Chapter 4
Designing Best Management Practices

To achieve New Hampshire's objectives for the control and treatment of stormwater, development and redevelopment projects will generally require the implementation of one or more structural practices for managing stormwater runoff. This Chapter presents a selection of stormwater Best Management Practices (BMPs) that may be used for projects in New Hampshire.

The BMPs identified in this Manual have been selected to be consistent with the requirements of the Alteration of Terrain Regulations and New Hampshire's Antidegradation Provisions. This Chapter provides a series of BMP descriptions, grouped according to the following categories:

- Pretreatment practices
- Treatment practices
- Groundwater recharge practices
- Conveyance practices

Erosion and sediment control practices are discussed separately in Volume 3 of the NH Stormwater Manual.

Within each of these categories, a summary is provided for each BMP, including the following information in standardized format:

- Brief description of each practice. In some cases, such as for stormwater treatment ponds, a group of practices is presented, followed by individual fact sheets on each practice within the group;
- Summary of general NH requirements applicable to the practice;
- Conceptual illustration or graphic depicting a typical design of the practice;
- Design considerations for the selection and application of the practice;
- Maintenance considerations regarding the practice;
- Citation of one or more design references, where additional detail about BMP design may be obtained;

- Specific design criteria for the practice, including criteria established in NH regulations as well as other recommended criteria for sizing and siting the practice.

These fact sheets are intended to provide specific sizing information for the practices presented, together with a conceptual overview of the practice. While the BMP "fact sheets" summarize the criteria for designing BMPs, they are meant to provide an overview of the measures discussed. There is extensive literature that describes the practices listed in this document, with many competent texts on the selection, siting, design, and operational characteristics of these devices. NHDES expects engineers and persons performing technical reviews to consult the design reference literature currently considered as accepted practice, in the development of designs for stormwater management facilities for projects in New Hampshire.

Please note that the following pages include design criteria based on the Alteration of Terrain regulations. However, if there is any discrepancy between the information presented here and the AoT Regulations, the Regulations take precedence. Project applicants are responsible for the design of projects in compliance with these regulations, and should refer to them directly to verify applicable criteria.

4-1. Low Impact Development (LID) "Interception Practices"

Low Impact Development (LID) involves a design approach that begins early in the site design process, well before the designer makes decisions about density, placement of buildings, configuration of roadways and other infrastructure, and the design of structural stormwater best management practices (BMPs). The strategy consists of a design approach that discerns how water moves through the landscape under existing conditions, and then works with those site characteristics and drainage patterns to integrate the development design with natural drainage features and functions. There are essentially three major components to LID design:

1. *Site Planning:* Overall site planning to preserve natural vegetation, minimize the creation of impervious surfaces, and maximize the use of existing drainage patterns and drainage features. This type of planning requires an analysis of the site and its local setting, to develop an understanding of natural features, existing drainage patterns, and the water courses that will receive drainage from the project. The preservation of Undisturbed Cover (UDC) is one component of this step in the LID design process, and is described in Volume 1 of the NH Stormwater Manual.

2. *Hydrologic Management:* Development design that provides for the "disconnection" of impervious surfaces from the site drainage collection system. This involves such measures as directing roof runoff and runoff from pavements to overland flow, to encourage surface infiltration and water quality treatment, to help reduce the increase of runoff that results from these paved surfaces. Disconnection practices help minimize Effective Impervious Cover (EIC), as described in Volume 1 of this manual.

3. *LID Structural Practices:* Application of structural Low Impact Development Best Management Practices (BMPs), to collect the remaining runoff generated by the development and manage it in facilities designed to promote infiltration and water quality treatment through natural processes (such as adsorption of contaminants within soil materials and uptake of nutrients by vegetation).

The following further outlines the LID design approach:

1. Site Planning:
    a. Use site hydrology as the integrating framework;
    b. Control stormwater at the source;
    c. Preserve natural drainage paths and features (not just the regulated resource areas);
    d. Consider ridges for development and valleys for stormwater management;
    e. Identify areas with soils most conducive to infiltration, and use them for that purpose;

f. Strategically place impervious areas where soils are less conducive to infiltration, to minimize the loss of natural recharge;
g. Minimize impervious surfaces – build "up" rather than "out;"
h. Minimize impervious surfaces – carefully consider road lengths and widths, parking requirements, pedestrian access;
i. Minimize directly connected impervious surfaces.

2. Hydrologic management techniques:
   a. Design to maximize roof disconnection;
   b. Provide for collection of roof runoff for irrigation purposes (rain barrels and cisterns);
   c. Maximize disconnection of impervious surfaces;
   d. Maximize drainage flow paths over pervious areas;
   e. Consider "country" drainage versus piped systems.

3. LID management practices:
   a. Minimize runoff from roofs (e.g., green roofs);
   b. Minimize runoff from pavements (e.g., permeable pavement systems);
   c. Convert concentrated flow to sheet flow (e.g., level spreaders);
   d. Manage sheet flow (e.g., vegetated buffers);
   e. Manage concentrated flow (e.g., vegetated channel BMPs)
   f. "Micromanage" discharges (e.g., dry wells, bioretention areas/rain gardens).

The following LID "Interception" practices are discussed in this Section:

1. Green Roof

2. Rain Barrel/Cistern

Other LID structural practices are discussed under "Treatment Practices," including:

- Bioretention Systems, including Rain Gardens (see Filtering Practices)

- Permeable (Pervious) Pavement: see Filtering Practices – Permeable Pavement

GREEN ROOFS

General Description

A green roof is a building roof that is partially or completely covered with vegetation and soil, or other type of growing medium. It can be applied to new construction or retrofitted to existing construction. A typical green roof includes vegetation planted in a substrate over a drainage layer and a root barrier membrane. Some green roofs are equipped with stormwater detention tanks with a recirculating system that allows for watering of the media during dry periods. There are generally two classes of greenroofs: 1) extensive; and 2) intensive.

Extensive green roofs generally have only a few inches of growth media and are relatively lighweight in structure. They are designed to be low-maintenance and are not designed for public access. Vegetation is typically limited to various species of sedums or other similar arid plants.

Intensive green roofs are designed to be used by the public or building inhabitants as a park or relaxation area. Intensive green roofs typically require more growth media, greater than six inches in depth, adding a significant additional weight loading to the building. This requires greater capital and maintenance investments than extensive green roofs.

Green roofs can be constructed layer by layer, or can be purchased as a system. Several vendors offer modular trays containing the green roof components.

Green roofs provide several benefits over conventional roofing, including:

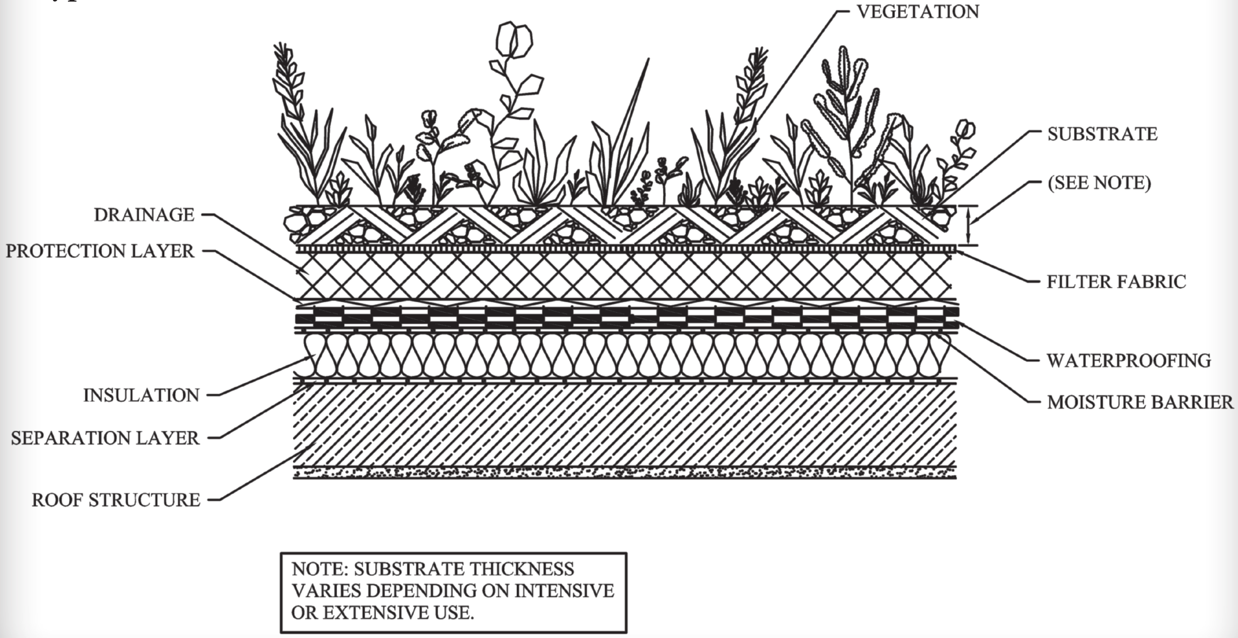
- Reduction of stormwater runoff from buildings through absorption, storage and evapotranspiration. This reduces overall peak flow discharge to a storm sewer system and can result in less in-stream scouring, lower water temperatures and better water quality;
- Reduction of urban heat island effects with increased building thermal insulation and energy efficiency;
- Increased roof durability and lifespan.

Design Considerations

- Green roofs can add significant weight load to a building. A structural engineer should be consulted to ensure the building can support the added weight at maximum water capacity or fully saturated conditions.
- On high pitched roofs, incorporate special design features, such as structural anti-shear protection, to prevent slumping and ensure plant survival.

Example Design

Typical Green Roof Profile



Maintenance Requirements

- Immediately after construction, inspect green roofs regularly until the vegetation has established. Water as needed to establish vegetation.
- After vegetation has established, inspect and fertilize extensive green roofs at least annually. Replace dead vegetation as needed.
- Weed green roofs as needed.
- Water extensive green roofs as needed during exceptionally dry periods.
- Maintain intensive green roofs as any other landscaped area. This will involve mulching, weeding, irrigation and the replacement of dead vegetation.

Design References

- Maine DEP (2006)
- EPA (2006a)

Design Criteria

Designers will need to work closely with building design professionals to identify applicable criteria, codes, and accepted standards of practice for the design of green roofs.

RAIN BARRELS / CISTERNS

Rain barrels and cisterns are storage devices used to collect rainwater from roof downspouts for later reuse. They provide the benefit of reduced stormwater runoff and conservation of water supplies when the water is reused. Stormwater collected in rain barrels and cisterns can typically be reused for such purposes as irrigation of lawns and gardens, wash water and other non-potable uses.

Rain barrels are most commonly used in residential applications to collect roof runoff for later watering of lawns and gardens. Rain barrels come in all shapes and sizes and can be purchased or made at home from existing materials. The low cost and maintenance associated with rain barrels makes them an attractive option for homeowners to manage rooftop runoff.

Cisterns are above or underground storage tanks used to collect roof runoff. While providing the same function as rain barrels, cisterns are generally larger and may include pumps and filtration devices to reuse the water. The larger storage capacity allows for greater reuse opportunities.

Design Considerations

- Rain barrels should hold a minimum of 55 gallons
- Rain barrels can be connected in series to provide larger storage volumes
- Size cisterns for the volume needed for the intended reuse of water
- Equip rain barrels with a drain spigot near the bottom of the barrel with garden hose threading to allow easy hook up and use for watering
- Incorporate the use of water pumps and filters into cisterns as needed for the intended reuse of the water
- Provide an overflow pipe
- Provide removable, child-resistant covers
- Provide mosquito screening on water entry holes to prevent mosquito breeding in standing water

Design References

- Maine DEP (2006)
- Low Impact Development Center (2007)

Example Design

Typical Rain Barrel

Maintenance Requirements

- Inspect rain barrel for potential leaks
- Inspect overflow pipe and overflow area to ensure that overflow is draining in non-erosive manner
- Inspect spigot to ensure it is functioning correctly
- Inspect screen and cover to ensure they still function as anticipated and replace if needed
- To prevent damage by freezing water, drain rain barrel and disconnect it from roof leader prior to winter; reconnect in spring.
- Inspect larger cisterns at least annually for accumulation of sediment and debris, and clean cistern as warranted by inspection. Cisterns may require servicing under the supervision of a qualified professional, including periodic disinfection to control bacteria growth, or application of larvicide to control mosquitoes

4-2. Source Control BMPs

Source control consists of measures to prevent pollutants from coming into contact with stormwater runoff. Preventing pollutant exposure to rainfall and runoff is an important management technique that can reduce the amount of pollutants in runoff and the need for stormwater treatment.

Source control practices and pollution prevention can include a wide variety of management techniques that address nonpoint sources of pollution. These practices are typically non-structural, require minimal or no land area, and involve moderate effort and cost to implement, when compared to structural treatment practices. Therefore, project planning and design should consider measures to minimize or prevent the release of pollutants so they are not available for mobilization by runoff. Source control measures typically address the following:

- Materials management, to prevent contact between substances handled on-site and precipitation or runoff;
- Lawn care and landscaping practices, to manage and control the storage and use of fertilizers, herbicides, and pesticides;
- Management of pet wastes, to minimize this source of nutrients and pathogens in stormwater;
- Street sweeping and cleaning of other pavement surfaces, to remove sand applied for winter ice management, as well as sediments, debris, and trash deposited by vehicle traffic, to prevent these materials from being introduced into the storm drainage system;
- Snow and ice management, particularly the application of sand and deicing agents (such as salt);
- Long-term BMP maintenance, to maintain the effectiveness of stormwater treatment measures and prevent the re-entrainment and discharge of pollutants previously captured by these structures.

Chapter 5 includes information on the development of source control plans for projects, particularly when the projects involve land uses with high volumes of traffic and other sites with higher potential pollutant loads. Chapter 5 also discusses long-term operation and maintenance.

The following Source Control practices are presented in this Section:

1. Street Sweeping
2. Snow and Ice Management

STREET SWEEPING

General Description

Street sweeping is a pollution prevention practice that removes sediment, debris and trash that accumulates along streets and roads from winter sanding practices and everyday use. Street sweeping is often performed to improve aesthetics and to reduce the export of sand to the drainage network and receiving waters. In addition to sediment, debris and trash, other pollutants that may be minimized through street sweeping include some nutrients, oxygen-demanding substances and trace metals.

There are three types of street sweepers commonly used. These include:

- Mechanical Sweepers: Mechanical sweepers use rotating brooms to force debris from the street surface into a hopper by a conveyor system. Water is usually sprayed on the pavement surface to control dust. This type of sweeper typically removes only coarse particles and therefore is less effective at removing nutrients, oxygen demanding materials, and toxic substances that are typically attached to fine particles.
- Regenerative-air Sweepers: Regenerative-air sweepers combine the rotating brooms of mechanical sweepers with forced air to dislodge the remaining dirt and use a high-power vacuum to pick up the dislodged particles. This allows for greater removal of fine particles and the associated pollutants.
- Vacuum-assisted Sweepers: Vacuum assisted sweepers combine the rotating brooms of mechanical sweepers with a high-power vacuum. Some will spray water to control dust and others operate completely dry with a continuous filtration system.

Vacuum sweepers and regenerative air sweepers are considered the more effective than the mechanical sweeper. The overall effectiveness of street sweeping to remove pollutants from a given area will depend on a number of variables including the type of street sweeper used, the frequency and location of sweeping, the ability to sweep on heavily traveled roads, the number of passes made and the operation speed of the sweeper.

Maintenance Requirements

- Inspect and maintain street sweeping equipment in accordance with manufacturer's recommendations.

Design References

- EPA (2006b)
- Zarriello, et al. (2002)

Design Considerations

- Identify areas of concern based on traffic volume, land use, field observations of sediment and trash accumulation and proximity to surface waters. Increase sweeping frequency in these areas to maximize pollutant removal benefits.
- Consider maintaining logs of the amount of waste collected by district, road, or area and use this information to develop/amend a street sweeping plan that targets areas that accumulate greater amounts of material, along with the appropriate frequency to achieve the greatest removal.
- Consider instituting parking policies to restrict parking in problematic areas during periods of street sweeping.
- Street sweeping waste must be disposed of or reused in accordance with *NHDES Environmental Fact Sheet WMD-SW-32 Management of Street Wastes*.

Design Criteria

As outlined under 'Design Considerations', street sweeping programs should be developed that accommodate areas of concern based on traffic volume, land use, field observations of sediment and trash accumulation and proximity to surface waters. At a minimum, street sweeping should be performed once annually, preferably as soon as possible after the snow melts to reduce the amount of sand, grit, and debris and associated pollutants from winter sanding from entering surface waters.

SNOW & ICE MANAGEMENT

General Description

To address the concerns associated with the application of chlorides and other deicing materials, NHDES recommends the development of a Road Salt and Deicing Minimization Plan when a development will create one acre or more of pavement, including parking lots and roadways. The plan should address the policies that the development will keep in place to minimize salt and other deicer use after the project has been completed. A component of the plan should include tracking the use of salt and other deicers for each storm event and compiling salt use data annually.

New Hampshire does not yet have salt reduction guidance, but recommends following the guidelines available in reference cited below.

References

- *Minnesota Snow and Ice Control* handbook, available at: http://www.mnltap.umn.edu/pdf/snowicecontrolhandbook.pdf

Design Criteria

Deicing application rate guidelines and a form for tracking salt and other deicer usage are included in Figures 4-1 and 4-2.

Deicing Application Rate Guidelines

24' of pavement (typcial two-lane road)

These rates are not fixed values, but rather the middle of a range to be selected and adjusted by an agency according to its local conditions and experience.

			Pounds per two-lane mile			
Pavement Temp. (°F) and Trend (↑↓)	Weather Condition	Maintenance Actions	Salt Prewetted / Pretreated with Salt Brine	Salt Prewetted / Pretreated with Other Blends	Dry Salt*	Winter Sand (abrasives)
> 30° ↑	Snow	Plow, treat intersections only	80	70	100*	Not recommended
	Freezing Rain	Apply Chemical	80 - 160	70 - 140	100 - 200*	Not recommended
30° ↓	Snow	Plow and apply chemical	80 - 160	70 - 140	100 - 200*	Not recommended
	Freezing Rain	Apply Chemical	150 - 200	130 - 180	180 - 240*	Not recommended
25° - 30° ↑	Snow	Plow and apply chemical	120 - 160	100 - 140	150 - 200*	Not recommended
	Freezing Rain	Apply Chemical	150 - 200	130 - 180	180 - 240*	Not recommended
25° - 30° ↓	Snow	Plow and apply chemical	120 - 160	100 - 140	150 - 200*	Not recommended
	Freezing Rain	Apply Chemical	160 - 240	140 - 210	200 - 300*	400
20° - 25° ↑	Snow or Freezing Rain	Plow and apply chemical	160 - 240	140 - 210	200 - 300*	400
20° - 25° ↓	Snow	Plow and apply chemical	200 - 280	175 - 250	250 - 350*	Not recommended
	Freezing Rain	Apply Chemical	240 - 320	210 - 280	300 - 400*	400
15° - 20° ↑	Snow	Plow and apply chemical	200 - 280	175 - 250	250 - 350*	Not recommended
	Freezing Rain	Apply Chemical	240 - 320	210 - 280	300 - 400*	400
15° - 20° ↓	Snow or Freezing Rain	Plow and apply chemical	240 - 320	210 - 280	300 - 400*	500 for freezing rain
0° - 15° ↑↓	Snow	Plow, treat with blends, sand hazardous areas	Not recommended	300 - 400	Not recommended	500 - 750 spot treatment as needed
< 0°	Snow	Plow, treat with blends, sand hazardous areas	Not recommended	400 - 600**	Not recommended	500 - 750 spot treatment as needed

* Dry salt is not recommended. It is likely to blow off the road before it melts ice.

** A blend of 6 - 8 gal/ton $MgCl_2$ or $CaCl_2$ added to NaCl can melt ice as low as -10°.

Figure 4-1. Deicing Application Rate Guidelines

Anti-icing Route Data Form				
Truck Station:				
Date:				
Air Temperature	Pavement Temperature	Relative Humidity	Dew Point	Sky
Reason for applying:				
Route:				
Chemical:				
Application Time:				
Application Amount:				
Observation (first day):				
Observation (after event):				
Observation (before next application):				
Name:				

Figure 4-2. Example Documentation Form for Anti-Icing

4-3. Treatment Practices

The following Treatment Practices are presented in this Section:

1. Stormwater Ponds
   - 1.a. Dry Extended Detention Pond With Micropool
   - 1.b. Wet Pond
   - 1.c. Wet Extended Detention Pond
   - 1.d. Multiple Pond System
   - 1.e. Pocket Pond
2. Stormwater Wetlands
   - 2.a. Shallow Wetland
   - 2.b. Extended Detention Wetland
   - 2.c. Pond/Wetland System
   - 2.d. Gravel Wetland
3. Infiltration Practices
   - 3.a. Infiltration Trench & Drip Edge
   - 3.b. Infiltration Basin
   - 3.c. Dry Well
   - 3.d. Permeable Pavement
4. Filtering Practices
   - 4.a. Surface Sand Filter
   - 4.b. Underground Sand Filter
   - 4.c. Bioretention System
   - 4.d. Tree Box Filter
   - 4.e. Permeable Pavement
5. Flow-through Treatment Swale
6. Vegetated Buffer (Vegetated Filter Strip)
   - 6.a. Residential or Small Pervious Area Buffer
   - 6.b. Developed Area Buffer
   - 6.c. Buffer on the Downhill Side of Roadway
   - 6.d. Ditch Turn-out Buffer

1. STORMWATER PONDS

General Description

Stormwater ponds are impoundments designed to collect, detain and release stormwater runoff at a controlled rate. They provide treatment through the use of a permanent pool, which helps settle solids and associated pollutants. Extended detention features can be incorporated into stormwater ponds by combining permanent micropools or other permanent pool storage with an extended drawdown time of the water quality volume.

In addition to water quality benefits, by providing additional storage capacity and a multi-stage outlet structure, stormwater ponds can also be designed to provide flood control. Refer to the Detention Basin description in this Chapter for more information on the design of facilities for controlling peak rates.

The following are examples of Stormwater Ponds:

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

General Requirements Applicable to All Stormwater Ponds

- The pond perimeter should be curvilinear
- Design must include a hydrologic budget to show sufficient water available to maintain permanent pool depth
- A qualified professional must develop a planting plan
- Inlet and outlet should be located as far apart as possible
- Provide a manually controlled drain, if elevations allow, to dewater pond over 24-hour period
- Provide energy dissipation at inlet and outlet for scour prevention
- Stormwater ponds are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued
- Provide small trash racks for outlets ≤ 6 inches in diameter or weirs ≤ 6 inches wide
- Additional requirements as listed in Design Criteria for each illustrated BMP

1a. Micropool Extended Detention Pond

An extended detention pond with a micropool temporarily stores and releases the Water Quality Volume over an extended drawdown time. The micropool is typically provided near the outlet, to enhance pollutant removal and to help prevent resuspension of captured sediments. Except for the micropool, the basin is designed to be dry between storms, once the WQV has been discharged. The basin provides pollutant removal by settling of sediments and associated pollutants.

Design Considerations

- Use may be limited by depth to groundwater or bedrock
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- May have a greater risk of sediment re-suspension than do wet ponds, wet extended detention ponds or stormwater wetlands
- May not remove soluble pollutants as effectively as wet ponds, extended detention wet ponds or stormwater wetlands

Maintenance Requirements

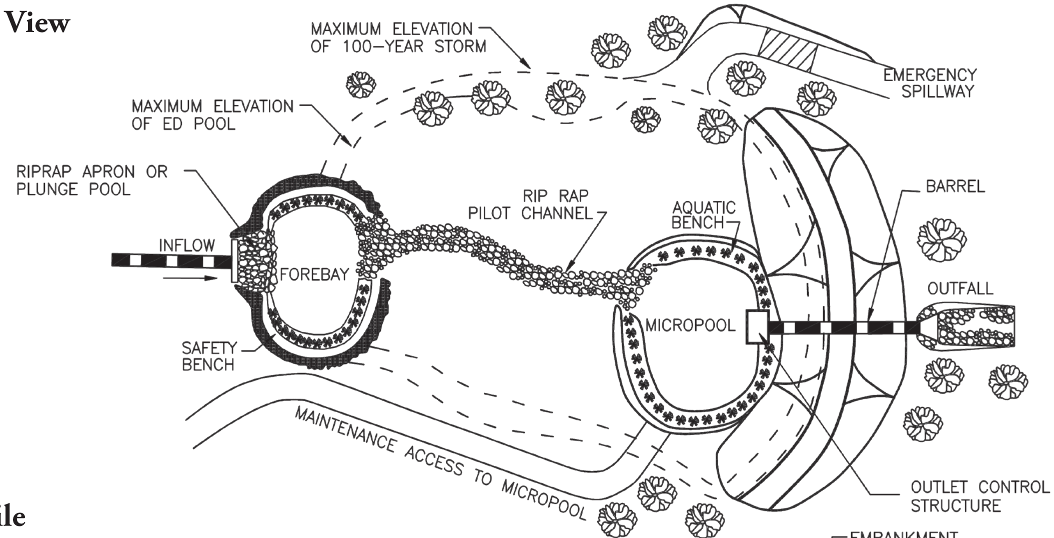
- Periodic mowing of embankments
- Removal of woody vegetation from fill embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)

Example Design

Plan View



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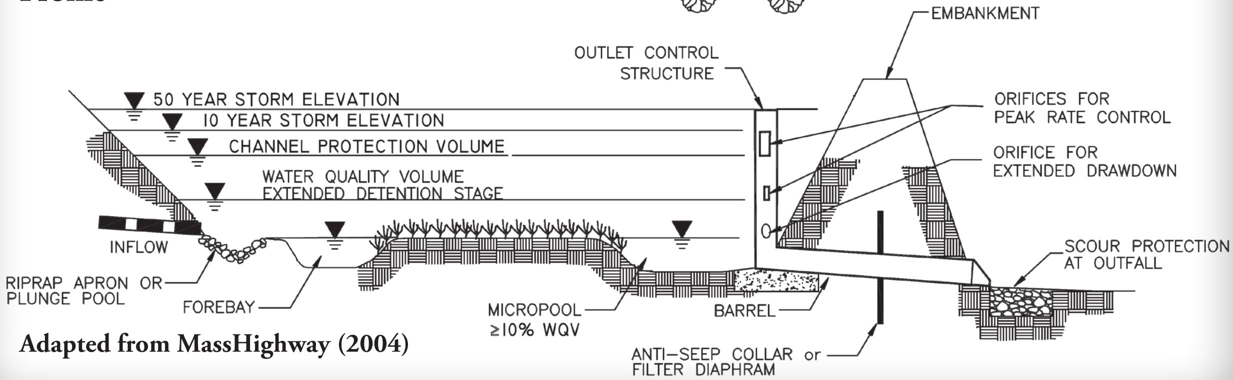


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Micropool + Extended Detention Volume	≥ WQV
Permanent Pool Depth	Average depth of 3 to 6 feet; no greater than 8 feet
Extended Detention Drawdown	24-hour minimum Size extended detention volume outlet to discharge at a maximum flow rate as follows: Qmax ≤ 2*Qavg; Qavg = EDV/24 hours Where EDV = the extended detention volume
Length to Width Ratio	3:1 minimum
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Micropool Volume	Approximately 10% of WQV
Micropool Area	Approximately 5% of surface area of WQV pool

1B. Wet Pond

Wet ponds are designed to maintain a permanent pool of water throughout the year. The pool, located below the outlet invert, allows for pollutant removal through settling and biological uptake or decomposition.

Wet ponds, if properly sized and maintained, can achieve high rates of removal for a number of urban pollutants, including sediment and its associated pollutants: trace metals, hydrocarbons, BOD, nutrients and pesticides. They also provide some treatment of dissolved nutrients through biological processes within the pond.

Where the temperature of receiving waters is a concern, the addition of an underdrained gravel trench in the bench area around the permanent pool allows for slow, extended release of stormwater, which minimizes the risk of the outlet structure clogging and provides effective cooling to avoid thermal impacts to receiving waters.

