Chapter 9 – Stormwater Retrofits

Introduction

> **What's New in this Chapter?**
> - Consistency with stormwater retrofit requirements in the CT DEEP stormwater general permits
> - New guidance on retrofit planning approaches
> - Updated information on stormwater retrofit types and applications
> - Use of stormwater retrofits for DCIA disconnection and reduction
> - Use of EPA stormwater BMP performance curves for retrofit sizing and crediting
> - Updated information on other resources and tools for stormwater retrofit planning and design

This chapter provides guidance for retrofitting sites that are already developed to reduce the adverse impacts of existing stormwater runoff. A "retrofit" is a project that modifies an existing developed site for the primary purpose of improving the quality of and reducing the quantity of stormwater discharge. This is primarily achieved through disconnecting, and therefore reducing, Directly Connected Impervious Area (DCIA), as defined in Chapter 2 - Stormwater Impacts.[66] Stormwater retrofits can be used to disconnect DCIA by converting impervious surfaces to pervious surfaces, redirecting runoff from impervious surfaces to adjacent pervious areas, and adding new or modifying existing structural stormwater Best Management Practices (BMPs) to infiltrate or reuse stormwater runoff from impervious areas.

This chapter describes the reasons for and benefits of stormwater retrofits, various retrofit approaches and types, identification and design of stormwater retrofits, quantifying retrofit benefits (i.e., crediting), and common retrofit applications. Additional guidance on stormwater retrofits can be found in the information resources at the end of this chapter.

Why Retrofit? – Objectives and Benefits of Stormwater Retrofits

The objective of stormwater retrofitting is to improve the water quality mitigation functions of existing developed sites either lacking or having insufficient stormwater controls. In Connecticut, prior to the 1970s, site drainage design did not require stormwater detention for controlling

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[66] Impervious area with a direct hydraulic connection to a storm drainage system or a waterbody via continuous paved surfaces, gutters, drainpipes, or other conventional conveyance and detention structures that do not reduce runoff volume is referred to as "Directly Connected Impervious Area (DCIA)." DCIA includes impervious surfaces that contribute stormwater runoff to a stream, other waterbody, or wetland. Impervious areas that are not directly connected to a storm drainage system, receiving waterbody, or wetland are considered "disconnected" and therefore not considered DCIA. DCIA can be disconnected through retrofits that retain and/or treat the appropriate portion of the Water Quality Volume as described in Chapter 4 - Stormwater Management Standards and Performance Criteria.

post-development peak flows. As a result, drainage, flooding, and erosion problems are common in many older developed areas. Furthermore, local and state stormwater regulatory requirements and the resulting stormwater designs in the 1980s and 1990s focused on detention and controlling peak rates of runoff, without regard for the quality of runoff, runoff volume, groundwater recharge, or other hydrologic impacts. Therefore, much of the existing, older development in Connecticut still lacks adequate stormwater controls.

Retrofits can be used to achieve stormwater and water quality objectives such as reducing pollutant loads to impaired water bodies and meeting pollutant load reduction targets in Total Maximum Daily Loads (TMDLs). Other related benefits of stormwater retrofits, particularly those that incorporate green infrastructure and Low Impact Development (LID) techniques, include:

- Recharging groundwater to support streamflow and drinking water supplies.
- Reducing flood risk by reducing runoff volumes.
- Mitigating impacts of climate change (increased precipitation, flooding, drought, and higher temperatures).
- Providing habitat.
- Improving community aesthetics and overall quality of life.

The CT DEEP MS4 General Permit requires regulated municipalities, CTDOT, and other state and federal entities to implement stormwater retrofits to disconnect and reduce DCIA and track the progress of their DCIA reduction efforts relative to specific reduction goals. Permit holders and/or municipalities can also identify stormwater retrofits as part of an off-site mitigation program for new development and redevelopment projects that are unable to fully comply with stormwater management requirements on-site.

Retrofit Approaches

There are two major approaches to implementing stormwater retrofits – the opportunistic approach and the retrofit planning approach (SNEP Network, 2022).[67] The two approaches can be used together in a complementary fashion to develop and implement a successful retrofit program.

Opportunistic Approach

The opportunistic approach involves integrating stormwater retrofits into already planned construction projects. Retrofits are generally more cost-effective when implemented in conjunction with planned infrastructure upgrades since construction of the retrofit can be coupled with other planned site disturbance and improvements. An example of an opportunistic retrofit is incorporation of bioretention planters, roadside bioswales, infiltrating catch basins, or underground infiltration chambers into a planned roadway improvement project. This approach

[67] Southeast New England Program (SNEP) Network. 2022. *Stormwater Retrofit Manual.* Developed in conjunction with University of New Hampshire Stormwater Center, EPA Region 1, and state agencies.

is best suited to Connecticut municipalities and the Connecticut Department of Transportation (CTDOT), who are responsible for regular planned maintenance and improvement projects. Stormwater retrofits can be incorporated into infrastructure improvements as part of municipal and state capital improvement plans.

The opportunistic approach is most effective when the project owner:

- Proactively identifies upcoming retrofit opportunities, such as construction projects identified in capital improvement plans, and includes retrofits in the planning and design of these projects.
- Develops a targeted suite of preferred structural stormwater BMPs to be used with retrofit projects, including typical details, specifications, and installation approaches that work best for the project owner.
- Selects and designs retrofits such that the BMPs can be maintained using available staff resources and equipment.
- Allows for some changes, as necessary, to the base design to maximize stormwater treatment.
- Budgets for some increases in project costs to include the retrofit in a planned improvement project as a trade-off for more costly stand-alone retrofits in the future.
- Tailors the scale and type of stormwater BMPs to the project they are being paired with. Projects that already impact grading and the drainage system likely provide additional opportunities to incorporate more sophisticated controls by allowing for changes to the stormwater system and taking advantage of mobilization of the required construction equipment. In addition, projects with larger overall construction costs may provide more opportunity to absorb relatively lower-cost SCMs.
- Seeks low-cost creative solutions as the first option. Small, inexpensive modifications to site drainage patterns can have large impacts. For example, a simple curb cut can allow stormwater runoff from an impervious area to be treated over an adjoining pervious area.

Planning Approach

In the planning approach, stormwater retrofit opportunities are identified and prioritized through a proactive planning process. This approach results in the selection of retrofits that will have the greatest water quality or other benefits at the lowest cost. The planning approach is typically most effective for identifying retrofits to meet the requirements of a permit, watershed plan, or TMDL implementation plan.

In Connecticut, the MS4 General Permits require regulated municipalities and the CTDOT to develop stormwater retrofit plans to meet the DCIA disconnection and reduction goals specified in the permit. The retrofit plan must identify and prioritize sites that may be suitable for retrofit and include a prioritized list of retrofit projects.

The MS4 General Permits also requires regulated municipalities and the CTDOT to allow for off-site stormwater mitigation when a new development or redevelopment project cannot fully meet the retention or treatment requirements on-site. The retrofit planning process can be used to identify retrofit projects that could be implemented as part of an off-site stormwater mitigation program, as described in Chapter 4 - Stormwater Management Standards and Performance Criteria. Eligible retrofits are typically located on another site within the same CT DEEP Subregional Basin or USGS HUC12 watershed (and preferably the same municipality) as the project site. 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.

