Chapter 7 – Overview of Structural Stormwater Best Management Practices

Introduction

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

What's New in this Chapter?

- Recategorized structural stormwater BMPs based on function, replacing previous "Primary and Secondary Treatment Practices" terminology and framework
- Increased flexibility for selection and design of structural stormwater BMPs to meet stormwater management standards and performance criteria
- General guidance on BMP design considerations to reduce or facilitate maintenance

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

Functional Categories of Structural Stormwater BMPs

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

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

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

Pretreatment BMPs

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

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

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

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

Infiltration BMPs

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

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

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

Filtering BMPs

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

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

- Bioretention
- Sand Filter
- Tree Filter

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

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

Stormwater Pond BMPs

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

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

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

Stormwater Wetland BMPs

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

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

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

Water Quality Conveyance BMPs

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

- Dry Water Quality Swale
- Wet Water Quality Swale

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

Stormwater Reuse BMPs

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

- Rain Barrel
- Cistern

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

Proprietary BMPs

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

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

Other BMPs and BMP Accessories

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

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

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

Pollutant Removal Mechanisms

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

Table 7- 1 Stormwater Pollutant Removal Mechanisms

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

BOD – Biochemical Oxygen Demand, COD – Chemical Oxygen Demand

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

BMP Effectiveness

Structural stormwater BMPs differ in their ability and effectiveness to provide specific management functions. Once LID site planning and design principles have been considered and

applied, structural stormwater BMPs should be selected and designed based on site characteristics to meet the stormwater management standards and performance criteria described in Chapter 4 - Stormwater Management Standards and Performance Criteria.

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

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

Use of Multiple BMPs in Series

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

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

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

Maintenance Considerations

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

BMP Design Considerations to Reduce and Facilitate Maintenance

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

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

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

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

- At a minimum, the access path should abut pretreatment facilities and provide safe access to all points that require routine maintenance or sediment removal. Consider the equipment type and any limitations including excavator reach and vacuum truck hose length. Also consider vegetation that may limit access, such as shrubs that would hinder the use of a hose.
- Depict the access path on the figure that will be incorporated with the long-term operation and maintenance plan.
- Evaluate the potential for snow storage on the stormwater BMP. Sediment/debris that accumulates within the plowed snow may impact the effectiveness of the BMP after the snow melts and the sediment/debris remains.
- BMPs will need to withstand anticipated snow loads if plowed/shoveled snow is permitted to accumulate over the BMP.
- Use transition curbs or steel plates where curb cuts are proposed to limit the potential for damage from snowplows.
- Depict any snow storage areas on the figure that will be incorporated with the long-term operation and maintenance plan. In areas where snow storage is not permitted, identify these areas as well.
- Place the least expensive and most easily maintained components of a stormwater BMP treatment train at the most upstream point in the treatment train to reduce the maintenance requirements of the downstream components.

General Inspection and Maintenance Requirements

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

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

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

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

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

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

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

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