Design Considerations

- Use may be limited by depth to bedrock
- Use may be limited by soils permeability or groundwater levels, or require special design measures to control exfiltration of retained water or inflow of groundwater
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- Safety issues must be addressed relative to establishing a permanent pool

Maintenance Requirements

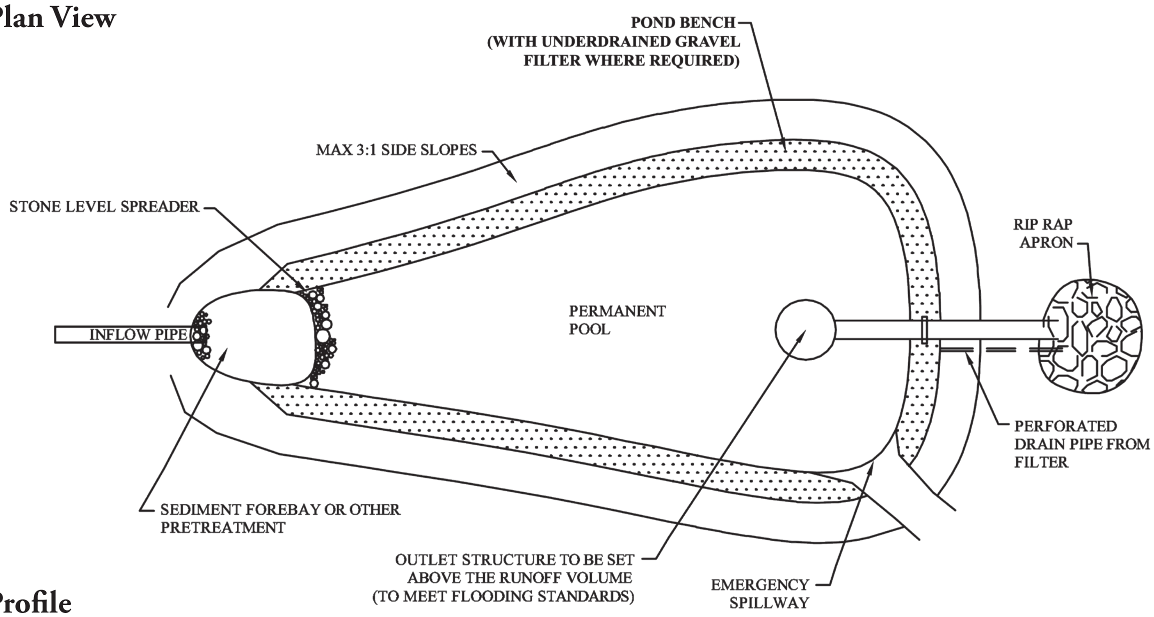
- Periodic mowing of embankments
- Removal of woody vegetation from fill embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)
- EPA (1999f)

Example Design

Plan View



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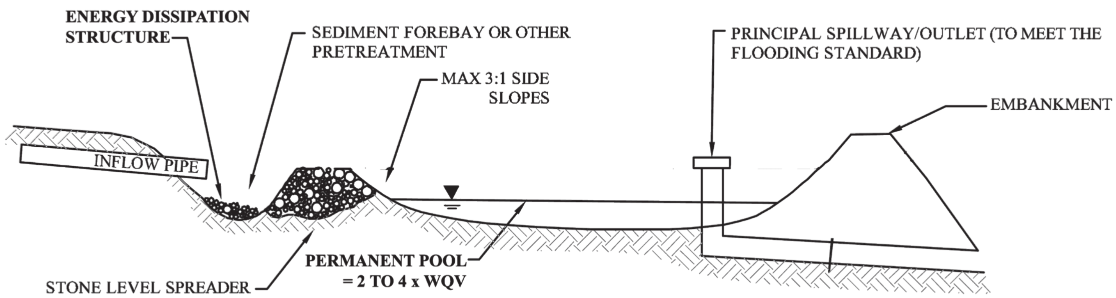


Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool Volume	2 – 4 times the WQV, recommended for enhancing pollutant removal effectiveness
Permanent Pool Depth	Average depth of 3 to 6 feet; no greater than 8 feet
Length to Width Ratio	3:1 minimum
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Recommended Drainage Area	At least 10 acres unless groundwater conditions will sustain permanent pool
Safety Bench	Recommended, > 10 feet width

1c. Wet Extended Detention Pond

Wet extended detention ponds combine the features of wet ponds and extended detention ponds. The combined permanent pool and extended detention volume can be used to treat the Water Quality Volume and meet Channel Protection requirements.

Design Considerations

- Use may be limited by depth to bedrock
- Use may be limited by soils permeability or groundwater levels, or require special design measures to control exfiltration of retained water or inflow of groundwater
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- Safety issues must be addressed relative to establishing a permanent pool

Maintenance Requirements

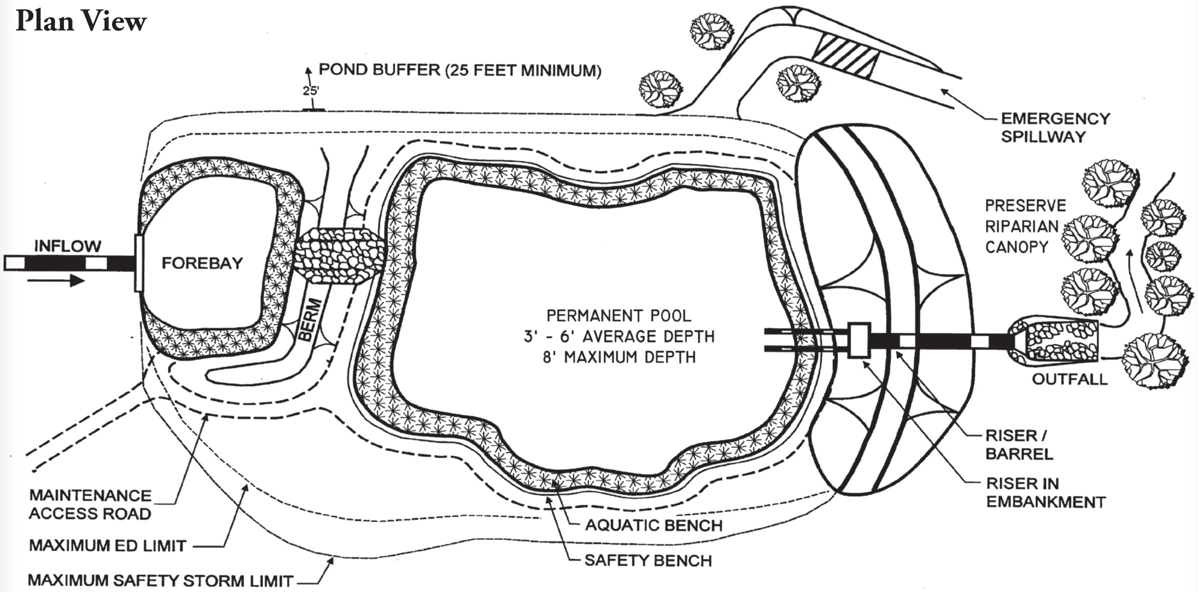
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)
- EPA (1999f)

Example Design

Plan View



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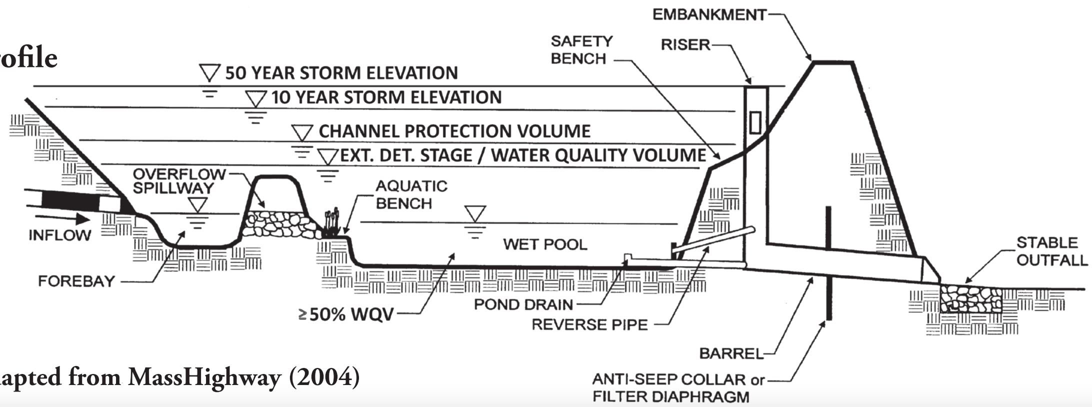


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Combined Volume, Permanent Pool and Extended Detention	≥ WQV
Permanent Pool Depth	≥ 50% of WQV
Length to Width Ratio	3:1 minimum
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of free-board should be provided.
Embankment Design	See criteria for Detention Basin
Recommended Drainage Area	At least 10 acres unless groundwater conditions will sustain permanent pool
Safety Bench	Recommended, > 10 feet width

1d. Multiple Pond System

The multiple pond system is similar to the wet pond, except that the total treatment volume is distributed over two or more pond "cells," rather than a single pond. This type of design can be useful for adapting the component ponds to fit a particular site layout, provide for a more aesthetic design, or address changes in elevation on a sloping site.

Design

- Use may be limited by depth to bedrock
- Use may be limited by soils permeability or groundwater levels, or require special design measures to control exfiltration of retained water or inflow of groundwater
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- Safety issues must be addressed relative to establishing a permanent pool

Maintenance Requirements

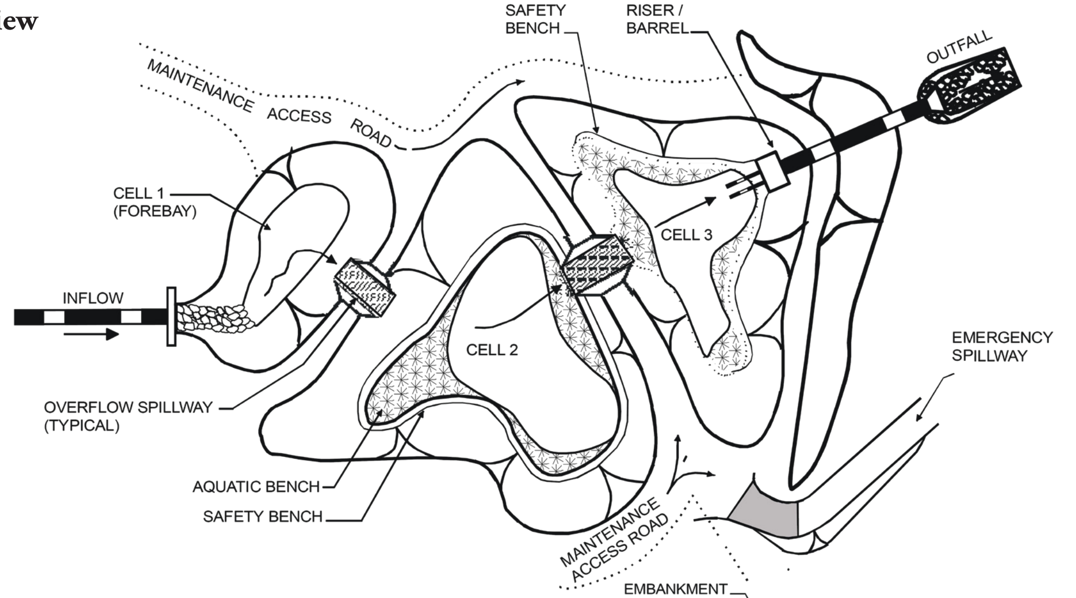
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)

Example Design

Plan View



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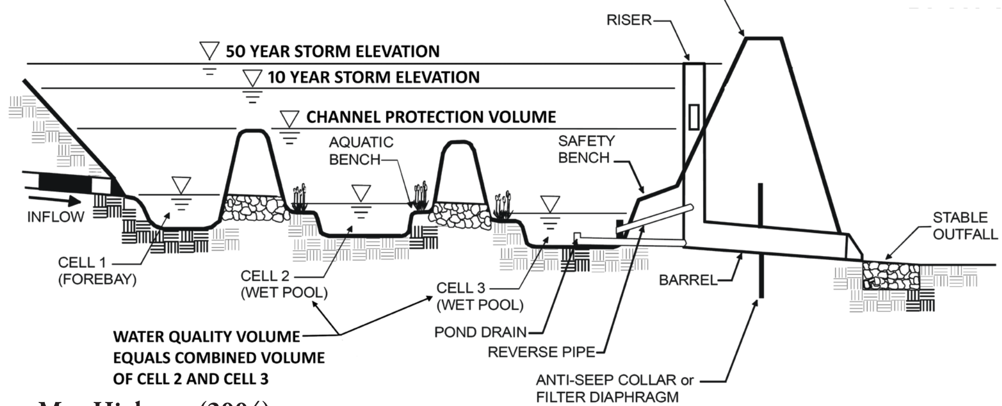


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool Volume	Combined volume of pond cells 2 and 3 ≥ WQV
Permanent Pool Depth	Average depth of 3 to 6 feet; no greater than 8 feet
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Recommended Drainage Area	At least 10 acres unless groundwater conditions will sustain permanent pool
Safety Bench	Recommended, > 10 feet width

1e. Pocket Pond

The pocket pond is a wet pond or wet extended detention pond designed to serve a small contributing area. While similar to other wet ponds and wet extended detention ponds in design, the water budget for this pond will likely depend on the presence of groundwater, because the smaller contributing watershed would not sustain a permanent pool.

Note that NHDES considers a “wet swale” type of water quality swale to be a “pocket pond.”

Design Considerations

- Use may be limited by depth to bedrock
- Use may be limited by soils permeability or groundwater levels, or require special design measures to control exfiltration of retained water or inflow of groundwater
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- Safety issues must be addressed relative to establishing a permanent pool

Maintenance Requirements

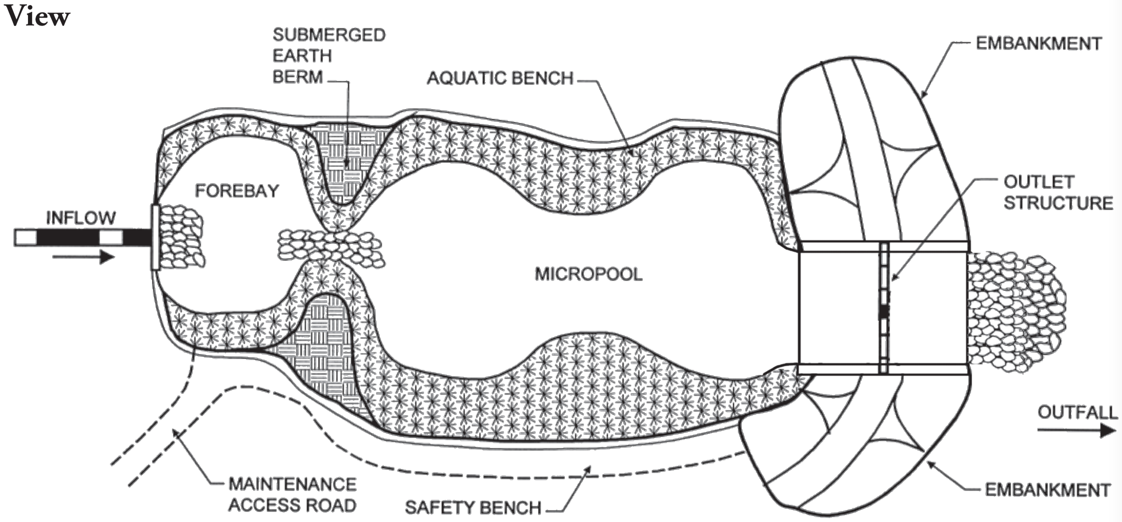
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, outlet structures, and appurtenances

Design References

- Schueler (1987)
- Schueler, et al. (1992)

Example Design

Plan View



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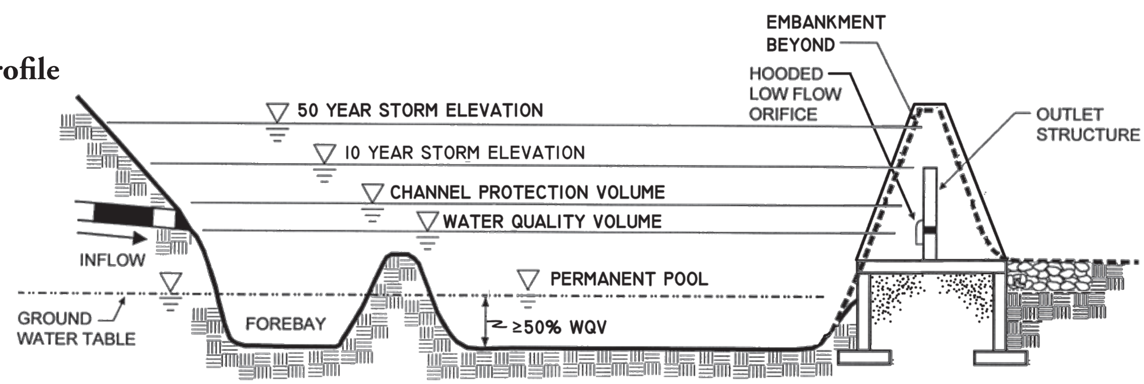


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Combined Volume, Permanent Pool and Extended Detention	≥ WQV
Permanent Pool Volume	≥ 50% of WQV
Permanent Pool Depth	Average depth of 3 to 6 feet; no greater than 8 feet
Length to Width Ratio	3:1 minimum
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of free-board should be provided.
Embankment Design	See criteria for Detention Basin
Groundwater Depth	Groundwater conditions should be present to support maintenance of a micropool
Safety Bench	As warranted by specific site conditions

2. STORMWATER WETLANDS

General Description

Stormwater wetlands are constructed depressions or impoundments designed to function similar to natural wetlands. However, unlike natural wetlands, stormwater wetlands are designed specifically to treat stormwater. Direct discharge of stormwater to natural wetlands is prohibited in New Hampshire due to critical impacts to wetland hydrology and potential habitat degradation.

Stormwater wetlands are similar to stormwater ponds in that the design includes a permanent pool of water. However, the retained pool is designed with varying depths to support a wetland plant community. In addition to the settling processes that occur in the permanent pool, stormwater wetlands provide pollutant removal/uptake by vegetation and by other biological activity supported within the wetland environment. In some stormwater wetlands, such as "gravel wetlands," the systems provide filtration, as well.

The following are examples of Stormwater Wetlands:

- Shallow wetlands (including "pocket wetlands")
- Extended detention wetlands
- Pond/wetland systems
- Gravel wetlands

Information is provided in this manual for each of these types of stormwater wetlands. The shallow, extended detention, and pond/wetland systems have a number of similarities, with the basic differences being the relative proportions of open water relative to marsh, and extended detention volume relative to permanent pool. The marsh areas typically include zones with the following depth ranges:

- Deepwater — Greater than 18 inch depth, up to the design maximum depth
- Low Marsh — 6 inch to 18 inch depth below normal pool
- High Marsh — Up to 6 inches depth below normal pool
- Semi-wet — Areas above normal pool that are periodically inundated and expected to support wetland vegetation

Recommended configurations for stormwater wetlands (other than gravel wetlands) are provided in Tables 4-1 and 4-2. Gravel wetlands involve a conceptually different type of design and are discussed separately in the Gravel Wetlands BMP description.

General Requirements Applicable to Stormwater Wetlands

- The wetland perimeter must be curvilinear;
- Design must include a hydrologic budget to show sufficient water available to maintain permanent pool depth;
- A qualified professional must develop a planting plan;
- Inlet and outlet should be located as far apart as possible;
- Provide a manually controlled drain, if elevations allow, to dewater ponds (if included in the design) over 24-hour period;
- Provide energy dissipation at inlet and outlet for scour prevention;
- Stormwater wetlands are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued;
- Provide small trash racks for outlets ≤ 6 inches in diameter or weirs ≤ 6 inches wide;
- Additional requirements as listed in Design Criteria for each illustrated BMP

Table 4-1. Recommended Design Criteria for Stormwater Wetlands Designs

Design Criteria	Shallow Wetland	Pond/Wetland	ED Wetland	Pocket Wetland
Wetland/Watershed Area Ratio	≥ 2.0%	≥ 1.0%	≥ 1.0%	≥ 1.0%
Minimum Drainage Area (acres)	≥ 25	≥ 25	≥ 10	1 to 10
Length to Width Ratio (minimum)	≥ 3:1	≥ 3:1	≥ 3:1	≥ 3:1
Extended Detention	no	option	yes	option
Percent Allocation of Treatment Volume (pool/marsh/ED)	30 / 70 / 0	70 / 30 / 0	≥ 20 / ≥30 / ≥50	20 / 80 / 0
Percent Allocation of Surface Area to Wetland Type	Refer to Table 4-2			
Cleanout Frequency (years)	2 to 5	10	2 to 5	10
Outlet Configuration	Reverse-slope pipe or hooded broad crest weir	Reverse-slope pipe or hooded broad crest weir	Reverse-slope pipe or hooded broad crest weir	Hooded broad crest weir

Source: Adapted from Schueler (1992).

Table 4-2. Recommended Allocation of Areas & Volumes for Stormwater Wetlands

Target Allocations	Shallow Wetland	Pond/ Wetland	ED Wetland	Pocket Wetland
% of Surface Area				
Forebay	5	0	5	5
Micropool	5	5	5	5
Deepwater	5	40	0	0
Lo Marsh	40	20	40	45
Hi Marsh	40	25	40	40
Semi-wet	5	5	10	5
% of Treatment Volume				
Forebay	10	0	10	10
Micropool	10	10	10	10
Deepwater	10	60	--	0
Lo Marsh	45	20	20	55
Hi Marsh	25	10	10	25
Semi-wet	0	0	50	0

Definition of terms:

Deepwater	Greater than 18 inch depth, up to the design maximum depth
Low Marsh	6 inch to 18 inch depth below normal pool
High Marsh	Up to 6 inches depth below normal pool
Semi-wet	Areas above normal pool that are periodically inundated and expected to support wetland vegetation

Source: Adapted from EPA (1999d).

2a. Shallow Wetlands

Shallow wetlands for stormwater treatment consist of pools ranging from 6 to 18 inches in depth under normal conditions, with some areas of deepwater pools. They may be configured with a variety of low marsh and high marsh "cells" with sinuous channels to distribute flows to maximize retention time and contact area. Shallow wetland systems are designed with wetland vegetation suitable for these varying depths. The entire Water Quality Volume is provided within the deepwater, low marsh, and high marsh zones.

Design Consdierations

- Requires sufficient contributing area and/or groundwater elevation to maintain permanent pool
- Use may be limited by depth to bedrock
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- May develop mono-culture of invasive plant species over time

Maintenance Requirements

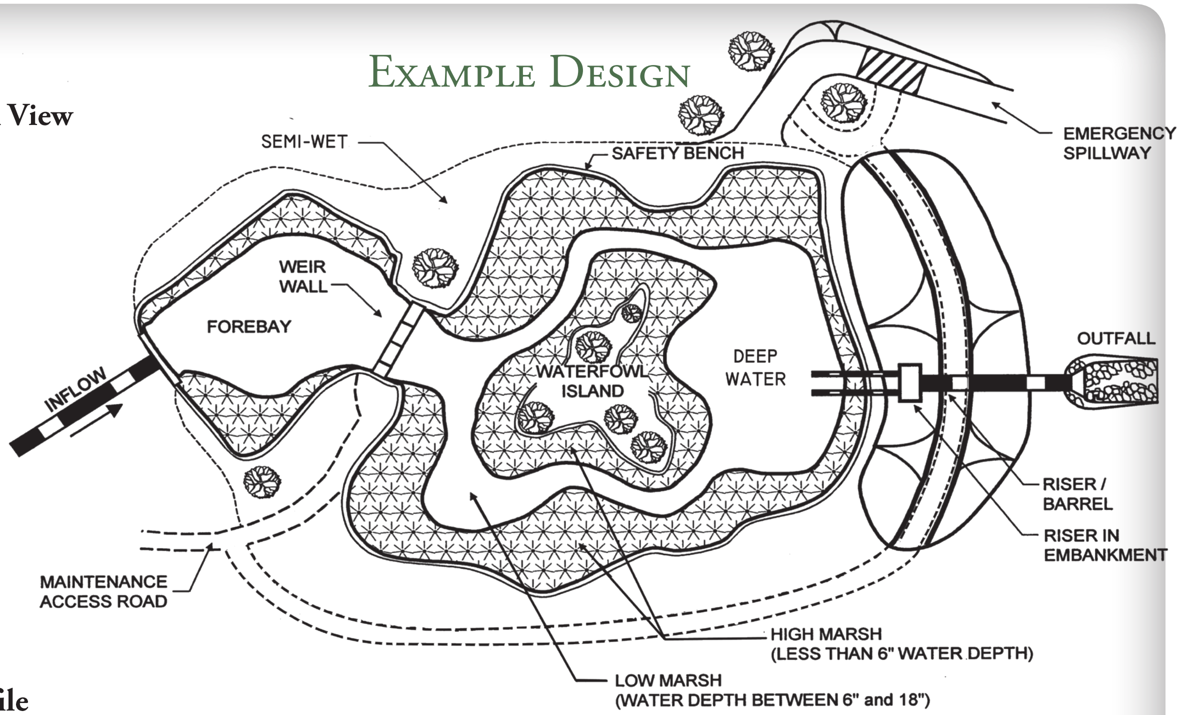
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of invasive species from semi-wet, marsh, and deepwater areas
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1992)
- Cappiella, et al. (2008)

Example Design

Plan View



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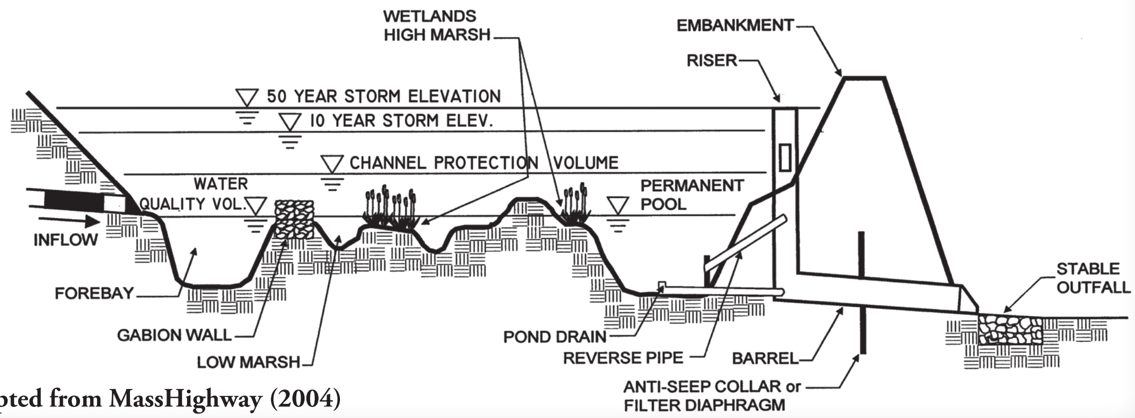


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool Volume	≥ WQV (combined deep water, low marsh, high marsh)
Permanent Pool Depth	≤ 8 feet
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Maximum Temporary Pool Depth	≤ 4 feet above permanent pool
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Marsh/Deepwater Ratios	See Tables 4-1 and 4-2

2b. Extended Detention Wetlands

Extended detention stormwater wetlands typically require less space than shallow wetlands systems, because part of the Water Quality Volume is stored above the level of the permanent pool. Deepwater areas tend to be less extensive and semi-wet areas more extensive than those provided for shallow wetlands. Wetland plants that tolerate both intermittent flooding and dry periods must be selected for the area above the permanent marsh.

