Chapter 4 – Stormwater Management Standards and Performance Criteria

Introduction

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

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.

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

<table>
<tr><th>Stormwater Management Standard</th><th>Performance Criteria</th></tr>
<tr><td>Standard 1 – Runoff Volume and Pollutant Reduction

Preserve pre-development hydrology and pollutant loads to protect water quality and maintain groundwater recharge.</td><td>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.</td></tr>
</table>

[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 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.

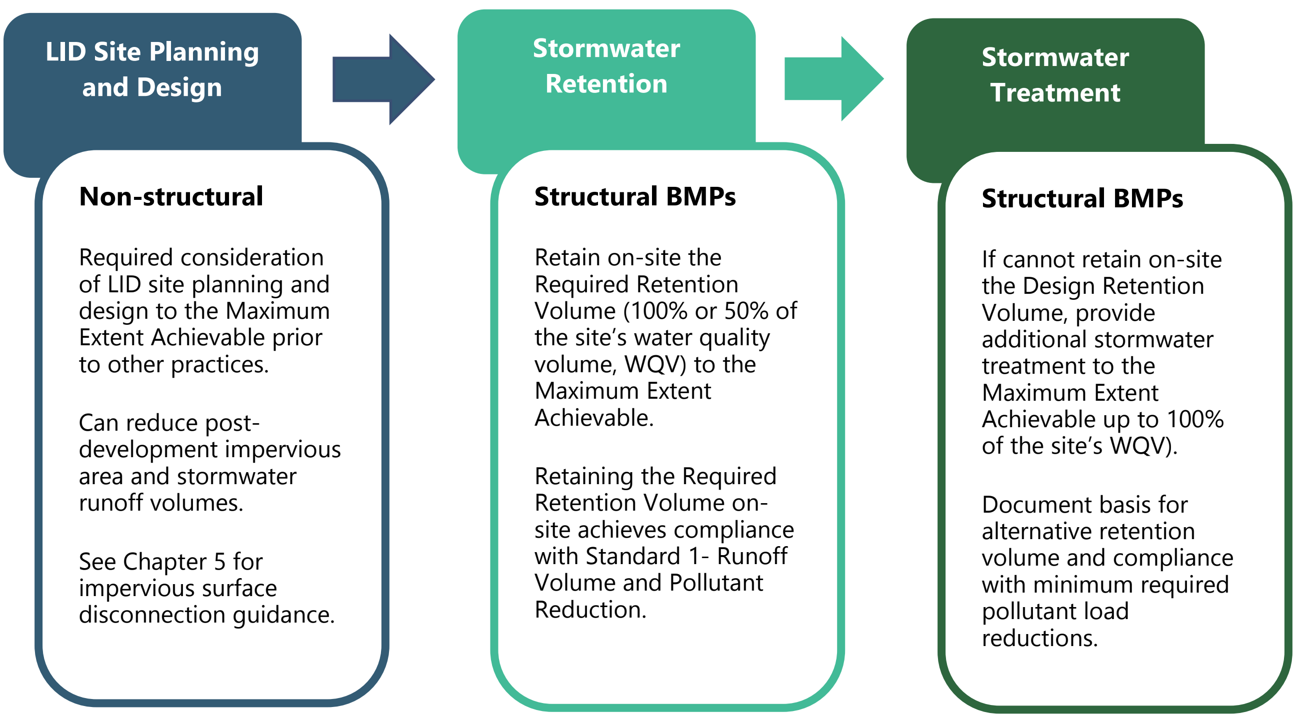
Note: Consult local and state regulations for additional stormwater management requirements. The above standards and criteria are recommended where local or state regulations are less stringent.

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 (90th 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

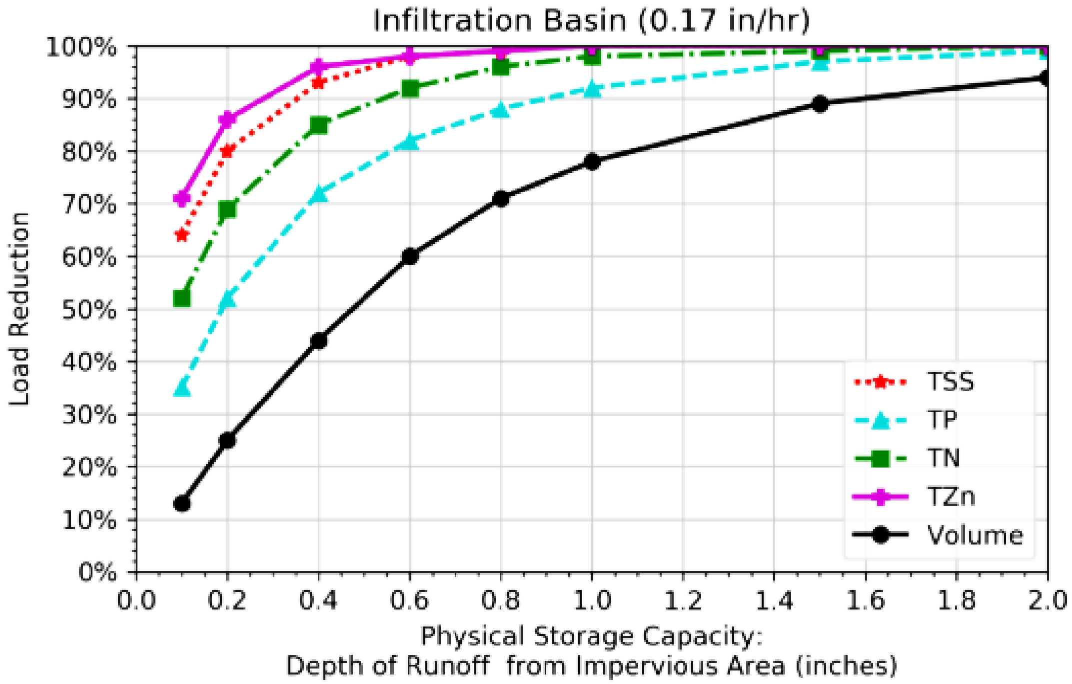
[48] On-site retention of the Required Retention Volume (100% or 50% of the site's WQV) using stormwater BMPs designed in accordance with the guidelines in this Manual is assumed to achieve average annual pollutant load reductions that exceed the minimum required values in Table 4-3 based on EPA Region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