Developing and implementing a stormwater retrofit plan typically involves the following basic steps:

Step 1. Identify and Quantify Goals

This first step involves identifying and quantifying specific goals for the retrofit program. Goals may include making progress towards DCIA reduction targets specified in the MS4 General Permits, pollutant reduction targets identified in a watershed plan or TMDL, installation of a specific type and/or number of retrofits, or implementing retrofits within a specified budget and timeframe. Preferences for or avoidance of certain types of BMPs, maintenance capabilities and limitations, and planned infrastructure improvement projects should be identified at this stage. Other program goals should also be identified such as flood reduction, reduced heat island effect, and other social, economic and community benefits.

Step 2. Gather Background Information and Data

The next step in the process involves gathering background information and data that are used in the desktop screening process in Step 3. Background information and data typically include:

- Aerial imagery.
- Drainage system mapping.
- Mapping of priority areas based on MS4 regulated areas, impervious cover, and water quality impairments.
- Parcel ownership and land use.
- Road classification and width for right-of-way opportunities.
- Topography/slope, soils, and other mapped physical site characteristics.

Step 3. Conduct Desktop Screening

Using the geospatial information gathered in Step 2, conduct a desktop screening analysis to initially identify potential sites for retrofits. Potential sites for consideration could be sites where a construction project is already planned or sites that could be retrofitted independently of other projects. Sites with older or ineffective stormwater BMPs can also be considered for retrofits in the form of upgrades and improvements. The initial screening process typically involves a desktop analysis to identify parcels or areas within the public right-of-way that meet certain site suitability criteria for structural stormwater BMPs (soils, depth to groundwater, impervious cover, available space, etc.), land ownership (i.e., publicly owned land often provides greater opportunity for retrofits), and other factors like public visibility and demonstration value.

Step 4. Perform Detailed Site Assessment

Once potential retrofit sites are identified, a more detailed assessment of each site is performed to verify the feasibility of retrofits, identify specific areas on the site best suited for retrofits, and identify possible stormwater BMP types. Site opportunities and constraints are identified during this process including site drainage patterns and areas, storm drainage system configuration, available space, utility conflicts, and site operations. In addition to a site walk and visual observation, the site assessment may also involve field data collection such as field survey, soil investigation (test pits, soil borings, and field infiltration testing), utility research, etc.

Step 5. Develop Design Concepts

Once the site assessment process is completed, the list of potential retrofit sites is refined by eliminating sites that are not suitable for retrofits. Retrofit concepts are typically developed for the remaining sites with the greatest potential for retrofits. Retrofit design concepts are then developed to a level of detail, often consisting of a plan view sketch and typical construction details, required to estimate benefits and costs for planning purposes.

Step 6. Estimate Benefits and Costs

Once the retrofit design concepts are developed, preliminary order-of-magnitude cost estimates are developed for each retrofit concept along with initial estimates of pollutant load reductions and/or DCIA reduction. The stormwater BMP performance curves developed by EPA and the University of New Hampshire Stormwater Center (see Chapter 4 – Stormwater Management Standards and Performance Criteria) and the section at the end of this chapter) can be used to quantify the pollutant load reduction benefit of specific BMP retrofits, as well as to inform retrofit prioritization and final BMP selection and sizing.

Step 7. Prioritize Sites for Implementation

Retrofit sites and BMPs are prioritized based on criteria that reflect the retrofit goals identified in Step 1. These criteria may include but are not limited to:

- Estimated total cost and available budget.
- Estimated pollutant reduction achieved.
- Estimated cost per pollutant reduction (i.e., cost effectiveness).
- Feasibility (ownership, ease of construction, access, physical site constraints, maintenance burden, community acceptance, etc.)

- Degree to which the retrofit achieves other goals (flood reduction, heat island reduction, reduced heat island effect, demonstration value, and other social, economic and community benefits).

The prioritization method can be quantitative (i.e., scoring and weighing factors), semi-quantitative (scoring combined with non-numeric ratings), or qualitative.

Step 8. Implement Retrofit Projects

Stormwater retrofits should be implemented (i.e., design, permitting, and construction) according to the priorities identified in the planning process as funding and opportunities become available. The final stormwater retrofit designs may be different than the concepts developed during the retrofit planning phase due to the collection and analysis of more detailed site information. During the design process, site specific survey, soil analysis, and site evaluation can present factors that may change the size, type, or exact location of the retrofit BMPs.

The opportunistic and planning approaches to stormwater retrofitting can also be combined. For example, the stormwater retrofit planning process may serve as a pipeline for retrofit projects to be included in a capital infrastructure plan, while planned capital projects may be identified for inclusion in a retrofit plan.

Retrofit Types

There are many types of stormwater retrofits that can be used to disconnect and reduce DCIA and provide other benefits as described earlier in this chapter. The major types of retrofits addressed in this Manual are described below.

Impervious Area Conversion

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.

Opportunities to convert impervious surfaces to pervious surfaces are common on older, developed sites where historical development patterns and zoning or subdivision regulations dictated excessive amounts of impervious coverage associated with parking lots, roads, and buildings. These developments also typically pre-date regulatory requirements for stormwater quality controls, so much of the impervious area on these sites is often directly connected to the drainage system or surface waters (i.e., DCIA).

Common examples of impervious area conversion retrofits include:

- Eliminating unused or underutilized parking spaces in parking lots and replacing them with vegetation or for impervious area disconnection strategies (see discussion below).
- Reducing paved shoulder widths.
- Reducing lane widths (e.g., road diet with pavement removal).
- Replacing pavement in parking lot islands and medians with vegetation.
- Replacing the center portion of paved cul-de-sac bulbs with vegetation or structural stormwater BMPs (see discussion below).

Such conversions should not preclude roadway and parking lot design and safety standards.

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 soils beneath the previously paved surface 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 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. A soil test by the University of Connecticut Soil Testing Laboratory, another university soil testing laboratory, or a commercial soil testing laboratory is recommended to determine the suitability of 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.

Chapter 5 - Low Impact Development Site Planning and Design Strategies provides design criteria for impervious area conversion in the context of redevelopment projects. The design guidance in Chapter 5 is also applicable to stormwater retrofits.

Impervious Area (Simple) Disconnection

Impervious area disconnection, also called "simple disconnection," involves re-directing stormwater runoff from impervious surfaces as sheet flow onto adjacent vegetated pervious surfaces where it has the opportunity for treatment and infiltration, as described further in Chapter 5 - Low Impact Development Site Planning and Design Strategies. For new development and redevelopment, impervious area disconnection is an important Low Impact Development (LID) site planning and design strategy. Impervious area disconnection is also a simple, low-cost stormwater retrofit technique by utilizing the existing vegetated areas (i.e., lawn, meadow, or woods) that are typically adjacent to impervious areas, such as roads, parking lots, and buildings, for stormwater management.

Common applications of impervious area disconnection retrofits include:

- Installing inlet curb cut openings to allow runoff from a roadway to sheet flow to an adjacent vegetated median.
- Installing inlet curb cut openings in a parking lot to allow runoff to bypass existing catch basins and sheet flow to vegetated areas around the perimeter of the lot. The existing catch basins in the parking lot can function as overflow structures to convey runoff in excess of the water quality storm.
- Grading an uncurbed parking lot towards a vegetated island.
- Disconnecting building roof downspouts from the drainage system to adjacent pervious areas.

