (Simple) Disconnection

Impervious area (simple) disconnection can be used to direct runoff from roofs, driveways, roads, parking lots, and solar arrays to natural or landscaped vegetated areas that are of sufficient size and with adequately permeable soils (also called "Qualifying Pervious Areas" or QPAs) to disperse and retained runoff without causing erosion, basement seepage, or negative impacts to adjacent downgradient properties. QPA's may also be referred to as Qualifying Natural Dispersion areas in other stormwater management guidance / manuals locally or nationally. QPAs with flatter slopes, pervious soils, and a dense stand of vegetation are better suited for maintaining dispersed flow. Level spreaders may also be used to disperse the discharge, enhance infiltration, and avoid flow concentration and short-circuiting through the pervious area.

Credit Description

An impervious area disconnection credit is available when runoff from rooftops, driveways, roads, parking lots, and solar arrays are directed to a QPA such that the appropriate portion of the site's WQV is dispersed and retained/infiltrated on-site without causing erosion, basement seepage, or negative impacts to adjacent downgradient properties. This technique involves grading the site to direct runoff as sheet flow to specially designed vegetated areas that can treat and infiltrate the runoff.

If stormwater runoff from an impervious area is directed to a QPA that meets the minimum criteria described below, the area can be deducted from the total impervious area, reducing the required Water Quality Volume and Required Retention Volume of the site and the size of the structural stormwater BMPs needed to meet the retention and treatment requirements of Standard 1.

Minimum Criteria for Credit

The impervious area disconnection credit is subject to the following general criteria and restrictions,[62] which apply to disconnection of runoff from all types of impervious surfaces.

General Criteria

- QPAs must be clearly shown and labeled as such on site plans.
- QPAs must be located outside of regulated wetland areas but may be used within the outer portion of wetland buffer areas (i.e., upland review areas) if allowed by the approving authority.
- Excessively fertilized lawn areas cannot be used as a QPA. For lawn areas to be considered as QPAs, they must consist of low-maintenance grasses adapted to the New England region (refer to Section 5.4.2 on the use of low-maintenance landscaping).
- QPAs can only receive runoff from land uses with higher potential pollutant loads (LUHPPLs), as defined in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems, provided that no runoff from the areas or activities that may generate runoff with a higher potential pollutant load is directed to a QPA.
- The QPA must be designed to not cause basement seepage. To prevent basement seepage, at a minimum, the QPA must be at least 10 feet away from any building foundation and must be directed away from any building foundation. This credit shall not be utilized in locations where there is a history of groundwater seepage and/or basement flooding.
- Construction vehicles must not be allowed to drive over the QPA to prevent compaction of the soil. If it becomes compacted, the soil must be amended, tilled, and re-vegetated once construction is complete to restore infiltration capacity.
- The QPA must have a minimum of 4 inches of topsoil or organic material. The QPA must sustain healthy vegetative cover (dense herbaceous vegetative ground cover) over the long term. Existing vegetation, grasses, and/or plantings are acceptable. Vegetation must

[62] These criteria have been adapted from the Rhode Island Stormwater Design and Installation Standards Manual (2015), MA MS4 General Permit Appendix F (2021), CTDOT Guidance for Natural Dispersion/Vegetative Filter Areas (2021), Trinkaus Engineering, LLC Morris, CT Low Impact Sustainable Development and Stormwater Management Design Manual (2018), CT DEEP Construction Stormwater General Permit Appendix I (Stormwater Management at Solar Array Construction Projects), and New Jersey Stormwater BMP Manual (2004).

cover 90% or more of the QPA. Forested areas used as QPAs must have dense herbaceous vegetative ground cover to effectively disperse flows and prevent soil erosion.

- The slope of the QPA shall be less than or equal to 8% for lawn and less than or equal to 15% for undisturbed meadow or forested areas. Full or partial credit for QPA's outside of this slope criteria may be given based on-site specific conditions and the design retention requirement as approved by the review authority.
- Flow from the impervious surface must enter the QPA as sheet flow. All discharges onto the QPA must be stable and non-erosive.
- Upon entering the QPA, all runoff must remain as sheet flow. The shape, slope, and vegetated cover in the QPA must be sufficient to maintain sheet flow throughout its length.
- A vegetated channel, swale, or structural stormwater BMP may be necessary downgradient of the QPA to manage stormwater from larger storm events that is not fully retained within the QPA for stormwater quantity control purposes.
- The flow path through the QPA should comply with the setbacks established for structural infiltration BMPs (refer to Chapter 10 - General Design Guidance for Stormwater Infiltration Systems).
- QPAs should have a depth to the seasonal high groundwater table shall be 18 inches or greater. HSG classification will influence infiltration rates see Chapter 10 for guidance regarding the classifications and expected rates. HSG classification and depth to seasonal high groundwater table must be field verified by a Qualified Professional through field evaluation (i.e., test pits or soil borings) (refer to soil evaluation guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems).
- The QPA must be included in the Operation and Maintenance (O&M) Plan required by Standard 4. The O&M Plan shall include measures to inspect the QPA at least annually to remove any deposited sediment (e.g., sand from winter sanding operations) and trash, address any ponding and erosion, and re-plant any vegetation that has died to maintain vegetative cover of 90% or greater.
- The QPA must be owned or controlled (e.g., drainage easement) by the property owner and must remain as a landscaped or natural vegetated area over the long term.

The following additional criteria and restrictions apply to disconnection of runoff from the specific types of impervious surfaces listed below.

Roof Runoff

- The rooftop area contributing runoff to any one downspout cannot exceed 1,000 ft^2.

- If designing for retention of the full WQV the length of the QPA (in feet) is recommended to be equal to or greater than the contributing rooftop area (in square feet) divided by 13.3 (e.g., for 1,000 ft^2 roof/13.3 = 75 ft). Treatment can be achieved at varying lengths and widths.

- If designing for retention of the full WQV the width of the QPA is recommended to be equal to or greater than the roof length. For example, if a roof section is 20 feet wide by 50 feet long (1,000 ft^2 roof), the width of the QPA shall be at least 50 feet. Treatment can be achieved at varying lengths and widths.

- Although they may abut, there shall be no overlap between QPAs. For example, the runoff from two 1,000 ft^2 sections of roof must be directed to separate QPAs. They shall not be directed to the same area.

- Where provided, downspouts must be at least 10 feet away from the nearest impervious surface (e.g., driveways) to prevent reconnection to the stormwater drainage system.

- Where provided, downspouts must have a splash pad, level spreader, or dispersion trench to reduce flow velocity and induce sheet flow in the QPA.