Design Consdierations

- Requires sufficient contributing area and/or groundwater elevation to maintain permanent pool
- Use may be limited by depth to bedrock
- May increase water temperature, which may affect use in watersheds of cold water fisheries; because of the smaller area of permanent marsh, this effect may be more moderate than for a shallow wetland or pond/wetland system
- May develop mono-culture of invasive plant species over time

Maintenance Requirements

- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of invasive species from semi-wet, marsh, and deepwater areas
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

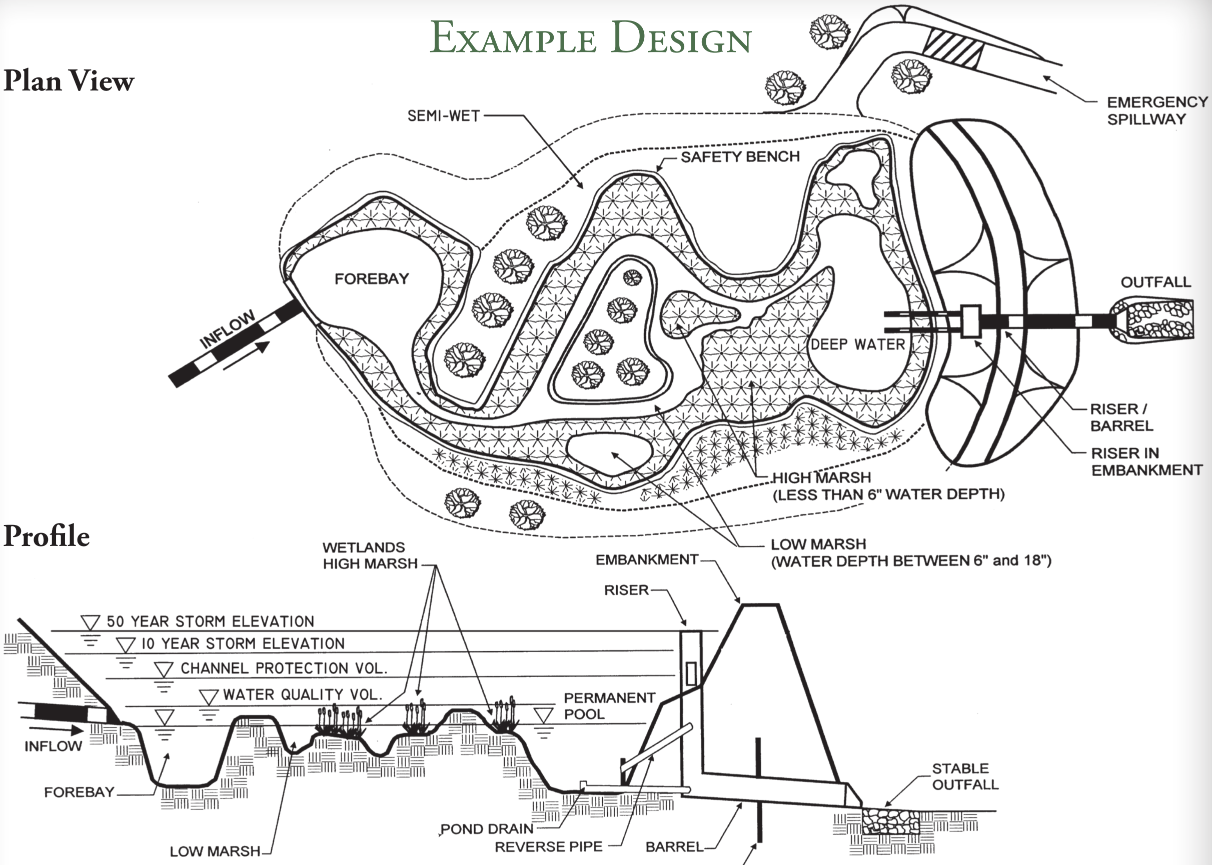
Design References

- Schueler (1992)
- Cappiella, et al. (2008)

Example Design

Plan View

Profile



Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool + Extended Detention Volume	≥ WQV (combined deep water, low marsh, high marsh and extended detention volume)
Extended Detention Volume	≤ 50% of WQV
Extended Detention Drawdown	24-hour minimum
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Permanent Pool Depth	≤ 8 feet
Maximum Temporary Pool Depth	≤ 4 feet above permanent pool
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Marsh/Deepwater Ratios	See Tables 4-1 and 4-2

2c. Pond/Wetland System

The wetlands/pond system for stormwater treatment consists of a series of cells using at least one wet pond in combination with shallow marsh wetlands. The first cell typically comprises the wet pond, which provides initial treatment primarily by settling of particles. The wet pond can also reduce the velocity of runoff entering the system. The shallow marsh provides subsequent additional treatment of the runoff, particularly for soluble pollutants through vegetative uptake and the biological activity associated with the wetland vegetation community. With the deeper pool of the wet pond, these systems can typically require less space than the shallow marsh system.

Design Considerations

- Requires sufficient contributing area and/or groundwater elevation to maintain permanent pool
- Use may be limited by depth to bedrock
- May increase water temperature, which may affect use in watersheds of cold water fisheries
- May develop mono-culture of invasive plant species over time

Maintenance Requirements

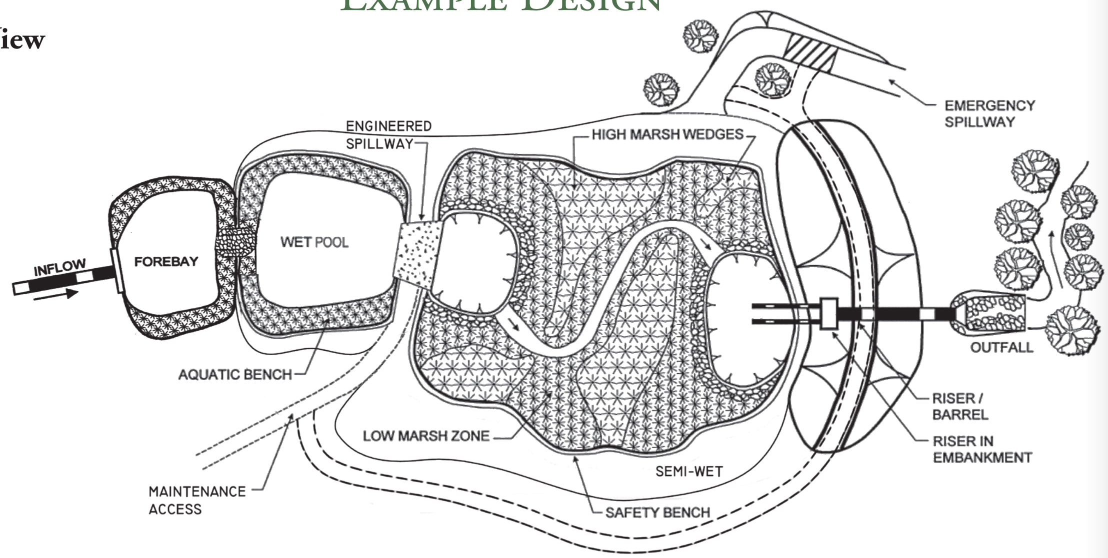
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of invasive species from semi-wet, marsh, and deepwater areas
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

- Schueler (1992)
- Cappiella, et al. (2008)

Example Design

Plan View



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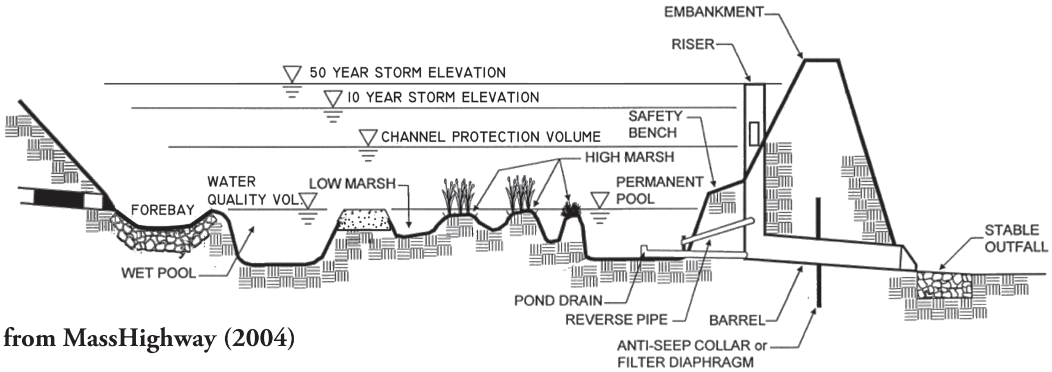


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool Volume	≥ WQV (combined wet pond, micropool (deepwater), low marsh, high marsh)
Extended Detention Volume	≤ 50% of WQV
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Permanent Pool Depth	≤ 8 feet
Maximum Temporary Pool Depth	≤ 4 feet above permanent pool
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin
Marsh/Deepwater Ratios	See Tables 4-1 and 4-2

2D. Gravel Wetlands

The gravel wetland system consists of one or more flow-through constructed wetland cells, preceded by a forebay. The cells are filled with a gravel media, supporting an organic substrate that is planted with wetland vegetation. During low-flow storm events, the system is designed to promote subsurface horizontal flow through the gravel media, allowing contact with the root zone of the wetland vegetation. The gravel and planting media support a community of soil microorganisms. Water quality treatment occurs through microbial, chemical, and physical processes within this media. Treatment may also be enhanced by vegetative uptake.

To accommodate higher flows, the system is designed to permit inundation of the wetland surface, and the system would function similar to other constructed wetland systems. Overflow from the wetland is provided by an outlet structure designed for this "extended detention" condition. Following such an event, remaining water on the surface of the wetland would infiltrate into the gravel media, and flow horizontally through the media as in the low flow condition.

The outlet of the wetland system is designed to keep the media submerged, to provide the hydrology to support the wetland plant community. The gravel media consists of either crushed rock or processed gravel. An organic soil layer is placed on top of this material, and the wetland plants are rooted in the media where they can directly take up pollutants.

The system can be designed to integrate some stormwater storage, and also to provide infiltration. With these features, the practice would not only remove pollutants, but also contribute to the attenuation of peak rates through temporary storage and reduction in runoff volume through infiltration and evapotranspiration.

Design Considerations

- This BMP is particularly suited to areas with limited available space.
- The BMP requires sufficient contributing area to maintain saturated conditions and support vegetation.
- Unless used to treat runoff from high load areas, gravel wetlands may intersect the groundwater table.
- The bottom of each treatment cell should be lined with an impermeable liner if located on hydrologic group A and B soils.
- Pretreatment measures are essential to prevent clogging of the gravel media and the pipe manifold system.

Maintenance Requirements

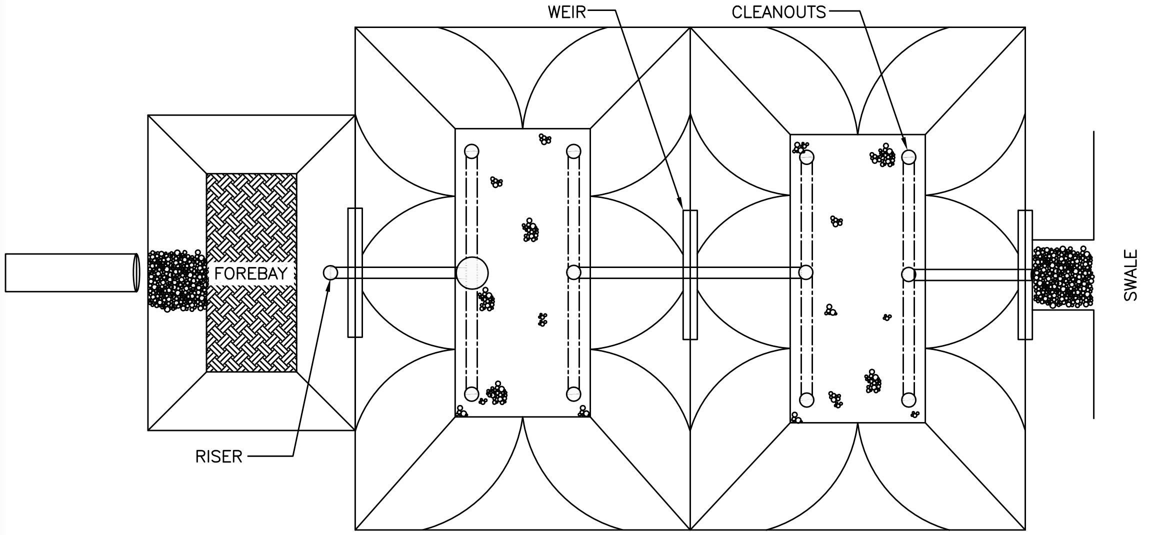
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from inlet and outlet structures
- Inspection and removal of sediment accumulation in the gravel bed
- Depending on sediment accumulation, bed may require periodic replacement and replanting
- Inspection and repair of containment structure (if applicable), inlet and outlet structures, and appurtenances

Design References

- UNH Stormwater Center

Example Design

Plan View



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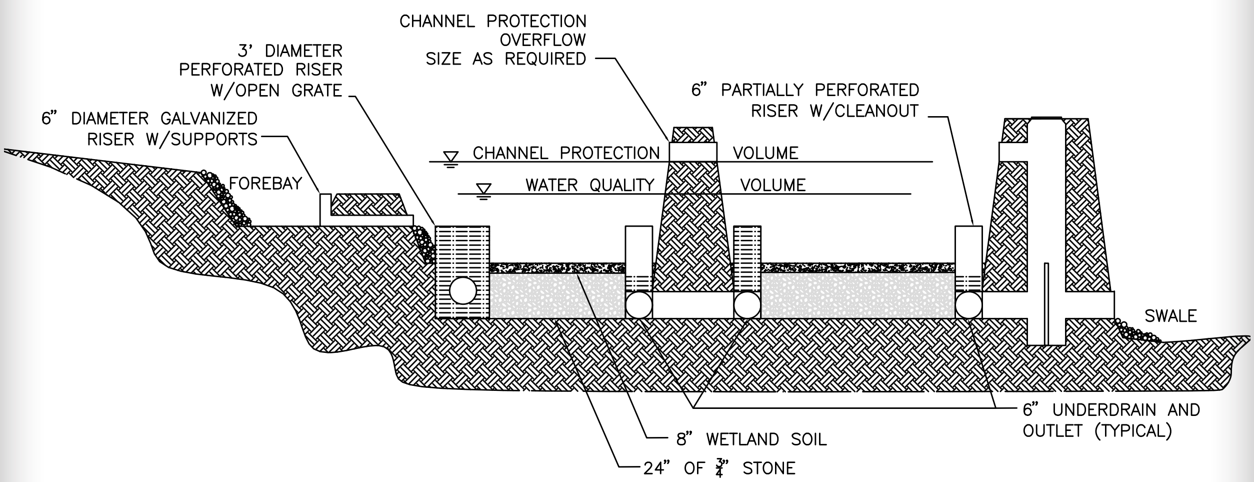


Adapted from UNH Stormwater Center (2007)

Design Criteria

Design Parameter	Criteria
Sediment Forebay	10% of WQV; see criteria for Sediment Forebay
Maximum Side Slopes	3:1
Permanent Pool + Extended Detention Volume	At a minimum: 10% of the WQV in the sediment forebay and 45% of the WQV in each treatment cell
Extended Detention Volume	≤ 50% of WQV
Extended Detention Drawdown	24 to 48 hours
Length to Width Ratio	3:1 minimum, applicable to each pond cell
Maximum Temporary Pool Depth	≤ 4 feet above permanent pool
Design Discharge Capacity	50-year, 24-hour storm without overtopping and at least one foot of freeboard should be provided.
Embankment Design	See criteria for Detention Basin

3. INFILTRATION PRACTICES

General Description

Infiltration practices are designed to capture and temporarily store the water quality volume of stormwater while it infiltrates into the soil. Infiltration practices help to recharge groundwater, but must be designed and maintained to avoid clogging and system failure. Pollutants are removed through adsorption of pollutants onto soil particles, and biological and chemical conversion in the soil.

Infiltration practices differ from filtering practices in that stormwater is infiltrated through native soil and allowed to recharge groundwater, while filtration practices typically employ non-native soil materials or other media, and may use underdrains to convey the filtered water to discharge.

Infiltration BMPs can be suitable for treating runoff from drainage areas (ranging up to 50 acres in size for infiltration basins) where subsoils, groundwater conditions, and depth to bedrock are appropriate. Infiltration BMPs can be used for a wide range of land uses, including commercial, residential, industrial, and gravel mining sites. However, some industrial and commercial areas have contaminants that may pose a risk of groundwater contamination. In this case, infiltration should not be used without adequate treatment of runoff prior to entering the device. In some cases, infiltration measures should be avoided in favor of other BMPs.

The following are examples of Infiltration Practices:

- Infiltration trenches
- Drip edges
- Infiltration basins
- Dry wells

Note that "permeable pavements," discussed under "Filtering Practices," may also be designed to provide for infiltration.

General Requirements Applicable to Infiltration Practices

- Infiltration is prohibited as follows:
    - Into areas of RSA 482-A jurisdiction unless a wetlands permit has been issued
    - Into groundwater protection areas where the stormwater is from a high-load area (see Chapter 3)
    - Into areas where contaminants occur in groundwater above ambient standards (Env-Or 603.03)
    - Into areas where contaminants occur in soil above site-specific standards (Env-Or 600)
    - Into areas where the soils have infiltration rates < 0.5 inches per hour
    - Into areas where the infiltration rate is too rapid to provide treatment (see Chapter 2 for a listing of these soils), unless treatment is either not necessary or has already been provided. Note, however, as described in Chapter 2, soils may be amended to reduce infiltration rate.
    - Into areas with slopes > 15%, unless calculations show that seepage will not cause slope instability.
    - From areas with soil contaminants above site-specific standards (Env-Or 600).
    - From areas with underground and aboveground storage tanks regulated by RSA 146-C or RSA 146-A, where gasoline is dispensed or otherwise transferred to vehicles.
- Pretreatment must be provided if the infiltration BMP will receive stormwater other than roof runoff.
- Design infiltration rates should be determined in accordance with Chapter 2, Design Criteria.
- BMPs used for to meet stormwater treatment or groundwater recharge objectives should be sized without depending on infiltration that occurs during the design event (static sizing method). However, BMPs used for channel protection or peak flow control may be sized accounting for infiltration during the design event (dynamic sizing method).

3a. Infiltration Trench

An infiltration trench is a stone-filled excavation used to temporarily store runoff and allow it to infiltrate into surrounding, natural soil. Typically, runoff enters the trench as overland flow after pretreatment through a filter strip or vegetated buffer. An infiltration trench is suitable for treating runoff from small drainage areas (less than 10 acres). Installations around the perimeter of parking lots, between residential lots, and along roads are most common. Infiltration trenches can also be incorporated along the center of a vegetated swale to increase its infiltration ability.

An infiltration drip edge is constructed similar to an infiltration trench, except that a drip edge intercepts only roof runoff, and does not require pretreatment.

Design Considerations

- Pretreatment is essential to the long-term function of infiltration systems.
- Preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
  - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent infiltration BMPs.
  - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
  - After the basin is excavated to the final design elevation, the floor should be deeply tilled with a rotary tiller or disc harrow to restore infiltration rates, followed by a pass with a leveling drag.
  - Do not place infiltration systems into service until the contributing areas have been fully stabilized.
- For any fill required for system construction, use clean, washed, well-sorted aggregate for infiltration media; the porosity of material provided for construction should be verified against the porosity specified by design.

- Drip edges are not recommended adjacent to buildings with foundation drains, as the intercepted runoff may adversely affect performance of the foundation drainage system. Also, if there is a foundation sub-drain beneath the drip edge trench, the sub-drain will likely prevent infiltration from occurring, by intercepting the flow and conveying it to discharge along with other foundation drainage.
- For more guidance on installing monitoring wells, see: Sprecher, S.W. 2008. Installing monitoring wells in soils (Version 1.0). National Soil Survey Center, NRCS, USDA, Lincoln, NE.

Maintenance Requirements

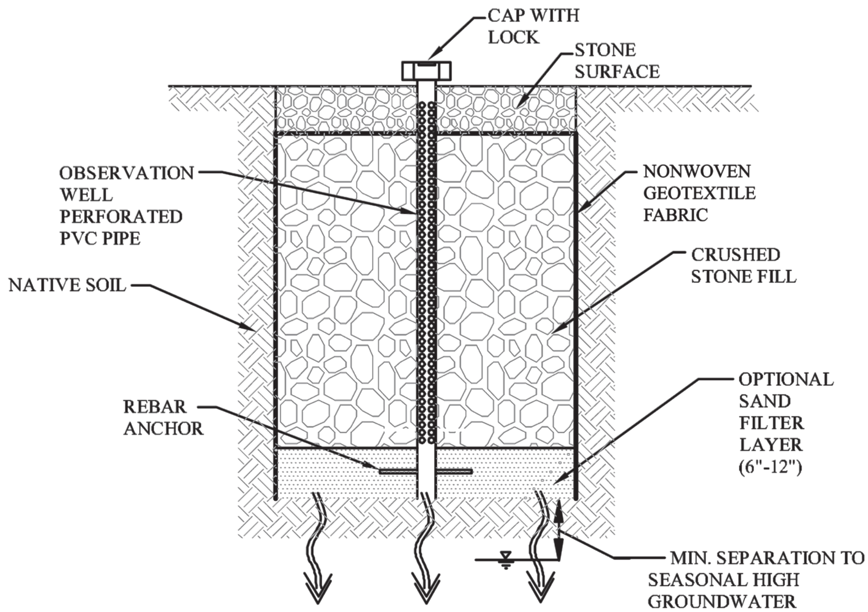
- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated sediment as warranted by inspection, but no less than once annually.
- If an infiltration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore infiltration function, including but not limited to removal of accumulated sediments or reconstruction of the infiltration trench.

Design References

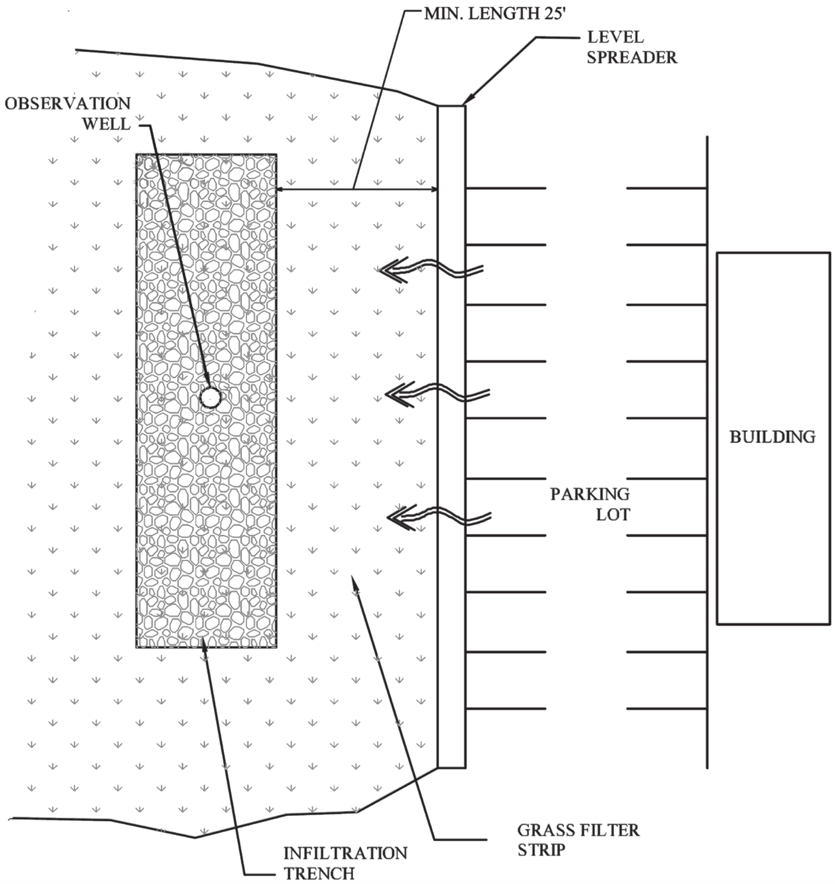
- Schueler (1987)
- Schueler, et al. (1992)
- Ferguson (1994)
- Sprecher (2008)

Example Design

Section



Planview



Design Criteria

Design Parameter	Criteria
Pretreatment	Required (see Section 4-4)
BMP Volume	≥ the larger of WQV or GRV, depending on purpose of BMP excluding sediment forebay capacity, if present, and exclude infiltration occurring during the design event
Minimum trench depth	4 feet
Maximum trench depth	10 feet
Design Infiltration Rate	See Section 2-4 for a discussion on selecting a design infiltration rate
Drain Time	< 72 hours for complete drainage of the water quality volume
Depth to Bedrock and Seasonal High Water Table Elevation	≥ 3 feet from bottom of BMP, except: ≥ 4 feet if within groundwater or water supply intake protection area ≥ 1 foot if runoff has been treated prior to entering the BMP
Overflow Discharge Capacity	10-year, 24-hour storm
Observation Well	Required along trench centerline
Infiltration Media Material	Clean, washed, uniform (well-sorted) aggregate Diameter 1.5 to 3 inches Porosity = 40%

3b. In-Ground Infiltration Basin

Infiltration basins are impoundments designed to temporarily store runoff, allowing all or a portion of the water to infiltrate into the ground. An infiltration basin is designed to completely drain between storm events. An infiltration basin is specifically designed to retain and infiltrate the entire Water Quality Volume. Some infiltration basins may infiltrate additional volumes during larger storm events, but many will be designed to release stormwater exceeding the water quality volume from the larger storms. In a properly sited and designed infiltration basin, water quality treatment is provided by runoff pollutants binding to soil particles beneath the basin as water percolates into the subsurface. Biological and chemical processes occurring in the soil also contribute to the breakdown of pollutants. Infiltrated water is used by plants to support growth or it is recharged to the underlying groundwater.

As with all impoundment BMPs, surface infiltration basins should be designed with an outlet structure to pass peak flows during a range of storm events, as well as with an emergency spillway to pass peak flows around the embankment during extreme storm events that exceed the combined infiltration capacity and outlet structure capacity of the facility.

Design Considerations

- Pretreatment is essential to the long-term function of infiltration systems.
- Preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent infiltration BMPs.
    - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
    - After the basin is excavated to the final design elevation, the floor should be deeply tilled with a rotary tiller or disc harrow to restore infiltration rates, followed by a pass with a leveling drag.
    - Vegetation should be established immediately.
    - Do not place infiltration systems into service until the contributing areas have been fully stabilized.

Maintenance Requirements

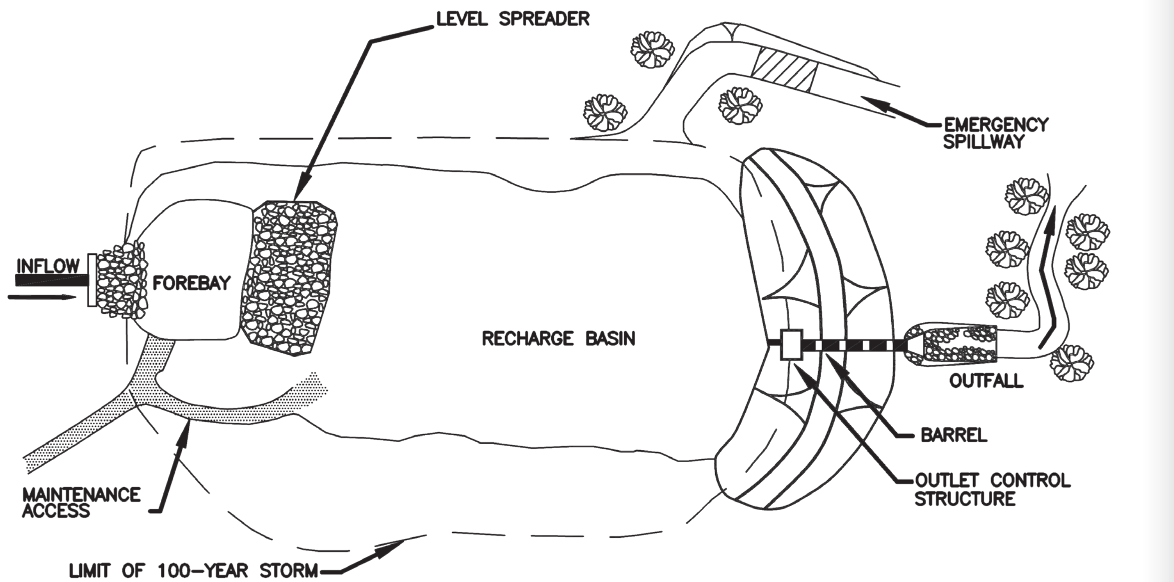
- Removal of debris from inlet and outlet structures
- Removal of accumulated sediment
- Inspection and repair of outlet structures and appurtenances
- Inspection of infiltration components at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Inspection of pretreatment measures at least twice annually, and removal of accumulated sediment as warranted by inspection, but no less than once annually.
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Inspection and repair of embankments and spillways
- If an infiltration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore infiltration function, including but not limited to removal of accumulated sediments or reconstruction of the infiltration trench.

