Low Impact Development and Stormwater Manual for the Town of Newington

November 2013

FUSS & O'NEILL

146 Hartford Road
Manchester, CT 06040

Planimetrics

70 County Road
Simsbury, CT 06070

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Acknowledgements

Fuss & O'Neill, Inc.

M. James Riordan, AICP, LEED AP
Erik V. Mas, PE

Planimetrics

Glenn Chalder, AICP

Low Impact Development Land Use Committee

Philip Block – Conservation Commission Chairman
Cathleen Hall – Planning and Zoning Commissioner
Craig Minor, AICP – Town Planner
Christopher Greenlaw, PE – Town Engineer

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Table of Contents
Low Impact Development and Stormwater Manual for the Town of Newington

Tables | Page

Figures | Page

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Table of Contents

Low Impact Development and Stormwater Manual for the Town of Newington

Table of Contents

Low Impact Development and Stormwater Manual for the Town of Newington

Figures		Page

Appendix		End of Document

1 Introduction

1.1 Purpose of the Manual

The Town of Newington Low Impact Development and Stormwater Manual (hereinafter, Town LID Manual) provides guidelines for land development activities and stormwater management in the Town of Newington. The manual is applicable to activities involving new development, redevelopment, and existing development, undertaken by private or municipal entities, including projects that are subject to review and approval by Town departments, land use boards, and other agencies. The manual provides guidance for developers, engineers, and local regulatory authorities to design and review projects in a technically sound and consistent manner.

1.2 Organization of the Manual

This manual is organized as follows:

- **Section 1**—describes the purpose, organization and use of the manual; and also provides an introduction to the use and benefits of low impact development (LID).
- **Section 2**—describes stormwater management standards for new development, redevelopment, and existing development.
- **Section 3**—describes basic LID planning principles and the recommended site planning and design process.
- **Section 4**—describes small-scale structural management practices that can be integrated throughout a site to meet the stormwater management standards in a variety of land-use settings.
- **Section 5**—contains design standards for structural and non-structural LID controls.
- **Section 6**—provides document references.

1.3 How to Use this Manual

This manual is intended to be used in conjunction with other existing stormwater design guidance documents including the Town of Newington *Stormwater Drainage Manual*, the Connecticut Department of Energy and Environmental Protection (CTDEEP) *Connecticut Stormwater Quality Manual* (as amended), and the Connecticut Department of Transportation (CTDOT) *Drainage Manual* (as amended). The Town LID Manual should be used specifically for the planning and design of LID stormwater management practices to augment these other existing stormwater and drainage design guidance documents.

The design practices described in this manual should be implemented by professional engineers licensed to practice in the State of Connecticut. The design engineer is responsible for field investigations, data collection and analysis, and design of stormwater management and drainage facilities based upon the guidance contained in this manual. Stormwater management is an evolving field. Existing stormwater management practices are being refined and new practices are being developed on a regular basis. The Town may periodically amend this manual to reflect new or modified technologies, practices, and regulatory requirements.

1.4 What is Low Impact Development

Low Impact Development (LID) is an approach to site development and stormwater management that aims to avoid or mitigate impacts to land and water. LID provides the necessary tools to plan and engineer sites in a manner that mimics predevelopment hydrology, protects water quality by treating runoff and reducing pollutant loads. LID also helps to address urban flooding by retaining flow so as to reduce runoff volume and flow rate.

Traditionally, stormwater has been managed with large, best management practices (BMPs) installed at the low end of development sites using land segments left over after subdividing property. This approach is sometimes referred to as end-of-pipe management and tends to focus on detention to remove sediment and treat stormwater. Experience over the last 30 years demonstrates that conventional end-of-pipe BMPs do not achieve desirable results in many instances.

The limitations of conventional urban stormwater management practices were a major driver for development of LID, which is an alternative and more effective approach. LID strives to combine effective site planning and small-scale structural practices located close to where rainfall lands—often right at the perimeter of impervious surfaces—using distributed retention and infiltration BMPs to mimic undeveloped landscapes. The placement of controls throughout a site increases runoff flow paths and travel time, dramatically reducing runoff volumes by increasing opportunities for infiltration and filtration within landscape features.