- Where a gutter/downspout system is not used, the rooftop runoff must be designed to sheet flow at low velocity away from the structure housing the roof using an infiltration trench or similar level spreader.

- To take credit for rooftop disconnection associated with a LUHPPL (for non-metal rooftops), the rooftop runoff must not commingle with runoff from any paved surfaces or activities or areas on the site that may generate higher pollutant loads.

Driveway, Road, and Parking Lot Runoff

- The maximum contributing flow path from driveway, road, and parking lot impervious areas shall be 75 feet.

- QPA Sizing (0-8% slope): The length of the QPA (i.e., the dimension parallel to the direction of flow) must be equal to or greater than the length of the contributing impervious area. The width of the QPA (i.e., the dimension perpendicular to the direction of flow) shall be no less than the width of the contributing impervious surface. For roads, the minimum QPA width is 25 feet.

- QPA Sizing (8-15% slope): The length of the QPA must be equal to or greater than the length of the contributing impervious area. The width of the QPA shall be no less than the twice the width of the contributing impervious surface. For roads, the minimum QPA width is 50 feet. Full or partial credit for QPA's outside of this slope criteria may be given based on site specific conditions and the design retention requirement as approved by the review authority.

- Although they may abut, there shall be no overlap between QPAs. For example, the runoff from two consecutive segments of road must be directed to separate QPAs. They shall not be directed to the same area.
- Runoff from driveways, roadways, and parking lots may be directed over soft shoulders, through curb cuts, or level spreaders to QPAs. Measures must be employed at the discharge point to the QPA to prevent erosion and promote sheet flow.
- The drainage design must account for snow shelf blocking runoff during winter months.
- Salt tolerant vegetation shall be chosen for all roadside applications.

Solar Array Runoff

Roadways, gravel surfaces, and transformer pads within the solar array are considered Directly Connected Impervious Area (DCIA) for the purposes of calculating WQV. Solar panels are considered unconnected and therefore eligible for the impervious area disconnection credit if all of the following criteria are met:

- Post-construction slopes below the solar panels are less than 15%.
    - For slopes less than or equal to 5%, appropriate vegetation shall be established that will ensure sheet flow conditions and that will provide sufficient ground cover throughout the site.
    - For slopes greater than 5% but less than 10%, practices including, but not limited to, level spreaders, terraces, or berms shall be used to ensure long term sheet flow conditions.
    - For slopes greater than or equal to 8%, use erosion control measures in accordance with solar array requirements contained in the CT DEEP Construction Stormwater General Permit and the Connecticut Soil Erosion and Sediment Control Guidelines, as amended.
    - For slopes equal to or greater than 10% and less than 15%, use engineered stormwater control measures[63] designed to provide permanent stabilization and non-erosive conveyance of runoff to the property line of the site or downgradient from the site.
- The vegetated area receiving runoff between rows of solar panels is equal to or greater than the average width of the row of solar panels draining to the vegetated area.

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[63] Engineered stormwater control measures does not refer to exclusively implemented by engineers, but rather the consideration that natural solutions may not solely provide the benefit needed.

- Overall site conditions and solar panel configuration within the array are designed and constructed such that stormwater runoff remains as sheet flow across the entire site and flows towards the intended stormwater management controls.

- The solar panels shall be designed and constructed in such a manner as to allow the growth of native vegetation beneath and between the panels. Pollinator-friendly vegetation is strongly encouraged. Chemical fertilization, herbicides, or pesticides cannot be used except as necessary to initially establish the vegetation.

- The lowest vertical clearance of the solar panels above the ground shall not be greater than 10 feet. The panels shall, however, be at an adequate height to support vegetative growth and maintenance beneath and between the panels. If the lowest vertical clearance of the solar panels above the ground is greater than 10 feet, non-vegetative control measures are required to prevent/control erosion and scour along the drip line or otherwise provide energy dissipation from water running off the panels.

- Appropriate vegetated buffers and setback distances between solar panels and downgradient wetlands or waters and property boundaries are maintained consistent with the requirements of the CT DEEP Construction Stormwater General Permit.

Additional Information Sources

- Sustainable Land Use Regulation Project and Model Regulations (Capitol Region Council of Governments)
- Livable Communities Toolkit: A Best Practices Manual for Metropolitan Regions (Capitol Region Council of Governments)
- Smart Growth Guidelines for Sustainable Design & Development (EPA and Capitol Region Council of Governments, November 2009)
- Transit Oriented Development Toolkit for CT (Connecticut Fund for the Environment, Partnership for Strong Communities, Regional Plan Association, Tri-State Transportation Campaign)
- Transit-Oriented Development and Responsible Growth Website (Connecticut Department of Economic and Community Development)
- Rhode Island Low Impact Development Site Planning and Design Guidance Manual (Rhode Island Department of Environmental Management and Rhode Island Coastal Resources Management Council, March 2011)
- The Rhode Island Conservation Development Manual: A Ten Step Process for the Planning and Design of Creative Development Projects (Rhode Island Department of Environmental Management, June 2003)
- City Green: Innovative Green Infrastructure Solutions for Downtowns and Infill Locations (EPA, May 2016)
- Smart Growth/Smart Energy Toolkit Modules – Open Space Design (OSD)/Natural Resource Protection Zoning (NRPZ) (Massachusetts Executive Office of Energy and Environmental Affairs)
- Water Quality Scorecard: Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales (EPA 2009)
- Better Site Design Code and Ordinance Worksheet – 2017 Update (Center for Watershed Protection (December 2017)
- EPA Smart Growth Publications
- Smart Growth Network
- Sustainable Sites Initiative

Chapter 6 – Source Control Practices and Pollution Prevention

Introduction

What's New in this Chapter?

- Clarified project types and land use activities for which source control practices and pollution prevention should be implemented
- Minimum requirements for source control practices and pollution prevention
- Updated information on source control and pollution prevention practices with website links to sources of additional information

Controlling the sources of pollution and preventing pollutant exposure to stormwater is an important aspect of an effective stormwater management strategy. Source control practices and pollution prevention are operational practices that limit the generation of stormwater pollutants at their source. Most are typically non-structural, require minimal or no land area, and can be implemented with moderate cost and effort as compared to structural measures.