The feasibility and success of impervious area disconnection depends on several factors including the ability to re-direct runoff from the impervious area to the pervious area (often requiring grading or a curb-cut), as well as the ability of the pervious area to disperse (via a level spreader) and infiltrate runoff for storm events up to the water quality design storm. Key characteristics of the receiving pervious area include:

- Ground slope.
- Soil infiltration capacity and depth to groundwater.
- Size of the pervious area relative to the size of the contributing impervious area.
- Density of vegetation.
- Use of devices such as level spreaders to disperse the discharge and provide sheet flow, as needed, to disperse the flow and avoid flow concentration and short circuiting through the pervious area.

Sites with flatter slopes, pervious soils, and a dense stand of vegetation are better suited for maintaining dispersed flow. Flows for larger storm events should bypass or exit the pervious area in a controlled manner.

Chapter 5 - Low Impact Development Site Planning and Design Strategies provides design criteria for impervious area disconnection focused on new development and redevelopment projects. The design guidance in Chapter 5 is also applicable to stormwater retrofits.

Modifying Existing Structural Stormwater BMPs

Existing stormwater BMPs and related stormwater infrastructure originally designed for conveyance and stormwater quantity control can be modified to improve pollutant and runoff reduction performance. Depending on site conditions, such enhancement may be more cost-effective than constructing new structural stormwater BMPs. These types of retrofits can include modification of existing BMPs and stormwater infrastructure that was not designed with stormwater quality in mind, as well as rehabilitation of existing functional stormwater BMPs to improve their performance.

Key considerations for identifying and evaluating the feasibility of these types of retrofits include:

- Will the retrofit meet the project objectives and qualify for retention and/or treatment credits by meeting the design requirements in this Manual?
- Is the retrofit feasible based on existing site conditions?
- Is the retrofit cost-effective when compared to other retrofit alternatives?

An evaluation of existing site conditions and the existing stormwater infrastructure is required to determine the need for modifications to the conveyance system, if the retrofitted system should be designed in an on-line or off-line configuration, and how these decisions may impact project feasibility and cost.

Common opportunities for modifying existing stormwater BMPs and related stormwater infrastructure for enhanced pollutant and runoff reduction performance include:

Detention Basin Retrofits

Traditional dry detention basins are effective for stormwater quantity control but provide very limited pollutant removal. Dry detention basins, which were commonly used as the sole stormwater management practice for many older developments, can be modified to function as dry extended detention basins, infiltration basins, stormwater ponds, or stormwater wetlands for more effective retention of stormwater and enhanced pollutant removal. This is one of the most common and easily implemented retrofits since it typically requires little or no additional land area, requires minimal or no earthwork, utilizes an existing facility for which there is already some resident acceptance of stormwater management, and involves minimal impacts to environmental resources.

Detention basin retrofits should result in improved pollutant and/or runoff volume reduction performance, without a significant reduction in stormwater quantity control performance. Some detention basin upgrades may result in a partial loss of flood storage and peak discharge control. Detention basin retrofits that result in reduced basin storage volume (e.g., conversion to stormwater wetlands or stormwater ponds) should include a hydrologic and hydraulic analysis of the existing system and proposed changes to ensure that the modified basin will continue to provide adequate stormwater quantity control and will not cause flooding or other undesirable conditions for adjacent infrastructure or site uses. The basin's total storage volume may need to be increased to offset loss of storage volume. If the existing basin is constructed with an earthen berm, the stability of the embankment should be also evaluated relative to the proposed modifications.

Conversion to Infiltration Basin. Detention basins that remain dry between storm events, are in well-drained soils, and have three feet or more of vertical separation between the bottom of the basin and the seasonal high groundwater table are good candidates for conversion to infiltration basins. The major benefit of this type of retrofit is retention of stormwater and the associated reduction in runoff volume and pollutant loads. Common modifications to convert detention basins to infiltration basins include:

- Conduct test pits or soil borings to confirm soil characteristics, depth to the seasonal high groundwater table, and depth to bedrock or other confining layer, and perform field infiltration testing consistent with the guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.

- Till or scarify the bottom of the existing basin to restore soil infiltration capacity or excavate and replace the existing soil with a more uniform, permeable soil or engineered soil media.

- Modify the existing outlet structure by plugging or capping the low-level orifice and creating a new raised orifice to retain and infiltrate the Required Retention Volume, while maintaining a high-level overflow or orifice for stormwater quantity control and to convey flows for larger storms.

- Incorporate pretreatment (e.g., sediment forebays) at basin inlets.

- Revegetate the bottom of the basin to stabilize the basin surface and to establish a healthy vegetative root system, which helps maintain soil infiltration capacity.

Refer to the Infiltration Basin section in Chapter 13 and Chapter 10 - General Design Guidance for Stormwater Infiltration Systems for additional design guidance.

Conversion to Stormwater Pond or Stormwater Wetland. Detention basins that tend to remain wet between storm events, are in poorly drained soils, or have minimal vertical separation between the bottom of the basin and the seasonal high groundwater table are ideal for conversion to wet stormwater ponds or stormwater wetlands. This type of retrofit can significantly improve the pollutant removal performance of the basin by introducing additional pollutant removal mechanisms associated with a permanent pool of water and wetland vegetation. Common modifications to convert detention basins to wet stormwater ponds or stormwater wetlands include:

- Conduct test pits or soil borings to confirm soil characteristics, depth to the seasonal high groundwater table, and depth to bedrock or other confining layer consistent with the soil evaluation guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.

- Modify the existing outlet structure by plugging or capping the low-level orifice and creating a new raised orifice to maintain a permanent pool of water and support wetland vegetation, while maintaining a high-level overflow or orifice for stormwater quantity control and to convey flows for larger storms.

- Excavate the basin bottom to intercept the groundwater table and create more permanent pool storage.

- Add gravel and underdrain piping if converting the basin to a subsurface gravel wetland.

- Increase the flow path from inflow to outflow and eliminate short-circuiting by using baffles, earthen berms, or micro-pond topography to increase residence time of water in the pond and improve settling of solids.

- Replace paved low-flow channels with meandering vegetated swales.

- Provide a high flow bypass to avoid resuspension of captured sediment/pollutants during high flows.

- Incorporate stilling basins at inlets and outlets and pretreatment (e.g., sediment forebays) at basin inlets.

    - Regrade the basin bottom to create a wetland area near the basin outlet or revegetate parts of the basin bottom with wetland vegetation to enhance pollutant removal, reduce mowing, and improve aesthetics.

    - Create a wetland shelf along the perimeter of a wet basin to improve shoreline stabilization, enhance pollutant filtering, and enhance aesthetic and habitat functions.

    - Create a low maintenance "no-mow" wildflower ecosystem in the drier portions of the basin.

Refer to the Stormwater Pond BMPs and Stormwater Wetland BMPs sections in Chapter 7 for additional design guidance.

Drainage Channel Retrofits

Conventional grass swales and ditches that were constructed primarily as surface stormwater drainage channels provide little if any pollutant removal and limited or no infiltration and volume reduction. Drainage channels are common along some roads and highways or as perimeter features around parking lots. Drainage channels can be modified to reduce flow velocities; create opportunities for ponding, infiltration, and establishment of wetland vegetation; and enhance pollutant removal.

Grass swales and ditches can be converted to wet or dry water quality swales, or linear bioretention systems (i.e., bioswales). Similar to detention basins, the most appropriate retrofit approach depends largely on the soil and groundwater conditions at the site. Drainage channels located in well-drained soils with adequate vertical separation to the seasonal high groundwater table are ideal for conversion to dry water quality swales or linear bioretention, while drainage channels in poorly drained soils and shallow groundwater are better suited for conversion to wet water quality swales.