LID offers a great deal of flexibility. With appropriate selection, application and design, LID principles and practices can be applied to virtually any land use, soil, and climate. For example, in soils with high infiltration rates (e.g., sandy soils), LID practices can be designed to infiltrate runoff to replenish stream baseflow. On the other hand, in high-density urban areas or retrofit situations, infiltration may not be desirable or practical. Filtration and retention (i.e., capture-and-use) practices may be more appropriate. Furthermore, proponents of LID have learned to design BMPs for application in cold climates such as New England, and these approaches have been incorporated in the standards of this manual.

LID's wide array of small-scale management principles and practices has led to the development of new tools to retrofit existing urban development. Small-scale practices can be integrated into existing green space, streetscapes and parking lots as part of the redevelopment process or through routine maintenance and repair of urban infrastructure. Redevelopment of urban areas using LID techniques can dramatically reduce pollutant loads to receiving waters.

Newington, like many Connecticut communities, places a strong emphasis on the stormwater basics of providing flood control and adequate drainage. The Town recognizes the multiple benefits of a holistic approach to stormwater management through the use of more natural systems and LID techniques. The stormwater management standards contained in this manual reflect the trend in stormwater management toward an integrated approach that combines effective site planning and structural stormwater controls to address the full range of hydrologic and water quality impacts resulting from development.
Though the Town prefers the use of LID, the Town recognizes that the LID approach is not a panacea. Hybrid approaches, which incorporate both conventional and LID practices, may be needed some situations. Notwithstanding, as LID's decentralized practices typically do a better job of reducing

adverse environmental effects than end-of-pipe approaches, so the Town will expect careful consideration of all feasible alternatives prior to selecting end-of-pipe stormwater controls.

Typical advantages of LID over the conventional end-of-pipe approach include:

- **Reduced consumption of land for stormwater management** – LID practices provide opportunities to integrate stormwater controls into all aspects of a site's hardscape and landscape features. This allows multifunctional use of the entire developed site, allowing the most cost-effective use of land. Less land is needed or consumed for end-of-pipe controls, often allowing for more developable space.
- **LID does not dictate particular land-use controls –** Since LID is a technological approach there is no need to change conventional zoning or subdivision codes, except to allow LID's use. LID does not reduce development potential and, with less land consumed for stormwater controls, lot yields may increase.
- **Reduced construction costs** – Traditional stormwater management requires significant storm sewering and earthwork. LID practices apply controls as close to sources of runoff as possible. Wherever practicable, conveyances incorporate natural flow paths and swales instead of pipes. Structures installed are small, thus reducing the need for excavation and construction materials.
- **Ease of maintenance** – LID practices require limited maintenance. Much of the maintenance required can be accomplished by the average landowner. Further many LID site planning, conservation, and grading techniques require no maintenance.
- **Takes advantage of site hydrology** – LID mimics natural site hydrology and capitalizes on the capability of undisturbed land to retain and absorb runoff from impervious surfaces. Runoff that is absorbed recharges groundwater and stream baseflow and does not need to be managed or controlled by an end-of-pipe practice. Reduced end-of-pipe discharge is also beneficial for streambank stability and habitat.
- **Better quality of discharge** – Recent research indicates that most constructed technologies are unable reduce pollutant concentrations below certain thresholds, which may exceed water quality standards. Landscapes that utilize LID practices minimize discharge and often retain all runoff from events smaller than the 2-year, 24-hour design storm. Pollution is minimized because discharge is minimized.
- **More aesthetically pleasing development –** Traditional stormwater management tends to incorporate the use of large, unnatural looking practices such as detention ponds. When neglected, these practices may present safety and mosquito concerns. LID practices utilize pre-development land features that are small and fit well into the natural landscape.
- **Improved marketability and property values** – The advantages of LID management translate into the marketplace. The benefits to developers include reduced land clearing and earth disturbance costs, reduced stormwater management costs, reduced infrastructure costs (roads, stormwater conveyance and treatment systems), and increased quality of building lots and community marketability.