Source control practices and pollution prevention should be incorporated, to the maximum extent practicable, into the site design and operational aspects of all land development projects, including but not limited to new development and redevelopment activities associated with:

- Commercial and industrial sites
- Institutional facilities
- Residential development
- Municipal facilities and operations

Over the past several decades, a large amount of information on stormwater source control and pollution prevention practices has been developed and refined as part of the CT DEEP stormwater general permit programs, including the MS4 General Permit (Good Housekeeping and Pollution Prevention for Municipal Operations), Industrial Stormwater General Permit, and Commercial Stormwater General Permit. Many other Connecticut-specific and regional information sources are available on these topics through organizations such as the CT Nonpoint Education for Municipal Officials (NEMO) Program, UConn Center for Land Use Education and Research (CLEAR), and watershed groups throughout the state.

This chapter has been revised and abbreviated to provide basic guidance on the use of source control practices and pollution prevention for common land development activities and land use settings in the State of Connecticut. Website links are provided to other available sources of more detailed information on each topic, rather than duplicating the information in this document, which may become outdated over time. CT DEEP may periodically update the website links and add or remove information sources.

Recommended Practices

This section provides guidance on the use of the following source control and pollution prevention practices for development-related activities in commercial, industrial, institutional, residential, and municipal settings. This list of practices is not exhaustive; the use of other source control and pollution prevention practices is also encouraged.

Street and Parking Lot Sweeping. Street and parking lot sweeping helps remove sediment and debris from paved surfaces, reducing exposure of these materials to stormwater runoff and transport to waterbodies.

Winter Road Materials Management. Salts, sand, and other materials are applied to roadways for improved safety during adverse winter weather conditions. Ant-icing and deicing materials can have adverse effects on surface waters, groundwater, drinking water supplies and public health, vegetation, soils, and aquatic life. Proper application and storage of anti-icing/deicing materials is important to avoid or minimize environmental and public health impacts.

Snow Storage and Disposal. Snow accumulated from plowing activities can be a source of contaminants and sediment to surface waters if not properly located and maintained.

Catch Basin Cleaning and Storm Drainage System Maintenance. Regular inspection and cleaning of catch basins and other storm drain system components preserves the stormwater management functions of the drainage system and helps reduce the discharge of pollutants from the drainage system. Inspection and maintenance of structural stormwater BMPs is addressed in other sections of this Manual.

Subsurface Sewage Disposal System Management. Approximately 40 percent of Connecticut's population relies on subsurface sewage disposal systems (also called septic systems). Failing or older, sub-standard systems can be major sources of pollution to surface waters and groundwater.

Illicit Discharge Detection and Elimination. Illicit discharges are unpermitted discharges to waters of the state that do not consist entirely of stormwater or uncontaminated groundwater, except certain allowable non-stormwater discharges. Wastewater connections to the storm drain system and illegal dumping are among the types of illicit discharges that can occur. Depending on the source, an illicit discharge may contain a variety of pollutants that can impact both human health and the aquatic environment. Identifying and eliminating these discharges is an important means of pollution source control in a stormwater drainage system.

Commercial and Industrial Pollution Prevention. Commercial and industrial facilities, including institutional facilities, can potentially contribute point or nonpoint pollution to stormwater through activities associated with operations, maintenance, and storage. CT DEEP provides general pollution prevention information and fact sheets applicable to a wide variety of industries.

Pet and Waste and Waterfowl Management. The fecal matter of domestic pets and waterfowl can be carried by stormwater runoff into nearby waterbodies or storm drainage systems. In addition to contributing solids to stormwater, animal fecal matter is a source of nutrients and pathogens, such as bacteria and viruses, in stormwater runoff. In Connecticut's coastal watersheds, domesticated animals (dogs and cats) and waterfowl, especially Canada geese, can be significant contributors in parks (including dog parks), landscaped shorelines, golf courses, and commercial areas.

Lawn and Landscape Management. Lawns and other managed landscape can contribute stormwater runoff pollution, resulting in adverse impacts to surface waters and groundwater, due to overfertilization, overwatering, overapplication of pesticides, and direct disposal of lawn clippings, leaves, and trimmings. The use of alternative landscaping techniques and judicious use of fertilizers and pesticides can reduce stormwater and nonpoint source pollution from lawns and managed landscapes in virtually all land use settings and project types.

Table 6- 1 summarizes the applicability of each type of practice for various land use settings, minimum requirements for use of each practice, and website links to suggested sources of additional information.

Source control and pollution prevention practices selected for a given project or site should be included in the post-construction Operation and Maintenance (O&M) Plan, which is a required element of a Stormwater Management Plan, as described in Chapter 12 – Stormwater Management Plan.

Table 6- 1 Guidance on the Use of Source Control and Pollution Prevention Practices

Practice Type	Land Use					Minimum Requirements	Sources of Additional Information
	Commercial	Industrial	Institutional	Municipal	Residential		
Street and Parking Lot Sweeping	♦	♦	♦	♦	♦	➢ Required by MS4 regulated municipalities and institutional facilities, and CTDOT, under MS4 General Permits. ➢ Reuse and/or dispose of street sweepings in accordance with CT DEEP guidelines and requirements (see reference). ➢ Minimum frequency of once per year, in spring as soon as possible after snow melt and following winter activities such as sanding to capture sand and debris before it is washed into the storm drainage system. ➢ More frequent sweeping in targeted areas based on consideration of pollutant sources, land use, water quality, and other factors. ➢ Conduct sweeping in dry weather; dry cleaning methods preferable (avoid wet cleaning or flushing of the pavement). ➢ Select sweeping equipment depending on level of debris.	CT DEEP Guideline for Municipal Management Practices for Street sweepings & Catch Basin Cleanings, as amended https://www.unh.edu/unhsc/news/clean-sweep-tech-memo-outreach-toolkit-developed

Practice Type	Land Use					Minimum Requirements	Sources of Additional Information
	Commercia	Industrial	Institutiona	Municipal	Residential		
Winter Road Materials Management		●	●	●		Application ➢ Minimize the use and optimize the application of chloride-based or other salts and anti-icing/deicing product (while maintaining public safety) and consider opportunities for use of alternative materials ➢ Application rate should be tailored to road conditions (i.e., high versus low volume roads, air & pavement temperature, weather forecast). ➢ Use anti-icing (pre-storm) application ➢ Trucks should be equipped with sensors that automatically control the deicer spread rate. ➢ Drivers and handlers of salt and other deicers should receive training to improve efficiency, reduce losses, and raise awareness of environmental impacts. Storage ➢ Salt storage piles should be completely covered, ideally by a roof and, at a minimum, by a weighted tarp, and stored on impervious surfaces. ➢ Runoff should be contained in appropriate areas. ➢ Spills should be cleaned up after loading operations. The material may be directed to a sand pile or returned to salt piles. ➢ Avoid storage in drinking water supply areas, water supply aquifer recharge areas, and public wellhead protection areas. Other ➢ Identify ecosystems such as wetlands that may be sensitive to salt. ➢ Use calcium chloride and CMA in sensitive ecosystem areas. ➢ To avoid over-application and excessive expense, choose deicing agents that perform most efficiently according to pavement temperature. ➢ Monitor the deicer market for new products and technology.	UConn Green SnowPro Program Winter Highway Maintenance Operations: Connecticut, A Report by the Connecticut Academy of Science and Engineering for the Connecticut Department of Transportation (July 2015) Road Salt Use in Connecticut Reference Guide Cary Institute of Ecosystem Studies, Road Salt