Conversion to Dry Water Quality Swale or Linear Bioretention. This type of retrofit can significantly improve the retention, infiltration, and volume reduction benefits of drainage channels. If the soils are not conducive to infiltration, the drainage channel can be converted to a lined bioretention system with an underdrain to improve the treatment effectiveness of the channel. Common modifications to convert conventional grass swales and ditches to dry water quality swales or linear bioretention systems include:

- Conduct test pits or soil borings to confirm soil characteristics, depth to the seasonal high groundwater table, and depth to bedrock or other confining layer, and perform field infiltration testing consistent with the guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.
- Conduct minor grading and/or reshaping of the channel cross section.
- Excavate and replace the existing soil with engineered bioretention soil media.
- Incorporate pretreatment (e.g., sediment forebays) at inlets to the channel.
- Add check dams.
- Add underdrain if necessary.
- Establish a dense vegetative cover or adequately stabilized landscaped surface throughout the channel to promote pollutant removal and infiltration.

Refer to the Dry Water Quality Swale and Bioretention sections in Chapter 13 for additional design guidance.

Conversion to Wet Water Quality Swale. This type of retrofit can significantly improve the pollutant removal performance of the drainage channel by introducing additional pollutant removal mechanisms associated with a permanent pool of water and wetland vegetation. Common modifications to convert conventional grass swales and ditches to wet water quality swales include:

- Conduct test pits or soil borings to confirm soil characteristics, depth to the seasonal high groundwater table, and depth to bedrock or other confining layer consistent with the soil evaluation guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems.
- Conduct minor grading and/or reshaping of the channel cross section.
- Modify or install an outlet structure to maintain a permanent pool of water and support wetland vegetation or excavate the channel bottom to intercept the groundwater table.
- Incorporate a high-level overflow or orifice in the outlet structure for stormwater quantity control and to convey flows for larger storms.
- Incorporate pretreatment (e.g., sediment forebays) at inlets to the channel.
- Add check dams.

- Plant with emergent wetland plants.

Refer to the Wet Water Quality Swale section in Chapter 13 for additional design guidance.

Note that these drainage channel retrofits are only applicable to man-made stormwater conveyances and should not be implemented within natural stream channels or regulated wetlands or watercourses.

Bioretention System Retrofits

Many existing bioretention systems constructed in the past 20 years were based on older, outdated designs. While these systems may still function adequately, their treatment and infiltration/retention performance may be improved by incorporating relatively simple modifications that reflect current state-of-the-practice for bioretention system design. These design modifications are part of the standard design guidance for new bioretention systems as presented in the Bioretention section of Chapter 13.

Internal Water Storage. For systems with an underdrain, modify the underdrain outlet structure to incorporate an upturned outlet (using an elbow or capped "T" pipe) to create a thicker saturated zone (also called an Internal Water Storage zone or Internal Storage Reservoir) that extends into the bottom of the bioretention soil media. This type of underdrain configuration increases infiltration and evapotranspiration and enhances removal of nitrogen through the creation of an anaerobic or anoxic Internal Water Storage zone. The combined volume reduction and nitrogen treatment benefits of this modification can result in significant nitrogen load reductions. The upturned pipe should be located inside the outlet structure, if possible, to facilitate maintenance access.

Filter Media Amendments. Many of the earlier bioretention system designs incorporated compost as the organic component of the bioretention soil mix. Compost-based bioretention soil mixes have been shown to export nutrients and are therefore no longer recommended. The soil media in aging bioretention systems that receive heavy pollutant loads may be beyond its useful life in terms of pollutant removal. In these instances, bioretention systems can be modified by amending the bioretention soil to enhance pollutant removal, particularly phosphorus removal, and extend the life of the bioretention soil media. Organic matter (sphagnum peat moss or wood derivatives such as shredded wood, wood chips, ground bark, or wood waste) can be mixed into the existing bioretention soil layer. Other soil amendments such as zerovalent iron and/or drinking water treatment residuals (alum) may be used to further enhance phosphorus sorption. This is an emerging area of research and practice that includes fungal mycelium, biochar, and other innovative filter media amendments.

Forebays. Sediment forebays and similar pretreatment measures not only facilitate bioretention maintenance but have also been shown to be effective for removal of phosphorus, nitrogen, and metals in addition to sediment.[68] The addition of a forebay can therefore enhance pollutant removal and extend the life of the bioretention soil media.

New Structural Stormwater BMPs

New structural stormwater BMPs can be strategically located to manage stormwater runoff from directly connected impervious areas on existing developed sites. Such areas are considered disconnected when stormwater runoff is retained on-site using Infiltration BMPs or Stormwater Reuse BMPs that are selected, sized, and designed following the guidance contained in other sections of this Manual. However, it is important to note that not all structural BMPs will disconnect DCIA, treatment alone does not treatment alone does not retain the WQV and strategic planning is necessary to do so.

Stormwater retrofits involving installation of new structural stormwater BMPs generally fall into three major categories depending on where the BMPs are applied:

Close to the Source. This is the most common type of stormwater retrofit, which involves installation of small-scale structural stormwater BMPs close to the source of runoff generation and prior to runoff entering the storm drainage system. Because they are located close to the source, these retrofits provide greater flexibility for siting, manage smaller runoff volumes, and are more cost-effective than drainage system or outfall retrofits. Numerous examples exist of these types of retrofits. Common examples include off-line infiltration systems located within parking lot or roadway medians, and rain barrels or cisterns used for collection and reuse of rooftop runoff.

Within the Drainage System. Existing drainage systems can be modified to improve pollutant removal and provide retention/infiltration. The pollutant removal benefits provided by these types of retrofits are typically limited to removal of coarse solids and floatables. They also commonly involve new subsurface structures and modification of the storm drainage system, which can be less cost-effective than other types of retrofits. In some cases, conventional drainage systems can be retrofitted with infiltrating catch basins, perforated pipe, and other underground infiltration systems to meet retention requirements. Drainage system retrofits are most cost-effective when combined with retrofits installed close to the source to reduce the volume of runoff that reaches the drainage system. Common examples of drainage system retrofits include:

- Replacing older style catch basins with deep-sump, hooded catch basins.
- Installing hoods on existing catch basins.
- Installing new infiltrating catch basins upgradient of existing catch basins or replacing existing catch basins with infiltrating catch basins.

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[68] Johnson J. & Hunt W. 2016. Evaluating the spatial distribution of pollutants and associated maintenance requirements in an 11-year-old bioretention cell in urban Charlotte, NC. Journal of Environmental Management. 184 (Pt 2), 363–370.

- Use of manufactured or proprietary devices (such as smaller grates) that catch sediments, trash, organic matter, and other particulates.
- Replacing existing storm drains with perforated drainpipe.
- Installing new tree filters upgradient of existing catch basins or replacing existing catch basins with tree filters.
- Installing proprietary filtration devices in existing catch basins (i.e., catch basin inserts) or other manufactured treatment devices within the drainage system to capture sediment and other pollutants.
- Elimination of curbing.

At the Outfall. New stormwater BMPs can be constructed at or just upgradient of the outfalls of existing drainage systems. Due to the "end-of-pipe" nature of these retrofits, such BMPs are commonly designed as off-line systems, requiring the use of flow diversion structures to retain and/or treat runoff from the water quality storm and bypass larger flows. Most structural stormwater BMPs can be used for this type of retrofit, given sufficient space and maintenance access. However, BMPs designed for wet conditions such as stormwater ponds and wetlands tend to be most conducive to outfall retrofits given the frequent presence of shallow groundwater and poorly drained soils at outfall locations. For these reasons, the feasibility of infiltration BMPs at outfalls is often limited.

