NEW HAMPSHIRE STORMWATER MANUAL

VOLUME 2

POST-CONSTRUCTION BEST MANAGEMENT PRACTICES SELECTION & DESIGN

DECEMBER 2008

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

COMPREHENSIVE ENVIRONMENTAL INC

NEW HAMPSHIRE STORMWATER MANUAL

VOLUME 2 Post-Construction Best Management Practices: Selection and Design

Written, **Compiled and Edited** by Comprehensive Environmental Inc.
& New Hampshire Department of Environmental Services

Design and Layout by Comprehensive Environmental Inc.

Illustrations by Jillian McCarthy

Photography by New Hampshire Department of Environmental Services

Cover Photograph by Raymond Reimold, New Hampshire Department of Environmental Services. Installation of pervious concrete at White Park in Concord, NH.

WD-08-20B

NEW HAMPSHIRE STORMWATER MANUAL

VOLUME 2
Post-Construction Best Management Practices: Selection and Design

December 2008
Revision 1.0

Thomas S. Burack, *Commissioner*

Michael J. Walls, *Assistant Commissioner*

Harry Stewart, P.E., *Director, Water Division*

This manual is funded in part through a Clean Water Act Section 319 Nonpoint Source Program grant and a Clean Water Act Section 104(b)(3) grant from the U.S. Environmental Protection Agency through the New Hampshire Department of Environmental Services, Watershed Assistance Section.

Printed on Recycled Paper

Acknowledgements

To the individuals who assisted in the creation of this manual, a special thank you for your time, commitment, and support, and for your dedication to the protection of New Hampshire's environment.

NHDES Project Team

Amy C. Clark, P.E., *NHDES Terrain Alteration Bureau*
Gregg Comstock, P.E., *NHDES Water Quality Section*
Paul Currier, P.E., *NHDES Watershed Management Bureau Administrator*
Ridgely Mauck, P.E., *NHDES Terrain Alteration Bureau*
Jillian McCarthy, *NHDES Watershed Assistance Section*
Eric Williams, *NHDES Watershed Assistance Section*

Provided Support and Assistance

Laura Aibel, *City of Concord, NH*
Arlene Allen, *NHDES Wetlands Bureau*
Jeffrey G. Andrews, P.E., *NHDES Wastewater Engineering Bureau*
Bill Arcieri, CPESC, *Vanasse Hangen Brustlin, Inc.*
Richard G. Ball, *Town of Belmont, NH*
Sara Carbonneau, *Town of Swanzey, NH*
Alicia Carlson, *NHDES Drinking Water and Groundwater Bureau*
Jeffrey K. Clifford, P.E., *Altus Engineering, Inc.*
Karen H. Dudley, CPSC, *Natural Resources Conservation Services*
Darlene Forst, *NHDES Wetlands Bureau*
James P. Gove, CSS, CWS, CPSC, CPESC, *Gove Environmental Services, Inc.*
Tony Marcotte, P.E., *MDP Development, Inc.*
Kevin A. McCaffery, P.E., *Stantec*
Tyler Phillips, CPESC, *Horizons Engineering*
Michael J. Redding, P.E., CPESC, *GeoInsight, Inc.*
Pierce Rigrod, *NHDES Drinking Water and Groundwater Bureau*
Robert Roseen, P.E., Ph.D., *University of New Hampshire*
Randall Shuey, CPESC, *New England Environmental, Inc.*
Gary Springs, CPESC, *Certified Erosion Control – NH*
J. Daniel Tatem, *Stantec*

Project Team at Comprehensive Environmental, Inc.

Rebecca Balke, P.E., Senior Engineer
Julia Capurso, E.I.T., Project Engineer
David Nyman, P.E., Project Manager
Eileen Pannetier, Program Director

Table of Contents

List of Tables

List of Figures

Chapter 1
Introduction

New Hampshire's surface waters are a valuable natural resource. Through their function and beauty, they power industry, provide vital habitat, supply drinking water, and offer recreational opportunities to residents and visitors throughout the state. However, as the population grows and development pressures increase to provide needed housing and services, it is becoming increasingly difficult to protect and maintain the quality of our surface waters for the fishing, swimming, and recreational activities that we are so used to enjoying in New Hampshire.


Pemigewasset River, New Hampshire

The responsibility falls on us all - federal, state, and local governments, developers, and private citizens - to plan and act responsibly and in a manner that protects and works with the landscape to meet both water quality and land use goals. Development and natural resource protection do not need to be at odds. Existing scientific knowledge and technology in the field of stormwater management provide us with tools that can minimize the impacts of development and balance the needs of a healthy environment with those of social and economic growth.

The New Hampshire Department of Environmental Services (NHDES) has developed this New Hampshire Stormwater Manual to provide communities, developers, designers, and regulatory personnel with a reference guide for the selection, design, and application of measures to manage stormwater from newly developed and redeveloped properties, while meeting environmental objectives in the New Hampshire regulatory setting. These measures include source controls, design techniques (including low impact development (LID) design approaches), structural practices, and construction practices designed to minimize adverse hydrologic and water quality impacts, protecting and enhancing the functions of our natural wetlands and waterways.

The remainder of this Chapter presents an overview of the three-volume New Hampshire Stormwater Manual, and summarizes the contents and organization of information presented in Volume 1.

1-1. About the New Hampshire Stormwater Manual


Odiorne State Park, Rye, New Hampshire

The New Hampshire Stormwater Manual is intended as a planning tool for the communities, developers, designers, and members of regulatory boards, commissions, and agencies involved in stormwater programs in New Hampshire. The Manual addresses measures to manage stormwater runoff through site design, pollutant source controls, structural Best Management Practices (including associated operation and maintenance measures), and construction-phase practices. These practices are expected to be applied to meet specific objectives under current state and federal regulatory programs. However, if any discrepancies are found between this manual and the New Hampshire Code of Administrative Rules for the programs discussed here, the Rules should be followed.

The Manual is issued in three volumes:

Volume 1: Stormwater and Antidegradation presents an overview of New Hampshire's stormwater program together with related federal program requirements, describes New Hampshire's "Antidegradation Provisions" with respect to controlling water quality impacts due to stormwater discharges, and provides an introduction to the non-structural and structural measures for managing stormwater.

Volume 2: Post-Construction Best Management Practices Selection and Design presents a detailed description of the structural Best Management Practices (BMPs) applicable for use in New Hampshire for the prevention, control, and treatment of stormwater. Volume 2 describes information applicable to the screening, selection, design, and application of particular post-construction BMPs.

Volume 3: Erosion and Sediment Controls During Construction provides a selection of practices applicable during the construction of projects, to prevent adverse impacts to water resources as a result of the land-disturbance activities typically associated with development and redevelopment projects.

NHDES intends the New Hampshire Stormwater Manual to serve as:

- A living document with the ability to be updated as needed to accommodate the changes in stormwater management as the wealth of information in this area grows, and as technology and research broaden its scope and our perspective.
- A resource for developers and engineers in site planning, source control, and pollution prevention measures, as well as the selection

and application of stormwater Best Management Practices (BMPs) to protect the surface waters of the state from potential adverse impacts of construction and post-construction stormwater runoff.

- A resource to local and state government officials, such as planning and zoning boards, town engineers, planners, conservation commissions, and New Hampshire state agencies involved in project review or approval to ensure that state and federal stormwater requirements are met, and that projects are reviewed in a consistent manner.

- A source of information on state and federal stormwater programs and their requirements that apply to development projects in New Hampshire, and a resource for selecting management measures to meet those requirements, including:

    - Stormwater management techniques commonly used, including BMPs and better site design techniques. Using better site design techniques in combination with traditional BMPs will result in more effective stormwater management systems to more easily meet the runoff volume and pollutant removal requirements of federal and state stormwater programs.

    - Selection criteria to assist in the selection of appropriate management techniques for a site and in the preparation of Stormwater Pollution Prevention Plans (SWPPPs) and other stormwater management planning documents.

    - Summaries of stormwater management techniques including the target pollutants, general site requirements, removal mechanisms, and pollutant removal efficiencies.

    - An explanation of various modeling tools that can be used as a surrogate to water quality monitoring to verify that pollutant loading requirements will be met in the post-development condition.

1-2. About Volume 2

Within this context, Volume 2 presents information to assist in the selection and design of Best Management Practices (BMPs) for controlling stormwater. This volume discusses Best Management Practice design criteria, screening and selection of BMPs to meet these stormwater management objectives, specific design guidance for a range of BMPs, and operation and maintenance considerations. The chapters are organized as follows:

Chapter 2: Design Criteria presents the design criteria for sizing Best Management Practices (BMPs) in the State of New Hampshire to protect New Hampshire waters from adverse impacts of development. Land development projects should include measures to control peak runoff rates, provide stormwater quality treatment, use stormwater for groundwater recharge, and provide for stream channel protection. This chapter presents specific parameters for sizing BMPs to meet these objectives. NHDES recommends these criteria for application by developers and municipalities on all projects, as well as those projects that must comply with the Alteration of Terrain (AoT) regulations (Chapter Env-Wq 1500).

Chapter 3: Screening and Selecting Best Management Practices provides guidance in selecting BMPs to meet New Hampshire's stormwater management objectives, including protection against water quality impacts during construction, post-construction pollutant removal, recharge, channel protection, peak runoff control, and protection of water quality. The chapter provides a matrix of BMPs and identifies BMP capabilities to meet the stormwater objectives. The Chapter also discusses screening and selecting BMPs based not only on BMP capabilities, but also on site specific factors such as land use, physical feasibility, watershed resources, community and environmental factors, and operation and maintenance considerations.

Chapter 4: Designing Best Management Practices presents a selection of Best Management Practices and provides a brief description of each BMP and lists key information for the design of the BMP to meet New Hampshire stormwater management objectives. While the BMP "fact sheets" summarize the criteria for designing BMPs, they are meant to provide an overview of the measures discussed. NHDES expects engineers to consult a diverse array of design references currently considered as accepted practice, in the development of designs for stormwater management facilities for projects in New Hampshire.

Chapter 5: Preparing for Stormwater System Operation, Maintenance, Inspection and Source Control affirms the importance of ongoing inspection, operation, maintenance, and repair and restoration activity to the effectiveness of stormwater facilities. The Chapter discusses general operation and maintenance (O&M) considerations for successfully meeting stormwater management objectives.

Chapter 2
Design Criteria

This Chapter presents design criteria for sizing BMPs in the State of New Hampshire to protect the state's waters from the adverse impacts of development. Land development projects should employ site design and Best Management Practices (BMPs) to control peak runoff rates, provide stormwater quality treatment, use stormwater for groundwater recharge, and provide for stream channel protection.

For projects that must comply with the AoT Regulations, specific parameters for sizing BMPs to meet these requirements are stipulated in the Env-Wq 1500. This Manual recommends these parameters for all development projects.

This Chapter addresses the following design criteria for sizing stormwater management practices:

- Water Quality Volume (WQV)
- Water Quality Flow (WQF)
- Groundwater Recharge Volume (GRV)
- Effective Impervious Cover (EIC)
- Undisturbed Cover (UDC)
- Channel Protection (CP)
- Peak Control

A summary of the requirements is included in Table 2-1, with detailed descriptions provided in the text that follows. In addition to these design criteria, other BMP-specific criteria also apply to the design of stormwater management practices. Those additional criteria are provided for each BMP in Chapter 4 – Designing Best Management Practices. Each of the criteria listed in Table 2-1 is further discussed below.

Table 2-1. Summary of Design Criteria[1]

Design Criteria	Description
Water Quality Volume (WQV)	WQV = (P)(Rv)(A) P = 1" of rainfall Rv = unitless runoff coefficient = Rv = 0.05 + 0.9(I) I = percent impervious cover draining to the structure converted to decimal form A = total site area draining to the structure
Water Quality Flow (WQF)	WQF = (q_u)(WQV) WQV = water quality volume calculated in accordance with Design Criteria above q_u = unit peak discharge from TR-55 exhibits 4-II and 4-III Variables needed for exhibits 4-II and 4-III: Ia = the initial abstraction = 0.2S S = potential maximum retention in inches = (1000/CN) – 10 CN = water quality depth curve number $= 1000/ (10+5P+10Q–10[Q^2 + 1.25(Q)(P)]^{0.5})$ P = 1" of rainfall Q = the water quality depth in inches = WQV/A A = total area draining to the design structure
Groundwater Recharge Volume (GRV)	GRV = $(A_I)(R_d)$ A_I = the total area of effective impervious surfaces that will exist on the site after development R_d = the groundwater recharge depth based on the USDA/NRCS hydrologic soil group, as follows: <u>Hydrologic Group</u> — <u>Rd (inches)</u> A — 0.40 B — 0.25 C — 0.10 D — 0.00
EIC & UDC	%EIC = area of effective impervious cover/total drainage area within a project area X 100 %UDC = area of undisturbed cover/total drainage area within a project area X 100
Channel Protection (CP)	If the 2 yr, 24-hr post-development storm volume <u>*does not increase*</u> due to development then: control the 2-year, 24-hour post-development peak flow rate to the 2-yr, 24-hr pre-development level. If the 2yr, 24-hr post development storm volume <u>*does increase*</u> due to development then: Control the 2-yr, 24-hr post-development peak flow rate to ½ of the 2-year, 24-hr pre-development level or to the 1-yr, 24-hr pre-development level.
Peak Control	Post-development peak discharge rates can not exceed pre-development peak discharge rates for the 10 & 50-yr, 24-hr storm events.

[1] Appendix A provides rainfall data for New Hampshire, for use with these design criteria.

2-1. Water Quality Volume (WQV)

Criteria

The Water Quality Volume (WQV) is the amount of stormwater runoff from a rainfall event that should be captured and treated to remove the majority of stormwater pollutants on an average annual basis. The recommended WQV is the volume of runoff associated with the first one-inch of rainfall, which is equivalent to capturing and treating the runoff from the 90th percentile of all rainfall. WQV should be calculated using the following equation:

WQV = (P)(Rv)(A)

Where:

P = 1 inch
Rv = the unitless runoff coefficient, Rv = 0.05 + 0.9(I)
I = the percent impervious cover draining to the structure, in decimal form
A = total site area draining to the structure

Rationale

Development impacts the water quality of streams, ponds, lakes and wetlands. Pollutant deposits on the land surface increase as the intensity of land use increases. These materials are then washed off by rain and runoff, increasing the pollutant load to receiving waters. Usually, the stormwater that initially runs off an area, often referred to as the 'first flush' will be more polluted than the stormwater that runs off later, after the rainfall has 'cleansed' the catchment.

Based on early studies in Florida that determined that the first flush generally carries 90 percent of the pollution from a storm (Novotny, 1995), treatment of the first half-inch of runoff was adopted as a water quality volume sizing criterion throughout most of the United States. However, more recent research has shown that pollutant removal achieved using the half-inch rule drops off considerably as site imperviousness increases.

Other water quality sizing methods were developed to achieve higher pollutant removals, including the "90 Percent Rule", in which the water quality volume is equal to the storage required to capture and treat 90 percent of annual runoff and consequently 90 percent of the pollutant load. In the Northeastern United States, capturing 90 percent of the annual runoff is on average, roughly equivalent to capturing and treating the first one-inch of stormwater runoff for each rainfall event.

Example Calculation: Water Quality Volume (WQV)

Given

P = 1" for New Hampshire
A = 0.80 acres draining to the structure, 0.60 acres of this area is impervious

Solution

I = 0.60 ac/0.80 ac = 0.75
Rv = 0.05 + 0.9(I) = 0.05 + 0.9(0.75) = 0.725
WQV = (1")(0.725)(0.80ac) = 0.58 ac-in

To convert to cubic feet, if desired:
WQV = 0.58 ac-in * 43,560 ft^2/ac * 1ft/12 in
= **2,100 ft^3**

WQV = 2,100 ft^3

Exhibit 4-II Unit peal discharge (q_u) for NRCS (SCS) type II rainfall distribution

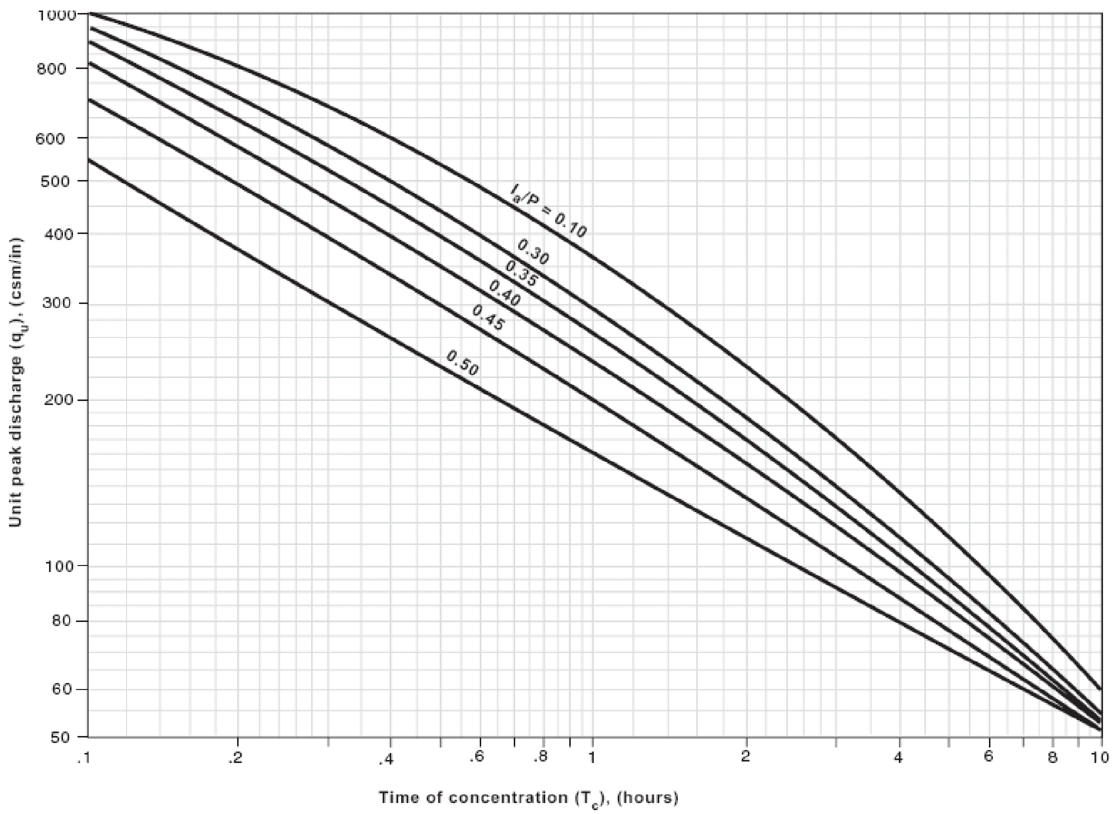


Exhibit 4-III Unit peal discharge (q_u) for NRCS (SCS) type III rainfall distribution

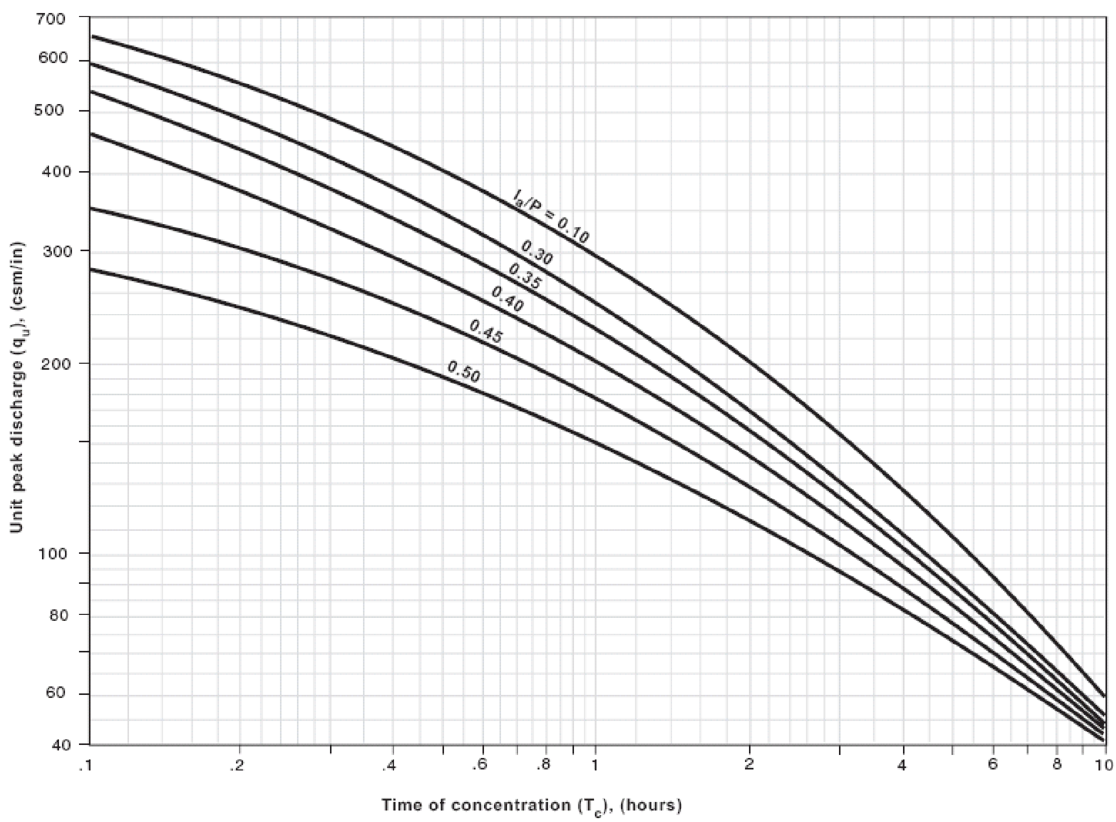


Figure 2-1. Exhibits 4-II and 4-III: Unit Peak Discharge for NRCS Rainfall Distributions

2-2. Water Quality Flow (WQF)

Criteria

The Water Quality Flow (WQF) is used to determine a flow rate associated with the WQV, for sizing flow-based treatment and pre-treatment practices (e.g., Treatment Swales, Pre-treatment Swales, Flow-Through Devices – see BMP descriptions in Chapter 4). The WQF is calculated using the WQV and the Natural Resource Conservation Service (NRCS), TR-55 Graphical Peak Discharge Method. WQF should be calculated using the following equations and steps:

1. Compute the NRCS Curve Number (CN) using the following equation:

   $$CN = 1000/\ (10+5P+10Q–10[Q^2 + 1.25(Q)(P)]^{0.5})$$

   Where:

   CN = Runoff Curve Number

   P = 1 inch

   Q = the water quality depth in inches = WQV/A

   WQV = water quality volume (calculations shown in previous section)

   A = total area draining to the design structure

   NOTE that this CN is not the same as the subcatchment's CN which is selected based on the land use and soil type. Rather it is a representative CN used to convert the water quality depth to a flow rate.

2. Compute the time of concentration (tc) using the methods described in Chapter 3 of TR-55.

3. Calculate potential maximum retention (S) in inches using the following equation:

   $$S = (1000/CN) – 10$$

4. Calculate initial abstraction (Ia) using the following equation:

   $$Ia = 0.2S$$

5. Read the unit peak discharge (qu) from TR-55 Exhibits 4-II or 4-III (reproduced below) based on the project's location.

6. Compute the water quality flow (WQF) using the following equation:

   $$WQF = (q_u)(WQV)$$

Example Calculation: Water Quality Flow (WQF)

Given

Location of project: Concord, New Hampshire
P = 1" for New Hampshire
A = 1 acre draining to the structure,
60% impervious cover
Tc = 12 minutes (0.2 hours)

Solution

WQV = (P)(Rv)(A)
Rv = 0.05 + 0.9(I) = 0.05 + 0.9(0.60) = 0.59
WQV = (1")(0.59)(1ac) = **0.59 ac-in**

Q = WQV/A = 0.59 ac-in / 1 ac = 0.59 in
Note that Q is not a function of area, as it may appear. Q reduces down to:
Q= (P)(Rv)(A)/(A) = P x Rv so when P = 1", ***Q = Rv***.

$CN = 1000/\ (10+5P+10Q-10[Q^2 + 1.25(Q)(P)]^{0.5})$
$= 1000/(10 + 5(1") + 10(0.59) - 10[0.59^2 + 1.25(0.59")(1")]^{0.5})$
$= 95.4$

S = (1000/CN) – 10
= 1000/95.4 – 10 = 0.48 in
Ia = 0.2S = 0.2(0.48) = 0.10 in
Ia/P = 0.10 in / 1 in = **0.10**

Concord is in the Type III rainfall distribution zone, therefore use exhibit 4-III from TR-55 and find qu in (csm/in) where Ia/P = 0.10 (solution above) and Tc = 0.2 hrs (given information) *Note csm = cfs/mi²*

$q_u = 560\ cfs/mi^2/in$

WQF = (q_u)(WQV)
= $560\ cfs/mi^2/in \times 0.59\ ac\text{-}in \times (1\ mi^2/640\ ac)$
= 0.52 cfs

WQF = 0.52 cfs

Rationale

Some treatment practices such as treatment swales and flow-through devices are more appropriately designed based on peak flow rate, rather than water quality volume, since they are designed to treat higher flow rates, thereby requiring less storage volume. The use of the NRCS, TR-55 Graphical Peak Discharge Method in conjunction with the water quality volume is the preferable method for computing the peak flow associated with the water quality design storm, since it can more appropriately estimate peak flows associated with smaller storm events and can also be used to predict runoff volumes.

2-3. Groundwater Recharge Volume (GRV)

Criteria

The purpose of the groundwater recharge volume criterion is to protect groundwater resources by minimizing the loss of annual pre-development groundwater recharge as a result of the proposed development. The Groundwater Recharge Volume (GRV) should be based on the site soils and the following equation:

GRV = $(A_I)(R_d)$

Where:
A_I = the total effective area of impervious surfaces that will exist on the site after development
R_d = the groundwater recharge depth based on the USDA/NRCS hydrologic soil group, as follows:

Hydrologic Group	R_d (inches)
A	0.40
B	0.25
C	0.10
D	0.00

The following criteria should also apply:

(a) If more than one soil type is present at the site, a weighted recharge depth should be computed based on the area of each soil group present.

(b) Infiltration rates for designing Groundwater recharge practices should be in accordance with Section 2-4 and the Alteration of Terrain regulations (Env-Wq 1500).

(c) No recharge is allowed within the setback areas provided in Table 3-3 or within 100 feet of a surface water that defines a water supply intake protection area, unless the recharge system receives stormwater from less than 0.5 acre and is not from a high-load area.

On some sites, existing soils or other conditions may severely constrain the use of infiltration systems for recharging groundwater. Examples include sites underlain by marine clays, sites in areas of karst geology, and urban redevelopment areas. In these areas, the recharge volume requirement may be reduced. However, stormwater management systems should still be provided to treat the full WQV and non-structural practices should be implemented to the maximum extent practicable to reduce runoff (e.g., filter strips that treat rooftop or parking lot runoff, sheet flow discharge to forested buffers, and grass channels that treat roadway runoff).

Additional requirements applicable to systems that infiltrate stormwater and that

Example Calculation: Groundwater Recharge Volume (GRV)

Given:

Total project area = 10 acres
Total impervious cover = 4 acres
Total effective impervious area = 1.5 acres

The effective impervious area will cover 1 acre of hydrologic group A soil and 0.5 acres of hydrologic group C soil.

Solution:

$GRV = (A_I)(R_d)$

Weighted R_d
$= [(1 \text{ ac})(0.40 \text{ in}) + (0.5 \text{ ac})(0.10 \text{ in})]/1.5 \text{ ac} = 0.30 \text{ in}$

GRV = 1.5 ac * 0.30 in = **0.45 ac-in**

To convert to cubic feet, *if desired:*
GRV = **0.45 ac-in** * 43,560 ft^2/ac * 1ft/12 in
= **1,630 ft^3**

GRV = 1,630 ft^3

would contribute to groundwater recharge are listed with the specific BMP descriptions included in Chapter 4.

Rationale

The groundwater recharge criterion is intended to maintain pre-development *annual* groundwater recharge volumes by capturing and infiltrating a portion of runoff from the post-development impervious surfaces for each individual storm event. Under this approach, a portion of runoff from larger storms, and all runoff from smaller precipitation events, is captured and infiltrated using appropriate BMPs.

The objective of the groundwater recharge criterion is to maintain water table levels, stream baseflow, and wetland moisture levels and to provide a filtering mechanism to "clean" surface water. Maintaining pre-development groundwater recharge conditions can also reduce the volume of runoff that must be managed to meet other design criteria (i.e., water quality, channel protection, and peak flow control), and thus the overall size and cost of stormwater management practices.

The objective of the groundwater recharge criterion is to mimic the average annual recharge that occurs on a site before it is developed. The recommended approach for calculating the GRV is a function of post-development site imperviousness and the prevailing infiltration capacity of existing soils. The hydrologic soil group approach uses the widely available NRCS Soil Survey maps and estimates of average annual infiltration rates for each hydrologic soil group. This method has been adopted in several other northeastern states with similar climates and average annual precipitation.

For each soils hydrologic group, the NHDES considers the recharge depth (R_d) the amount of runoff that must be captured from an impervious surface and infiltrated for each storm, in order to make up for the loss of recharge that would otherwise result from that impervious surface. For example, if a site development creates impervious surfaces on an area with soils in Hydrologic Group A, then for every storm event, the stormwater system should capture and infiltrate the first 0.4 inches of runoff from all pavements and roofs; for small storm events that generate less than 0.4 inches of runoff, the system should capture and infiltrate all runoff from the new impervious surfaces. The cumulative effect of capturing and infiltrating the initial volume of runoff from multiple events is to approximate the annual recharge occurring during pre-development conditions.

2-4. Design Infiltration Rate

Chapter 4 presents information on a number of Best Management Practices that rely on stormwater infiltration (e.g.; infiltration practices, filtering practices, and groundwater recharge practices). This section outlines the procedures for selecting a design infiltration rate.

Site Feasibility Confirmation Testing

Initial screening identifies the potential for using infiltration methods and determines potential locations on the site for infiltration facilities. Initial screening establishes the feasibility of installation of infiltration methods on the site and identifies where fieldwork may be needed for subsequent field verification.

» INITIAL SCREENING PARAMETERS

The initial stormwater infiltration screening evaluation involves seven screening parameters, to identify site-specific characteristics of the proposed development site. Information regarding the following seven parameters should be obtained and evaluated relative to applicable regulations, the BMP descriptions provided in Chapter 4, and the guidelines discussed in this Chapter:

1. Site topography and slopes greater than 15%.
2. Site hydrologic soil groups or Ksat values. If a site specific soil map as defined in accordance with the Society of Soil Scientists of Northern New England (SSSNNE) Special Publication No. 3, Site-Specific Soil Mapping Standards for New Hampshire and Vermont, December 2006 (or most recent), has been created for the developed site area, this will be very useful in the initial screening process.
3. Potential depth to bedrock and seasonal high water table (SHWT).
4. Presence of potentially vulnerable groundwater areas (Water Supply Well Setback areas, Groundwater Protection Areas, and Water Supply Intake Protection Areas).
5. Presence or nearby proximity to known areas with identified soil or groundwater contamination, including but not limited to:
    - Existing or closed remediation sites, or
    - underground storage tanks within or adjacent to the project parcel.
6. Presence of sensitive ecological habitat (including wetlands and threatened or endangered species habitat).
7. Presence of flood plains.

The following list of soils typically have infiltration rates too rapid to provide treatment; therefore, stormwater should already be treated prior to discharging to these soils or these soils should be field tested to ensure that the infiltration rate, prior to adding a factor of safety, is less than 10 inches per hour. If the infiltration rate is greater than 10 inches per hour, the soils should be amended to an infiltration rate less than 10 inches per hour and then field tested to confirm a maximum infiltration rate of 10 inches per hour:

Abenaki, Adams, Agawam, Boscawen, Caesar, Champlain, Colton, Croghan, Deerfield, Haven, Hermon, Hinckley, Hoosic, Metallak, Quonset, and Warwick.

Standardized Test Pit/Boring Protocol

Test pits and/or borings are required in the infiltration area to a minimum depth of 5 feet below the proposed bottom of the infiltration facility. The following steps describe the main elements necessary to support test pit/boring requirements:

1. Excavate a test pit or drill a boring to a depth of at least 5 feet below the proposed facility bottom or to the depth of bedrock or the SHWT, whichever is less. Test pits should be of adequate size, depth, and construction to allow a person to enter and exit the pit and complete a morphological soil profile description. If borings are drilled, continuous soil borings should be taken using a bucket auger, probe, split-spoon sampler, or Shelby tube. Samples should have a minimum 2-inch diameter. A minimum number of test pits and/or borings should be provided for each infiltration facility as designated in Table 2-2).
2. Determine depth to SHWT (if potentially within 5 feet below the base of the facility).
3. Determine US Department of Agriculture (USDA) or Unified Soil Classification (USC) System soil textures at the proposed bottom and to 5 feet below the bottom of the infiltration facility.
4. Describe soil horizons and determine depth to bedrock (if within 5 feet of proposed bottom of facility).
5. The location of the test pit or boring should correspond to the BMP location; test pit/ soil boring stakes should be clearly labeled and left in the field for inspection and surveyed location.

» FIELD VERIFICATION

Field verification of information collected during the initial site feasibility screening process includes further investigation of specific areas on a development site that have been considered potentially suitable for infiltration.

Sites should be tested for depth to SHWT and depth to bedrock to verify findings from initial screening.

For existing soils, natural or man-made, test pits or borings should be performed to verify soil infiltration capacity characteristics and to determine depth to the SHWT and depth to bedrock. A standardized test pit/boring protocol is described below.

The following information should be recorded for field verification of the potential sites as a result of the initial screening:

1. The date or dates the data were collected.
2. A legible site plan/map that:
   a. Is drawn to scale.

b. Illustrates the entire development site.
c. Shows all areas of planned filling and/or cutting.
d. Includes a permanent vertical and horizontal reference point.
e. Shows the percent and direction of land slope for the site or contour lines, and highlights areas with slopes over 15%.
f. Shows all flood plain information that is pertinent to the site.
g. Shows the locations of all test pits/borings included in the report.
h. Shows the locations of wetlands as field delineated and surveyed.
i. Shows the locations of water supply wells and setbacks, groundwater protection areas, and water supply intake protection areas if within 100 feet of the development site.

