LID Guidance Manual for Maine Communities

Approaches for implementation of Low Impact Development practices at the local level

September 21, 2007




Prepared for:
Maine Coastal Program
State Planning Office
38 State House Station
Augusta, Maine 04333

Submitted by:
Horsley Witten Group
21 Pleasant Street, Suite 216
Newburyport, MA 01950

TABLE OF CONTENTS

Chapter 1. Introduction

1.1 Purpose of this Guidance Manual

The purpose of this guidance manual is to help municipalities implement Low Impact Development practices on small, locally permitted development projects. This manual provides a recommended set of low impact development (LID) standards and guidance on implementing LID practices to comply with those standards. LID practices are a set of site development strategies that are designed to mimic natural hydrologic function by reducing stormwater runoff and increasing groundwater recharge and pollutant treatment. LID practices are almost always small in scale and diffuse across a project site; they are generally surface vegetative systems that are integrated with the site development infrastructure.

This manual is intended to guide municipalities that review development of subdivisions and small commercial projects and issue building permits for single family construction or building renovations and additions. This manual provides recommenations for those municipalities to ensure that a basic level of stormwater management is incorporated into those projects using LID practices. These projects, which often have minimal or no requirements for stormwater management, can have a cumulative effect on downstream properties and receiving waters in terms of increased flooding, increased erosion, and increased pollution.

This manual provides guidance on basic and alternative LID standards that municipalities can use in reviewing small subdivisions and non-residential developments, and in issuing building permits for single family construction. It also provides guidance for both the reviewing agency and the project applicant in selecting and designing appropriate LID practices for a given type of project. In addition, this manual includes a separate section geared toward LID improvements to existing development that will improve the stormwater management on a site. Use of these practices to "retrofit" existing development sites can be simply a voluntary improvement to a site, to solve existing stormwater problems or improve conditions within a watershed, or they can be required as a condition of a building permit or site plan review for a building renovation or expansion.

Chapter 5 contains detailed "Practice Profiles" for a suite of LID management strategies adapted to these smaller scale projects. These include:

- Underdrain soil filters (bioretention, rain gardens and swales);
- Vegetative buffers;
- Infiltration practices (dry wells and infiltration trench);
- Pervious pavements;
- Rain barrels and cisterns;
- Green roofs;
- Stormwater planters; and
- Micro-bio inlet.

1.2 Low Impact Development – Concept and Application

Low Impact Development is a process of developing land in a manner that mimics the natural hydrologic balance on a site. It combines site design strategies and best management practices to achieve this goal. Conventional development can create large areas of impervious surfaces in the form of rooftops, driveways, parking areas, walkways, patios and roadways, and often results in significant reduction in forest or other natural vegetated land cover to accommodate the development and the construction process. This change in land cover translates into an increase in stormwater runoff volume and rate, and a reduction in groundwater recharge. The goal of LID is to reduce the volume and flows of runoff from the developed site and to treat and recharge precipitation in a way that mimics the natural hydrology of the site. LID helps to manage the impacts that stormwater runoff has on wetlands, streams, lakes and coastal environments, and helps to recharge natural groundwater aquifers.

> "The Goal of LID is to reduce the volume and flows of runoff from the developed site and to treat and infiltrate precipitation in a way that mimics the natural hydrology of the site."

Under natural conditions, rainfall infiltrates into the ground, recharges the groundwater aquifers and provides baseflow to streams, rivers and wetlands. Another significant portion of rainfall is cycled back to the atmosphere through evapotranspiration, a combination of evaporation from the ground and vegetation surfaces and the natural process of transpiration that occurs in plants. The remainder of rainfall is converted to runoff and flows into surface waters.

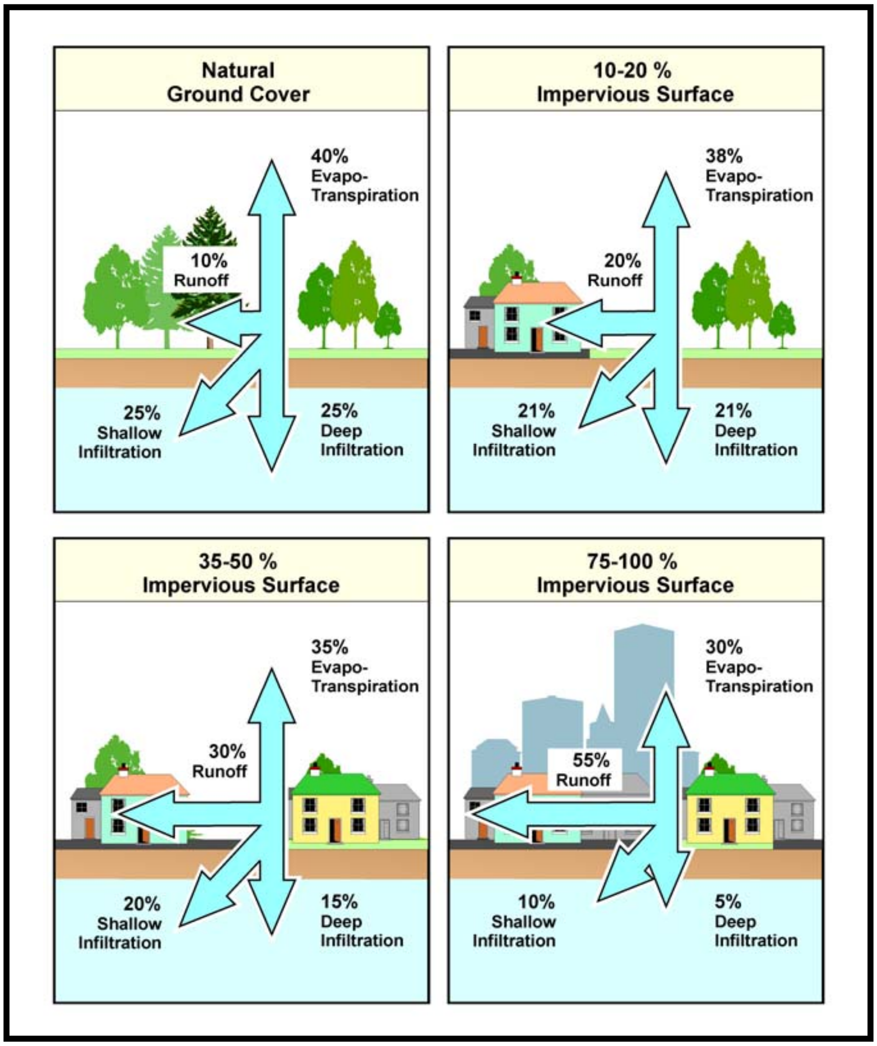
Development changes the natural water balance on a site by:

- increasing impervious area and reducing the amount of ground area capable of infiltration,
- converting naturally vegetated areas to impervious or manicured areas, and
- compacting natural soils.

This change in the water balance is demonstrated by the arrows in Figure 1. Development also traditionally connects impervious areas to create long runoff pathways that often terminate in direct discharges to surface waters. This creates the following hydrologic changes:

- larger volumes of runoff than under natural conditions,
- less recharge to groundwater, and
- higher peak flow rates than under natural conditions.

Figure 1. Effects of Impervious Surface on the Water Balance



LID is a concept that changes the way a site is designed in order to mimic the natural water balance as much as possible. This is done by maintaining as much of the natural vegetative cover on a site as possible and siting buildings, driveways and parking areas in a way that avoids and minimizes impacts to wetlands, surface water, source water protection areas and other important features. Once the basic site design is created, LID practices can be integrated into the design to further improve stormwater management to reduce the pollutant load carried in the stormwater, reduce erosion, reduce peak flows, reduce runoff volumes and increase infiltration on the site to maintain a more natural system.

An important concept related to LID is the concept of Better Site Design. Better site design is a set of related tools that help to reduce the environmental footprint of a development on the site, and help to reduce the need for stormwater management techniques. Better site design includes techniques such as maintaining natural vegetated areas and reducing manicured lawn areas, maintaining or planting native vegetation that is more hearty and requires less irrigation and fertilizer than non-native species, reducing pavement size by reducing driveway and roadway lengths and widths, reducing unnecessary sidewalks, building up rather than out to reduce building footprint, and avoiding natural resource areas such as wetlands, springs, wellhead areas, or special habitat areas.

1.3 Benefits and Limitations of LID

The benefits of low impact development are generally linked to better management of stormwater, but LID also can result in lower development costs, lower drinking water consumption, lower energy usage, and improved aesthetics. LID techniques provide water quality benefits by filtering out pollutants, such as sediment, bacteria, and nutrients bound to the sediments, or by taking up nutrients, such as nitrogen and phosphorus in vegetation, prior to infiltration or discharge. The LID techniques can also provide benefits by reducing flooding. Techniques that slow the movement of runoff and promote the infiltration of runoff close to the source can help to reduce flooding during the more frequent small and medium storms. LID techniques reduce the volume of runoff, by reducing the amount of impervious surfaces that create runoff and breaking up and slowing the flow path(s) of runoff from a site.

The use of LID and better site design can have a number of **benefits** that extend beyond improving water quality and stormwater runoff management that include:

- Reduced construction costs;
- Reduced long term operation and maintenance costs;
- Increased property values;
- Easier compliance with wetland and other resource protection regulations;
- More open space for recreation;
- More pedestrian friendly neighborhoods;
- Protection of sensitive forests, wetlands, and habitats; and
- More aesthetically pleasing and naturally attractive landscape.

Certain site conditions can limit the applicability and effectiveness of LID practices. These **limitations** can include:

- High water table;
- Presence of ledge at or just below the land surface;
- Impermeable or saturated soils;
- Steep slopes; and
- Site location within a wellhead protection area.

Most LID practices can be designed to work within a number of limitations of a site, even if it means that the practices will provide water quality filtration but will have to forego the benefits of infiltration. Practices can be adapted to local conditions by using an underdrain system, a liner, an irregular layout design, using a second practice as pretreatment to provide additional pollutant removal, or by placing the practice in a different location on the site.

1.4 Regulatory Implementation

The proposed LID standards and this guidance manual address projects that fall below the review threshold for Chapter 500 under the Maine Stormwater Management Law and the Site Law. These projects are not large enough to be reviewed at the state level for stormwater management and are reviewed by local boards and zoning officers through the local Subdivision Regulations, Site Plan Review ordinance, and Building Permit process. The local review process often differs between municipalities as some municipalities may not have a local site plan review ordinance, different communities have different levels of staffing for project review and some communities have tailored their subdivision regulations in various ways to meet community needs over time. Municipalities should consider incorporating these LID standards into their project review and permitting processes.

The LID standards proposed in this document are designed to be easily adapted into existing subdivision regulations, for minor subdivisions, local site plan review ordinances, or the local building permit issuance process. These standards could be implemented by the local Planning Board or the local Zoning Codes Enforcement Officer, depending on the type and size of the project.

1.5 The Nature of LID Strategies

Individual sites can vary in land use, soil conditions, topography, and groundwater depth, which can all affect how water drains across the site and which LID techniques will be appropriate. LID techniques can generally be used and designed for a range of drainage area sizes (though a drainage area of five acres to any one practice is probably the maximum), hydrologic soil groups, depths to water table, and land areas. The variety of LID practices and adaptability in design provide flexibility in selecting appropriate practices for most sites.

The goal of LID is to mimic the natural site hydrology as closely as possible. The potential hydrologic alteration of a large commercial area with several stores and large parking lost is vastly different from the potential impact of a single family home or a small commercial office or single store with a handful of parking spaces. Therefore, the selection, size and number of LID practices that would be required to address runoff on each type of site will differ accordingly. Smaller development sites warrant the use of simpler, smaller, and more affordable practices than a larger development that may disturb an acre or more of land. Guidance on stormwater requirements and stormwater practices, including LID practices, for larger sites can be found in the Manual Stormwater Management for Maine (ME DEP).

LID practices vary in the maintenance requirements, construction costs, level of benefits and limitations. Some practices, such as a buffer, a swale or a rain barrel, are well-suited to single family residential lots because of their simplicity, ease of maintenance, and adaptability. Conversely, certain practices, such as a stormwater planter, a large infiltration trench, or a green roof, may be more appropriate for use at a small commercial site than on a residential lot. A number of LID practices can be uniquely adapted for making stormwater management improvements at existing developed sites.

Selection Matrix 1 below provides an overview of a menu of LID practices that are recommended for use in three categories of small development: new single family residential development, new non-residential development and multifamily, and renovation of existing development for which stormwater improvements can be made.

Selection Matrix 1. Selecting Appropriate Practices for Different Land Use Types

LID Practices	Single Family Residential Lot	Small Non-Residential/ Multifamily Lot	Existing Development
Underdrain Soil Filters			
Bioretention System	○	●	⦿
Rain Garden	●	○	⦿
Swale	●	●	⦿
Vegetated Buffer	●	●	●
Infiltration Practices[1]			
Dry well	●	●	●
Infiltration Trench	⦿	●	●
Pervious Pavement	●	●	⦿
Rain Barrel/ Cistern	●	●	⦿
Green Roof	○	●	●
Stormwater Planter	○	●	●
Micro-bio Inlet	○	○	●

Key: ● = suitable, ⦿ = sometimes suitable with careful design, ○ = rarely suitable

1. Infiltration practices are not appropriate in wellhead protection zones, and must have pretreatment to remove sediments that can clog the system unless the practice collects rooftop runoff only.

Within each of these land use categories, there are certain areas that create runoff and convey pollutants. These areas, in general terms, are:

- rooftops,
- non-rooftop impervious areas (driveways, parking areas, walkways, patios), and
- disturbed pervious areas (lawn).

Some LID practices are better suited than others for to collecting and treating runoff from each of these areas. Selection Matrix 2 provides guidance in selecting the appropriate LID practice to address runoff form these three areas. This matrix should be used in conjunction with Selection Matrix 1 so that once the LID practices that are suitable for a given land use are selected, they can be further designated to treat each of the three runoff source areas. All three runoff source areas must be treated in order to provide effective runoff management for the site.

Selection Matrix 2. Selecting Appropriate Practices for Different Runoff Source Areas

LID Practices	Rooftop	Non-Rooftop Impervious Areas	Disturbed Pervious Areas (Lawn)
Underdrain Soil Filters			
Bioretention System	●	●	●
Rain Garden	●	●	●
Swale	●	●	●
Vegetated Buffer	●	●	●
Infiltration Practices[1]			
Dry well	●	○	○
Infiltration Trench	●	●	○
Pervious Pavement	○	●	○
Rain Barrel/ Cistern	●	○	○
Green Roof	●	○	○
Stormwater Planter	●	○	○
Micro-bio Inlet	○	●	●

1. Infiltration practices are not appropriate in wellhead protection zones, and must have pretreatment to remove sediments that can clog the system unless the practice collects rooftop runoff only.

Key: ● = suitable, ○ = unsuitable

1.6 How to use this Guidance Manual

The remainder of this guidance manual is divided in to four sections, plus appendices:

Chapter 2. New Single Family Residential Development,
Chapter 3. New Non-Residential and Multifamily Development, and
Chapter 4. Existing Development
Chapter 5. Practice Profiles
Appendix A. Submittal Requirements for LID Compliance
Appendix B. Example Application Forms
Appendix C. Definitions for Local Code

The first two chapters include a description of the LID standards for that type of development, as well as a set of guidance information for selection and design of LID practices appropriate for that type of development. Two optional sets of LID standards are provided for each type of development. First, a default LID standard is presented that prescribes set of practices, including a buffer, a maximum impervious cover area, and a minimum natural area preservation requirement. This default LID standard, the Basic LID Standard, represents a “minimal impact” threshold of development that is presumed to meet the “natural hydrologic function” of a LID implementation approach. If the default standard cannot be met on a site due to site constraints or site design preference, the Alternative LID Standards for that land use type must be met. These alternative standards require a more “engineered” approach to incorporate LID practices that mimic the lost function of preserved natural areas and buffer areas and/or to manage the runoff from a larger impervious area.

Chapter 4 is targeted at existing development that can benefit from the use of LID to make improvements to the site hydrology and stormwater management. These improvements are not required to meet a standard, but can be implemented to reduce and manage stormwater impacts from the existing development. The guidance provided in this chapter will assist landowners in selecting effective practices and in designing and maintaining them appropriately.

Chapter 5 presents a suite of “practice profiles” that provide detailed guidance on the appropriate LID practices for each type of development. These profiles include a description of the practice; guidance on benefits and limitations; selection and location; sizing and design; and planning level costs.

The Appendices provide guidance to communities on application forms for new residential development, new non-residential or multifamily development and retrofit or expansion projects. They also include example submittal requirements, and a list of definitions that help to understand this manual, and may be incorporates into local code.