Structural stormwater BMPs should be selected to address the water quality objectives for the site (e.g., for specific target pollutants associated with a water quality impairment) and any secondary objectives or co-benefits such as flood reduction, habitat restoration, and community enhancement. Potential constraints may include site conditions, owner preferences and limitations, maintenance considerations, cost/budget considerations, and the overall approach (opportunistic versus planning approach). Refer to Chapter 8 - Selection Considerations for Stormwater BMPs for selection of appropriate BMPs for retrofit applications.

Once suitable structural stormwater BMPs are selected based on water quality objectives and site constraints, the BMPs should be sized to meet the retention and/or treatment requirements presented in Chapter 4 - Stormwater Management Standards and Performance Criteria. Retrofit BMPs are generally sized to maximize retention/treatment performance given the site and project constraints. Stormwater BMP Performance Curves can be used for optimizing sizing in terms of costs and benefits. Retrofit sizing and credits (i.e., quantifying the pollutant and DCIA reduction benefits), including the use of the BMP Performance Curves for retrofit sizing, are further described in the Retrofit Sizing and Crediting section of this chapter. Chapter 10 - General Design Guidance for Stormwater Infiltration Systems and the BMP-specific design guidance in Chapter 13 - Structural Stormwater BMP Design Guidance provide additional design considerations for retrofits involving new structural stormwater BMPs.

Retrofit Applications

Retrofits can be incorporated into a wide range of land use settings and sites, including within the roadway right-of-way (ROW) as well as on public and privately-owned developed parcels of land. The following sections summarize common ROW and parcel-based retrofit applications.

Roads and Right-of Way Retrofits

Retrofit opportunities exist along most types of roads. The road functional classification (interstate, arterial, collector, and local), intensity of adjacent development (urban, suburban, rural), and other right-of-way characteristics will dictate the suitability of retrofit types and specific structural stormwater BMPs.

Divided Highways

Open spaces associated with highway ROW areas such as medians, shoulders, and interchanges present opportunities to incorporate new stormwater BMPs. Opportunities also exist to retrofit existing linear stormwater conveyances (i.e., grass drainage channels) and detention basins, such as the drainage channel retrofits described in the previous section, to provide increased retention and enhanced treatment of stormwater. Traffic, safety, and maintenance access are important considerations for determining appropriate locations for highway ROW retrofits. Common retrofit approaches for highway ROW areas include:

- Pavement disconnection to a vegetated filter strip or other qualifying pervious area adjacent to the highway (i.e., simple disconnection).
- Conversion of existing grass swales to water quality swales or linear bioretention using check dams and other modifications.
- Conversion of existing dry detention basins to infiltration basins or stormwater ponds or wetlands.
- Installation or new linear vegetated stormwater BMPs in grassed medians.
- Replacing older style catch basins with deep-sump, hooded catch basins or infiltrating catch basins.
- Retrofit of drainage system outfalls that discharge directly to receiving waterbodies using off-line retention or treatment stormwater BMPs.

Urban Roads

Roads and streets in urban settings such as downtown areas, village centers, and heavily developed commercial corridors present a variety of retrofit opportunities as well as some unique challenges associated with urban development. Urban landscape features such as streets, sidewalks, parkways, and green spaces can be modified to be multi-functional by incorporating small-scale vegetated surface stormwater BMPs (also referred to as “green infrastructure” or "green stormwater infrastructure) to provide retention and filtration of stormwater, while achieving other functions such as accommodating bicycle lanes, providing traffic calming, and aesthetic/streetscape improvements (i.e., "green streets" approaches). Given limited space and numerous physical constraints that typically exist in urban settings, opportunities also exist for subsurface retrofits within the ROW to intercept, store belowground, and infiltrate stormwater that would otherwise enter the existing drainage system using underground infiltration systems located below the road surface or sidewalks.

Urban roads with limited vegetation/trees, wide roads and sidewalks, and large amounts of impervious area tend to be good candidates for retrofits. Common retrofit approaches for urban roads include:

- Addition of bioretention stormwater planters, bioswales, and tree filters within existing green space between the road and sidewalks.
- Creation of bioretention bump outs to reduce impervious area, manage stormwater, provide traffic calming, and improve pedestrian safety.
- Use of curb inlets to intercept and divert surface runoff into new off-line stormwater BMPs, while using the existing drainage system as the overflow to convey runoff from larger storm events.
- Use of permeable pavement for on-street parking stalls, sidewalks, crosswalks, etc.
- Use of underground infiltration systems (chambers and infiltrating catch basins) below roads and sidewalks in areas with inadequate land area or space to accommodate surface practices.
- Narrowing of wide sidewalks and re-grading to vegetated filter strips.

Surface and subsurface utilities can pose significant challenges to the design, construction, and maintenance of stormwater BMPs, especially in urban areas. Utility management should be considered early in the planning and design of urban retrofits. Effective planning and design of urban retrofits should include the following considerations:

- Coordinate with public and private utilities to determine the presence of existing utilities within the project limits as well as design and construction requirements for utility-related construction.
- Locate existing utilities during the design phase.
- Verify separation requirements between proposed stormwater BMPs and existing on-site utilities with the utility owner.

- Where stormwater BMP are proposed with sidewalks, utility poles should be at the back of the sidewalk. Where possible, locate utilities outside the sidewalk limits. Sidewalks should continue to meet accessibility requirements following the installation of the retrofits.
- If fire hydrants are present near the proposed stormwater BMPs or must be relocated, coordinate with the local fire department/district and water utility owner for design and construction requirements.
- Consider the potential for conflict with overhead utilities. These conflicts include both permanent fixed objects and constructability issues. Consult the utility pole owner, and NESC & OSHA guidelines.
- Relocating utilities should be carefully considered during the selection of a stormwater BMP. Relocation can be costly and requires early coordination with the utility owner. The proposed relocation design must be reviewed and approved by the utility owner.
- The configuration of a stormwater BMP must allow utility owner access to all mains and service laterals for maintenance.
- Infiltrating BMPs should not be sited adjacent to or above existing utility trenches, which can result in "short circuiting" of the BMP drainage mechanisms if preferential flow is through the bedding material of the utility trench. Impermeable liners can be used to minimize the potential for short-circuiting.

Residential Subdivisions

Many older residential subdivisions have wide roads, traditional curb and gutter drainage systems, limited existing vegetation/trees, and limited stormwater quality controls. Opportunities exist to reduce or disconnect impervious areas within the ROW, coupled with potential on-lot improvements that can be made by private property owners to further disconnect driveways, roof, patios, etc. from the municipal drainage system. Common retrofit approaches for residential subdivisions and similar suburban residential neighborhoods include:

- Narrowing road widths and replacing sidewalks on one side of the road with vegetated filter strips or water quality swales.
- Replacing older style catch basins with deep-sump, hooded catch basins or infiltrating catch basins.
- Elimination of curbing and closed drainage systems.
- Addition of bioretention stormwater planters, bioswales, and tree filters within existing green space between the road and sidewalks.
- Creation of bioretention bump outs to reduce impervious area, manage stormwater, provide traffic calming, and improve pedestrian safety.

- Conversion of large, paved cul-de-sac bulbs to vegetated surfaces or installation of bioretention of infiltration BMPs within these areas.
- Providing incentives for homeowners to disconnect roof leaders and runoff from other impervious surfaces on their lots using simple disconnection, rain barrels, dry wells, and permeable pavement.