Design References

- Schueler (1987)
- Schueler, et al. (1992)
- Ferguson (1994)

Example Design

Plan View



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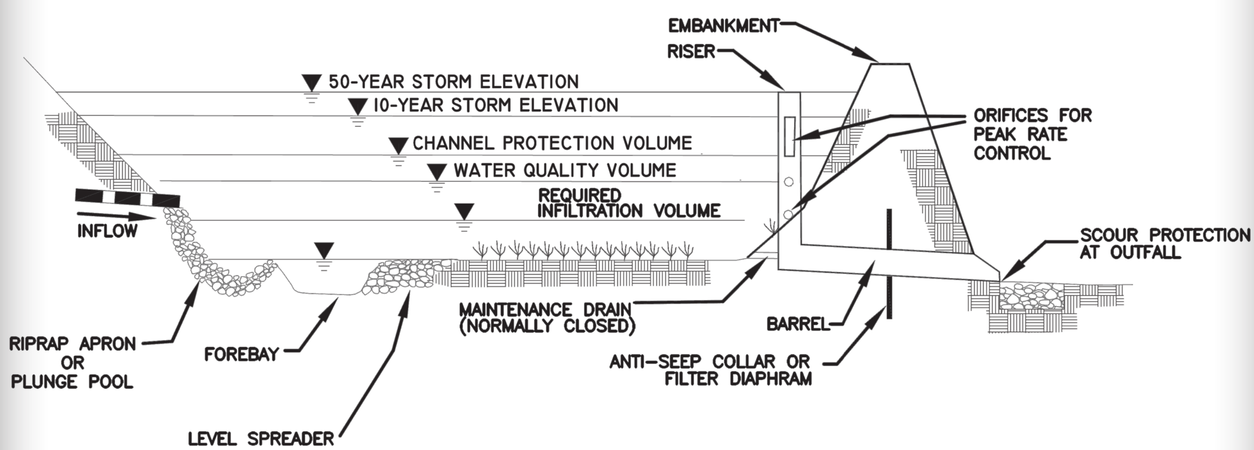


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Pretreatment	Required (see Section 4-4)
BMP Volume	≥ the larger of WQV or GRV, depending on purpose of BMP excluding sediment forebay capacity, if present, and exclude infiltration occurring during the design event
Layout	The pond perimeter should be curvilinear
Maximum Side Slopes	3:1
Minimum Side Slopes	20:1
Slope of Basin Floor	0% (flat)
Design Infiltration Rate	See Section 2-4 for a discussion on selecting a design infiltration rate
Drain Time	< 72 hours for complete drainage of the water quality volume
Depth to Bedrock and to Seasonal High Water Table Elevation	≥ 3 feet from bottom of BMP, except: ≥ 4 feet if within groundwater or water supply intake protection area ≥ 1 foot if runoff has been treated prior to entering the BMP
Basin Floor Preparation	6” layer of coarse sand or 3/8 “ pea gravel; Grass turf that can be inundated for 72+ hrs; or Coarse organic material such as erosion control mix or composted mulch, that is tilled into the soil, soaked, and allowed to dry.
Design Discharge Capacity	50-year, 24-hour storm without overtopping

3c. Underground (Subsurface) Infiltration Basin

Infiltration basins are structures designed to temporarily store runoff, allowing all or a portion of the water to infiltrate into the ground. The structure is designed to completely drain between storm events. An underground infiltration basin is specifically designed to retain and infiltrate the entire Water Quality Volume. Some infiltration basins may infiltrate additional volumes during larger storm events, but many will be designed to release stormwater exceeding the water quality volume from the larger storms. In a properly sited and designed infiltration basin, water quality treatment is provided by runoff pollutants binding to soil particles beneath the basin as water percolates into the subsurface. Biological and chemical processes occurring in the soil also contribute to the breakdown of pollutants. Infiltrated water is recharged to the underlying groundwater.

Subsurface infiltration basins may comprise a subsurface manifold system with associated crushed stone storage bed, or specially-designed chambers (with or without perforations) bedded in or above crushed stone.

Design Considerations

- Pretreatment is essential to the long-term function of infiltration systems.
- Preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent infiltration BMPs.
    - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
    - Do not place infiltration systems into service until the contributing areas have been fully stabilized.

Maintenance Requirements

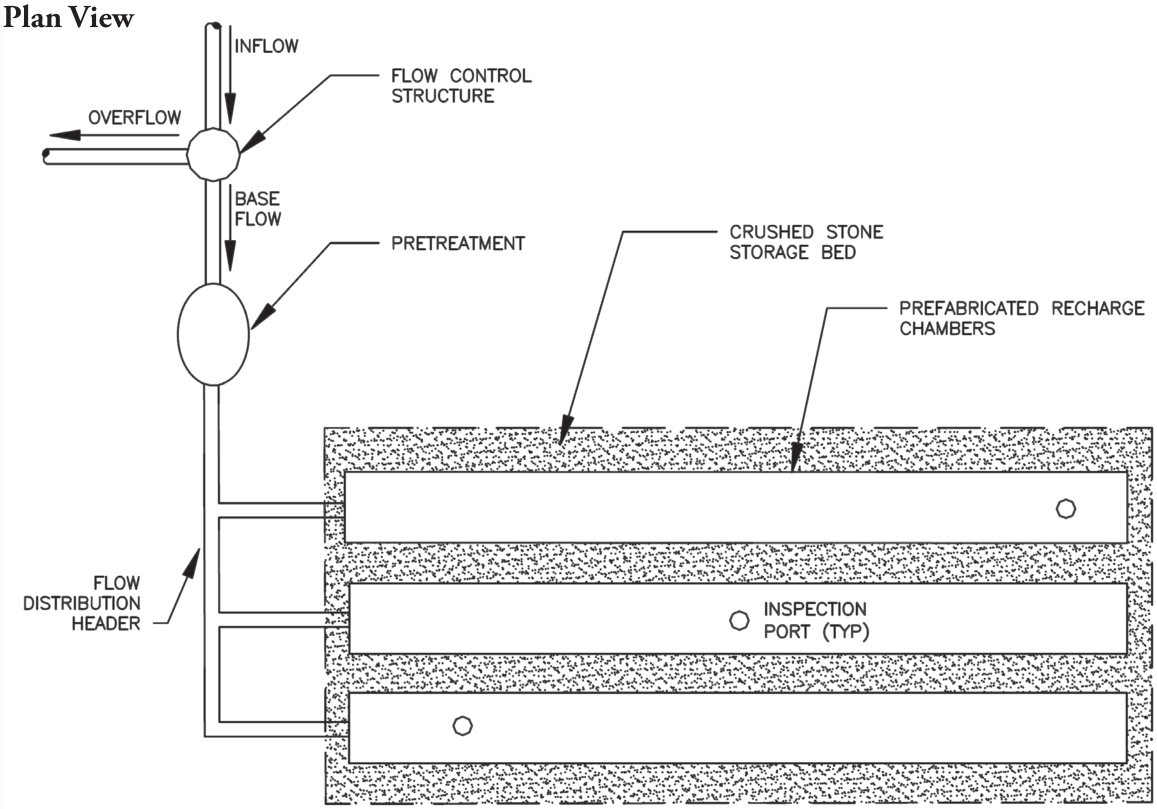
- Removal of debris from inlet and outlet structures
- Removal of accumulated sediment
- Inspection and repair of outlet structures and appurtenances
- Inspection of infiltration components at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Inspection of pretreatment measures at least twice annually, and removal of accumulated sediment as warranted by inspection, but no less than once annually.
- If an infiltration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore infiltration function, including but not limited to removal of accumulated sediments or reconstruction of the infiltration trench.

Design References

- Schueler (1987)
- Schueler, et al. (1992)
- Ferguson (1994)

Example Design

Plan View



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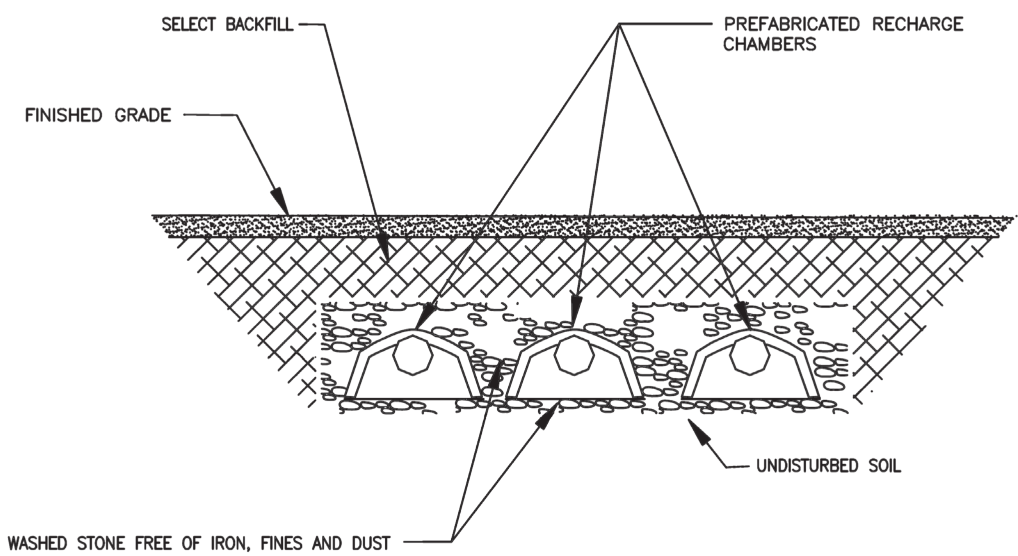


Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Pretreatment	Required (see Section 4-4)
BMP Volume	≥ the larger of WQV or GRV, depending on purpose of BMP excluding sediment forebay capacity, if present, and exclude infiltration occurring during the design event
Slope of Basin Floor	0% (flat)
Design Infiltration Rate	See Section 2-4 for a discussion on selecting a design infiltration rate
Drain Time	< 72 hours for complete drainage of the water quality volume
Depth to Bedrock and to Seasonal High Water Table Elevation	≥ 3 feet from bottom of BMP, except: ≥ 4 feet if within groundwater or water supply intake protection area ≥ 1 foot if runoff has been treated prior to entering the BMP
Design Overflow Discharge Capacity (Subsurface Capacity)	10-year, 24 hour storm
Infiltration Media Material (if used for subsurface basin)	Clean, washed, uniform (well-sorted) aggregate Diameter 1.5 to 3 inches Porosity = 40%
Observation Well (subsurface basin)	Well or accessible manhole structure required

3d. Dry Well & Leaching Basin

Dry wells are essentially small subsurface leaching basins. It consists of a small pit filled with stone, or a small structure surrounded by stone, used to temporarily store and infiltrate runoff from a very limited contributing area. Runoff enters the structure through an inflow pipe, inlet grate, or through surface infiltration. The runoff is stored in the structure and/or void spaces in the stone fill. Properly sited and designed dry wells provide treatment of runoff as pollutants become bound to the soils under and adjacent to the well, as the water percolates into the ground. The infiltrated stormwater contributes to recharge of the groundwater table.

Dry wells are well-suited to receive roof runoff via building gutter and downspout systems. With the small size and manageable cost of these BMPs, they are particularly suited for use in subdivisions and for single-family homes. When used for roof drainage, pretreatment of runoff is not typically required.

Leaching basins are dry wells used in well drained soils for the discharge of roadway or parking area runoff. In this case, pretreatment is required prior to discharge to the leaching basin. A typical arrangement is to use a deep sump, hooded catch basin in combination with a leaching basin.

Dry wells, leaching basins, and similar devices should meet the design criteria applicable to subsurface infiltration basins.

Design Considerations

- Pretreatment is essential to the long-term function of infiltration systems.
- Preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
  - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent infiltration BMPs.
  - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
  - Do not place infiltration systems into service until the contributing areas have been fully stabilized.

Maintenance Requirements

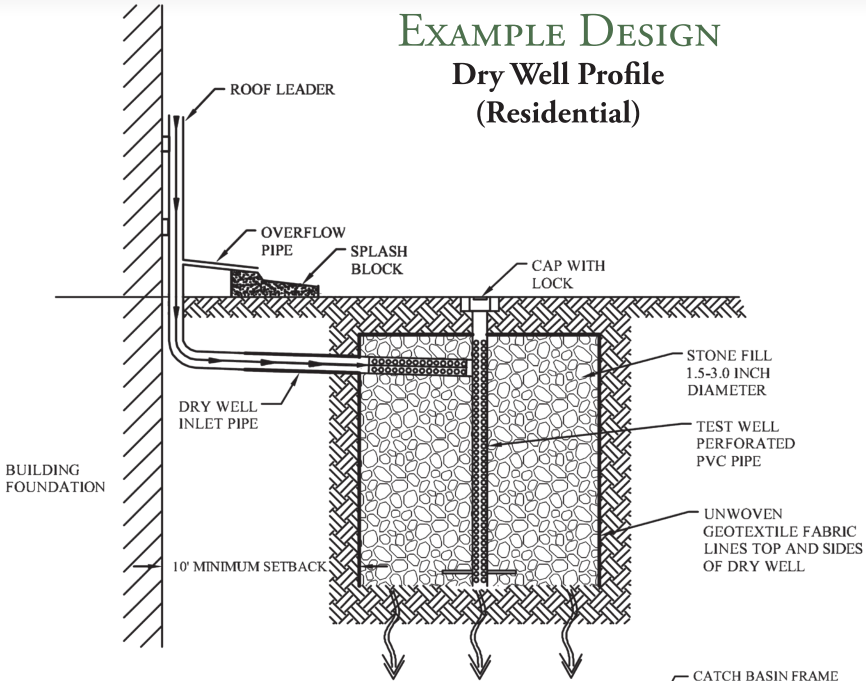
- Removal of debris from inlet and outlet structures
- Removal of accumulated sediment
- Inspection and repair of outlet structures and appurtenances
- Inspection of infiltration components at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- If an infiltration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore infiltration function, including but not limited to removal of accumulated sediments or reconstruction of the infiltration trench.

Design Criteria

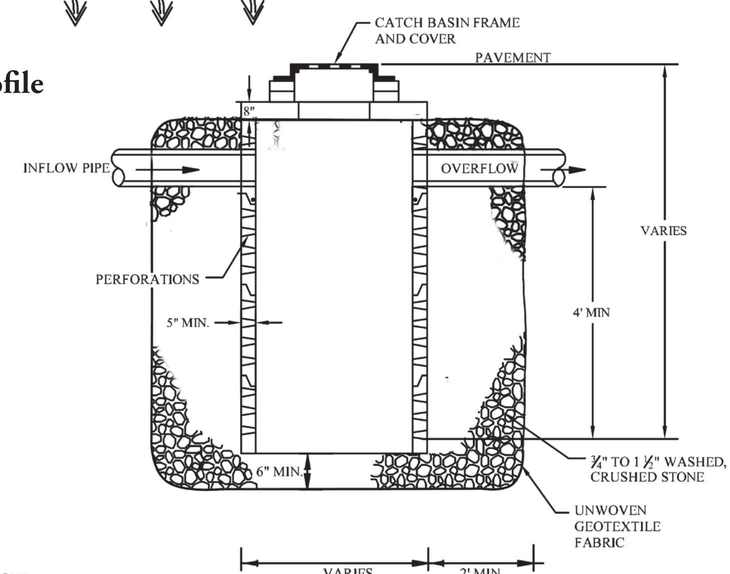
Design Parameter	Criteria
Pretreatment	Required (see Section 4-4)
BMP Volume	≥ the larger of WQV or GRV, depending on purpose of BMP excluding sediment forebay capacity, if present, and exclude infiltration occurring during the design event
Design Infiltration Rate	See Section 2-4 for a discussion on selecting a design infiltration rate
Drain Time	< 72 hours for complete drainage of the water quality volume
Depth to Bedrock and to Seasonal High Water Table Elevation	≥ 3 feet from bottom of BMP, except: ≥ 4 feet if within groundwater or water supply intake protection area ≥ 1 foot if runoff has been treated prior to entering the BMP

Example Design

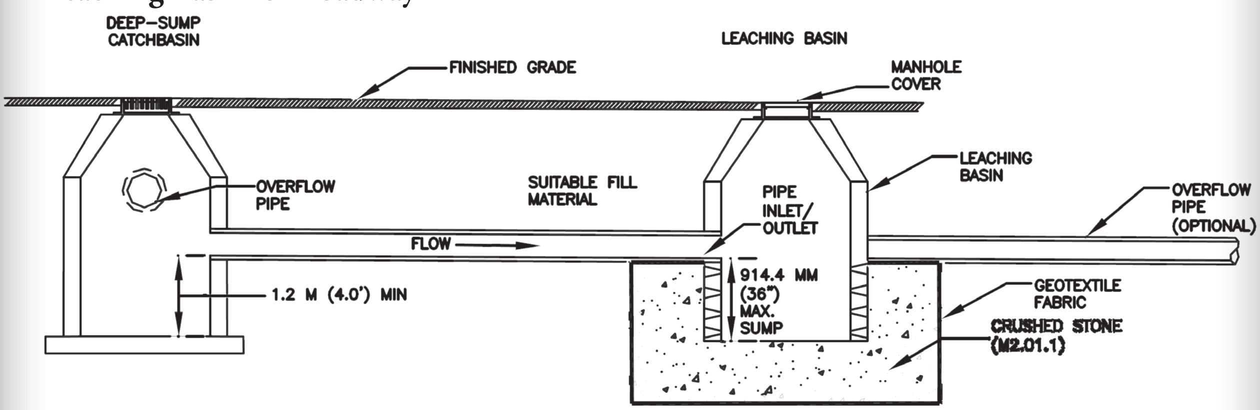
Dry Well Profile (Residential)



Leaching Basin Profile



Leaching Basin for Roadway



Source: MassHighway (2004)

4. FILTERING PRACTICES

General Description

Filtering practices treat stormwater runoff by capturing and passing the water quality volume through a bed of sand, other soil material, or other acceptable treatment media to remove pollutants from the water. Sediments and other pollutants are removed by physical straining and adsorption. Filters can be constructed using common materials, or proprietary systems using various filter media can be employed. Filtration BMPs have shown to be very effective at removing a wide range of pollutants from stormwater runoff, particularly when organic soil filter media have been used.

Filtering practices differ from infiltration practices in that the stormwater filters through an engineered filter media, rather than native soil. However, filtering practices can be constructed in combination with infiltration practices, where the filtered water is discharged into the ground beneath the BMP.

Alternatively, filters can be designed with an underdrain to collect the treated water and convey it to discharge. Underdrained filters can be lined to isolate the filters from the adjacent soil material or underlying groundwater.

The following are examples of filtering practices:

- Surface sand filters
- Underground sand filters
- Bioretention systems
- Tree box filters
- Pervious asphalt and pervious concrete (permeable pavement)

General Requirements Applicable to Filtering Practices

- Filtering practices are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued.
- Filtering practices are prohibited as follows, unless an impermeable liner is provided:
  - Into areas groundwater protection areas where stormwater is from a high-load area
  - Into areas where contaminants occur in groundwater above ambient standards (Env-Or 603.03)
  - Into areas where contaminants occur in soil above site-specific standards (Env-Or 600)
  - Into areas with slopes > 15%, unless calculations show that seepage will not cause slope instability
  - From areas with soil contaminants above site-specific standards (Env-Or 600)
  - From areas with underground or aboveground storage tanks regulated by RSA 146-C or RSA 146-A, where gasoline is dispensed or transferred
- Pretreatment is required (see Section 4-4) if BMP will receive stormwater other than roof runoff (except permeable pavements do not require pretreatment of runoff from their surfaces)
- Underdrain system is required if underlying native soil or fill soil has an infiltration rate < 0.5 inches per hour
- Where infiltration applies, the design infiltration rates must be determined in accordance with the protocols discussed in Chapter 2.
- Provide recommended clearances to seasonal high water table, to maintain adequate drainage, prevent structural damage to the filter, and minimize the potential for interaction with groundwater.

4a. Surface Sand Filter

The surface sand filter is typically designed as an off-line device, so that storms exceeding the water quality volume are diverted from the BMP. Thus, the system usually includes a flow splitter, used to divert the first flush of runoff into a pretreatment device, such as a sedimentation chamber (wet or dry) where coarse sediments settle out of the water. Pretreated runoff then enters the sand filter, saturating the filter bed and filling temporary storage volume provided above the bed. As the water filters down through the sand bed, pollutants are strained from the water or adsorbed to the filter media. The top surface of the sand filter is exposed to the elements, but is kept free of vegetation.

If the filter is designed for infiltration, the treated water is allowed to percolate into the underlying native soil. Alternatively, the filter can be designed with a perforated underdrain system to collect treated water at the bottom of the sand filter and direct it to a suitable outlet. If necessary, the underdrained sand filter can be designed with a liner to isolate it from adjacent soil material and prevent discharge of treated water to the groundwater table.

Design Considerations

- Sand and other media filters may be advantageous for specialized applications where specific target pollutants must be addressed.
- Sand and other media filters may be advantageous for sites with limited space.
- Pretreatment is essential to the long-term function of surface sand filtration systems.
- Where ultimate discharge from the filter is by infiltration into the subsoil, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
  - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent filtration/infiltration BMPs.
  - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.
- Do not place filtration systems into service until the contributing areas have been fully stabilized.

Maintenance Requirements

- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated sediment as warranted by inspection, but no less than once annually.
- Trash and debris should be removed at each inspection.
- Manufactured filter media should be replaced periodically per manufacturer's specifications
- At least once annually, system should be inspected for drawdown time. If a filtration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore filtration function, including but not limited to removal of accumulated sediments or reconstruction of the filter.

Design References

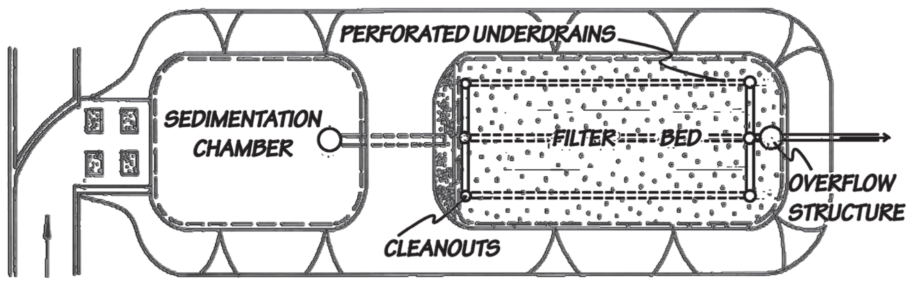
- Claytor & Schueler (1996)
- UNH Stormwater Center
- EPA (1999c)

Table 4-3. Filter Mixtures

Component Material	Percent of Mixture by Volume	Gradation of Material	
		Sieve No.	Percent by Weight Passing Standard Sieve
Filter Media Option A			
ASTM C-33 concrete sand	50 to 55		
Loamy sand topsoil, with fines as indicated	20 to 30	200	15 to 25
Moderately fine shredded bark or wood fiber mulch, with fines as indicated	20 to 30	200	< 5
Filter Media Option B			
Moderately fine shredded bark or wood fiber mulch, with fines as indicated	20 to 30	200	< 5
Loamy coarse sand	70 to 80	10	85 to 100
		20	70 to 100
		60	15 to 40
		200	8 to 15

Example Design

Plan View



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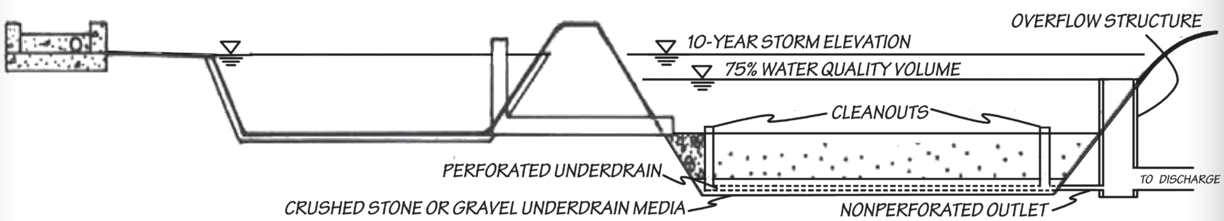

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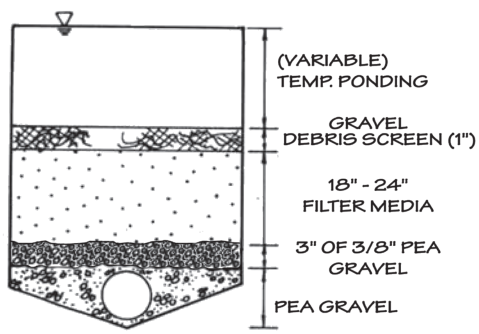


Adapted from Claytor & Schueler (1996)

Design Criteria

Design Parameter	Criteria
Filter Volume	≥ 75% WQV (including storage area above filter, filter media voids, and pre-treatment area)
Watershed	< 10 acres of contributing drainage area
Depth of Filter Media	18 to 24 inches
Filter Media	See Table 4-3 Filter should not be covered with grass
Filter Appurtenances	Must have access grate
Drain Time	< 72 hours for complete drainage
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 3/4 to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner: ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the *practice* to the SHWT or • 1 foot of separation from the bottom of the filter course material *and* twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm

4b. Underground Sand Filter

The underground sand filter operates in a similar fashion to the surface sand filter, except that the system is enclosed in a below-grade structure. The structure may consist of a multi-chambered vault that accommodates pretreatment, as well as the filtration component of the system. The structure is made accessible through manholes or grate openings.

A typical structure incorporating pretreatment will consist of a three-chambered vault, with the first chamber comprising a sedimentation chamber, the second chamber consisting of the filter, and the final chamber serving as the outlet control for the system. The first chamber provides pretreatment by settling coarse sediments and by trapping floating materials such as trash and oil. The pretreated water then enters the sand filter. A permeable layer of gravel may be installed on top of the filter to help prevent clogging of the filter media. A perforated underdrain at the bottom of the filter directs treated water towards an outlet. Similar to the surface sand filter, the subsurface filter should be designed as an off-line device, with capacity to treat the Water Quality Volume, with larger storm events diverted from the device.

Typical subsurface filter systems are fully enclosed in structures. However, some systems may be designed with an open bottom in contact with native soils, allowing for infiltration to occur. In these systems, the “hybrid” BMP needs to be designed to meet the requirements of Subsurface Infiltration Systems, in addition to the requirements for the filter system.

Design Considerations

- Sand and other media filters may be advantageous for specialized applications where specific target pollutants must be addressed.
- Sand and other media filters may be advantageous for sites with limited space.
- Pretreatment is essential to the long-term function of surface sand filtration systems.
- Do not place filtration systems into service until the contributing areas have been fully stabilized.
- Where ultimate discharge from the filter is by infiltration into the subsoil, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - o Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to permanent filtration/infiltration BMPs.
    - o Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.

Maintenance Requirements

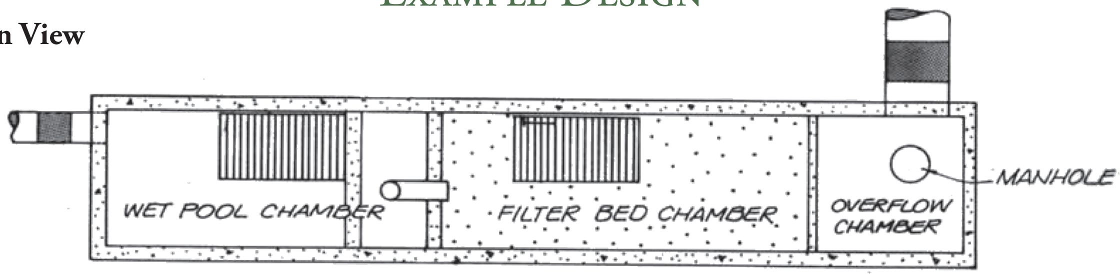
- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated sediment as warranted by inspection, but no less than once annually.
- Trash and debris should be removed at each inspection.
- Manufactured filter media should be replaced periodically per manufacturer's specifications.
- At least once annually, system should be inspected for drawdown time. If a filtration system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore filtration function, including but not limited to removal of accumulated sediments or reconstruction of the filter.

Design References

- Claytor & Schueler (1996)
- EPA (1999c)

Example Design

Plan View



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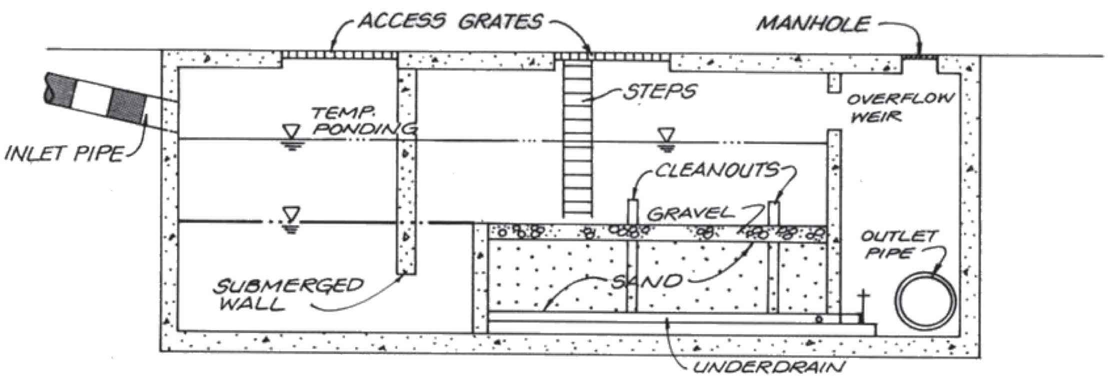

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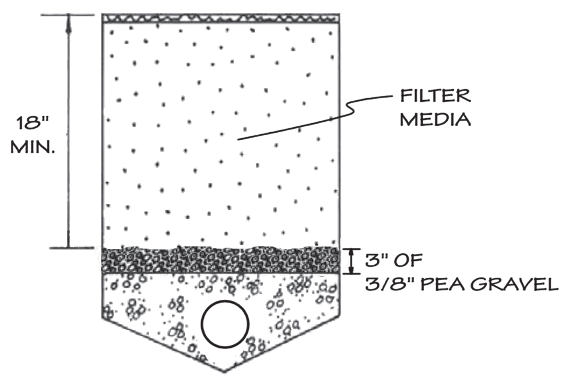


Adapted from Claytor & Schueler (1996)

Design Criteria

Design Parameter	Criteria
Filter Volume	≥ 75% WQV (including storage area above filter, filter media voids, and pre-treatment area)
Watershed	< 10 acres of contributing drainage area
Depth of Filter Media	≥ 24 inches
Filter Media	See Table 4-3
Filter Appurtenances	Must have access grate
Drain Time	< 72 hours for complete drainage
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 1- to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner: ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the *practice* to the SHWT or • 1 foot of separation from the bottom of the filter course material *and* twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm

4c. Bioretention System

A bioretention system (sometimes referred to as a "rain garden") is a type of filtration BMP designed to collect and filter moderate amounts of stormwater runoff using conditioned planting soil beds, gravel beds and vegetation within shallow depressions. The bioretention system may be designed with an underdrain, to collect treated water and convey it to discharge, or it may be designed to infiltrate the treated water directly to the subsoil. Bioretention cells are capable of reducing sediment, nutrients, oil and grease, and trace metals. Bioretention systems should be sited in close proximity to the origin of the stormwater runoff to be treated.