3. It is recommended that soil profile descriptions be written in accordance with the descriptive procedures, terminology, and interpretations found in the "USDA Field Book for Describing and Sampling Soils" (USDA NRCS 2002, or most recent). In addition to the soil data determined above, soil profiles should include the following information for each soil horizon or layer:
   a. Thickness, in inches or decimal feet.
   b. Munsell soil color notation.
   c. Soil redoximorphic feature color, abundance, size, and contrast.
   d. Using the USDA Textural Triangle, soil textural class with rock fragment modifiers
   e. Soil structure, grade size, and shape.
   f. Soil consistence
   g. Root abundance and size.
   h. Soil boundary.
   i. Occurrence of saturated soil, groundwater, bedrock, or disturbed soil.

NOTE: If the material is frozen, it should be thawed prior to conducting evaluations for soil color, texture, structure and consistency.

Table 2-2. Minimum Number of Test Pits/Borings Required

Facility	Minimum Number of Test Pits / Borings Required
Infiltration Basins Less than 2,500 sf	1 test
Infiltration Basins 2,500 sf or more	2,500 sf – 20,000 sf = 2 tests 20,000 sf – 30,000 sf = 3 tests 30,000 – 40,000 = 4 tests 1 additional test for every additional 10,000 sf.
Infiltration Trenches	0 LF – 100 LF = 1 test 100 LF – 200 LF = 2 tests 200 LF – 300 LF = 3 tests 1 additional test for every additional 100 LF.

» EVALUATION OF SPECIFIC INFILTRATION AREAS

At specific locations identified for stormwater infiltration facilities, this step consists of soils evaluation to confirm that the locations are suitable for infiltration and provide the required information to design the facilities. The minimum number of test pits and/or borings should be provided for each infiltration facility as discussed above.

The following information should be recorded for this evaluation:

1. All the information obtained in initial screening and field verification steps.

2. A legible site plan/map that:
   a. Is drawn to scale or fully dimensional;
   b. Illustrates the locations of the proposed infiltration facilities;
   c. Shows the locations of all test pits and borings; and
   d. Shows distance to wetlands.

3. The results and supporting information for one of the following methods used to determine the design infiltration rate:

A. Default Rate
Default values may be used for native materials only. Default values maybe easier to obtain, however the designer should note that this method is considered conservative. To select a default rate, first use the Site Specific soil map and determine which soil series are at the location of the practice.

Example: Selecting a Default Infiltration Rate

Given:

Location: Concord, NH (Merrimack County)
Elevation of the bottom of the proposed filtering practice: 24 inches below native ground.
SSSS mapped as: 166B - Canterbury and test pits confirm this

Solution Steps:

1. Go to the Merrimack County soil data in NRCS's Soil Data Mart located on the web at: http://soildatamart.nrcs.usda.gov and look up the ranges of values for saturated hydraulic conductivity reported for the Canterbury soil layers at or below the bottom of the infiltration system or contact your local NRCS office.

Result:

Depth (inches)	Ksat (micrometers/second)	Ksat (inches/hour)
0-2	4.0 - 42.0	0.6 - 6.0
2 - 6	4.2 - 14.1	0.6 - 2.0
6 - 28	4.2 - 14.1	0.6 - 2.0
28 - 65	0.42 - 4.2	0.06 - 0.6

Conversion: 1 micrometer/second = 0.1417 inches/hour

Second, determine the limiting layer (slowest Ksat) reported beneath the proposed bottom of the practice using the Physical Soil Properties reported by the USDA NRCS. The reported Ksat for a given layer typically has a range of values. Select the slowest value for the default rate. Use a weighted average by area if more than one soil series is present. Lastly, apply a minimum factor of safety of 2.

1. Select the slowest value reported below the bottom of the practice: Results: The limiting layer, at or below 24", is 0.06 inches per hour.

2. Apply a factor of safety
   Result: design infiltration rate = 0.06 inches per hour/2 = 0.03 inches per hour.

B. Field Measured Infiltration Rate

For the purposes of determining a design infiltration rate for stormwater BMPs a saturated hydraulic conductivity (Ksat) test should be performed with the following testing protocol:

- The Ksat should be measured with a Guelph Permeameter; a Compact Constant Head Permeameter; a Double-Ring Infiltrometer (ASTM 3385), where the inner ring is at least 12 inches in diameter; or a Borehole Infiltration test, see Table 2-3 for the testing protocol.
- The test should be performed and/or supervised by a qualified professional such as a certified soil scientist, a professional geologist, or an engineer.
- The test location should be within the footprint of the final location of the infiltration facility.
- The test should be conducted at the proposed bottom elevation of the infiltration facility.
- See Table 2-4 below for the minimum number of testing locations
- If a Guelph Permeameter or Compact Constant Head Permeameter test is used, the test should be performed a minimum of 3 times for each test location.

Example: Determining a Field Measured Infiltration Rate

Field testing results on natural soils using a compact head parameter are as follows:

Test location A.

Run 1 = 2.2 inches per hour
Run 2 = 5.8 inches per hour
Run 3 = 2.4 inches per hour
Run 4 = 3.8 inches per hour
Run 5 = 1.4 inches per hour
Average = 3.1 inches per hour

Testing Location B.

Run 1 = 1.2 inches per hour
Run 2 = 2.4 inches per hour
Run 3 = 1.9 inches per hour
Average = 1.8 inches per hour

Testing Location C.

Run 1 = 7.4 inches per hour
Run 2 = 8.1 inches per hour
Run 3 = 9.4 inches per hour
Average = 8.3 inches per hour

Average of the tests
= (3.1 + 1.8 + 8.3)/ 3
= 4.4 inches per hour

Result: design infiltration rate
= 4.4 inches per hour/2
= 2.2 inches per hour

Table 2-3. Borehole Infiltration Test Protocol	
Infiltration Testing Requirements	
1.	Install casing (solid 4 - 6 inch diameter, 30" length) to 24" below proposed bottom of the practice (see Figure 2-1).
2.	Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate. Remove all loose material from the casing. Upon the tester's discretion, a two (2) inch layer of coarse sand or fine gravel may be placed to protect the bottom from scouring and sediment. Fill casing with clean water to a depth of 24" and allow to pre-soak for twenty-four hours
3.	Twenty-four hours later, refill casing with another 24" of clean water and monitor water level (measured drop from the top of the casing) for 1 hour. Repeat this procedure (filling the casing each time) three additional times, for a total of four observations. The observations should be averaged.
4.	May be done though a boring or open excavation.
5.	Upon completion of the testing, the casings should be immediately pulled, and the test pit should be back-filled.

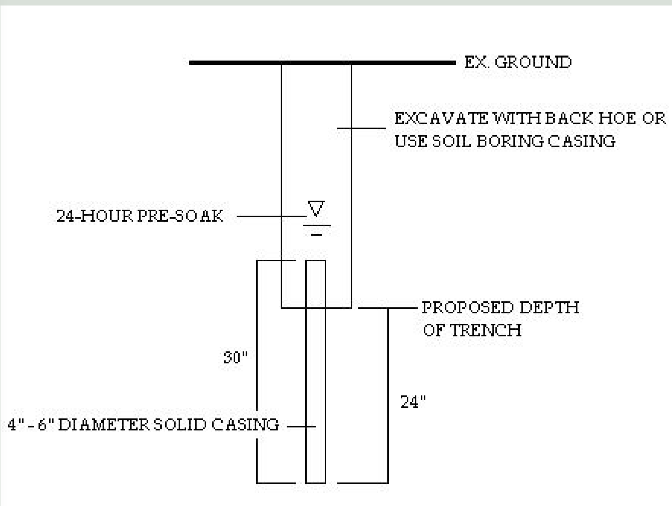


Figure 2-2. Borehole Infiltration Test Setup

- Test locations should be located on plans by survey.
- Final infiltration testing data should be documented, and include a description of the infiltration testing method. This is to ensure that the tester and reviewer fully understand the procedure.
- Apply a minimum factor of safety of 2 to the field measured infiltration rate. See example below:

C. Lab Measured Infiltration Rate

The following protocol should only be used for initial design for proposed fill material:

- The Ksat should be measured with test methods described in ASTM D-2434, "Standard Test Method for Permeability of Granular Soils (Constant Head)" or ASTM D-5856, "Standard Test Methods for Measurement of Hydraulic Conductivity of Porous Material Using a Rigid-Wall, Compaction-Mold Permeameter";
- Apply a minimum factor of safety by dividing the representative Ksat by 2.0 and use the result as the design infiltration rate.
- Once the fill is in place, the soil should be field tested to confirm the design rate. To confirm the rate, run the field test in accordance with section B. above.

» LIMITATIONS & CONSIDERATIONS

The following limitations on discharging stormwater into the ground should be recognized.

Infiltration practices, Unlined Filtering Practices, and Groundwater Recharge Practices should not be installed in the following areas:

1. Within groundwater protection areas, where the stormwater comes from a high-load area;

2. Within areas that have contaminants in groundwater above the ambient groundwater quality standards established in Env-Or 603.03

3. Within areas having soil above site-specific soil standards developed pursuant to Env-Or 600;

4. In any area, if the stormwater comes from areas that have contaminants in soil above site-specific soil standards developed pursuant to Env-Or 600;

5. In any area, if the stormwater comes from areas with underground storage tanks regulated under RSA 146-C or aboveground storage tanks regulated under RSA 146-A, where gasoline is dispensed or otherwise transferred to vehicles;

6. Within areas having slopes greater than 15%, unless the system has been carefully engineered to prevent seepage forces from causing instability;

7. Within areas where the design infiltration rate is less than 0.50 inches per hour. For filtering practices such as a bioretention area or permeable pavement, no minimum infiltration rate should be required if these facilities are designed with a "daylighting" underdrain system.

8. Within areas having soils with infiltration rates greater than 10 inches per hour) unless the stormwater has first been treated by an acceptable BMP, or the soil has been amended to reduce the infiltration rate and the reduction is confirmed by further testing.

Infiltration into fill soils should be used with extreme caution!

Table 2-4. Minimum Number of Test Locations

Facility	Minimum Number of Test Pits / Borings Required
Infiltration Basins (no manmade soils present)	1 test for each 2,500 sf of basin area
Infiltration Basins (manmade soils present)	1 test for each 1,000 sf of basin area
Infiltration Trenches (no manmade soils present)	1 tests for each 100 LF of trench
Infiltration Trenches (manmade soils present)	1 tests for each 50 LF of trench

The following should be considered to enhance the use of, or avoid problems with, an infiltration facility:

1. Groundwater monitoring wells can be used to determine the seasonal high water table. Large sites considered for infiltration systems may need to be evaluated for the direction of groundwater flow.

2. One or more areas within a development site may be selected for infiltration. A development site with many areas suitable for infiltration is a good candidate for a dispersed approach to infiltration. Smaller infiltration devices dispersed around a development are usually more sustainable than a single regional device that is more likely to have maintenance and groundwater mounding problems.

3. Stormwater infiltration devices may fail prematurely if there is:
   a. An inaccurate estimation of the Design Infiltration Rate;
   b. An inaccurate estimation of the seasonal high water table;
   c. Excessive compaction or sediment loading during construction;
   d. Inadequate pretreatment of post-development stormwater flows;
   e. Inadequate maintenance of the infiltration system and pretreatment facilities.

4. No construction-related sediment should enter the infiltration device. This includes sediment resulting from initial site grading as well as subsequent home building and related construction. If possible, rope off areas selected for infiltration during grading and construction. This will preserve the infiltration rate and extend the life of the device. In addition, infiltration facilities should only be placed into service after the contributing areas are fully stabilized.

2-5. Effective Impervious Cover (EIC) and Undisturbed Cover (UDC)

Volume 1, Chapter 5 of the Stormwater Manual describes the concepts of Effective Impervious Cover and Undisturbed Cover. These parameters are used to determine the applicability of proposed Antidegradation Requirements, as discussed in Volume 1.

NHDES has proposed a target of 10% effective impervious cover (%EIC) maximum and a 65% undisturbed cover (%UDC) minimum for development sites to be used as a surrogate to conducting pollutant loading analysis. This is informally called the "1065 Rule." It is proposed that eligible sites[1] that meet the 1065 Rule do not have to perform a loading analysis under the antidegradation requirements.

1 The "1065 Rule" pertains to Tier 2 – High Quality Waters that have useable assimilative

- %EIC – The percent effective impervious cover (%EIC) is computed by dividing the area of effective impervious cover within a project area by the drainage area within a project area, using equal units of measure, and then multiplying the result by 100.
- %UDC – The undisturbed cover (%UDC) is computed by dividing the area of undisturbed cover within a project area by the drainage area within a project area, using equal units of measure, and then multiplying the result by 100.

2-6. Channel Protection (CP)

Criteria

The purpose of this design criterion is to protect stream channels, downstream receiving waters, and wetlands from erosion and associated sedimentation resulting from urbanization within a watershed. This criterion limits the total amount of time that a receiving stream exceeds an erosion-causing threshold based on pre-developed conditions. Off-site flows, or flows into receiving channels within the project area, must meet one of the following criteria to satisfy channel protection requirements:

1. If the 2 year, 24-hour post-development storm volume has not increased over the pre-development volume, then control the 2-year, 24-hour post-development peak flow rate to the 2-year, 24-hour pre-development peak flow rate.
2. If the 2 year, 24-hour post-development storm volume has increased over the pre-development volume, then control the 2-year, 24-hour post-development peak flow rate to 50 percent of the 2-year,

Example Calculation: Channel Protection (CP)

Given:

Prior to development, stormwater is collected immediately off-site to one point of analysis (POA). After development, all of the stormwater is collected at the same POA after being treated and recharged, as necessary.

1 year pre-development 24-hour peak discharge rate
= 1.4 cfs with 0.24 ac-ft of runoff

2 year pre-development 24-hour peak discharge rate
= 2.6 cfs with 0.34 ac-ft of runoff

Solution options:

If the 2 yr post-development runoff volume at the POA is ≤ 0.34 ac-ft
Then: the 2 yr post-development 24-hour peak discharge rate should be
≤ **2.6 cfs.**

If the 2 yr post-development runoff volume at the POA is > 0.34 ac-ft
Then: 2 yr post-development 24-hr peak discharge rate should be
≤ ½ x 2.6 cfs ≤ **1.3 cfs**
or the 2 yr post-development 24-hr peak discharge rate should be ≤ **1.4 cfs**

capacity remaining. Volume 1, Section 5-2 includes more information on project eligibility for this surrogate measure.

24-hour pre-development peak flow rate or to the 1-year, 24-hour pre-development peak flow rate.

Rationale

One of the earliest and most common methods developed to protect stream channels involved the control of post-development peak flows associated with the 2-year, 24-hour storm event to pre-development levels. More recent research indicates that this method does not adequately protect stream channels from erosion and may actually contribute to erosion, since banks are exposed to more frequent and longer duration of erosive bankfull events (MacRae, 1993 and 1996, McCuen and Moglen, 1988).

This is illustrated in Figure 2-3, which compares typical hydrographs for an undeveloped site, the same site developed with no control of peak rates, and the developed site with facilities to attenuate peak rates. As expected, the uncontrolled post-development hydrograph shows a higher peak runoff rate and greater volume of runoff than the pre-development hydrograph. To control peak rates, attenuation facilities are designed to store runoff and release it over an extended period, in order to control the release rate to pre-development levels. While this controls the rate, the period of time during which the receiving water experiences the flow is extended. The extended duration is significant, because flows approaching and larger than the 2-year storm comprise the erosive, channel-forming events. The net result is that receiving channels experience greater erosion due to the increased frequency and duration of bankfull events. The Channel Protection criterion addresses this condition.

2-7. Peak Runoff Control

Criteria

The purpose of peak runoff controls is to address increases in the magnitude of flooding caused by development. The following criteria should be met to control peak discharge rates and improve the overall effectiveness of the stormwater treatment systems:

1. The 10-year, 24-hour post-development peak flow rate should not exceed the 10-year, 24-hour pre-development peak flow rate for all flows leaving the site;

2. The 50-year, 24-hour post-development peak flow rate should not exceed the 50-year, 24-hour pre-development peak flow rate for all flows leaving the site;

3. The project should provide supporting information showing that there is no impact to properties as a result of developing within the100-year floodplain;

4. The design must ensure that the conveyance system and land grading direct runoff to the peak control structure for all pertinent storm events. On some sites, detention facilities are designed for one storm event, while pipes are designed for a different event. For example, the control structure may be designed for the 25-year storm, while the drainage system may only be sized to handle a ten-year storm, with larger storms flooding the distribution system and traveling overland. In this case, the design should ensure that this overflow will be directed into the peak control structure;

5. On some sites, stormwater enters the site from adjacent property. If this stormwater must be handled by the project's drainage system, then the system design and supporting calculations should account for this condition for each design storm, in both pre- and post-development conditions;

6. The design should provide for an emergency spillway for any peak rate control structure that requires an embankment (dam). The emergency spillway's purpose is to protect against embankment failure, in the event the primary outlet cannot handle flows discharging form the impoundment (see description of Detention Basin in Chapter 4).

7. Use NRCS (formerly SCS) methods (TR-20 or TR-55) to develop hydrographs and peak flow rates for the proposed development site. The hydrograph time interval (dT) in TR-20 should be no greater than 0.1 hours. All areas should be accounted for in the pre/post

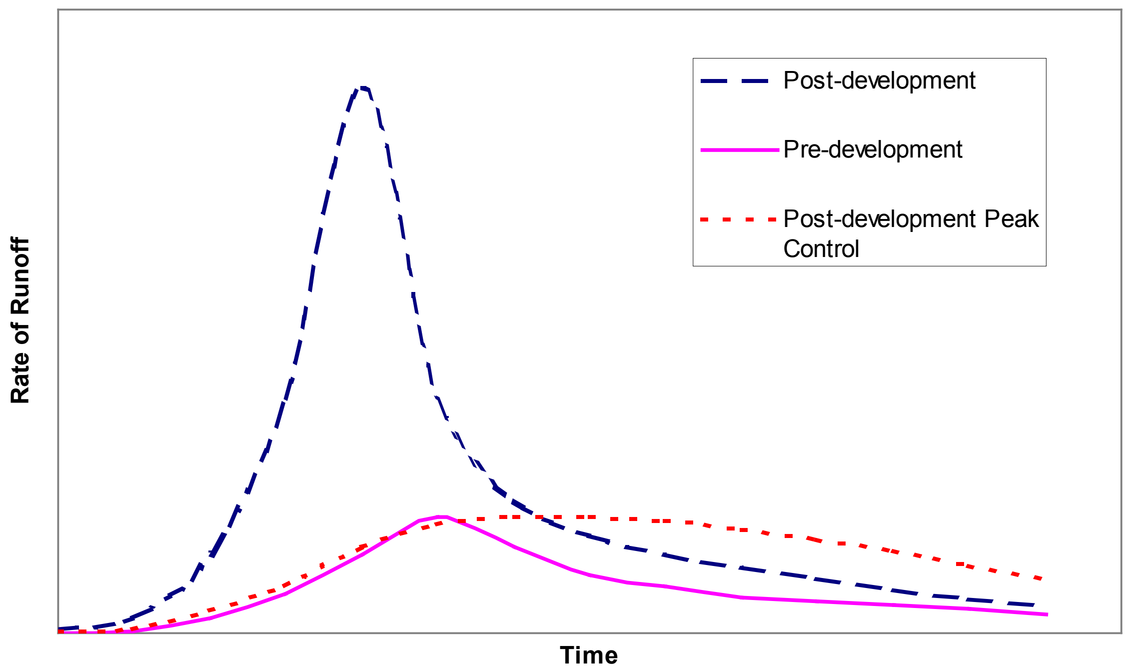


Figure 2-3. Pre- and Post-Development Hydrographs

runoff calculations. The total tributary area that contributes flow to the proposed site, including runoff entering the site through piped drainage or surface runoff from off-site sources, should be included even if a portion does not contribute flow to the site BMPs. The objective is for the development's storm drain design to account for total runoff leaving the site;

8. Any site that was wooded within the last ten years should be considered undisturbed woods for all pre-construction runoff conditions, regardless of clearing or cutting activities that may have occurred on the site during that pre-application period;

9. For all areas that are not modeled in "good" condition, photo documentation should be obtained.

10. Off-site areas should be modeled as present land use condition for all design storm events for both pre and post development calculations; and

11. The length of overland sheet flow used in time of concentration (tc) calculations should be limited to no more than 100 feet for pre- and post-development conditions.

In general, peak runoff controls as described in 1) and 2) above may not be necessary if the project area abuts and discharges to a large receiving waterbody. This typically can be shown through off-site drainage calculations for the 10-year and 50-year, 24-hour storm, showing that at a point immediately downstream from the project site, the post-development peak flow rate from the site and the off-site contributing area does not exceed the pre-development peak flow rate at that point.

Rationale

This criterion is generally consistent with storm drainage system design in New Hampshire, with some added provisions to help guide the design of peak attenuation structures.

The provision to consider any site that was wooded within the last ten years as undisturbed woods for all pre-construction runoff conditions is incorporated to address properties that are cleared with an intent to develop, before the development application process is triggered. Without this provision, the pre-development peak discharge rate may be overestimated, since cleared land produces more runoff than forested land, resulting in a lesser degree of control when the development actually occurs.

Chapter 3
Screening and Selecting Best Management Practices

To meet stormwater management objectives for a particular development or redevelopment project, designers can select from a wide array of Best Management Practices. This selection must be based not only on the ability of each BMP to meet specific management objectives (such as peak rate control and water quality treatment), but also on site specific factors such as land use, physical feasibility, watershed resources, community and environmental factors, and operation and maintenance considerations. This Chapter addresses the screening and selection of BMPs to meet stormwater management objectives in New Hampshire, in consideration of these site specific conditions.

The design of each site should consider the following stormwater management objectives:

- Temporary Water Quality Protection During Construction
- Cold Weather Site Stabilization
- Pollutant Removal
- Recharge
- Channel Protection
- Peak Runoff Control
- Antidegradation Requirements
- Long-Term Operation & Maintenance

There are a wide range of stormwater BMPs that can be used to meet these objectives, when designed in accordance with applicable regulations and Chapter 2 Design Criteria. NHDES recommends the BMPs listed in Table 3-1 to meet stormwater management objectives. The list identifies the objective(s) each BMP meets, and references the NH Administrative Rule that applies to the design of the BMP. Table 3-2 lists the post-construction BMPs, and summarizes the applicability of the various screening factors discussed in the remainder of this Chapter. Erosion and sediment control BMPs are discussed further in Volume 3 of the NH Stormwater Manual.

Recognizing that there is no single stormwater BMP that is appropriate for every development site, this chapter outlines criteria for screening and selecting the best BMP(s) based on site specific factors, including:

Table 3-1. Best Management Practice Selection (Objectives)

BMP Type	Best Management Practice	Chapter Env-Wq 1500 Reference	Basic AOT Requirements (1503.17): Temporary Water Quality Protection Measures	Cold Weather Stabilization	Permanent Water Quality Protection Measures 1507.02: Pollutant Removal	Limit changes in hydrology: Recharge	Channel Protection	Peak Runoff Control	Protect Water Quality (Anti-degradation)	Operation & Maintenance	Stormwater Handbook Volume Reference
			1505.04	1505.05	1507.03	1507.04	1507.05	1507.06	1507.07	1507.08	
Low Impact Development (LID)											Volume 1
	Site Management Practices										
	Comprehensive LID Site Design					●	●	●	●		
	Disconnect Impervious Area					●	●	●	●		
	Minimize Disturbance Area					●	●	●	●		
	Minimize Site Imperviousness					●	●	●	●		
	Flow Path Practices					●	●	●	●		
	Preserve Infiltratable Soils					●	●	●	●		
	Preserve Natural Depression Areas					●	●	●	●		
	Other: Natural Vegetation Preservation, Soil Amendment						○	○			
	Interception or Recharge Practices (constructed BMPs)										
	Green Roof						○	○	○	X	
	Rain Barrel/Cistern (with on-site re-use)						○	○	○	X	
	Rain Garden/Bioretention				●	○*	○	○	○	X	
	Pervious Pavers/Pervious Pavement				●	○*	●	●	●	X	
Source Control BMPs											Volumes 1 and 2
	Street Sweeping				○				○	X	
	Snow and Ice Management				○				○	X	
Treatment BMPs											
	Stormwater Ponds	1508.03									
	Dry Extended Detention Pond With Micropool				○		○	●	○	X	
	Wet Pond				●		○		●	X	
	Wet Extended Detention Pond				●		○	●	●	X	
	Multiple Pond System				●		○	●	●	X	
	Pocket Pond				●		○		●	X	
	Stormwater Wetlands	1508.04									
	Shallow Wetland				●		○		●	X	
	Extended Detention Wetland				●		○	○	●	X	
	Pond/Wetland System				●		○	○	●	X	
	Gravel Wetland				●		○	○	●	X	
	Infiltration Practices	1508.05									
	Infiltration Trench and Drip Edge				○	●	●	●	●	X	
	In-ground Infiltration Basin				○	●	●	●	●	X	
	Underground Infiltration Basin				○	●	●	●	●	X	
	Dry Well				○	●	○	●	●	X	
	Permeable Pavement				●	●	●	●	●	X	
	Filtering Practices	1508.06									
	Surface Sand Filter				●				●	X	
	Underground Sand Filter				●				●	X	
	Bioretention System (underdrained)				●				●	X	
	Permeable Pavement (with sand bed, underdrain, and piped outlet)				●				●	X	
	Flow-Through Treatment Swale	1508.07			●				●	X	
	Vegetated Buffer (vegetated filter strip)	1508.08									
	Residential or Small Pervious Area Buffer				○	○			○	X	
	Developed Area Buffer				○	○			○	X	
	Buffers on Downhill Side of Roadway				○	○			○	X	

Table 3-1. Best Management Practice Selection (Objectives)

BMP Type	Best Management Practice	Chapter Env-Wq 1500 Reference	Basic AOT Requirements (1503.17): Temporary Water Quality Protection Measures	Cold Weather Stabilization	Permanent Water Quality Protection Measures 1507.02: Pollutant Removal	Recharge	Limit changes in hydrology: Channel Protection	Peak Runoff Control	Protect Water Quality (Anti-degradation)	Operation & Maintenance	Stormwater Handbook Volume Reference
			1505.04	1505.05	1507.03	1507.04	1507.05	1507.06	1507.07	1507.08	
Pretreatment BMPs											Volumes 1 and 2
	Sediment Forebay	1508.10			●				○	X	
	Vegetated Filter Strip	1508.11			●	○			○	X	
	Pre-treatment Swale	1508.12			●				○	X	
	Flow-through Structures	1508.13									
	Water Quality Inlet				●				○	X	
	Proprietary Devices				●				○	X	
	Deep-sump Catch Basin	1508.14			●					X	
Groundwater Recharge Practices		1508.15									
	Infiltration Practices	1508.05			●	●	○	○	●	X	
	Filtering Practices Which Include Infiltration	1508.06			●	●	○	○	●	X	
	Permeable Surfaces				●	●	○	○	●	X	
Conveyance Practices											
	Detention Basin	1508.16						●		X	
	Stone Berm Level Spreader	1508.17	○							X	
	Conveyance Swale	1508.18	○							X	
	Terraced Slopes or Benching	1508.19	○							X	
	Flow Splitters									X	
	Permanent Outlet Protection		○							X	
Erosion and Sediment Control Practices											Volume 3
	Erosion Control Methods During Construction										
	Construction Phasing		●	●							
	Dust Control		●	○							
	Grading practices		●	○							
	Soil Stockpile Practices		●	●							
	Temporary and Permanent Mulching	1506.01	●	●							
	Vegetation	1506.02	●								
	Temporary Erosion Control Blanket	1506.03	●	●							
	Diversion		●	●							
	Slope Drain		●								
	Sediment Control Methods										
	Silt Fence	1506.04	●	●							
	Turbidity Curtain		●	○							
	Erosion Control Mix Berms	1506.05	●	●							
	Straw or Hay Bale Barrier	1506.06	●	●							
	Temporary Check Dam	1506.07	●	○							
	Temporary Storm Drain Inlet Protection	1506.08	●	●							
	Temporary Construction Exit	1506.09	●	●							
	Temporary Sediment Traps	1506.10	●	○							
	Temporary Sediment Basins		●	○							
	Construction Dewatering	1506.11	●	○							
	Flocculants	1506.12	●								

● Applicable

○ May be applicable w/ careful design

X Must be addressed in O&M Plan

* Rain gardens, bioretention areas, and pervious paver/pavement systems may provide recharge, if designed without underdrains to meet infiltration practice requirements.

Table 3-2. Best Management Practice Selection (Factors)

BMP Type	Best Management Practice	Chapter Env-Wq 1500 Reference	Physical Feasibility Factors: Drainage Area (acres) 0-5	5-10	10-25	25-50	50+	Soil Infiltration Capacity (inches per hour) <0.15	≥0.15 and ≤6.5	>6.5	Depth to High Water Table / Depth to Bedrock* 0-3 ft	3+ ft	Land Area: Requires Large Land Area	Requires Small Land Area	Slope	Maintenance Sensitivity
Low Impact Development (LID)																
	Site Management Practices															
	Comprehensive LID Site Design		●	●	●	●	●	●	●	●	●	●		●		◇
	Disconnect Impervious Area		●	●	●	●	●	●	●	●	●	●		●		◇
	Minimize Disturbance Area		●	●	●	●	●	●	●	●	●	●		●		◇
	Minimize Site Imperviousness		●	●	●	●	●	●	●	●	●	●		●		◇
	Flow Path Practices		●	●	●	●	●	●	●	●	●	●		●		◇
	Preserve Infiltratable Soils		●	●	●	●	●	●	●	●	●	●		●		◇
	Preserve Natural Depression Areas		●	●	●	●	●	●	●	●	●	●		●		◇
	Other: Natural Vegetation Preservation, Soil Amendment		●	●	●	●	●	●	●	●	●	●		●		◇
	Interception or Recharge Practices (constructed BMPs)															
	Green Roof							●	●	●	●	●		●		◈
	Rain Barrel/Cistern (with on-site re-use)		●	●	●	●	●	●	●	●	●	●		●		◇
	Rain Garden/Bioretention		●					○	●	●	●	●		●	<15%	◆
	Pervious Pavers/Pervious Pavement		●	●	●	●	●	○	●	●	○	●			<15%	◆
Source Control BMPs																
	Street Sweeping		●	●	●	●	●	●	●	●	●	●				◆
	Snow and Ice Management		●	●	●	●	●	●	●	●	●	●				◆
Treatment BMPs																
	Stormwater Ponds	1508.03														
	Dry Extended Detention Pond With Micropool							●	○	○	●	○	●			◇
	Wet Pond							●	○	○	●	○	●			◇
	Wet Extended Detention Pond							●	○	○	●	○	●			◇
	Multiple Pond System							●	○	○	●	○	●			◇
	Pocket Pond							●	○	○	●	○		●		◇
	Stormwater Wetlands	1508.04														
	Shallow Wetland							●	○	○	●	○				◈
	Extended Detention Wetland							●	○	○	●	○	●			◇
	Pond/Wetland System							●	○	○	●	○		●		◇
	Gravel Wetland							●	○	○	●	○				◈
	Infiltration Practices	1508.05														
	Infiltration Trench and Drip Edge		●	●					●	○		●		●	<15%	◆
	In-ground Infiltration Basin			●	●	●			●	○		●	●		<15%	◆
	Underground Infiltration Basin		●						●	○		●			<15%	◆
	Dry Well		●						●	○		●		●	<15%	◆
	Permeable Pavement		●	●	●	●	●		●	○		●			<15%	◆

Table 3-2. Best Management Practice Selection (Factors)

BMP Type	Best Management Practice	Chapter Env-Wq 1500 Reference	Physical Feasibility Factors: Drainage Area (acres) 0-5	5-10	10-25	25-50	50+	Soil Infiltration Capacity (inches per hour) <0.15	≥0.15 and ≤6.5	>6.5	Depth to High Water Table / Depth to Bedrock* 0-3 ft	3+ ft	Land Area: Requires Large Land Area	Requires Small Land Area	Slope	Maintenance Sensitivity
Treatment BMPs, Continued																
	Filtering Practices	1508.06														
	Surface Sand Filter		●	●				●	●	●	●	●				◆
	Underground Sand Filter		●	●				●	●	●	●	●				◆
	Bioretention System (underdrained)		●					●	●	●	●	●		●		◆
	Permeable Pavement (with sand bed, underdrain, and piped outlet)		●	●	●	●	●	●	●	●	●	●				◆
	Flow-Through Treatment Swale	1508.07									○	●				◇
	Vegetated Buffer (vegetated filter strip)	1508.08														
	Residential or Small Pervious Area Buffer		●					●	●	●	●	●	●		<15%	◈
	Developed Area Buffer		●					●	●	●	●	●	●		<15%	◈
	Buffers on Downhill Side of Roadway		●					●	●	●	●	●	●		<20%	◈
	Ditch Turn-out Buffer		●					●	●	●	●	●	●		<15%	◈
	Other practices	1508.09														
Pretreatment BMPs																
	Sediment Forebay	1508.10	●	●	●	●	●	●	●	●	●	●		●		◇
	Vegetated Filter Strip	1508.11	●					●	●	●	●	●	●			◈
	Pre-treatment Swale	1508.12						●	●	●	●	●		●		◇
	Flow-through Structures	1508.13														
	Water Quality Inlet		●					●	●	●	●	●		●		◆
	Proprietary Devices		●					●	●	●	●	●		●		◆
	Deep-sump Catch Basin	1508.14	●					●	●	●	●	●		●		◆
Groundwater Recharge Practices		1508.15														
	Infiltration Practices	1508.05	●	●	●	●	●		●	●		●			<15%	◆
	Filtering Practices Which Include Infiltration	1508.06	●	●					●	●	●	●			<15%	◆
	Permeable Surfaces		●	●	●	●	●		●	●		●			<15%	◆
Conveyance Practices																
	Detention Basin	1508.16		●	●	●	●	●	●	●	●	●	●			◇
	Stone Berm Level Spreader	1508.17	●					●	●	●	●	●			<15%	◆
	Conveyance Swale	1508.18						●	●	●	●	●				◇
	Terraced Slopes or Benching	1508.19														◇
	Flow Splitters		●	●	●	●	●	●	●	●	●	●				◇
	Permanent Outlet Protection		●	●	●	●	●	●	●	●	●	●				◈

● Applicable
○ May be applicable w/ careful design
* See Table 3-4 for a summary of BMP restrictions associated with high load and protected resources.