Parcel Based Retrofits

Parking lots and building roof areas (i.e., large impervious areas that are directly connected to the existing drainage system) provide numerous opportunities for potential for parcel-based stormwater retrofits on public and private property. All of the retrofit types described in the previous section – conversion of existing impervious areas to pervious areas, simple disconnection, and addition of new stormwater BMPs – can be implemented as parcel-based retrofits.

Publicly owned (e.g., municipal- or state-owned) parcels typically offer the most immediate potential for retrofits because they avoid the cost of land acquisition, the need for cooperation with private landowners, and allow the municipal or state jurisdiction to have direct control over retrofit construction and maintenance. Certain types of private parcels such as institutional facilities (e.g., private colleges and universities) and commercial properties with large impervious areas may be good candidates for retrofits but require landowners who are willing to construct and maintain the retrofits. Stormwater utility fees and associated impervious area reduction credits can be used to incentivize retrofits on private property.

Parking Lots

Parking lots in municipal, commercial, and institutional land use settings can be ideal candidates for a wide range of stormwater retrofits. Sites with excess or under-utilized parking provide opportunities for conversion of impervious areas to pervious areas and the use of pervious pavement in parking stalls or overflow parking areas. Small-scale infiltration and treatment BMPs (bioretention, tree filters, water quality swales, etc.) can be added to existing landscaped areas in parking islands and around the perimeter of parking lots, depending on the configuration of the existing storm drainage system and location of drainage structures relative to the existing green space. Curb cuts and grading can be used to disconnect portions of parking lots by re-directing sheet-flow to adjacent vegetated areas. Parking lots also provide opportunities for subsurface retrofits (infiltrating catch basins and underground infiltration systems) where space is limited, or existing surface drainage structures are not conveniently located.

Repaving or replacement of existing parking lots, as well as redevelopment of older commercial properties (often designed with excess parking, high impervious coverage, and limited stormwater controls) are good opportunities for incorporating retrofits in conjunction with other planned infrastructure improvements. Common examples of parking lot stormwater retrofits include:

Incorporating Bioretention into Parking Lot Islands and Landscaping. Parking lot islands and landscaped areas can be converted into functional bioretention areas, tree filters, and dry water quality swales using curb cuts located upgradient of existing catch basins.

Removing Curbing and Adding Slotted Curb Stops. Curbs along the edges of parking lots can sometimes be removed or slotted to re-route runoff to vegetated areas, buffer strips, or bioretention facilities. The capacity of existing swales may need to be evaluated and expanded as part of this retrofit option.

Incorporating New BMPs around the Perimeter of Parking Lots. New retention and treatment BMPs such as infiltration trenches and basins, bioretention, tree filters, and dry water quality swales can often be incorporated into the green space around the perimeter of parking lots provided there is adequate setbacks to adjacent properties and infrastructure.

Use of Permeable Paving Materials. Existing conventional pavement in overflow parking or other low-traffic areas can sometimes be replaced with alternative, permeable materials. Site-specific factors including traffic volumes, soil permeability, maintenance, sediment loads, and land use must be carefully considered for the successful application of permeable paving materials for retrofit applications.

Installation of Subsurface Retrofits. Underground infiltration systems such as infiltration chambers can be installed below parking lots on space-constrained sites. Existing catch basins can also be retrofitted or replaced with infiltrating catch basins.

Building Roof Areas

Building roofs that are directly connected to the storm drainage system are ideal candidates for disconnection using infiltration BMPs, stormwater reuse BMPs, or green roof installations. In residential settings, roof runoff can typically be disconnected by re-directing downspouts to lawn areas, rain gardens, dry wells, or rain barrels. Commercial and institutional buildings typically generate larger volumes of runoff and contain high pollutant levels, requiring adequate pretreatment and more space for surface infiltration/filtration systems or larger underground infiltration systems. Common examples of stormwater retrofits for building rooftops include:

- Disconnecting residential roof downspouts and re-directing them to existing vegetated areas (i.e., simple disconnection), dry wells, or rain barrels.
- Disconnecting roof leaders from larger commercial and institutional buildings, which are often hard piped into the existing storm drainage system, and re-directing them to existing vegetated areas (i.e., simple disconnection), infiltration basins, bioretention cells, or underground infiltration systems.
- Capture of roof runoff at sites with landscaped areas or turf fields (e.g., schools, playgrounds, outdoor recreational facilities) using cisterns and stormwater reuse systems for irrigation to reduce runoff volumes and municipal water usage.

- Conversion of flat building roof areas to vegetated roofs using modular green roof systems.

Retrofit Selection

While some form of retrofitting is possible on most sites, existing developed sites often have characteristics that can limit the type of stormwater retrofits and structural stormwater BMPs that are possible and their overall effectiveness. Table 9- 1 lists site-specific factors to consider in determining the appropriateness of stormwater retrofits for a particular site.

Table 9- 1 Site Considerations for Determining the Appropriateness of Stormwater Retrofits

Factor	Consideration
Retrofit Purpose	➢ What are the primary and secondary (if any) purposes of the retrofit project? ➢ Are the retrofits designed primarily for DCIA and pollutant reduction, stormwater quantity control, or a combination of both? ➢ Will the retrofit project meet or make cost-effective progress towards goals? ➢ Will the retrofit accomplish other goals/benefits (e.g., flood reduction, habitat creation, community enhancements)?
Space	➢ Is there adequate space and setback distances for new surface-based stormwater BMPs?
Existing Drainage Patterns and Storm System Configuration	➢ Are existing catch basins located adjacent to and at a higher elevation than nearby green space? ➢ Does the existing configuration of the storm drainage system allow for use of the existing catch basins as overflow structures or are new overflow devices and flow diversion structures required, which would increase cost?
Contributing Drainage Area	➢ Is the retrofit compatible with the size of the contributing drainage area? ➢ Can the retrofit be sized with sufficient storage to meet the retention/treatment standards? ➢ Is the drainage area sufficient to maintain the required hydrology and vegetation for wet practices?
Site Slope	➢ Is the site topography consistent with the recommended slope limitations of the proposed retrofit?

Factor	Consideration
Subsurface Conditions	➢ Are the subsurface conditions at the site (soil infiltration capacity, depth to the seasonal high groundwater table, and depth to bedrock) consistent with the proposed retrofit? ➢ Does site contamination present a conflict for the proposed retrofits?
Utilities	➢ Do the locations of existing utilities (including private wells and on-site wastewater systems) present conflicts with the proposed retrofits or require relocation or design modifications?
Conflicting Land Uses	➢ Are the retrofits compatible with existing uses of the site and adjacent land uses of nearby properties?
Wetlands, Sensitive Receiving Waters, and Vegetation	➢ How do the retrofits affect adjacent or downgradient wetlands, sensitive receiving waters, and vegetation? ➢ Do the retrofits minimize or mitigate impacts where possible?
Construction/Maintenance Access	➢ Does the site have adequate construction and maintenance access and sufficient construction staging area? ➢ Are maintenance responsibilities for the retrofits clearly defined and who will be performing the maintenance? ➢ Is the owner aware of and willing to take responsibility for O&M costs? ➢ What is the required inspection and maintenance frequency? ➢ Are there special maintenance equipment needs?
Permits and Approvals	➢ Which local, state, and federal regulatory agencies have jurisdiction over the proposed retrofit project? ➢ Can regulatory approvals be obtained for the retrofits?
Public Safety	➢ Does the retrofit increase the risk to public health and safety?
Cost	➢ What are the capital and long-term maintenance costs associated with the stormwater retrofits? ➢ Are the retrofits cost-effective in terms of anticipated benefits?