2 Stormwater Management Standards

This section describes the stormwater management requirements (i.e., standards) for the Town of Newington and the types of activities to which they apply (i.e., applicability). These standards promote the use of LID to protect water quality, reduce runoff volume, maintain groundwater recharge, and address peak flows and flooding during larger storms. These standards shall be met for each design or discharge point from a site (i.e., the catchment area that contributes to a BMP). Compliance with the standards by sizing BMPs to accept flow from more than one catchment area may be allowed at the discretion of the Town Engineer; however, such an approach will not typically be accepted for development projects.

The standards are generally consistent with the stormwater management approaches and design guidance contained in the Connecticut Department of Energy and Environmental Protection *Connecticut Stormwater Quality Manual* and the Connecticut Department of Transportation *Drainage Manual*, but also reflect the town's unique natural resources and development characteristics.

2.1 Standards

Standard 1: Use of Low Impact Development to Reduce Stormwater Runoff and Pollutants

LID techniques shall be used to the maximum extent practicable (MEP) to reduce stormwater runoff and pollutant loads. LID practices, both nonstructural and structural, are to be given preference over conventional end-of-pipe approaches. The Town anticipates that virtually all projects will manage and treat the Water Quality Volume or WQV (see discussion below) using LID.

MEP is intended to allow flexibility in situations where LID is best used in combination with conventional practices. For the purposes of this manual, MEP requires that applicants demonstrate the need to use non-LID approaches by:

- Documenting reasonable efforts to include LID for management of at least the WQV or the Water Quality Flow (WQF) for flow-based BMPs (see below).
- Documenting use of LID BMPs as described elsewhere in this manual.
- Documenting the highest reasonable level of LID-based stormwater management if full compliance with this standard cannot be practicably achieved.

<u>Water Quality Volume</u>

Added together, storms of up to one-inch depth make up about 90% of Newington's total annual rainfall. Untreated, these storms are responsible for the majority of stormwater pollution in our town. The water quality volume (WQV) refers to the volume of runoff from a given storm that a stormwater system shall be designed to collect and treat in order to remove the majority of pollutants. The WQV shall be equal to 1 inch of precipitation times the impervious surface in the catchment or 0.2 inches of precipitation times the total catchment area, whichever is larger. The WQV shall be calculated using the following equation:

$$WQV = \frac{(1'')(i)}{12} or \frac{(0.2'')(A)}{12} \text{ (whichever is larger)}$$

where: *WQV* = water quality volume (acre-feet)
i = impervious area of the catchment (acres)
A = area of the catchment excluding undeveloped areas (acres)

The above equation differs from the runoff coefficient calculation specified in the *Connecticut Stormwater Quality Manual*. The intent of the above equation is to account for both impervious surfaces and pervious areas with the potential to contribute stormwater pollutant loads.

Impervious and pervious areas that are disconnected from the stormwater drainage system or receiving waterbodies using techniques described in *Section 5.3* of this manual may be excluded from the WQV calculation. Where off-site areas also contribute to the site's drainage due to drain line interconnections or other factors such as run-on from upgradient areas, the off-site areas may be included in the calculation of WQV at the discretion of the Town.

Excluding disconnected areas is intended to encourage the use of stormwater disconnection as a LID practice.

Water Quality Flow

The water quality flow (WQF) is the peak flow rate associated with the water quality design storm or WQV. BMPs that are designed based on flow rate, rather than volume, such as grass channels and proprietary BMPs, should be designed to treat the WQF. The WQF shall be calculated using the NRCS, TR-55 Graphical Peak Discharge Method or other methods recommended by the manufacturers of proprietary BMPs, as described in the *Connecticut Stormwater Quality Manual*.