The major difference between bioretention systems and other filtration systems is the use of vegetation. A typical surface sand filter is designed to be maintained with no vegetation, whereas a bioretention cell is planted with a variety of shrubs and perennials whose roots assist with pollutant uptake. The use of vegetation allows these systems to blend in with other landscaping features.

Design Considerations

- Bioretention areas should be located close to the source of runoff.
- Bioretention areas are particularly adaptable to integration with site landscaping, and offer an aesthetically attractive opportunity to provide highly effective stormwater treatment.
- Bioretention areas can also be used to meet recharge objectives, where allowed by land use and receiving water characteristics.
- Do not place bioretention systems into service until the BMP has been planted and its contributing areas have been fully stabilized.
- Where ultimate discharge from the bioretention area is by infiltration into the subsoil, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to the bioretention area during any stage of construction.
    - Do not traffic exposed soil surface with construction equipment. If feasible, perform excavations with equipment positioned outside the limits of the infiltration components of the system.

Maintenance Requirements

- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated sediment as warranted by inspection, but no less than once annually.
- Trash and debris should be removed at each inspection.
- At least once annually, system should be inspected for drawdown time. If bioretention system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore filtration function or infiltration function (as applicable), including but not limited to removal of accumulated sediments or reconstruction of the filter media.
- Vegetation should be inspected at least annually, and maintained in healthy condition, including pruning, removal and replacement of dead or diseased vegetation, and removal of invasive species.

Design References

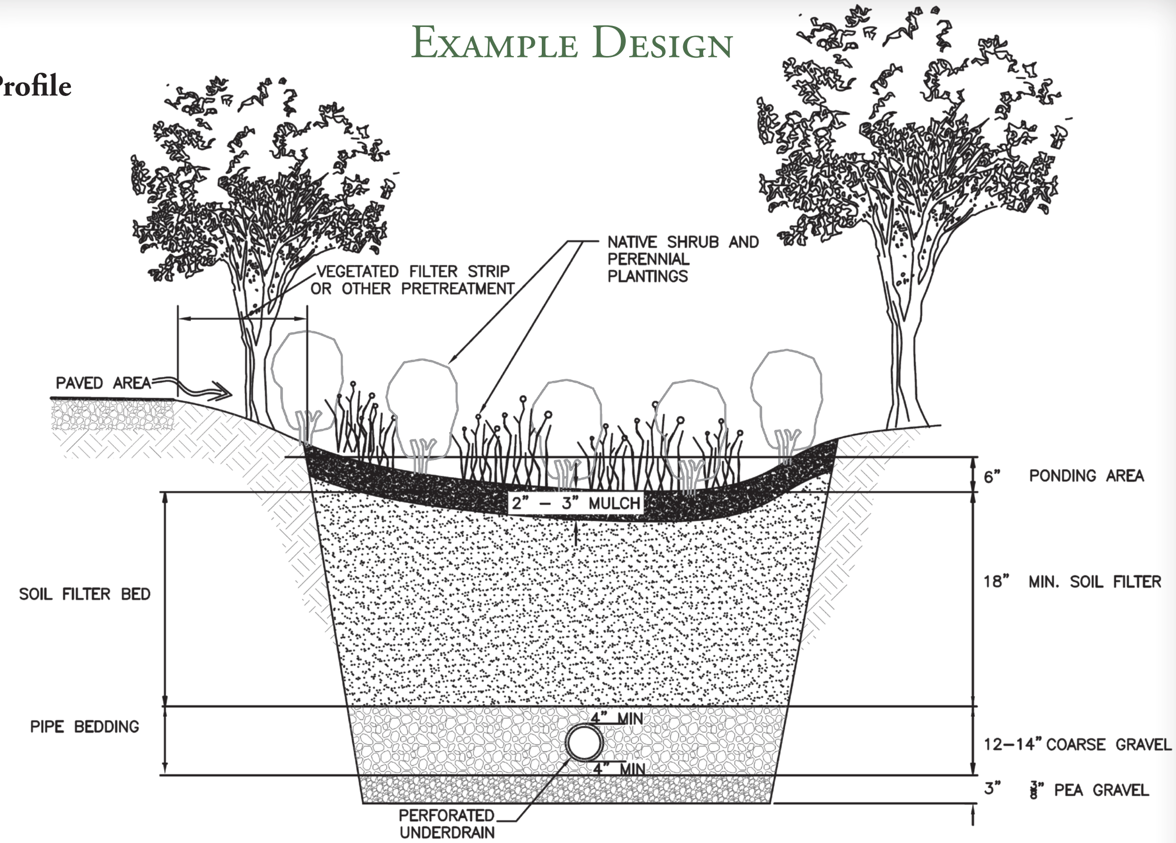
- UNH Stormwater Center
- EPA (1999a)

Table 4-4. Bioretention Filter Media

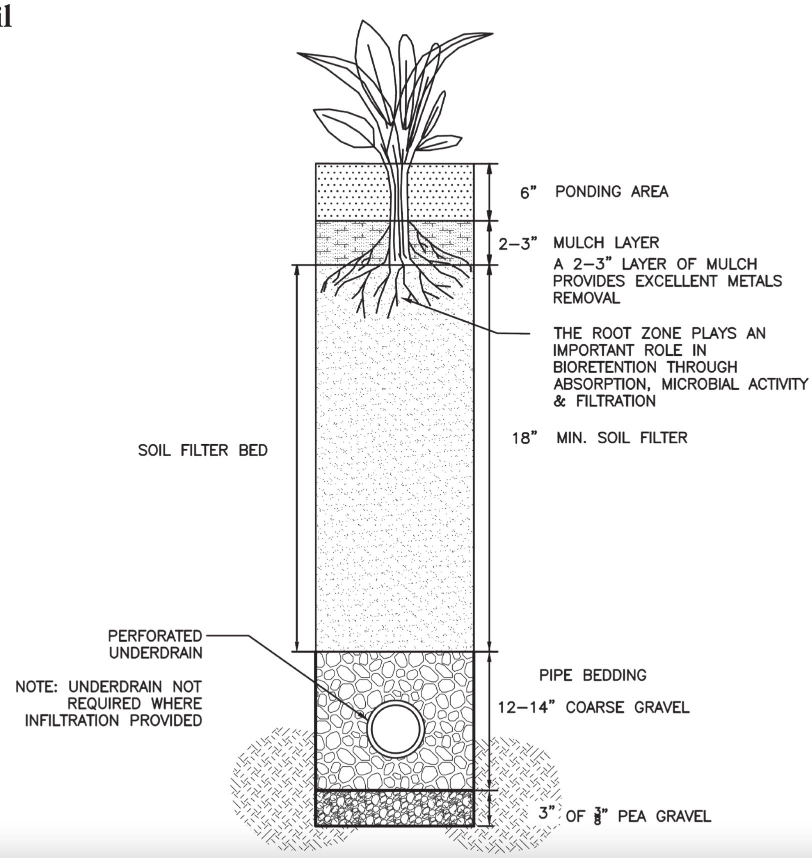
Component Material	Percent of Mixture by Volume	Gradation of Material	
		Sieve No.	Percent by Weight Passing Standard Sieve
Filter Media Option A			
ASTM C-33 concrete sand	50 to 55		
Loamy sand topsoil, with fines as indicated	20 to 30	200	15 to 25
Moderately fine shredded bark or wood fiber mulch, with fines as indicated	20 to 30	200	< 5
Filter Media Option B			
Moderately fine shredded bark or wood fiber mulch, with fines as indicated	20 to 30	200	< 5
Loamy coarse sand	70 to 80	10	85 to 100
		20	70 to 100
		60	15 to 40
		200	8 to 15

Example Design

Profile



Column Detail



Design Criteria

Design Parameter	Criteria
Bioretention Volume	≥ WQV (including storage area above filter and filter media voids)
Watershed	< 5 acres of contributing drainage area
Depth of Filter Media	18 – 24 inches
Filter Media	See Table 4-4
Drain Time	< 72 hours for complete drainage
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 1- to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner: ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the *practice* to the SHWT or • 1 foot of separation from the bottom of the filter course material *and* twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm
Maximum Side Slopes	2:1
Surface Covering	2 to 3 inches well-aged shredded bark mulch (uniform in color, free of foreign and plant material)
Planting Design	Only native, non-invasive species Random and natural plant layout No woody vegetation near inflow locations Only facultative wetland species directly over the filter media Provide trees or large shrubs along perimeter Establish a tree canopy with an understory of shrubs and herbaceous plants Vegetation should be drought tolerant

4d. Tree Box Filter

The Tree Box Filter is essentially a small bioretention system, combining the function of a curb-side drainage inlet with the water quality treatment functions of a vegetated soil media. It consists of an open bottom or closed bottom concrete box or barrel filled with a porous soil media. An underdrain system, consisting of a perforated pipe bedded in crushed gravel, is provided beneath the soil media. A tree is planted in the soil media. Stormwater is directed from surrounding impervious surfaces through the top of the soil media.

If the device has an open bottom, the stormwater percolates through the media into the underlying ground. If the filtered stormwater exceeds the infiltration capacity of the underlying natural soil, the excess will be intercepted by the underdrain, where it may be directed to a storm drain, other device, or surface water discharge.

Where a closed bottom box filter is used, such as where necessary to protect groundwater resources, the filter is isolated from the underlying soil. In this case, all of the stormwater that passes through the soil media filter will be intercepted by the underdrain and conveyed to a suitable outlet.

Design Considerations

- Tree box filters should be carefully integrated into the design of parking areas and streets, to provide a sufficient number of units in suitable locations for capturing the required Water Quality Volume. Generally, these systems are sized and spaced similarly to catch basin inlets.
- Tree box filters are particularly adaptable to integration with site landscaping, and offer an aesthetically attractive opportunity to provide highly effective stormwater treatment.
- Do not use tree box filters to treat runoff from high-load areas (see the discussion of high load areas in Section 3-1 of this manual).
- Tree box filters can be used to meet recharge objectives, where underlying soils are suitable and where allowed by land use and receiving water characteristics.
- Do not place tree box filters into service until the BMP has been planted and its contributing areas have been fully stabilized.
- Where ultimate discharge from the tree box filter is by infiltration into the subsoil, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
    - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) to the tree box filter during any stage of construction.
    - Do not traffic or compact exposed soil surface within the area of the filter with construction equipment. Perform excavation for the construction of this BMP with equipment positioned outside the limits of the system.

Maintenance Requirements

- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Trash and debris should be removed at each inspection.
- If inspection indicates that the system does not drain within 72-hours following a rainfall event, then a qualified professional should assess the condition of the tree box filter to determine measures required to restore filtration function or infiltration function (as applicable), including but not limited to removal of accumulated sediments or reconstruction of the filter media.
- The tree should be inspected at least annually, and maintained in healthy condition, including pruning. A dead or diseased tree, or a tree in stressed condition because of the constricted root space in the filter, should be removed and replaced. Filter media should be replaced when the tree is replaced.

Design References

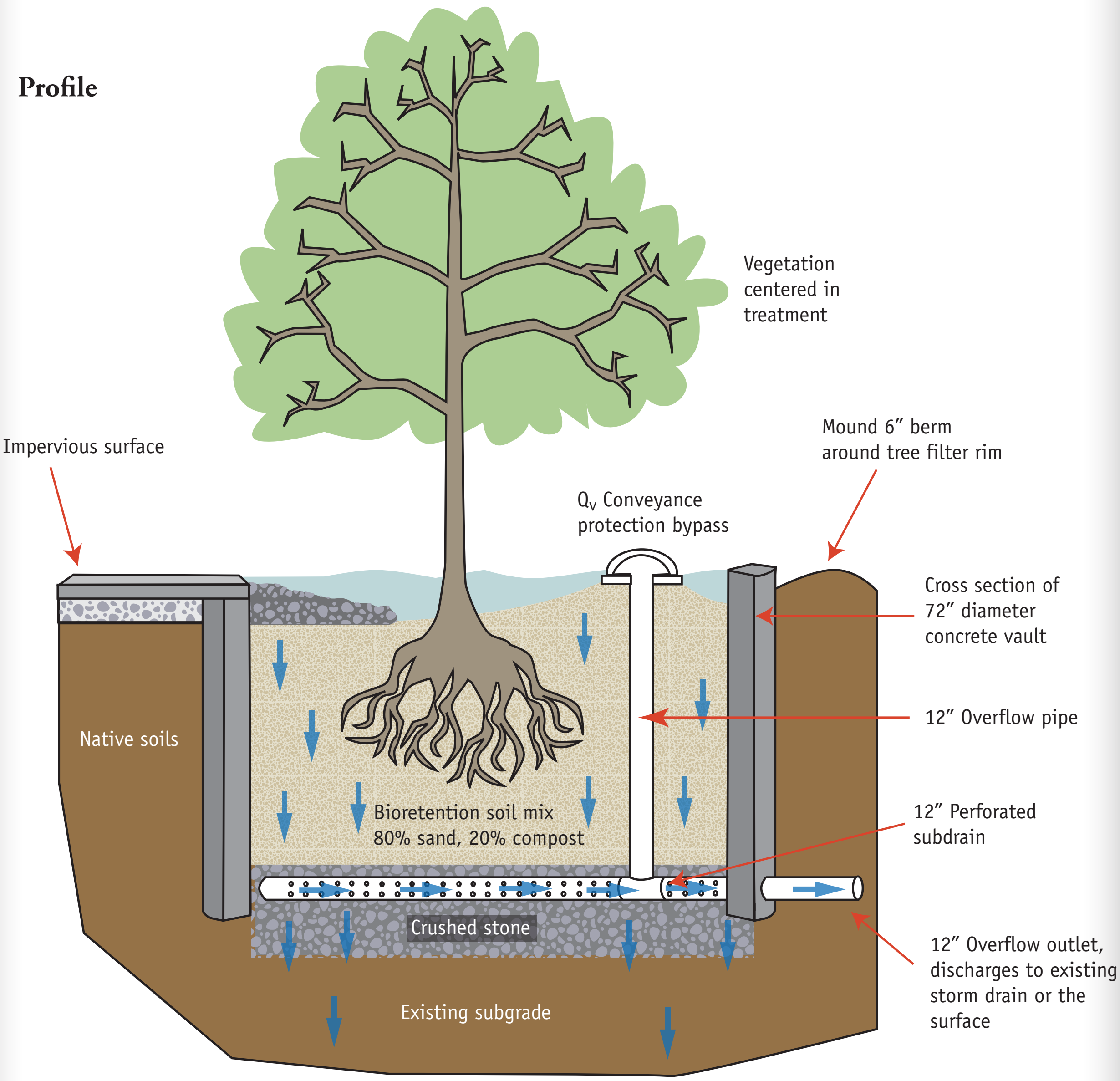
- UNH Stormwater Center (2007a)

Table 4-5. Tree Box Filter Media

Component Material	Percent of Mixture by Volume	Required Material Characteristics
Sand	80	ASTM C-33 concrete sand
Organic material, ***composted*** bark mulch recommended	20	< 5 % passing #200 Sieve
General requirements applicable to the mixture	1. Soil mix should be uniform, free of stones, stumps, roots, or similar materials larger than 2 inches. 2. Soil pH should be between 5.5 and 6.5	

Example Design

Profile



Source: UNH Stormwater Center (2007a)

Design Criteria

Design Parameter	Criteria
Pretreatment	Pretreatment not required. However, tree box filters should not be used for high-load areas.
Tree Box Filter Volume	≥ WQV (including storage area above filter and filter media voids)
Depth of Filter Media	36 inches, minimum
Filter Media	See Table 4-5
Drain Time	< 72 hours for complete drainage
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 1- to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner (or vault with integral bottom): ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the practice to the SHWT or • 1’ of separation from the bottom of the filter course material and twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm
Planting Design	Vegetation selected for these systems should consist of native, drought-tolerant and salt-tolerant species. Plants with aggressive root growth may clog the sub-drain, and therefore may not be suitable for this type of system.

4e. Permeable Pavement

Permeable pavement consists of a porous surface, base, and sub-base materials which allow penetration of runoff through the surface into underlying soils. The surface materials for permeable pavement can consist of paving blocks or grids, pervious asphalt, or pervious concrete. These materials are installed on a base which serves as a filter course between the pavement surface and the underlying sub-base material. The sub-base material typically comprises a layer of crushed stone that not only supports the overlying pavement structure, but also serves as a reservoir to store runoff that penetrates the pavement surface until it can percolate into the ground.

Although traffic loading capacities vary, permeable pavement alternatives are generally appropriate for low traffic areas (e.g. sidewalks, parking lots, overflow parking, residential roads). Pavement type and thickness are selected based on anticipated load (light, moderate, heavy) and maintenance requirements. Careful maintenance is essential for long term use and effectiveness.

Frequently, permeable pavements filter only the runoff generated on the pavement surface itself. However, runoff from other areas can be directed to permeable pavement if properly designed. Runoff generated from adjacent areas of the site may require pretreatment prior to discharge to the pavement surface, to prevent clogging of the pavement structure and (where the pavement is used to infiltrate as well as filter the runoff) the underlying soils.

Porous asphalt is very similar to conventional asphalt except that it is mixed without particles smaller than coarse sand (less than 600 µm or No. 30 sieve). Without these smaller size particles, water is able to pass through the surface and into a crushed stone storage area. The lack of fine particles in the asphalt, however, limits the loading capacity of the asphalt relative to conventional asphalt. Because of this limitation, pervious asphalt should not be used in high-traffic areas. An advantage to the use of porous asphalt is the reduced need for stormwater conveyance systems and other additional BMPs.

Pervious concrete uses carefully controlled amounts of water and cementitious materials to create a thick coating around aggregate particles, but retaining significant void space in the placement of the mixture. A pervious concrete mixture contains little or no sand, creating this void content. The installed surface will typically have between 15% and 25% voids in the hardened concrete, capable of passing water at extremely high flow rates through the surface. The low mortar content and high porosity reduce the strength of this surface compared to conventional concrete mixtures, which limits the use of the surface to low load-bearing areas, as is the case for porous asphalt. The pervious concrete surface is placed over an aggregate filter and storage layer, similar in characteristics to porous asphalt.

Design Considerations

- Permeable pavements are generally applicable to low-traffic access ways, residential drives, overflow or low-use parking areas, pedestrian access ways, alleys, bikepaths, and patios. Because of the reduced strength of pavement associated with permeable pavement surfaces such as porous asphalt and concrete, these surfaces are not typically appropriate for high traffic or heavy vehicle loads.

- Particular care must be taken during construction to assure preparation of subgrade, placement of aggregates, and installation of pavements meets design specifications.

- On sloping pervious pavement surfaces, impermeable trench berms should be considered within the filter and reservoir courses to minimizing flow laterally within the pavement courses. The berm should be sized to a depth necessary to retain the stormwater for sufficient time to infiltrate.
- Where infiltration is provided by the design, the preservation of infiltration function of underlying soils requires careful consideration during construction. To prevent degradation of infiltration function:
  - Do not discharge sediment-laden waters from construction activities (runoff, water from excavations) into areas designated for permeable pavement.
  - Do not allow stormwater from other areas of the site to flow onto the completed permeable pavement until those areas have been fully stabilized.

Maintenance Requirements

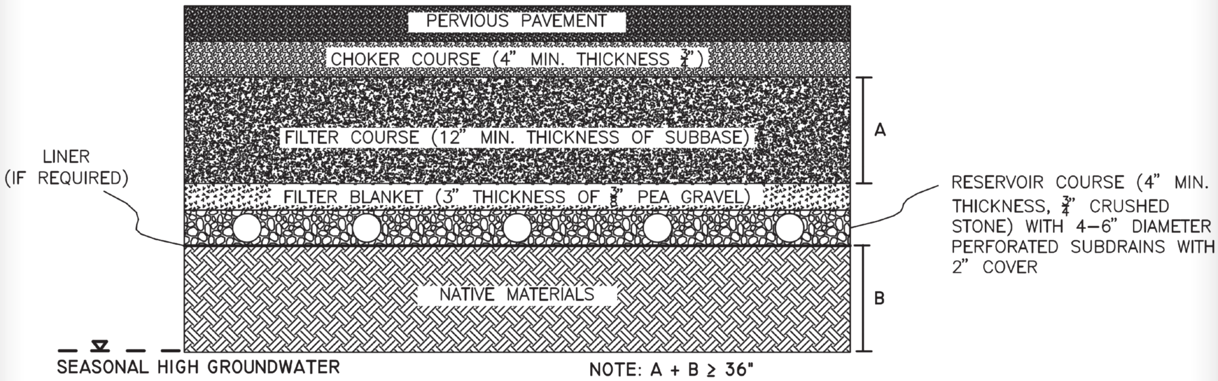
- Provision of signs is recommended, to indicate locations of permeable pavements and the applicability of special maintenance measures.
- No winter sanding of permeable pavements is permitted.
- Minimize application of salt for ice control.
- Never reseal or repave with impermeable materials.
- Inspect annually for pavement deterioration or spalling.
- Monitor periodically to ensure that the pavement surface drains effectively after storms
- For porous asphalt and concrete, clean periodically (2-4 times per year) using a vacuum sweeper. Power washing may be required prior to vacuum sweeping, to dislodge trapped particles.
- For interlocking paving stones, periodically add joint material to replace lost material
- For seeded grid systems, periodic reseeding of grass pavers to fill in bare spots
- Major clogging may necessitate replacement of pavement surface, and possibly filter course and sub-base course.

Design References

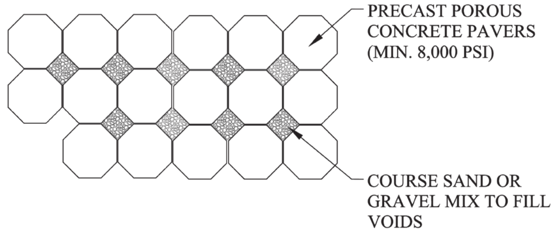
- See Design Criteria references for type of surfacing.

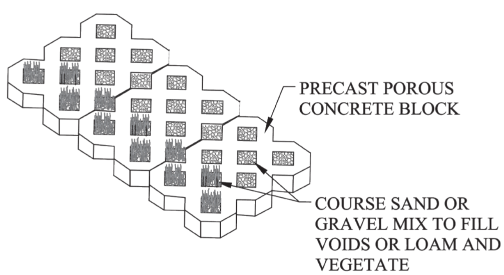
Example Design

Permeable Pavement Profile



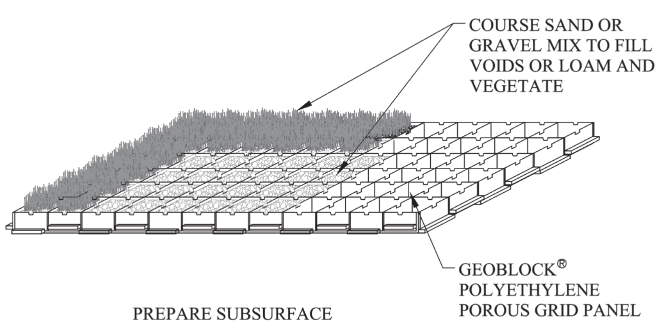
Permeable Concrete Pavers





PREPARE SUBSURFACE RESERVOIR TO MATCH BELOW

Geoblock Porous Pavement



PREPARE SUBSURFACE RESERVOIR TO MATCH BELOW

Design Criteria

Design Parameter	Criteria
Porous asphalt design	UNHSC (2007b)
Porous concrete design	American Concrete Institute (2006)
Porous concrete installation	Conractor certified by the National Ready Mix Concrete Association (NRMCA) through the NRMCA Pervious Concrete Contractor Certification program
Pervious interlocking paver design	Interlocking Concrete Pavement Institute (2002)
Filter Course Material	NHDOT (2006) sand, Item 304.1
Filter Course Thickness	> 12 inches for any section which receives only direct rainfall to its surface; or > $\frac{\text{12 inches * Total contributing area}}{\text{area of the surface}}$
Total Section Thickness	65% of the frost depth. Typically the frost depth in New Hampshire is about 48 inches. Therefore, total section thickness (top of pervious pavement to the native ground) should be at least 32”.
Aggregate Storage Volume (Reservoir Course, Filter Blanket, Filter Course, Choker Course)	≥ Larger of WQV or Recharge Volume, as applicable for purpose of BMP
Underdrain (where required)	≥ 6-inch diameter perforated PVC or HDPE set in 1- to 2-inch diameter stone or gravel free of fines and organic material
Depth to Bedrock and Seasonal High Water Table Elevation	If not providing an impermeable liner: ≥ 1 foot below the bottom of the filter course material. If within groundwater or water supply intake protection area the practice should also have: • 1 foot of separation from the bottom of the *practice* to the SHWT, or • 1’ of separation from the bottom of the filter course material *and* twice the depth of the filter course material recommended.
Overflow Discharge Capacity	10-year, 24-hour storm
Overflow outlet	Provide overflow from aggregate storage layer
Observation Well(s)	Necessary to monitor conditions in reservoir course

5. TREATMENT SWALES

General Description

Treatment swales are designed to promote sedimentation by providing a minimum hydraulic residence time within the channel under design flow conditions (Water Quality Flow). This BMP may also provide some infiltration, vegetative filtration, and vegetative uptake. Conventional grass channels and ditches are primarily designed for conveyance. Treatment swales, in contrast, are designed for hydraulic residence time and shallow depths under water quality flow conditions. As a result, treatment swales provide higher pollutant removal efficiencies. Pollutants are removed through sedimentation, adsorption, biological uptake, and microbial breakdown.

Treatment swales also differ from practices such as underdrained swales (for example, "dry swales" and "bioretention swales"), which are essentially filtration practices, and "wet swales," which are similar in function to pocket ponds.

General Requirements Applicable to Treatment Swales

- Swales are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued
- Swales are prohibited in groundwater protection areas receiving stormwater from a high-load area unless an impermeable liner is provided
- Swale shape should be trapezoidal or parabolic
- Swale must have ≥ 85% vegetated growth prior to receiving runoff
- Bottom of swale must be above seasonal high water table

Design Considerations

- Flow-Through Swales must be designed so that the flow travels the full length to receive adequate treatment. For this reason, flow must be directed to the inlet end of the swale, rather than the swale collecting water continuously along its length.
- All channels should be designed for capacity and stability. A channel is designed for capacity when it can carry the maximum specified design flow within the design depth of the channel (allowing for recommended freeboard). A channel is designed for stability when the channel lining (vegetation, riprap, or other material) will not be eroded under maximum design flow velocities. Analyses of these conditions must account for both the type of lining and its condition (for example, capacity analysis for a grassed channel must consider the

resistance of the maximum height of grass, while the stability analysis must consider the grass under its shortest, mowed condition).

- Vegetation should be selected based on site soils conditions, planned mowing requirements (height, frequency), and design flow velocities.
- The roughness coefficient, n, varies with the type of vegetative cover and flow depth. At very shallow depths, where the vegetation height is equal to or greater than the flow depth, the n value should be approximately 0.15. This value is appropriate for flow depths up to 4 inches typically. For higher flow rates and flow depths, the n value decreases to a minimum of 0.03 for grass channels at a depth of approximately 12 inches. The n value must be adjusted for varying flow depths between 4" and 12" (see chart below).

Maintenance Requirements

- Inspect annually for erosion, sediment accumulation, vegetation loss, and presence of invasive species.
- Perform periodic mowing; frequency depends on location and type of grass. Do not cut shorter than Water Quality Flow depth (maximum 4-inches)
- Remove debris and accumulated sediment, based on inspection.
- Repair eroded areas, remove invasive species and dead vegetation, and reseed with applicable grass mix as warranted by inspection.