Practice Type	Land Use					Minimum Requirements	Sources of Additional Information
	Commercial	Industrial	Institutional	Municipal	Residential		
Snow Storage and Disposal	⬮	⬮	⬮	⬮		➢ Snow disposal and storage activities, including selection of appropriate snow disposal sites, should adhere to CT DEEP guidelines and requirements (see reference). ➢ Snow accumulations removed from roadways, bridges, and parking lots should be placed in upland areas only, where sand and other debris will remain after snowmelt for later removal. ➢ Snow should not be pushed or dumped into waterbodies or wetlands, structural stormwater BMPs, stormwater drainage swales or ditches, or on top of catch basins. ➢ Snow should not be stored near drinking water areas, waterbodies, or wetlands. A minimum of 100 ft is recommended (the review authority may require more if site conditions are not adequate). ➢ Snow should not be stored in areas immediately adjacent to (within at least 100 feet) private or public drinking water well supplies (due to the possible presence of road salt). ➢ Avoid storing snow in areas that are unstable, areas of potential erosion, or high points where snow may melt and collect debris as runoff before it enters the stormwater system. ➢ Consider sun exposure when storing snow. Snow in areas with higher sun exposure will melt faster but may require deicers if the snowmelt refreezes.	CT DEEP Best Management Practices for Disposal of Snow Accumulations from Roadways and Parking Lots, as amended

Practice Type	Land Use					Minimum Requirements	Sources of Additional Information
	Commercial	Industrial	Institutional	Municipal	Residential		
Catch Basin Cleaning and Storm Drainage System Maintenance	💧	💧	💧	💧		➢ Required by MS4 regulated municipalities and institutional facilities, and CTDOT, under MS4 General Permits. ➢ Establish a catch basin cleaning frequency such that no catch basin at any time will be more than fifty (50) percent full ➢ Clean more frequently catch basins with known heavier sediment and debris loads, near sensitive waterbodies, drainage problems, flat grades, etc. ➢ Cleaning should include removal of sediment from sump and removal of trash and debris from grate. ➢ Additional maintenance recommended in the fall to remove trash, leaves, and other debris. In rural areas and areas that experience significant accumulation of leaves, the recommended fall maintenance should be performed after leaf fall and before the first snowfall. ➢ Catch basin cleanings (solid material, such as sand, silt, leaves, and debris removed from storm drainage systems during cleaning operations) should be properly disposed of either via reuse, or via disposal at an approved site. (Note: Before reuse of the sand and organic matter it is recommended the material should be tested as they can carry various contaminants such as heavy metals.) ➢ Handle and dispose of catch basin and storm drainage system cleanings in accordance with CT DEEP guidelines and requirements (see reference)	CT DEEP Guideline for Municipal Management Practices for Street sweepings & Catch Basin Cleanings, as amended

Practice Type	Land Use					Minimum Requirements	Sources of Additional Information
	Commercial	Industrial	Institutional	Municipal	Residential		
Subsurface Sewage Disposal System Management	●	●	●	●	●	➢ Stormwater management plans should describe appropriate operation and management for all subsurface disposal systems on the project site. ➢ Regularly inspect system and pump septic tank every three years by a septic service professional. Refer to CT DPH septic system inspection reporting form for inspection requirements. ➢ Do not park on, plant trees near, or discharge rainwater/stormwater near drain field. ➢ Maintain, upgrade, and repair system. ➢ Use water efficiently and properly dispose of waste (do not flush anything besides human waste and toilet paper).	CT DEEP Subsurface Sewage Treatment and Disposal System website CT DPH Subsurface Sewage website CT DPH Connecticut Recommended Minimum Existing Septic System Inspection Report CT DPH Septic Systems 101: Operation and Maintenance of a Subsurface Sewage Disposal System US EPA Septic Smart Homeowners

Practice Type	Land Use					Minimum Requirements	Sources of Additional Information
	Commercial	Industrial	Institutional	Municipal	Residential		
Illicit Discharge Detection and Elimination	●	●	●	●	●	➢ Required by MS4 regulated municipalities and institutional facilities, and CTDOT, under MS4 General Permits. ➢ Employees, contractors, and property owners should be alert for evidence of illicit discharges or the threat of an illicit discharge into the storm drainage system at any point or any time. ➢ No illicit discharges are allowed as part of new development, redevelopment, or retrofit projects. ➢ Any illicit discharges discovered during site development or ongoing site operations shall be investigated and eliminated consistent with the CT DEEP MS4 General Permits and any local illicit discharge ordinances or regulations. ➢ Include storm drain marking (e.g., stenciling, glue-on or self-adhesive markers, or permanent pre-cast markings) at existing and new catch basin inlets to discourage dumping.	UConn CLEAR and NEMO, Connecticut MS4 Guide, Illicit Discharge Detection and Elimination Guide to Storm Drain Marking, Town of Wellesley DPW, Engineering Division