Source: Adapted from Claytor, Center for Watershed Protection, 2000.[69]

Physical constraints that are common on existing developed sites can present design challenges that limit the ability of stormwater retrofits to fully meet the stormwater management standards, performance criteria, and BMP-specific design guidance presented in this Manual. For example,

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[69] Claytor, R.A. Center for Watershed Protection. 2000. *The Practice of Watershed Protection*. Ellicott City, Maryland.

the minimum recommended horizontal setback distance between a proposed infiltration retrofit and an existing building may not be feasible, although a groundwater mounding analysis or use of an impermeable liner may mitigate the risk of water intrusion into the building foundation. Similarly, conversion of an existing dry detention basin to an infiltration basin may not fully meet the require Required Retention Volume, given the need to preserve storage for peak flow attenuation, but the modification would provide substantial retention of stormwater as compared to existing conditions while providing adequate stormwater quantity control.

Retrofitted facilities may not be as effective in reducing pollutant loads as newly designed and installed facilities. However, in most cases, some improvements in pollutant reduction, runoff reduction, groundwater recharge, and stormwater quantity control are possible even if the retrofit does not fully meet all the management standards, performance criteria, and design guidance due to site constraints. Research and recent practice have shown that retrofits designed for less-than-optimal conditions can still provide significant pollutant reduction and hydrologic benefits. This approach to stormwater retrofitting is based on the following rationale:

- Implementing small-scale retrofits is better than not retrofitting.
- Providing some retention and infiltration is better than none.
- Where retention/infiltration is not possible, providing some pretreatment and treatment is better than none.
- Any impervious surface disconnection is an improvement over existing condition.

Rather than preclude the use of retrofits that cannot fully meet the management standards, performance criteria, and design guidance, this Manual promotes the use of retrofits whenever possible by providing flexibility in retrofit sizing and crediting, as discussed in the following section.

For retrofits involving the addition of new structural stormwater BMPs or upgrades to existing stormwater BMPs, the guidance provided in Chapter 8 - Selection Considerations for Stormwater BMPs should be consulted to screen out unsuitable retrofits and help select the most appropriate retrofits for a given site.

Retrofit Sizing and Crediting

This section provides guidance on sizing of stormwater retrofits and quantifying the benefits of retrofits (i.e., credits) in terms of disconnecting and reducing DCIA.

Stormwater BMP Performance Curves

As introduced in Chapter 4 - Stormwater Management Standards and Performance Criteria, the EPA Region 1 stormwater BMP performance curves can be used to help select, size, and quantify the pollutant reduction benefits of stormwater retrofits. Use of the performance curves is becoming widely accepted in New England for sizing and quantifying the benefits of stormwater BMPs in general, including retrofit applications.

Benefits of Using Performance Curves for Stormwater Retrofit Design

The curves (SNEP Network, 2022):

- Are highly flexible to accommodate site constraints.
- Encourage the use of multiple smaller BMPs when larger retrofits are not feasible.
- Credit a range of sizes including smaller sizes.
- Credit a range of pollutants to help connect performance with specific pollutant goals.
- Allow for crediting non-conforming designs (i.e., designs that cannot fully meet the stormwater management standards, performance criteria, and design guidance).
- Allow for crediting existing systems as they are currently functioning.
- Support optimization and cost-effective designs.
- Are based on the most recent stormwater BMP performance data.

The performance 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 performance 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 (TSS, TP, TN, Zinc, and fecal indicator bacteria). 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.

Chapter 4 - Stormwater Management Standards and Performance Criteria provides an overview of the performance curves, how they were developed, and their basic use for quantifying the pollutant reduction benefits of structural stormwater BMPs and documenting compliance with the minimum required pollutant load reductions when the Required Retention Volume cannot be retained on-site. 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.

The Stormwater Retrofit Manual developed by the Southeast New England Program (SNEP) Network in collaboration with the University of New Hampshire Stormwater Center, EPA Region 1, and state agencies and the other information sources listed at the end of this chapter provide additional information on the use of stormwater BMP performance curves for retrofit design.

Retrofit Sizing Guidance

In retrofit settings, similar to new development and redevelopment applications, stormwater BMPs should be designed to meet the retention and treatment requirements of Standard 1 – Runoff Volume and Pollutant Reduction as follows (refer to Table 4-2 in Chapter 4):

- Retain on-site the applicable post-development stormwater runoff volume (i.e., the "Required Retention Volume"), which is equal to 100% or 50% of the site's Water Quality Volume (WQV) depending on the existing DCIA of the site and the amount of proposed land disturbance. When the Required Retention Volume is retained on-site using suitable stormwater retention practices (refer to Table 8- 1.), the retrofit is presumed to meet or exceed the minimum required average annual pollutant load reductions for TSS, TP, and TN, as described in Chapter 4 - Stormwater Management Standards and Performance Criteria.

- In cases where the volume of stormwater runoff retained on-site does not fully meet the Required Retention Volume due to physical site constraints or other factors, retain runoff on-site to the "Maximum Extent Achievable" (for the definition see Standard 1 Section of Chapter 4) and provide additional stormwater treatment without retention for the post-development runoff volume above that which can be retained up to 100% of the site's WQV.

- In cases where the additional stormwater treatment requirement cannot be achieved on-site, provide stormwater treatment to the "Maximum Extent Achievable."

Where stormwater treatment is proposed in addition to or in lieu of stormwater retention (i.e., when the retrofit cannot fully meet the retention requirement), the designer should use the stormwater BMP performance curves to:

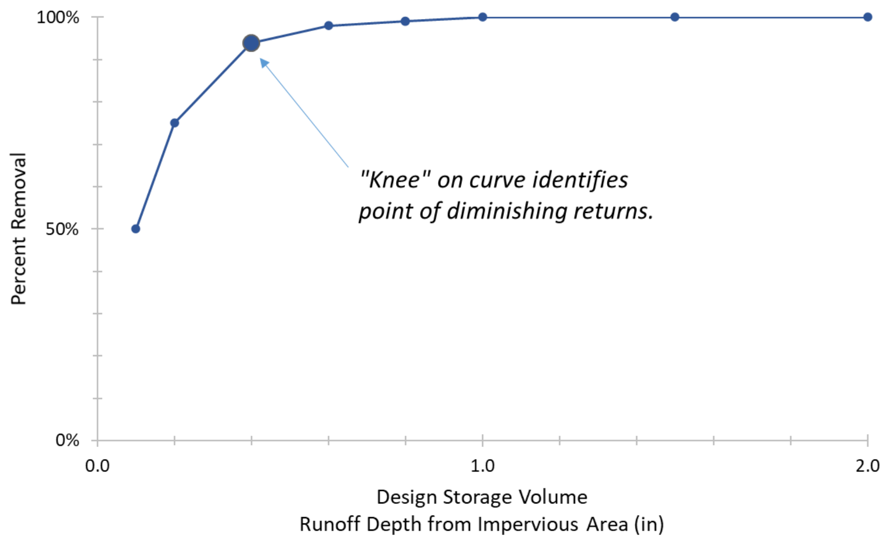
- Optimize retrofit sizing based on anticipated pollutant reduction performance, and

- Document that the proposed retrofit meets or exceeds the minimum required average annual pollutant load reductions for TSS, TP, and TN, as described in Chapter 4 - Stormwater Management Standards and Performance Criteria and Appendix C – BMP Performance Curves and Static Storage Volume Calculation Methods

The performance curves show significant pollutant reduction for design storage volumes in the smaller range (0.1 to 0.5-inch over the contributing impervious area), providing flexibility for retrofits that cannot fully meet the retention and/or treatment requirements. Stormwater BMPs with a design storage volume smaller than 0.1 inch likely do not provide sufficient pollutant reduction benefit due to their lack of capacity to capture, hold, and treat stormwater and therefore are not recommended. Structural stormwater BMPs sized to store less than the WQV 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.