Each of the following three chapters (Chapters 2-4) can be viewed independent of the others, but should be used in conjunction with this introductory chapter, Chapter 5, the practice profiles, and the Appendices.

Chapter 2. New Single Family Residential Development

Single family residential development, including individual lots and minor subdivisions, will be regulated by the standards described below. A Basic LID Standard is provided that presumes a minimal hydrologic alteration will result from the project and consequently the objectives of LID are met at the site. If an applicant meets this standard, they are not required to do any further stormwater management on the site. If an applicant cannot or elects not to meet the Basic LID Standard, the Alternative LID Standards apply.

It is expected that these LID practices will provide sufficient treatment, erosion control and flood mitigation to protect downstream properties and receiving waters from development impacts. Municipalities may wish to tailor these standards to better address known concerns in the community. In addition, municipalities may wish to adopt more stringent standards for lots located within watersheds to impaired or sensitive waterbodies. These could be locally designated waters or waters designated by the state in Chapter 502 as Lakes Most at Risk from New Development and Urban Impaired Streams.

A single family residential development, including development of an individual lot of any size and development of a subdivision, that does not require review under Chapter 500 must meet either the Basic LID Standard described in Section 2.1 or the Alternative LID Standards described in Section 2.2.

2.1 Basic LID Standard for New Development

The following basic LID Standard applies to new development of individual residential lots or small residential subdivisions that fall below the threshold for state stormwater review under Chapter 500. A project must meet all provisions of the standard.

BASIC LID STANDARD
Requirements for New Single Family Lot Development:
• Disturbance on an individual lot must be less than 15,000 square feet (including building, driveway, walkways, lawn area, construction access, grading).
• A minimum natural vegetated buffer must be maintained downgradient of all developed area on the lot. This buffer shall be 35 feet wide if naturally forested or 50 feet wide if maintained as a natural meadow. *
• No more than 7,500 square feet of impervious cover is located on the property.
• A minimum of 25 percent of the lot area must be maintained as undisturbed natural area.*
Requirements for a New Subdivision Development:
• Each lot within the subdivision must meet the Basic LID Standard for single family residential development listed above.
• The access road must be open section road (served by roadside swales) with a pavement width of no more than 22 feet.

* Note: If the lot or a portion of the lot is located within a watershed to a Lake Most at Risk from New Development, Urban Impaired Stream, or other impaired or sensitive waterbodies as designated by the municipality for the purposes of this standard, a minimum buffer of 50 feet if naturally forested or 75 feet if maintained as a meadow must be maintained downgradient of all developed area on the lot, and a minimum of 40 percent of the lot area must be maintained as undisturbed natural area. If the existing land has been disturbed by prior activities, a natural vegetated buffer and/or undisturbed natural area may be proposed through restoration and revegetation.

2.2 Alternative LID Standards for New Development

A property owner or developer may choose not to meet the Basic LID Standard due to site constraints or design preference. In situations where the Basic LID Standards are not met on a project, the project must meet the following Basic LID Standards.

ALTERNATIVE LID STANDARDS
Requirements for New Single Family Residential Lot Development:
• Use LID practices from those listed in Section 2.3 and described in Chapter 5, sized to treat 0.5 inches of runoff from all impervious surfaces on the site, and 0.2 inches of runoff from all disturbed pervious areas of the site (lawn).*
• The LID practices installed on the site must be maintained in perpetuity. If necessary, LID practices may be replaced with new LID practices as long as the overall site treatment standard above is met.
Requirements for a New Subdivision Development:
• Each lot within the subdivision must meet the Alternative LID Standards for single family residential development listed above.
• The access road must be open section road (served by roadside swales) with a pavement width of no more than 22 feet.

* Note: If the lot or a portion of the lot is located within watersheds to Lakes Most at Risk from New Development or other impaired or sensitive waterbodies as designated by the municipality for the purposes of this standard, the project must treat one inch of runoff from impervious surfaces and 0.4 inch from disturbed pervious surfaces.

Meeting this standard may require the use of more than one LID practice on the site, due to existing site topography and the layout of the property. For example, half of the roof may drain to the front of a building while the other half drains to the back of the building, and the lawn and driveway/parking area drain off to one side of the property. Drainage in each of these directions must be captured and treated using an LID practice. The selection, size and location of the LID practices used on a given site will depend on the size of the area draining to each practice and the area of impervious versus lawn area. While this may not always be feasible, applicants are encouraged to maintain natural buffers to the extent possible as a primary LID technique, which can then be augmented by other practices on the site. Guidance on how to size each LID practice to meet these Alternative LID Standards is provided in Chapter 5.

Appropriate LID practices for use in single family residential settings are described in the following section.

2.3 LID Practices

LID practices can be used to capture and treat runoff from residential rooftops, non-rooftop impervious areas such as paved driveways, patios and walkways, and maintained lawn areas. While there are a number of practices considered to be LID practices, this section lists just those that are appropriate for single family residential lots. These are:

- Buffer/filter strips
- Underdrain soil filters (rain gardens and swales)
- Dry wells
- Permeable pavers
- Rain barrels/cisterns

Each of the project profiles for these practices are included in Chapter 5 and include a description of the benefits and limitations of these practices, a discussion of selecting appropriate practices and appropriate locations for those practices, sizing guidelines, estimated planning level costs and maintenance requirements.

Chapter 3. New Non-Residential and Multifamily Development

Non- residential and multifamily residential development, including individual lots and minor non-residential subdivisions, will be regulated by the standards described below. The Basic LID Standard presumes that a minimal hydrologic alteration will result from the project and consequently the objectives of LID are met at the site. If an applicant meets this standard, they are not required to do any further stormwater management on the site. If an applicant cannot or elects not to meet the Basic LID Standard, the Alternative LID Standards apply.

It is expected that these LID practices will provide sufficient treatment, erosion control and flood mitigation to protect downstream properties and receiving waters from development impacts. However, certain municipalities may wish to tailor these standards to better address known concerns in the community. In addition, municipalities may wish to adopt more stringent standards for projects located within watersheds to impaired or sensitive waterbodies. These could be locally designated waters or waters designated by the state in Chapter 502 as Lakes Most at Risk from Development or Urban Impaired Streams.

A non-residential or multifamily residential development, including development of an individual lot of any size and development of a non-residential subdivision, that does not require review under Chapter 500 must meet either the Basic LID Standard described in Section 3.1 or the Alternative LID Standards described in Section 3.2.

3.1 Basic LID Standard for New Development

The following Basic LID Standard applies to new development of multifamily and non-residential lots and small subdivisions that fall below the threshold for state stormwater review under Chapter 500. A project must meet all provisions of the standard.

BASIC LID STANDARD
Requirements for New Multifamily and Non-Residential Lot Development:
• Disturbance on an individual lot must be less than 1 acre (43,560 square feet, including building, driveway, walkways, lawn area, construction access, grading).
• A minimum 60-foot natural vegetated buffer must be maintained along downgradient property boundaries except where access to the property is provided. If the runoff flow path between developed areas and the buffer exceeds 60 feet for impervious surfaces or 100 feet for pervious surfaces, then a level spreader must be installed*
• No more than 15,000 square feet of impervious cover is located on the property.
• A minimum of 15 percent of the lot area must be maintained as undisturbed natural area.*

Requirements for New Multifamily and Non-Residential Subdivision Development:
• Each lot within the subdivision must meet the Basic LID Standards for new multifamily and non-residential development listed above.
• The access road must be open section road (served by roadside swales) with a pavement width of no more than 22 feet.

* Note: If the lot or a portion of the lot is located within a watershed to a Lake Most at Risk from New Development, Urban Impaired Stream, or other impaired or sensitive waterbodies as designated by the municipality for the purposes of this standard, a minimum 100-foot natural vegetated buffer must be maintained along downgradient property boundaries, and a minimum of 25 percent of the lot area must be maintained as undisturbed natural area. If the existing land has been disturbed by prior activities, a natural vegetated buffer and/or undisturbed natural area may be proposed through restoration and revegetation.

3.2 Alternative Standards for New Development

A developer may choose not to meet the Basic LID Standard due to site constraints or design preference. In situations where the Basic LID Standard is not met on a project, the project must meet the following Alternative LID Standard.

ALTERNATIVE LID STANDARD
Requirements for New Multifamily and Non-Residential Lot Development:
• Use LID practices from those listed in Section 3.3 and described in Chapter 5, sized to treat 0.5 inches of runoff from all impervious surfaces on the site, and 0.2 inches of runoff from all disturbed pervious areas of the site (lawn).*
• The LID practices installed on the site must be maintained in perpetuity. If necessary, old LID practices may be replaced with new LID practices to ensure the overall site treatment standard above is met.
Requirements for New Multifamily and Non-Residential Subdivision Development:
• Each lot within the subdivision must meet the Alternative LID Standards for multifamily and non-residential development listed above.
• The access road must be open section road (served by roadside swales) with a pavement width of no more than 22 feet.

* Note: If the lot or a portion of the lot is located within a watershed to a Lake Most at Risk from New Development, Urban Impaired Stream, or other impaired or sensitive waterbodies as designated by the municipality for the purposes of this standard, the project must treat one inch of runoff from impervious surfaces and 0.4 inch from disturbed pervious surfaces.

Meeting this standard may require the use of more than one LID practice on the site, due to existing site topography and the layout of the property. For example, half of the roof may drain to the front of a building while the other half drains to the back of the building, and the lawn and driveway/parking area drain off to one side of the property. Drainage in each of these directions must be captured and treated using an LID practice. The selection, size and location of the LID practices used on a given site will depend on the size of the area draining to each practice and the area of impervious versus lawn area. While this may not always be feasible, applicants are encouraged to maintain natural buffers to the extent possible as a primary LID technique, which can then be augmented by other practices on the site. Guidance on how to size each LID practice to meet these Alternative LID Standards is provided in Chapter 5.

Appropriate LID practices for use in non-residential and multifamily settings are described in the following section.

3.3 LID Practices

LID practices can be used to capture and treat runoff from multifamily residential and non-residential rooftops, non-rooftop impervious areas such as paved driveways, patios and walkways, and maintained lawn areas. While there are a number of practices considered to be LID practices, this chapter includes fact sheets for those that are appropriate for multifamily residential and non-residential development. These are:

- Buffer/filter strip
- Underdrain soil filters (bioretention system, swales)
- Dry well/infiltration trench
- Stormwater Planter
- Permeable pavers
- Cistern
- Green roof

Each of the practice profiles for these practices are included in Chapter 5 and include a description of the benefits and limitations of these practices, a discussion of selecting appropriate practices and appropriate locations for those practices, sizing guidelines, estimated planning level costs and maintenance requirements.

Chapter 4. Existing Development

A number of LID techniques can be used to effectively improve the stormwater management on an existing developed site. Retrofitting of existing site to improve stormwater management can have a significant impact both on a given site and the area downstream of that site. Some landowners may be interested in making improvements to the stormwater management on their site, but do not know exactly what stormwater practices are appropriate. Some municipalities may want to promote the use of LID practices to retrofit the drainage and stormwater treatment from existing development as a way to help remedy a water quality or flooding problem. The goal of this chapter is to help guide individuals and towns in selecting appropriate LID practices to improve stormwater management on existing sites.

The use of LID techniques on existing developments can help to improve the water quality and quantity problems that may be occurring downstream or on downstream sections of a property, and can help to reduce erosion and sedimentation from large concentrated stormwater flows that may be discharging from an existing site. This chapter will help to guide property owners in selecting appropriate practices to retrofit an existing development, based on benefits, limitations and estimated costs of the practices, as well maintenance requirements and engineering design requirements. This guidance also could be used to help municipalities or watershed organizations to perform stormwater management and hydrologic improvements to restore a water body that may be impaired by stormwater runoff.

Below is a description of a number of LID practices that are suitable for retrofitting the stormwater management on existing development. These practices include:

- Buffer/filter strip
- Underdrain soil filters (rain garden, bioretention system, swales)
- Dry well/infiltration trench
- Permeable pavers
- Rain barrel/cistern
- Stormwater Planter
- Micro-bio Inlet
- Green roof

Practice profiles for each of these practices are provided in Chapter 5. Each practice profile includes a description of the benefits and limitations of these practices, a discussion of selecting appropriate practices and appropriate locations for those practices, sizing guidelines, estimated planning level costs and maintenance requirements.

Some communities may wish to make LID a part of the permit process for improvement or expansion projects, in addition to new development projects. These types of projects typically receive approval from the building inspector/ zoning enforcement officer. The following pages provide a recommended set of submittal requirements and a suggested application form that could be used in conjunction with a building permit for building improvements or building expansion projects.

Chapter 5. Practice Profiles

This chapter provides a profile of each of the recommended LID practices described in the LID Guidance Manual for Maine Communities. The following LID practices are presented:

- Vegetative buffers;
- Underdrain soil filters (bioretention, rain gardens and swales);
- Infiltration practices (dry wells and infiltration trench);
- Pervious pavements;
- Rain barrels and cisterns;
- Green roofs;
- Stormwater planters; and
- Micro-bio inlet.

Each profile includes the following information:

- Description of the practice;
- Benefits and Limitations;
- Selection and Location Guidance;
- Sizing and Design Guidance;
- Cost Information; and
- Maintenance Requirements.

Additional information about using these LID practices can be found in the guidance manual Stormwater Management for Maine, Volumes 1 and 3 (ME DEP, January 2006 or latest version). The following additional resources are also recommended:

- The Stormwater Managers Resource Center, a website developed and maintained by the Center for Watershed Protection through a grant from the U.S. Environmental Protection Agency (www.stormwatercenter.net);

- The University of New Hampshire Stormwater Center (www.unh.edu/erg/cstev); and

- The Low Impact Development Urban Design Tools website, developed under a cooperative agreement between the U.S. Environmental Protection Agency and the Low Impact Development Center, Inc. (http://www.lid-stormwater.net/).

Buffers / Filter Strips

Summary

Vegetated filter strips or buffers are engineered stormwater treatment areas (e.g., planted sheet-flow structure on a roadside) or undisturbed natural areas (e.g., forested conservation areas) where vegetation serves as a buffer to manage stormwater runoff and can be used to treat (e.g., filter pollutants) and control stormwater flows from generally smaller areas of a development project or single family lot.

Description

Vegetation buffers consist of a prescribed horizontal length of vegetation that serves to disperse and infiltrate stormwater runoff immediately adjacent to streams, rivers, shorelines and wetland resources. Buffers are particularly crucial in minimizing pollutant delivery into waterbodies (Figure 1,) but are also very effective stormwater management tools when created or maintained along property boundaries or other areas downgradient of disturbed areas. Buffers can be distributed throughout a watershed to treat runoff from adjacent development locations, and are not limited to areas adjacent to water bodies. However, riparian buffers are an important special class of buffer or natural conservation area along a stream, wetland or shoreline where development is restricted or prohibited. Their primary function is to protect and physically separate a stream, lake, coastal shoreline, or wetland from disturbance or encroachment from existing or future development. If properly designed, a buffer can provide stormwater management functions, can act as a right-of-way during floods, and can help sustain the integrity of water resource ecosystems and habitats.

Figure 1: Vegetated Filter Strip

Buffers comprised of natural forest vegetation can be preserved as part of new development projects to serve as a filter for runoff, and to provide storage and infiltration of rainwater. When preservation of vegetation is not possible to create a natural buffer, a vegetated buffer such as a meadow buffer can be created. Stormwater flowing into these buffer areas should be sheet flow and may require the use of a level spreader. New vegetated buffers are designed to disperse the flow of stormwater runoff as sheet flow, reduce runoff velocity and therefore serve to protect areas from erosion, as well as serve as pollutant filters.

Filter strips are shallow pitched vegetated areas. Grasses and herbaceous layers or low-lying groundcovers are often used in areas accessible to pedestrians and potential recreation activities. Trees and shrubs can be added or preserved as part of vegetation buffers or large filter strips.

The objective in utilizing natural areas for stormwater infiltration is to intercept smaller drainage areas and then distribute flow evenly as sheet flow to the buffer or natural area. This is frequently accomplished using a level spreader. A mechanism for the bypass of higher flow events is often provided to reduce erosion or damage to a buffer or undisturbed natural area.