Groundwater Recharge Volume

As described in the *Connecticut Stormwater Quality Manual*, the groundwater recharge standard is intended to maintain groundwater recharge rates. The Town generally recommends the use the "Hydrologic Soil Group Approach," which involves determining the average annual pre-development recharge volume at a site based on the existing site Hydrologic Soil Groups (HSG) as defined by the United States Natural Resources Conservation Service (NRCS) County Soil Surveys. Based on this approach, the GRV shall be calculated as the depth of runoff to be recharged, multiplied by the area of impervious cover, as shown below:

$$GRV = \frac{(D)(A)(I)}{12}$$

where: *GRV* = groundwater recharge volume (acre-ft)
D = recharge depth (inches), see *Table 2.1*
A = site area (acres)
I = post-development site imperviousness (decimal, not percent) for new development projects or the net increase in site imperviousness for re-development projects

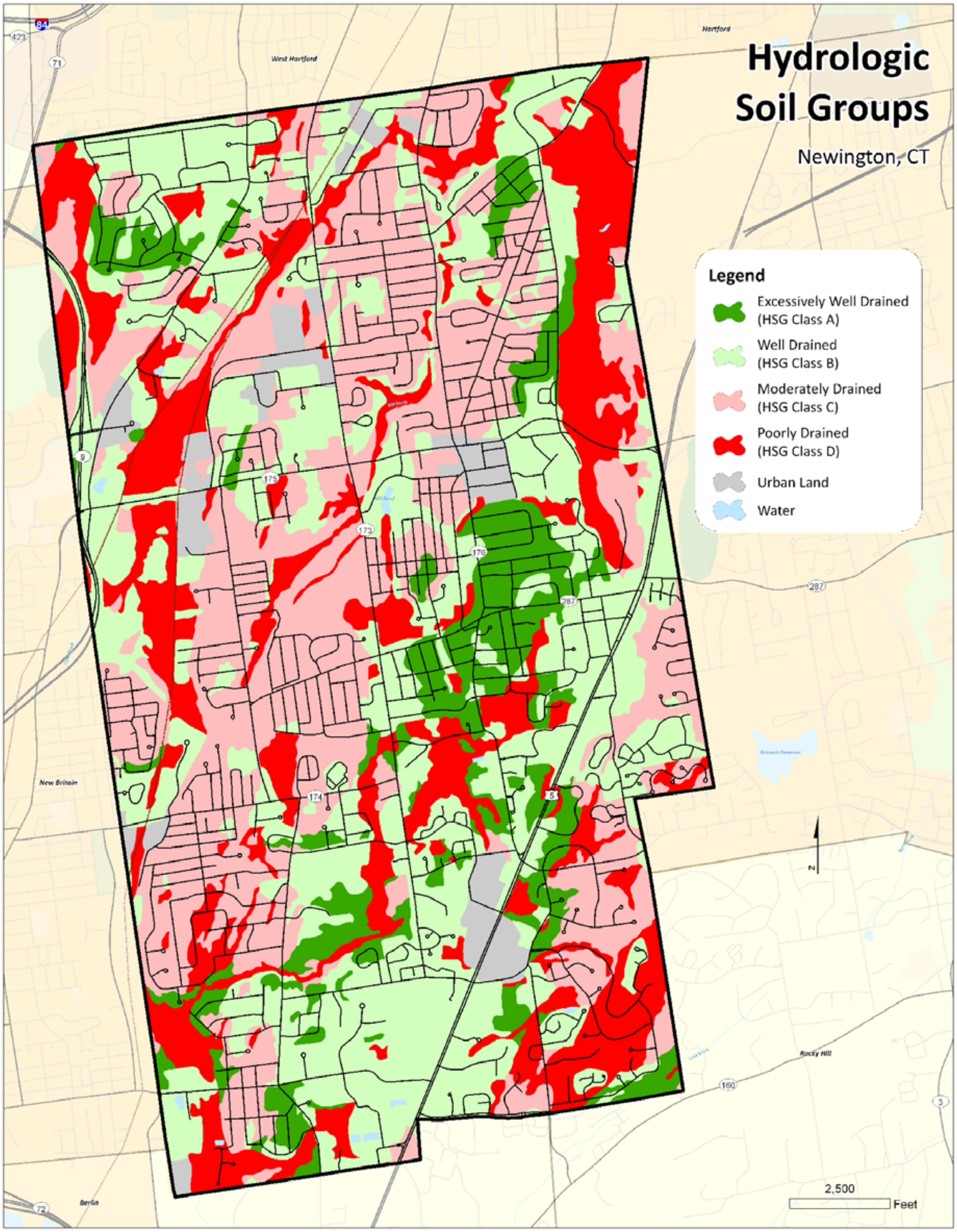

Figure 2.1 – Hydrologic Soil Groups in Newington

Table 2.1
Recharge Depth by Hydrologic Soil Group

Hydrologic Soil Group	Recharge Depth (D) (in)
A	0.40
B	0.25
C	0.10
D	Waived

Where more than one hydrologic soil group is present on a site, a composite or weighted recharge depth shall be calculated based upon the relative area of each soil group. The GRV should be infiltrated in the most permeable soil group available on the site. *Figure 2.1* shows the approximate location of soil type by HSG throughout the Town.

Standard 2: Peak Flow Control and Flood Protection

Post-development peak rates of runoff must be managed to protect against stream channel erosion, to reduce the potential for flooding during larger storms, and to safely convey stormwater to, from, and through stormwater management systems.

Stream channel protection, conveyance protection, and emergency outlet sizing shall be managed in accordance with the *Connecticut Stormwater Quality Manual*.

Peak runoff attenuation is specified for 2-year, 5-year, and 10-year, 24-hour storms in the *Connecticut Stormwater Quality Manual*. As described in the Connecticut manual, the post-development peak flow rates shall not exceed the pre-development peak flow rates for all flows off site for the 2-year, 5-year, and 10-year, 24-hour design storms. Peak runoff attenuation for larger design storms (i.e., 25-year, 50-year, and 100-year storms) may be required, at the discretion of the Town, for large developments and special or sensitive situations. The Town may also, at its discretion, require the project proponent to evaluate pre- and post-development peak runoff rates associated with more intense, shorter-duration storm events or less intense, longer-duration storm events to reflect potential changes in rainfall characteristics due to climate change or other factors. This standard may be waived, at the discretion of the Town, for sites that discharge to a large river, lake, estuary, tidal waters, or land subject to coastal storm flows, as described in the *Connecticut Stormwater Quality Manual*.