Maintenenance Sensitivity - a practice's susceptibility to reduced performance if not adequately maintained.
◆ Significant
◈ Moderate
◇ Least

- Land Use
- Physical Feasibility
- Watershed Resources
- BMP Capabilities
- Maintenance
- Community and Environmental Factors

The following sections discuss how these factors affect the selection of BMPs. Please note that the following discussion is intended as general guidance. The design and review of stormwater management systems must consider a wide range of factors that affect design, and final selection of BMPs will require professional judgment based on site-by-site analysis of stormwater management objectives and applicable constraints.

3-1. Land Use Criteria

Nearly any BMP can be adapted for a particular land use, as long as the physical feasibility factors discussed under Section 3-2 can be met. However, there are some land uses, specifically high-load areas and water supply areas where the use of some BMPs are restricted to avoid potential contamination of water resources. These uses are described below, followed by a summary table of restrictions for BMP implementation in these areas (Table 3-3).

High-Load Areas

High-load areas are defined as:

1. Any land use or activity in which regulated substances are exposed to rainfall or runoff, with the exception of road salt applied for deicing of pavement on the site;
2. Any land use or activity that typically generates higher concentrations of hydrocarbons, metals or suspended solids than are found in typical stormwater runoff, including but not limited to:
    - Industrial facilities subject to the NPDES Multi-Sector General Permit, not including areas where industrial activities do not occur, such as at office buildings and their associated parking facilities or in drainage areas at the facility where a certification of no exposure pursuant to 40 CFR §122.26(g) will always be possible;
    - Petroleum storage facilities;
    - Petroleum dispensing facilities;

- Vehicle fueling facilities;
- Vehicle service, maintenance and equipment cleaning facilities;
- Fleet storage areas;
- Public works storage areas;
- Road salt facilities;
- Commercial nurseries;
- Non-residential facilities with uncoated metal roofs with a slope flatter than 20%;
- Facilities with outdoor storage, loading, or unloading of hazardous substances, regardless of the primary use of the facility; and
- Facilities subject to chemical inventory under Section 312 of the Superfund Amendments and Reauthorization Act of 1986 (SARA).

Water Supply Areas

Water supply areas include water supply wells, groundwater protection areas and water supply intake protection areas, which are defined below. The locations of water supply wells and groundwater protection areas are available from the NHDES OneStop GIS website.

Water Supply Well – as defined under RSA 482-B:2, a water supply well used as a source of water for human consumption and is not a public water supply.

Groundwater Protection Areas – wellhead protection areas (WHPAs) for community and non-transient, non-community public water supply wells; and areas of groundwater reclassified as GA1 or classified as GA2 pursuant to RSA 485-C and Env-Wq 401 or successor rules, Env-Dw 901.

Water Supply Intake Protection Areas – areas within 250 feet from the normal high water mark of a surface water source or its tributaries within ¼ mile radius of an intake point, excluding areas outside the watershed of the surface water.

Tables 3-3 and 3-4 summarize setback distances and other restrictions on BMPs installed in the vicinity of water supply resources.

Table 3-3. Water Supply Well Set-Backs		
Well Type	**Well Production Volume (gallons per day)**	**Setback from Well (feet)**
Private Water Supply Well	Any Volume	75
Non-Community Public Water Supply Well	0 to 750	75
	751 to 1,440	100
	1,441 to 4,320	125
	4,321 to 14,400	150
Community Public Water Supply Well	0 to 14,400	150
Non-Community and Community Public Water Supply Well	14,401 to 28,800	175
	28,801 to 57,600	200
	57,601 to 86,400	250
	86,401 to 115,200	300
	115,201 to 144,000	350
	Greater than 144,000	400

3-2. Physical Feasibility Factors

Physical site constraints such as the infiltration capacity of the soil, depth to bedrock or water table, size of the drainage area, and slope can limit the selection of stormwater BMPs. Depending on the physical site constraints, certain BMPs may be too costly to install or may be ineffective. Physical feasibility factors are described below with their applicability to BMP selection summarized in Table 3-2.

Soil Infiltration Capacity

Soil infiltration capacity affects the design of stormwater management systems in several ways:

- In designing a site to minimize the generation of runoff, it is easier to maintain or mimic the natural hydrology of a site if impervious surfaces are located over areas that naturally have low infiltration capacity. This in turn helps minimize the loss of natural infiltration and/or preserves higher-capacity soils for the siting of BMPs designed to promote infiltration;

- Soils infiltration capacity must be evaluated to determine whether infiltration practices can be used to remove pollutants from stormwater runoff or recharge stormwater runoff. If soil infiltration rates do not fall within accepted ranges (see Table 3-5), then the top three feet, or more of soil must be amended to fall within these ranges or other BMPs will be required to provide water quality treatment.

<table>
<tr><th colspan="3">Table 3-4. Summary of BMP Restrictions Associated with High-Load and Protected Resources</th></tr>
<tr><th>Protected Resources</th><th>Stormwater from High-load Areas</th><th>Stormwater From Non High-load Areas</th></tr>
<tr><td rowspan="2">All Areas</td><td>• No filtering or infiltration practices allowed from gasoline dispensing areas under regulated RSA 146-A or RSA 146-C
• Use of unlined detention ponds or unlined swales prohibited
• Source control plan required[1]</td><td>• Pretreatment is required prior to all filtering or infiltration practices
• Infiltration practices must have 3’ of separation from the bottom of the practice to the SHWT
• Filtering practices must have an impermeable liner or 1’ of separation from the bottom of the filter course to the SHWT</td></tr>
<tr><td colspan="2">• No infiltration or unlined filtering practices within areas identified by NHDES with contaminated soils or groundwater, as defined under Env-Or 600.</td></tr>
<tr><td rowspan="2">Water Supply Wells</td><td colspan="2">• Minimum setbacks between stormwater discharge and water supply wells (see Table 3-3)</td></tr>
<tr><td>• No Exemption to minimum setbacks</td><td>• Exemption to minimum setbacks – if the stormwater management system receives runoff from less than 0.5 ac.</td></tr>
<tr><td>Groundwater Protection Areas</td><td>• Infiltration practices prohibited
• Unlined filtering practices prohibited</td><td>• Infiltration practices must have 4’ of separation from the SHWT
• Filtering practice should have:
• impermeable liner, or
• 1’ 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</td></tr>
<tr><td rowspan="2">Water Supply Intake Protection Areas</td><td colspan="2">• Infiltration practices must have 4’ of separation from SHWT
• Filtering practice should have:
  • Impermeable liner, or
  • 1’ 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
• Minimum 100’ setback between stormwater discharge and the WSIPA</td></tr>
<tr><td>• Shut-off mechanism required where bulk oil or hazardous material is transferred</td><td>• Exemption to 100’ setback – if the stormwater management system receives runoff from less than 0.5 ac.</td></tr>
</table>

[1] “Source control plans” are designed to minimize the volume of stormwater coming into contact with regulated substances. Chapter 5 provides further discussion of the preparation of the Source Control Plan to specify necessary structural controls and/or operational practices to minimize contact between stormwater and regulated substances.

- Soils infiltration capacity is ultimately used in the sizing of infiltration practices when they are applicable, with soils with low infiltration capacity requiring more surface area than those with high infiltration capacity to treat the same volume of water.

The applicability of infiltration practices and groundwater recharge are summarized in Table 3-5. See Chapter 2 for a discussion on selecting a design infiltration rate.

Water Table

Table 3-5. Infiltration practices, Unlined Filtering Practices, and Groundwater Recharge Practices should not direct stormwater into the following areas:
Into groundwater protection areas where the stormwater comes from a high-load area;
Into areas that have contaminants in groundwater above the ambient groundwater quality standards established in Env-Or 603.03 or into soil above site-specific soil standards developed pursuant to Env-Or 600;
Into areas where the stormwater comes from areas that have contaminants in soil above site-specific soil standards developed pursuant to Env-Or 600;
Into areas where the stormwater comes from areas with underground storage tanks regulated under RSA 146-C or aboveground storage tanks regulated under RSA 146-A, where gasoline is dispensed or otherwise transferred to vehicles;
Into areas with slopes greater than 15%, unless the system has been carefully engineered to prevent seepage forces from causing instability.
Into areas where the infiltration rate is less than 0.5 inches per hour. If a filtering practice is used, an underdrain should be placed to assist draining
Untreated stormwater should not be infiltrated into soils where the rate is too rapid to provide treatment.

The depth to the seasonal high water table will influence the selection of BMP practices to manage stormwater runoff. High groundwater may be appropriate for some BMPs where a permanent pool is required, since the interception of groundwater will aid in maintaining such a pool. Other BMPs, such as infiltration structures, may not be appropriate if the separation between the bottom of the infiltration device and groundwater table is not sufficient to allow for water to drain from the device and to adequately remove pollutants from stormwater runoff. Table 3-2 summarizes the appropriateness of BMPs relative to the seasonal high water table.

Drainage Area

Large drainage areas typically result in a greater volume and velocity of stormwater runoff than small drainage areas. Some types of stormwater BMPs can be sized to handle the contributing volume of stormwater runoff from both small and large drainage areas. However, some BMPs provide more efficient treatment and are more appropriate for small drainage areas. Also, other BMPs (such as treatment ponds or wetlands) rely on larger drainage areas to help sustain permanent pools included in their design. The applicability of BMPs to certain size drainage areas is summarized in Table 3-2.

Slope

Water flows down hill. The steeper the slope, the faster the water flows. Sites with steep slopes are more susceptible to erosion and the generation of sediment loads due to the increased velocity of the stormwater. In selecting a stormwater BMP, the slope at and adjacent to the treatment practice, the slope of the contributing drainage area, and the flow path should all be considered. The applicability of BMPs to various slopes is summarized in Table 3-2.

3-3. Watershed Resource Factors

It is important to look not only at the impacts the development will have at a site, but also how downstream resources may be impacted by development activities. Table 3-6 summarizes the downstream water resources that should be considered when selecting stormwater BMPs. Each of these resources is discussed further below.

Table 3-6. Watershed Resource Criteria

Sensitive Receiving Waters	If cold water fisheries are present, select BMPs that will reduce thermal impacts.
Water Supplies: Aquifers Maximize infiltration following setbacks in Table 3-3.	Maximize infiltration following setbacks in Table 3-3.
Surface Water Supplies & Lakes and Ponds	Select BMPs with high phosphorus and sediment removal to reduce the rate of eutrophication. Select BMPs with high bacteria removal when waters are used for recreation.
Estuary and Coastal Areas	Select BMPs with high nitrogen and bacteria removal to reduce closure of swimming beaches and shellfish beds.

Sensitive Receiving Waters

Impaired waters, outstanding resources waters (ORWs), coldwater fisheries, prime wetlands , and wetlands that have highly rated functions and values are a few examples of receiving waters that may be more sensitive to development activities and could require additional measures to protect or restore their unique properties. Toxic pollutants such as metals, soluble organic compounds, and bacteria are of particular concern for waters that could serve as future water supply sources. Rivers that support cold water fisheries are very sensitive to increases in water temperature, which are often caused by stormwater running over heated impervious surfaces that lack of sufficient buffers to provide shade. Downstream flooding and channel erosion are also important considerations.

Water Supplies: Aquifers and Surface Waters

Over 60 percent of New Hampshire residents rely on groundwater for their drinking water from either private wells or public water supply wells. Because of this, it is important to maintain pre-development groundwater recharge rates and to avoid groundwater contamination in order to maintain adequate, high quality groundwater supplies for drinking water, as well as to maintain dry weather base flows in streams and rivers. The remaining residents in the state are served by public surface water reservoirs. Surface water supplies are particularly susceptible to contamination by bacteria and other pollutants. Because of the potential for groundwater and surface water contamination of drinking water supplies, the NHDES has established BMP setback requirements (see discussion under "Land Uses") as summarized in Table 3-3 based on the type of water supply and withdrawal amount, and in Table 3-4 in relation to high-load areas.

Lakes and Ponds

Lakes, ponds, and other freshwater systems are more sensitive to phosphorus loading than salt water systems as phosphorus is typically the limiting nutrient in freshwater systems. Excess phosphorus in a freshwater system, such as a lake or a pond, can result in algal blooms and an increased rate of eutrophication. Because of this, development activities near lakes and ponds, as well as their tributaries, should include site design techniques and BMPs for sediment and nutrient removal.

Estuary and Coastal Areas

Estuaries and other coastal areas are more sensitive to nitrogen loading than freshwater systems as nitrogen is typically the limiting nutrient in salt water systems. The other major pollutant of concern in coastal waters is bacteria. New Hampshire's coastal beaches host nearly half a million visitors each year. New Hampshire coastal waters are also home to a variety of shellfish including clams and oysters. Public swimming beaches and shellfish beds are extremely sensitive to high bacteria levels and result in closures of swimming beaches and shellfish beds.

3-4. BMP Capability Factors

Various field and laboratory tests have determined average expected pollutant removal efficiencies for various management practices. These values, expressed as a percentage of the total load, are provided in Appendix B. As more studies are conducted and the amount of pollutant removal efficiency data grows, these estimates may change to more accurately reflect the level of stormwater treatment provided through these practices.

Pollutant removal efficiencies are dependent on many variables including proper selection, sizing and installation of the BMP, proper placement of the BMP on a site, and proper maintenance. Appendix B should be used in conjunction with Tables 3-1 and 3-2, to identify stormwater BMPs that will effectively meet the NHDES stormwater management objectives of groundwater recharge and total runoff volume reduction, stream channel protection, peak flow reduction, and pollutant load reduction.

3-5. Maintenance Factors

Regular Inspection and Maintenance

Regular inspections and maintenance are essential for long-term effectiveness of stormwater BMPs. BMPs are also very expensive to repair and replace. Sediment, trash, and other debris can accumulate in BMPs and needs to be removed periodically. If not properly maintained, the BMP will not operate as designed and will not provide effective treatment of stormwater runoff. This jeopardizes water quality and may violate permit conditions. All stormwater BMPs require maintenance, however, the frequency and difficulty of maintenance activities and the equipment needed to carry them out varies. Table 3-2 summarizes the relative level of maintenance required by each stormwater BMP. Inspectors and those overseeing or performing maintenance should be well trained and thoroughly familiar with the as-built plans for each BMP. They should be provided with detailed inspection and maintenance procedures, preferably developed by the designer who is familiar with the as-built plans.

Pretreatment

Pre-treatment devices, such as sediment forebays, can reduce the amount of sediment accumulation in the primary treatment device; however, pre-treatment practices also require maintenance. Inspections and maintenance for pretreatment devices may need to be more frequent, especially soon after construction, than the primary BMP.

Vegetated BMPs

Rain gardens, tree box filters, gravel wetlands and any BMPs with vegetation require special care. Water and fertilizer will be needed, especially when the vegetation is first established. Periodic watering may be necessary in times of drought. The amount of fertilizer used may need to be limited to the exact needs of the plants if the BMP is designed to remove nutrients. Drought or salt tolerant species may need to be specified when selecting vegetated BMPs.

Likelihood of Maintenance being Performed

Inspections and maintenance may not be assured. Even though requirements may be described in deeds, neighborhood association documents and performance bonds, the possibility exists the maintenance will not be performed. The chance of this happening increases when there is no oversight by a regulatory authority. An example would be a small non-MS4 community without a code enforcement officer. For these cases BMPs without any important routine maintenance and those that would not be costly to repair upon failure should be chosen. It may also make sense to have designs features that draw attention to the unit prior to failure, such as installing pretreatment devices in series.

Accessibility for Inspections

It is important to provide adequate access for all necessary inspections, monitoring and maintenance when designing or selecting BMPs. Below ground structures and sensitive BMPs (see below) require special design features including access manholes, clean outs, water level monitoring wells, etc. Infiltration chambers may also need groundwater (quality) monitoring wells to comply with Underground Injection Control (UIC) permit requirements. Difficult access situations, including those with safety concerns, must also be considered. These include BMPs in close proximity to buildings, high traffic areas, vegetated islands in stormwater wetlands/ponds and green roofs. Oil/water separation BMPs must also address confined space entry concerns.

Sensitive BMPs

BMPs or parts of them can be susceptible to damage during inspections and maintenance and due to environmental factors. Liners and steep side slopes of basins can be damaged when oversized vehicles are used to remove accumulated sediment. Sediment removal activities can damage many other BMPs as well, especially when vehicles such as backhoes are used. Loss of infiltration capacity is an important concern. Hand removal of sediment may be the best option. Environmental factors such as cold temperatures, human (vehicles and vandalism), salt runoff or salt air (corrosion), flooding and wildlife (damage to vegetation) should all be considered when designing or specifying BMPs to minimize maintenance requirements.

3-6. Community and Environmental Factors

It is important to think about how a stormwater BMP will fit into the community. Some community and environmental concerns that should be addressed in the selection and design of the BMP include:

- **Safety** – Does the BMP pose a safety risk? Knowledge of the surrounding community is needed to determine whether certain safety features need to be incorporated into the design and/or whether some types of BMPs should be avoided altogether. For example, deep water, as in wet ponds, may be unsuitable for a residential area with small children or may require fencing to prevent access.

- **Aesthetics** – Some BMPs are more attractive than others and can be designed to blend in with the existing or proposed landscape. The surrounding land use and users should be considered when selecting and designing a BMP. For example, will the BMP be visible? Who will see the BMP?

- **Habitat** – Some BMPs, such as stormwater ponds and wetlands, can provide wildlife and wetland habitat. The need for this habitat should be considered when selecting and designing the BMP.

- **Compatibility with Municipal Maintenance Programs** – Consider community needs when selecting and designing a BMP. If the community will be maintaining the BMP, make sure it is compatible with the community's available maintenance equipment and desired maintenance schedule.

- **Health Concerns** – Understand community concerns about mosquito breeding and the diseases carried by mosquitoes and consider these concerns when selecting and designing BMPs. BMPs with standing water for more than 72 hours may create breeding grounds for mosquitoes. Consider whether there is other standing water nearby and the surrounding land uses when deciding whether to use wet ponds, wetlands, or other BMPs with permanent standing water. When using BMPs that will have permanent pools, consider designs that maximize habitat for natural predators of mosquitoes.

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:

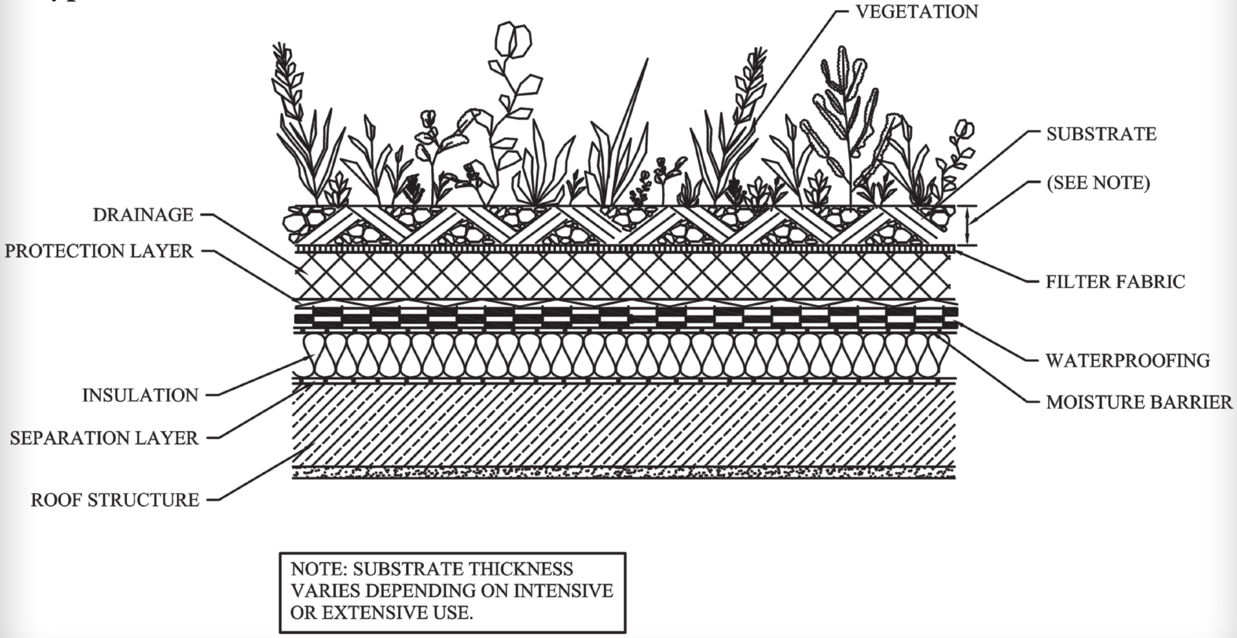
- Reduction of stormwater runoff from buildings through absorption, storage and evapotranspiration. This reduces overall peak flow discharge to a storm sewer system and can result in less in-stream scouring, lower water temperatures and better water quality;
- Reduction of urban heat island effects with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

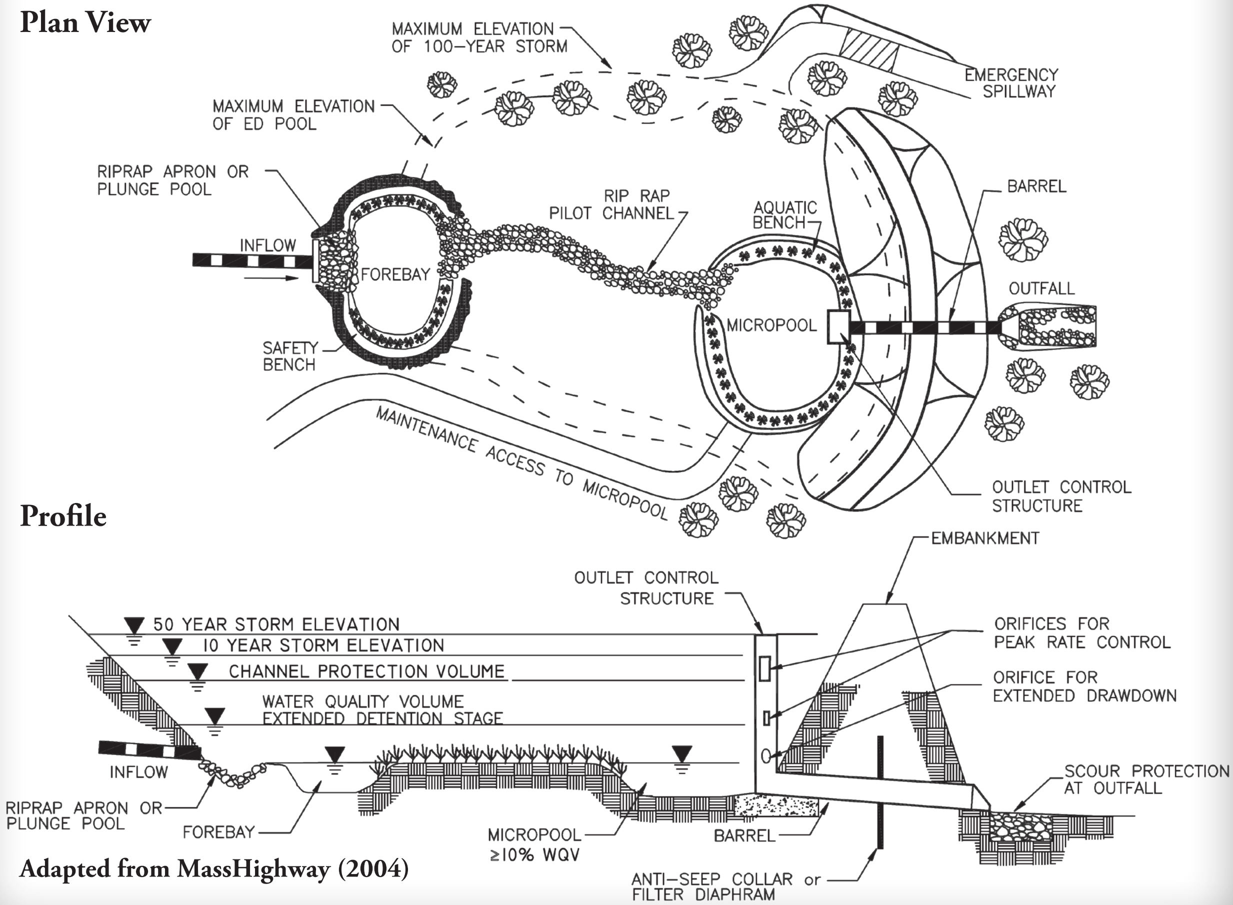
Maintenance Requirements

- 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



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

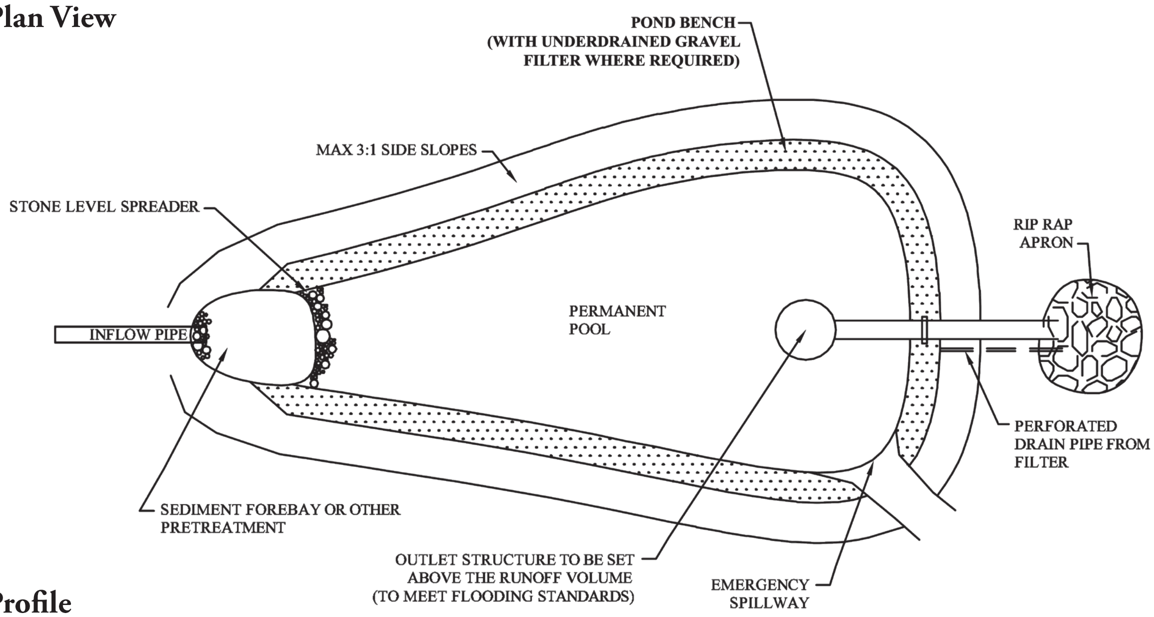
- Periodic mowing of embankments
- Removal of woody vegetation from fill embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

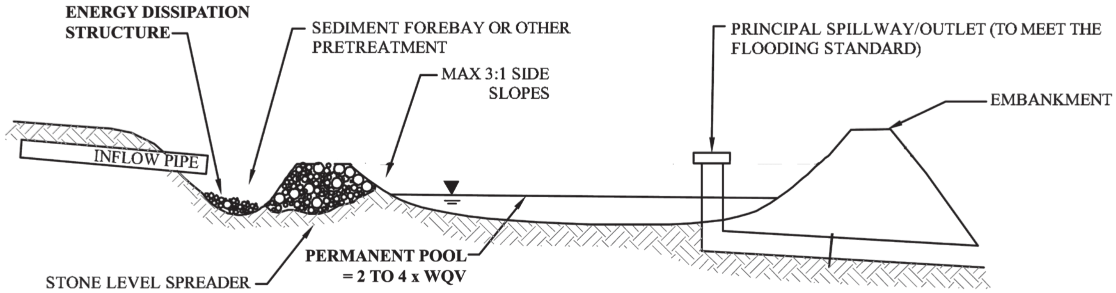
- Schueler (1987)
- Schueler, et al. (1992)
- EPA (1999f)

Example Design

Plan View



Profile



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

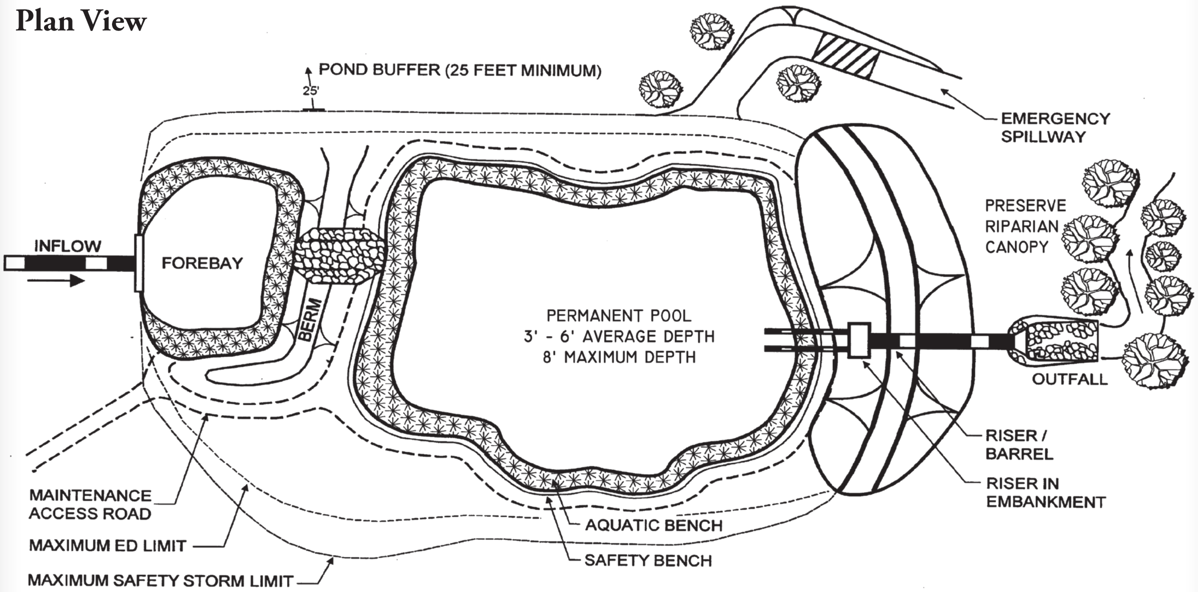
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, inlet and outlet structures, and appurtenances

Design References

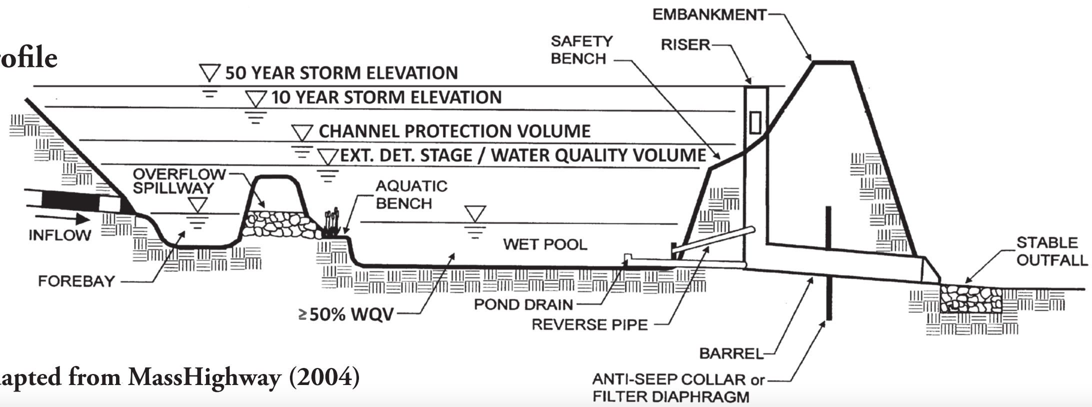
- Schueler (1987)
- Schueler, et al. (1992)
- EPA (1999f)

Example Design

Plan View



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
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

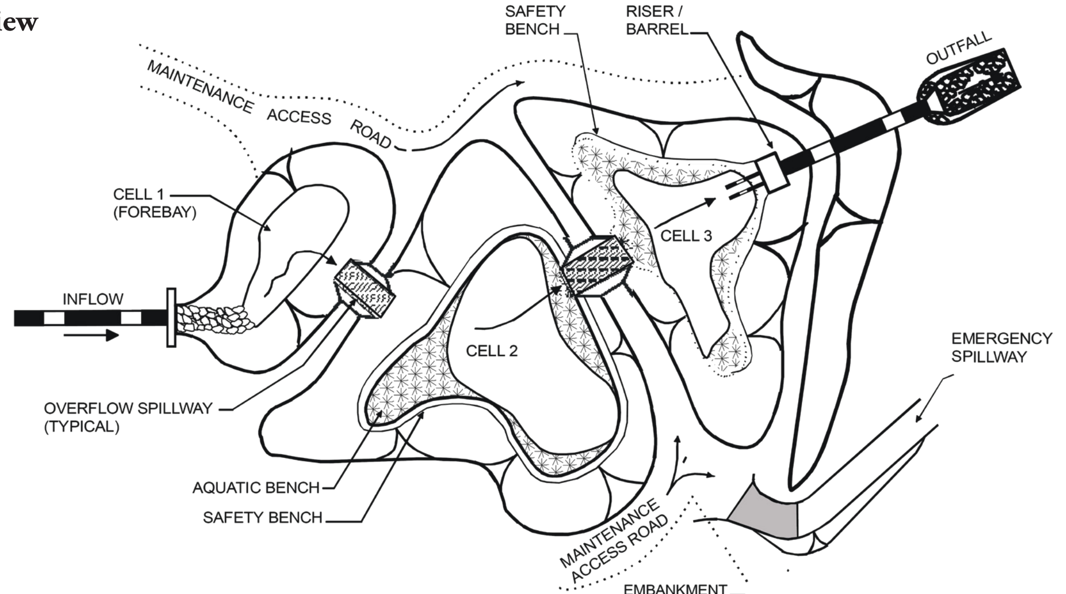
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, outlet structures, and appurtenances