Practice Type	Land Use					Minimum Requirements	Sources of Additional Information
	Commercial	Industrial	Institutional	Municipal	Residential		
Commercial and Industrial Pollution Prevention	●	●		●		➢ Projects involving commercial businesses/facilities regulated under the CT DEEP Commercial Stormwater General Permit should reference the required Stormwater Management Plan and associated source controls and pollution prevention practices. ➢ Projects involving industrial facilities and activities regulated under the CT DEEP Industrial Stormwater General Permit should reference the required Stormwater Pollution Prevention Plan (SWPPP) and associated source controls and pollution prevention practices. ➢ Commercial businesses and industrial facilities not subject to the CT DEEP Commercial or Industrial Stormwater General Permits should implement source controls and pollution prevention practices to the maximum extent practicable to minimize stormwater pollution.	CT DEEP Industrial Stormwater General Permit Program UConn CLEAR and NEMO, Industrial Stormwater General Permit CT DEEP Commercial Stormwater General Permit Program UConn CLEAR and NEMO, Construction Stormwater General Permit CT DEEP Pollution Prevention (P2) for Business, Industry, and Healthcare
Pet and Waterfowl Waste Management	●		●	●	●	➢ Required by MS4 regulated municipalities and institutional facilities, and CTDOT, under MS4 General Permits. ➢ Pet waste stations with pet waste bags and waste containers are recommended at municipal parks and open space areas where dog walking occurs, and at residential developments, particularly multi-unit dwellings such as apartments, town houses, and condominiums. ➢ On municipal or privately-owned land where geese or other waterfowl populations could contribute bacteria to the storm drainage system or directly to waterbodies (i.e., land with open water), prohibit the feeding of geese or waterfowl and implement a program to manage geese and waterfowl populations.	CT DEEP Pet Waste (Feces) Management Pet Waste Management, Think Blue Connecticut River CT DEEP Problems with Canada Geese

<table>
<tr><th rowspan="2">Practice Type</th><th colspan="5">Land Use</th><th rowspan="2">Minimum Requirements</th><th rowspan="2">Sources of Additional Information</th></tr>
<tr><th>Commercial</th><th>Industrial</th><th>Institutional</th><th>Municipal</th><th>Residential</th></tr>
<tr><td>Lawn and Landscape Management</td><td>♦</td><td>♦</td><td>♦</td><td>♦</td><td>♦</td><td>➢ Required by MS4 regulated municipalities and institutional facilities, and CTDOT, under MS4 General Permits.
➢ Use alternatives to managed turf. Use native plants that are adapted to Connecticut's climate and that require minimal watering, fertilizer, and pesticide application. Choose vegetation that is best suited to the local conditions and desired level of maintenance.
➢ Improve soils by adding soil amendments or using mulches to reduce the need for watering by increasing the moisture retained in the soil.
➢ Test soils every 1 to 3 years to determine suitability for supporting a lawn, and to determine how to optimize growing conditions.
➢ Use efficient irrigation techniques, watering only when needed and allowing the water to penetrate deeper into the soil will encourage deeper root growth. Consider use of rain barrels or rain gardens for stormwater reuse.
➢ Mow high and keep mower blades sharp. Lawns should not be cut shorter than 3 inches. Keep clippings on the lawn to release stored nutrients back into the soil.
➢ Mulch mow grass clippings into the lawn in order to help soil retain moisture and to recycle nutrients, which can help reduce need for future fertilizer applications.
➢ Most lawns require little or no fertilizer to remain healthy. Avoid the use of conventional fertilizers and pesticides. Use organic lawn care methods to the maximum extent practicable (see references on organic lawn care practices). If fertilizer is to be used, follow best management practices to minimize and optimize fertilizer usage (see sources to right):
    o Fertilize no more than twice a year - once in May-June (not before spring green up), and once in September</td><td>CT DEEP, Organic Lawn Care website

CT DEEP, Transitioning to Organic Land Care (OLC) In Your Town

CT DEEP, Sustainable Practices and Resources for the Landscaping and Lawn Care Industry

Connecticut Chapter of the Northeast Organic Farming Association:

Final Report to the New England and New York State Environmental Agency Commissioners: Regional Clean Water Guidelines for Fertilization of Urban Turf (NEIWPCC)

University of Connecticut, New England Regional Nitrogen and Phosphorus Fertilizer and Associated Management Practice Recommendations

University of Massachusetts Cooperative Extension, Best Management Practices for Lawn and Landscape Turf</td></tr>
</table>

Practice Type	Land Use					Minimum Requirements	Sources of Additional Information
	Commercial	Industrial	Institutional	Municipal	Residential		
Lawn and Landscape Management (continued)						○ Use slow-release formulations (50 percent or more water-insoluble nitrogen) to encourage more complete uptake. ○ Fertilize at a rate of no more than ½ pound of nitrogen per 1000 square feet. Typically apply one-half to one-third (or less) of that recommended on the fertilizer bag label and then monitor lawn response and adjust as needed. ○ Use a phosphorus-free fertilizer on lawns near or bordering waterbodies, unless soil tests indicate that the soils are low in phosphorus. ○ Do not apply fertilizer prior to when rain is forecast, which can reduce fertilizer effectiveness and increase the risk of surface and groundwater contamination. ○ Do not apply fertilizer to saturated or frozen ground. Avoid spreading fertilizer on impervious surfaces (sidewalks, patios, driveways, etc.). ○ Leave a buffer strip of unfertilized grass or other vegetation around waterbodies.	University of Connecticut Cooperative Extension, Sustainable Landscapes CT DEEP, BMPs for Grass Clipping Management University of Connecticut - Soil Nutrient Analysis Laboratory: UConn Cooperative Extension System's Home & Garden Education Center:
General Pollution Prevention and Good Housekeeping Practices	●	●	●	●	●	➢ Refer to requirements listed above	UConn CLEAR and NEMO, Connecticut MS4 Guide, Pollution Prevention & Good Housekeeping

Chapter 7 – Overview of Structural Stormwater Best Management Practices

Introduction

> **What's New in this Chapter?**
>
> - Recategorized structural stormwater BMPs based on function, replacing previous "Primary and Secondary Treatment Practices" terminology and framework
> - Increased flexibility for selection and design of structural stormwater BMPs to meet stormwater management standards and performance criteria
> - General guidance on BMP design considerations to reduce or facilitate maintenance

Structural stormwater Best Management Practices (BMPs) – also commonly called Stormwater Treatment Practices, Stormwater Treatment Systems, Stormwater Control Measures, etc. – are constructed stormwater management systems used to reduce the discharge of pollutants and the volume of runoff from developed sites to maintain pre-development hydrology, pollutant loads, and groundwater recharge. Structural stormwater BMPs can be designed to collect, store, treat, infiltrate, and evapotranspire stormwater runoff. BMPs that primarily rely on vegetation and soils to mimic natural processes and manage rainwater close to where it falls are also commonly referred to as "Green Infrastructure (GI)."

As described in Chapter 3 - Preventing and Mitigating Stormwater Impacts of this Manual, structural stormwater BMPs are one element of a comprehensive stormwater management approach and should be selected and designed only after consideration of Low Impact Development (LID) site planning and design strategies (see Chapter 5 - Low Impact Development Site Planning and Design Strategies) and in combination with operational source control practices and pollution prevention (see Chapter 6 - Source Control Practices and Pollution Prevention). Such an approach can reduce the need for or the size and cost of structural stormwater BMPs and related structural drainage system components, as well as reduce maintenance needs. This Manual does not provide the details regarding every BMP type but rather the functional classes, general design guidance for each class and a few examples. It is anticipated that using these guiding principles will open the door for a multitude of BMP options and provide maximum flexibility for the best site design.