Benefits and Limitations

Benefits:

- Filter strips and buffers can be used to filter and infiltrate stormwater runoff to reduce pollutant loading;
- Filter strips may provide groundwater recharge as runoff infiltrates into the soil;
- Filter strips are inexpensive to construct, especially when compared to conventional enclosed drainage systems, and may significantly reduce the need for storm drains, thus reducing stormwater infrastructure costs;
- Filter strips can receive runoff from areas as small as residential lawns or as large as moderately sized commercial parking areas;
- Vegetated filter strips help to accent the natural landscape by providing green space adjacent to parking lots and roadways;
- Some buffers may serve as recreational areas;
- A buffer of adequate width is part of the Basic LID Standard for single family lots and non-residential sites to meet stormwater management objectives;
- Larger buffers located in natural depressions can provide inexpensive storage and detention of stormwater flows; and
- In cold climates, buffer areas and filter strips can be used as a snow storage area, which will also help to trap and treat the salt, sand, and other pollutants in meltwater. When used for this purpose, or if used to treat parking lot runoff, the filter strip should be planted with salt tolerant, and non-woody plant species;
- Vegetated filter strips also reduce runoff velocities and peak discharge rates.

Limitations:

Limitations	Methods to Overcome them
Buffers require space	*Use in areas where land is available and land costs are not significantly high.*
Buffers or filter strips may be inappropriate in areas of higher pollutant loading due to direct infiltration of pollutants.	*Integrate with other practices to ensure adequate treatment prior to discharge.*
Undersized buffers and filter strips can gully and erode during larger storms	*Limit the drainage area and contributory flow path to no more than 60 feet from impervious surfaces and 100 feet from pervious surfaces; use erosion control matting and level spreaders to maintain sheet flow entering the buffer strip. No more than 0.75 acres of impervious area should drain to a single buffer.*

Selection and Locations

A few things to consider when selecting this practice:

- Delineate and preserve naturally vegetated buffers, including riparian buffers, first (define the width, identify the target vegetation, designate methods to preserve the buffer indefinitely);
- Ensure that buffers and native vegetation are protected throughout planning, design, construction and occupancy;
- Direct runoff towards buffers and undisturbed areas using sheet flow or a level spreader to ensure sheet flow;
- Utilize natural depressions for runoff storage;
- Examine the slope, soils and vegetative cover of the buffer/filter strip;
- Disconnect impervious areas to these areas;
- Choose vegetation to help meet certain environmental control objectives (e.g., nutrient or pathogen management) or to suit pre-existing conditions (e.g., sunlight and water available);
- During construction, runoff from unstabilized areas should be diverted away from filter strips and the underlying soil should be protected from compaction to the extent possible (e.g., work from outside the boundaries of the filter strip or use oversized tires and lightweight equipment);
- Consult local planning authority for minimum buffer width and/or recommended width.

Sizing Guidelines

<u>Filter Strips</u>

- Flowrate is the main limiting sizing factor for filter strips.
- Minimum length should be 20’ long (perpendicular to flow) to provide water quality treatment.
- Minimum width is 8’ or 0.2 X length of flow over the impervious surface upstream of the filter strip.

<u>Buffers</u>

- Maximum contributing area to vegetated buffers: 60 feet for impervious surfaces, and 100 feet for pervious surfaces (flow concentration increases with distance). If the runoff flow path between developed areas and the buffer exceeds these distances, then a level spreader must be installed.
- Maintain a 35-foot minimum width naturally forested buffer or a 50-foot minimum width meadow buffer down-gradient from disturbed areas on single family lots (50 feet for naturally forested and 75 feet for meadow buffers for sites in watersheds to impaired or sensitive waterbodies).
- Maintain a 60-foot minimum width down-gradient from disturbed areas on non-residential and multifamily lots (100 feet for sites in watersheds to impaired or sensitive waterbodies).Other buffers can be created or maintained along property boundaries or other areas downgradient of disturbed areas.

General

- The slope should preferably be between 1% and 5%, but slopes up to 15% are acceptable, with erosion control matting.
- The top and toe of the slope should be as flat as possible.
- Maximum normal velocity of 1.0 feet/second for design flow, with maximum permissible velocity of 3.0 feet/second for peak discharge during 10-year storm. Use Manning's equation to calculate velocity. The vegetative cover selected for the area should withstand calculated flow velocities.
- Maximum depth of sheetflow for the design storm: ½ inch.
- If a level spreader is used to maintain sheetflow into the buffer, it should be at least 10 feet long for every 5,000 square feet of impervious area that drains to it.

Costs

Costs for establishing vegetative buffers will vary dramatically depending on the type of vegetation chosen and the extent to which existing buffers will simply be maintained. Grass seed for drought tolerant species or wildflower mixes will generally cost between $300 and $600 per acre of newly established buffer. If a mature forest is the desired goal for a newly established buffer, trees will cost between $100 to $300 each depending on the type and caliper. If clearing and grubbing are required for the initial grow-in of vegetated areas, a cost estimate of $12 per square foot is a reasonable expectation. The most significant cost of filter strips may be an indirect expense, which is the cost of the land, which may be very valuable in dense urban settings. In many cases, however, open spaces and buffers are required by municipal landscaping or zoning regulations, and filter strips may be used to satisfy these requirements. Established vegetated buffers may also add value to a property.

Maintenance

Maintenance of buffer areas depends on the type of buffer that is established. For all buffered areas, however, a moderate amount of trash pick-up and general housekeeping is expected depending on the level of pedestrian traffic. If buffered areas are more intensely landscaped or contain engineered features such as swales,depressions, or level spreaders, these areas may require mowing, pruning and regular inspection after rainfall to ensure upkeep and integrity. However, simple drought tolerant buffers require little maintenance beyond periodic housekeeping. Routine maintenance activities should include:

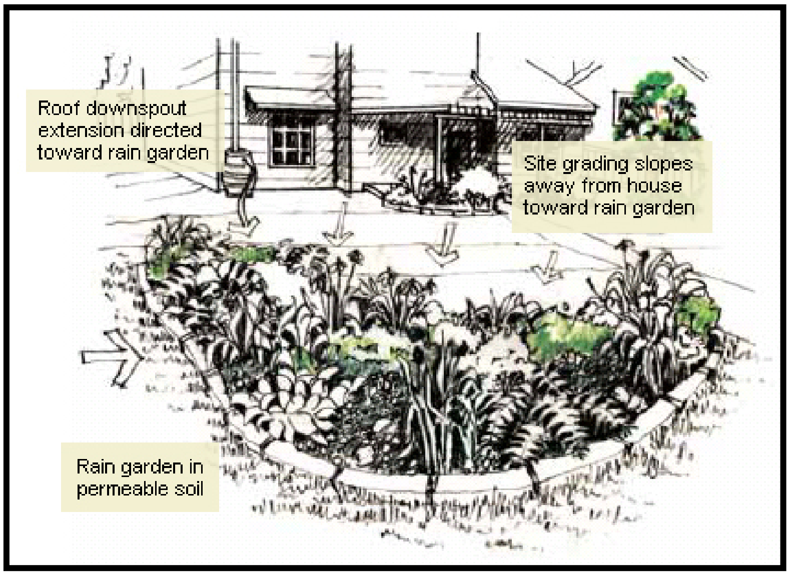
- Inspect level spreader monthly and remove built-up sediment or correct flow deficiencies.
- Inspect vegetation monthly for rills and gullies and correct. Fill any depressions or channels. Seed,sod, or re-vegetate bare areas.
- In the year following construction, inspect the filter strip regularly to ensure that vegetation has established. If not, replace with an alternative species. Allow natural succession by native grasses and shrubs if it occurs.
- Mow grass (if applicable), as rarely as 2-3 times per year, to maintain 4" to 6" of dense grass cover. Grass clippings should be composted into the filter strip if not too abundant. Provide a minimum of fertilizer only during initial establishment. Mow when the soil is dry and firm to prevent rutting.
- Semi-annually, remove sediment that has accumulated to prevent gullying or channeling.

Underdrain Soil Filters - Rain Garden

Description

Underdrain Soil Filters treat stormwater by capturing and retaining runoff and passing it through a filter bed comprised of specific soil media. Rain gardens are specific types of soil filter systems or vegetated biofilter systems, which can be designed with an underdrain mechanism. Rain gardens are well-suited for on-lot residential designs. They can be landscaped depressions on the lot used to mitigate rooftop runoff, or can be designed as the low point of a lot to treat all stormwater on-site. Rain gardens are vegetated with plantings that are both aesthetically pleasing and well suited to an environment periodically inundated with water. Rain gardens can be designed at different scales to suit different levels of runoff. Adequate sizing of these gardens will allow for infiltration for the most common smaller rain events, while runoff from larger events will overflow into other stormwater infrastructure or a receiving water body.

Figure 1: Layout of a typical rain garden



The planting soil is typically composed of organic matter in the form of leaf mulch (20%) blended into a sandy soil (50%) and about 30% top soil. The planting soil mixture provides a source of water and nutrients for the plants to sustain growth. Finer soil particles adsorb heavy metals, hydrocarbons and other pollutants. An organic mulch layer at the top provides for the decomposition of organic material, and also plays an important role in the removal of pollutants.

Benefits and Limitations

Benefits:

- Rain gardens can remove stormwater pollutants through the uptake by plants.
- Rain gardens are low maintenance systems. Once established, they require no fertilizer, watering, or mowing. A once a year cleanup, addition of shredded hardwood mulch to keep the surface moist and tidy, and removal of weeds and invasive species are all that are required.
- Rain gardens can contribute to groundwater recharge.
- A rain garden project can be part of the educational toolbox used by a community stormwater education team.
- Rain garden plants create wildlife habitat and attract butterflies, birds, and other wildlife.

Limitations:

- Drainage areas cannot be too large for rain gardens and slopes leading to it should be mild since large volumes of rain or runoff moving at high velocities will simply overwhelm these facilities.
- Where subsurface soils do not naturally allow for good drainage, these soils should be replaced or mixed with sandier materials.
- Rain gardens require relatively flat slopes to be able to accommodate runoff filtering through the system. Some design modifications can address this constraint through the use of berms and timber or block retaining walls on moderate slopes.
- Soils compacted by construction and heavy clay soils needs more augmentation than sandy soils, though all soils should be prepared to specification. In compacted soils and clay, additional excavation is necessary, along with a gravel bed and, under some circumstances, an underdrain system.
- Rain gardens should not be located in areas with heavy tree cover, as the root systems will make installation difficult and may be damaged by the excavation.

Selection and Locations

Rain gardens that are used in a residential setting should be located close enough to the home to catch roof runoff or within a lawn area to collect runoff from both the lawn and roof.
A few things to consider when selecting and locating a rain garden:

- First consider how the rain garden can be incorporated into the yard/site with the existing landscape.
- Runoff from driveways and other paved surfaces should be directed to the rain garden at a non-erosive rate through shallow swales, or allowed to sheet flow across short distances.
- Rain gardens should be located at least 10 feet from the house to prevent potential structural damage due to wetness or flooding.
- Rain gardens should never be located directly over a septic system.
- Locate a rain garden in areas where water typically drains, but not necessarily where puddles persist after storms. The goal of a rain garden is to encourage infiltration, and these wet patches typically represent a poor infiltration rate. Soils within these areas can be amended to increase infiltration capacity.
- Build the rain garden in full or partial sun, not directly under a shady tree, to speed up the drying cycle, assist in killing pathogens, and promote better plant growth and encourage evapotranspiration.
- It is best to place rain garden in a flatter portion of the yard and avoid steep slopes. For example, a rain garden 10 feet wide on a 10% slope must be 12 inches deep to be level, unless topsoil is imported.

Sizing Guidelines

The surface area of the rain garden can be almost any size, but time and cost will always be important considerations in sizing decisions. A typical residential rain garden ranges from 100 to 300 square feet. The size of the rain garden will depend on how deep the garden will be, what type of soils the garden will be planted in, and how much roof and/or lawn will drain to the garden. This information, along with the sizing factor will determine the surface area of the rain garden.

In general, the following considerations should be given to design of the rain garden:

- Ponding depth above the rain garden bed should not generally exceed 6 inches. The recommended maximum ponding depth of 6 inches provides surface storage of stormwater runoff, but is not too deep to affect plant health, safety, or create an environment of stagnant conditions. On perfectly flat sites, this depth is achieved through excavation of the rain garden and backfilling to the appropriate level; on sloping sites, this depth can be achieved with the use of a berm on the downslope edge, and excavation/backfill to the required level.
- Surface area is dependent upon storage volume requirements but should not exceed a maximum loading ratio of 10:1 (drainage area to infiltration area, where drainage area is assumed to be 100% impervious; to the extent that the drainage area is not 100% impervious, the loading ratio may be reduced).
- A length to width ratio of 2:1, with the long axis perpendicular to the slope and flow path is recommended.

Costs

Costs for rain garden installation will vary depending on the scale of the project. When compared with the costs of conventional landscaping, however, there is little difference in the overall budget. Increased costs would include any engineering design for larger gardens and may also include excavation for incorporating more permeable soils into the subsurface layers.

Maintenance

Maintenance of rain gardens is limited to erosion gully repair and regular landscaping activities such as mulching, weeding or irrigation during the dry seasons. The amount of irrigation required will depend in part on the type of plantings selected for the gardens. As with all landscaped areas, proper plant selection can make the difference between a success and failure. A planting plan design should include species that tolerate extremes. There will be periods of water inundation and very dry periods. Most riparian plant species will do well in rain gardens. The choice of species should include plants that mimic forest habitat and have an aesthetic landscape value such as flowers, berries, interesting leaves or bark. Groundcovers, perennials shrubs and trees should be incorporated into the planting design.

Underdrain Soil Filters - Bioretention

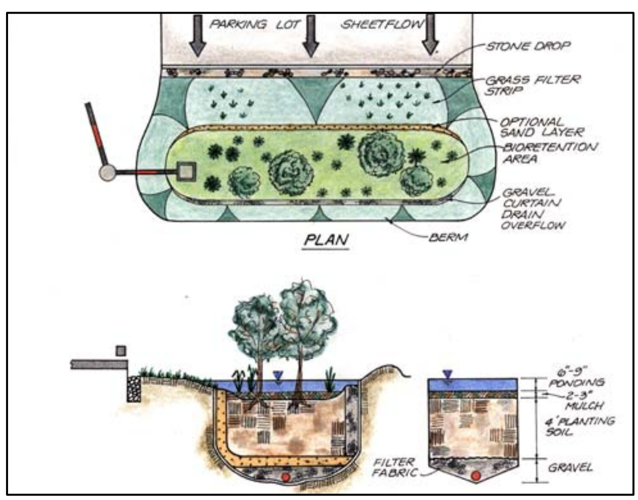
Description

Underdrain Soil Filters treat stormwater by capturing and retaining runoff and passing it through a filter bed comprised of specific soil media. Bioretention systems (also known as Biofiltration) are specific types of soil filter systems or vegetated biofilter systems, which can be designed with an underdrain mechanism. Bioretention areas are vegetated structural stormwater treatment facilities that offer an aesthetically pleasing alternative to pavement or traditional stormwater facilities (Figure 1). They resemble landscaped depressions and can contain grasses, wildflowers, or trees depending on the size of the facility.

Figure 1: An Example of a Bioretention System
(This system was recently planted and will fill in with vegetation over time.)

The practice manages and treats stormwater runoff using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression (Figure 2). The method combines physical filtering and adsorption with biological processes. Stormwater runoff is delivered by channels, filter strips, curb cuts or piping into these depressions where it temporarily ponds on the surface before seeping through an organic underground filter system and discharging to an underdrain network or infiltrating to the underlying soils. The gravel underdrain component of the system is utilized to collect and distribute treated runoff downstream to the drainage network or receiving waters. Typically, the under drain system consists of a gravel layer with a 4 or 6 inch perforated piping system (maintaining a 2 inch cover of gravel over the pipe). Treatment of stormwater includes attenuation of sediment, metals, bacteria and nutrients.

Figure 2: Schematic of a Bioretention System (Claytor & Schueler, 1996)



Benefits and Limitations

Benefits:

- Bioretention systems receive runoff from areas as small as residential lawns or as large as commercial parking areas.
- Using bioretention and other on-site treatment can significantly reduce the need for storm drains thus reducing stormwater infrastructure costs.
- Bioretention can be incorporated into roadway design as well, such as in the center of a cul-de-sac or within roadway rights-of-way or easements following sheet flow from the road surface.
- In cold climates, bioretention areas can be used as a snow storage area. When used for this purpose, or if used to treat parking lot runoff, the bioretention area should be planted with salt-tolerant, and non-woody plant species.