Design References

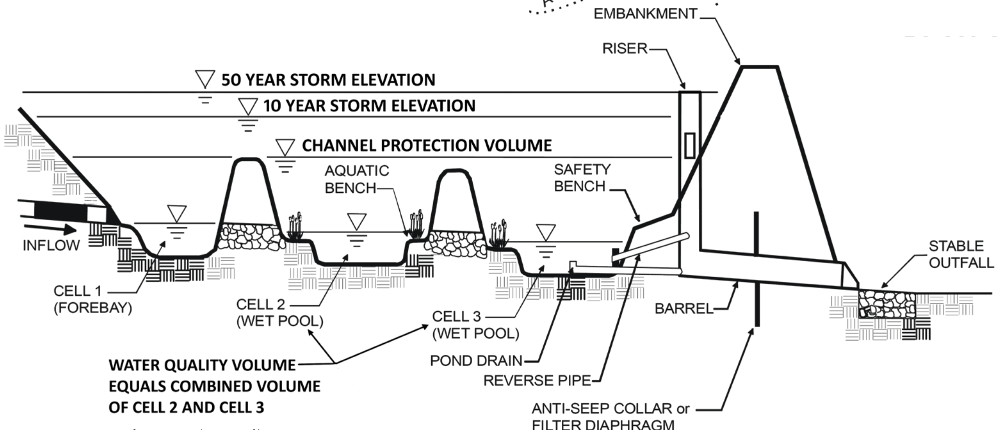
- Schueler (1987)
- Schueler, et al. (1992)

Example Design

Plan View



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 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

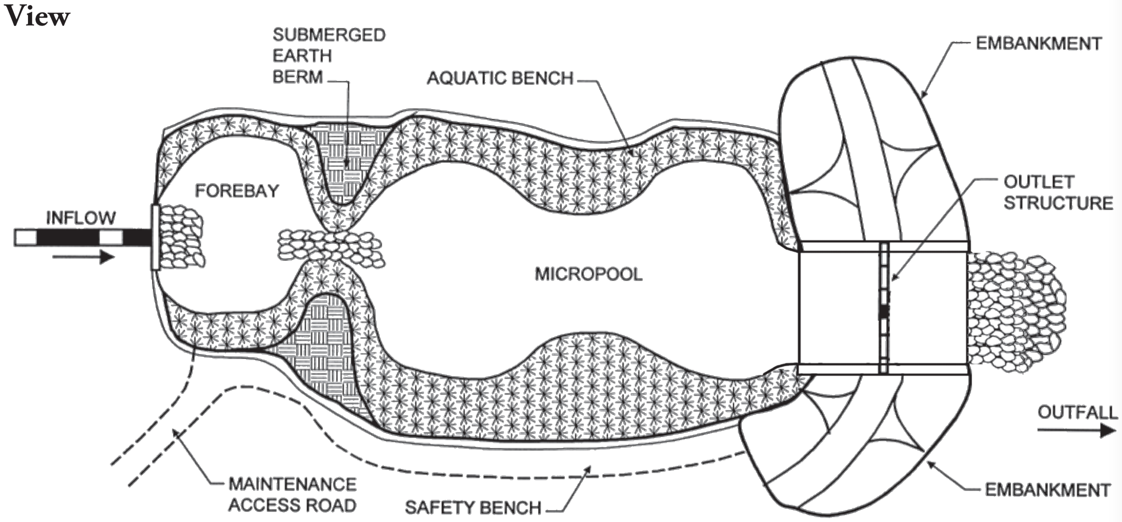
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection and repair of embankments, outlet structures, and appurtenances

Design References

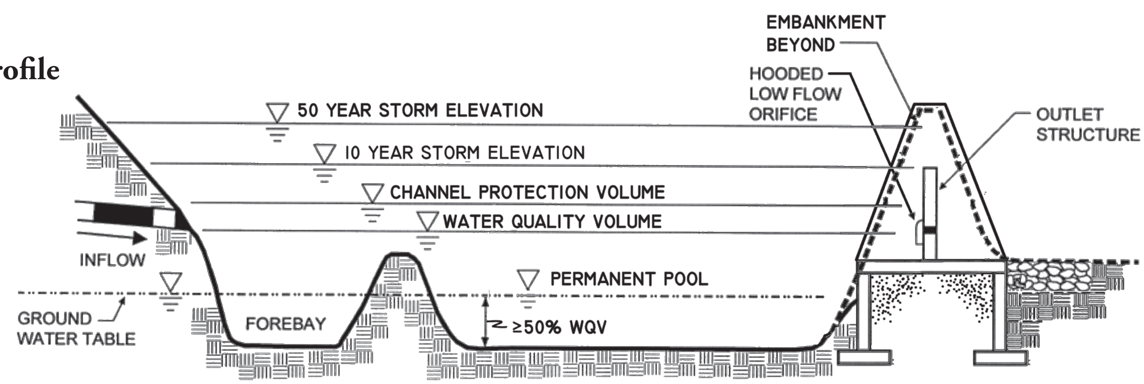
- Schueler (1987)
- Schueler, et al. (1992)

Example Design

Plan View



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
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

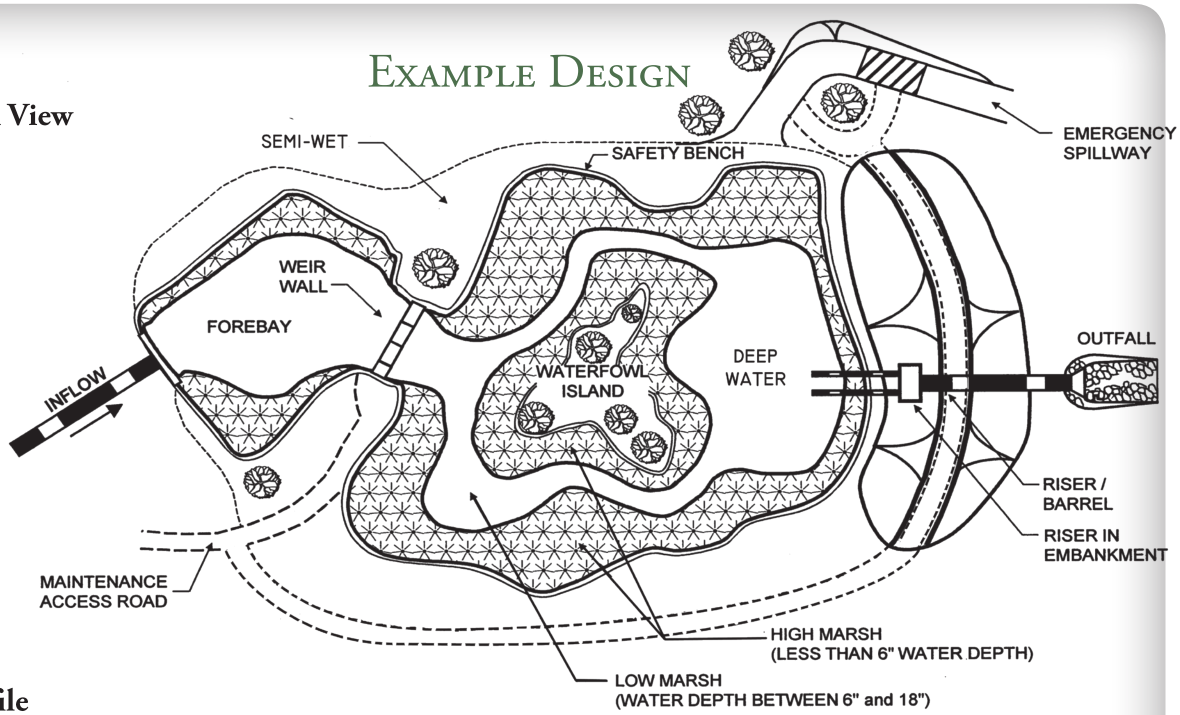
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of invasive species from semi-wet, marsh, and deepwater areas
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection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

Design References

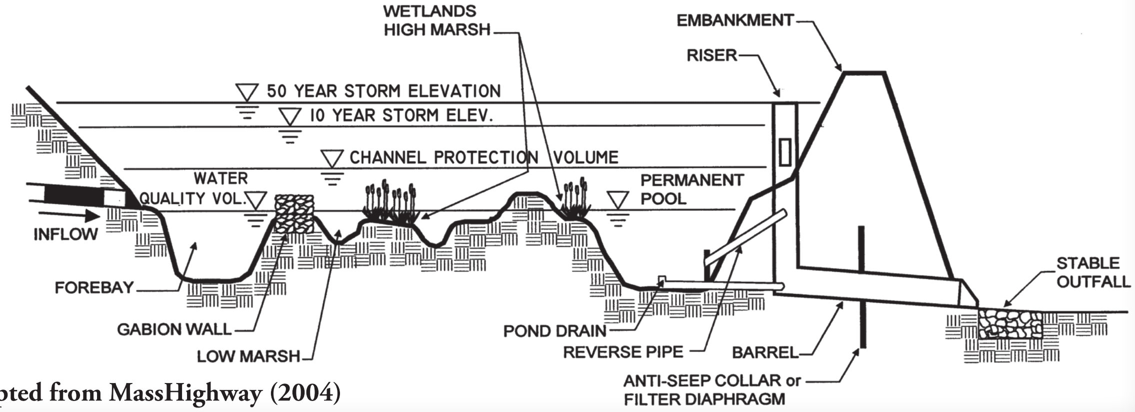
- Schueler (1992)
- Cappiella, et al. (2008)

Example Design

Plan View



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 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

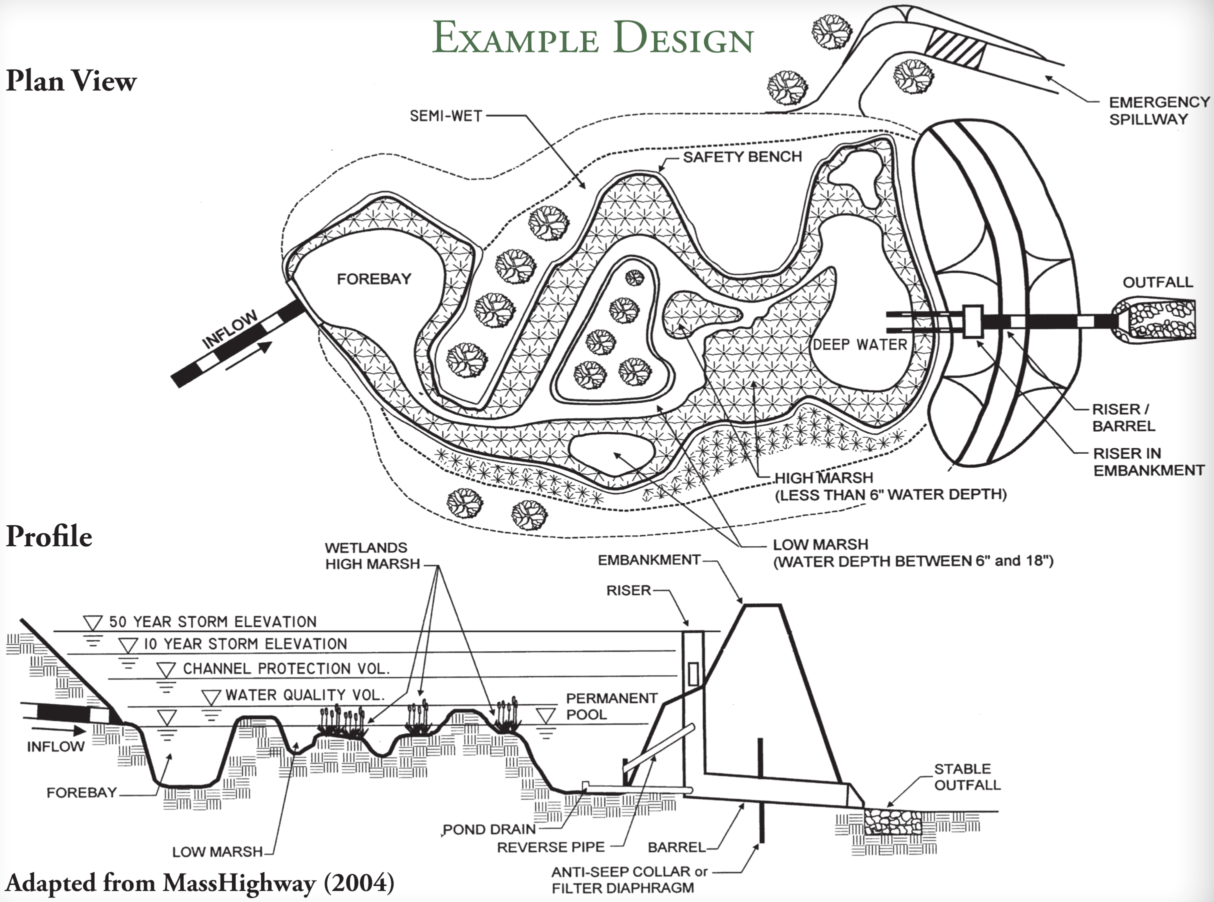
Maintenance Requirements

- 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



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

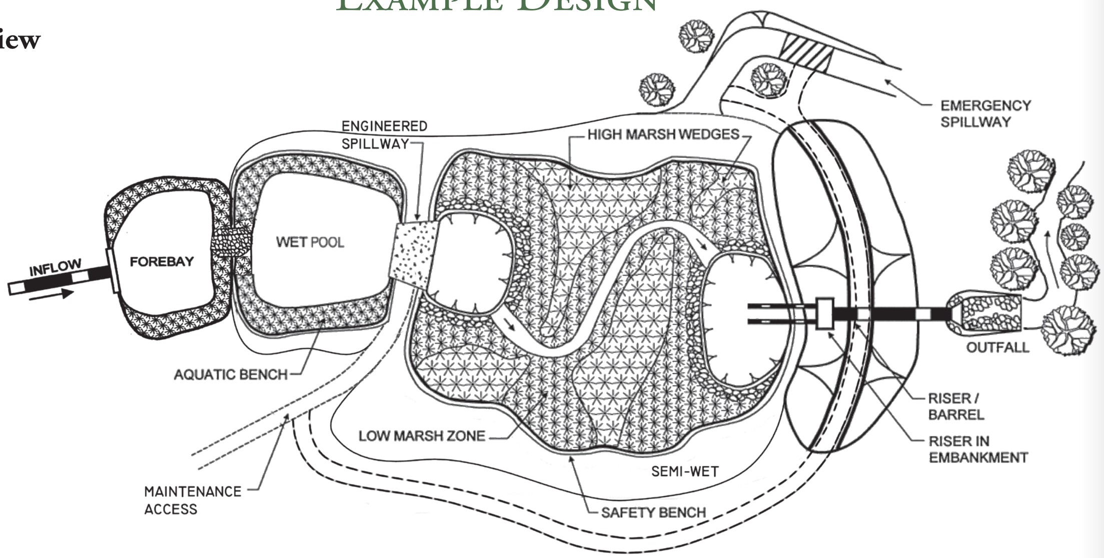
- Periodic mowing of embankments
- Removal of woody vegetation from embankments
- Removal of invasive species from semi-wet, marsh, and deepwater areas
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from outlet structures
- Removal of accumulated sediment
- Inspection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

Design References

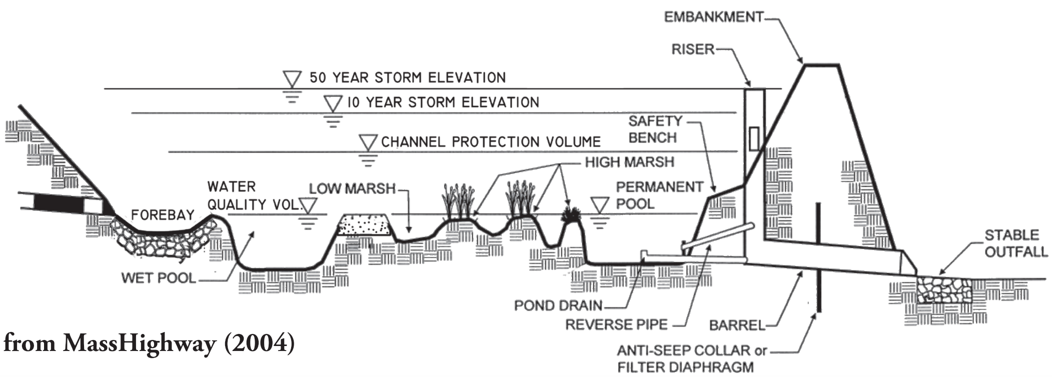
- Schueler (1992)
- Cappiella, et al. (2008)

Example Design

Plan View



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 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

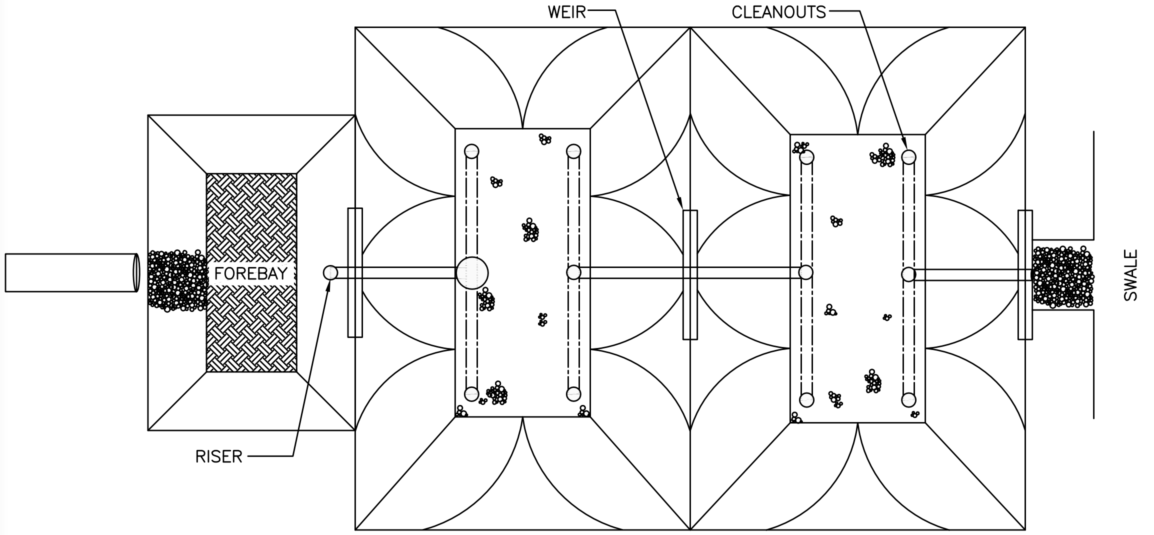
- Monitoring and replanting, as warranted, of wetland vegetation
- Removal of debris from inlet and outlet structures
- Inspection and removal of sediment accumulation in the gravel bed
- Depending on sediment accumulation, bed may require periodic replacement and replanting
- Inspection and repair of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

Design References

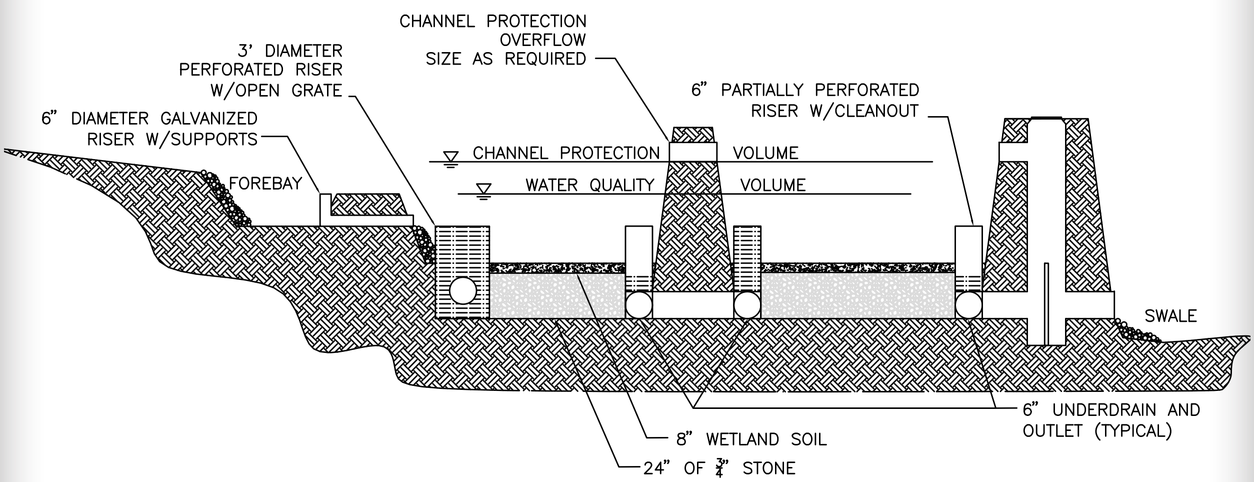
- UNH Stormwater Center

Example Design

Plan View



Profile



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

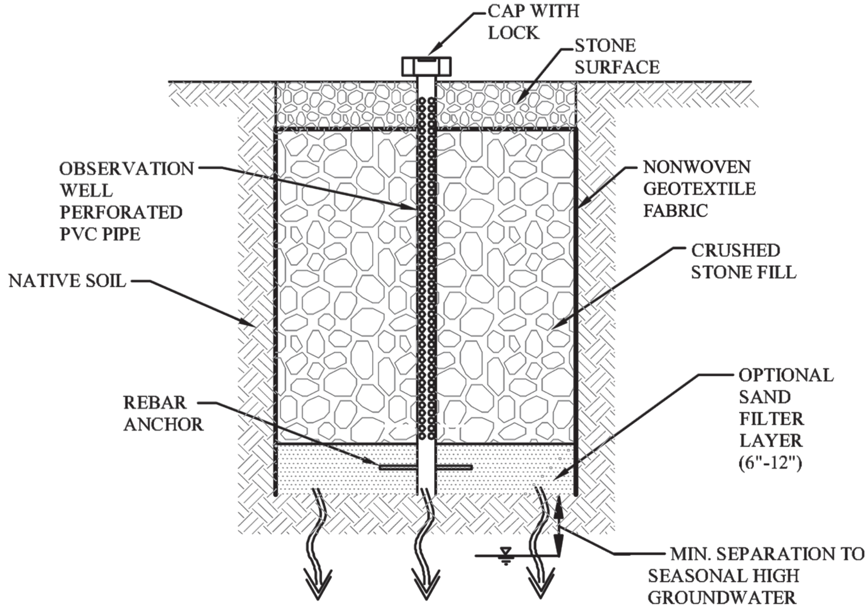
- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated 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

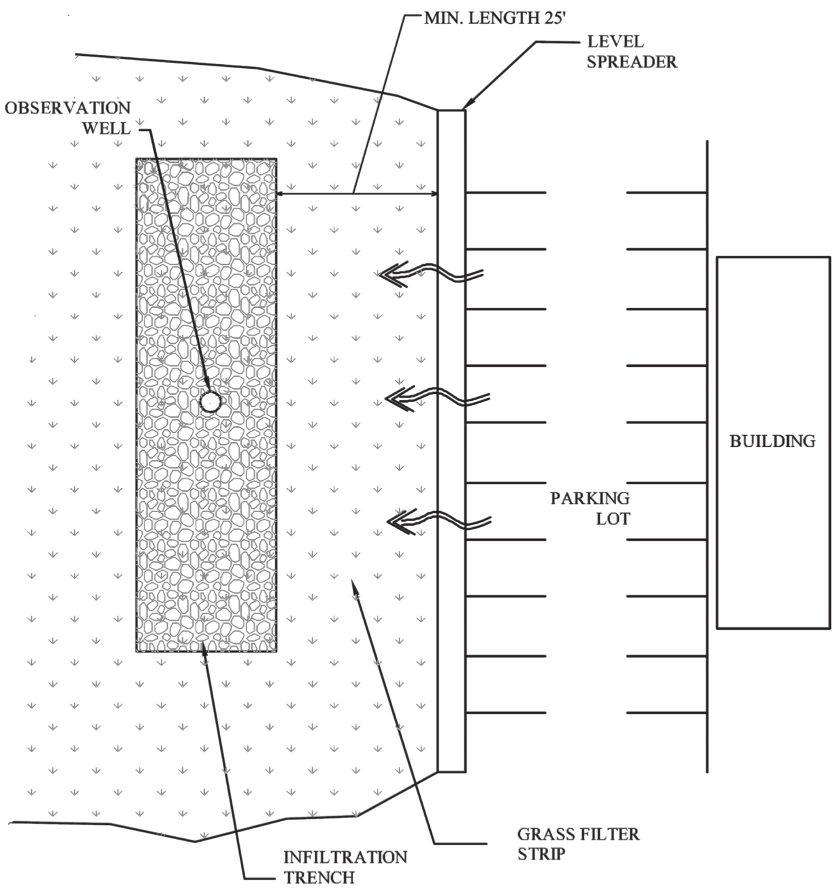
- Schueler (1987)
- Schueler, et al. (1992)
- Ferguson (1994)
- Sprecher (2008)

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

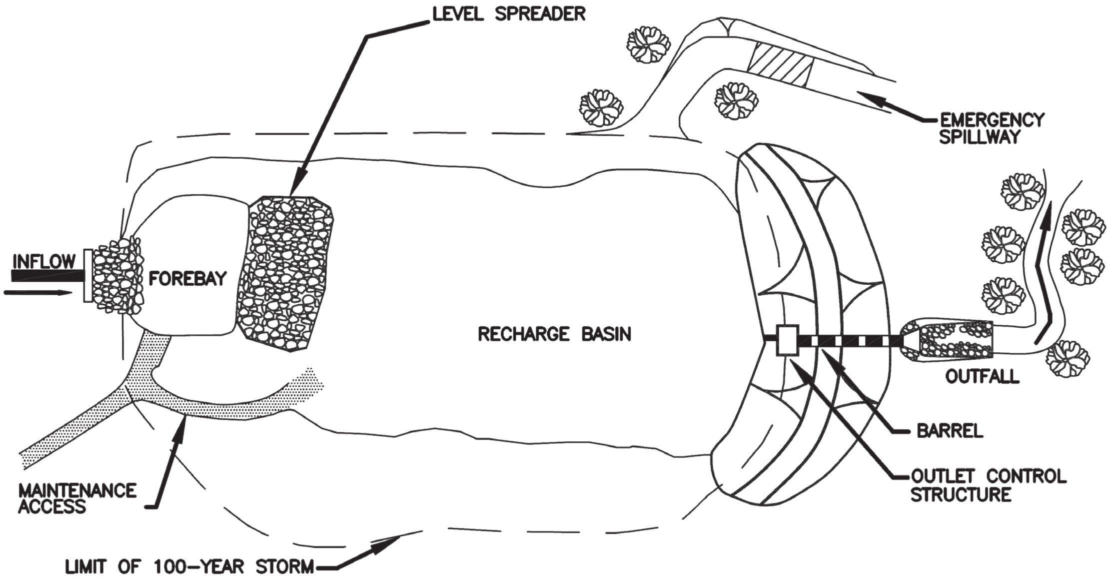
- Removal of debris from inlet and outlet structures
- Removal of accumulated sediment
- Inspection and repair of outlet structures and appurtenances
- Inspection of infiltration components at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance 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

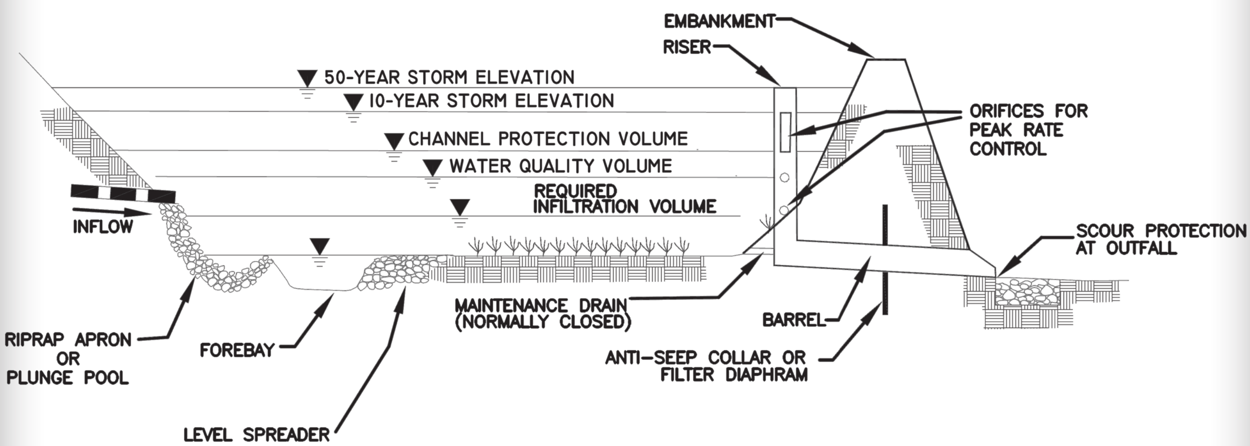
- Schueler (1987)
- Schueler, et al. (1992)
- Ferguson (1994)

Example Design

Plan View



Profile



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

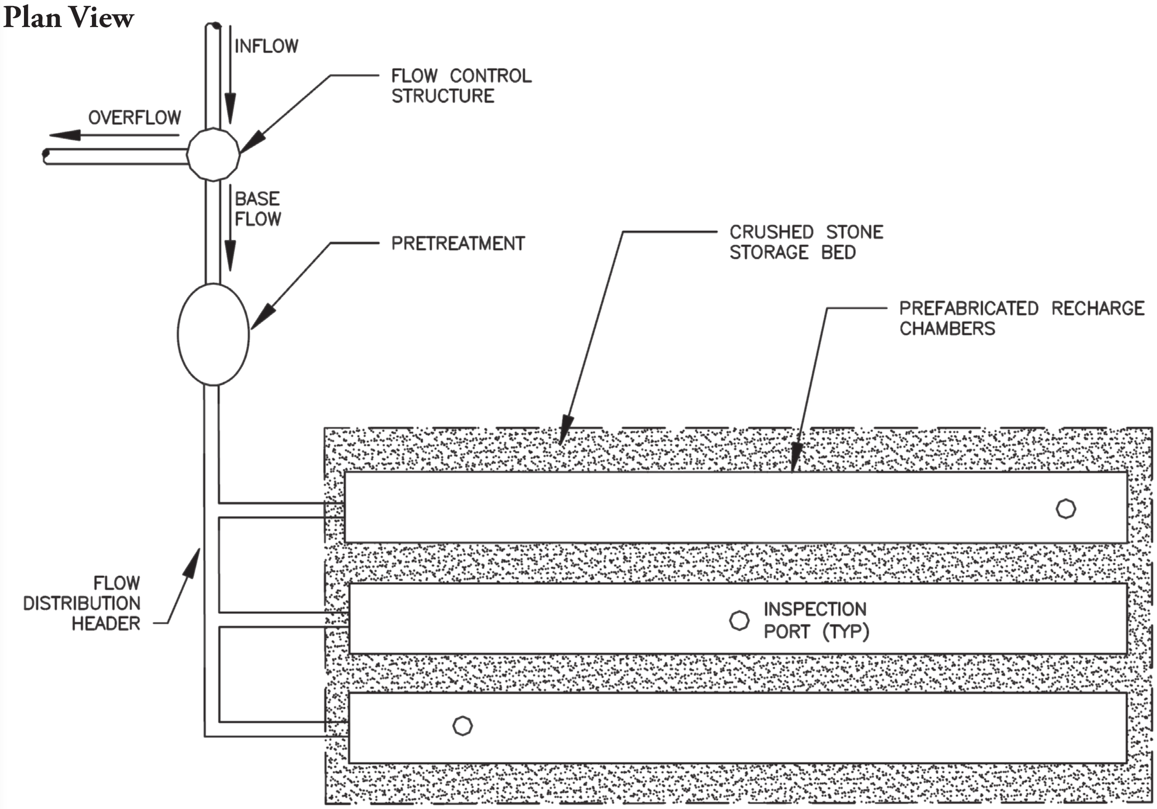
- Removal of debris from inlet and outlet structures
- Removal of accumulated sediment
- Inspection and repair of outlet structures and appurtenances
- Inspection of infiltration components at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance 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

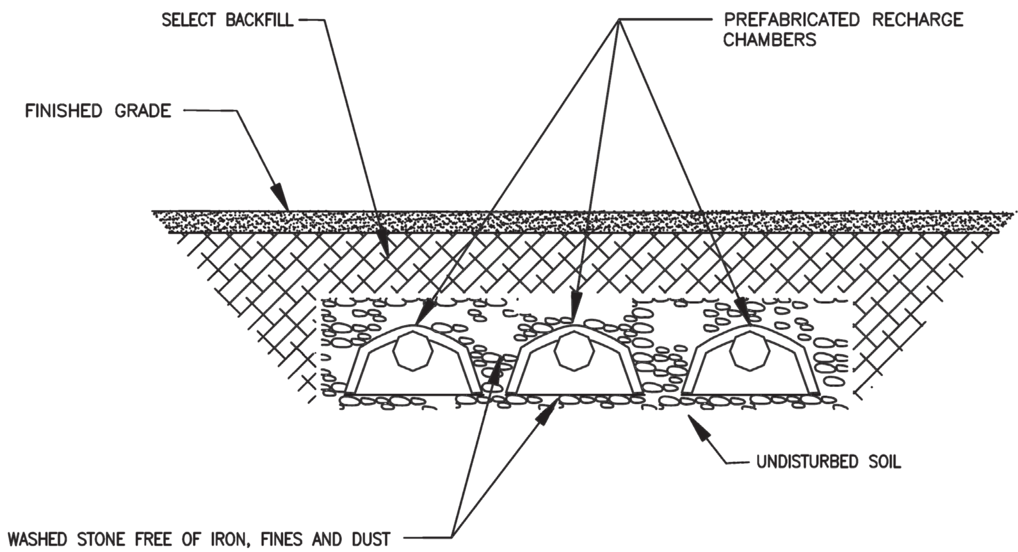
- Schueler (1987)
- Schueler, et al. (1992)
- Ferguson (1994)