Functional Categories of Structural Stormwater BMPs

This section introduces the following major categories and types of structural stormwater BMPs that are recommended for use in Connecticut, based on their primary function:

- Pretreatment BMPs
- Infiltration BMPs
- Filtering BMPs
- Stormwater Pond BMPs
- Stormwater Wetland BMPs
- Water Quality Conveyance BMPs
- Stormwater Reuse BMPs
- Proprietary BMPs
- Other BMPs and BMP Accessories

Selection, design, construction, and maintenance considerations for structural stormwater BMPs are addressed in later sections of this Manual.

Pretreatment BMPs

Pretreatment BMPs remove coarse sediment and debris (e.g., trash, leaves, floatables) upstream of another structural stormwater BMP, while consolidating maintenance to a specific location. Properly designed Pretreatment BMPs help preserve pollutant removal efficiency, extend service life and reduce maintenance costs of the main stormwater BMP. All pretreatment practices require regular maintenance to function properly.

Pretreatment BMPs can be designed as an integral component of another BMP, such as a sediment forebay within another practice, or as a separate structure preceding the main stormwater BMP, such as an upstream structure or proprietary device. Pretreatment BMPs can also be configured as on-line or off-line. On-line systems are designed to treat the applicable Water Quality Volume or Water Quality Flow and safely convey larger flows through the system. Off-line systems are designed to treat a specified discharge rate or volume, such as the Water Quality Volume or Water Quality Flow, and bypass larger flows. Pretreatment BMPs addressed in this Manual include:

- Sediment Forebay
- Pretreatment Vegetated Filter Strip
- Pretreatment Swale
- Flow-through Devices
    - Deep Sump Hooded Catch Basin
    - Oil Grit Separator
    - Proprietary Pretreatment Device

Pretreatment BMPs are only suitable as pretreatment for other stormwater BMPs and cannot be used alone to meet the retention or treatment performance criteria, except for proprietary pretreatment devices. When designed to achieve the minimum required pollutant load reductions described in Chapter 4 - Stormwater Management Standards and Performance Criteria, proprietary devices can be used for stormwater treatment.

Infiltration BMPs

Infiltration BMPs reduce stormwater runoff volumes and pollutant loads, and help to recharge groundwater, by capturing, temporarily storing, and infiltrating stormwater in permeable soils below the bottom of the BMP. Pollutant removal occurs through physical filtering, adsorption of pollutants onto soil particles, and subsequent biological and chemical conversion in the soil. Infiltration practices must be carefully designed and maintained to prevent clogging and system failure. Infiltration BMPs addressed in this Manual include:

- Infiltration Trench
- Underground Infiltration System
- Infiltration Basin
- Dry Well
- Infiltrating Catch Basin
- Permeable Pavement

Unlike the Filtering BMPs described in the next category, the Infiltration BMPs in this category are not designed with underdrains (unless located in Hydrologic Soil Group C or D soils) and therefore are not considered “filtering” practices. Infiltration BMPs can be used to meet the retention and treatment performance criteria and can also be designed for stormwater quantity control.

Filtering BMPs

Filtering BMPs treat stormwater runoff by capturing, temporarily storing, and filtering stormwater through sand, soil, organic material, or other porous media. As the water flows through the filter media, sediment particles and attached pollutants, as well as some soluble pollutants, are removed through physical straining and adsorption. The filtered water is then collected via an underdrain and discharged back to the drainage system or to a receiving waterbody. Pretreatment is generally required to remove debris and floatables and to prolong the service life of the filter media.

Filtering BMPs are generally less cost-effective than Infiltration BMPs and therefore are typically used where site characteristics limit the use of Infiltration BMPs, such as in areas with low permeability soils, where minimum setback distances cannot be met, or where infiltration of stormwater may contaminate groundwater. Each of these filtering practices can be designed as infiltration systems (i.e., exfiltration into the underlying soils) using a raised underdrain and when used in areas with sufficiently permeable soils. Filtering BMPs addressed in this Manual include:

- Bioretention
- Sand Filter
- Tree Filter

Unless specifically designed for infiltration, Filtering BMPs do not provide significant retention or runoff volume reduction and therefore may not fully meet the retention performance criterion.

Filtering BMPs are suitable for providing treatment in combination with other BMPs or in situations where the retention performance criterion cannot be fully achieved.

Stormwater Pond BMPs

Stormwater ponds maintain either a permanent pool of water or a combination of a permanent pool and extended detention. The permanent pool of water in these systems enhances pollutant removal through mechanisms such as sedimentation, biological uptake, microbial breakdown, gas exchange, volatilization, and decomposition. This category of stormwater ponds does not include traditional dry detention basins or dry flood control basins, which do not provide significant water quality treatment functions. Stormwater Pond BMPs addressed in this Manual include:

- Wet Pond
- Micropool Extended Detention Pond
- Wet Extended Detention Pond
- Multiple Pond System

Stormwater ponds do not provide sufficient retention or runoff volume reduction through infiltration or other processes and therefore cannot be used to meet the Standard 1 retention performance criterion of this Manual. Stormwater ponds are suitable for treatment and stormwater quantity control.

Stormwater Wetland BMPs

Stormwater wetlands are constructed wetland systems designed to treat polluted stormwater runoff by several mechanisms, including sedimentation, adsorption, biological uptake, photodegradation, and microbial breakdown. Stormwater wetlands typically include sediment forebays, shallow and deep pool areas, meandering flow paths, and vegetative measures to enhance pollutant removal. Stormwater wetlands are engineered specifically for pollutant removal and flood control purposes. They typically do not have the full range of ecological functions of natural wetlands or wetlands constructed for compensatory storage or wetland mitigation. Stormwater Wetland BMPs addressed in this Manual include:

- Subsurface Gravel Wetland
- Shallow Wetland
- Extended Detention Shallow Wetland
- Pond/Wetland System

Stormwater wetlands do not provide sufficient retention or runoff volume reduction through infiltration or other processes and therefore cannot be used to meet the Standard 1 retention performance criterion of this Manual. Stormwater wetlands are suitable for treatment and stormwater quantity control.