Design References

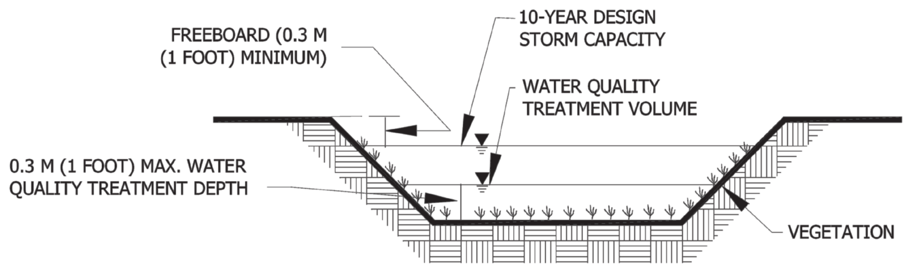
- Minton (2005)

Design Criteria

Design Parameter	Criteria
Minimum Length	≥ 100 feet (not including portions in a roadside ditch)
Bottom Width	4 to 8 feet (widths up to 16 feet are allowable with dividing berm/structure such that neither channel width exceeds 8 feet)
Longitudinal Slope	0.5% to 2% without check dams 2% to 5% with check dams
Maximum Side Slopes	3:1
Flow Depth	4 inches maximum at the WQF
Hydraulic Residence Time	> 10 minutes during the WQF
Design Discharge Capacity	10-year, 24-hour storm without overtopping

Example Design

Section



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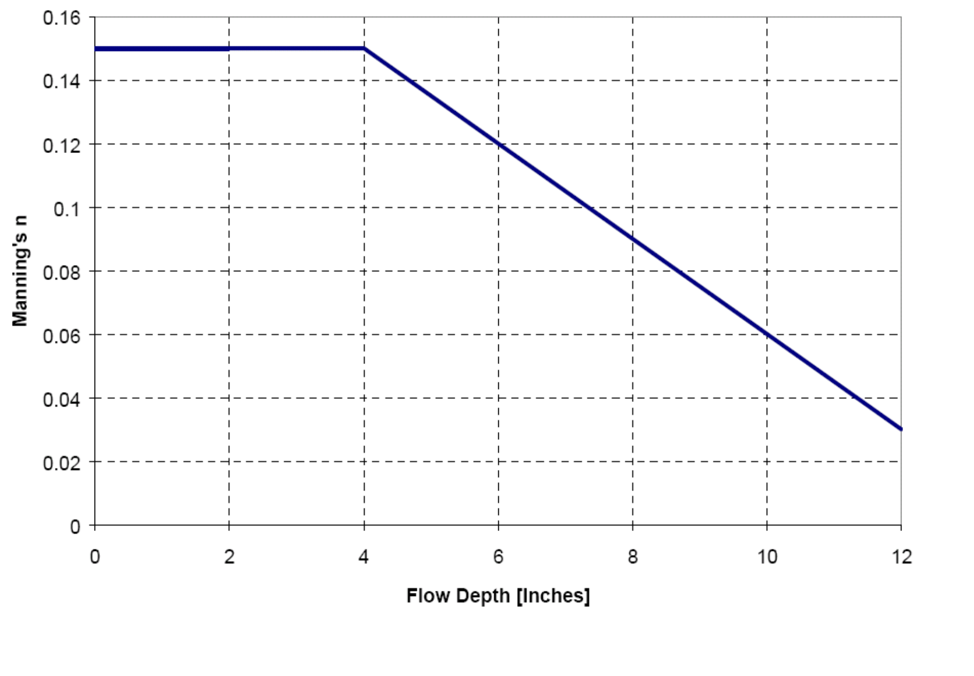


Figure 4-3. Manning's n Value with Varying Flow Depth (Source: Claytor and Schueler, 1986)

6. VEGETATED BUFFERS

General Description

Vegetated buffers are areas of natural or established vegetation allowed to grow with minimal to no maintenance. Natural, undisturbed buffers are particularly desirable along shorelines of waterbodies and wetlands, as well as along connecting habitat corridors. Buffers reduce the velocity of runoff, promote groundwater recharge, filter out sediments and provide shade to reduce the thermal impacts of runoff to receiving waters. Buffers also provide habitat for wildlife.

Vegetated buffers include, but are not limited to:

- Residential or small pervious area buffers
- Developed area buffers
- Roadway Buffers

General Requirements Applicable to Vegetated Buffers

- Ditch turn-out buffers
- Buffers shall not be located in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued
- Buffers should be directly adjacent to the area being treated and receive runoff as sheet flow
- Buffers should not be interrupted by any intermittent or perennial stream channel or other drainage way
- Sizing of buffer will be a function of:
    - Vegetative cover type: forest, meadow, or combination forest/meadow (determine required sizing using a weighted average based on percent of buffer with each cover type)
    - Hydrologic soil group: (determine required buffer size using a weighted average based on percent of buffer in each soil type)
- Buffers must be identified on plans and protected by deed restrictions, covenants, or both, to ensure that buffer remains in an unaltered state

6a. Residential or Small Pervious Area Buffer

This type of vegetated buffer is for individual residential lots or for developments with limited areas of impervious surface, where runoff enters the buffer as sheet flow without the aid of a level spreader. This type of buffer can be sited adjacent to single family or duplex residential structures, or impervious surfaces where flow length over the surfaces is limited. This design is not appropriate for treating large impervious areas where there is the likelihood for runoff flows to concentrate and create channels through the buffer instead of discharging as dispersed sheet flow.

Design Considerations

- Care is required to prepare site so that flow enters the buffer as sheet flow.

Maintenance Requirements

- Inspect buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless erosion occurs.
- If erosion of the buffer (forested or meadow) occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Design References

- Maine DEP (2006)

Design Criteria

Design Parameter	Criteria
Allowable Contributing Area	• Single family or duplex residential lot • Developed area < 10% impervious cover, flow path over developed area ≤ 150 feet • Impervious area ≤ 1 acre where flow path across impervious area ≤ 100 feet
Maximum Slope	15 %, slope must be uniform
Length of Buffer Flow Path	Size flow length of buffers per Tables 4-6 and 4-7.
Width of Buffer	Buffer should extend the width of the contributing impervious surface

Example Design

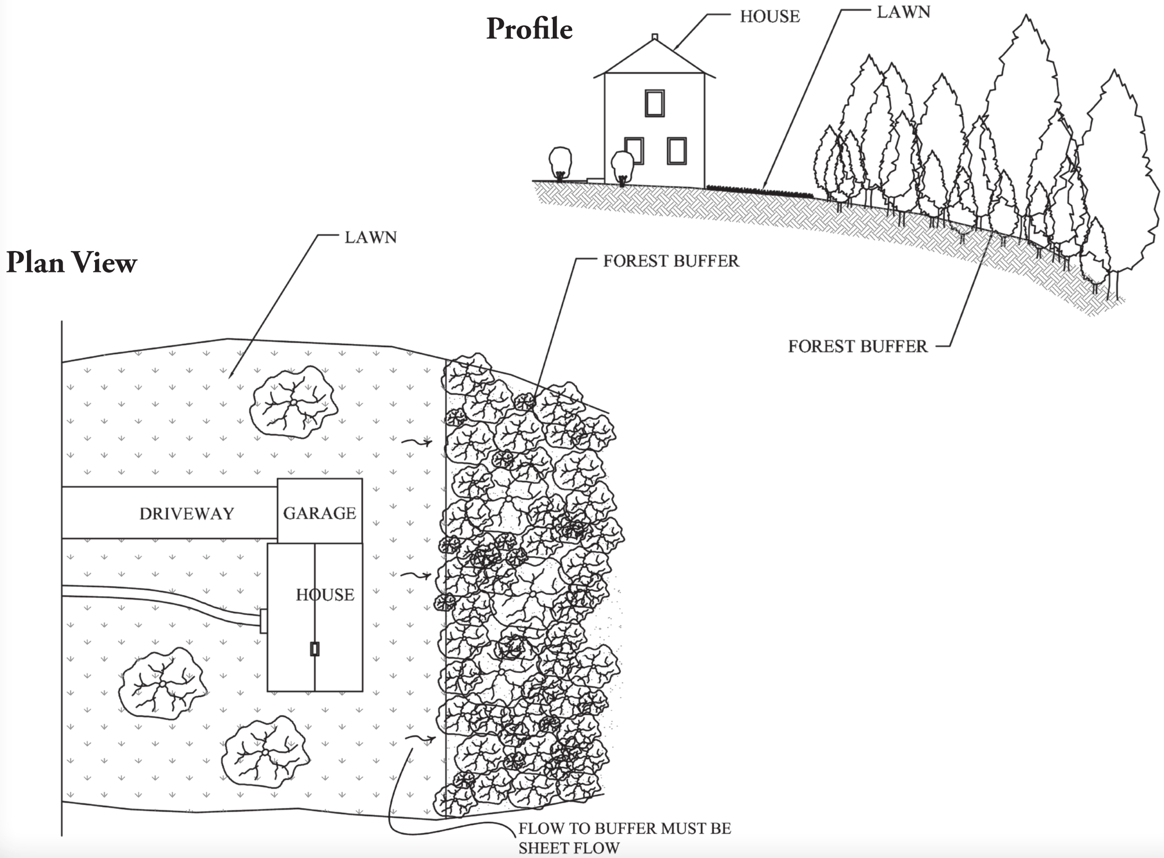


Table 4-6. Required Buffer Flow Path Length per Soil and Vegetative Cover Types with 0% to 8% Buffer Slope		
Hydrologic Soil Group of Soil in Buffer	Length of Flow Path for Forested Buffer (feet)	Length of Flow Path for Meadow Buffer (feet)
A	45	75
B	60	85
C	75	100
D	150	Not Applicable

Table 4-7. Required Buffer Flow Path Length per Soil and Vegetative Cover Types with Greater Than 8% to 15% Buffer Slope		
Hydrologic Soil Group of Soil in Buffer	Length of Flow Path for Forested Buffer (feet)	Length of Flow Path for Meadow Buffer (feet)
A	55	90
B	70	100
C	90	120
D	180	Not Applicable

Note: If a detention structure is used upstream of the level spreader, Tables 4-6 and 4-7 may be used with the assumption that 1.0 acre of impervious area is equivalent to a peak flow of 1.0 cfs during the 2-year, 24-hour storm.

6b. Developed Area Buffer

Developed Area Buffers serve areas that exceed the thresholds for "residential or small pervious area buffers." They may also be used for small areas where the runoff is discharged as concentrated flow, rather than sheet flow. Developed area buffers require the use of stone-berm level spreaders to discharge runoff into the buffers as sheet flow.

Runoff is directed to the channel upstream of the stone berm, which is located along the contour of the slope at the upper margin of the buffer area. This stone berm spreads the runoff so that it uniformly seeps through the berm and evenly distributes across the top of the buffer as sheet flow.

Design Considerations

- Proper grading is essential to establish the level spreader along the contour, so that the outlet of the device is level and distributes discharge as sheet flow over the width of the buffer.
- Soil stabilization measures should be implemented to prevent erosion and local rill and gulley formation until permanent vegetation is established.

Maintenance Requirements

- Inspect level spreader and buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless erosion occurs.
- If erosion of the buffer (forested or meadow) occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Design References

- Maine DEP (2006)

Design Criteria

Design Parameter	Criteria
Allowable contributing area	Maximum area will be governed by the available width of buffer.
Maximum Slope	15 %, slope must be uniform
Length of Buffer Flow Path	Size flow length of buffers per Tables 4-8 and 4-9.
Minimum Level Spreader Length	20 feet
Stone Berm Level Spreader	Must meet the requirements for level spreaders described in Section 4.6.

Table 4-8. Required Level Spreader Berm Length Per Acre of Impervious Area and Lawn Area Draining to the Buffer for a Given Buffer Length with 0% to 8% Buffer Slope

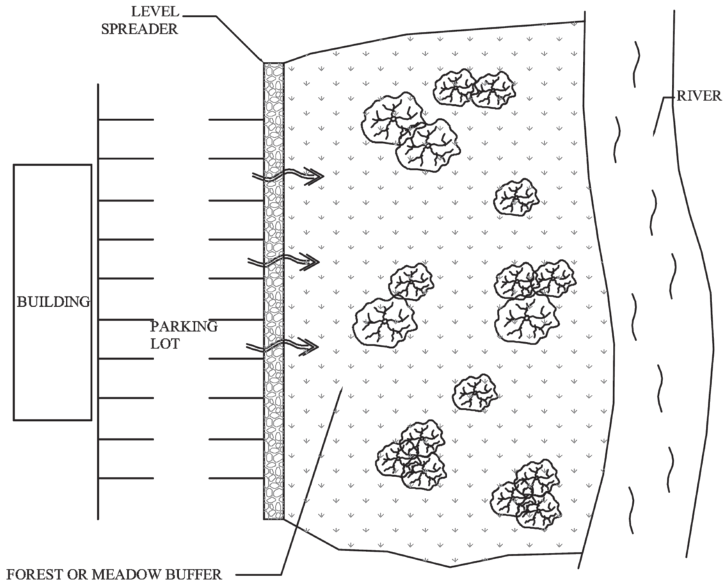
Hydrologic Soil Group of Soil in Buffer	Available Buffer Length (feet)	Level Spreader Berm Length to a Forested Buffer (feet)		Level Spreader Berm Length to a Meadow Buffer (feet)	
		Impervious Area	Lawn Area	Impervious Area	Lawn Area
A	75	75	25	125	35
	100	65	20	75	25
	150	50	15	60	20
B	75	100	30	150	45
	100	80	25	100	30
	150	65	20	75	25
C	75	125	35	150	45
	100	100	30	125	35
	150	75	25	100	30
D	150	150	45	200	60

Table 4-9. Required Level Spreader Berm Length Per Acre of Impervious Area and Lawn Area Draining to the Buffer for a Given Buffer Length with Greater than 8% to 15% Buffer Slope					
Hydrologic Soil Group of Soil in Buffer	Available Buffer Length (feet)	Level Spreader Berm Length to a Forested Buffer (feet)		Level Spreader Berm Length to a Meadow Buffer (feet)	
		Impervious Area	Lawn Area	Impervious Area	Lawn Area
A	75	90	30	150	40
	100	80	25	90	30
	150	60	20	70	25
B	75	120	35	180	55
	100	95	30	120	35
	150	80	25	90	30
C	75	150	40	180	55
	100	120	35	150	40
	150	90	30	120	35
D	150	180	55	240	70

Note: If a detention structure is used upstream of the level spreader, Tables 4-8 and 4-9 may be used with the assumption that 1.0 acre of impervious area is equivalent to a peak flow of 1.0 cfs during the 2-year, 24-hour storm.

Example Design

Plan View



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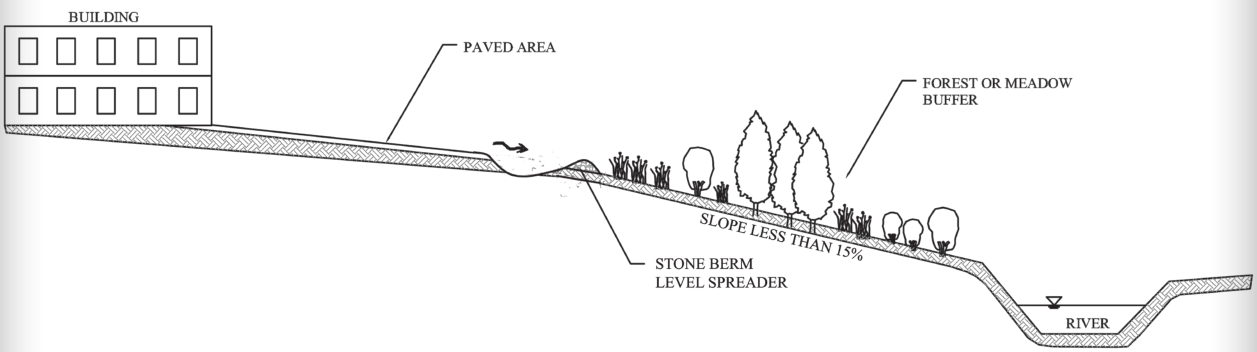


6c. Roadway Buffer

A buffer adjacent to the down-hill side of a road should be sited directly adjacent to the roadway. In addition, the road must be parallel to the contour of the slope. Runoff must sheet immediately into the buffer, and must not include runoff from areas other than the adjacent road surface and shoulder. The buffer may consist of man-made buffer, natural buffer, or a combination.

Design Considerations

- Care is required to prepare site so that flow passes through the buffer as sheet flow. The buffer slope should be planar or convex in shape; concave (or "dish-shaped") slopes tend to concentrate runoff, increasing the potential for erosion and short-circuiting of runoff through the buffer.
- Roadside buffers are not suited to steep terrain.

Maintenance Requirements

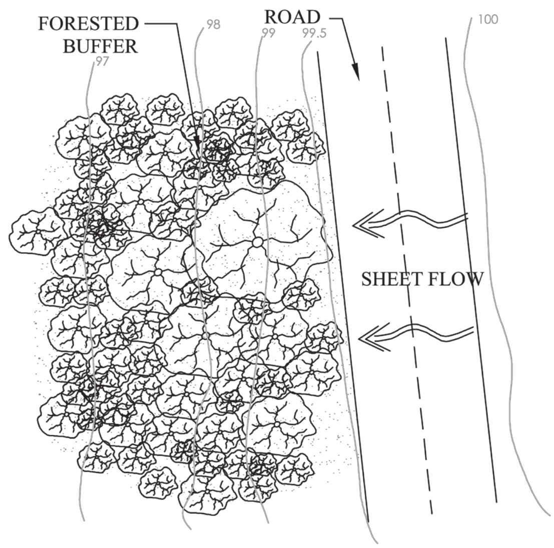
- Inspect buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless erosion occurs.
- If erosion of the buffer (forested or meadow) occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Design References

- Maine DEP (2006)

Example Design

Plan View



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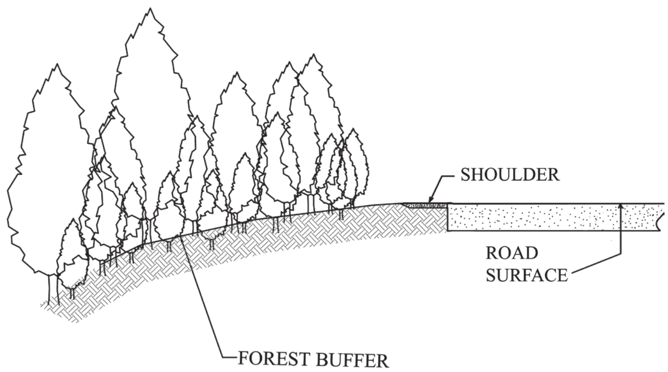


Design Criteria

Design Parameter	Criteria
Contributing Road Surface	• Road surface and shoulder must sheet flow directly into the buffer • No areas other than the road surface and shoulder should be directed to the buffer • Road should parallel the contour of the buffer slope
Buffer Slope Requirements	Man made buffer slope must be uniform and ≤ 15 %; except: A maximum of 20 feet of vegetated roadway embankment slope of 3:1 or flatter may count toward the total required buffer length Natural buffer slope must be uniform and ≤ 20%
Length of Buffer Flow Path	≥ 50 feet flow path for one travel lane ≥ 80 feet flow path for two travel lanes
Other	Buffer should be vegetated

6d. Ditch Turn-out Buffer

A ditch turn-out buffer diverts runoff collected in a roadside ditch into a buffer. A combination of check dams and bermed level lip spreaders convert the concentrated ditch flows into sheet flow. The sheet flow distributes across the top of the buffer.

Design Considerations

- Proper grading is essential to establish the level spreader along the contour, so that the outlet of the device is level and distributes discharge as sheet flow over the width of the buffer.
- Soil stabilization measures should be implemented to prevent erosion and local rill and gulley formation until permanent vegetation is established.

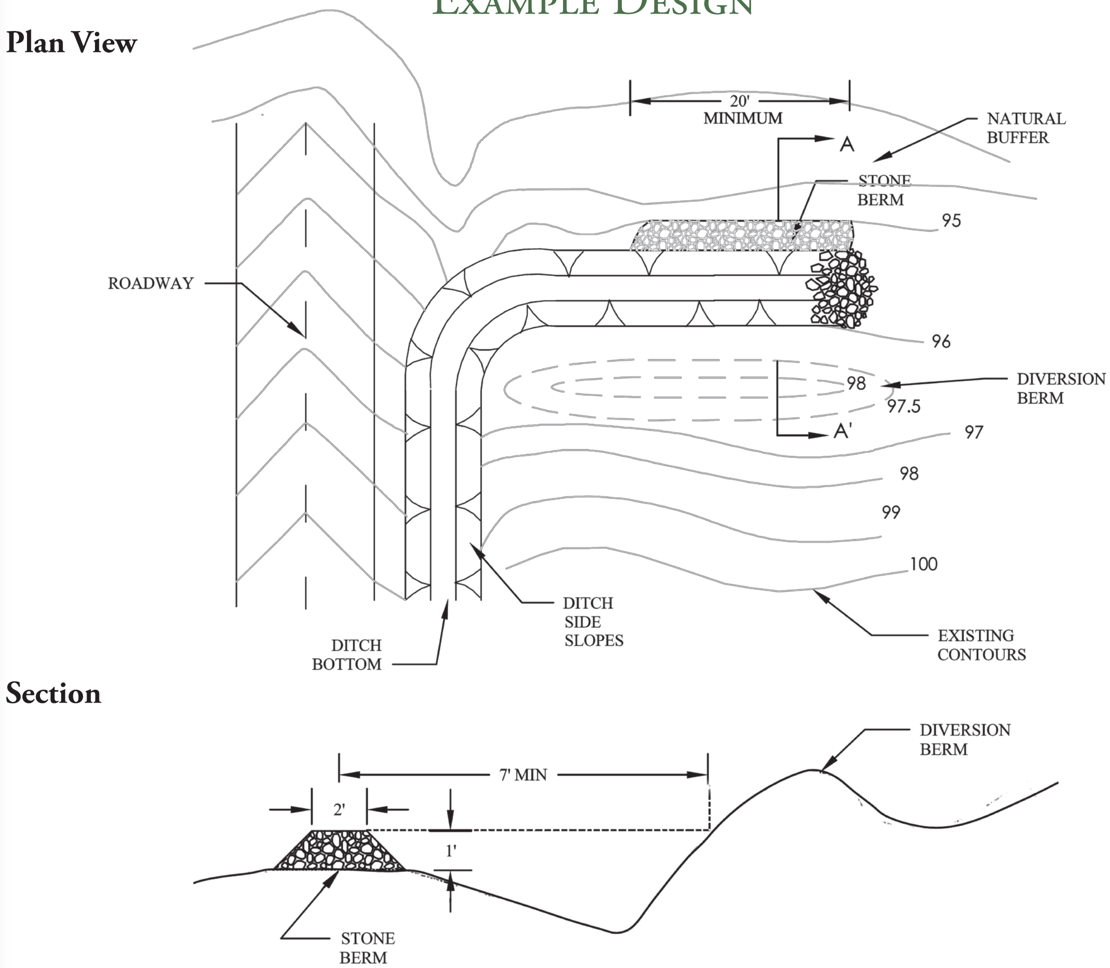
Maintenance Requirements

- Inspect level spreader and buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless erosion occurs.
- If erosion of the buffer (forested or meadow) occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Design References

- Maine DEP (2006)

Example Design



Design Criteria

Design Parameter	Criteria
Allowable Contributing Area	• No areas other than road surface, shoulder, and road ditch • ≤ 500 feet of 1 travel lane + ditch • ≤ 250 feet of 2 travel lanes + ditch • ≤ 6,000 sq. ft. of pavement, if > 2 lanes + ditch are directed to the buffer
Maximum Slope	15 %, slope must be uniform
Length and Width of Buffer	Size flow length of buffers per Tables 4-10 and 4-11.
Minimum Level Spreader Length	20 feet
Stone Berm Level Spreader	Must meet the requirements for level spreaders described in Section 4.6.

Table 4-10. Required Buffer Flow Path Length per Length of Road or Ditch with 0% to 8% Buffer Slope			
Hydrologic Soil Group of Soil in Buffer	**Maximum Length of a One Lane road or Ditch Draining to a Buffer (feet)**	**Length of Flow Path for Forested Buffer (feet)**	**Length of Flow Path for Meadow Buffer (feet)**
A or B	200	50	70
	300	50	85
	400	60	100
C	200	60	100
	300	75	120
	400	100	Not Applicable
D	200	100	150

Table 4-11. Required Buffer Flow Path Length per Length of Road or Ditch with Greater than 8% to 15% Buffer Slope			
Hydrologic Soil Group of Soil in Buffer	**Maximum Length of a One Lane road or Ditch Draining to a Buffer (feet)**	**Length of Flow Path for Forested Buffer (feet)**	**Length of Flow Path for Meadow Buffer (feet)**
A or B	200	60	85
	300	60	100
	400	70	120
C	200	70	120
	300	90	145
	400	120	Not Applicable
D	200	120	180

4-4. Pretreatment Practices

The following Treatment Practices are presented in this Section:

1. Sediment Forebay

2. Vegetated Filter Strip

3. Pre-treatment Swale

4. Flow-Through Structures
    4.a. Water Quality Inlet
    4.b. Proprietary Devices

5. Deep Sump Catch Basin

1. SEDIMENT FOREBAYS

General Description

A sediment forebay is an impoundment, basin, or other storage structure designed to dissipate the energy of incoming runoff and allow for initial settling of coarse sediments. Forebays are used for pretreatment of runoff prior to discharge into the primary water quality treatment BMP. In some cases, forebays may be constructed as separate structures but often, they are integrated into the design of larger stormwater management structures.

General Requirements Applicable to All Sediment Forebays

- Provide a fixed vertical sediment marker to measure depth of accumulated sediment.
- Re-stabilize all disturbed areas upon completion of maintenance in accordance with approved plans.

Design Considerations

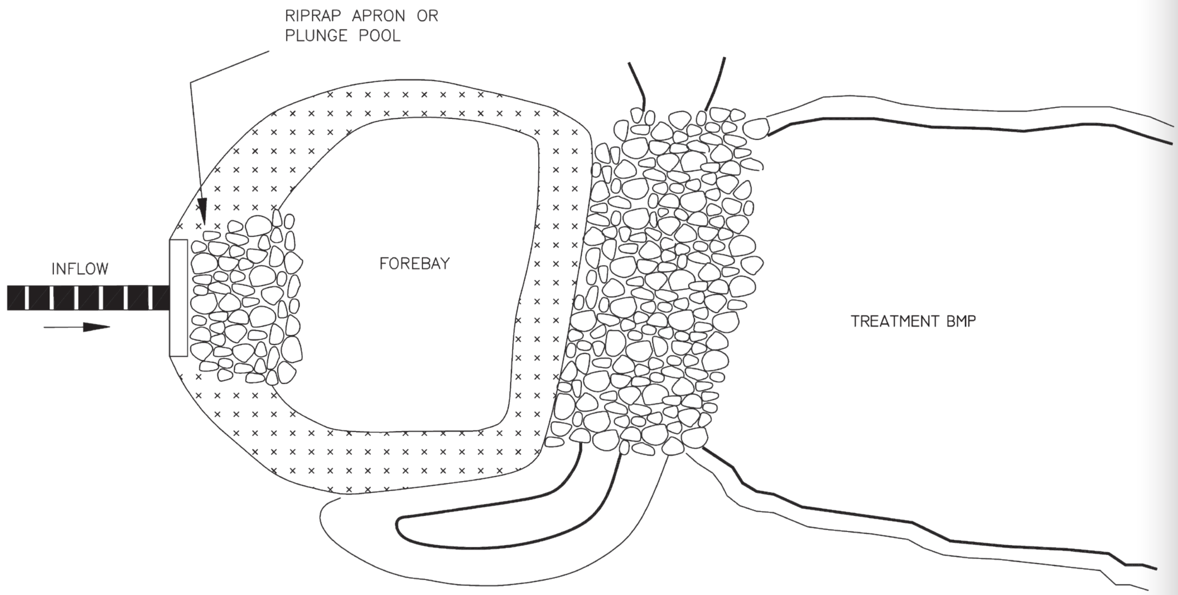
- Maintenance access must be provided;
- Embankment design must be engineered to meet applicable safety standards (see description of Detention Basins);
- Exposed earth slopes and bottom of basin should be stabilized using seed mixes appropriate for soils, mowing practices, and exposure to inundation;
- Exit velocities from the forebay should be non-erosive;
- As an alternative to an earthen basin, an underground structure may serve as a forebay. However, use of fully enclosed structures must consider accessibility for inspection and cleaning.

Maintenance Requirements

- Forebays help reduce the sediment load to downstream BMPs, and will therefore require more frequent cleaning.
- Inspect at least annually;
- Conduct periodic mowing of embankments (generally two times per year) to control growth of woody vegetation on embankments;
- Remove debris from outlet structures at least once annually;
- Remove and dispose of accumulated sediment based on inspection;
- Install and maintain a staff gage or other measuring device, to indicate depth of sediment accumulation and level at which clean-out is required.