Example Design

Plan View



Profile



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

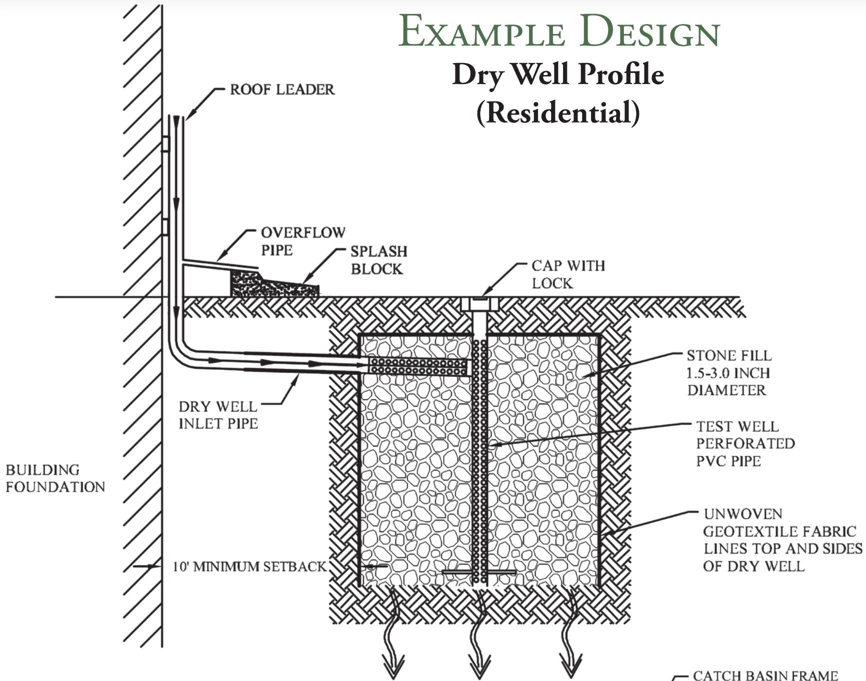
- Removal of debris from inlet and outlet structures
- Removal of accumulated sediment
- Inspection and repair of outlet structures and appurtenances
- Inspection of infiltration components at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance 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

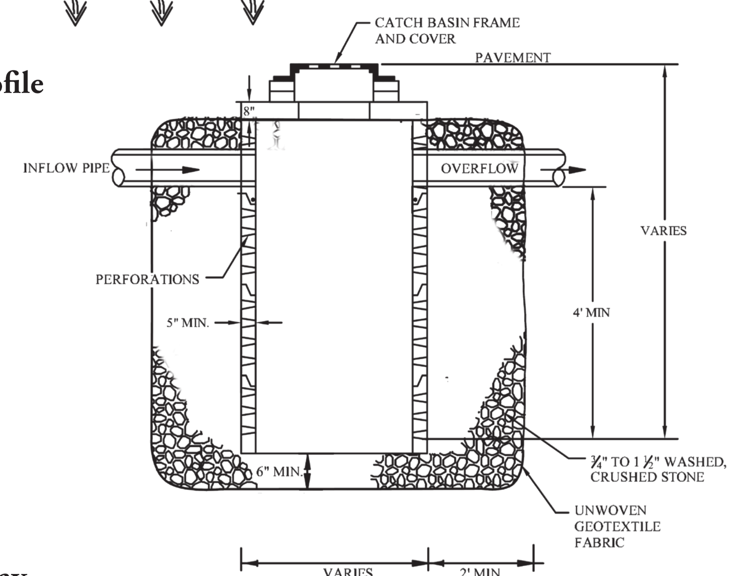
Design Parameter	Criteria
Pretreatment	Required (see Section 4-4)
BMP Volume	≥ the larger of WQV or GRV, depending on purpose of BMP excluding sediment forebay capacity, if present, and exclude infiltration occurring during the design event
Design Infiltration Rate	See Section 2-4 for a discussion on 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

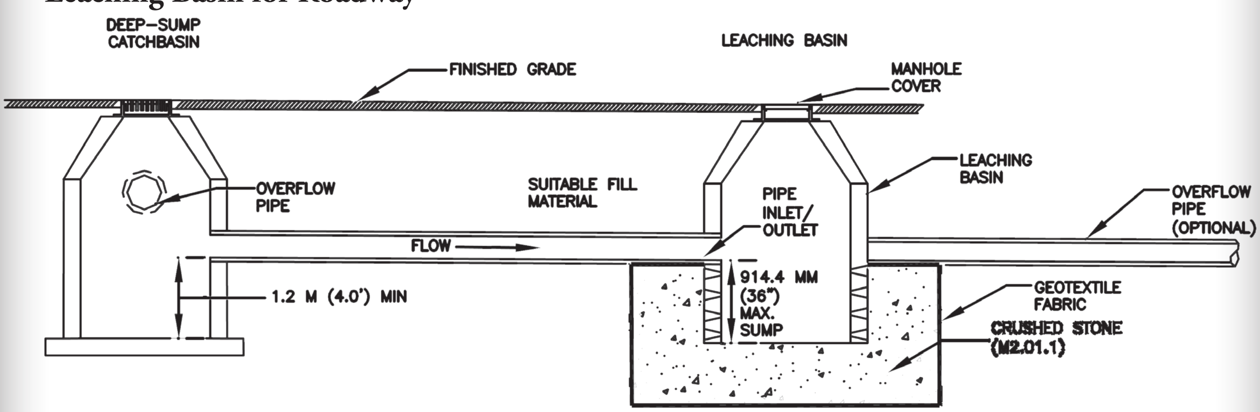
Dry Well Profile (Residential)



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

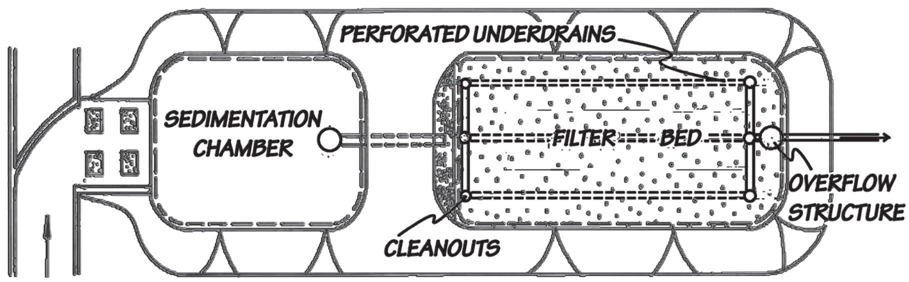
- Claytor & Schueler (1996)
- UNH Stormwater Center
- EPA (1999c)

Table 4-3. Filter Mixtures

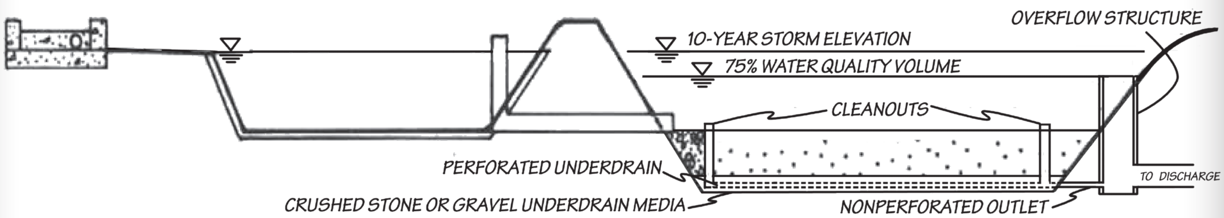
Component Material	Percent of Mixture by Volume	Gradation of Material	
		Sieve No.	Percent by Weight Passing Standard Sieve
Filter Media Option A			
ASTM C-33 concrete sand	50 to 55		
Loamy sand topsoil, with fines as indicated	20 to 30	200	15 to 25
Moderately fine shredded bark or wood fiber mulch, 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

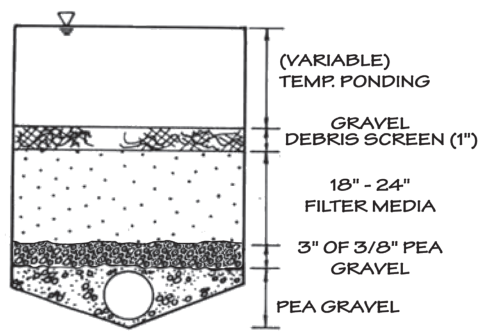
Plan View



Profile



Section



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:
    - 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.

Maintenance Requirements

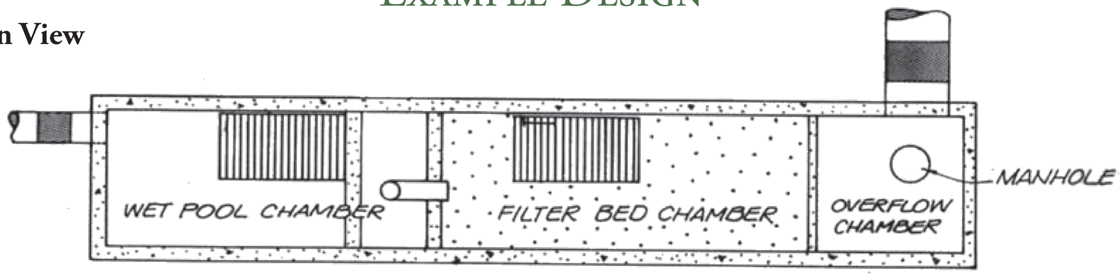
- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24 hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated 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

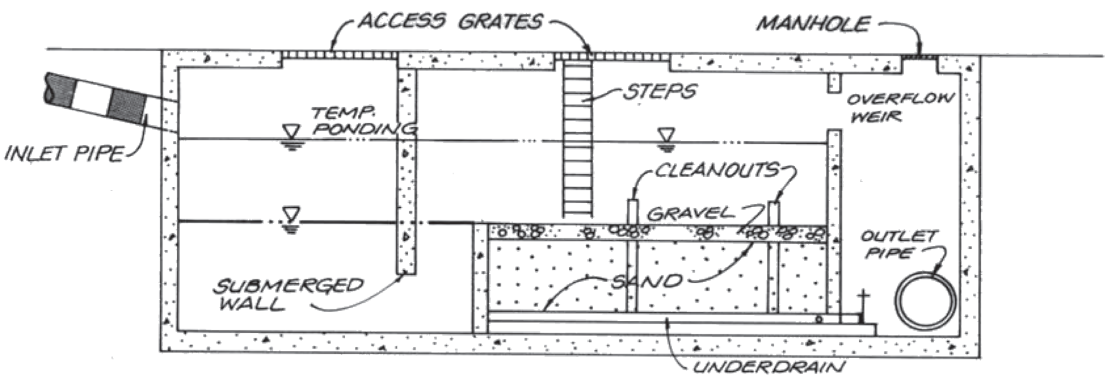
- Claytor & Schueler (1996)
- EPA (1999c)

Example Design

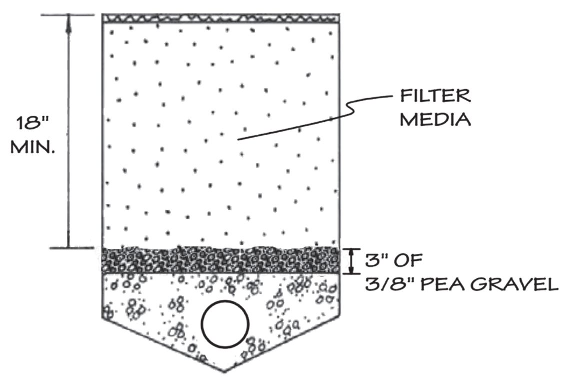
Plan View



Profile



Section



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

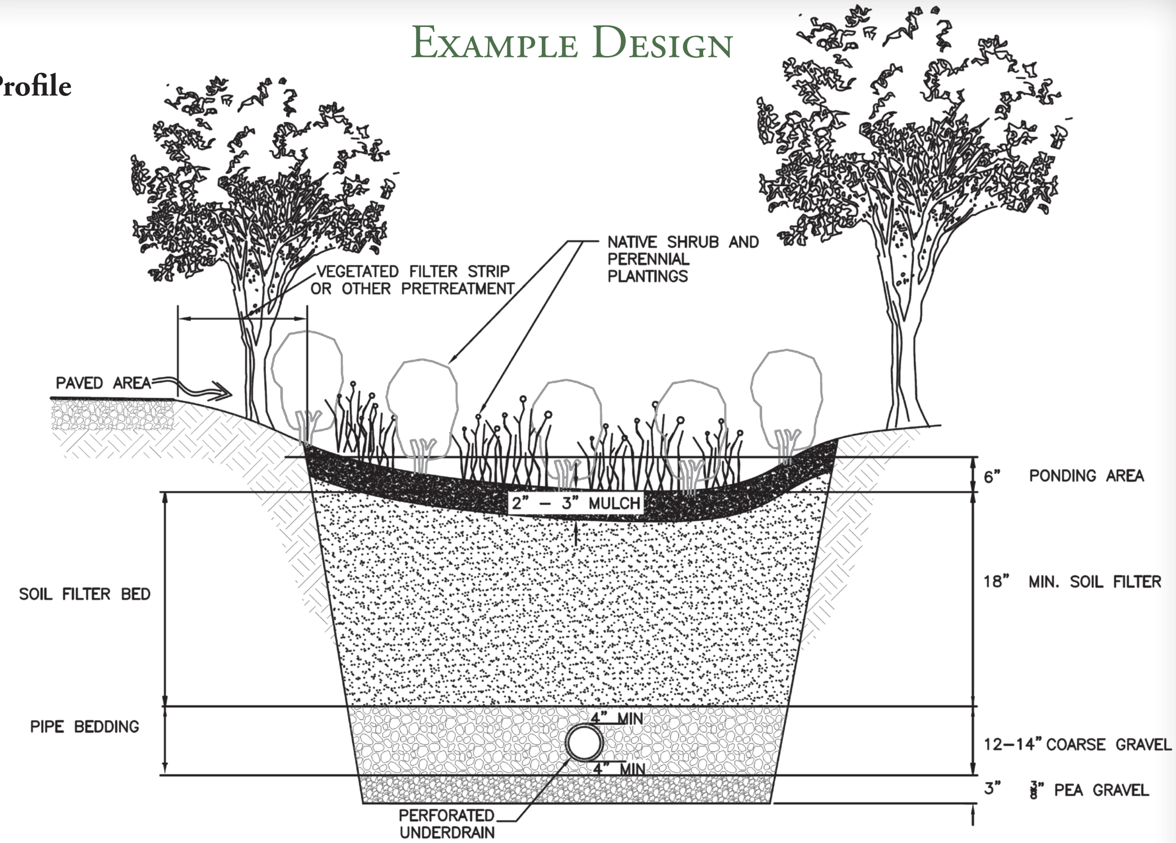
- UNH Stormwater Center
- EPA (1999a)

Table 4-4. Bioretention Filter Media

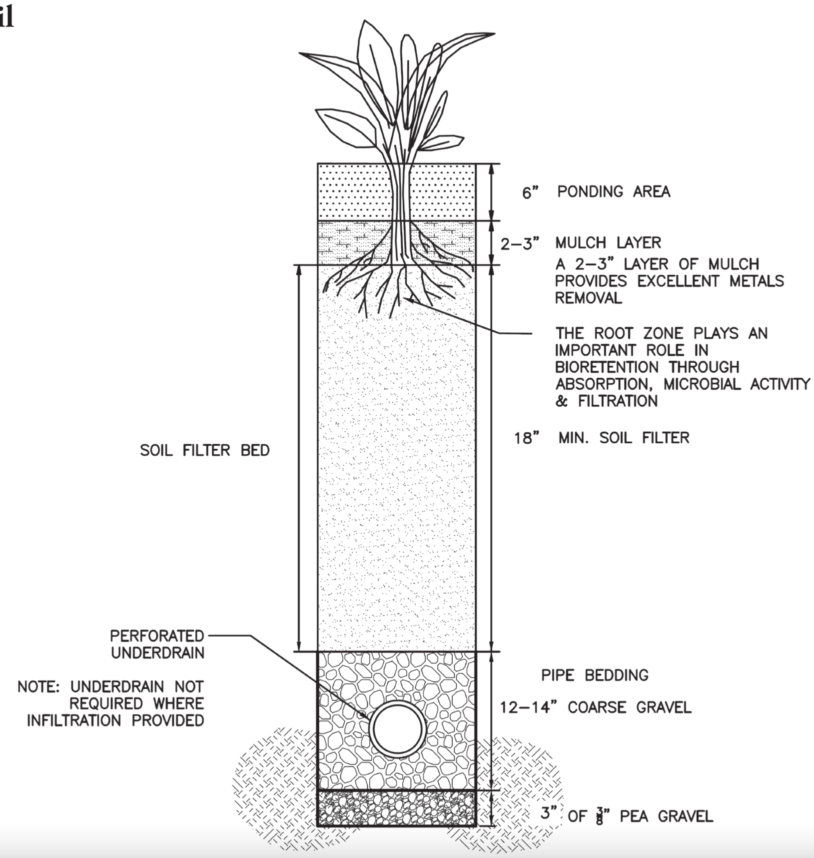
Component Material	Percent of Mixture by Volume	Gradation of Material	
		Sieve No.	Percent by Weight Passing Standard Sieve
Filter Media Option A			
ASTM C-33 concrete sand	50 to 55		
Loamy sand topsoil, with fines as indicated	20 to 30	200	15 to 25
Moderately fine shredded bark or wood fiber mulch, 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

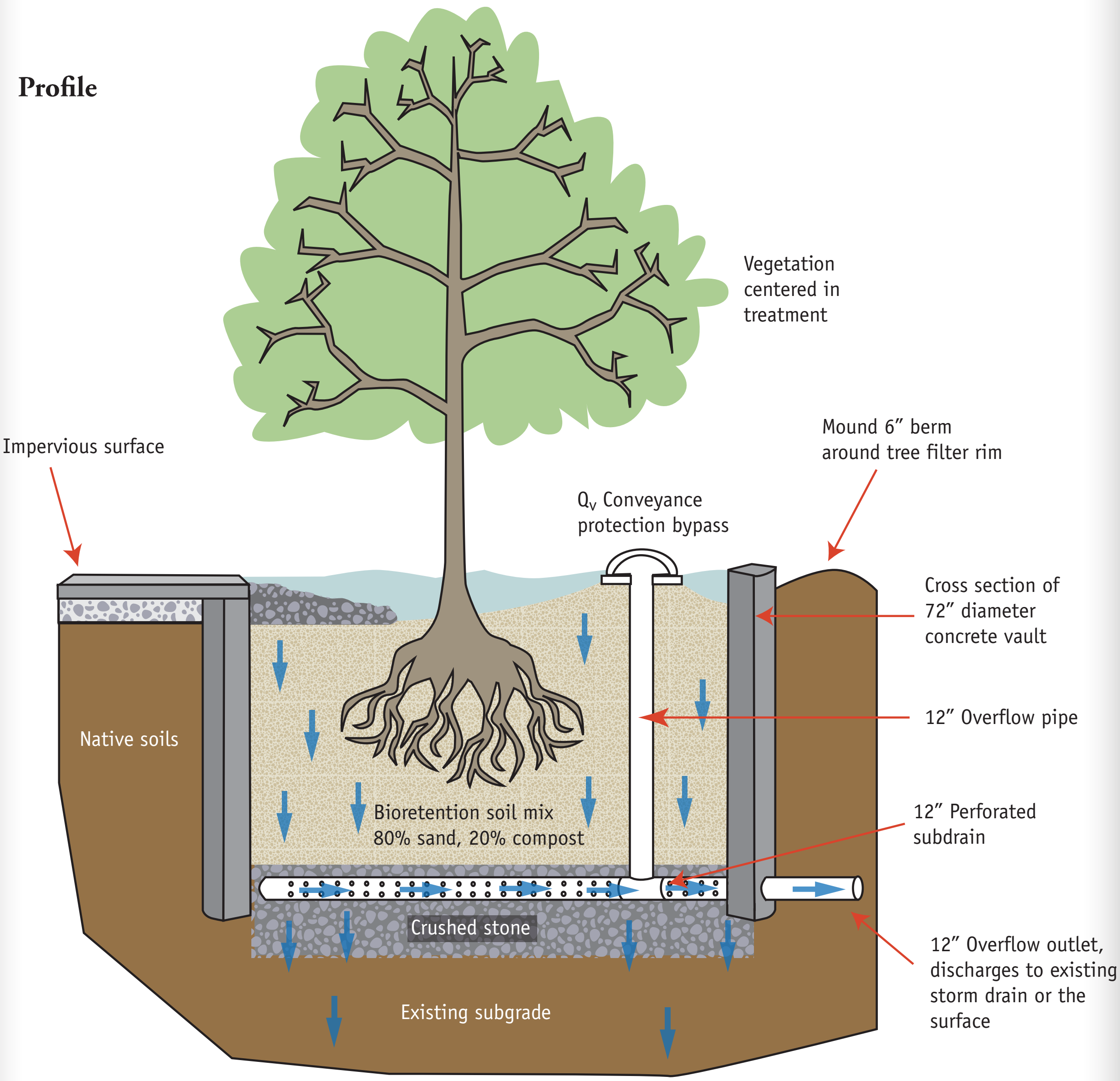
- UNH Stormwater Center (2007a)

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

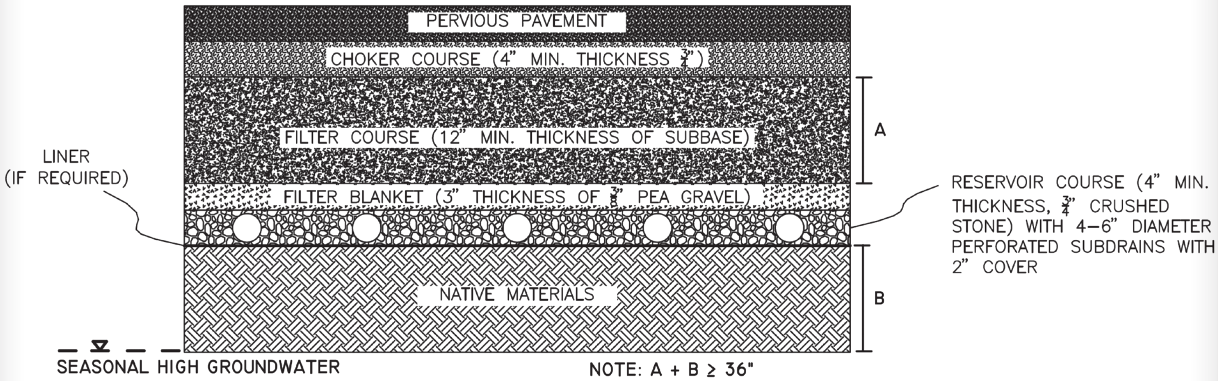
- Provision of signs is recommended, to indicate locations of permeable pavements and the applicability of special maintenance measures.
- No winter sanding of permeable pavements is permitted.
- Minimize application of salt for ice control.
- Never reseal or repave with impermeable materials.
- Inspect 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

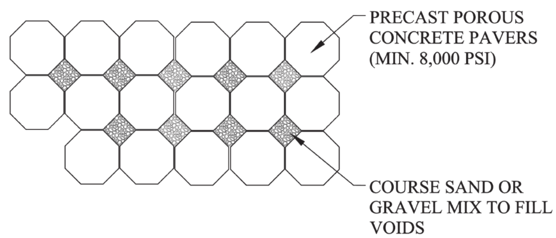
- See Design Criteria references for type of surfacing.

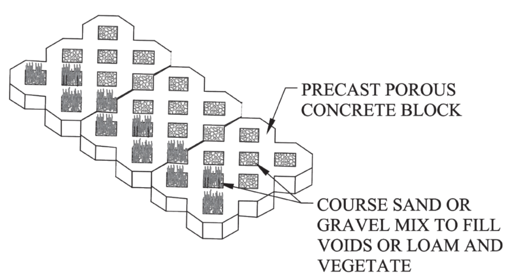
Example Design

Permeable Pavement Profile



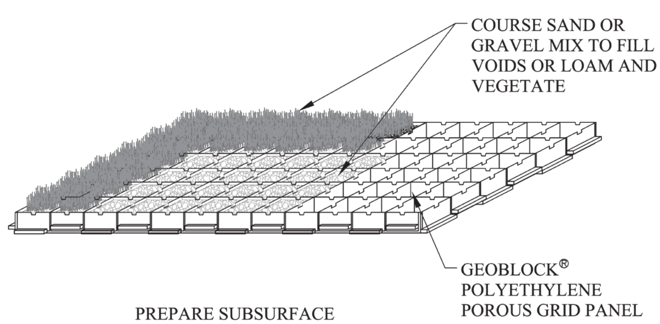
Permeable Concrete Pavers





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 > 12 inches * Total contributing area / 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

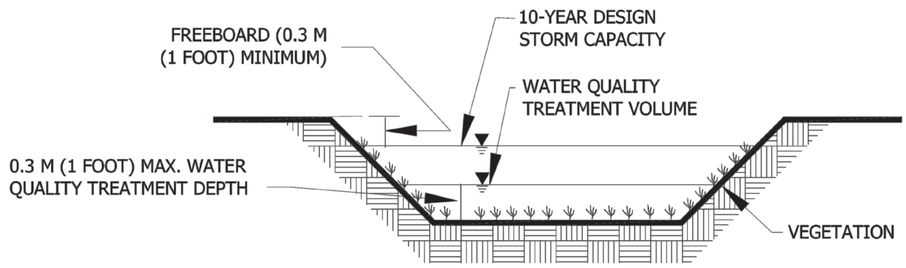
- Minton (2005)

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



Adapted from MassHighway (2004)

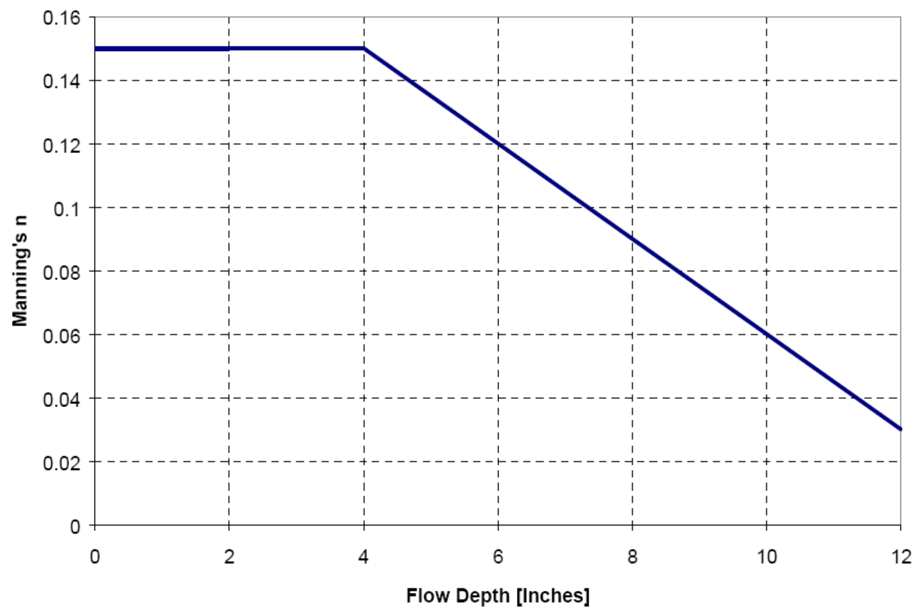


Figure 4-3. Manning's n Value with Varying Flow Depth (Source: Claytor and Schueler, 1986)

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

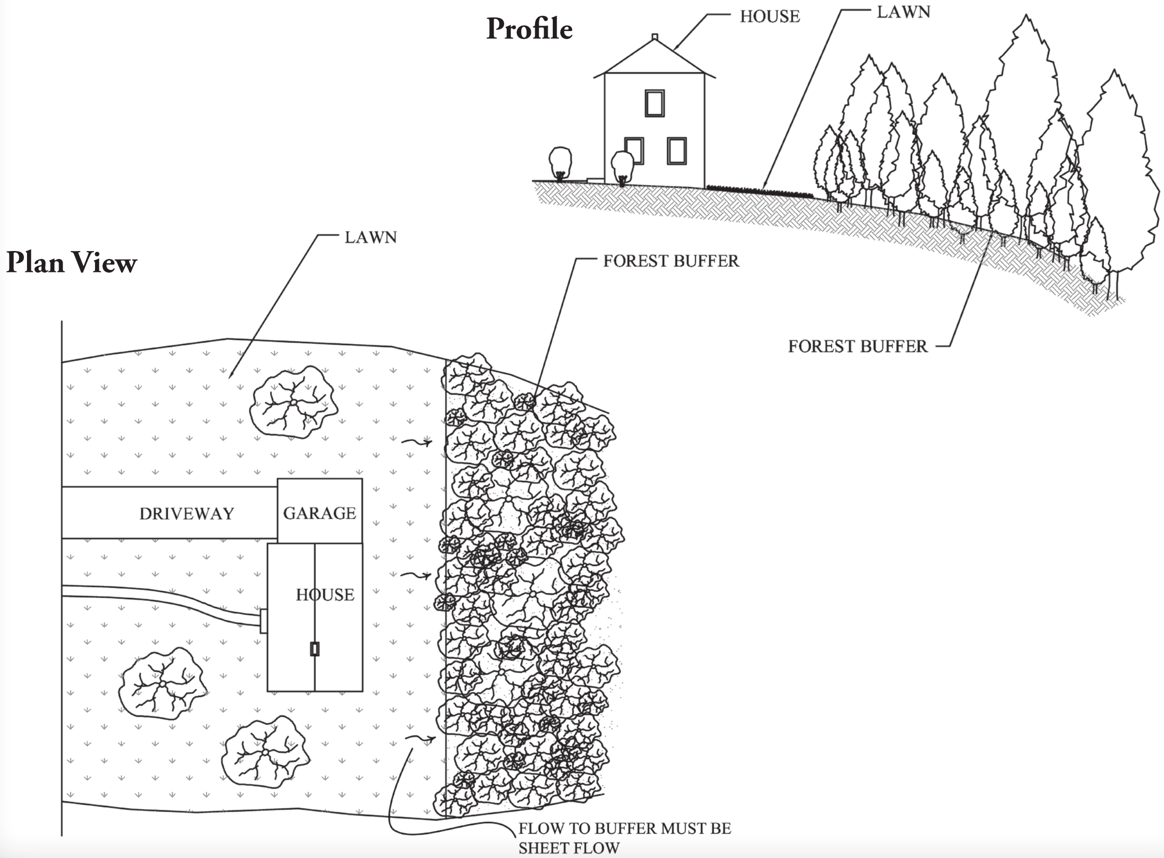


Table 4-6. Required Buffer Flow Path Length per Soil and Vegetative Cover Types with 0% to 8% Buffer Slope		
Hydrologic Soil Group of Soil in Buffer	Length of Flow Path for Forested Buffer (feet)	Length of Flow Path for Meadow Buffer (feet)
A	45	75
B	60	85
C	75	100
D	150	Not Applicable

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

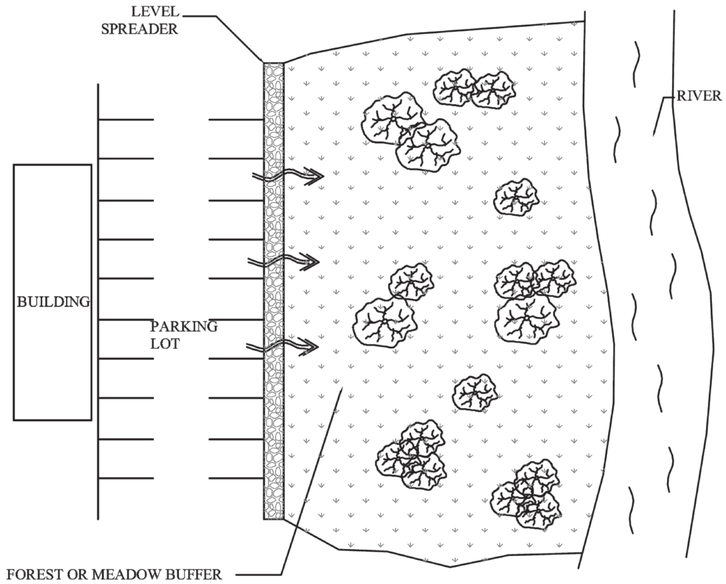
Hydrologic Soil Group of Soil in Buffer	Available Buffer Length (feet)	Level Spreader Berm Length to a Forested Buffer (feet)		Level Spreader Berm Length to a Meadow Buffer (feet)	
		Impervious Area	Lawn Area	Impervious Area	Lawn Area
A	75	75	25	125	35
	100	65	20	75	25
	150	50	15	60	20
B	75	100	30	150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

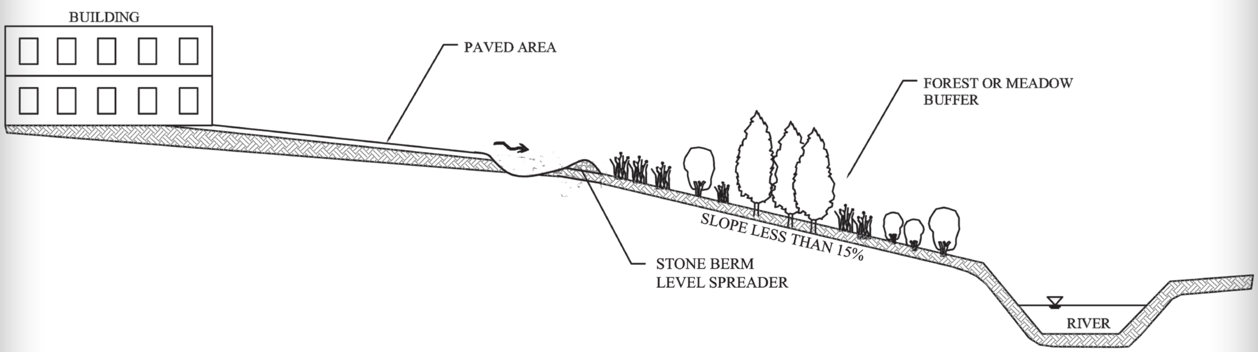
Note: If a detention structure is used upstream of the level spreader, Tables 4-8 and 4-9 may be used with the assumption that 1.0 acre of impervious area is equivalent to a peak flow of 1.0 cfs during the 2-year, 24-hour storm.