Water Quality Conveyance BMPs

Water Quality Conveyance BMPs include several types of water quality swales. Water quality swales reduce the velocity of, and temporarily store, stormwater runoff and promote infiltration. Pollutant removal mechanisms in water quality swales are similar to constructed wetlands and include sedimentation, adsorption, biological uptake, and microbial breakdown. These practices differ from conventional grass channels and ditches that are designed for conveyance only, as they provide higher levels of pollutant removal. Water Quality Conveyance BMPs addressed in this Manual include:

- Dry Water Quality Swale
- Wet Water Quality Swale

Given their reliance on infiltration, dry water quality swales can be used for stormwater retention, while wet water quality swales are generally more suitable for treatment.

Stormwater Reuse BMPs

Stormwater Reuse BMPs, also commonly called "stormwater or rainwater harvesting and use" are designed to collect, store, potentially treat, and later use the water to meet various demands such as landscape irrigation. Less common uses include drinking, washing, cooling, and flushing. Stormwater Reuse BMPs addressed in this Manual include:

- Rain Barrel
- Cistern

Stormwater Reuse BMPs reduce the volume of runoff from a site and therefore can be used for meeting the retention performance criterion. Small-scale Stormwater Reuse BMPs (i.e., rain barrels) alone may be insufficient to retain the runoff volume required to fully meet the retention performance criterion.

Proprietary BMPs

Proprietary stormwater BMPs are manufactured systems that use proprietary settling, filtration, absorption/adsorption, vortex principles, vegetation, and other processes to remove pollutants from stormwater runoff. The most common types of proprietary

BMPs include hydrodynamic separators, filtration systems, wet vaults, and catch basin inserts. Underground storage and infiltration systems are not considered proprietary BMPs since treatment typically occurs in the soil below the structure, not in the structure itself. Proprietary BMPs may be used for pretreatment (in conjunction with other BMPs) or as stand-alone treatment; however, proprietary BMPs alone cannot be used to meet the stormwater retention performance criterion since they generally do not reduce runoff volumes. Chapter 11 - Proprietary Stormwater BMPs of this Manual addresses criteria for evaluating the use of proprietary BMPs when proposed as stand-alone treatment, including existing systems and emerging/innovative systems and new technologies.

Other BMPs and BMP Accessories

This Manual includes other common structural practices that are used as part of an overall stormwater management system:

- Green Roof
- Dry Extended Detention Basin
- Underground Detention (no infiltration)
- Inlet and Outlet Controls

Green roofs can be used for on-site retention, thereby reducing runoff volumes and peak runoff rates, but are generally not used for stormwater treatment because they capture rainwater that falls directly on the roof surface before it encounters pollutant sources or nearby sources of pollution may perpetually deposit pollutants on all surfaces. Dry extended detention basins and underground detention systems are designed to provide peak runoff attenuation through surface and subsurface storage, respectively, but do not provide sufficient levels of pollutant removal or infiltration to meet stormwater treatment or retention goals. Inlet and outlet controls measures manage runoff into and out of structural stormwater BMPs.

Pollutant Removal Mechanisms

Structural stormwater BMPs remove pollutants from stormwater through various physical, chemical, and biological mechanisms. Table 7- 1 lists the major stormwater pollutant removal mechanisms and the affected stormwater pollutants.

Table 7- 1 Stormwater Pollutant Removal Mechanisms

Mechanism	Pollutants Affected
Gravity settling of particulate pollutants	Solids, BOD, pathogens, particulate COD, phosphorus, nitrogen, synthetic organics, particulate metals
Filtration and physical straining of pollutants through a filter media or vegetation	Solids, BOD, pathogens, particulate COD, phosphorus, nitrogen, synthetic organics, particulate metals
Infiltration of particulate and dissolved pollutants	Solids, BOD, pathogens, particulate COD, phosphorus, nitrogen, synthetic organics, particulate metals
Adsorption on particulates and sediments	Dissolved phosphorus, metals, synthetic organics, petroleum hydrocarbons
Photodegradation	COD, petroleum hydrocarbons, synthetic organics, pathogens
Gas exchange and volatilization	Volatile organics, synthetic organics
Biological uptake and biodegradation	BOD, COD, petroleum hydrocarbons, synthetic organics, phosphorus, nitrogen, metals
Chemical precipitation	Dissolved phosphorus, metals
Ion exchange	Dissolved metals
Oxidation	COD, petroleum hydrocarbons, synthetic organics
Nitrification and denitrification	Ammonia, nitrate, nitrite
Density separation and removal of floatables	Petroleum hydrocarbons, trash

BOD – Biochemical Oxygen Demand, COD – Chemical Oxygen Demand

Since many pollutants in stormwater runoff are attached to solid particles, BMPs designed to remove suspended solids from runoff will remove other pollutants as well. Exceptions to this rule include nutrients (particularly nitrogen), which are often in a dissolved form, soluble metals and organics, some deicing constituents such as chloride, and extremely fine particulates (i.e., diameter smaller than 10 microns), which can only be removed by treatment processes other than traditional separation methods.

BMP Effectiveness

Structural stormwater BMPs differ in their ability and effectiveness to provide specific management functions. Once LID site planning and design principles have been considered and applied, structural stormwater BMPs should be selected and designed based on site characteristics to meet the stormwater management standards and performance criteria described in Chapter 4 - Stormwater Management Standards and Performance Criteria.

Pollutant-specific treatment efficiency and the ability of BMPs to retain runoff on-site are important factors for preserving pre-development hydrologic characteristics and pollutant loads. Stormwater BMPs that can retain the required runoff volume on-site, such as infiltration systems and stormwater reuse BMPs, are suitable for meeting the stormwater retention performance criterion, while other "treatment-only" stormwater BMPs such as filtering BMPs and stormwater ponds/wetlands, can be used to treat runoff in situations where the retention performance criterion cannot be fully achieved. Pretreatment BMPs are restricted in their use as pretreatment for other stormwater BMPs only. Other types of BMPs that provide substantial storage volumes, such as stormwater ponds and wetlands and underground chambers, can be used either alone or in combination with other BMPs to meet the stormwater quantity control standards for larger storms.

- Chapter 5 - Low Impact Development Site Planning and Design Strategies, identifies acceptable LID site planning and design strategies and structural stormwater BMPs for meeting specific stormwater management standards and performance criteria.
- Chapter 8 - Selection Considerations for Stormwater BMPs provides additional guidance on the selection of structural stormwater BMPs to meet specific stormwater management objectives for a particular site.