Limitations:

Limitations	Methods to Overcome them
Bioretention areas may be expensive.	*Using bioretention and other on-site treatment can significantly reduce the need for storm drains thus reducing stormwater infrastructure costs*
Biofiltration structures require regular maintenance.	*Regular maintenance amounts to general landscaping duties such as trash removal, mulching, weeding, and irrigation.*
In general, the bioretention systems cannot be located where the water table is very close to the ground surface.	*In situations where groundwater is encountered, the bioretention system and underain can be designed with an impermeable liner to separate treated stormwater from groundwater.*

Selection and Locations

A few things to consider when selecting this practice:

- Bioretention can be integrated into a parking lot, roadway design, and on-lot residential designs, as a retrofit or in redevelopment projects.
- Closely examine runoff volumes and velocities to ensure runoff enters bioretention in a distributed manner and in a non-erosive condition.
- Bioretention must have proper pre-treatment (e.g., grass channel, filter strip, gravel diaphragm/stone drop and/or a mulch layer).
- Locate the system in an area where groundwater limitations can be managed. The bottom of the underdrain filter should be 1 foot above seasonal high groundwater, unless an impermeable liner is used.

Sizing and Design Guidelines

Bioretention facility surface areas will typically be sized at a ratio of 5% of the impervious area and 2 % of the landscaped area draining to the facility to capture, manage, and treat runoff from the 1.0 inch storm event. In addition, there are several physical geometry recommendations that should be considered in the layout and design of bioretention facilities (Table 1).

Table 1: General Sizing/Design Guidance for a Bioretention System

Minimum width	10 feet
Minimum length	15 feet
Length to width ratio	2:1
Maximum ponding depth	6 inches
Planting soil depth	4 feet
Underdrain system	6" pipe in 8" gravel bed
Plant spacing	trees at 10-foot centers, shrubs at 5-foot centers, herbaceous materials at 1- to 2-foot centers

See the *Maine Stormwater Best Management Practices Manual, Volume III. BMP Technical Design Manual* (ME DEP, 2006) for specific design and sizing criteria.

Costs

Bioretention areas can be relatively expensive. The following cost equation was developed by Brown and Schueler (1997), adjusting for inflation:

$C = 7.30\ V^{0.99}$

Where:
C = Construction, Design and Permitting Cost ($)
V = Volume of water treated by the facility (cubic feet)
This amounts to about $6.80 per cubic foot of required water quality storage. Recent installations have been constructed from between $25 to $50 per square foot of facility.

An important consideration when evaluating the costs of bioretention is that it often replaces area that would likely be landscaped anyway. Thus, the true cost of the bioretention area may be less than the construction cost reported. Similarly, maintenance costs for bioretention areas are not very different from normal landscaping maintenance.

Maintenance

Inspections are an integral part of bioretention system maintenance. The following activities are recommended on an annual basis or as needed:

- Inspect system at least twice, or more, during the six months after construction, annually thereafter, and following precipitation events of at least 0.5 inch to ensure that the system is functioning properly.
- Minor soil erosion gullies should be repaired when they occur.
- Pruning or replacement of woody vegetation should occur when dead or dying vegetation is observed. Separation of herbaceous vegetation root shock should occur when over-crowding is observed, or approximately once every 3 years. The mulch layer should also be replenished (to the original design depth) every other year as directed by inspection reports.

- If at least 50 percent vegetation coverage is not established after two years, a reinforcement planting should be performed.
- If the surface of the bioretention system becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the surface should be roto-tilled or cultivated to breakup any hard-packed sediment, and then revegetated.

Underdrain Soil Filters – Grassed Swale

Description

The term "swale" (a.k.a., grassed channel, dry swale and wet swale) refers to a series of vegetated, open channel practices that are designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. As stormwater runoff flows through the swale, it is treated through filtering by the vegetation in the swale, filtering through a subsoil matrix, and/or infiltration into the underlying soils. There are many swale design variations, including the grassed channel, dry swale and wet swale. The specific design features and treatment methods differ in each design, but all are improvements on the traditional drainage ditch. Each incorporates modified geometry and other design features to use the swale to treat and convey stormwater runoff (Figure 1).

Grass channels are the most similar to a conventional drainage ditch, with the major differences being that they are designed with flatter side slopes and longitudinal slopes, and a slower design velocity for water quality treatment of small storm events (Figure 2). The best application of a grassed channel is as pretreatment to other structural stormwater treatment practices. Grass channels do not generally provide as much pollutant removal as dry swales or wet swales.

Dry swales are similar in design to bioretention areas. These designs incorporate a fabricated soil bed into the bottom of the channel. Existing soils are replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system is also installed under the soil bed. Typically, the underdrain system is created by a gravel layer which encases a perforated pipe. Stormwater treated by the soil bed flows into the underdrain, which conveys treated stormwater back to the storm drain system (see Figure 3).

Figure 1: Example of Grass Channel adjacent to a parking lot

Wet swales are similar to stormwater wetlands in their use of wetland vegetation to treat stormwater runoff (Figure 4). The water quality treatment mechanism relies primarily on settling of suspended solids, adsorption, and uptake of pollutants by vegetative root systems (Claytor & Schueler, 1996). Wet swales are designed to retain runoff for 24 hours.

Figure 2: Schematic of a Grass Channel (Vermont Agency of Natural Resources, 2002)

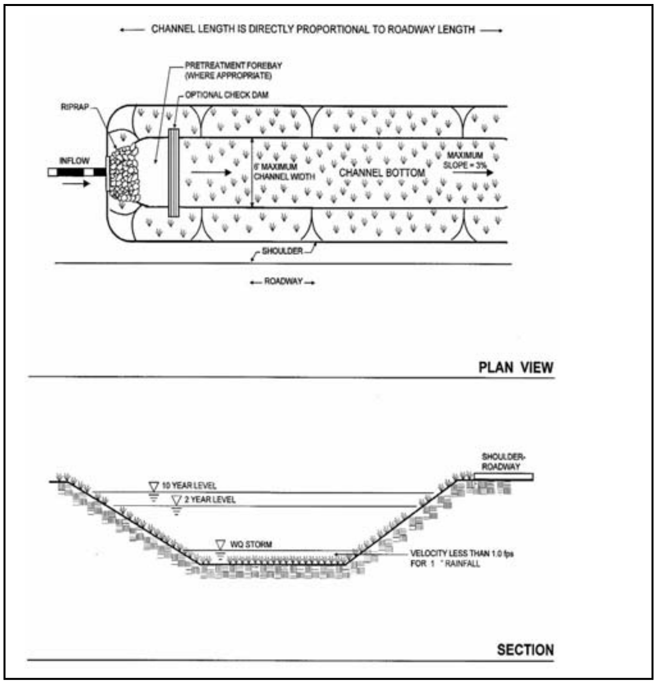


Figure 3: Schematic of a Dry Swale (Claytor & Schueler, 1996)

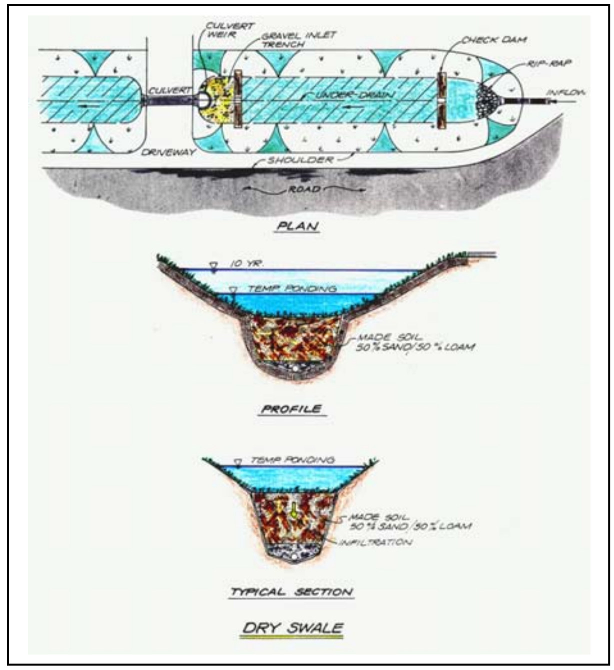
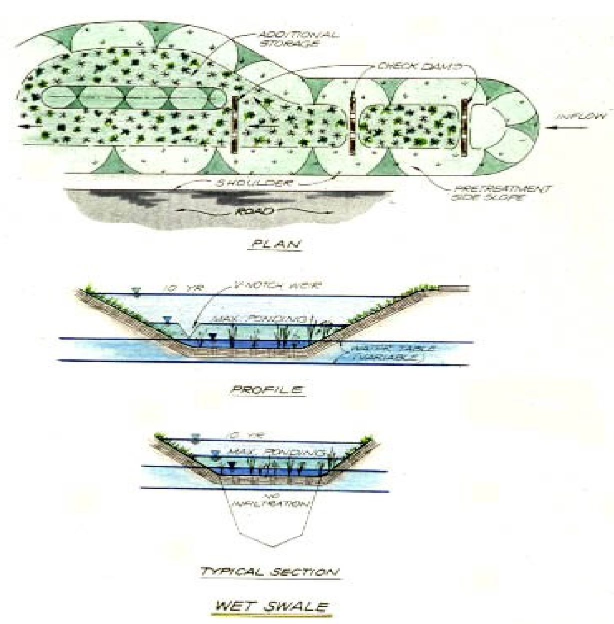


Figure 4: Schematic of a Wet Swale (Claytor & Schueler, 1996)



Benefits and Limitations

Benefits:

- Swales accent the natural landscape, break up impervious areas, and are appropriate alternatives to curbed roadways.
- They treat runoff from lower density areas and roadways where other practices can not be used due to sizing or aesthetic issues.
- They are an effective pretreatment system, often used in combination with other stormwater management practices as a part of the runoff conveyance system.
- Swales are a good treatment practice for watersheds that support cold water fisheries. They do not pond water for a long period of time, and often induce infiltration. As a result, standing water will not typically be subjected to warming by the sun in this practice.
- Swales can easily replace existing drainage ditches in retrofit situations.

Limitations:

- Individual swales cannot treat a very large drainage area.
- Swales do not appear to be effective at reducing bacteria levels in stormwater runoff.
- Wet swales may become a nuisance due to mosquito breeding.
- If designed improperly (e.g., proper slope is not achieved), grassed channels will have very little pollutant removal and may result in erosive conditions.
- A thick vegetative cover is needed for proper function.
- Swales should not generally be used in highly impermeable soils.

Selection and Locations

A few things to consider when selecting this practice:

- Vegetated swales are very difficult to establish and maintain on steep slopes (> 4%). Flow velocities can be erosive without the addition of erosion control fabrics.
- Swales in residential communities should be designed to be easily mowed and to drain quickly. Ideal geometry is a parabolic section with an underdrain for rapid drawdown.
- Pretreatment of roadside runoff is not realistic and swales will tend to accumulate road sand from winter snow plowing operations. Dry swales are therefore probably not appropriate for high volume road sections where heavy winter sanding is likely.
- Swales should be used in conjunction with other treatment options as part of a treatment train approach.

Sizing and Design Guidelines

A major difference between the grassed channel and other stormwater treatment practices is the method used to size the practice. Most stormwater treatment practices are sized by volume of runoff. The grassed channel, on the other hand, is sized based on flow rate (i.e., a peak flow) from the water quality storm: The precipitation value that yields 0.5 inches of runoff from impervious surfaces and 0.2 inches from pervious surfaces (in sensitive or impaired watersheds this value should be increased to 1.0 inch of runoff from impervious surfaces and 0.4 inches of runoff from pervious surfaces).Grass channels should be designed to maintain an average velocity of 1.0 feet per second during this small storm and ensure that an average residence time of ten minutes is maintained to flow from the top to the bottom of the channel. Table 1 lists recommended design guidelines for grass channels.

Table 1: Sizing/Design Criteria for Grass Channels (Claytor and Schueler, 1996)

Design Criteria	
Bottom Width	2 feet minimum, 6 feet maximum, widths up to 12 feet are allowable if a dividing berm or structure is used
Side Slopes	3:1 or flatter
Longitudinal Slope	1.0% minimum, 4.0% maximum
Flow Depth and Capacity	4 inch for water quality treatment
Flow Velocity	1.0 fps for water quality treatment, 4.0 to 5.0 fps for 2 year storm, 7.0 fps for 10-year storm
Length	Length necessary for 10-minute residence time

See the Maine *Stormwater Best Management Practices Manual, Volume III. BMP Technical Design Manual* (ME DEP, 2006) for specific design and sizing criteria.

Costs

Grass channels have an estimated cost of approximately $10 to $15 per linear foot (assuming a 2 foot bottom width, 3:1 side slopes, and a 1 foot depth). Dry swales are more costly due to the filtration media, underdrain system and related drainage infrastructure; a typical dry swale can cost between $25 and $35 per linear foot (again, assuming a 2 foot bottom width, 3:1 side slopes, and an 18 inch soil media depth). The annual maintenance cost can range from 5 to 7% of the construction cost (SWRPC, 1991).

Maintenance

The design life for swales is directly proportional to the maintenance frequency. The following activities are recommended on an as needed basis:

- Stabilization of eroded side slopes and bottom.
- Nutrient and pesticide use management.
- Dethatching swale bottom and removal of dead vegetation.
- Aeration of swale bottom.
- Scraping of the channel bottom and removal of sediment to restore original cross section and infiltration rate (generally every five years).
- Seeding or sodding to restore ground cover (as necessary).
- Inspections on an annual basis and just after storms of greater than or equal to 0.5 inch of precipitation.
- Structural and vegetative components should be inspected and repaired. When sediment accumulates to a depth of approximately one-half the channel design depth, it should be removed, and the swale should be reconfigured to its original dimensions.
- The grass in the swale should be mowed at least 2 times during the growing season to maintain an average grass height of 6 inches.

- If the surface of dry swale becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the bottom should be roto-tilled or cultivated to break up any hard-packed sediment, and then reseeded.
- Trash and debris should be removed and properly disposed of.

Infiltration - Dry Well / Infiltration Trench

Description

Drywells and infiltration trenches are two similar types of infiltration structures consisting of underground chambers either filled or surrounded by crushed stone. These practices are well suited for residential applications or small buildings (i.e., small drainage areas, <5 acres). Infiltration structures provide groundwater recharge, mimic existing hydrologic conditions, and reduce runoff and pollutant export.

A dry well is an underground chamber, or large vertical pipe filled and/or surrounded with stone, typically used to collect and infiltrate roof runoff (Figure 1). Water running directly from rooftops can generally be diverted directly into the dry well. Dry wells can be used to manage other sources of runoff after preliminary treatment to avoid clogging materials that shorten the life-cycle of this type of system, as well as increase the potential groundwater contamination. Similarly, to avoid clogging, infiltration trenches should have some type of pretreatment of stormwater runoff (e.g., grass swales, deep sump catch basins, filter strips after level spreaders, stilling basins or sediment forebays) before it enters the trench. After the pretreatment, infiltration into a trench allows for the removal of most remaining pollutants within the natural soil profile. Depending on soil conditions, stormwater may remain in the trench or well for several days.

Figure 1: Dry well

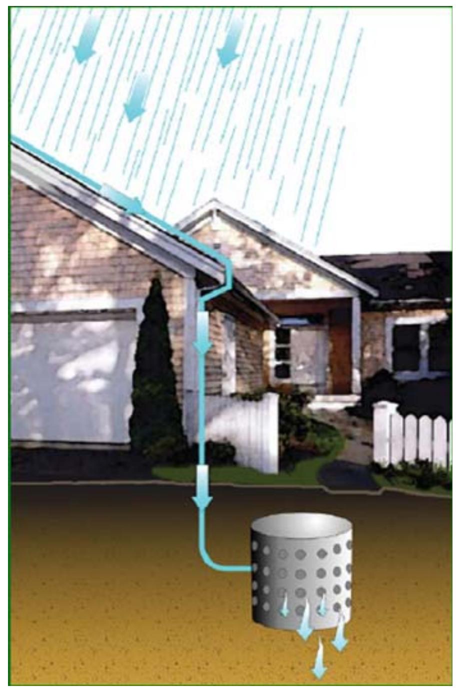
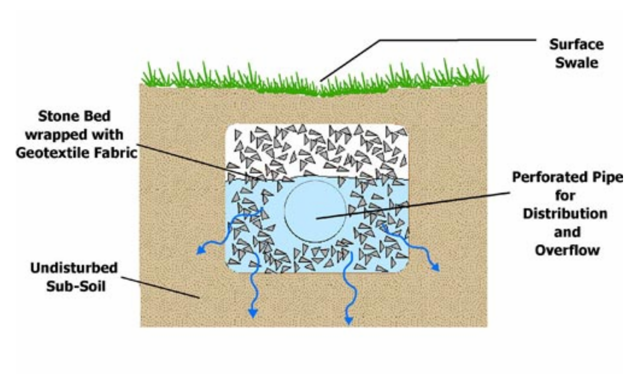


Figure 2: Schematics of an infiltration trench



Source: Adapted from Cahill & Associates.
http://www.thcahill.com/infiltrench.html

An infiltration trench (a.k.a. infiltration galley) is a rock-filled trench with no outlet that receives stormwater runoff. Stormwater runoff passes through some combination of pretreatment measures and into the trench where runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix (Figure 2). Higher infiltration rates and adequate separation between bedrock and groundwater are therefore necessary requirements for the installation of a dry well or infiltration trench. In addition, an overflow outlet is frequently needed for runoff from large storms that cannot be fully infiltrated.