Unless otherwise specified by the Town, the 24-hour design storm rainfall amounts shall be obtained from the on-line web tool for extreme precipitation analysis developed as a joint collaboration between the Northeast Regional Climate Center (NRCC) and the USDA Natural Resources Conservation Services (NRCS), http://precip.eas.cornell.edu, for New York and New England. The design storm rainfall amounts provided by this web tool offer advantages over previous products (e.g., "Rainfall Frequency Atlas of the United States," Technical Paper No. 40, U.S. Department of Commerce, Weather Bureau and NOAA Technical Memorandum "NWS Hydro-35," June 1977, U.S. Department of Commerce, National Weather Service) since the design storm rainfall amounts are based on a much longer period of record, including updates as new rainfall data is collected. Designers shall refer to the web tool for additional information such as design rainfall amounts for shorter design storms (less than 24 hours) and intensity-duration-frequency data.

Standard 3: Construction Erosion and Sediment Control

A plan to control construction related impacts, including erosion, sedimentation, and other pollutant sources during construction and land disturbance activities (construction period erosion, sedimentation, and pollution prevention plan) must be developed and implemented in accordance with the *Connecticut Guidelines for Soil Erosion and Sediment Control* (as amended) and the requirements of the CTDEEP *General Permit for the Discharge of Stormwater and Dewatering Wastewaters from Construction Activities.*

All development, regardless of the area of disturbance, must implement erosion and sedimentation controls prior to and during construction. Additionally, temporary controls shall be removed from a site and disposed of properly after the site has been stabilized.

Standard 4: Operation and Maintenance

A long-term operation and maintenance (O&M) plan shall be developed and implemented to ensure that stormwater management systems function as designed. This plan shall be reviewed and approved as part of the review of the proposed stormwater management system. Execution of the O&M plan shall be considered a condition of approval of a development plan. The Town shall require a project proponent to establish a homeowners association or similar entity to maintain the stormwater management system.