Furthermore, the performance curves show that stormwater BMPs provide diminishing pollutant reduction benefits above a certain size (the "knee" of the curve – see Figure 9-1 for an example). Some curves are steeper and have a more obvious point of diminishing returns while some are flatter and show more gradual increases in performance. The knee of the curve is typically in the range of 0.35 to 0.5 inches of runoff over the impervious area for all pollutants and BMP types.[70]

Figure 9-1. Example of Stormwater BMP Performance Curve Showing Point of Optimal Pollutant Load Reduction Performance (Knee of the Curve)[68]



It is important to note the following issues regarding use of the performance curves for retrofit sizing:

- While the knee of the curve represents a point of diminishing returns in terms of cost-effectiveness, the design storage volume corresponding to the knee may not achieve the minimum required average annual pollutant load reductions as outlined in Chapter 4 - Stormwater Management Standards and Performance Criteria, in which case larger design storage volumes may be necessary to demonstrate compliance with Standard 1.

- The performance curves provide flexibility to select and size retrofits in a cost-effective manner, but the curves should not be used to minimize treatment. Instead, they should be used to maximize/optimize retention and treatment performance given physical site constraints. The performance curves provide a basis for justifying the use of smaller retrofits strictly in terms of pollutant load reduction, but their use is not meant to replace the retention standard and associated design guidance described in Chapter 4 - Stormwater Management Standards and Performance Criteria and elsewhere in this Manual. On-site retention of stormwater volumes up to the Required Retention Volume

[70] Southeast New England Program (SNEP) Network. 2022. *Stormwater Retrofit Manual.* Developed in conjunction with University of New Hampshire Stormwater Center, EPA Region 1, and state agencies.

(100% or 50% of the site's WQV) is important to maintain or restore pre-development /hydrology (i.e., volume, rate, and temperature of runoff) and groundwater recharge, in addition to providing pollutant load reduction benefits.

Getting Credit for Retrofits – DCIA Disconnection

DCIA is considered disconnected when the appropriate portion of the Water Quality Volume has been retained and/or treated as described in Chapter 4 - Stormwater Management Standards and Performance Criteria. This can be accomplished by using any of the stormwater retrofit types described previously in this chapter, including impervious area conversion, impervious area (simple) disconnection, new structural stormwater BMPs, and modifying existing stormwater BMPs.

Each type of retrofit must meet specific criteria and conditions to receive credit for DCIA disconnection and to meet Standard 1 – Runoff Volume and Pollutant Reduction of this Manual. Table 9- 2 summarizes, for each major type of retrofit, the criteria and conditions that must be met for DCIA to be considered disconnected, and the amount of DCIA reduction credit associated with the disconnection.

Additional Information and Resources on Stormwater Retrofits

The following documents provide additional information and resources on the planning and design of stormwater retrofits from organizations within Connecticut, elsewhere in New England, and nationally.

- Stormwater Retrofit Manual, Southeast New England Program (SNEP) Network (2022)
- Connecticut Department of Transportation MS4 Resources, CTDOT
- Rhode Island Department of Transportation Linear Stormwater Manual, RIDOT (2019)
- Coastal Stormwater Management Through Green Infrastructure: A Handbook for Municipalities, US EPA (2014)

Table 9- 2 Stormwater Retrofit Criteria for DCIA Disconnection and Reduction Credit

Retrofit Type	When is DCIA Considered Disconnected?	DCIA Reduction Credit
Impervious Area Conversion	➢ Existing excess impervious surfaces (pavement, buildings, etc.) are removed and replaced with pervious vegetated surfaces (lawn, meadow, woods), AND ➢ The infiltration rate and porosity of the underlying soils are restored to pre-development conditions through scarification, ripping (tilling), or use of a shatter-type soil aerator, as necessary, AND ➢ The soil is amended, as necessary, to support vegetation. ➢ Soil testing or other documentation to the satisfaction of the review authority is needed to classify / demonstrate the permeability of the restored pervious area.	**Full Credit** Impervious area[1] (in acres) converted and restored to pervious area.
Impervious Area (Simple) Disconnection	➢ Stormwater runoff from impervious surfaces is re-directed as sheet flow onto adjacent vegetated pervious areas (i.e., lawn, meadow, or woods), AND ➢ The contributing impervious area and the receiving pervious area meet the design criteria for simple disconnection as described in Chapter 5 - Low Impact Development Site Planning and Design Strategies ➢ Soil testing is needed to classify the permeability of the receiving pervious area.	**Full Credit** Impervious area[1] (in acres) from which runoff is re-directed to adjacent vegetated pervious areas.
New or Modified Structural Stormwater BMPs	➢ The applicable post-development stormwater runoff volume (i.e., Required Retention Volume) is fully retained on-site using suitable stormwater retention practices as described in Chapter 4 - Stormwater Management Standards and Performance Criteria.	**Full Credit** Impervious area[1] (in acres) from which stormwater is retained using new or modified stormwater BMP.

[1]Credit only available if existing impervious area is directly connected.

Retrofit Type	When is DCIA Considered Disconnected?	DCIA Reduction Credit
	➢ The applicable post-development stormwater runoff volume retained on-site does not fully meet the Required Retention Volume due to physical site constraints or other factors, but runoff is retained on-site to the "Maximum Extent Achievable" (see Chapter 4 - Stormwater Management Standards and Performance Criteria.) and additional stormwater treatment without retention is provided for the post-development runoff volume above that which can be retained up to 100% of the Water Quality Volume, AND ➢ The proposed retrofit meets or exceeds the minimum required average annual pollutant load reductions (TSS, TP, TN) as demonstrated using stormwater BMP performance curves.	**Full Credit** Impervious area[1] (in acres) from which stormwater is retained or treated using new or modified stormwater BMP.
New or Modified Structural Stormwater BMPs continued	➢ In cases where the additional stormwater treatment requirement cannot be achieved on-site, but stormwater is treated to the "Maximum Extent Achievable" (see Chapter 4 - Stormwater Management Standards and Performance Criteria.)	**Partial Credit** **(X% Reduction)** The amount of DCIA reduction is determined using the stormwater BMP performance curves. • Obtain DCIA (also called "Effective IA" in the BMP performance curves) reduction percentage from the appropriate performance curve based on the type of BMP and the appropriate Hydrologic Soil Group. • Multiply the DCIA reduction percentage by the impervious area[1] draining to the stormwater BMP. If a stormwater BMP performance curve for DCIA or Effective IA does not exist for a given BMP type, estimate the DCIA reduction percentage based on the most representative curve. Table 4-2 of the Regional Retrofit Manual describes a crosswalk of appropriate representative curves. Should a BMP not be mentioned in this table justification for choosing the appropriate curve should be based on function and where necessary HSG.

[1]Credit only available if existing impervious area is directly connected.