Example Design

Plan View



Profile



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

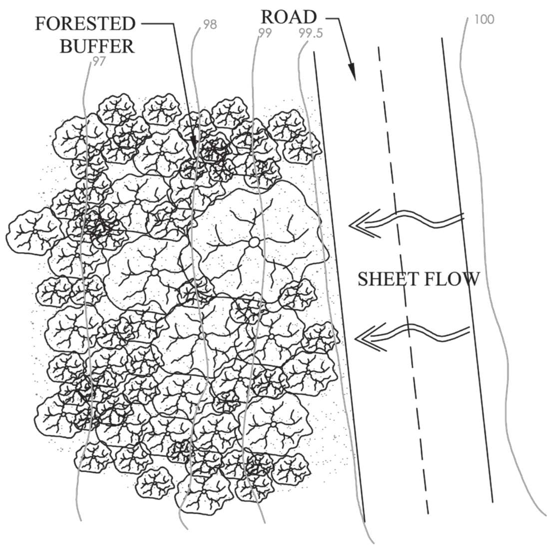
- Inspect buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless 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

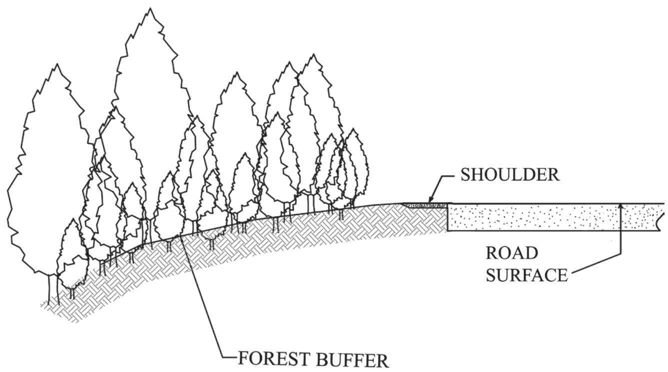
- Maine DEP (2006)

Example Design

Plan View



Profile



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

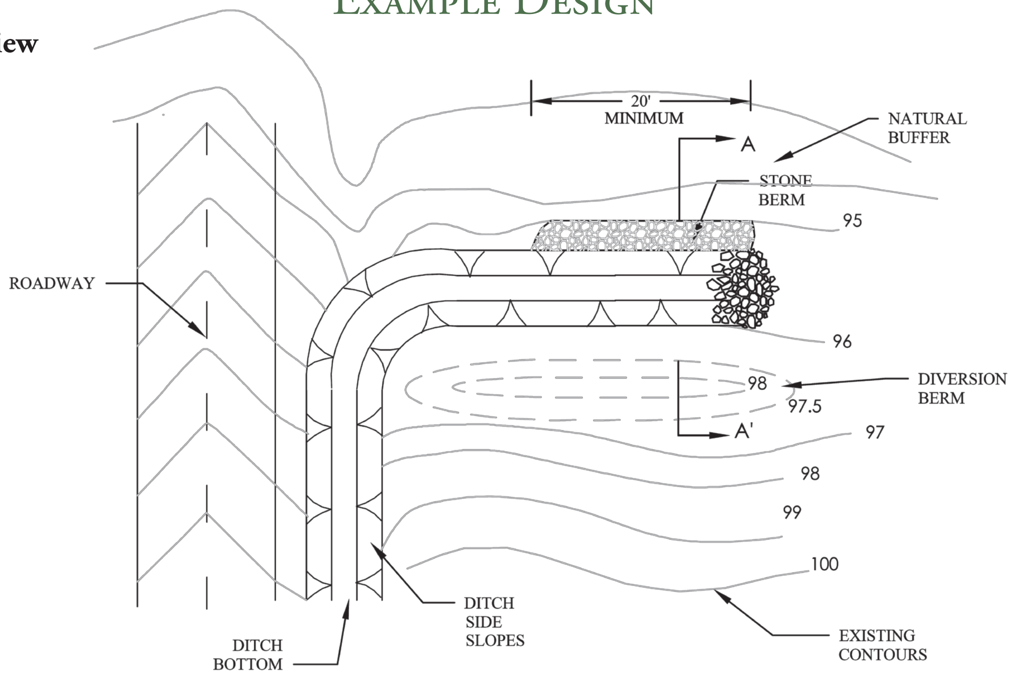
- Inspect level spreader and buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed 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

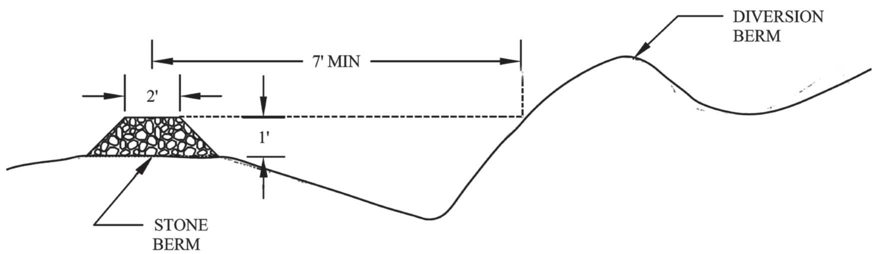
- Maine DEP (2006)

Example Design

Plan View



Section



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

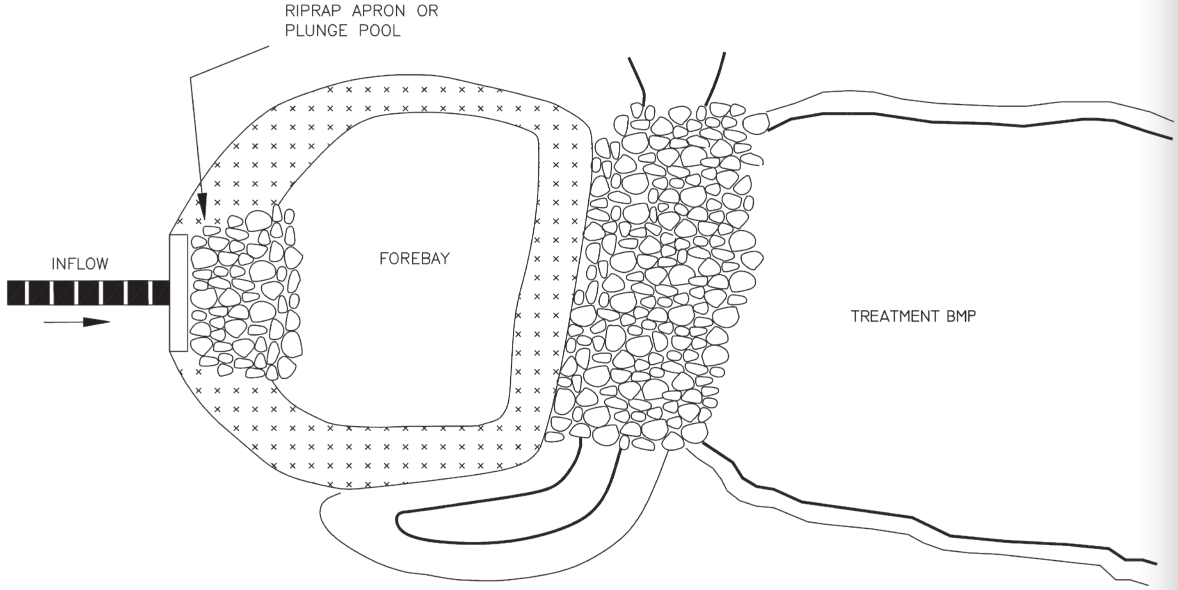
- Maintenance access must be provided;
- Embankment design must be engineered to meet applicable safety standards (see description of Detention Basins);
- Exposed earth slopes and bottom of basin should be stabilized using seed mixes appropriate for soils, mowing practices, and exposure to inundation;
- 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

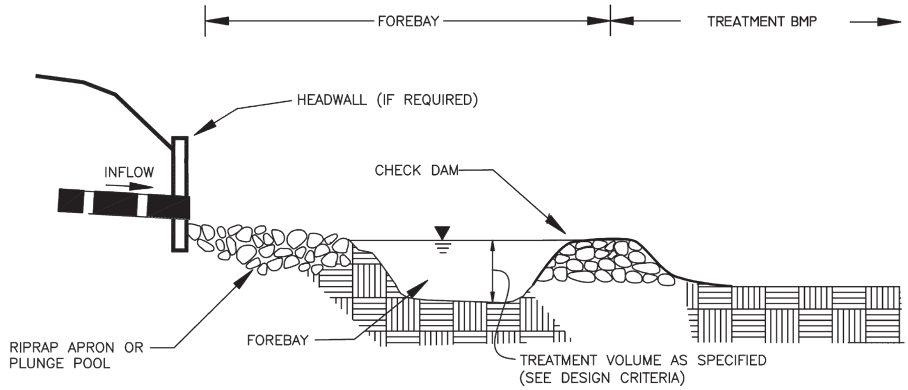
- Forebays help reduce the sediment load to downstream BMPs, and will therefore require more frequent cleaning.
- Inspect at least annually;
- Conduct periodic mowing of embankments (generally two times per year) to control growth of woody vegetation on embankments;
- Remove debris from outlet structures 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



Profile



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

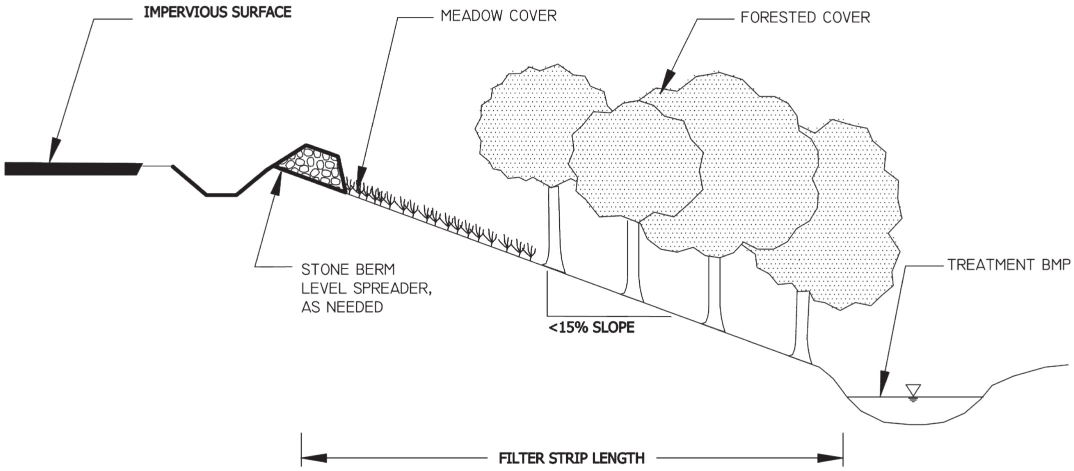
- Effectiveness of filter strip is dependent on shallow diffuse flow. Care is required to select or prepare the site, so that flow enters the filter strip as sheet flow and does not re-concentrate after entering the filter strip.
- The filter strip should be continuous for its entire length (flow path),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

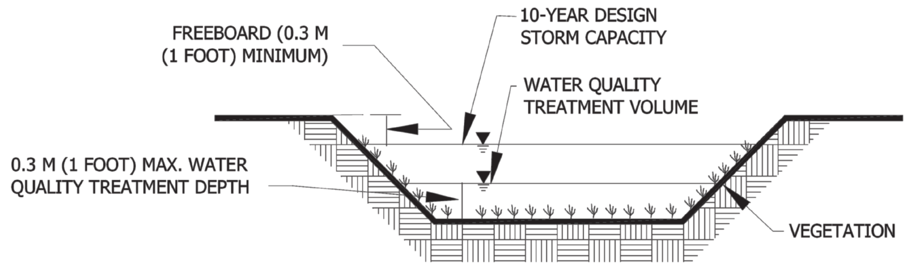
- Inspect annually for erosion, sediment accumulation, vegetation loss, and presence of invasive species.
- Perform periodic mowing; frequency depends on location and type of grass. Do not cut shorter than Water Quality Flow depth (minimum 4-inches)
- Remove debris and accumulated sediment, based on 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

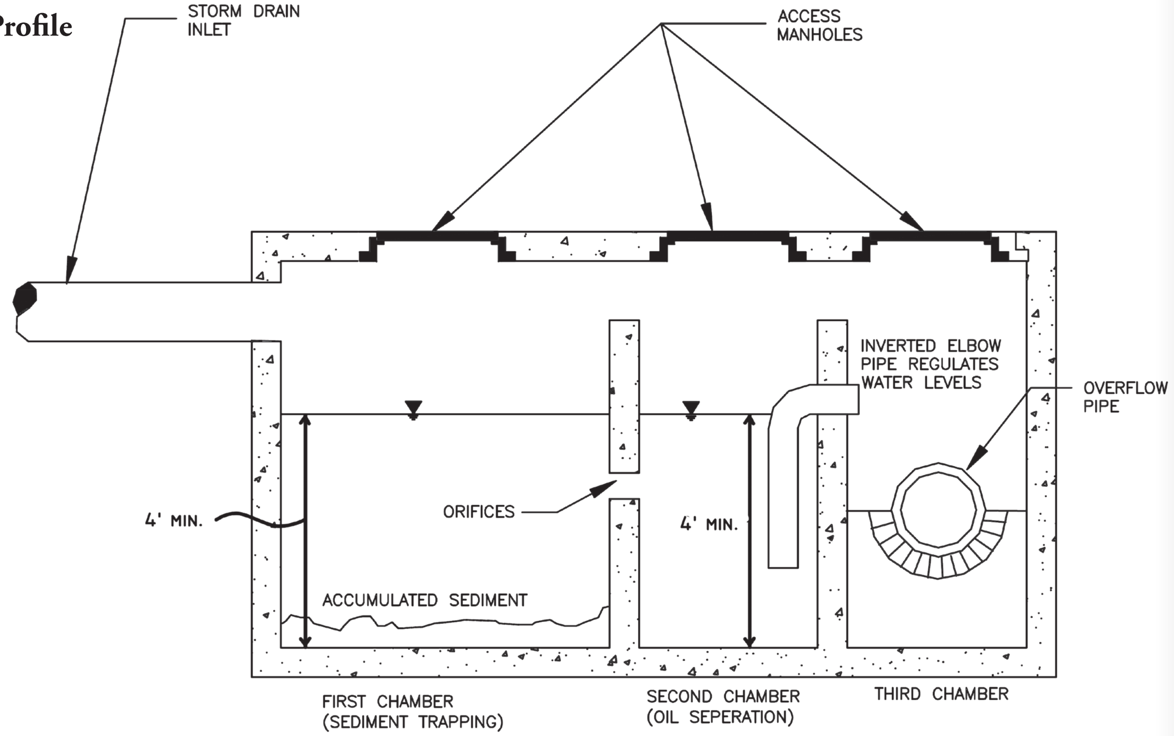
- Inspect Water Quality Inlet quarterly. Remove and legally dispose of floating debris at each inspection.
- Remove sediment when inspection indicates depth is approaching half the depth to the lowest orifice or other outlet in the first chamber baffle. However, it is recommended that the unit be cleaned 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

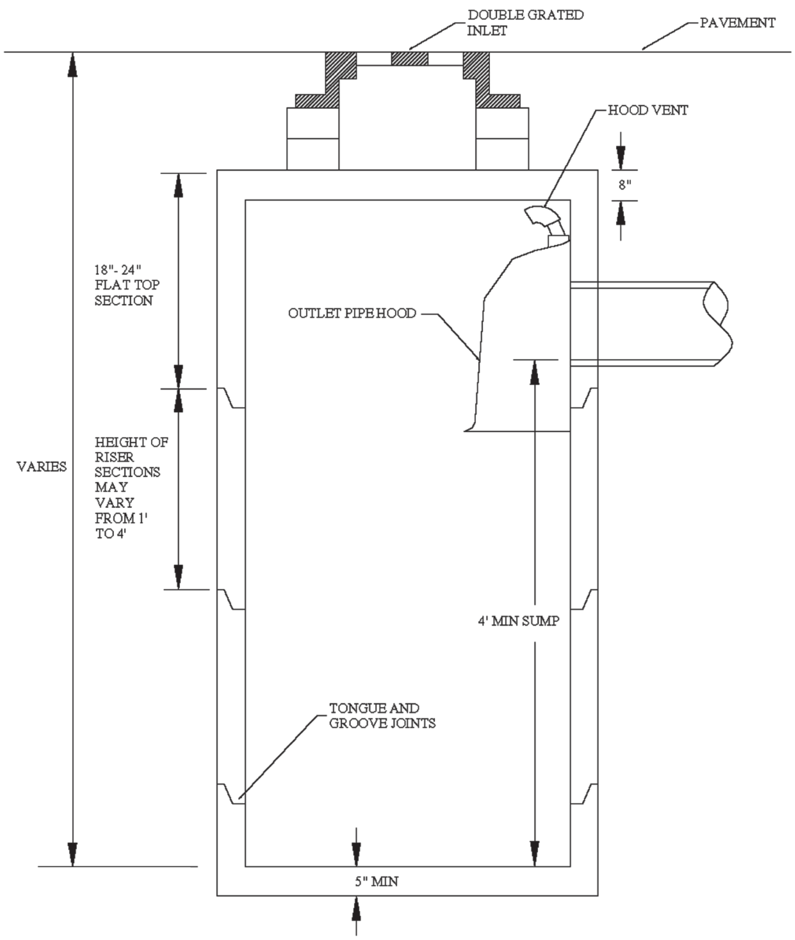
- Deep sump catch basins used as pretreatment devices must be located "off-line."
- Hoods may be susceptible to displacement or damage from cleaning activities. This should be considered in the configuration of the tops of structures (e.g., use of eccentric cones or flat tops with the inlet off-set from 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

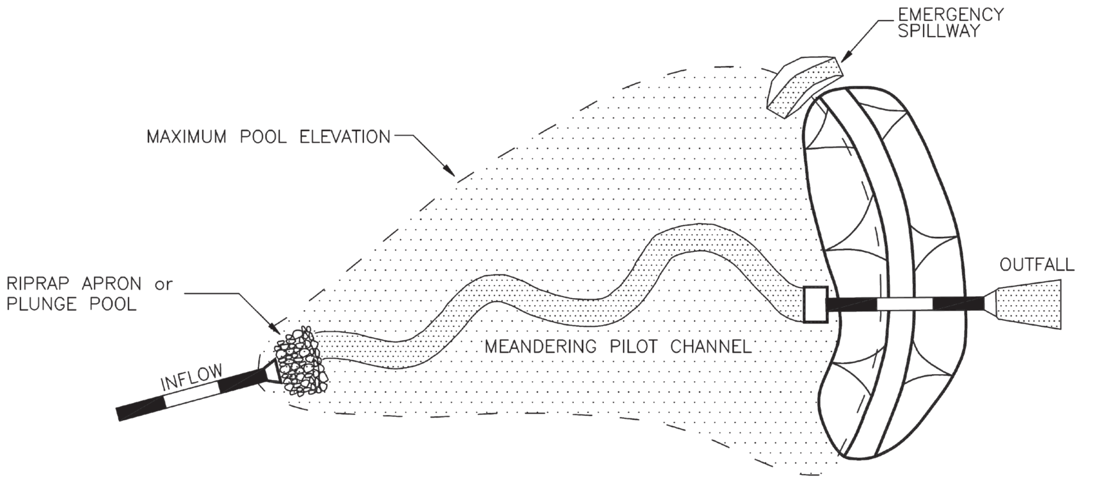
Design Parameter	Criteria
Side Slopes	2:1 or flatter (2.5:1 or flatter recommended, see Note 1)
Minimum Crest Width	4 feet (6 feet recommended, see Note 2)
Design Discharge	50-year, 24-hour storm without overtopping embankment crest, 1' of free-board required.
Emergency Spillway	Required for basins that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

Notes:

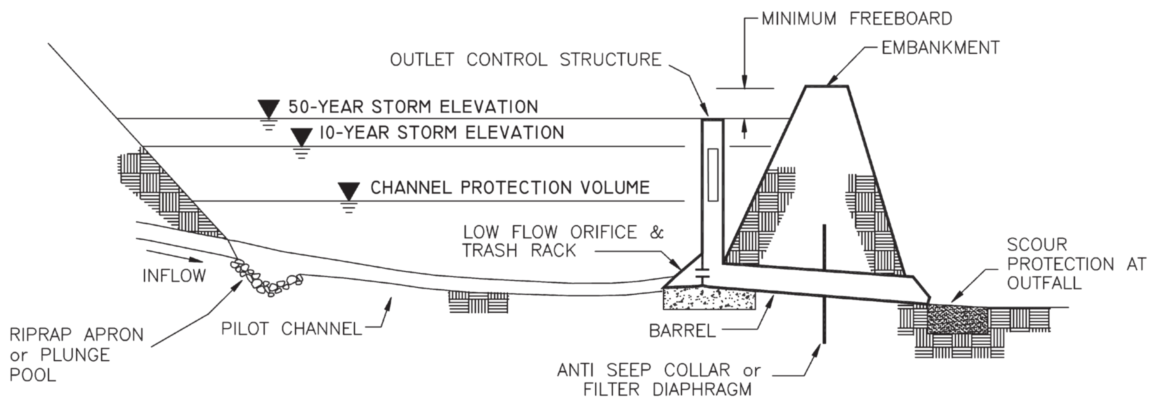
1. Env-Wr 403.02 requires embankment slopes of dams subject to jurisdiction to be no steeper than 2.5 horizontal to 1 vertical unless a specific design for a steeper slope shows that the embankment is stable and capable of being safely maintained.
2. Env-Wr 403.02 requires embankment crests of dams subject 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

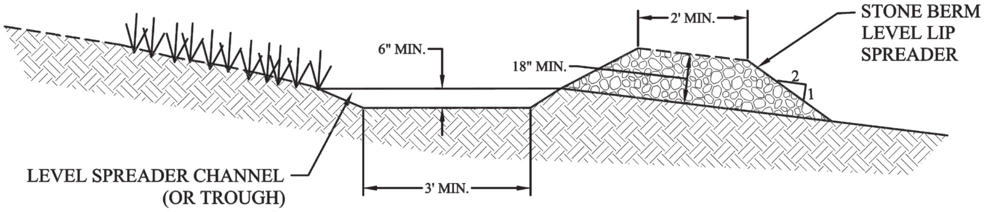
Design Parameter	Criteria
Slope of Receiving Area	< 15% (along flow path)
Level Spreader Grade	Bottom of spreader channel, and base and top of berm should be 0% grade
Spreader Channel Cross Section	6-inch deep trapezoidal trough
Spreader Channel Bottom Width	≥ 3 feet
Side Slopes	2:1 or flatter (level 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

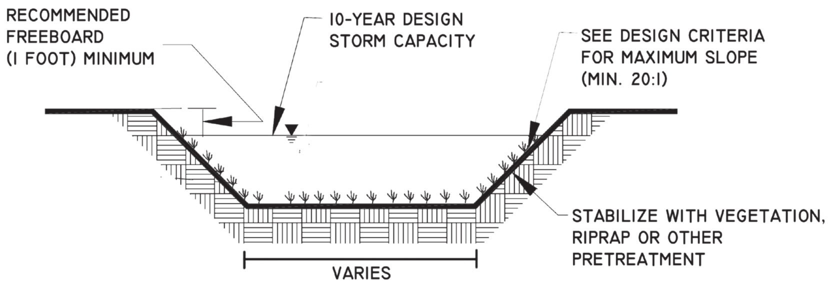
- Swales receiving stormwater from high-load areas must be lined (impermeable liner) to isolate the runoff from contact with underlying soil and groundwater.

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

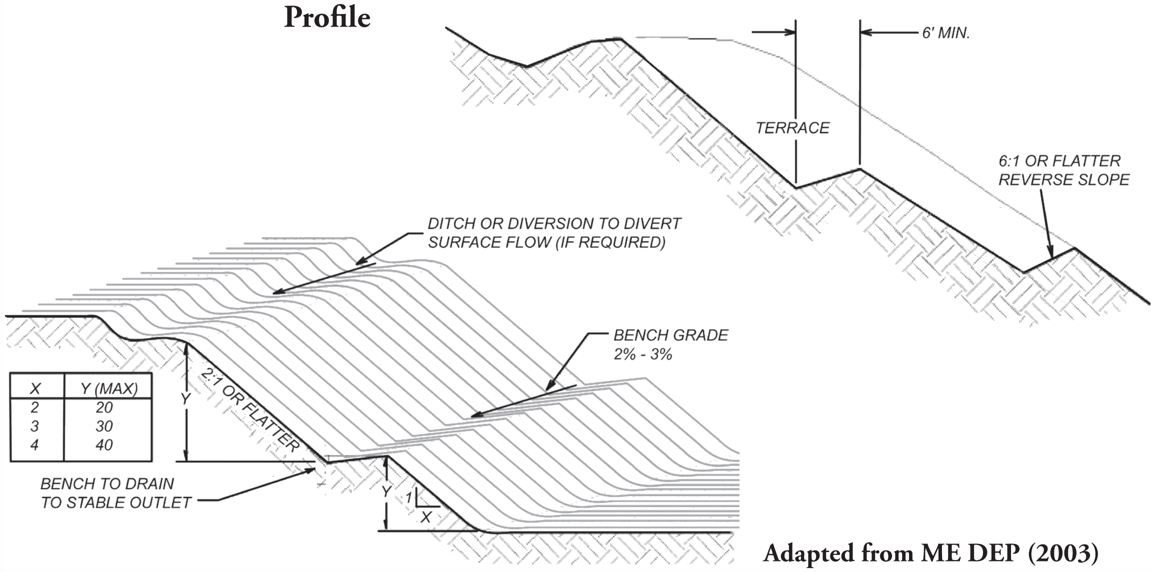
- Grassed slopes should be mowed to grass height and frequency specified by design.
- Vegetated slopes should be inspected periodically for signs of vegetation loss or damage, with restoration as needed.
- Terraces and slopes should be inspected periodically for any sign of rill or gully erosion, and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

Design References

- Connecticut DEP (2002)

Example Design

Profile



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

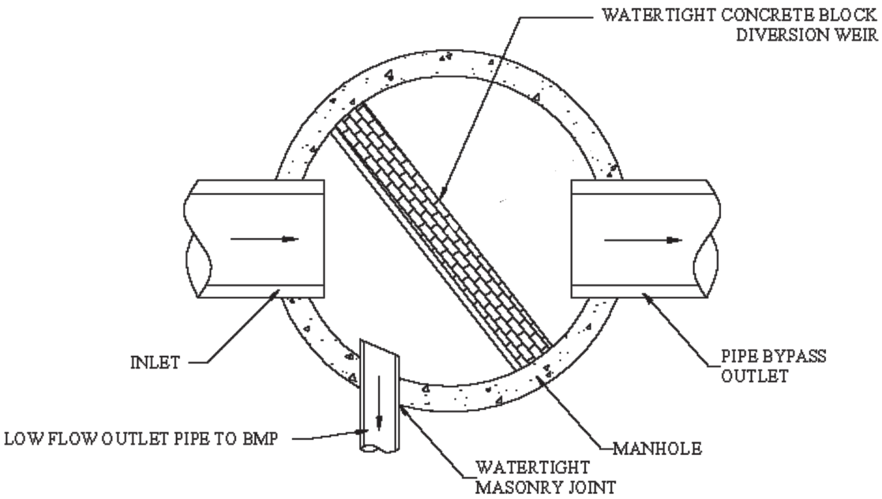
- Flow splitters should be inspected concurrently with the conveyance and treatment practices served by the devices. It is recommended that the device be inspected and maintained at least once annually.
- Sediments and debris should be removed and disposed as for other components of the drainage system.

Design Criteria

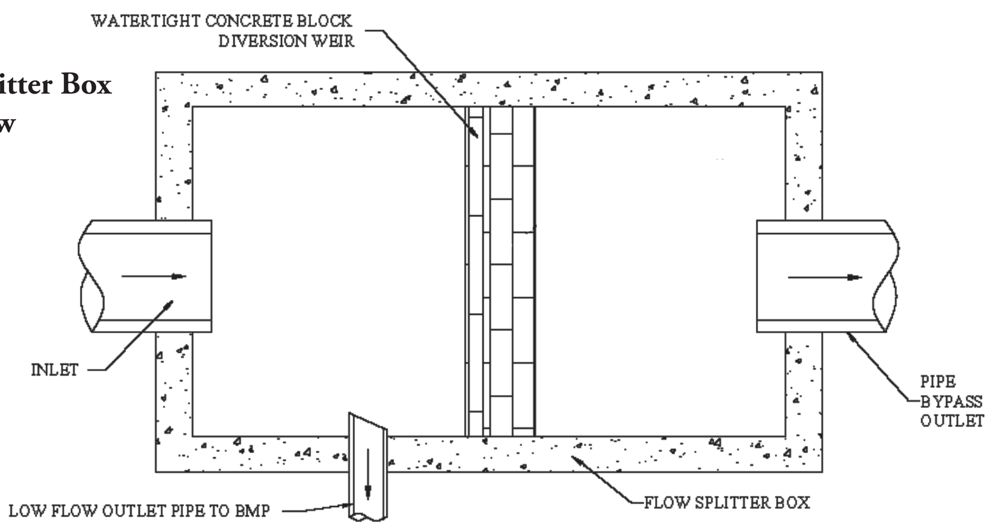
- Engineers are responsible for developing hydraulic, structural, and other design criteria specific to the project site.

Example Design

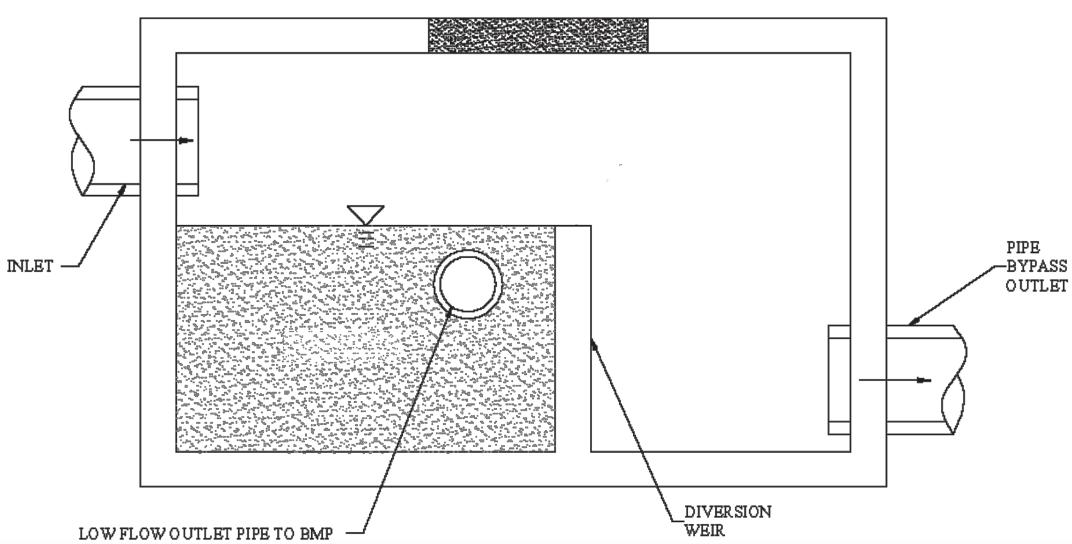
Manhole Plan View



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.

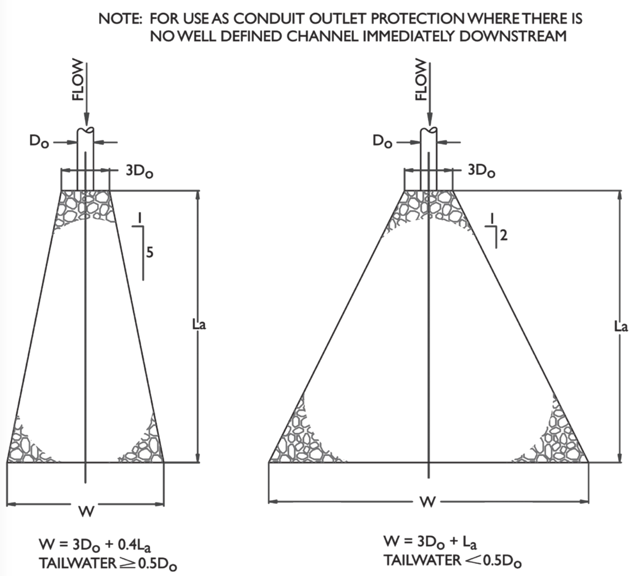
Maintenance Requirements

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

Example Designs

Apron

Plan View

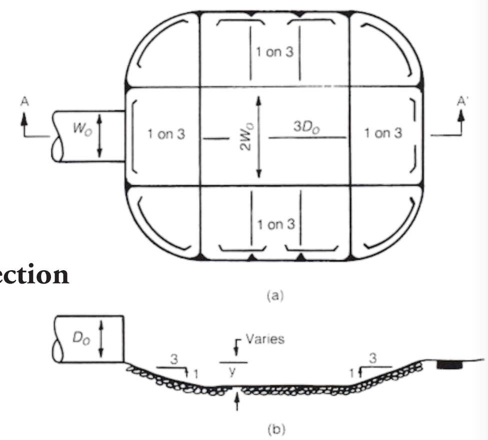


Source: CT DEP (2002)

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	$L_a = 1.8Q/D_o 1.5 + 7D_o$ (when $TW < D_o/2$) $L_a = 3.0Q/D_o 1.5 + 7D_o$ (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.

Chapter 5 Operation, Maintenance, Inspection & Source Control

The operation and maintenance of a stormwater management system and its individual components is as critical to system performance as the design. Also, implementation of source controls is an important aspect of the operation of a site to prevent contaminants from exposure to runoff, thus minimizing the pollutants that need to be treated by the stormwater management system. This Chapter addresses the operation and maintenance considerations of stormwater design, the preparation of an Inspection and Maintenance (I&M) Manual, and the preparation of a Source Control Plan.

Thus, the design process must give serious consideration to maintenance issues to develop stormwater management facilities with realistic maintenance expectations. Proper operation and maintenance will ensure that the stormwater system and individual BMPs will remain effective at removing pollutants as designed and meeting New Hampshire's water quality objectives. Proper maintenance will:

- Maintain the volume of stormwater treated over the long term;
- Sustain the pollutant removal efficiency of the BMP;
- Reduce the risk of re-suspending sediment and other pollutants captured by the BMP;
- Prevent structural deterioration of the BMP and minimize the need for expensive repairs;
- Decrease the potential for failure of the BMP.