Benefits and Limitations

Benefits:

- Increase in base flow, which benefits the hydrologic cycle by increasing the groundwater recharge.
- Reduction of stormwater runoff volume and peak runoff rates so that downstream stormwater management structures (e.g., pipes and basins) can be smaller;
- Good to excellent pollutant removal within the unsaturated zone of the native soil profile; and
- Dry wells have an unobtrusive presence given their underground location.

Limitations:

Limitations	Methods to Overcome them
Infiltration structures cannot receive untreated stormwater runoff, except rooftop runoff.	*Providing proper pretreatment such as grass swales or filter strips.*
Rehabilitation of failed infiltration structures requires complete reconstruction.	*Proper system design, construction, and ongoing operation and maintenance will prevent premature failure.*
Infiltration structures are not effective for infiltrating the runoff from large storms because of their limited size.	*Overflow from trenches and dry wells may be directed to a swale or other conveyance, sized to prevent erosion.*
Infiltration structures are difficult to apply in slowly permeable soils or in fill areas.	*Careful siting and appropriate design avoids placement within unsuitable soils and ensures proper sizing within soils of lower permeability. Infiltration structures should not generally be constructed in fill soils.*

Selection and Locations

Infiltration practices need to be sited extremely carefully. In particular, designers need to ensure that the soils on site are appropriate for infiltration and that designs minimize the potential for ground water contamination and long-term maintenance. A few things to consider when selecting this practice:

- Infiltration trenches should be placed on more level terrain, but the slopes of the site draining to the practice can be as steep as 15 percent.
- Soils must be sufficiently permeable to ensure that the stormwater can infiltrate quickly enough after a design storm event. In addition, soils that infiltrate too rapidly may not provide sufficient treatment, creating the potential for ground water contamination. The infiltration rate should generally range between 0.5 and 3 inches per hour. In addition, the soils should have no greater than 20 percent clay content, and less than 40 percent silt/clay content (MDE, 2000).

- Infiltration practices should be separated from drinking water wells by at least 100 feet horizontally. Separation of at least two feet from the bottom of the infiltration trench and the seasonally high ground water table should be provided.
- Closely examine potential sources of nutrients, salts, and hydrocarbons to prevent groundwater contamination (certain sites may require additional pretreatment).
- Ensure that drainage areas to infiltration trenches and dry wells are completely stabilized to avoid potential clogging problems.
- Locate the system at least 10 feet away from large trees to prevent puncturing or tearing of the filter fabric by tree roots (it may be necessary to remove certain trees of the infiltration structure and replace them with shallow-rooted shrubs and grasses);

Sizing and Design Guidelines

Maine Design Criteria for small-scale single family, multi-family and non-residential land uses:

- Sediment pretreatment devises such as grassed swales, filter strips and sediment traps are required.
- Retain a runoff volume equal to 0.5 inch times the subcatchment's impervious area, plus 0.2 inches times the subcatchment's landcaped area for any area draining to the facility
- Use a porosity value of 0.4 in the design of stone reservoirs.
- Bottom of a drywell system must be at least 2 feet above seasonal high groundwater if managing only rooftop runoff. Facilities that capture runoff from driveways, roads, and/or parking lots should have a 3 foot separation to groundwater.
- Design the infiltration system to drain completely within 72 hours following a runoff event.
- Setback from steep slopes (downhill greater that 3:1): 25 feet.
- Setback from floodplains: 10 feet from 100-yr floodplain.
- Setback from property lines (10 feet) and natural resources (stream, river, lake, estuary): 25 feet for drywells, 75 feel for infiltration trenches.
- Setback from building foundations: 10 feet for dry wells, 20 feet for infiltration trenches, and 100 from downslope buildings.
- Setback from wastewater disposal systems: see Maine Subsurface Wastewater Disposal Rules, 144A CMR 241.

Specific designs may vary considerably, depending on site constraints or preferences of the designer or community. The following guidelines should be incorporated into most infiltration designs:

- Pretreatment is particularly important for infiltration practices. To ensure that pretreatment mechanisms are effective, designers should incorporate multiple pretreatment pathways, using practices such as grassed swales, vegetated filter strips, detention, or a stilling basin in series.
- Treatment design features enhance the pollutant removal of a practice. During the construction process, the upland soils of infiltration trenches need to be stabilized to ensure that the trench does not become clogged with sediment. Only use larger double washed gravel for the storage reservoir (ranging in size between 1.5 and 3 inches) that can retain the volume of water to be treated in the voids. This practice should be sized so that the volume to be treated can infiltrate out of the trench bottom in 24 hours.

- Designers need to be particularly careful in ensuring that channels leading to an infiltration practice are designed to minimize erosion. Infiltration trenches should be designed to treat only small storms; therefore, these practices should be designed "off-line," using a structure to divert only small flows to the practice. The sides of an infiltration trench should be lined with a geotextile fabric to prevent flow from causing rills along the edge of the practice. The bottom of infiltration trenches should be filled with a 6” filter layer of washed, compacted sand.

See the *Maine Stormwater Best Management Practices Manual, Volume III. BMP Technical Design Manual* (ME DEP, 2006) for further information regarding sizing and design.

Costs

Construction of a dry well or an infiltration trench is moderately expensive. Depending on their size, drywell systems cost from $1,500 to $2,000 including installation. In addition to construction, developers and property owners should plan for a maintenance budget as lack of maintenance is the primary cause for premature failure of infiltration structures. Infiltration trenches can vary considerably in cost as a function of site constraints, but reasonable planning level cost is approximately $6 to $10 per cubic foot of storage.

Maintenance

- After construction and at least for the major storms occurring over the first few months, dry wells and infiltration trenches should be inspected to ensure stabilization and proper function.
- Observation wells should be checked 3 days after a major storm, failure to percolate within this time period indicates clogging.
- Any pretreatment devices and diversion structures should be inspected for sediment and oil build-up, and structural damage semi-annually.
- If ponding occurs on the surface of an infiltration trench, the topsoil or first layer of stone as well as the top layer of filter fabric should be removed and replaced.
- Upon failure, total rehabilitation of the dry well should be performed.

Permeable Pavers

Description

Permeable pavers are a broadly defined group of pervious types of pavements used for roads, parking, sidewalks, and plaza surfaces. Permeable pavers are designed to reduce stormwater runoff from a site, as well as reduce the impacts of impervious cover. Permeable pavers provide an alternative to conventional asphalt and concrete surfaces and are designed to infiltrate rainfall through the surface. In addition, permeable paving augments recharge of groundwater through infiltration, and provides some pollutant uptake in the underlying soils.

The different types of paving can be broken into two basic design variations: porous pavement and permeable pavers.

- *Porous pavement* is a permeable asphalt or concrete surface that allows stormwater to quickly infiltrate to an underlying stone reservoir. Precipitation percolates directly into the underlying soil, which recharges groundwater and the soil helps to remove stormwater pollutants. Accumulated precipitation can also be drained out of a stone reservoir through an underdrain system connected to the stormdrain system. Porous pavement looks similar to conventional pavement, but is formulated with larger aggregate and less fine particles, which leaves void spaces for permeable flow through the media.
- *Permeable pavers* include concrete grid and grass pavers, interlocking concrete modules, and brick pavers (Figure 1). Designs may not have an underground stone reservoir or may have only a partial reservoir, but they still provide some infiltration and surface detention of precipitation to reduce runoff volume.

Figure 1. Installation of Permeable Pavers in a Driveway*. Photo courtesy of Casco Bay Estuary Partnership.*

Permeable pavers consist of a durable, load bearing, pervious surface overlying a crushed stone base allowing rainwater to percolate through the paving and into the ground where it is stored before it infiltrates into the underlying soil.

Permeable paving can be used to treat low traffic roads (i.e., a few houses or a small cul-de-sac), single-family residential driveways, overflow parking areas, sidewalks, plazas, and courtyard areas. Good opportunities can be found in larger parking lots in overflow parking areas, schools, municipal facilities, and urban hardscapes. Permeable paving is intended to capture and manage small frequent rainfall events less than the one-inch precipitation event. These events can include as much as 50 to 70 % of the annual precipitation volume (Driscoll, 1989). The practice does not readily work for storms greater than 1-inch or with high rainfall intensities. The practice can be applied in both redevelopment and new development scenarios.

Benefits and Limitations

Benefits:

- Groundwater recharge augmentation.
- Runoff reduction to ease flow limitations in storm drain networks.
- Effective pollutant treatment for solids, metals, nutrients, and hydrocarbons in underlying soils .
- Aesthetic improvement to otherwise hard urban surfaces (e.g., interlocking permeable pavers, lattice pavers).
- Reduced runoff results in reduction in the size and volume of conventional stormwater management practices.

Limitations:

Limitations	Methods to Overcome them
Permeable paving can be prone to clogging from sand and fine sediments that fill void spaces and the joints between pavers.	*Provide periodic maintenance and avoid permeable paving in high traffic areas where frequent winter sanding is necessary, or in areas with high amounts of sediment-laden runoff.*
Snow plows can catch the edge of grass pavers and some paving stones.	*Avoid using in high traffic areas; and attach rollers to the bottom edge of snowplow blades.*
Chlorides (from salt used in cold climates) can easily migrate into the groundwater.	*Avoid using salt or care should be taken when applying salt to permeable pavement*
Permeable paving surfaces cannot prevent spills from migrating into groundwater	*Porous pavement/permeable pavers should not be specified for land uses with modest to high spill potential or within wellhead protection areas.*

Selection and Locations

A few things to consider when selecting this practice:

- Permeable paving is appropriate for pedestrian-only areas and for low-volume, low-speed areas (e.g., residential driveways, alleys, overflow parking areas).
- Locate the system in an area with an adequate depth to groundwater (generally 2’ or more between the bottom of the stone reservoir and the seasonally high groundwater table).
- Ensure that the site soils have moderate to high infiltration capacities (unless an underdrain system is incorporated).
- Ensure that drainage areas around the permeable paving areas are completely stabilized to avoid potential clogging problems.

- In cold weather climates, design features should incorporating frost heave reduction by having at least a 24 inch subsurface reservoir.
- Use of any type of permeable pavers requires approval by the Maine Department of Environmental Protection.

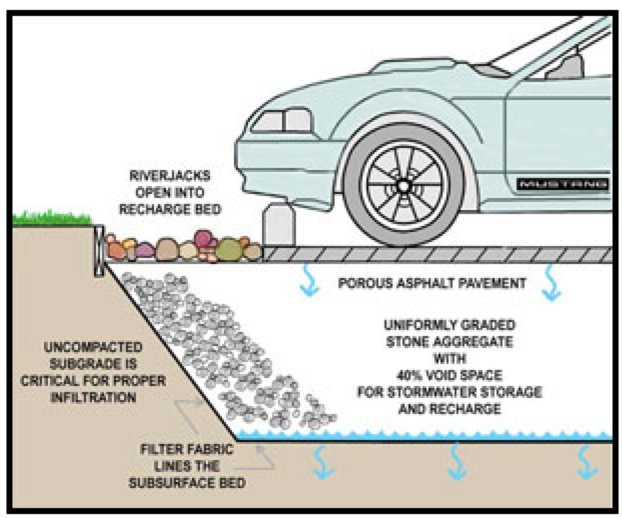
Sizing and Design Guidelines

The two types of permeable paving, *porous pavement* and *permeable pavers*, have specific sizing guidelines, which are described below.

Porous pavement areas are generally designed to accommodate a 1-inch or less design storm. Storms greater than that will either sheet flow off the site or, if not graded properly, will pond on-site. Other design considerations for porous pavement include:

- Soils permeability should be no less than 0.5 inches per hour.
- Clean, washed aggregate must be specified for the gravel bed/stone reservoir (Figure 2).
- The bottom of the stone reservoir should not exceed a slope of 5 percent. Ideally it should be completely flat so that the infiltrated runoff will be able to infiltrate through the entire surface. Perforated pipes may be used to distribute runoff through the reservoir evenly.
- Located at least 3 feet above the seasonally high groundwater table, and at least 100 horizontal feet away from drinking water wells.
- As a back-up measure in case of clogging, permeable paving practices can be designed with a perimeter trench to provide some overflow treatment should the surface clog. The trench may be connected to the stone reservoir
- The contributing drainage area should generally be less than 5 acres, and where feasible, water should sheet flow onto the practice.
- If stormwater flows onto a permeable paving surface the use of pretreatment practices should be considered so effective pollutant removal can be achieved.

Figure 2: Porous pavement with a gravel bed/stone reservoir



Source: http://www.wbdg.org/design/lidtech.php

The basic equation for sizing the required porous surface area is as follows:

$$A_p = Vw / (n \times d_t)$$

where:
A_p = the required porous pavement surface area [square feet]
Vw = the design volume [cubic feet]
n = porosity of gravel bed/reservoir (assume 0.4)
d_t = depth of gravel bed/reservoir (maximum of four feet, and separated by at least three feet from seasonally high groundwater) [feet]

Permeable paver (e.g., interlocking block, concrete gird pavers, etc.) areas are most effective when designed to accommodate small rainfall depths (e.g., less than 1 inch) that fall directly on the paver areas. They are less effective and more prone to clogging when used to also receive runoff from other areas. Unless underlying soils are extremely permeable, larger storms will either sheet flow off the site, or if not graded properly, will pond on the site.

For permeable pavers, treatment level will be based on the area covered by permeable pavers multiplied by a "discount factor" (F), a reduction that accounts for the likely effectiveness of the paver based on the application.

$$TA = (\text{permeable paver surface area}) \times (F)$$

where:
TA = Treatment Area
F = 0.5 or 0.75 (based on high or low usage area designation, respectively)

High-usage areas: 0.5 discount factor: This includes sites where permeable pavers are likely to receive higher levels of traffic, potential compaction, or where the underlying soils have lower infiltration capacity (e.g., hydrologic soil groups C and D). Examples include multi-family driveways/parking areas and commercial overflow parking areas. The assumption is that these areas will be more prone to clogging and compaction of the void spaces and decreased function over time.

Low-usage areas: 0.75 discount factor: This includes low-traffic areas such as single family residential uses, institutional overflow parking with only periodic use, emergency access areas, and grass paving systems, and includes sites with sandy parent materials. The assumption is that these areas will maintain some infiltration capacity and will have minor compaction and clogging issues.

An example calculation for permeable pavers is provided in Table 1.

Table 1: Permeable Pavers Simple Sizing Example
Area covered by permeable pavers = 10,000 ft^2 of commercial overflow parking and 2,000 ft^2 of emergency access road/path
Solving for treatment area (TA): TA = 10,000 ft^2 x 0.5 + 2,000 ft^2 x 0.75 **TA = 6,500 ft^2**

See the *Maine Stormwater Best Management Practices Manual, Volume III. BMP Technical Design Manual* for specific design and sizing criteria.

Costs

Costs for permeable paving are significantly more than traditional pavement (Table 2) and can vary considerably depending on the type of porous pavement used. However, incorporating savings from not having to build a separate stormwater structure, or building a smaller facility in addition to paving, the overall project costs are more reasonable.

The estimated annual maintenance cost for a porous pavement parking lot is $200 per acre per year (EPA, 1999). This cost assumes four inspections each year with appropriate jet hosing and vacuum sweeping.

Table 2: Cost Guides for Permeable Pavement System (LID)

Paver System	***Cost Per Square Foot (Installed)***
Asphalt	$1.00 to $2.00
Porous Concrete	$6.00 to $10.00
Grass/gravel pavers	$3.00 to $6.00
Interlocking Concrete Paving Blocks	$6.00 to $12.00

Maintenance

The type of permeable paving and the location of the site dictate the required maintenance level and failure rate. Concrete grid pavers and plastic modular blocks require less maintenance because they are not clogged by sediment as easily as porous asphalt and concrete. Areas that receive high volumes of sediment will require frequent maintenance activities, and areas that experience high volumes of vehicular traffic will clog more readily due to soil compaction. Typical maintenance activities for permeable paving are summarized below (Table 3).