Example Design

Plan View



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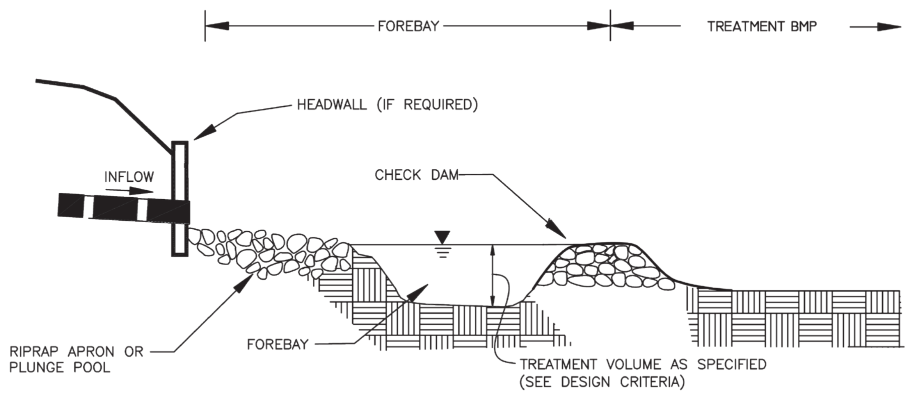


Adapted from MassHighway (2004)

Design References

- Schueler (1987)
- Schueler, et al. (1992)

Design Criteria

Design Parameter	Criteria
Forebay Volume	10% of the WQV, at a minimum. See specific Treatment Practice for appropriate size.
Minimum Depth	2 feet
Maximum Depth	6 feet
Maximum Side Slopes	3:1

2. VEGETATED FILTER STRIPS

General Description

Vegetated Filter Strips are gradually sloped areas of land with natural or established vegetation allowed to grow with minimal to no maintenance. They are designed to receive runoff as sheet flow. The vegetation slows runoff and allows water to infiltrate as sediments settle. A level spreader may be necessary to convert runoff to sheet flow as it enters the filter strip. Vegetation may consist of meadow, forest, or a combination.

Vegetated Filter Strips may have substantially shorter lengths of flow path than "Vegetated Buffers" (see BMP description), and would not be anticipated to provide the level of treatment afforded by buffers sized in accordance with this Manual. Therefore, Filter Strips are not considered "Treatment Practices" under the AoT requirements, but may be used as pretreatment practices.

General Requirements Applicable to Vegetated Filter Strips

- Vegetative cover type should be forest, meadow, or combination forest/meadow

Design Considerations

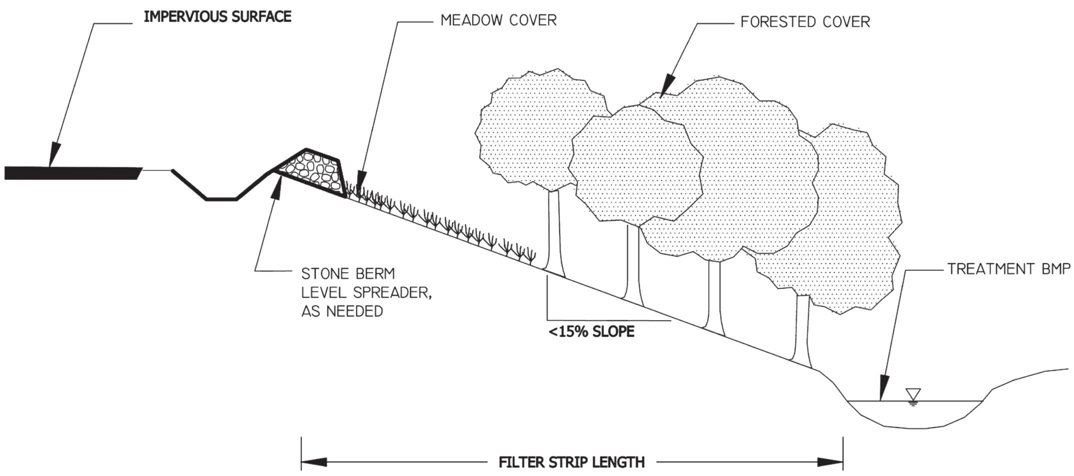
- Effectiveness of filter strip is dependent on shallow diffuse flow. Care is required to select or prepare the site, so that flow enters the filter strip as sheet flow and does not re-concentrate after entering the filter strip.
- The filter strip should be continuous for its entire length (flow path), not interrupted by other site features.

Maintenance Requirements

- Inspect filter strip at least annually for signs of erosion, sediment buildup, or vegetation loss.
- Along the upper edge of the filter strip, the deposition of sediment may form a "berm" that obstructs flow into the filter area or concentrates flow. The filter strip and level spreader (if applicable) should be inspected at least annually to detect this condition, and accumulated sediment removed to restore sheet flow into the filter area.
- If a meadow, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested filter strip, maintain in an undisturbed condition, unless erosion occurs.
- If erosion of either forested area or meadow occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Example Design

Profile



Adapted from MassHighway (2004)

Design References

- Maine DEP (2006)

Design Criteria

Design Parameter	Criteria
Maximum Length of Overland Flow to the Filter Strip	75 feet
Maximum Longitudinal Slope	15% measured along flow path
Minimum Filter Strip Length	25 feet measured along flow path
Filter Strip Width	Equal to width of the area draining to the strip

3. PRE-TREATMENT SWALES

General Description

Pre-treatment swales are shallow, vegetated, earthen channels designed to convey flows, while capturing a limited amount of sediment and associated pollutants. A pre-treatment swale differs from a Treatment Swale in that the grass swale is not designed for a specified hydraulic residence time, but only for a minimum length. Therefore, pre-treatment swales do not necessarily provide sufficient time for the removal of pollutants other than those associated with larger sediment particles, and may only be used for pretreatment.

The Treatment Swale is described in this manual under Treatment Practices, and provides enhanced pollutant removal through filtration through vegetation, infiltration into underlying soils and physical settling.

General Requirements Applicable to Pre-treatment Swales

- Swales are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued
- Swales are prohibited in groundwater protection areas receiving stormwater from a high-load area unless an impermeable liner is provided
- Swale shape should be trapezoidal or parabolic
- Bottom of swale should not be within the seasonal high water table.
- Swale should be vegetated.

Design Considerations

- Pre-treatment swales must be designed so that the flow travels the full length to receive adequate pretreatment. For this reason, flow must be directed to the inlet end of the swale, rather than the swale collecting water continuously along its length.
- Vegetation should be selected based on site soil conditions, anticipated mowing requirements (height, frequency), and design flow velocities.
- All channels should be designed for *capacity* and *stability*. A channel is designed for capacity when it can carry the maximum specified design flow within the design depth of the channel (allowing for recommended freeboard). A channel is designed for *stability* when the channel lining (e.g., vegetation) will not be eroded under maximum design flow velocities. Analyses of these conditions must account for both the type of lining and its condition (for example, capacity analysis for a grassed channel must consider the resistance of the maximum height of grass, while the stability analysis must consider the grass under its shortest, mowed condition).

Maintenance Requirements

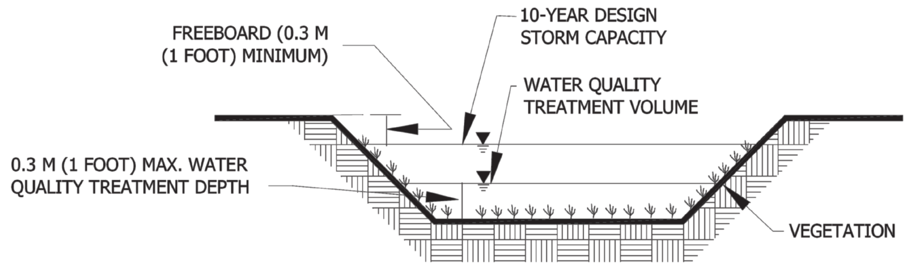
- Inspect annually for erosion, sediment accumulation, vegetation loss, and presence of invasive species.
- Perform periodic mowing; frequency depends on location and type of grass. Do not cut shorter than Water Quality Flow depth (minimum 4-inches)
- Remove debris and accumulated sediment, based on inspection.
- Repair eroded areas, remove invasive species and dead vegetation, and reseed with applicable grass mix as warranted by inspection.

Design References

- EPA (1999e)

Example Design

Section



Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Minimum Length	≥ 50 feet (not including portions in a roadside ditch)
Bottom Width	4 to 8 feet
Longitudinal Slope	0.5% to 2% without check dams 2% to 5% with check dams
Maximum Side Slopes	3:1
Flow Depth	4 inches maximum at the WQF
Design Discharge Capacity	10-year, 24-hour storm without overtopping

4. FLOW-THROUGH DEVICES

General Description

The AoT Regulations recognize the following flow-through devices as BMPs for pre-treatment of stormwater runoff before entering a treatment practice:

- Water Quality Inlets
- Proprietary Flow-through Devices (Such as Oil/Particle Separators and Hydrodynamic Separators)

General Requirements Applicable to Flow-Through Devices

- Design devices according to manufacturer's recommendations based on the Water Quality Flow (WQF) to achieve required removal rate
- Document that devices remove a minimum of 80% of U.S. Silica grade OK-110 at the WQF.

4a. Water Quality Inlet

A water quality inlet is an underground storage structure with multiple chambers, designed to capture coarse sediments, floating debris, and some hydrocarbons from stormwater runoff. Such inlet devices are typically used for pretreatment of runoff prior to discharge to another treatment practice.

The devices use baffles with weirs or orifices to control flow and help capture sediment, and inverted baffles or hooded outlets to help capture floating materials. Depending on the design of the unit and the magnitude of peak flow events, the captured sediments may be subject to re-suspension and flushing from the device. Floating hydrocarbons captured in the unit can be removed for disposal during maintenance operations by skimming or by use of sorbent materials. Note, however, that hydrocarbons carried by stormwater frequently are dispersed in suspension or adsorbed to fine-grained sediment particles or organic materials, and may not necessarily be captured in the unit.

To limit potential for re-suspension of captured materials, the device is usually designed as an "off-line" unit sized for the Water Quality Flow. Larger storm events would then bypass the unit.

Design Considerations

- Recommended installation as an off-line device;
- Inspection and maintenance may require "confined space" safety procedures;
- Limited capacity for fine sediment removal, together with potential for re-suspension, result in limited overall pollutant removal capability. The device should only be used for pre-treatment.

Maintenance Requirements

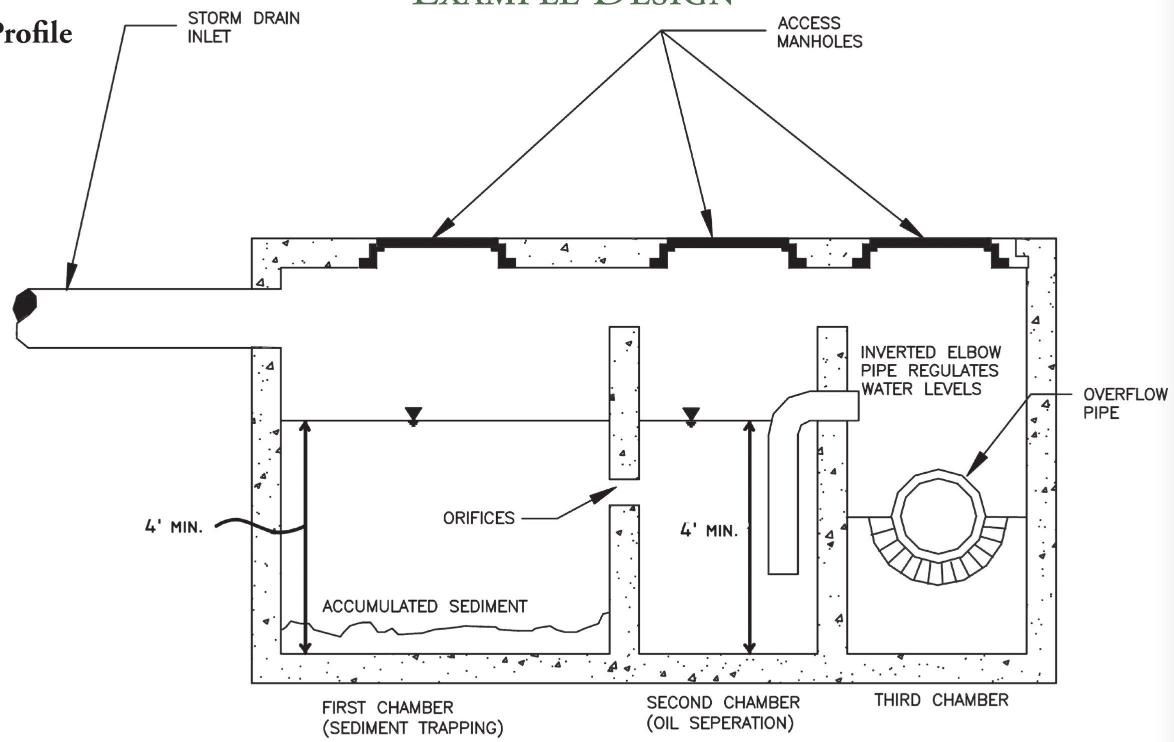
- Inspect Water Quality Inlet quarterly. Remove and legally dispose of floating debris at each inspection.
- Remove sediment when inspection indicates depth is approaching half the depth to the lowest orifice or other outlet in the first chamber baffle. However, it is recommended that the unit be cleaned at least once per year;
- Remove floating hydrocarbons immediately whenever detected by inspection;
- Dispose of sediments and other wastes in conformance with applicable local, state, and federal regulations.

Design References

- Schueler (1987)
- Schueler, et al. (1992)

Example Design

Profile



Adapted from MassHighway (2004)

Design Criteria

Design Parameter	Criteria
Required chamber arrangement	3 chambers, each with separate manhole
Minimum Sump Depth	4 feet
Combined Volume of 1st & 2nd Chamber	≥ 400 cubic feet per acre of contributing impervious area
Maximum recommended contributing area	< 1 acre of impervious area

4b. Proprietary Flow Through Devices

Including Hydrodynamic Separators & Oil/Particle Separators

Several manufacturers offer a number of proprietary flow-through stormwater treatment devices. These devices are variously referred to as "oil/particle separators," "oil/grit separator," or "hydrodynamic separators." Some of these devices use multiple chambers arranged horizontally or vertically to help trap and retain sediments and floating substances. Some use internal components to promote a swirling flow path to help enhance removal and retention of sediment.

These flow-through devices are normally sited close to the source of runoff, often receiving stormwater from relatively small areas that are mostly, if not entirely, impervious surface. They may only be used as pretreatment of stormwater prior to discharge to other treatment BMPs.

Because runoff is detained briefly in conventional separators, only moderate removal of coarse sediments, oil and grease can be expected. Soluble pollutants, fine-grained sediment, and pollutants attached to the sediment such as trace metals or nutrients will likely pass through the separator.

With their comparatively small size and underground installation, they can be conveniently located to facilitate access for inspection and maintenance. However, given their limited capacity they require frequent maintenance. Also, because they are enclosed underground structures, selection, design, and installation should consider whether maintenance activities will be subject to confined-space safety procedures.

Design Considerations

- Flow-through units must be installed as an off-line device;
- Inspection and maintenance may require "confined space" safety procedures;
- Limited capacity for removal of fine sediment and dissolved contaminants, may result in limited overall pollutant removal capability. The devices may only be used for pre-treatment.

Maintenance Requirements

- Inspect quarterly, or more frequently as recommended by manufacturer. Remove and legally dispose of floating debris at each inspection.
- Based on inspection, remove sediment when it reaches level specified by manufacturer. However, it is recommended that the unit be cleaned at least once per year, or more frequently as recommended by manufacturer;
- Remove floating hydrocarbons immediately whenever detected by inspection;
- Dispose of sediments and other wastes in conformance with applicable local, state, and federal regulations.

Design References

- New Hampshire Department of Environmental Services (2002)

Design Criteria

Design Parameter	Criteria
Minimum Sump Depth	4 feet
Maximum Drainage Area	1 acre of impervious area
Minimum Permanent Pool Storage Volume	400 cubic feet per acre of contributing impervious area
Maximum contributing impervious drainage area	≤ 1 acre
Off-line configuration	Required
Manhole access	Each chamber must be accessible by separate manhole

5. DEEP SUMP CATCH BASIN

General Description

A deep sump catch basin consists of a manhole-type structure with an inlet grate, an outlet pipe connected to the piped drainage system, and a sump with a depth several times the diameter of the outlet pipe. The inlet grate is located at the surface, and is sometimes combined with a vertical inlet integrated with a street or parking area curb. The sump's purpose is to capture coarse sediments and debris from the runoff intercepted by the structure. The outlet pipe can be fitted with a "hood" consisting of a cast metal or formed plastic fitting, designed to prevent floating materials from exiting the structure.

Deep sump catch basins used as pretreatment are most effective if sited "off-line" since flow-through basins are more susceptible to sediment re-suspension. The outlet hood provides benefits for trapping floating trash, as well as for short-term spill containment.

Design Considerations

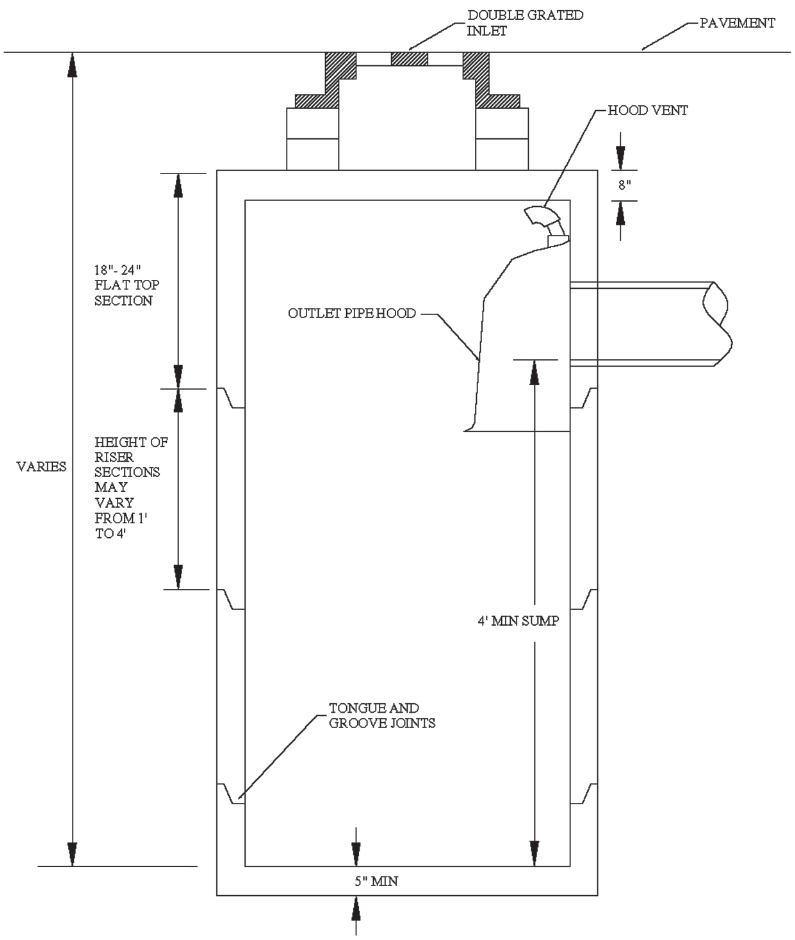
- Deep sump catch basins used as pretreatment devices must be located "off-line."
- Hoods may be susceptible to displacement or damage from cleaning activities. This should be considered in the configuration of the tops of structures (e.g., use of eccentric cones or flat tops with the inlet off-set from alignment with the hood) to minimize risk of damage from cleaning equipment. However, the configuration should also permit access for repositioning or replacing the hood.

Maintenance Requirements

- Catch basins may require frequent maintenance. Depending on location, this may require several cleanings of the sumps each year. At a minimum, it is recommended that catch basins be inspected at least twice annually, once following snow-melt and once following leaf-drop, and cleaned as indicated by inspection.
- Sediment should be removed when it approaches half the sump depth.
- If floating hydrocarbons are observed during an inspection, the material should be removed immediately by skimming, absorbent materials, or other method and disposed in conformance with applicable state and federal regulations.
- Cleaning may require Vacuum-truck instead of "clam-shell" to avoid damage to hood.
- Damaged hoods should be replaced when noted by inspection

Example Design

Profile



Design Criteria

Design Parameter	Criteria
Maximum Drainage Area	≤ 0.25 acre of impervious area
Off-line configuration (no storm drain inlet pipes to the device)	Required
Minimum Catch Basin Diameter	4 feet
Depth from Outlet Invert to Sump Bottom	≥ 4 times the diameter of the outlet pipe
Hooded Outlet	Required. Horizontal hood opening ≥ 1 foot below outlet invert

4-5. Groundwater Recharge Practices

The AoT Regulations provide for the use of methods to infiltrate stormwater into the ground. The regulations cite practices discussed in section 4-3 of this Manual under other BMP categories, including the following:

- Infiltration Practices
- Filtering Practices that incorporate infiltration into native soils

4-6. Conveyance Practices

The following Conveyance Practices are presented in this Section:

1. Detention Basin

   Note:
   Several of the Treatment Practices (e.g., stormwater treatment ponds, stormwater wetlands, infiltration basins) may serve a combined function of providing treatment and control of peak discharge rates. As such, these other BMPs will incorporate design elements applicable to Detention Basins. Therefore, the detention basin design criteria should be used as guidance in developing the designs of these other structural BMPs.

2. Stone Berm Level Spreader
3. Conveyance Swale
4. Terraced Slopes or Benching
5. Flow Splitter
6. Permanent Outlet Protection

1. DETENTION BASINS

General Description

A detention basin is an impoundment designed to temporarily store runoff and release it at a controlled rate, reducing the intensity of peak flows during storm events. Conventional detention basins are typically designed to control peak runoff rates under a range of storm conditions, and can be used to control discharges as required under the AoT Regulations and other requirements, including, but not necessarily limited to:

- Storage and peak rate control to meet Channel Protection Requirements (see Section 2-17);
- Storage and peak rate control to meet Peak Runoff Control Requirements (see Section 2-18) (10-year and 50-year frequency, 24-hour storm events);
- Storage and peak rate control to prevent flood impacts within the 100-year flood plain;
- Storage and peak rate control to meet other regulatory requirements, including local permitting standards.

Detention basins may consist of surface basins (pond-type structures) or subsurface basins (enclosed structures located below ground. Surface basins should be designed with an emergency spillway or bypass meeting applicable dam safety standards (Env-Wr 100 - 700: Dam Safety Rules). Subsurface basins should also be designed to safely bypass flows exceeding the engineered capacity of the structure.

Detention basins may be combined with treatment BMPs discussed in this guidance document, to provide for other stormwater management objectives. For example, a stormwater pond may be designed to provide treatment as well as detention. However, a detention basin is not by itself considered a “Treatment Practice” under the AoT Regulations.

General Requirements Applicable to Detention Basins

- Detention basins are prohibited in areas of RSA 482-A jurisdiction unless a wetlands permit has been issued;
- A dam permit may be needed prior to construction (RSA 482), and any criteria set by the Dam Bureau more stringent than those listed in this document or the AoT Regulations apply (Env-Wr 100 - 700: Dam Safety Rules);
- Detention basins receiving stormwater from high-load areas must be lined;
- Provide small trash racks for outlets ≤ 6 inches in diameter or weirs ≤ 6 inches wide;
- Provide energy dissipation at inlets and outlets to prevent scour;
- Provide vegetation suitable to the soil type, moisture content, sun exposure, and the level of inundation anticipated for all areas of the detention basin, including the basin floors, side slopes, berms, impoundment structures, or other earthen structures;

- Underground detention basins must have access manholes located upstream, downstream, and at intermediate locations for providing maintenance.

Design Considerations

- Although detention basins are effective at controlling peak discharge rates leaving a site, in some cases, the timing of the release of water from the basin may be such that the peak flow in receiving waters further downstream may actually increase. The design of detention basins should consider such potential effects. The engineer should carefully select analysis points to account for the impacts of detention on the local drainage system, and may need to analyze flows at selected downstream hydraulic structures, in addition to the flows at the property line of a project.
- The design and construction of basins and impoundment structures must consider depth to bedrock, depth to groundwater, existing soil conditions, foundation conditions for embankments and structures, and other factors. The design of these structures should only be completed by licensed Professional Engineers qualified in this area of practice.
- Detention basins constructed with impoundment structures may be considered as dams subject to regulation under applicable New Hampshire Reservoir and Dam Safety Standards (Env-Wr 100 - 700: Dam Safety Rules). Also, see discussion of embankment design in Table 4-12.
- Maintenance access should be provided.
- Earth slopes and basin bottoms should be stabilized using seed mixes as recommended by NRCS.
- For a detention basin intended to be dry between storm events, consider the use of a pilot channel, together with sloped basin floor, to facilitate the drainage of the structure.

Maintenance Requirements

- The bottoms, interior and exterior side slopes, and crest of earthen detention basins should be mowed, and the vegetation maintained in healthy condition, as appropriate to the function of the facility and type of vegetation.
- Vegetated embankments that serve as “berms” or “dams” that impound water should be mowed at least once annually to prevent the establishment of woody vegetation.

Maintenance Requirements

- Embankments should be inspected at least annually by a qualified professional for settlement, erosion, seepage, animal burrows, woody vegetation, and other conditions that could degrade the embankment and reduce its stability for impounding water. Immediate corrective action should be implemented if any such conditions are found.
- Inlet and outlet pipes, inlet and outlet structures, energy dissipation structures or practices, and other structural appurtenances should be inspected at least annually by a qualified professional, and corrective action implemented (e.g., maintenance, repairs, or replacement) as indicated by such inspection;
- Trash and debris should be removed from the basin and any inlet or outlet structures whenever observed by inspection;
- Accumulated sediment should be removed when it significantly affects basin capacity.

Design References

- See Table 4-12

Design Criteria

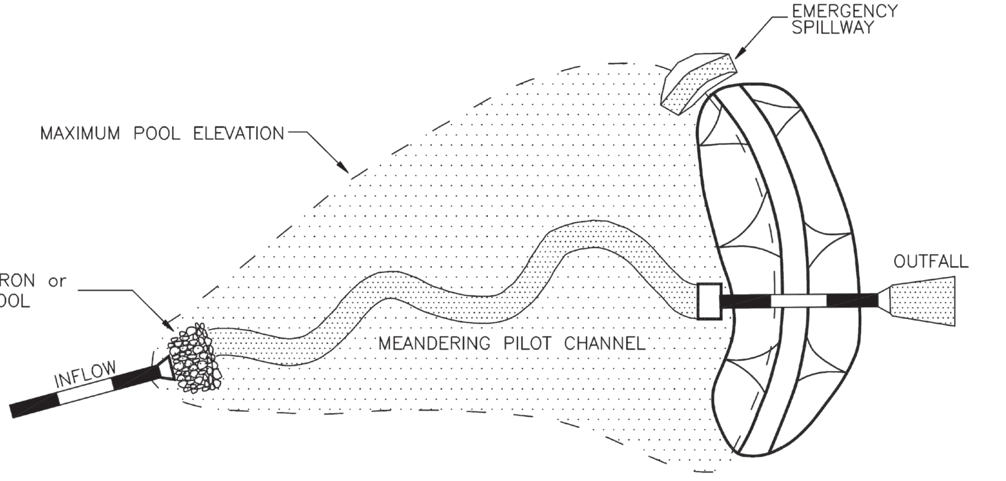
Design Parameter	Criteria
Side Slopes	2:1 or flatter (2.5:1 or flatter recommended, see Note 1)
Minimum Crest Width	4 feet (6 feet recommended, see Note 2)
Design Discharge	50-year, 24-hour storm without overtopping embankment crest, 1' of free-board required.
Emergency Spillway	Required for basins that impound water above existing ground elevation, see Note 3.

Notes:

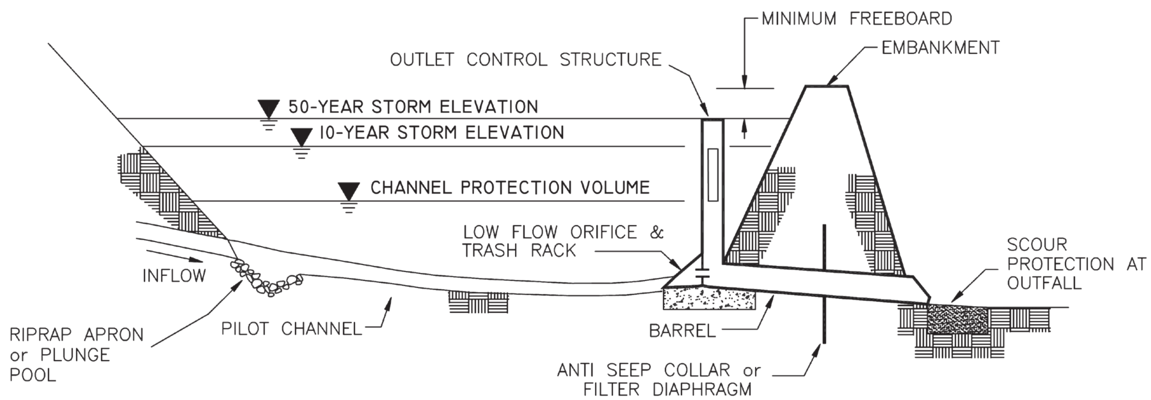
1. Env-Wr 403.02 requires embankment slopes of dams subject to jurisdiction to be no steeper than 2.5 horizontal to 1 vertical unless a specific design for a steeper slope shows that the embankment is stable and capable of being safely maintained.
2. Env-Wr 403.02 requires embankment crests of dams subject to jurisdiction to be at least 6 feet in width.
3. Emergency spillways must be provided to protect against embankment failure when the primary outlet fails to function. Generally, emergency spillways should be constructed in existing ground, not in the embankment section. Freeboard from top of embankment to the design water surface in the spillway should meet the requirements of Env-Wr 403.02. If no freeboard is specified, use a minimum of one foot.