Without proper maintenance, BMPs are likely to become functionally impaired or to fail, providing reduced or no treatment of stormwater. Design must consider how facilities will be accessed for inspection and maintenance, what activities are needed to maintain each facility, the frequency these activities must be performed, and who will be responsible for inspection and maintenance. The location and sizing of BMPs must account for these considerations. Also, the site design may require development of easements or deed restrictions to provide for access to perform necessary maintenance and repairs.

In addition, the AoT regulations require the development of an Inspection and Maintenance (I&M) Manual for stormwater management systems, identifying responsible parties for implementing the required maintenance activities, detailing the activities that are necessary, and documenting the implementation of the activities.

5-1. Operation and Maintenance Issues

The stormwater management system operation and maintenance program should encompass the activities necessary for effective system performance, but should also be realistic. The following are common issues that design of any project should consider when selecting BMPs and developing the I&M Manual:

- Does the responsible party have the authority, as well as the technical and financial resources, to carry out the I&M program?
- Does the owner/responsible party understand how the system functions?
- Does the owner/responsible party understand the maintenance requirements?
- Is there a legal mechanism needed and in-place for a municipality to perform corrective maintenance and back-charge the owner/responsible party?
- Can inspections be easily performed or can the facility be easily observed on a routine basis, so that the responsible party is readily aware of conditions requiring attention?
- Is equipment required for maintenance activity, and if so, is there adequate access?
- Are easements needed for access? Are easements needed for the public to obtain access for corrective action, even if the facility's primary maintenance is under private management?
- Are maintenance schedules adequate, or is the frequency of maintenance too high to be realistic?
- Can cleaning or other routine maintenance be conducted without requiring major renovation of the facility? For example, removal of sediment from an infiltration trench may require reconstructing the trench.
- Have provisions been considered for the proper disposal of waste materials from maintenance activities, including compliance with local, state, and federal regulations?
- Are the proposed maintenance activities consistent with regulatory requirements and obligations?

5-2. Design and Construction Guidelines

The following design and construction guidelines address anticipated maintenance practices:

1. **Provide Pre-Treatment:**

   Pre-treatment devices are generally required for each BMP under the AoT regulations.

2. **Sediment Loading/Removal Schedule:**

   Pre-treatment devices should be designed to accommodate a minimum of one year's worth of sediment. The estimated annual sediment accumulation should be documented in the project design calculations. Sediment loadings from both pervious and impervious areas must be considered.

   For pervious areas, the Revised Universal Soil Loss Equation (RUSLE) recommends to calculate sediment generated from the contributing watershed.

   For roadways and parking areas, sand deposits from winter storm applications should be accounted for in the design of the pre-treatment system. This estimate should be based on local practices for the application of sand for ice management. Absent such information, it is recommended to use a rate of 500 lbs/acre for sanding of parking areas and access drives, a sand density of 90 lbs per cubic foot and an assumed minimum frequency of ten sandings per year. Sanding rates and numbers of storms may need to be adjusted based on specific application rates in a community.

3. **Make Maintenance Needs Apparent:**

   For some BMP designs (such as ponded forebays, surface ponds or detention basins, and channels), the need for maintenance can be readily apparent from casual observation. Other BMPs, particularly underground structures, require disciplined inspection to monitor the conditions that warrant cleaning or that signal potential failure. The Inspection & Maintenance Manual should clearly define the inspection frequency and the maintenance or failure indicators, so that the party responsible for maintenance is alert to conditions warranting cleaning and repair. This is particularly true for off-line BMPs, where bypasses automatically carry flows around the devices if they are in "failure" condition.

4. **Sediment Marker:**

For BMPs that accumulate sediment, particularly pre-treatment practices, a sediment marker should be provided to enable determination of an accurate and consistent depth of sediment when inspections are performed.

5. **Design for Anticipated Pollutants:**

   Pretreatment devices must be designed to capture anticipated pollutants, such as oil and grease, as well as floating trash. Design should provide for access to remove these materials. I&M Manuals should include directions for the use of appropriate means for removing and disposing of petroleum hydrocarbons and legal disposal of the waste.

6. **Accessibility:**

   All devices must be designed and located to be easily accessible for inspection and for the necessary equipment for maintenance. Formal access must be provided, and may require easements.

5-3. Inspection and Maintenance (I&M) Manual

A formal operation and maintenance plan for a stormwater system will assist the party responsible for maintenance in understanding how the system functions and the maintenance activities needed to maintain that function. Such a plan clearly identifies inspection activities, schedules, record keeping requirements, and contingency measures for ensuring the long-term integrity of the stormwater management facilities. Typically, such a plan identifies each BMP used on the site and its specific maintenance activities and schedules.

The AoT regulations (Env-Wq 1500) require the long term maintenance of stormwater practices, and stipulate the establishment of a mechanism to provide for ongoing inspections and maintenance. Such a mechanism includes the preparation of an Inspection and Maintenance (I&M) Manual. This manual must include, at a minimum, the following:

1. The names of the responsible parties who will implement the required reporting, inspection, and maintenance activities identified in the I&M manual;

2. The frequency of inspections;

3. An inspection checklist to be used during each inspection;

4. An inspection and maintenance log to document each inspection and maintenance activity;

5. A deicing log to track the amount and type of deicing materials applied to the site;

6. A plan showing the locations of all the stormwater practices described in the I&M manual; and

7. Actions to be taken if any invasive species begin to grow in the stormwater management practices.

All record keeping required by the I&M manual shall be maintained by the responsible parties, and any transfer of responsibility for I&M activities or transfer in ownership shall be documented to the DES in writing.

5-4. Source Control Plan

Source control consists of measures to prevent pollutants from coming into contact with stormwater runoff. 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 management of industrial materials and other substances that could be sources of pollutants; management of lawn care and landscaping activities, particularly with respect to the storage and use of fertilizers, herbicides, and pesticides; pavement sweeping and cleaning; and snow and ice management.

Project I&M Plans should include provisions for source controls appropriate to the type and scale of the project. Alternatively, for projects with "high load areas" or other projects posing potential greater risk for pollutant exposure to stormwater, a separate source control plan may be warranted. The NH Alteration of Terrain regulations require submittal of a source control plan for any high-load area and any commercial parking area with over 1,000 trip ends per day (as determined with reference to Trip Generation, published by Institute of Transportation Engineers, Washington , D.C., 7th Edition, 2003).

"High-load areas" typically include:

- land uses or activities in which regulated substances are exposed to rainfall or runoff (with the exception of areas where the only regulated substance exposed to rainfall or runoff is road salt that has been applied for deicing of pavement on the site; or

- Any land use or activity that typically generates higher concentrations of hydrocarbons, metals, or suspended solids than are found in typical stormwater runoff, including but not limited to the following:

    - Industrial facilities subject to the NPDES Multi-Sector General Permit, not including areas where industrial activities do not occur, such as at office buildings and their associated parking facilities or in drainage areas at the facility where a certification of no exposure pursuant to 40 CFR §122.26(g) will always be possible;

    - Petroleum storage facilities;

- Petroleum dispensing facilities;
- Vehicle fueling facilities;
- Vehicle service, maintenance and equipment cleaning facilities;
- Fleet storage areas;
- Public works storage areas;
- Road salt storage and handling facilities;
- Commercial nurseries;
- Non-residential facilities having uncoated metal roofs with a slope flatter than 20%;
- Facilities with outdoor storage, loading, or unloading of hazardous substances, regardless of the primary use of the facility; and
- Facilities subject to chemical inventory under Section 312 of the Superfund Amendments and Reauthorization Act of 1986 (SARA).

The source control plan should be developed to minimize the volume of stormwater coming into contact with regulated substances, and segregate relatively clean stormwater from stormwater with a potentially higher concentration of pollutants. The plan should address the following:

1. Identification of the party responsible for the implementation and periodic update of the plan. This should include names and contact information for the owner of the facility, the persons (if other than the owner) designated for supervising the implementation of the plan; and persons comprising the "chain of command" for contact during an emergency condition;

2. An overview of how source controls, including structural or operational management practices, will prevent or minimize the amount of regulated substances from mixing with clean stormwater;

3. A list of regulated substances expected to be present on the site in quantities of 5 gallons or more;

4. The location(s) of groundwater protection areas, if any, within 1,000 feet of the site perimeter;

5. A plan depicting the drainage area with exposed regulated substances and the locationsof stormwater practices or discharge points serving those areas;

6. The locations and containment methods to be employed for storage of regulated substances;

7. A plan depicting the locations where regulated substances will be handled, including the storage, loading and unloading, transportation, or conveyance of any raw material, intermediate product, finished product, by-product, or waste product;

8. A plan showing the locations of snow storage areas;

9. A description of spill prevention and control or containment measures;

10. A program of training to familiarize employees with the plan and to ensure its implementation;

11. Provisions for regular internal review, evaluation, and periodic update of the plan.

References

Chapter 2. Design Criteria

USDA Soil Conservation Service. *National Engineering Handbook, Section 4 - Hydrology.* Engineering Division, Soil Conservation Service, USDA. Washington, DC. 1985.

USDA Soil Conservation Service. *Technical Release 55: Urban Hydrology for Small Watersheds, 2nd Edition.* Engineering Division, Soil Conservation Service, USDA. Washington, DC. 1986.

Chapter 3. Screening and Selection of Best Management Practices

New Hampshire Department of Environmental Services. *The DES Guide to Groundwater Protection Answers to Questions about Groundwater Protection in New Hampshire.* February 1996, revised December 2004.

Connecticut Department of Environmental Protection. *2004 Connecticut Stormwater Quality Manual.* 2004.

Center for Watershed Protection. *New York State Stormwater Management Design Manual.* August 2003.

Chapter 4. Designing Best Management Practices

Agricultural Service Research Publication ARS-76. *Scour at Cantilevered Pipe Outlets – Plunge Pool Energy Dissipator Design Criteria.* 1989.

American Concrete Institute. *Pervious Concrete.* Reported by ACI Committee 522. ACI 522R-06. April 2006.

American Society of Agricultural Engineers. “Plunge Pool Design at Submerged Pipe Spillway Outlets.” Volume 37(4):1167-1173. 1994.

American Society of Civil Engineers. *Design and Construction of Urban Stormwater Management Systems, ASCE – Manuals and Reports on Engineering Practice No. 77.* American Society of Civil Engineers and the Water Environment Federation. New York, NY. 1992.

American Society of Civil Engineers. *Sedimentation Engineering.* Manuals and reports on engineering practice No. 54, ASCE, New York. 1975.

American Society of Civil Engineers and the Water Environment Federation. *Design and Construction of Urban Stormwater Management Systems*. Manual and Reports of Engineering Practice No. 77, and WEF Manual of Practice FD-20, ASCE, New York. 1992.

Brown, T. and D. Caraco. Channel Protection. *Water Resources IMPACT.* V3, n6, 16-19. November 2001.

Cappiella, K., L. Fraley-McNeal, M. Novotney, and T. Schueler. *The Next Generation of Stormwater Wetlands.* Wetlands & Watersheds Article #5. Center for Watershed Protection, Ellicott City, MD. February 2008.

Claytor, Richard A. and Thomas R. Schueler. *Design of Stormwater Filtering Systems.* The Center for Watershed Protection, Ellicott City, MD. December 1996.

Comprehensive Environmental Inc. *City of Nashua, New Hampshire Alternative Stormwater Management Methods Part 2. Designs & Specifications.* March 2003.

Connecticut Department of Environmental Protection. *2004 Connecticut Stormwater Quality Manual.* Hartford, CT. 2004.

Connecticut Department of Environmental Protection. *2002 Connecticut Guidelines for Soil Erosion and Sediment Control.* Hartford, CT. May 2002.

Environmental Protection Agency. *Green Roofs.* Fact Sheet: Innovative BMPs for Site Plans. 2006a. Available at: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=114

Environmental Protection Agency. *Parking Lot and Street Cleaning.* Fact Sheet: Municipal Activities. 2006b. Available at: http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=99

Environmental Protection Agency. *Stormwater Technology Fact Sheets: Bioretention.* EPA 832-F-99-012. September 1999a.

Environmental Protection Agency. *Stormwater Technology Fact Sheets: Hydrodynamic Separators.* EPA 832-F-99-017. September 1999b.

Environmental Protection Agency. *Stormwater Technology Fact Sheets: Sand Filters.* EPA 832-F-99-007. September 1999c.

Environmental Protection Agency. *Stormwater Technology Fact Sheets: Storm Water Wetlands.* EPA 832-F-99-025. September 1999d.

Environmental Protection Agency. *Stormwater Technology Fact Sheets: Vegetated Swales.* EPA 832-F-99-006. September 1999e.

Environmental Protection Agency. *Stormwater Technology Fact Sheets: Wet Detention Ponds.* EPA 832-F-99-048. September 1999f.

Ferguson, B.K. *Stormwater Infiltration.* Lewis Publishers. Boca Raton, FL. 1994.

Interlocking Concrete Pavement Institute. *Permeable Interlocking Concrete Pavement: A Comparison Guide to Porous Asphalt and Pervious Concrete.* Washington, DC. February 2008.

Low Impact Development Center, Inc. *Rain Barrels and Cisterns.* Urban Design Tools Website. 2007. Available at: http://www.lid-stormwater.net/raincist_home.htm

Maine Department of Environmental Protection. *Maine Erosion and Sediment Control BMPs.* Publication No. DEPLW0588. March 2003.

Maine Department of Environmental Protection. *Stormwater Management for Maine: Vol. 3. BMPs Technical Design Manual.* Publication No. DEPLW0738. January 2006.

Massachusetts Department of Environmental Protection. *Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas.* Prepared by Franklin, Hampden, Hampshire Conservation Districts. Northampton, MA. 1997.

Massachusetts Department of Environmental Protection. *Massachusetts Nonpoint Source Pollution Management Manual.* January 2006.

Massachusetts Department of Environmental Protection. *Massachusetts Stormwater Handbook. February 2008.* Available at: http://www.mass.gov/dep/water/laws/policies.htm#storm

MassHighway. *Storm Water Handbook for Highways and Bridges.* Massachusetts Highway Department, Boston, MA. May, 2004.

MDE. *2000 Maryland Stormwater Design Manual, Volume 1, Stormwater Management Criteria.* Prepared by Center for Watershed Protection and the Maryland Department of the Environment. Baltimore, Maryland. 2000.

Minton, Gary. 2005. *Stormwater Treatment.* Resource Planning Associates. Seattle, WA.

NAHM Research Center, Inc. *The Practice of Low Impact Development.* July 2003.

New Hampshire Department of Environmental Services. Innovative *Stormwater Treatment Technologies Best Management Practices Manual.* May 2002.

New Hampshire Department of Transportation. *Standard Specification for Road and Bridge Construction.* 2006.

Prince George's County, Maryland Department of Environmental Resources, Programs and Planning Division. *Low Impact Design Strategies: An Integrated Design Approach.* January 2000.

Rockingham County Conservation District. *Stormwater Management and Erosion and Sediment Control Handbook for Urban and Developing Areas in New Hampshire.* Prepared for New Hampshire Department of Environmental Services. Exeter, NH. August, 1992.

Schueler, T. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Department of Environmental Programs, Metropolitan Washington Council of Governments, Washington, DC. 1987.

Schueler, T. *Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Mid-Atlantic Region.* Metropolitan Washington Council of Governments. Washington, DC. 1992.

Schueler, T., D. Hirschman, M. Novotney, and J. Zielinski, P.E. *Urban Stormwater Retrofit Practices.* Urban Subwatershed Restoration Manual No. 3. Center for Watershed Protection, Ellicott City, MD. July 2007.

Schueler, T., P. Kumble, and M. Heraty. *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone.* Department of Environmental Programs, Metropolitan Washington Council of Governments, Washington, DC. 1992.

Smith, D.R. *Permeable Interlocking Concrete Pavements (3rd ed.).* Interlocking Concrete Pavement Institute. Washington, DC. 2006.

United States Environmental Protection Agency. "National Pollutant Discharge System Menu of BMPs." 2006. 16 June 2005. http://cfpub.epa.gov/npdes/ stormwater/menuofbmps/index.cfm

University of New Hampshire Stormwater Center. *2007 Annual Report.* Durham, NH. 2007a. Available at: http://ciceet.unh.edu/unh_stormwater_report_2007/SC_Report_2007.pdf

University of New Hampshire Stormwater Center. *Bioretention System.* Treatment Unit Fact Sheet. Available at: http://www.unh.edu/erg/cstev/fact_sheets/bioretention.pdf

University of New Hampshire Stormwater Center. *Gravel Wetland.* Treatment Unit Fact Sheet. Available at: http://www.unh.edu/erg/cstev/fact_sheets/gravel_wetland.pdf

University of New Hampshire Stormwater Center. *Surface Sand Filter.* Treatment Unit Fact Sheet. Available at: http://www.unh.edu/erg/cstev/fact_sheets/surface_sand_filter.pdf

University of New Hampshire Stormwater Center. *UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds.* Durham, NH. 2007b.

USDA NRCS. *Earth Dams and Reservoirs.* Technical Release No. 60. U.S. Department of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division. July, 2005.

U.S. Department of the Interior, Bureau of Reclamation. *Hydraulic Design of Stilling Basins and Energy Dissipators*, Engineering Monograph No. 25.

U.S. Department of Transportation, Federal Highway Administration. *Hydraulic Design of Energy Dissipators for Culverts and Channels*, Hydraulic Engineering Circular No. 14. December 1975.

U.S. Environmental Protection Agency. "Erosion and sediment control, surface mining in the Eastern U.S." EPA-625/3-76-006, Washington, D.C. 1976.

Zarriello, P.J., R.F. Breault and P.K. Weiskel. P*otential Effects of Structural Controls and Street Sweeping on Stormwater Loads to the Lower Charles River, Massachusetts.* USGS Water Resources Investigations Report 02-4220. Northborough, MA. 2002.

General References

Center for Watershed Protection. 2003. *Impacts of Impervious Cover on Aquatic Systems.* Watershed Protection Research Monograph No. 1. March 2003.

Center for Watershed Protection. "A Stormwater Design Manual Toolbox". 2006. 24 Feb 2006. http://www.stormwatercenter.net/intro_manual.htm#about.

Chow, V.T., D.R. Maidment, and L.W. Mays. *Applied Hydrology.* McGraw-Hill Book Company. New York, NY. 1988.

Comprehensive Environmental Inc. City of Nashua, New Hampshire *Alternative Stormwater Management Methods Planning and Guidance*. Part 1. March 2003.

Maine Department of Environmental Protection. *Stormwater Management for Maine*. No. DEPLW0738. January 2006.Massachusetts Department of Environmental Protection. Massachusetts Nonpoint Source Pollution Management Manual the Clean Water Toolkit. May 4, 2006.

Minnesota Stormwater Steering Committee. *Minnesota Stormwater Manual.* September, 2006.

Prince George's County Maryland Department of Environmental Resources, Programs and Planning Division. *Low Impact Development Design Strategies An integrated Design Approach.* January 2000.

United States Environmental Protection Agency. *National Management Measures to Control Nonpoint Source Pollution from Urban Areas.* 2006.

Appendix A.
New Hampshire Rainfall Tables

TOWN	24-hour SCS Rainfall*					
	1 yr	2 yr	10 yr	25 yr	50 yr	100 yr
ACWORTH	2.3	2.7	4.1	4.8	5.4	6.1
ALBANY	2.7	3.2	4.8	5.5	6.1	6.4
ALEXANDRIA	2.4	2.7	4.1	4.9	5.3	6.0
ALLENSTOWN	2.5	2.9	4.3	5.1	5.6	6.3
ALSTEAD	2.3	2.7	4.1	4.9	5.4	6.1
ALTON	2.4	2.9	4.2	5.1	5.5	6.2
AMHERST	2.5	2.9	4.3	5.1	5.7	6.4
ANDOVER	2.3	2.8	4.1	4.9	5.4	6.0
ANTRIM	2.4	2.8	4.2	5.0	5.6	6.2
ASHLAND	2.4	2.8	4.2	5.0	5.4	6.0
ATKINSON	2.5	3.0	4.4	5.2	5.8	6.5
ATKINSON & GILMANTON ACADEMY GRANT	2.3	2.5	3.8	4.6	4.9	5.4
AUBURN	2.5	3.0	4.3	5.1	5.7	6.4
BARNSTEAD	2.4	2.9	4.2	5.1	5.6	6.2
BARRINGTON	2.5	3.0	4.3	5.1	5.7	6.3
BARTLETT	3.0	3.5	5.1	5.9	6.4	7.0
BATH	2.3	2.5	3.9	4.7	5.0	5.7
BEAN'S GRANT2.80	3.6	4.5	5.9	6.4	7.2	
BEAN'S PURCHASE	3.0	3.7	5.2	6.1	6.6	7.2
BEDFORD	2.5	2.9	4.3	5.1	5.7	6.4
BELMONT	2.4	2.8	4.2	5.0	5.5	6.1
BENNINGTON	2.4	2.8	4.2	5.0	5.6	6.3
BENTON	2.3	2.6	4.0	4.8	5.1	5.8
BERLIN	2.5	3.2	4.4	5.0	5.6	6.2
BETHLEHEM EAST	2.4	3.3	4.5	5.2	6.0	6.6
BETHLEHEM WEST	2.4	2.8	4.0	4.9	5.2	5.9
BOSCAWEN	2.4	2.8	4.2	5.0	5.5	6.1
BOW	2.4	2.9	4.2	5.0	5.6	6.3
BRADFORD	2.3	2.8	4.1	4.9	5.5	6.1
BRENTWOOD	2.6	3.0	4.3	5.2	5.7	6.4
BRIDGEWATER	2.4	2.7	4.1	4.9	5.4	6.0
BRISTOL	2.4	2.7	4.1	4.9	5.4	6.0
BROOKFIELD	2.4	2.9	4.2	5.2	5.5	6.2
BROOKLINE	2.5	2.9	4.3	5.1	5.7	6.4
CAMBRIDGE	2.5	2.8	4.0	4.9	5.2	6.0
CAMPTON	2.4	2.8	4.2	4.9	5.3	6.0
CANAAN	2.3	2.6	4.0	4.8	5.3	5.9
CANDIA	2.5	3.0	4.3	5.1	5.7	6.3
CANTERBURY	2.4	2.8	4.2	5.0	5.5	6.2
CARROLL	2.5	3.2	4.5	5.1	6.0	6.4
CENTER HARBOR	2.4	2.8	4.2	5.0	5.4	6.0
CHANDLER'S PURCHASE	2.8	3.6	5.0	5.8	6.4	7.1

*Rainfall data is interpolated from *Technical Paper No. 40 (TP40) Rainfall Frequency Atlas of the Eastern United States* . Other data may be used (e.g., *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada* by Cornell University, Northeast Regional Climate Center, September, 1993.)

TOWN	24-hour SCS Rainfall*					
	1 yr	2 yr	10 yr	25 yr	50 yr	100 yr
CHARLESTOWN	2.3	2.7	4.1	4.8	5.4	6.0
CHATHAM	3.0	3.6	5.2	6.2	6.6	7.2
CHESTER	2.5	3.0	4.3	5.1	5.7	6.4
CHESTERFIELD	2.3	2.8	4.2	4.9	5.5	6.2
CHICHESTER	2.4	2.9	4.2	5.1	5.6	6.2
CLAREMONT	2.3	2.6	4.1	4.8	5.3	6.0
CLARKSVILLE	2.3	2.5	3.7	4.5	4.9	5.3
COLEBROOK	2.3	2.5	3.8	4.6	4.9	5.4
COLUMBIA	2.3	2.5	3.8	4.6	4.9	5.5
CONCORD	2.4	2.9	4.2	5.0	5.6	6.2
CONWAY	3.0	3.3	5.0	5.7	6.2	6.6
CORNISH	2.3	2.6	4.0	4.8	5.3	5.9
CRAWFORD'S PURCHASE	2.5	3.5	4.8	5.5	6.2	7.1
CROYDON	2.3	2.7	4.0	4.8	5.3	6.0
CUTT'S GRANT	2.9	3.7	5.2	6.0	6.6	7.2
DALTON	2.4	2.6	4.0	4.9	5.1	5.8
DANBURY	2.3	2.7	4.1	4.9	5.4	6.0
DANVILLE	2.5	3.0	4.3	5.2	5.8	6.4
DEERFIELD	2.5	2.9	4.3	5.1	5.7	6.3
DEERING	2.4	2.8	4.2	5.0	5.6	6.2
DERRY	2.5	3.0	4.3	5.2	5.8	6.4
DIX'S GRANT	2.3	2.5	3.8	4.6	4.9	5.5
DIXVILLE	2.3	2.5	3.8	4.7	4.9	5.5
DORCHESTER	2.3	2.6	4.0	4.8	5.2	5.8
DOVER	2.5	3.0	4.3	5.2	5.7	6.4
DUBLIN	2.4	2.8	4.2	5.0	5.6	6.3
DUMMER	2.4	2.6	4.0	4.9	5.1	5.9
DUNBARTON	2.4	2.9	4.2	5.0	5.6	6.3
DURHAM	2.5	3.0	4.3	5.2	5.7	6.4
EAST KINGSTON	2.6	3.1	4.4	5.2	5.8	6.5
EASTON	2.4	2.6	4.0	4.8	5.2	5.8
EATON	2.7	3.1	4.8	5.2	6.1	6.2
EFFINGHAM	2.5	3.0	4.5	5.2	5.6	6.2
ELLSWORTH	2.4	2.7	4.2	4.9	5.2	5.9
ENFIELD	2.3	2.6	4.0	4.8	5.3	5.9
EPPING	2.5	3.0	4.3	5.2	5.7	6.4
EPSOM	2.5	2.9	4.3	5.1	5.6	6.2
ERROL	2.4	2.6	3.9	4.8	5.1	5.8
ERVING'S LOCATION	2.3	2.5	3.8	4.7	5.0	5.6
EXETER	2.6	3.0	4.4	5.2	5.8	6.4
FARMINGTON	2.5	2.9	4.3	5.1	5.6	6.2
FITZWILLIAM	2.4	2.9	4.2	5.0	5.6	6.3
FRANCESTOWN	2.4	2.9	4.2	5.0	5.6	6.3
FRANCONIA	2.4	2.8	4.2	5.0	5.4	6.0

*Rainfall data is interpolated from *Technical Paper No. 40 (TP40) Rainfall Frequency Atlas of the Eastern United States* . Other data may be used (e.g., *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada* by Cornell University, Northeast Regional Climate Center, September, 1993.)

TOWN	24-hour SCS Rainfall*					
	1 yr	2 yr	10 yr	25 yr	50 yr	100 yr
FRANKLIN	2.4	2.8	4.1	5.0	5.4	6.1
FREEDOM	2.5	3.0	4.6	5.2	5.9	6.2
FREMONT	2.5	3.0	4.3	5.2	5.7	6.4
GILFORD	2.4	2.8	4.1	5.0	5.5	6.1
GILMANTON	2.4	2.9	4.2	5.0	5.5	6.2
GILSUM	2.3	2.8	4.1	4.9	5.5	6.2
GOFFSTOWN	2.5	2.9	4.2	5.1	5.7	6.3
GORHAM	2.7	3.4	4.9	5.4	6.2	6.7
GOSHEN	2.3	2.7	4.1	4.8	5.4	6.1
GRAFTON	2.3	2.7	4.0	4.8	5.3	5.9
GRANTHAM	2.3	2.6	4.0	4.8	5.3	5.9
GREENFIELD	2.4	2.9	4.2	5.0	5.6	6.3
GREENLAND	2.6	3.1	4.4	5.2	5.8	6.4
GREEN'S GRANT	3.0	3.7	5.2	6.1	6.6	7.2
GREENVILLE	2.5	2.9	4.3	5.1	5.7	6.4
GROTON	2.3	2.6	4.1	4.8	5.3	5.9
HADLEY'S PURCHASE	2.9	3.6	5.1	5.9	6.4	7.1
HALE'S LOCATION	3.0	3.4	5.0	5.8	6.3	6.7
HAMPSTEAD	2.5	3.0	4.3	5.2	5.8	6.4
HAMPTON	2.6	3.1	4.4	5.2	5.8	6.5
HAMPTON FALLS	2.6	3.1	4.4	5.2	5.8	6.5
HANCOCK	2.4	2.8	4.2	5.0	5.6	6.3
HANOVER	2.3	2.6	4.0	4.7	5.2	5.8
HARRISVILLE	2.4	2.8	4.2	5.0	5.6	6.3
HART'S LOCATION	2.9	3.6	5.0	5.8	6.3	7.1
HAVERHILL	2.3	2.5	3.9	4.7	5.1	5.7
HEBRON	2.4	2.7	4.1	4.9	5.3	5.9
HENNIKER	2.4	2.8	4.2	5.0	5.5	6.2
HILL	2.3	2.7	4.1	4.9	5.4	6.0
HILLSBOROUGH	2.4	2.8	4.2	4.9	5.5	6.2
HINSDALE	2.3	2.8	4.2	5.0	5.6	6.3
HOLDERNESS	2.4	2.8	4.2	5.0	5.4	6.0
HOLLIS	2.5	3.0	4.3	5.1	5.8	6.4
HOOKSETT	2.5	2.9	4.3	5.1	5.7	6.3
HOPKINTON	2.4	2.8	4.2	5.0	5.6	6.2
HUDSON	2.6	3.0	4.3	5.2	5.8	6.4
JACKSON	3.0	3.7	5.2	6.2	6.6	7.2
JAFFREY	2.4	2.9	4.2	5.0	5.6	6.3
JEFFERSON	2.5	3.1	4.3	5.0	5.6	6.1
KEENE	2.3	2.8	4.2	4.9	5.5	6.2
KENSINGTON	2.6	3.1	4.4	5.2	5.8	6.5
KILKENNY	2.4	2.8	4.1	4.9	5.3	6.1
KINGSTON	2.6	3.0	4.4	5.2	5.8	6.5
LACONIA	2.4	2.8	4.1	5.0	5.4	6.1

*Rainfall data is interpolated from *Technical Paper No. 40 (TP40) Rainfall Frequency Atlas of the Eastern United States* . Other data may be used (e.g., *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada* by Cornell University, Northeast Regional Climate Center, September, 1993.)

TOWN	24-hour SCS Rainfall*					
	1 yr	2 yr	10 yr	25 yr	50 yr	100 yr
LANCASTER	2.4	2.6	4.0	4.9	5.2	5.9
LANDAFF	2.4	2.5	3.9	4.8	5.1	5.8
LANGDON	2.3	2.7	4.1	4.8	5.4	6.1
LEBANON	2.3	2.6	4.0	4.7	5.2	5.8
LEE	2.5	3.0	4.3	5.2	5.7	6.4
LEMPSTER	2.3	2.7	4.1	4.9	5.4	6.1
LINCOLN	2.5	3.0	4.5	5.1	5.6	6.2
LISBON	2.4	2.5	3.9	4.8	5.1	5.7
LITCHFIELD	2.5	3.0	4.3	5.1	5.7	6.4
LITTLETON	2.4	2.5	3.9	4.8	5.1	5.8
LIVERMORE	2.6	3.3	4.7	5.4	6.1	6.5
LONDONDERRY	2.5	3.0	4.3	5.1	5.7	6.4
LOUDON	2.4	2.9	4.2	5.0	5.6	6.2
LOW & BURBANK'S GRANT	3.0	3.5	4.8	5.6	6.2	6.8
LYMAN	2.4	2.5	3.8	4.7	5.0	5.7
LYME	2.3	2.5	4.0	4.7	5.2	5.8
LYNDEBOROUGH	2.4	2.9	4.2	5.0	5.7	6.3
MADBURY	2.5	3.0	4.3	5.2	5.7	6.4
MADISON	2.7	3.1	4.7	5.2	6.1	6.2
MANCHESTER	2.5	2.9	4.3	5.1	5.7	6.4
MARLBOROUGH	2.4	2.8	4.2	5.0	5.6	6.3
MARLOW	2.3	2.7	4.1	4.9	5.5	6.1
MARTIN'S LOCATION	3.0	3.6	5.1	5.9	6.4	7.1
MASON	2.5	2.9	4.3	5.1	5.7	6.4
MEREDITH	2.4	2.8	4.1	5.0	5.4	6.0
MERRIMACK	2.5	3.0	4.3	5.1	5.7	6.4
MIDDLETON	2.5	2.9	4.2	5.1	5.5	6.2
MILAN	2.4	3.0	4.2	4.9	5.3	6.1
MILFORD	2.5	2.9	4.3	5.1	5.7	6.4
MILLSFIELD	2.4	2.5	3.9	4.8	5.0	5.7
MILTON	2.5	2.9	4.3	5.1	5.6	6.2
MONROE	2.4	2.5	3.8	4.6	5.0	5.6
MONT VERNON	2.5	2.9	4.3	5.1	5.7	6.3
MOULTONBOROUGH	2.5	2.9	4.3	5.1	5.5	6.2
NASHUA	2.6	3.0	4.3	5.2	5.8	6.4
NELSON	2.4	2.8	4.2	4.9	5.6	6.3
NEW BOSTON	2.5	2.9	4.2	5.0	5.7	6.3
NEW CASTLE	2.6	3.1	4.4	5.2	5.8	6.5
NEW DURHAM	2.5	2.9	4.2	5.1	5.5	6.2
NEW HAMPTON	2.4	2.8	4.1	4.9	5.4	6.0
NEW IPSWICH	2.5	2.9	4.3	5.1	5.7	6.4
NEW LONDON	2.3	2.7	4.1	4.8	5.4	6.0
NEWBURY	2.3	2.7	4.1	4.9	5.4	6.1

*Rainfall data is interpolated from *Technical Paper No. 40 (TP40) Rainfall Frequency Atlas of the Eastern United States* . Other data may be used (e.g., *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada* by Cornell University, Northeast Regional Climate Center, September, 1993.)