Table 3: Typical Maintenance Activities for Permeable Paving (WMI, 1997)

Activity	***Schedule***
Ensure that paving area is clean of debris	Monthly
Ensure that paving dewaters between storms	Monthly and after storms >0.5 in.
Ensure that the area is clean of sediments	Monthly
Mow upland and adjacent areas, and seed bare areas	As needed
Vacuum sweep frequently to keep surface free of sediments	Typically 3 to 4 times a year
Inspect the surface for deterioration or spalling	Annual

When maintenance of permeable paving areas is required, the cause of the maintenance should be understood prior to commencing repairs so unnecessary difficulties and recurring costs can be avoided (Ferguson, 2005). Generally, routine vacuum sweeping and high-pressure washing (with proper disposal of removed material and washwater) can maintain infiltration rates when clogged or crusted material is removed. Signs can also be posted visibly within a permeable paving area to prevent such activities as resurfacing, the use of abrasives, and to restrict truck parking.

References/Further Resources

Driscoll, E.D., 1989. Analysis of Storm Event Characteristics for Selected Rainfall Gages Throughout the United States. U.S. EPA, Woodward-Clyde Consultants, Oakland, CA.

Ferguson, 2005.

United States Environmental Protection Agency (EPA), 1999. “Storm Water Technology Fact Sheet, Porous Pavement”, September 1999.

Rain Barrel/Cistern

Description

Stormwater may be collected and reused or “harvested” for non-potable water uses within a house or building or for landscape irrigation purposes via the use of Rain Barrels and Cisterns. Uses can include reusing water in toilets and at hose bibs. Reducing the water used from the municipal water system can reduce a site’s water bill and reduces the demand for potable water supplies.

Rain Barrels and Cisterns are designed to retain water that runs off of roofs for an extended period of time. Rain barrels are smaller structures ranging generally from 20 to 100 gallons, while cisterns can store thousands of gallons depending on the design. Construction material for rain barrels is generally plastic although recycled whiskey barrels have been used. Cisterns can be constructed of metal, wood or concrete. Stormwater stored in these structures is generally used for irrigation, although more complex designs incorporate water into everyday uses such as toilet flushing and shower water. Where new development is taking place, there is generally more opportunity to incorporate the harvested water into everyday use with more complex plumbing design.

Figure 1. Residential rain barrel


Source: MA EOEA, 2005

Figure 2. Commercial Use of a Cistern


http://rainwaterharvesting.tamu.edu/

- Flow control: The use of rain barrels and cisterns can provide significant flow-reduction benefits, particularly in areas where on-site infiltration is not feasible. Depending on the size of the water storage facility and the rate of use, a considerable percentage of the annual runoff volume can be reused. Rainwater harvesting can also be used to manage a portion of the flow and lessen the overall flow control requirement.
- Pollution reduction: The use of rain barrels and cisterns also results in a reduction of stormwater pollutants due to the sheer reduction in flow across polluted surfaces.

- High Performance: Rain barrels are a simple concept and virtually guaranteed to perform well as long as an appropriate capacity barrel has been chosen for a particular downspout. Cisterns, although more complex, also have a long history of use and an equally long history of success with regard to storage and conveyance.

Selection and Locations

A few things to consider when selecting this practice:

- Screens on gutters and downspouts to remove sediment and particles as the water enters the barrel. A completely enclosed system is less likely to promote mosquito breeding.
- Provide an option of draining the system completely for maintenance.
- Provide aesthetic features that are compatible with the lot's landscaping plan.
- Private stormwater maintenance agreements may be needed between the property owner and any potential second and third parties.
- Adequate storage capacity for the roof area draining to a structure.
- Provide an overflow to property accommodate flow beyond the storage capacity of the structure (a drywell is a good option).
- Allow for drawdown between storms to ensure a minimum storage volume available for stormwater attenuation.

Depending on local regulations, the water collected with a rain barrel or cistern may also be used for potable (drinking) or other domestic water use if sufficient treatment is provided. According to the Low Impact Development Center, water treatment techniques for rainwater catchment systems include:

- *Screening*. The use of strainers and leaf screens located in the gutters and downspouts are designed to prevent debris, like leaves, from entering the tank.
- *Settling.* Sedimentation within the tank is necessary to settle out any potential particulate matter and solids.
- *Filtering.* The use of filters can include in-line multi cartridge systems, activated charcoal, reverse osmosis, mixed media systems and slow sand filters; all designed to remove potential contaminants either at the pump, tank or tap.
- *Disinfecting.* The use of boiling/distilling, chemical treatment (chlorine, iodine), ultraviolet light and/or ozonation are all designed to kill microorganisms, usually directly within the tank.

Sizing and Design Guidelines

The required capacity of a rain barrel or cistern is a function of the rooftop surface area that drains to it, the inches required to fill the barrel, and water losses (due to evapotranspiration). A general rule of thumb to size these systems is that 1 inch of rainfall on a 1000 square foot roof will yield approximately 600 gallons. However, rain barrel and cistern volume can be determined by calculating the roof top water yield for any given rainfall, using the following general equation[1]:

[1] The Texas Water Development Board-Rainwater Harvesting Web Page, (www.twdb.state.tx.us/assistance/conservation/Rain.htm)

Equation 1. $V = A^2 \times R \times 0.9 \times 7.5$ *gals./ft.*^{3} where:

V = volume of rain barrel (gallons)
A^2 = surface area roof (square feet)
R = rainfall (feet)
0.90 = losses to system (no units)
7.5 = conversion factor (gallons per cubic foot)

Example: one 60-gallon barrel would provide runoff storage from a rooftop area of approximately 215 square feet for a 0.5 inch (0.042 ft.) of rainfall:
(60 *gallons* = 215 $ft.^2 \times 0.042$ *ft.* $\times 0.90 \times 7.5$ *gallons*/ft^3).

Overflow is important

It is important to note, however, that commercial or industrial sites may require large capacity cisterns due to the size of rooftops, the amount of imperviousness of the drainage area, causing increased runoff volume and peak discharge rates. Individual cisterns can be located beneath each downspout, or the desired storage volume can be provided in one large, common cistern that collects rainwater from several sources. Pre-manufactured residential-use cisterns come in sizes ranging from 100 to 1,400 gallons. Cisterns designed for more than just supplemental use, for full time domestic use, should be sized based upon a minimum of 30 gallons per day per person when considering all potential domestic water uses[2]. A sample cistern model can be viewed at http://www.treepeople.org/trees/cistern2.htm.

See the *Maine Stormwater Best Management Practices Manual, Volume III. BMP Technical Design Manual* for specific design and sizing criteria.

Costs

Rain barrels are relatively inexpensive storage structures and range from $50 to $300 per unit depending on the material and design. Capital costs for cisterns can be significant ranging from a few hundred dollars for plastic units to over ten thousand dollars for large structures. As with other stormwater BMPs, relative capital costs are reduced when designs are incorporated early in the development of larger projects. Long-term costs for water use need to be considered when weighing the overall benefits of installing large cisterns.

Maintenance

Rain barrel maintenance is generally limited to periodic cleaning, checking for leaks, inspection of mosquito netting, inspection of spigot (if available) and roof catchments, at least twice a year, preferably during a dry season. Maintenance of cisterns generally consists of routine inspection of pipes and any mechanical pumps that have been incorporated into more complex designs (e.g., screens, filters, cleanout, etc.). Maintenance requirements for rain-fed potable (drinking) water systems are higher than those of systems designed for irrigation or stormwater control. Typical

[2] The Low Impact Development Center Web Page (http://www.lid-stormwater.net/raincist/raincist_sizing.htm)

maintenance activities consists of keeping gutters and cistern screens clean as well as periodic inspection and replacement of any water treatment components and equipment. The tank also needs thorough cleaning, usually in the summer when its water levels tend to be lower. Backflow prevention devices also require annual inspection.

Green Roof

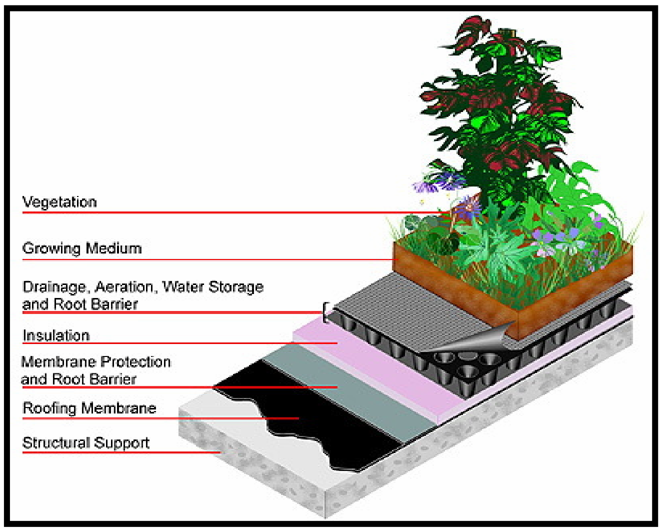
Description

Green roofs consist of a layer of vegetation and soil installed on top of a conventional flat or sloped roof (Figure 1). The rooftop vegetation captures rainwater allowing evaporation and evapotranspiration processes to reduce the amount of runoff entering downstream systems, effectively reducing stormwater runoff volumes and attenuating peak flows. There are two types of green roof designs, *extensive* and *intensive*. *Extensive* green roofs have a thin soil layer so are lighter, less expensive, and generally require low maintenance. *Intensive* green roofs often have pedestrian access and are characterized by a deeper soil layer with a greater weight, higher capital cost, increased plant diversity, and more maintenance requirements.

The general components of any green roof system include (Figure 1):

- A roof structure capable of supporting the weight of a green roof system;
- A waterproofing system designed to protect the building and roof structure;
- A drainage layer consisting of a porous media capable of water storage for plant uptake;
- A geosynthetic layer to prevent fine soil media from clogging the porous media;
- Soil with appropriate characteristics to support selected green roof plants; and
- Plants with appropriate tolerance for harsh rooftop conditions and shallow rooting depths.

Figure 1: Green roof components



http://www.uwm.edu/Dept/GLWI/ecoli/Greenroof/images/greenroofcom.jpg

Benefits and Limitations

Green roofs reduce runoff volumes and delay peak flows while providing a number of other benefits to the urban environment, private building owners, and the public. The most notable benefits include:

- Green roofs help achieve stormwater management goals by reducing total annual runoff volumes (Roofscapes, Inc., 2005).
- The layers of soil and vegetation on the rooftop moderate interior building temperatures, and provide insulation from the heat and cold. As a result the amount of energy required to heat and cool the building is reduced, providing energy savings to the owner. The

increased insulation reduces HVAC infrastructure requirements, and therefore building construction costs.

- The additional rooftop insulation protects rooftop materials from ultraviolet radiation and extreme temperature fluctuations, which deteriorates standard roofing materials. It is estimated that green roofs can extend the life of a roof by as long as 20 years (Velazquez, 2005).
- Green roofs can also be designed to insulate the building interior from outside noise, and sound-absorbing properties of green roof infrastructure can make surrounding areas quieter (Figure 2).
- Fully saturated green roofs can provide fire resistance and inhibit the spread of fire from adjacent buildings.
- Green roofs reduce the urban heat island effect by cooling and humidifying the surrounding air.
- Green roofs help filter and bind airborne dust and other particulates, improving air quality (Barr Engineering Company, 2003).
- The additional rooftop vegetation within an urban or suburban environment creates habitat for birds and butterflies.
- With thoughtful design, green roofs can be aesthetically pleasing and improve views from neighboring buildings as illustrated in Figure 3, with a high-rise residential building in Manhattan.

Figure 2: Green roof installed on a sloped roof

Figure 3: Green roof installed on an apartment building in Manhattan.

Limitations:

The primary limitation to the implementation of green roofs is increased design and construction costs. Green roof designs need to include any structural requirements necessary to support the additional weight of soil, vegetation, and possibly pedestrians. For retrofit projects, a licensed structural engineer or architect must conduct a structural analysis of the existing structure, which will dictate the type of green rooftop system and any necessary structural reinforcement. Other limitations include:

- Damage to or failure of waterproofing elements present a risk of causing water damage. However, similar to traditional roof installations, a warranty can help guarantee that any damage to the water proofing system will be repaired.

- Extreme weather conditions can impact plant survival.

- Green roof maintenance is higher than for traditional roofs.
- The need to provide safe access to the rooftop for construction and maintenance.
- Supplemental irrigation during the first year may be necessary to establish vegetation, and a long-term supplemental irrigation system may be required for some intensive systems.
- In cold climates, snow loads need to be accounted for when determining the structural capacity required to install a green roof system.

Selection and Locations

A few things to consider when selecting this practice:

- Green roofs are suitable for retrofit or redevelopment projects as well as new buildings, and can be installed on small garages or larger industrial, commercial and municipal buildings.
- Green roofs present an above ground management alternative when the on-site space availability for stormwater practices is limited. Aesthetic features that are compatible with the lot's landscaping plan.
- Green roofs can be installed on flat roofs or on roofs with slopes up to 30% provided special strapping and erosion control devices are used (Peck and Kuhn, 2003).
- Green roofs are most effective in reducing runoff volume and rates for land uses with high percentages of rooftop coverage such as commercial, industrial and multifamily housing (Stephens *et al.*, 2002).

Sizing and Design Guidelines

Green roofs can be counted as pervious area that can be applied towards meeting the total impervious cover reduction target for redevelopment sites that can be accepted as a deviation from the technical standards. Simple sizing calculations can also be made to check the actual storage volume provided by a proposed green roof design. Stormwater treatment in green roofs occurs via evaporation, transpiration, and filtration. A simplified (and conservative) approach to estimating the volume of water that can be effectively managed and treated by a green roof system is outlined below and based on an instantaneous volume that can be stored in the soil media, drainage layer, and surface ponding area together.

$$WQv \leq V_{SM} + V_{DL} + (D_P \times A_{GR})$$

$$V_{SM} = A_{GR} \times D_{SM} \times n_{SM}$$

$$V_{DL} = A_{GR} \times D_{DL} \times n_{DL}$$

where:

V_{SM} = volume of the soil media [cubic feet]

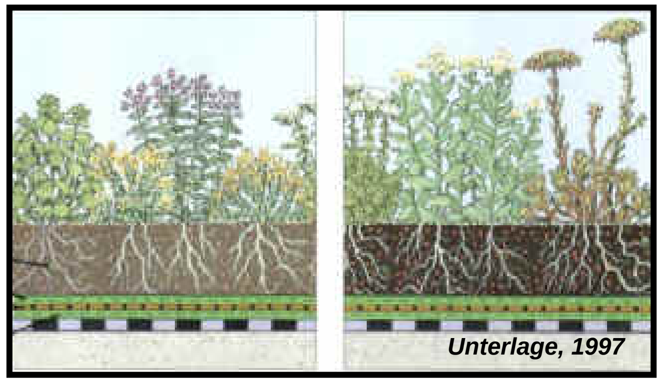
V_{DL} = volume of the drainage layer [cubic feet]

A_{GR} = green roof surface area [square feet]
D_{SM} = depth of the soil media [feet]
D_{DL} = depth of the drainage layer [feet]
D_P = depth of ponding above surface [feet]
n_{SM} = porosity of the soil media (~20%)
n_{DL} = porosity of the drainage layer (~25%)
WQv = Water Quality Volume [cubic feet] = 0.5 inches

See the *Maine Stormwater Best Management Practices Manual, Volume III. BMP Technical Design Manual (ME DEP, 2006)* for specific sizing information.

There are two levels of green room systems that require lightly different design techniques: Extensive, characterized by low weight, lower capital cost, and minimal plant diversity (Figure 5); and Intensive, having a deeper soil layer and a corresponding greater weight. Data is presented here for only the extensive green roof system.

Figure 5: Extensive Cross-Section



In the extensive system the growing medium is usually a mixture of sand, gravel, crushed brick, peat, or organic matter combined with soil. The soil media ranges between two and six inches in depth and increases the roof load by 16 to 35 pounds per square foot when fully saturated. Since the growing medium is shallow and the microclimate is harsh, plant species used in extensive systems should be low and hardy, which typically involves alpine, arid, or indigenous species.

Each green roof project is unique, given the purpose of the building, its architecture and the preferences of its owner and end user. However, several key design features should be kept in mind during the design, of any green rooftop systems. The four principle components of any green roof system are the roof structure, waterproofing, drainage system, and soil media. General design guidelines for each of these components are described below.

Roof Structure: The load bearing capacity of the roof structure is critical for the support of soil, plants, and any people who will be accessing the green roof (for either maintenance or recreation). Generally, green roofs weighing more than 17 pounds per square foot saturated require consultation with a structural engineer (Barr Engineering, 2003). As a fire resistance measure, non-vegetative materials, such as stone or pavers should be installed around all rooftop openings and at the base of all walls that contain openings (Barr Engineering, 2003). On sloped roofs additional erosion control measures, such as cross-battens, are generally necessary towards the bottom of the sloped roof to stabilize drainage layers.