Example Design

Plan View



Profile



Adapted from MassHighway (2004)

Table 4-12. Considerations for Small Impoundment Structures

The design of Stormwater Management BMPs frequently involves the development of containment basins to store runoff from the contributing watershed. In some instances, these basins can be constructed by excavation. More frequently, the impoundments are created by earthen embankments, with ancillary discharge control structures.

These structures should be designed by professional engineers versed in the analysis and design of impoundments, and based on site specific information relative to watershed hydrology, site soils conditions, hydraulic behavior of receiving waters, hydraulic characteristics of inlet and outlet structures, and other parameters. In some instances, the design of the structures will be subject to regulatory review and licensing under governmental dam safety statutes, rules, and regulations, including, but not necessarily limited to the New Hampshire Reservoir and Dam Safety Standards (Env-Wr 100 - 700: Dam Safety Rules).

The following are some suggested general guidelines for parameters typically applied to the design of the relatively small impoundments used for stormwater management. However, this listing is not necessarily complete, and may not apply to particular site conditions. The design engineer on any particular project is responsible for research of applicable design standards, including regulatory requirements and codes, selection of methodologies, and performance of the analyses, calculations, and design procedures required to meet accepted engineering practice for the design of impoundments. Users of the following assume all risk associated with the application of this information to the design of impoundment structures.

Design References

Refer to New Hampshire Reservoir and Dam Safety Standards (Env-Wr 100 - 700: Dam Safety Rules), for design information and for information on accepted design references.

Embankment

- Top width per design reference guidelines for structural stability and access
- Side slopes for surface and structural stability
- Suitable foundation conditions
- Freeboard capacity during maximum design flood
- Construction materials for stability
- Seepage control
- Allowance for post-construction settlement
- Surface stabilization (vegetation, armor, etc.)
- Provisions for controlling undesirable vegetation on embankment slopes
- Where pipes or other conduits penetrate the embankment, provisions for “drainage diaphragm(s)” (specially designed layers of free-draining soil materials) or anti-seep collar(s) to prevent “piping” along exterior surface of conduit

Table 4-12. Considerations for Small Impoundment Structures

Principal Spillway (Outlet Structure)

- Capacity for controlled release of design storms (multiple-stage control of peak discharges)
- Capacity for overflow in storms exceeding design capacity of impoundment
- Provisions for intercepting and managing trash and debris
- Provisions for intercepting and managing floating pollutants
- Accessibility for routine maintenance and emergency servicing
- Provisions to prevent piping along exterior of conduit (see embankment guidelines)

Emergency Spillway

- Location to protect integrity of embankment (generally, the emergency spillway should not be located in the embankment, but in undisturbed original ground)
- Capacity to pass the routed design emergency storm (event based on applicable regulation); this emergency scenario may need to consider the primary outlet structure as non-functional during the event
- Adequate freeboard above emergency impoundment stage

Other

- Provisions for drawdown and maintenance of permanent pools
- Provisions for cleaning of forebays, cleaning and interior maintenance of basin
- Provisions for lining if needed for maintaining permanent water levels, or preventing direct discharge of stored runoff into sub-soils
- Provisions for contingency response to spills of oil or hazardous materials, which may be discharged into the basin

Note: Appendix C provides information on determining whether an impoundment structure is defined as a dam under the New Hampshire Reservoir and Dam Safety Standards.

2. STONE BERM LEVEL SPREADERS

General Description

A stone berm level spreader is an outlet structure constructed at zero percent grade across a slope used to convert concentrated flow to "sheet flow." It disperses or "spreads" flow thinly over a receiving area, usually consisting of undisturbed, vegetated ground. The conversion of concentrated flow to shallow, sheet flow allows runoff to be discharged at non-erosive velocities onto natural ground. To stabilize the spreader outlet, a stone berm is provided to dissipate flow energy, and help disperse flows along the length of the spreader.

Level spreaders are not designed to remove pollutants from stormwater; however, some suspended sediment and associated phosphorous, nitrogen, metals and hydrocarbons will settle out of the runoff through settlement, filtration, infiltration, absorption, decomposition and volatilization.

General Requirements Applicable to Stone Berm Level Spreaders

- The spreader must discharge to a vegetated receiving area with capacity to convey the discharge without erosion;
- The receiving area must be stable prior to construction of level spreader.

Design Considerations

- It is critical to install level spreaders at a zero percent grade along the length of the discharge lip. Flow must discharge uniformly along the length of the spreader.
- Care must be exercised in siting the spreader, so that it discharges onto a gently sloping grade, where runoff exiting the spreader will not re-concentrate and cause erosion. A slope that is concave in shape (such as a shallow swale) is not suitable for receiving the discharge from a level spreader. Suitable slopes are planar or convex in shape, so that flow will continue as dispersed sheet flow across the site.
- It is essential to stabilize the outlet lip of the spreader, and to discharge onto a well stabilized receiving area (preferably undisturbed vegetation) to prevent erosion.

Maintenance Requirements

- Inspect at least once annually for accumulation of sediment and debris and for signs of erosion within approach channel, spreader channel or down-slope of the spreader.
- Remove debris whenever observed during inspection.
- Remove sediment when accumulation exceeds 25% of spreader channel depth.
- Mow as required by landscaping design. At a minimum, mow annually to control woody vegetation within the spreader.
- Snow should not be stored within or down-slope of the level spreader or its approach channel.
- Repair any erosion and re-grade or replace stone berm material, as warranted by inspection.
- Reconstruct the spreader if down-slope channelization indicates that the spreader is not level or that discharge has become concentrated, and corrections cannot be made through minor re-grading.

Design References

- Maine DEP (2006)

Design Criteria

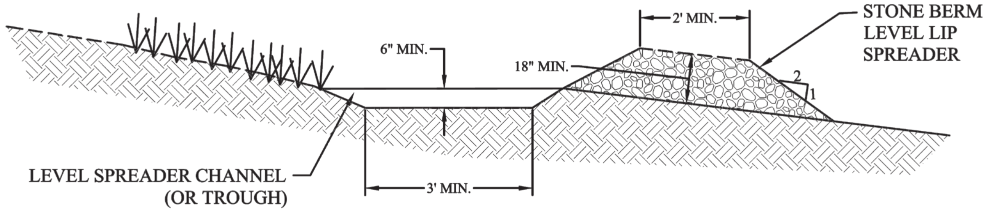
Design Parameter	Criteria
Slope of Receiving Area	< 15% (along flow path)
Level Spreader Grade	Bottom of spreader channel, and base and top of berm should be 0% grade
Spreader Channel Cross Section	6-inch deep trapezoidal trough
Spreader Channel Bottom Width	≥ 3 feet
Side Slopes	2:1 or flatter (level spreader channel and berm)
Berm Top Width	≥ 2 feet
Berm Height	≥ 18 inches
Stone Gradation	See Table 4-13
Length of Spreader	When part of a Treatment Practice, the length should be as required for that practice. If not, the length should be no less than 5 feet.

Table 4-13. Gradation of Stone for Level Spreader Berm

Sieve Designation	Percent by Weight Passing Square Mesh Sieve
12-inch	100%
6-inch	84% - 100%
3-inch	68% - 83%
1-inch	42% - 55%
No. 4	8% - 12%

Example Design

Profile



3. CONVEYANCE SWALES

General Description

Conveyance swales are stabilized channels designed to convey runoff at non-erosive velocities. They may be stabilized using vegetation, riprap, or a combination, or with an alternative lining designed to accommodate design flows while protecting the integrity of the sides and bottom of the channel. Conveyance channels may provide incidental water quality benefits, but are not specifically designed to provide treatment. Conveyance swales are not considered a Treatment or Pretreatment Practice under the AoT regulations, unless they are also designed to meet the requirements of an acceptable Treatment/Pretreatment Practice as described elsewhere in this Chapter.

General Requirements Applicable to Conveyance Swales

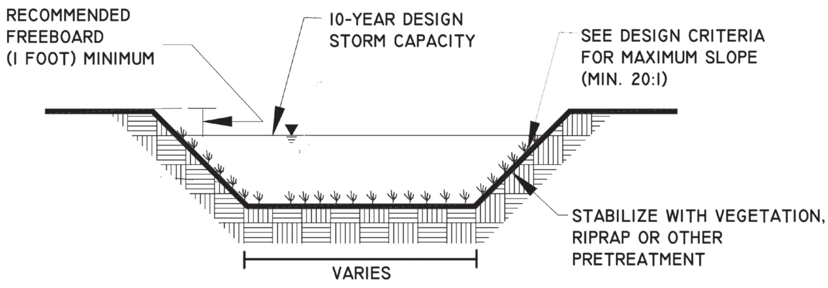
- Swales receiving stormwater from high-load areas must be lined (impermeable liner) to isolate the runoff from contact with underlying soil and groundwater.

Design Considerations

- All channels should be designed for *capacity* and *stability*. A channel is designed for *capacity* when it can carry the maximum specified design flow within the design depth of the channel (allowing for recommended freeboard). A channel is designed for *stability* when the channel lining (vegetation, riprap, or other material) will not be eroded under maximum design flow velocities. Analyses of these conditions must account for both the type of lining and its condition (for example, capacity analysis for a grassed channel must consider the resistance of the maximum height of grass, while the stability analysis must consider the grass under its shortest, mowed condition).
- Vegetation should be selected based on site soil conditions, anticipated mowing height and frequency, and design flow velocities.
- If channels must be lined with an impermeable liner, the design should take into consideration the effects of hydrostatic uplift by seasonal high water table (if present).

Example Design

Section



Adapted from MassHighway (2004)

Maintenance Requirements

- Grassed channels should be inspected periodically (at least annually) for sediment accumulation, erosion, and condition of surface lining (vegetation or riprap). Repairs, including stone or vegetation replacement, should be made based on this inspection.
- Remove sediment and debris annually, or more frequently as warranted by inspection.
- Mow vegetated channels based on frequency specified by design. Mowing at least once per year is required to control establishment of woody vegetation. It is recommended to cut grass no shorter than 4 inches.

Design References

- EPA (1999e)

Design Criteria

Design Parameter	Criteria
Shape	Trapezoidal or parabolic
Side Slopes	3:1 or flatter (if not lined with riprap) 2:1 (if lined with riprap) Alternative slopes may be possible with properly designed turf reinforcement. Such design should be documented.
Design Capacity	10-year, 24-hour storm

4. TERRACED SLOPES OR BENCHING

General Description

The land grading practice of providing terraced slopes or benching consists of shaping disturbed land surfaces to control the length of flow down steep slopes. Intermediate terraces (or benches) are incorporated into slopes that exceed 4:1 gradient. These terraces are then used to convey runoff laterally to a safe discharge (or to a constructed drainage system). The purpose of this practice is to provide for erosion control and vegetative establishment on those areas where the existing land surface is to be reshaped by grading.

Provisions should be made to safely conduct surface runoff collected by the terraced slope to storm drains, stabilized channels, or other stable conveyance practices or water courses. Runoff should also be intercepted at the top of the slopes and directed to a stable outlet.

General Requirements Applicable to Conveyance Swales

- Benches are required wherever the vertical height of a slope meets the conditions listed in the Design Criteria table;
- Benches, when required, must divide the slope face into equal parts;
- Benches must convey stormwater to a stable outlet.

Design Considerations

- Designs should address soil conditions, seeps, rock outcrops, the up-slope contributing drainage area, and other site conditions in the design of benches.
- All disturbed areas should be stabilized structurally or with vegetation.
- All graded or disturbed areas including slopes should be protected during clearing and construction in accordance with the approved erosion and sediment control plan until they are adequately stabilized.
- Surface water should generally be diverted from the face of cut and/or fill slopes by the use of diversions, ditches and swales or conveyed downslope by the use of a designed structure, except where the face of the slope has been specifically engineered to receive such drainage, in which case:
  - The face of the slope must be stabilized with vegetation, riprap, or other stabilization measure and the face of all graded slopes will be protected from surface runoff until stabilized, and
  - The face of the slope must not be subject to any concentrated flows of surface water such as from natural drainage ways, graded swales, roof drain outlets, drainage system outlets, and other sources.

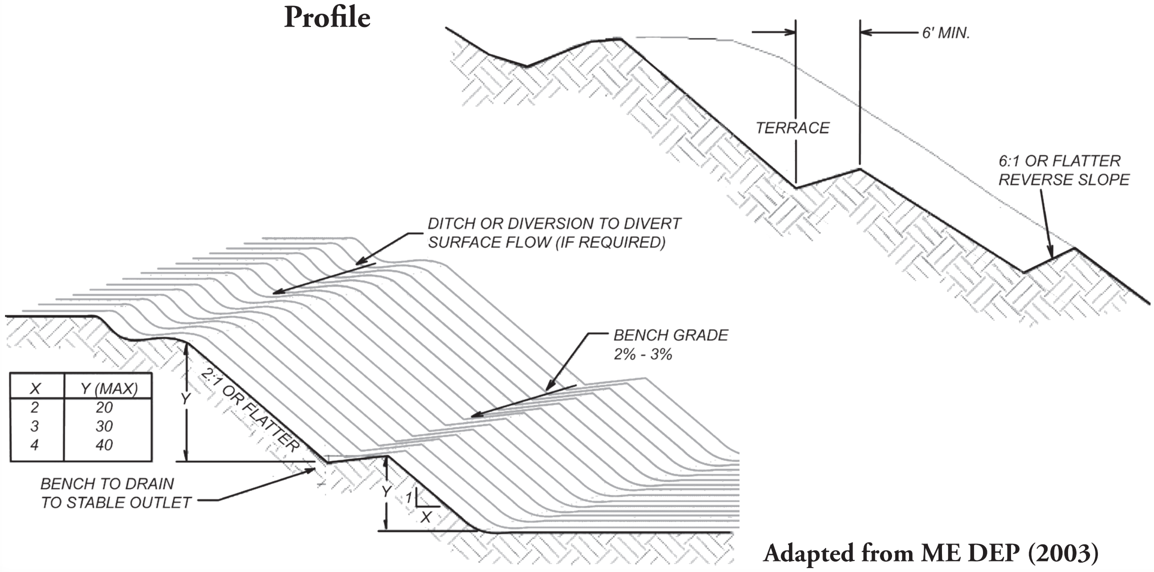
Maintenance Requirements

- Grassed slopes should be mowed to grass height and frequency specified by design.
- Vegetated slopes should be inspected periodically for signs of vegetation loss or damage, with restoration as needed.
- Terraces and slopes should be inspected periodically for any sign of rill or gully erosion, and if such conditions are noted, the area should be immediately investigated and repaired as needed.

Design References

- Connecticut DEP (2002)

Example Design



Adapted from ME DEP (2003)

Design Criteria

Design Parameter	Criteria
Slopes Requiring Terracing/Benching	Any 2:1 slope with vertical height ≥ 20 feet Any 3:1 slope with vertical height ≥ 30 feet Any 4:1 slope with vertical height ≥ 40 feet
Minimum Bench Width	≥ 6 feet
Bench Reverse Slope	6:1 or flatter (reverse slope from top of lower slope to toe of upper slope) and minimum 1' in depth
Bench Gradient to Outlet	2% to 3%
Maximum Flow Length Along Bench	≤ 800 feet
Bench Gradient to Outlet	2% to 3%
Maximum Flow Length Along Bench	≤ 800 feet

5. FLOW SPLITTERS

General Description

A flow splitter is an engineered structure used to divide flow into two or more directions. The structure typically consists of a manhole, precast concrete vault, or other structure divided into chambers, with the chambers separated by hydraulic control elements. Various hydraulic devices (such as pipes, weirs, or orifices) can be used to control the direction and quantity of flow entering the structure. Generally, a flow splitter consists of a structure with one inlet and two outlets set at different elevations. One outlet conveys low flows, such as those during small storms or at the beginning of a large storm. The other outlet conveys high flows occurring later in the storm. The flows are conveyed in different directions for water quantity or quality control.

The flow splitter is typically used to direct base flows and smaller storm flows to an "off-line" water quality treatment or pretreatment practice, with larger storms directed to an alternative outlet to bypass, and thus prevent overloading of, the treatment system. This simple type of device works on hydraulic principles and does not require mechanical components or instrumentation.

Design Considerations

- Design must be compatible with the hydraulic capacities of the devices located downstream of the flow splitter outlets.
- Design requires careful evaluation of hydraulic performance of the system, and must account not only for inlet and outlet flow rates, but also for headwater and tailwater conditions, and head losses at transitions through the structure.
- Flow splitters should be accessible for maintenance, and sufficient manhole access should be provided to enable inspection, cleaning, and repair of each chamber.

Maintenance Requirements

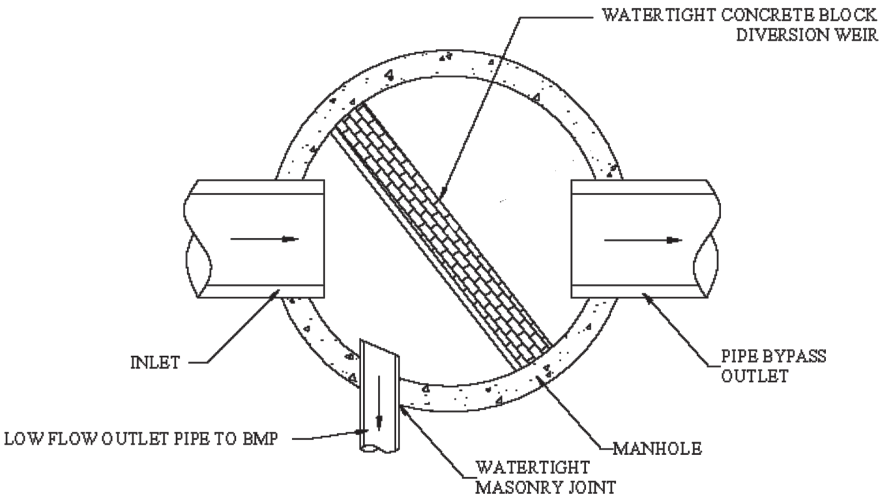
- Flow splitters should be inspected concurrently with the conveyance and treatment practices served by the devices. It is recommended that the device be inspected and maintained at least once annually.
- Sediments and debris should be removed and disposed as for other components of the drainage system.

Design Criteria

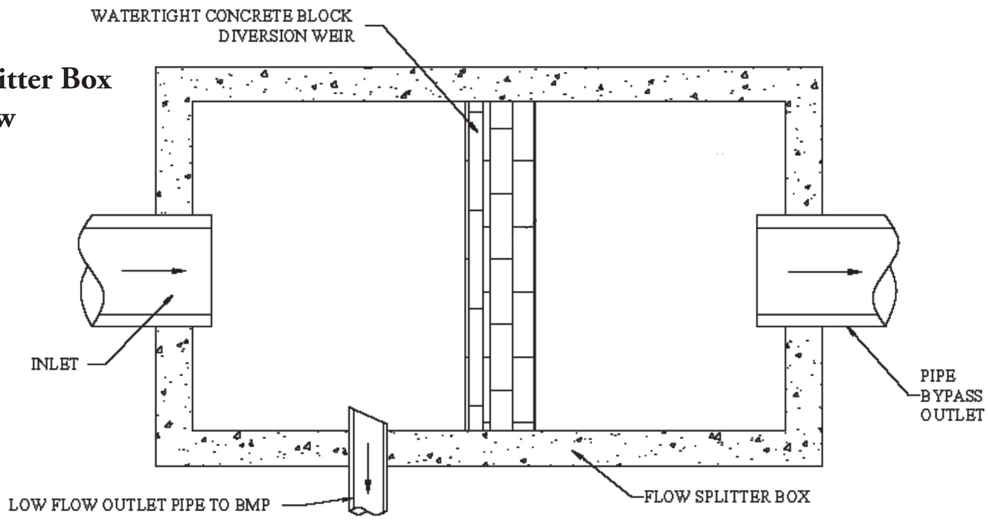
- Engineers are responsible for developing hydraulic, structural, and other design criteria specific to the project site.

Example Design

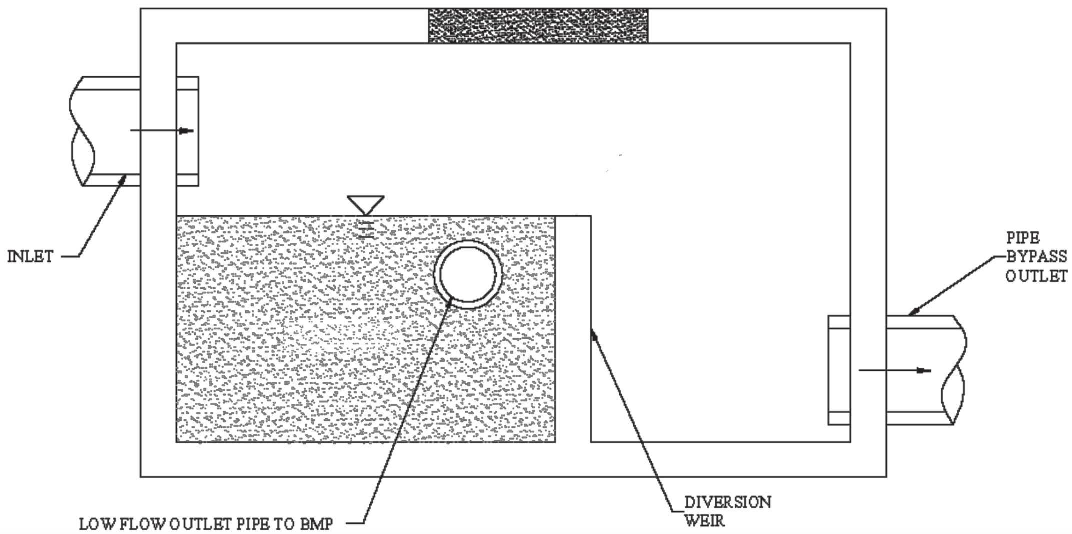
Manhole Plan View



Flow Splitter Box Plan View



Profile



6. OUTLET PROTECTION

General Description

Outlet protection is typically provided at stormwater discharge conduits from structural best management practices to reduce the velocity of concentrated stormwater flows to prevent scour and minimize the potential for downstream erosion. Outlet protection is also provided where conduits discharge runoff into an in-ground stormwater management practice (e.g., pond or swale) to prevent scour where flow enters the BMP.

Standard engineering practices allow for many different types of outlet protection which provide energy dissipation. Common outlet protection measures include:

- Riprap aprons, the design of which is covered within this section;
- Riprap lined scour holes, stilling basins or plunge pools. Design references for stilling basins are provided under 'Design References'.

Other outlet protection practices may be used, if documented by applicable technical literature.

Design Considerations

- The entire length of the flow path from the outlet of the conduit, channel or structure to the point of entry into an existing stream or publicly maintained drainage system should be evaluated for the need for outlet protection.
- There should be no bends or curves at the intersection of the conduit and apron.
- There should be no overfall from the end of the apron to the receiving channel.
- The design criteria presented below typically apply to pipes that are designed to be full at the 25 year storm. Where pipes do not flow full, designers should consult applicable design references for alternative apron sizing, particularly where the construction of the apron would disturb existing water resources. For example, wetland crossings should seek alternative apron sizing so as to not over-design, thereby limiting the wetland impacts to only those that are necessary.

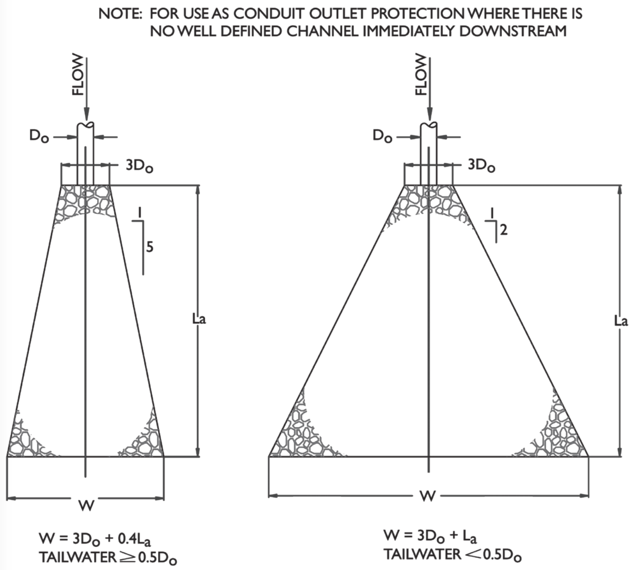
Maintenance Requirements

- Inspect the outlet protection annually for damage and deterioration. Repair damages immediately.

Example Designs

Apron

Plan View

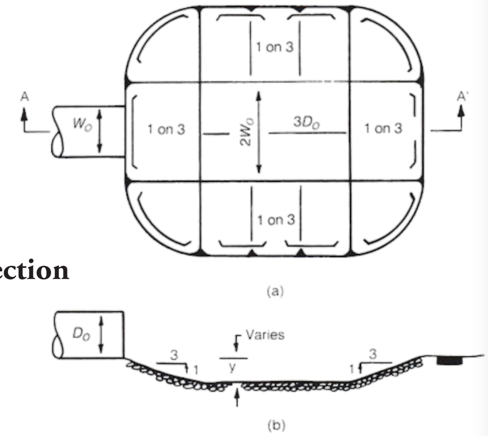


Source: CT DEP (2002)

Preformed Scour Hole

Plan View

Section



Source: ASCE (1992)

Design References

- Agricultural Service Research Publication ARS-76. (1989).
- American Society of Agricultural Engineers. (1994).
- American Society of Civil Engineers. (1975).
- American Society of Civil Engineers and the Water Environment Federation. (1992).
- U.S. Department of the Interior, Bureau of Reclamation, Engineering Monograph No. 25.
- U.S. Department of Transportation, Hydraulic Engineering Circular No. 14. (1975).
- U.S. Environmental Protection Agency. (1976).

Table 4-14. Allowable Design Flow Velocities for Various Soils

Soil Texture	Allowable Velocity (feet per second)
Sand and sandy loam	2.5
Silt loam	3.0
Sandy clay loam	3.5
Clay loam	4.0
Clay, fine gravel, graded loam to gravel	5.0
Cobbles	5.5
Shale	6.0

Source: Connecticut DEP (2002)

Design Criteria

Design Parameter	Criteria
Apron Length	$L_a = 1.8Q/D_o1.5 + 7D_o$ (when $TW < D_o/2$) $L_a = 3.0Q/D_o1.5 + 7D_o$ (when $TW > D_o/2$) Where: L_a = length of the apron (feet) D_o = maximum inside width of outlet pipe or channel (feet) Q = outlet discharge (cfs) TW = tailwater elevation (feet)
Apron Width at the Outlet End of the Apron (when there is a well-defined channel downstream of the apron)	Bottom width of the apron > bottom width of channel. The structural lining should extend at least 1 foot above the tailwater elevation but no lower than 2/3 of the vertical conduit dimension above the conduit invert
Apron Width at the Outlet End of the Apron (when there is ***no*** well-defined channel ddownstream of the apron)	$W = 3D_o + L_a$ (when $TW < D_o/2$) $W = 3D_o + 0.4L_a$ (when $TW > D_o/2$) Where: W = width of the apron (feet) L_a = length of the apron (feet) D_o = maximum inside width of outlet pipe or channel (feet) TW = tailwater elevation (feet)
Apron Width at the Culvert Outlet	$W = 3 D_o$
Side Slopes of Channel Bank Adjacent to Apron	2:1 or flatter
Bottom Grade	0%
Riprap Diameter	$D_{50} = 0.02Q^{1.3}/(TW*D_o)$ Where: D_{50} = median stone diameter (feet) Q = outlet discharge (cfs) TW = tailwater elevation (feet) D_o = maximum inside width of outlet pipe or channel (feet) 50% of stone by weight should be smaller than D_{50}. The largest stone size should be 1.5 times D_{50}. Gabions or precast cellular blocks may be substituted for riprap if the D_{50} size calculated above is less than or equal to the thickness of the gabions or concrete revetment blocks.
Preformed Scour Hole	If preformed scour hole is used instead of an apron, see *ASCE (1992)* in lieu of the above criteria.