TOWN	24-hour SCS Rainfall*					
	1 yr	2 yr	10 yr	25 yr	50 yr	100 yr
NEWFIELDS	2.6	3.0	4.4	5.2	5.7	6.4
NEWINGTON	2.6	3.0	4.4	5.2	5.7	6.4
NEWMARKET	2.6	3.0	4.3	5.2	5.7	6.4
NEWPORT	2.3	2.7	4.1	4.8	5.3	6.0
NEWTON	2.6	3.1	4.4	5.2	5.8	6.5
NORTH HAMPTON	2.6	3.1	4.4	5.2	5.8	6.5
NORTHFIELD	2.4	2.8	4.2	5.0	5.5	6.1
NORTHUMBERLAND	2.4	2.5	4.0	4.9	5.1	5.9
NORTHWOOD	2.5	2.9	4.3	5.1	5.6	6.3
NOTTINGHAM	2.5	3.0	4.3	5.1	5.7	6.4
ODELL	2.4	2.5	3.9	4.7	5.0	5.7
ORANGE	2.3	2.6	4.0	4.8	5.3	5.9
ORFORD	2.3	2.6	4.0	4.7	5.1	5.8
OSSIPEE	2.5	2.9	4.3	5.2	5.5	6.2
PELHAM	2.6	3.0	4.4	5.2	5.8	6.5
PEMBROKE	2.4	2.9	4.2	5.0	5.6	6.2
PETERBOROUGH	2.4	2.9	4.2	5.0	5.6	6.3
PIERMONT	2.3	2.5	3.9	4.7	5.1	5.8
PINKHAM'S GRANT	3.0	3.8	5.2	6.2	6.6	7.2
PITTSBURG	2.3	2.4	3.7	4.4	4.9	5.2
PITTSFIELD	2.5	2.9	4.2	5.1	5.6	6.2
PLAINFIELD	2.3	2.6	4.0	4.8	5.2	5.9
PLAISTOW	2.6	3.1	4.4	5.2	5.8	6.5
PLYMOUTH	2.4	2.7	4.2	4.9	5.3	5.9
PORTSMOUTH	2.6	3.1	4.4	5.2	5.8	6.5
RANDOLPH	2.7	3.3	4.6	5.2	6.1	6.4
RAYMOND	2.5	3.0	4.3	5.1	5.7	6.4
RICHMOND	2.4	2.8	4.2	5.0	5.6	6.3
RINDGE	2.4	2.9	4.2	5.0	5.7	6.4
ROCHESTER	2.5	3.0	4.3	5.1	5.6	6.3
ROLLINSFORD	2.5	3.0	4.3	5.2	5.7	6.4
ROXBURY	2.4	2.8	4.2	4.9	5.6	6.3
RUMNEY	2.4	2.6	4.1	4.9	5.3	5.9
RYE	2.6	3.1	4.4	5.2	5.8	6.5
SALEM	2.5	3.0	4.4	5.2	5.8	6.5
SALISBURY	2.4	2.8	4.1	4.9	5.5	6.1
SANBORNTON	2.4	2.8	4.1	5.0	5.4	6.1
SANDOWN	2.5	3.0	4.3	5.2	5.7	6.4
SANDWICH	2.5	3.0	4.4	5.1	5.5	6.2
SARGENT'S PURCHASE	2.9	3.8	5.2	6.1	6.6	7.2
SEABROOK	2.6	3.1	4.4	5.2	5.8	6.5
SECOND COLLEGE GRANT	2.3	2.5	3.8	4.7	5.0	5.5
SHARON	2.4	2.9	4.2	5.0	5.7	6.4

*Rainfall data is interpolated from *Technical Paper No. 40 (TP40) Rainfall Frequency Atlas of the Eastern United States* . Other data may be used (e.g., *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada* by Cornell University, Northeast Regional Climate Center, September, 1993.)

TOWN	24-hour SCS Rainfall*					
	1 yr	2 yr	10 yr	25 yr	50 yr	100 yr
SHELBURNE	2.7	3.5	5.1	5.4	6.2	6.8
SOMERSWORTH	2.5	3.0	4.3	5.2	5.7	6.3
SOUTH HAMPTON	2.6	3.1	4.4	5.2	5.8	6.5
SPRINGFIELD	2.3	2.7	4.1	4.8	5.3	6.0
STARK	2.4	2.6	4.0	4.9	5.1	5.9
STEWARTSTOWN	2.3	2.4	3.7	4.5	4.9	5.3
STODDARD	2.4	2.8	4.1	4.9	5.5	6.2
STRAFFORD	2.5	2.9	4.3	5.1	5.6	6.3
STRATFORD	2.4	2.5	3.8	4.7	5.0	5.6
STRATHAM	2.6	3.1	4.4	5.2	5.8	6.4
SUCCESS	2.5	3.2	4.5	5.1	5.6	6.2
SUGAR HILL	2.4	2.6	3.9	4.8	5.1	5.8
SULLIVAN	2.3	2.8	4.2	4.9	5.5	6.2
SUNAPEE	2.3	2.7	4.1	4.8	5.4	6.0
SURRY	2.3	2.8	4.1	4.9	5.5	6.2
SUTTON	2.3	2.7	4.1	4.9	5.4	6.1
SWANZEY	2.4	2.8	4.2	5.0	5.6	6.3
TAMWORTH	2.5	3.1	4.6	5.2	6.0	6.2
TEMPLE	2.4	2.9	4.2	5.0	5.7	6.4
THOMPSON & MESERVE'S PURCHASE	3.0	3.6	5.0	5.9	6.5	7.1
THORNTON	2.5	2.9	4.3	5.0	5.3	6.0
TILTON	2.4	2.8	4.2	5.0	5.5	6.1
TROY	2.4	2.8	4.2	5.0	5.6	6.3
TUFTONBORO	2.5	2.9	4.2	5.2	5.5	6.2
UNITY	2.3	2.7	4.1	4.8	5.4	6.0
WAKEFIELD	2.4	2.9	4.2	5.2	5.5	6.2
WALPOLE	2.3	2.7	4.1	4.9	5.4	6.1
WARNER	2.4	2.8	4.2	4.9	5.5	6.1
WARREN	2.4	2.6	4.0	4.8	5.2	5.8
WASHINGTON	2.3	2.7	4.1	4.9	5.5	6.1
WATERVILLE VALLEY	2.5	3.1	4.5	5.1	5.7	6.2
WEARE	2.4	2.9	4.2	5.0	5.6	6.3
WENTWORTH	2.4	2.6	4.0	4.8	5.2	5.8
WENTWORTH'S LOCATION	2.3	2.5	3.9	4.7	5.0	5.7
WESTMORELAND	2.3	2.8	4.1	4.9	5.5	6.2
WHITEFIELD	2.4	2.9	4.1	4.9	5.3	6.0
WILMOT	2.3	2.7	4.1	4.9	5.4	6.0
WILTON	2.5	2.9	4.3	5.1	5.7	6.4
WINCHESTER	2.4	2.8	4.2	5.0	5.6	6.3
WINDHAM	2.5	3.0	4.3	5.2	5.8	6.5
WINDSOR	2.4	2.8	4.2	4.9	5.5	6.2
WOLFEBORO	2.4	2.9	4.2	5.2	5.5	6.2
WOODSTOCK	2.4	2.7	4.2	4.9	5.3	5.9

*Rainfall data is interpolated from *Technical Paper No. 40 (TP40) Rainfall Frequency Atlas of the Eastern United States* . Other data may be used (e.g., *Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada* by Cornell University, Northeast Regional Climate Center, September, 1993.)

Appendix B.
BMP Pollutant Removal Efficiency

Pollutant Removal Efficiencies for Best Management Practices for Use in Pollutant Loading Analysis

Best Management Practice (BMP) removal efficiencies for pollutant loading analysis for total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP) are presented in the table below. These removal efficiencies were developed by reviewing various literature sources and using best professional judgment based on literature values and general expectation of how values for different BMPS should relate to one another. The intent is to update this information and add BMPs and removal efficiencies for other parameters as more information/data becomes available in the future.

NHDES will consider other BMP removal efficiencies if sufficient documentation is provided.

Please note that all BMPs must be designed in accordance with the specifications in the Alteration of Terrain (AoT) Program Administrative Rules (Env-Wq 1500). If BMPs are not designed in accordance with the AoT Rules, NHDES may require lower removal efficiencies to be used in the analysis.

BMP in Series: When BMPs are placed in series, the BMP with the highest removal efficiency shall be the efficiency used in the model for computing annual loadings. Adding efficiencies together is generally not allowed because removals typically decrease rapidly with decreasing influent concentration and, in the case of primary BMPs (i.e., stormwater ponds, infiltration and filtering practices), pre-treatment is usually part of the design and is therefore, most likely already accounted for in the efficiencies cited for these BMPs.

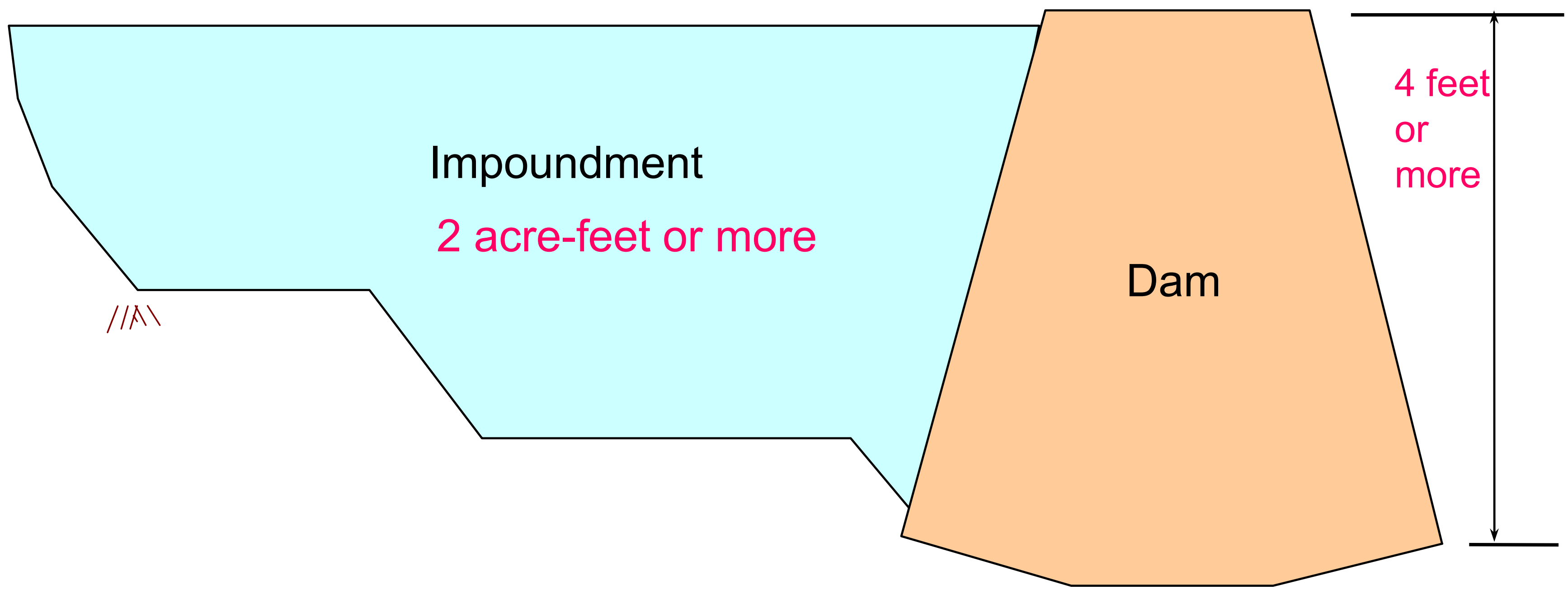
Pollutant Removal Efficiencies for Best Management Practices for Use in Pollutant Loading Analysis				Values Accepted for Loading Analyses		
BMP Type	**BMP**	**Notes**	**Lit. Ref.**	**TSS**	**TN**	**TP**
Stormwater Ponds	Wet Pond		B, F	70%	35%	45%
	Wet Extended Detention Pond		A, B	80%	55%	68%
	Micropool Extended Detention Pond	TBA				
	Multiple Pond System	TBA				
	Pocket Pond	TBA				
Stormwater Wetlands	Shallow Wetland		A, B, F, I	80%	55%	45%
	Extended Detention Wetland		A, B, F, I	80%	55%	45%
	Pond/Wetland System	TBA				
	Gravel Wetland		H	95%	85%	64%
Infiltration Practices	Infiltration Trench (≥75 ft from surface water)		B, D, I	90%	55%	60%
	Infiltration Trench (<75 ft from surface water)		B, D, I	90%	10%	60%
	Infiltration Basin (≥75 ft from surface water)		A, F, B, D, I	90%	60%	65%
	Infiltration Basin (<75 ft from surface water)		A, F, B, D, I	90%	10%	65%
	Dry Wells			90%	55%	60%
	Drip Edges			90%	55%	60%
Filtering Practices	Aboveground or Underground Sand Filter that infiltrates WQV (≥75 ft from surface water)		A, F, B, D, I	90%	60%	65%
	Aboveground or Underground Sand Filter that infiltrates WQV (<75 ft from surface water)		A, F, B, D, I	90%	10%	65%
	Aboveground or Underground Sand Filter with underdrain		A, I, F, G, H	85%	10%	45%
	Tree Box Filter	TBA				
	Bioretention System		I, G, H	90%	65%	65%
	Permeable Pavement that infiltrates WQV (≥75 ft from surface water)		A, F, B, D, I	90%	60%	65%
	Permeable Pavement that infiltrates WQV (<75 ft from surface water)		A, F, B, D, I	90%	10%	65%
	Permeable Pavement with underdrain		Use TN and TP values for sand filter w/ underdrain and outlet pipe	90%	10%	45%

Pollutant Removal Efficiencies for Best Management Practices for Use in Pollutant Loading Analysis				Values Accepted for Loading Analyses		
BMP Type	**BMP**	**Notes**	**Lit. Ref.**	**TSS**	**TN**	**TP**
Treatment Swales	Flow Through Treatment Swale	TBA				
Vegetated Buffers	Vegetated Buffers		A, B, I	73%	40%	45%
Pre-Treatment Practices	Sediment Forebay	TBA				
	Vegetated Filter Strip		A, B, I	73%	40%	45%
	Vegetated Swale		A, B, C, F, H, I	65%	20%	25%
	Flow-Through Device - Hydrodynamic Separator		A, B, G, H	35%	10%	5%
	Flow-Through Device - ADS Underground Multichamber Water Quality Unit (WQU)		G, H	72%	10%	9%
	Other Flow-Through Devices	TBA				
	Off-line Deep Sump Catch Basin		J, K, L, M	15%	5%	5%

Appendix C.
New Hampshire Reservoir and Dam Safety Standards: Defining a Dam

New Hampshire's Definition of a Dam

(RSA 482:2, II & Env-Wr 101.12)



A Dam is any artificial barrier which impounds or diverts water which:

- has a height of 4 feet or more

or

- a storage capacity of 2 acre feet or more

or

- is located at the outlet of a great pond

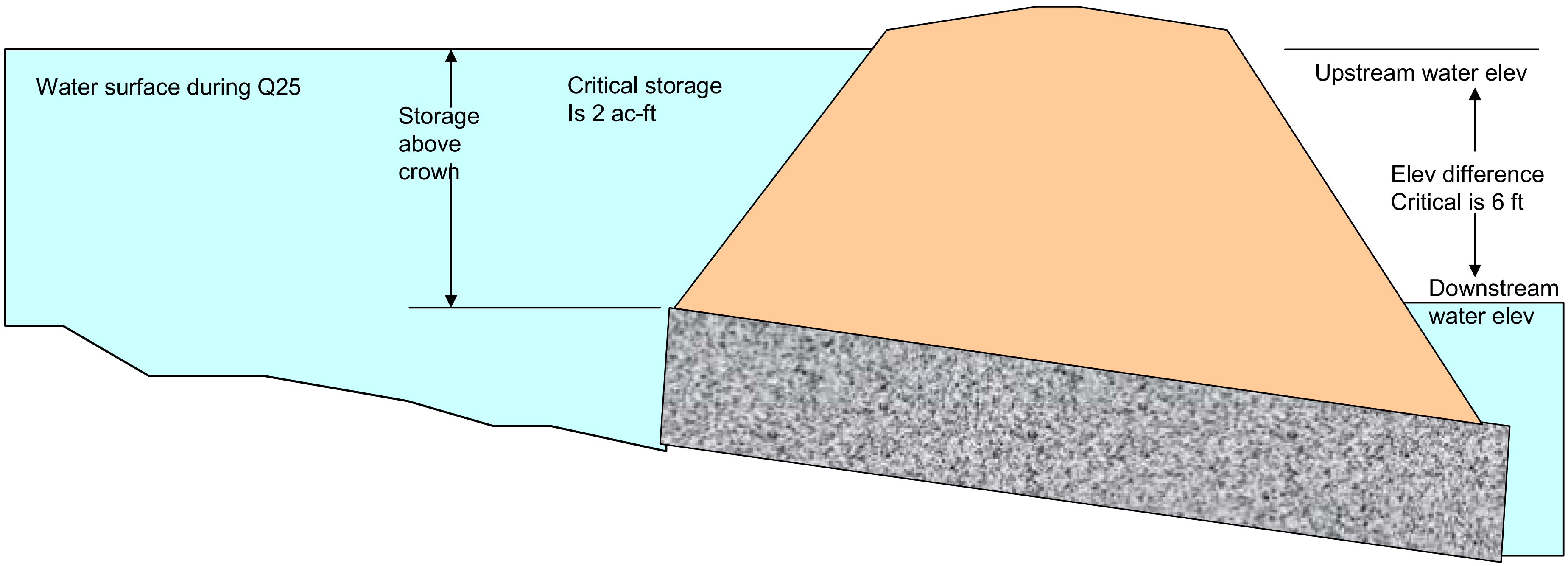
or

- is an artificial barrier which impounds liquid Industrial or liquid commercial wastes, or septage or sewage, regardless of height or storage.

Some Roadway Culverts are considered dams.
Certain Storm Water Detention Ponds are exempted. (See attached pages)

The DES Home Page: *http://www.des.nh.gov/dam*

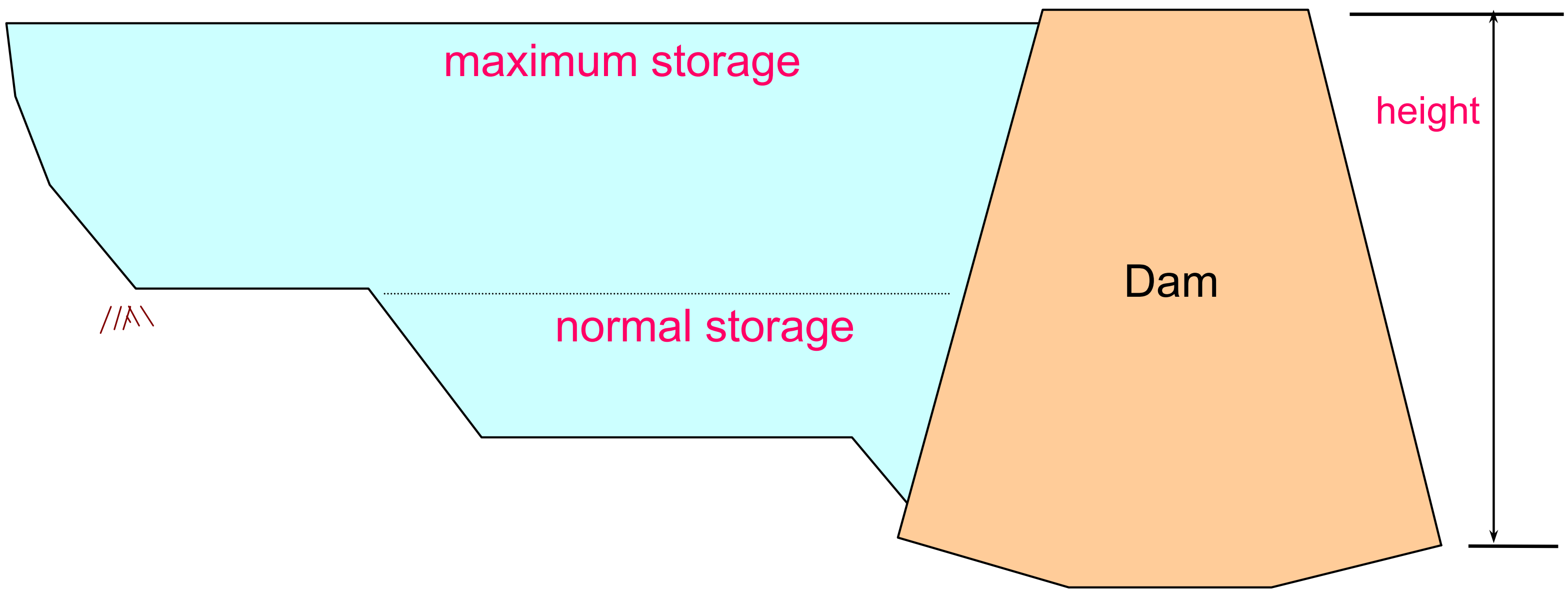
When is a Roadway Culvert NOT a Dam? (Env-Wr 101.12 &301.03)



A roadway culvert is not a dam if:
- its invert is at the natural streambed and
- it has adequate discharge capacity and
- it does not impound water under normal circumstances

A roadway embankment whose culvert is set at the natural streambed shall be a dam if during the 25 year storm:
•the water surface elevation at the culvert inlet is 6 feet above the water surface elevation at the culvert outlet and
•It impounds 2 ac-ft or more of water over the crown of the culvert.

When is a Storm Water Detention Pond NOT a Dam?



An artificial barrier at a storm water detention which impounds 0.50 acre-feet or less of water during normal conditions, shall not be considered a dam unless its height is 10 feet or greater or its maximum storage is 6 acre-feet or greater.

Effective 08/18/06

REVISED DAM DEFINITION

EFFECTIVE FRIDAY, AUGUST 18, 2006

WORDING IN BOLD ITALIZED FONT IS NEW
WORDS THAT ARE STRIKEN OUT HAVE BEEN DELETED

Dam; Certain Storm Water Detention Basins Exempted. Amend RSA 482:2, II to read as follows:

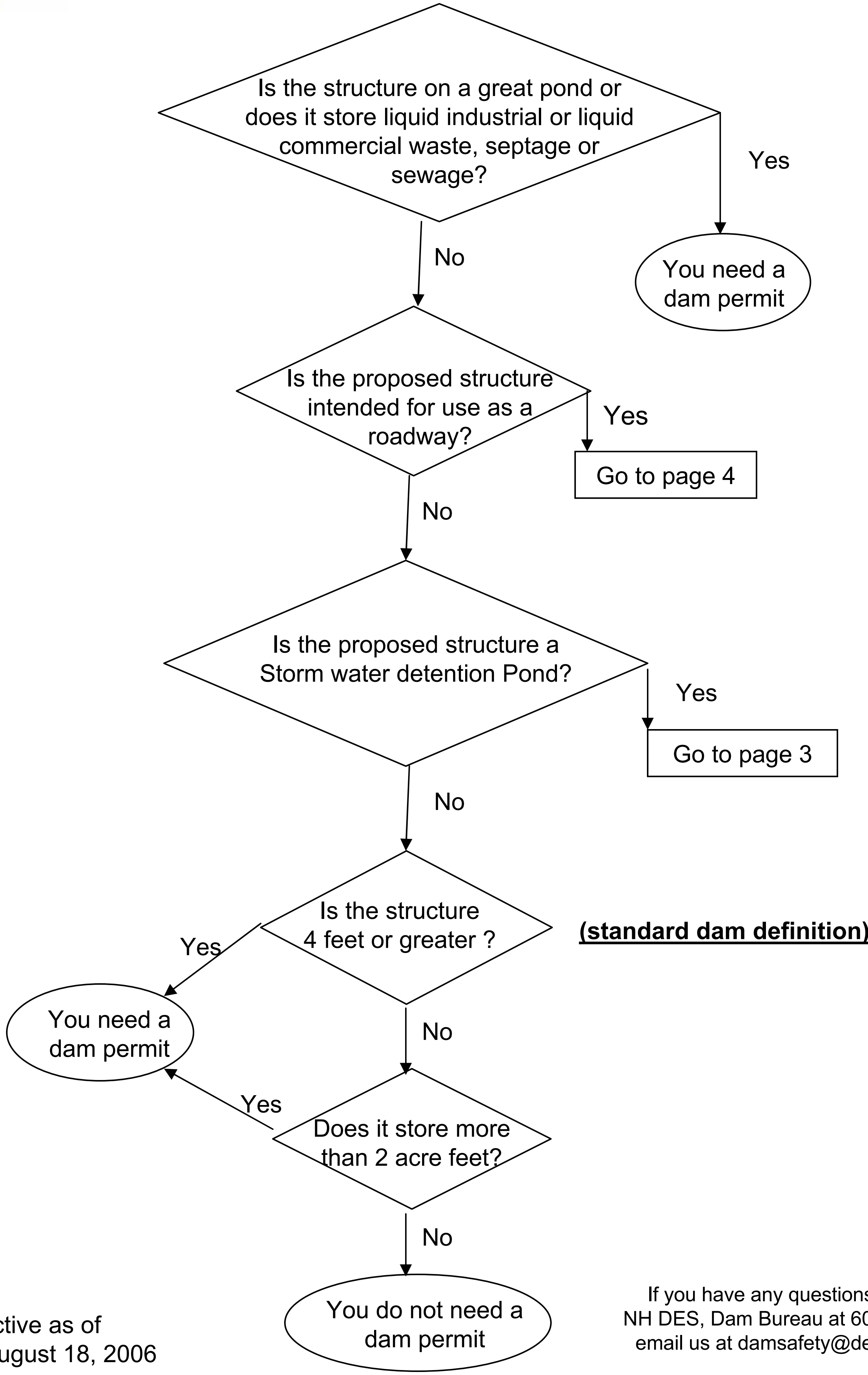
II.***(a)*** "Dam" means any artificial barrier, including appurtenant works, which impounds or diverts water, and which has a height of 4 feet or more, or a storage capacity of 2 acre-feet or more, or is located at the outlet of a great pond. A roadway culvert shall not be considered a dam if its invert is at the natural bed of the water course, it has adequate discharge capacity, and it does not impound water under normal circumstances. Artificial barriers which create surface impoundments for liquid industrial or liquid commercial wastes***, septage,*** or [~~municipal~~] sewage, regardless of height or storage capacity, shall be considered dams.

(b) An artificial barrier at a storm water detention basin, which impounds 0.5 acre-foot or less of water during normal conditions, shall not be considered a dam unless its height is 10 feet or greater or its maximum storage is 6 acre-feet or greater.

Attached is a flow chart to assist in determining if a dam application is required.

If you have any questions please call NH DES, Dam Bureau at 603-271-3406 or email us at damsafety@des.state.nh.us

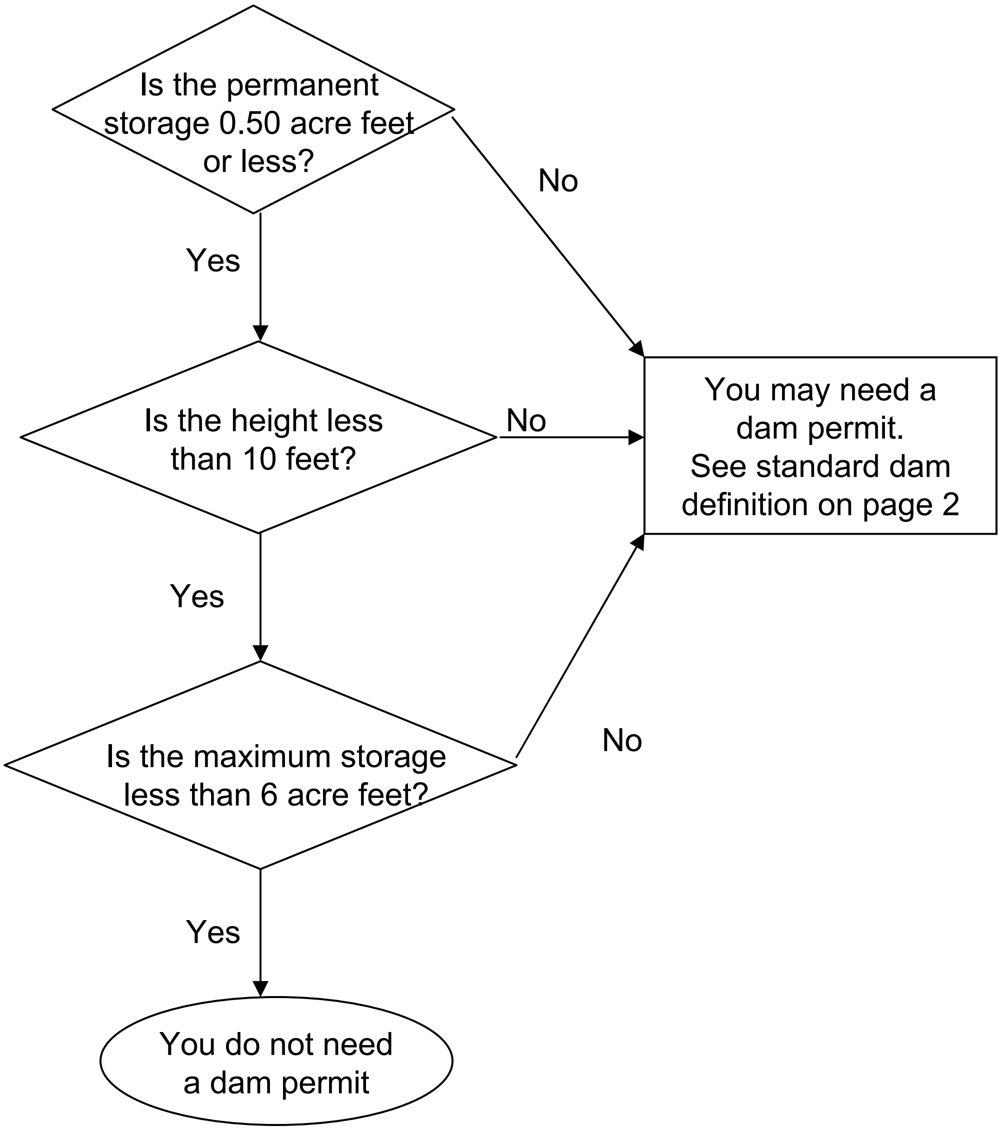
Do you need a dam permit ?



Effective as of
Friday, August 18, 2006

If you have any questions please call
NH DES, Dam Bureau at 603-271-3406 or
email us at damsafety@des.state.nh.us

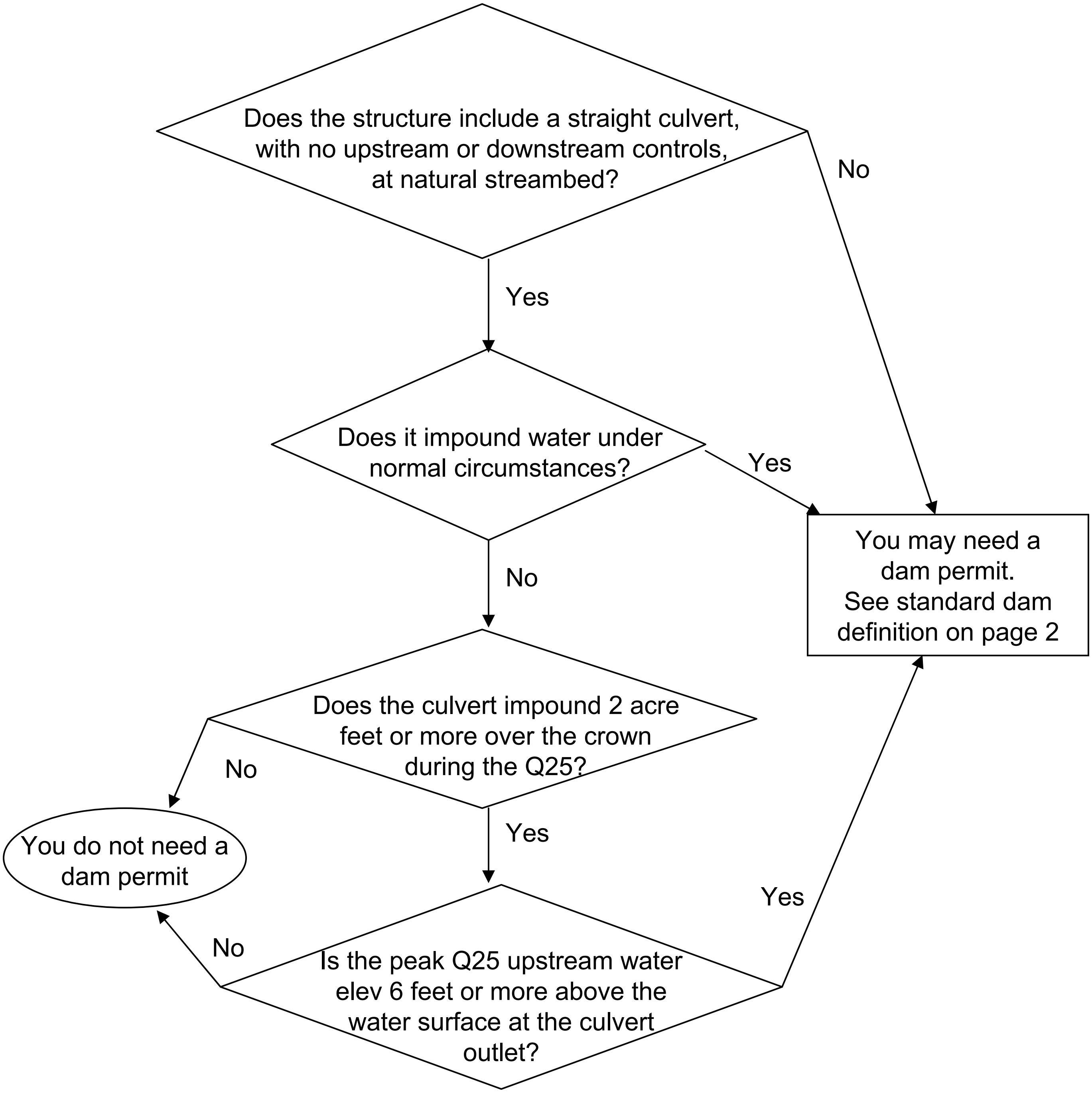
Is your Storm Water Detention Pond a dam?



If you have any questions please call
NH DES, Dam Bureau at 603-271-3406 or
email us at damsafety@des.state.nh.us

Effective as of
Friday, August 18, 2006

Is your Roadway culvert a dam?



Effective as of
Friday, August 18, 2006

If you have any questions call
NH DES, Dam Bureau at 603-271-3406 or
email us at damsafety@des.state.nh.us