Waterproofing: In a green roof system the first layer above the roof surface is a waterproofing membrane. Two common waterproofing techniques used for the construction of green roofs are monolithic and thermoplastic sheet membranes. An additional protective layer is generally placed on top of either of these membranes followed by a physical or chemical root barrier. Once the waterproofing system has been installed it should be fully tested prior to construction of the drainage system.

Drainage System: The drainage system typically includes a porous drainage layer and a geosynthetic filter mat to prevent fine soil particles from clogging the porous media. The drainage layer can be made up of gravels or recycled-polyethlylene materials that are capable of water retention and efficient drainage. The depth of the drainage layer depends on the load bearing capacity of the roof structure and the stormwater retention requirements. Once the porous media is saturated, excess water is then directed to a traditional rooftop storm drain system. The porosity of the drainage system should be greater than or equal to 25% (Cahill Associates, 2005).

Soil: The soil layer above the drainage system is the growing media for the plants in a green roof system. Soils used in green roofs are generally lighter than standard soil mixes, and consist of 75% mineral and 25% organic material (Barr Engineering, 2003), and no clay size particles. The chemical characteristics of the soil (e.g., pH, nutrients, etc.) should be carefully selected in consideration with the planting plan. The porosity of the soil layer, measured as non-capillary pore space at field capacity, should be greater than or equal to 15% (Cahill Associates, 2005).

See the *Maine Stormwater Best Management Practices Manual, Volume III. BMP Technical Design Manual (ME DEP, 2006)* for specific design criteria.

Costs

The cost of creating a residential green roof can vary widely depending on the location, whether demolition will be involved and how close equipment can get to the building. A safe estimate, including the cost of waterproofing the roof, is anywhere from $18 to $25 per square foot (Roofscapes, Inc. 2004) According to the Low impact Development Center, costs for green roofs in the United States are estimated to average between $15 to $20 per square foot for all use types, i.e., high density residential, commercial, industrial etc. These costs include all aspects of green roof development, from the waterproofing membrane to soil substrate creation to planting. Green roof retrofit projects may have increased cost associated with resource scheduling concerns as well as the on-site availability of equipment and materials. Green roof technology often requires that maintenance costs be built into the original budget, especially with more elaborate, extensive green roof covers.

Maintenance

Green roof maintenance may include watering, fertilizing and weeding, and is typically greatest in the first two years as plants become established. Maintenance largely depends on the type of green roof system installed and the type of vegetation planted. Maintenance requirements in intensive systems are generally more costly and continuous, compared to extensive systems. The use of native vegetation is recommended to reduce plant maintenance in both extensive and intensive systems.

A green roof should be monitored after completion for plant establishment, leaks and other functional or structural concerns. Vegetation should be monitored for establishment and viability, particularly in the first two years. Irrigation and fertilization is typically only a consideration during the first year before plants are established. After the first year, maintenance consists of two visits a year for weeding of invasive species, and safety and membrane inspections (Magco, 2003).

References/Further Resources

Barr Engineering Company. 2003. *Minnesota Urban Small Sites BMP Manual: Stormwater Best Management Practices for Cold Climates*. Metropolitan Council Environmental Services. St. Paul, Minnesota. http://www.metrocouncil.org/environment/Watershed/bmp/manual.htm

Cahill Associates, Inc. January 2005. *Draft Pennsylvania Stormwater Best Management Practices Manual*, Department of Environmental Protection, Bureau of Stormwater Management, and Division of Waterways, Wetlands, and Erosion Control.

City of Portland. 2000. *Stormwater Management Manual*. City of Portland. Portland, Oregon.

Hill, Lori. 2004. *Up on the Roof: Environmentally conscious homeowners fiddle with their rooftops. Quote from* Charlie Miller, owner of Roofscapes Inc.

Magco, Inc. Accessed 2003. *Intensive and Extensive Green Roofs*. http://www.magco.com/extensive_intensive.html

Maine Department of Environmental Protection. January 2006. Stormwater Management for Maine, Volumes 1 and 3.

Maryland Department of the Environment. Green Roof - Fact Sheet. Maryland's Stormwater Management Manual. http://www.mde.state.md.us/assets/document/sedimentStormwater/SWM_greenroof.pdf

Peck, S. and M. Kuhn. Accessed 2003. *Design Guidelines for Green Roofs*. http://www.cmhc-schl.gc.ca/en/imquaf/himu/himu_002.cfm

Roofscapes, Inc. Accessed 2005. *Green Technology for the Urban Environment.* www.roofmeadow.com.

Stephens, K. A., Graham, P. and D. Reid. 2002. *Stormwater Planning: A Guidebook for British Columbia*. British Columbia Ministry of Water, Land and Air Protection.

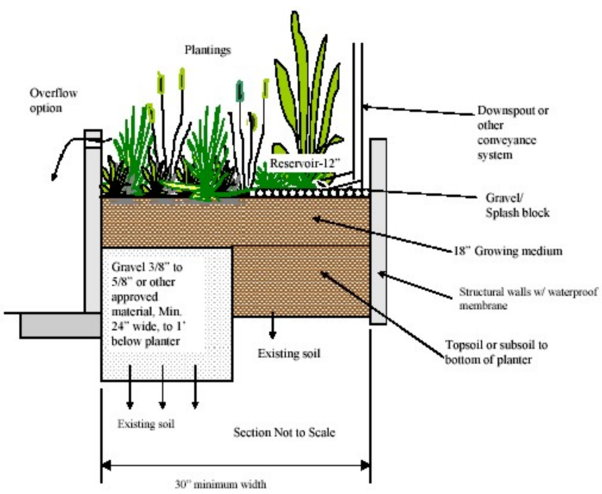
Velazquez, L. S. 2005. *Greenroofs.com*. http://www.greenroofs.com

Stormwater Planter

Description

Stormwater planters are small-scale, stormwater treatment systems comprised of organic soil media and plants in a confined planter box. Stormwater planters generally look like large vaulted plant boxes and can contain anything from basic wildflower communities to complex arrangements of trees and flowering shrubs. The method combines physical filtering and adsorption with bio-geochemical processes to remove pollutants.

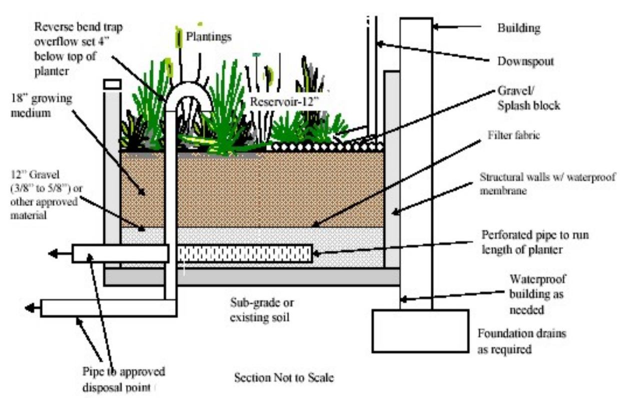
Figure 1: Infiltration Planter (City of Portland, Stormwater Mgmt. Manual, 2002)



There are three basic variations of the stormwater planters: the contained system, the infiltration system, and the flow-through system. Contained planters are self-contained planters found on terraces, desks and sidewalks. Infiltration planter boxes are designed to allow runoff to filter through the planter soils and then infiltrate into the native soils (Figure 1). Flow-through planter boxes are designed with impervious bottoms or placed on impervious surfaces. This flow-through system consists of an inflow component (usually a downspout), a treatment element (soil medium), an overflow structure, plant materials, and an underdrain collection system to divert treated runoff back into the downstream drainage system (Figure 2).

Stormwater planters are ideally adapted for non-residential and multifamily development as well as urban redevelopment projects. Roof runoff can be directed from the downspout directly into the planters. Runoff from rooftop areas contains nutrients carried in rainwater, sediments and dust from rooftops, and bacteria from bird traffic. These pollutants can all be attenuated to a significant degree during small rain events.

Figure 2: Flow-Through Planter. (Portland Stormwater Mgmt. Manual)



Benefits and Limitations

Benefits:

- Planters can be effective in reducing the velocity and volume of stormwater discharge from rooftops areas.
- Stormwater planters add aesthetic elements by improving the surrounding streetscape.
- Multiple planter units can be used to help manage large-scale commercial developments.

Limitations:
The primary limiting factor on the use of stormwater planters is sizing. They are by definition small-scale stormwater treatment cells that are not well-suited to treat runoff from large storm events, or large surface areas. They can however be used in series or to augment alternative stormwater treatment practices. For all three types of stormwater planters, if the infiltration capacity of the soil is exceeded, the planter will overflow. Excess stormwater needs to be directed to a secondary treatment system or released untreated to the storm drain system.

Selection and Locations

A few things to consider when selecting this practice:

- Facility dimensions and setbacks from property lines and structures.
- Planter wall material and waterproofing membrane specification.
- Drain rock and filter fabric specification.
- Stormwater piping associated with the facility, including pipe materials, sizes, slopes, and invert elevations at every bend or connection.
- Landscaping plan.

Sizing and Design Guidelines

Stormwater planters should initially be sized to satisfy water quality requirements for the impervious surface area draining to the practice. This does not apply to contained planters because they are designed to decrease impervious area, not receive additional runoff from adjacent surfaces. The equation for sizing an infiltration or flow-through stormwater planter based upon the contributing area is as follows:

$$WQv = \frac{A_f \times [k \times (h_f + d_f)(t_f)]}{d_f}$$

where:

A_f = the required surface area [square feet]
Vol = the treatment volume [cubic feet]
d_f = depth of the soil medium [feet]
k = the hydraulic conductivity [in ft/day, usually set at 4 ft/day, but can be varied depending on the properties of the soil media]
h_f = average height of water above the planter bed [maximum 12 inches]
t_f = the design time to filter the treatment volume through the filter media [usually set at 3 to 4 hours]

WQv = water quality volume [cubic feet] = 0.5 inch from impervious surfaces and 0.2 inches from pervious surfaces for small scale projects (or 1.0 inch from impervious surfaces and 0.4 inches from pervious surfaces in watersheds to sensitive or impaired waterbodies).

Specific design considerations are shown below.

Table 1: General Design Guidance for a Stormwater Planter

Minimum width	18-30 inches
Wall height	11 inches + standpipe diameter (in inches) above finished soil level
Width to length ratio	2:1
Minimum depth to seasonal high groundwater	3 feet
Gravel depth	11.8 inches
Planting soil depth	1.5 feet
Maximum ponding depth	12 inches (in less than 12 hours)
Growing medium depth	18 inches
Infiltration rate for native and growing medium soil	2 inches per hour
Infiltration rate for drainage layer soil	5 inches per hour
Drainage Layer (flow-through and infiltration planters)	12 inches
Minimum Plant Requirements (per 100 square feet of area)	4 large shrubs/small trees (3-gallon containers or equivalent), 6 shrubs/large grass-like plants (1-gallon containers or equivalent), ground cover plants planted 12 inches on center, or seed or sod, tree planting is encouraged in or near planters, where practical.

Costs

Stormwater planters are generally considered cost effective stormwater treatment practices. The cost of proprietary stormwater planters, or tree box filters, is approximately $24,000 per acre ($0.55 per square foot) of impervious surface. Recent costs for site specific stormwater planters are in the range of $25 to $50 per square foot of planting bed area. Annual maintenance cost is approximately 2% to 8% of the system cost or in the range of $200 to $2,000 per impervious acre treated (Flinker, 2005).

Maintenance

In well designed stormwater planters, maintenance includes measures to keep the planter structure functioning, maintaining inflow locations (i.e., gutters and downspouts) and general landscaping duties such as occasional irrigation, weeding and mulching. Periodic maintenance can also include any clogging that may occur in underground piping or overflow structures. Suggested maintenance duties include:

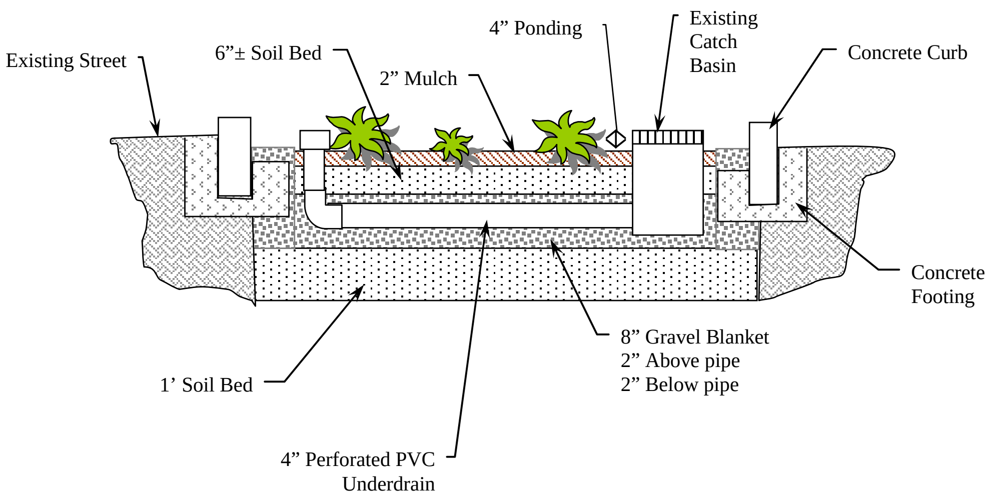
- Remove any debris or garbage caught in the planter facility (as needed).
- Inspect and replace damaged downspout and overflow pipe (as needed).
- Remove sediment built up in the planter (as needed).
- Inspect and replace any damaged, diseased, or dead plants (as needed).
- Inspect and replace damaged splash guards/erosion control measures (as needed).
- Inspect for structural integrity and proper function and repair any deficiencies (annually).

Micro-Bio Inlet

Description

Micro-bio inlets are small-scale versions of bioretention systems (Figure 1). They are recommended at locations where a full-size bioretention system will not fit. Existing roadside catch basins can be used as the overflow structure, and the filter media and plantings can be installed around it, forming an island. Curbing with inlet cuts is required to prevent damage from vehicles while still allowing stormwater to enter. A curtain of stone or gravel should be used to provide pretreatment of the stormwater prior to the filter portion of this BMP. In some cases traffic bollards are provided to identify the practice from vehicular traffic.

Figure 1: Micro-bio plan profile



Micro-Bio Inlet Schematic Profile

The general components of any micro-bio inlet system include:

- An existing inlet or catchbasin that accommodates larger flows;
- A planted soil media to filter runoff for treatment and attenuation;
- An underdrain system to collect filtered runoff into the overflow catchbasin;
- Vegetation within the planting soil;
- Curbing to direct runoff into the treatment area;
- Traffic barriers, as necessary, to clearly separate the practice from vehicular traffic.

Benefits and Limitations

Benefits

These practices provide water quality treatment in small areas where other practices are not feasible. They can also be used to retrofit catch basins in areas where stormwater from existing development is causing water quality problems. Notable benefits form micro-bio inlets include:

- Effective pollutant treatment for solids, metals, nutrients and hydrocarbons;
- Aesthetic improvement to otherwise hard urban surfaces;
- Effective retrofit of traditional stormwater catch basins
- Ease of maintenance, coupling routine landscaping maintenance with effective stormwater management control

Limitations

The micro-bio inlet is small, so the drainage area for the practice must be appropriately small. These may not be appropriate in some areas where the roadway or parking alignment is not wide enough to allow for them. By it very nature, the practice cannot incorporate a substantial pre-treatment component and therefore the maintenance burden may be disproportionate with the anticipated benefits. The practice is relatively new and long-term performance is uncertain.

Selection and Locations

Micro-bio inlets are appropriate for very small drainage areas, typically less than 1 acre in area. They are appropriate where other more conventional practices are not feasible and where some level of treatment is absolutely necessary, such as a physically constrained drainage area to a swimming beach. The micro-bio inlet requires a limited head, so it is ideally suited to coastal or shoreline areas with high groundwater and relatively flat terrain.

Sizing and Design Guidelines

See the Maine *Stormwater Best Management Practices Manual, Volume III. BMP Technical Design Manual* (ME DEP, 2006) for specific design and sizing criteria.

Costs

Costs for Micro-bio inlets are similar to bioretention systems due to the same components used. Typical capital construction costs are in the range of approximately $ 50 to $ 75 per square foot of treatment practice area (including all system components, such as curbing, underdrain, inlet modifications, etc.). Annual maintenance cost is approximately 5 to 7% of capital construction costs.