Use of Multiple BMPs in Series

Stormwater BMPs can be combined in series to meet water quality and stormwater quantity control objectives. The use of multiple structural stormwater BMPs in series is referred to as a "treatment train" approach. The use of a treatment train approach can:

- Accomplish multiple stormwater management objectives to meet the stormwater management standards and performance criteria
- Increase the level and reliability of system performance
- Increase the lifespan of stormwater BMPs by distributing pollutant removal over multiple practices
- Allow multiple BMPs to target different pollutants to improve overall treatment effectiveness.

A treatment train typically consists of a pretreatment BMP, followed by a retention and/or treatment BMP to meet the runoff volume and pollutant reduction (retention/treatment) standard, and potentially another stormwater BMP to fully meet the stormwater runoff quantity control standard.

Maintenance Considerations

Structural stormwater BMPs require regular maintenance to perform successfully. Failure to perform adequate maintenance can lead to reductions in pollutant removal efficiency or increase pollutant loadings and aggravate downstream impacts. Stormwater BMPs should be routinely inspected and maintained following construction to ensure that the controls are in proper working condition and operating as designed.

BMP Design Considerations to Reduce and Facilitate Maintenance

Effective design of stormwater BMPs can reduce maintenance requirements and help facilitate routine maintenance activities, which can improve the long-term operation and function of the BMP. General design recommendations to reduce and facilitate BMP maintenance include:

- Identify the parties responsible for conducting long-term inspections and maintenance and develop BMP designs that align with their operation and maintenance capabilities.
- Place inlet/outlet structures along the perimeter of the stormwater BMP for easier access.
- Place a 4-foot high (minimum) flexible delineator post adjacent to infrastructure that may become hidden and can potentially become a safety hazard (e.g., trip and fall), may be damaged during maintenance, or may damage maintenance equipment. Examples include inlet structures, clean-outs, observation wells, and raised outlet structures.
- Identify adequate space to stage maintenance activities and equipment. Consider parking lot use and on-street parking limitations when identifying this area. Access paths can also serve as a staging area for equipment during maintenance.
- Consider the weight of the maintenance equipment and portable weight displacement tracks/plywood. Equipment should not adversely impact the functionality of the stormwater BMP (i.e., compacting the subsurface soil media). For instance, not relying on sediment removal equipment (e.g., excavator) accessing surfaces where water infiltrates as well as ensuring that surfaces to be mowed by larger mowing equipment can withstand typical tire pressures from such equipment.[64]
- Designate safe entry and exit points to the stormwater BMP; design to allow for safe approach and exit speeds for BMPs near roads.
- Consider existing and proposed barriers (e.g., guardrail, fence, etc.) that may hinder access to the BMP. Provide a gap, gate, etc. in the barrier accordingly.
- Provide the appropriate level of access to the varying components of the stormwater BMP. For instance, it is necessary to provide vehicular access to the BMP, but it may only be

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[64] Strategies for mitigating these impacts can be found in the Soil Erosion and Sediment Control Guidelines

necessary to provide access for mowing equipment to the vegetated portions within the BMP.

- At a minimum, the access path should abut pretreatment facilities and provide safe access to all points that require routine maintenance or sediment removal. Consider the equipment type and any limitations including excavator reach and vacuum truck hose length. Also consider vegetation that may limit access, such as shrubs that would hinder the use of a hose.

- Depict the access path on the figure that will be incorporated with the long-term operation and maintenance plan.

- Evaluate the potential for snow storage on the stormwater BMP. Sediment/debris that accumulates within the plowed snow may impact the effectiveness of the BMP after the snow melts and the sediment/debris remains.

- BMPs will need to withstand anticipated snow loads if plowed/shoveled snow is permitted to accumulate over the BMP.

- Use transition curbs or steel plates where curb cuts are proposed to limit the potential for damage from snowplows.

- Depict any snow storage areas on the figure that will be incorporated with the long-term operation and maintenance plan. In areas where snow storage is not permitted, identify these areas as well.

- Place the least expensive and most easily maintained components of a stormwater BMP treatment train at the most upstream point in the treatment train to reduce the maintenance requirements of the downstream components.

General Inspection and Maintenance Requirements

General maintenance guidelines for stormwater BMPs are summarized below. Chapter 13 - Structural Stormwater BMP Design Guidance provides recommended maintenance for specific stormwater BMPs. Appendix B contains BMP-specific maintenance inspection checklists.

- **Inspections.** Inspections should be performed at regular intervals to ensure proper operation of structural stormwater BMPs. Inspections should be conducted at least annually, with additional inspections following large storms. Inspections should include a comprehensive visual check for evidence of the following (not all items apply to every BMP type):
    - Accumulation of sediment or debris at inlet and outlet structures
    - Erosion, settlement, or slope failure
    - Clogging or buildup of fines on infiltration surfaces
    - Vegetative stress and appropriate water levels for emergent vegetation

- Algae growth, stagnant pools, or noxious odors
- Deterioration of pipes or conduits
- Seepage at the toe of ponds or wetlands
- Deterioration or sedimentation in downstream channels and energy dissipators
- Evidence of vandalism
- Evidence of structural damage by beavers, muskrats, and other wildlife

➢ **Routine Maintenance.** Routine maintenance should be performed on a regular basis to maintain proper operation and aesthetics. Routine maintenance should include:

- Debris and litter removal
- Silt and sediment removal
- Terrestrial vegetation maintenance
- Aquatic vegetation maintenance
- Maintenance of mechanical components (valves, gates, access hatches, locks)

➢ **Non-routine Maintenance.** Non-routine maintenance refers to corrective measures taken to repair or rehabilitate stormwater BMPs to proper working condition. Non-routine maintenance is performed as needed, typically in response to problems detected during routine maintenance and inspections, and can include:

- Erosion and structural repair
- Sediment removal and disposal
- Nuisance control (odors, mosquitoes, weeds, excessive litter)

Stormwater BMP maintenance requirements are an integral part of a site stormwater management plan (see Chapter 12 – Stormwater Management Plan). These requirements should include, at a minimum, detailed inspection and maintenance tasks, schedules, responsible parties, and financing provisions. The owner typically maintains stormwater treatment practices at commercial, industrial, and rental residential developments. These facilities generally have staff dedicated to maintenance activities or contract for such services. Maintenance of non-rental residential installations is typically performed by private landowners or property/homeowner associations, which in many cases do not have the technical expertise, resources, or funds to inspect and maintain their stormwater systems. In some cases, municipalities may accept responsibility for inspecting and maintaining stormwater BMPs. Municipalities should require legally binding maintenance agreements for stormwater treatment practices to clearly delineate maintenance responsibilities.