Maintenance

Maintenance requirements are similar to bioretention systems. Inspections are an integral part of system maintenance. During the six months immediately after construction, micro-bio inlets should be inspected at least twice, or more, following precipitation events of at least 0.5 inch to ensure that the system is functioning properly. Thereafter, inspections should be conducted on an annual basis and after storm events of greater than or equal to the water quality storm event. Accumulated sediment should be removed, and minor soil erosion gullies should be repaired when they occur. Pruning or replacement of woody vegetation should occur when dead or dying vegetation is observed. Separation of herbaceous vegetation root stock should occur when over-crowding is observed, or approximately once every 3 years. The mulch layer should also be replenished (to the original design depth) every other year as directed by inspection reports. The previous mulch layer would be removed, and properly disposed of, or roto-tilled into the soil surface. If at least 50% vegetation coverage is not established after two years, a reinforcement planting should be performed. If the surface of the facility becomes clogged to the point that standing water is observed 48 hours after precipitation events, the surface should be roto-tilled or cultivated to breakup any hard-packed sediment, and then re-vegetated.

Appendix A. Submittal Requirements for LID Compliance

Note: Items in [italics] should be decided upon by each individual town, and should be tailored to fit the permit process in each community.

The applicant shall file with the __________ [*authority] [three (3)*] copies of a completed application package for LID approval. Approval is required prior to any site altering activity. While the applicant can be a representative, the person responsible for meeting approval requirements is the owner of the site or holder of an easement.

The [*Site Plan, Subdivision, Building Permit, other*] LID Application shall include the following for purposes of compliance with the LID standard:

1. A complete LID application form (select the appropriate application for new residential, new non-residential/multifamily, or retrofit/expansion projects)

2. Site Plan or Sketch, as directed on the application form

3. Operation and Maintenance Plan, as directed on the application form

4. Supporting calculations and data, such as depth to groundwater or soils information, used to evaluate site hydrology and determine LID Practice design sizing.

Appendix B1. Example Application for New Single Family Residential Development

LID APPLICATION FORM – New Residential Development

1. **PROJECT ADDRESS:** ______________________________
2. **APPLICANT NAME:** ______________________________

   APPLICANT ADDRESS: ______________________________

   ____
3. **OWNER NAME:** ______________________________

   (if different from applicant) ______________________________

   OWNER ADDRESS: ______________________________

   (if different from applicant) ______________________________

4. **BRIEF PROJECT DESCRIPTION:** ______________________________

____

____

____

____

____

____

(Use additional pages if necessary.)

5. LID STANDARDS

This project is: ☐ an individual lot development. ☐ a subdivision.

This project is located within: ☐ a watershed to a Lake Most at Risk from New Development,

☐ a watershed to an Urban Impaired Stream, or

☐ a watershed to another impaired water body (as designated by the Town).

Name of lake or other impaired water body: ______________________________

This project will meet the (*pick one*):

☐ Basic LID Standards *Complete section 5A below.*

☐ Alternative LID Standards *Complete section 5B below.*

5A. Basic LID Standards *(skip to Section 6 after you have completed this section)*

☐ Total disturbed area on each lot is < 15,000 square feet

☐ Buffers at least 30 feet wide* are provided along all lot boundaries

☐ Each lot has no more than 7,500 square feet of impervious cover

☐ At least 25% of each lot* is maintained as undisturbed natural area

☐ This project is a subdivision:

☐ If yes, the access road is open section road with pavement width no more than 22 feet.

* *In a watershed to a Lake Most at Risk from New Development, an Urban Impaired Stream, another impaired waterbody, a* ***75-foot buffer*** *is required and a minimum of* ***40%*** *undisturbed natural area must be maintained.*

5B. Alternative LID Standards ***(Go to Section 6 after you have completed this section)***
Complete the following information for each lot (use additional sheets as needed):

i. Calculate impervious areas:

Rooftop (s.f.): ______________________________ _Walkways (s.f.): __________________________

Driveway (s.f.):_____________________________ _Patio (s.f.):_______________________________

Other (s.f.): ________________________________

TOTAL Impervious Area: ____

ii. Calculate disturbed pervious areas:

Lawn (s.f.): ________________________________ _Other (s.f.): ______________________________

TOTAL Disturbed Pervious Area: ____

iii. Treatment:

☐ The first 0.5 inches of runoff from the impervious surfaces above will be treated with LID practices.

☐ The first 0.2 inches of runoff from the disturbed pervious areas will be treated with LID practices.

Note: If the project is located within a watershed to a Lake Most at Risk from New Development, Urban Impaired Stream, or other impaired water body, as designated by the town, you must treat the first 1 inch of runoff from impervious surfaces and the first 0.4 inches of runoff from disturbed pervious areas with LID practices.

Please mark the number of each practice that will be used to treat runoff from impervious and pervious surfaces:

Impervious Surfaces	PRACTICE	Disturbed Pervious Surfaces
______	Raingarden (underdrain soil filter)	_____
______	Swale (underdrain soil filter)	_____
______	Dry Well	_____
______	Permeable Pavement	X
______	Rain Barrel/Cistern	X
______	Vegetated Buffer/ Filter Strip	_____

6. SITE PLAN:

Provide a plan of the lot, showing locations (labeled) of impervious areas, disturbed pervious areas, and LID practices. The plan can be a hand drawn sketch for an individual single family lot (see example). For a subdivision, a plan at a scale no smaller than 1 inch equals 80 feet must be provided, stamped by a surveyor or engineer licensed in the State of Maine.

☐ A site plan is attached.

7. OPERATIONS AND MAINTENANCE PLAN:

☐ An Operations and Maintenance plan narrative is attached, and it describes the responsible party for ensuring maintenance occurs.

Appendix B2. Example Application for New Non-Residential and MultiFamily Development

File Number:_____________

LID APPLICATION FORM – New Non-Residential or Multifamily Development

1. **PROJECT ADDRESS:** ______________________________
2. **APPLICANT NAME:** ______________________________

   APPLICANT ADDRESS: ______________________________

   ____
3. **OWNER NAME:** ______________________________

   (if different from applicant) ______________________________

   OWNER ADDRESS: ______________________________

   (if different from applicant) ______________________________

4. **BRIEF PROJECT DESCRIPTION:** ______________________________

____

____

____

____

____

____

(Use additional pages if necessary.)

5. LID STANDARDS

This project is: ☐ an individual lot development. ☐ a subdivision.

This project is located within: ☐ a watershed to a Lake Most at Risk from New Development,

☐ a watershed to an Urban Impaired Stream, or

☐ a watershed to another impaired water body (as designated by the Town).

Name of lake or other impaired water body: ______________________________

This project will meet the (*pick one*):

☐ Basic LID Standards *Complete section 5A below.*

☐ Alternative LID Standards *Complete section 5B below.*

5A. Basic LID Standards *(skip to Section 6 after you have completed this section)*

☐ Total disturbed area on each lot is < 1 acre

☐ Buffers at least 50 feet wide* are provided along all lot boundaries

☐ Each lot has no more than 15,000 square feet of impervious cover

☐ At least 15% of each lot* is maintained as undisturbed natural area

☐ This project is a subdivision:

☐ If yes, the access road is open section road with pavement width no more than 22 feet.

* *In a watershed to a Lake Most at Risk from New Development, an Urban Impaired Stream, another impaired waterbody, a **100-foot buffer** is required and a minimum of **25%** undisturbed natural area must be maintained.*

5B. Alternative LID Standards ***(Go to Section 6 after you have completed this section)***
Complete the following information for each lot (use additional sheets as needed):

i. Calculate impervious areas:

Rooftop (s.f.): ________________________________ _Walkways (s.f.): ____________________________

Driveway (s.f.):_______________________________ _Patio (s.f.):_________________________________

Other (s.f.): __________________________________

TOTAL Impervious Area: ____

ii. Calculate disturbed pervious areas:

Lawn (s.f.): __________________________________ _Other (s.f.): ________________________________

TOTAL Disturbed Pervious Area: ____

iii. Treatment:

☐ The first 0.5 inches of runoff from the impervious surfaces above will be treated with LID practices.

☐ The first 0.2 inches of runoff from the disturbed pervious areas will be treated with LID practices.

Note: If the project is located within a Lake Most at Risk from New Development or other impaired water body, as designated by the town, you must treat the first 1 inch of runoff from impervious surfaces and the first 0.4 inches of runoff from disturbed pervious areas with LID practices.

Please mark the number of each practice that will be used to treat runoff from impervious and pervious surfaces:

Impervious Surfaces	PRACTICE	Disturbed Pervious Surfaces
_______	Bioretention System (underdrain soil filter)	______
_______	Swale (underdrain soil filter)	______
_______	Dry Well/Infiltration Trench	______
_______	Stormwater Planter	______
_______	Permeable Pavement	N/A
_______	Cistern	N/A
_______	Green Roof	N/A
_______	Vegetated Buffer/ Filter Strip	______

6. SITE PLAN:

Provide a plan of the lot, showing locations (labeled) of impervious areas, disturbed pervious areas, and LID practices, as well as locations of any wetlands or other surface water on or adjacent to the site. A plan at a scale no smaller than 1 inch equals 80 feet must be provided, stamped by a surveyor or engineer licensed in the State of Maine.

☐ A site plan is attached.

7. OPERATIONS AND MAINTENANCE PLAN:

☐ An Operations and Maintenance plan narrative is attached, and it describes the responsible party for ensuring maintenance occurs.

Appendix B3. Example Application for Retrofit/Expansion Projects

File Number:_____________

LID APPLICATION FORM – Retrofit/Expansion Project

1. **PROJECT ADDRESS:** ______________________________
2. **APPLICANT NAME:** ______________________________

   APPLICANT ADDRESS: ______________________________

   ____
3. **OWNER NAME:** ______________________________

   (if different from applicant) ______________________________

   OWNER ADDRESS: ______________________________

   (if different from applicant) ______________________________

4. BRIEF PROJECT DESCRIPTION: ______________________________

____

____

____

____

____

____

(Use additional pages if necessary.)

This project is located within:
- ☐ a watershed to a Lake Most at Risk from New Development,
- ☐ a watershed to an Urban Impaired Stream, or
- ☐ a watershed to another impaired water body (as designated by the Town).

Name of lake or other impaired water body: ______________________________

5. LID PRACTICES

This project will install the following LID practices to treat runoff from impervious and disturbed pervious areas (*indicate the approximate square footage of area draining to the practice number for each practice*):

PRACTICE	**Approx. Drainage Area (s.f.)**			
	Impervious	Disturbed Pervious	Other	Total

(Use additional pages if necessary)

6. SITE PLAN:

Provide a plan of the lot, showing locations (labeled) of impervious areas, disturbed pervious areas, and LID practices being installed, as well as locations of any wetlands or other surface water on or adjacent to the site. The plan can be a hand drawn sketch for an individual single family lot (see example). For a subdivision or non-residential development, a plan at a scale no smaller than 1 inch equals 80 feet must be provided, stamped by a surveyor or engineer licensed in the State of Maine.

☐ A site plan is attached.

7. OPERATIONS AND MAINTENANCE PLAN:

☐ An Operations and Maintenance plan narrative is attached, and it describes the responsible party for ensuring maintenance occurs.

Appendix C. LID Definitions for Local Code

ALTER: Any activity, which will measurably change the ability of a ground surface area to absorb water or will change existing surface drainage patterns. Alter may be similarly represented as "alteration of drainage characteristics," and "conducting land disturbance activities."

APPLICANT: A property owner or agent of a property owner who has filed an application for a Subdivision, a Site Plan, or a Building Permit.

BEST MANAGEMENT PRACTICE (BMP): Structural, non-structural and managerial techniques that are recognized to be the most effective and practical means to prevent and/or reduce increases in stormwater volumes and flows, reduce point source and nonpoint source pollution, and promote stormwater quality and protection of the environment. "Structural" BMPs are devices that are engineered and constructed to provide temporary storage and treatment of stormwater runoff. "Nonstructural" BMPs use natural measures to reduce pollution levels, do not require extensive construction efforts, and/or promote pollutant reduction by eliminating the pollutant source.

BETTER SITE DESIGN: Site design approaches and techniques that can reduce a site's impact on the watershed through the use of nonstructural LID Management practices. Better site design includes conserving and protecting natural areas and greenspace, reducing impervious cover, and using natural features for LID Management.

DEVELOPER: A person who undertakes or proposes to undertake land disturbance activities.

DEVELOPMENT: The modification of land to accommodate a new use or expansion of use, usually involving construction.

DISTURBANCE OF LAND: Any action that causes a change in the position, location, or arrangement of soil, sand, rock, gravel or similar earth material. This includes stripping, grading, grubbing, filling, or excavating at any time during the site preparation or removal of vegetation for, or construction of, a project.

DISTURBED PERVIOUS AREA: Any area of land that is disturbed during the development project, but remains pervious after the project. Disturbed pervious area is defined to include, without limitation, lawns and other Landscaped Areas, as defined in Maine Chapter 500L Stormwater Management, Section 3.

GRADING: Changing the level or shape of the ground surface.

GROUNDWATER: All water beneath any land surface including water in the soil and bedrock beneath water bodies.

IMPERVIOUS SURFACE or AREA: Any material or structure on or above the ground that prevents water from infiltrating through the underlying soil. Impervious surface is defined to include, without limitation: paved parking lots, sidewalks, roof tops, driveways, patios, and paved, gravel and compacted dirt surfaced roads.

INFILTRATION: The act of conveying surface water into the ground to permit groundwater recharge and the reduction of stormwater runoff from a project site.

LAKES MOST AT RISK FROM NEW DEVELOPMENT: This definition shall be the definition provided by the Maine DEM in the Maine Chapter 500 and 502 Stormwater Standards, latest version. The latest definition, at publication, is

LANDSCAPED AREA: An area of land that has been disturbed and replanted or covered with one or more of the following: lawn or other herbaceous plants, shrubs, trees, or mulch; but not including area that has reverted to a natural, vegetated condition. A field or meadow is considered landscaped if it is mowed more than twice per twelve month period.

LOW IMPACT DEVELOPMENT (LID): A more sustainable land development pattern that results from a site planning process that first identifies critical natural resources, then determines appropriate building envelopes, and incorporates a range of best management practices (BMPs) that preserve the natural hydrology of the land.

NATURAL VEGETATED BUFFER: A strip of vegetated, non-lawn land that is not altered by any new development or redevelopment, or construction associated with new development or redevelopment. [*This definition varies from the Vegetated Buffer definition in Appendix F of Maine CH. 500: Stormwater Management Regulations, in that a Natural Vegetated Buffer is not required to be located only downgradient of from a project site. For the purposes of this manual, a natural vegetated buffer can occur along the downgradient boundary of the property, as well as along other property boundaries, regardless of whether they are upgradient or downgradient. Buffers help to filter, slow the rate of flow and infiltrate runoff from a site, and they also produce significantly less runoff than lawn or impervious surfaces*.]

NEW DEVELOPMENT: Any construction or land disturbance of a parcel of land that is currently in a natural vegetated state (prior to the proposed project) and does not contain alteration by man-made activities.

OPERATION AND MAINTENANCE PLAN: A plan that defines the functional, financial and organizational mechanisms for the ongoing operation and maintenance of a LID Management system to insure that it continues to function as designed.

OWNER: A person with a legal or equitable interest in a property.

PERSON: Any individual, group of individuals, association, partnership, corporation, company, business organization, trust, estate, the State of Maine or political subdivision thereof to the extent subject to Town Ordinances, administrative agency, public or quasi-public corporation or body, the Town of *[_____]*, and any other legal entity, its legal representatives, agents, or assigns.

REDEVELOPMENT: Any construction, alteration, transportation, improvement exceeding land disturbance of *[5,000]* square feet, where the existing land use is commercial, industrial, institutional, or multi-family residential.

RESTORATION: Returning a damaged or degraded site or portion of a site back to its natural ecologically-functioning state to the extent possible, usually through soil replacement or amendments, revegetation, returning hydrologic characteristics, and/or regrading, or another method of returning the ecological function to the site.

REVEGETATION: The act or process of planting new vegetation to cover a bare land surface.

RUNOFF: Rainfall, snowmelt, or irrigation water flowing over the ground surface.

SITE: The parcel of land being developed, or a designated planning area in which the land development project is located.

LOW IMPACT DEVELOPMENT: The use of structural or non-structural practices that are designed to reduce storm water runoff pollutant loads, discharge volumes, and/or peak flow discharge rates.

UNDISTURBED NATURAL AREA: An area that is undeveloped, has naturally-occurring vegetation, and has no clear signs of recent human impacts to the site, such as clearing, grading, stockpiling, construction, or other human activity that is damaging to the vegetation, water or soils onsite.