The O&M plan shall identify:

- Stormwater management system(s) owners.
- The party or parties responsible for operation and maintenance including how future property owners will be notified of the presence of the stormwater management system and the requirement for proper operation and maintenance.
- The routine and non-routine maintenance tasks to be undertaken after construction is complete and a schedule for implementing those tasks.
- Log form or checklist for recording operation and maintenance activities.
- The maintenance agreement in place.
- Plan that is drawn to scale and shows the location of all stormwater BMPs along with the discharge points.
- Seal and signature of a professional engineer.

The project proponent shall provide a legal mechanism for implementing and enforcing the O&M plan (i.e., stormwater maintenance declaration), which shall be filed on the Town of Newington land records. A copy of the stormwater maintenance declaration is provided in *Appendix A*. The maintenance declaration shall contain (or reference as an attachment) a legal description of the property for which the declaration applies, a map showing the location of each stormwater management practice affected by the declaration, and a description of those activities that must be carried out to maintain compliance with the declaration.

In the event that the stormwater BMPs will be operated and maintained by an entity, municipality, state agency or person other than the sole owner of the lot upon which the stormwater management facilities are placed, the proponent shall provide a plan and easement deed that provides a right of access for the legal entity to be able to perform said operation and maintenance functions, including inspections.

Parties responsible for the operation and maintenance of a stormwater management system shall keep records of the installation, maintenance and repairs to the system, and shall provide such records to the Town upon request.

When the responsible party fails to implement the O&M plan, the Town may assume responsibility for their implementation and to secure reimbursement for associated expenses from the responsible party, including, if necessary, placing a lien on the subject property.

Standard 5: Redevelopment

Redevelopment is defined as alteration or improvement of real property that reconfigures existing impervious areas. Some examples of redevelopment include:

- Construction of building additions over an existing paved area.
- Demolition and replacement of buildings for any use.
- Paving of unsurfaced or gravel parking lots.
- Excavation and resurfacing of existing paved areas (Milling and resurfacing of an existing paved area may be allowed without meeting Standard 5 at the discretion of the Town Engineer).

Redevelopment standards are intended to enhance stormwater management through the increased use of LID in developed areas without discouraging redevelopment.

Redevelopment must meet stormwater Standards 2 – 4 in the same manner as development projects; however, Standard 1 may be met as follows:

- Achieve a net 50% reduction in existing impervious surfaces within the project limits of disturbance either by removing impervious surface (i.e., converting the impervious surface to a pervious surface) or by managing the WQV from the impervious surface through the use of LID BMPs.

Projects that entail both redevelopment and new development must:

- Achieve 100% management of the WQV of the net increase in impervious area through the use of LID BMPs in accordance with Standard 1.
- Achieve a net 50% reduction in existing impervious surfaces as described above.

Update of *Newington Stormwater Drainage Manual* (May 2000) Standards

The following discussion is intended to clarify certain standards in the *Newington Stormwater Drainage Manual* for the narrow purposes of facilitating the implementation of LID. This discussion is not intended to address other changes in stormwater and drainage techniques that may have been developed since the publication of the *Newington Stormwater Drainage Manual* nor is this discussion intended to be a comprehensive review of the *Newington Stormwater Drainage Manual*.

Proponents of projects involving stormwater management should consider the following clarifications:

Section A.I.C.4 "Riparian Buffers"
LID BMPs may be allowed in riparian buffers at the discretion of the Town in accordance with the *Inland Wetlands and Water Course Regulations*.

Section A.I.C.8 "Discharge Location"
Discharges may be directed to infiltration or overland flow in accordance with standards of this LID Manual.

Section A.III.B.5. [Hydrology Methods]
24-hour rainfall amounts should be based on the Natural Resources Conservation Service Type III precipitation distribution. Rainfall amounts should be obtained from the Northeast Regional Climate Center the unless otherwise required by the Town.

Section A.III.B.2 [Peak Flow Attenuation]
Techniques available for attenuation should be considered to include, but not necessarily be limited to, the management practices described in *Section 4* of this LID Manual.

Section A.IV.C.1 [Catch Basins]
LID is the Town's preferred stormwater management approach; therefore, catch basin installation is required where structural conveyance systems are necessary to supplement the use of LID.

Section A.VI.A [Easements and Rights-of-Way]
Easements and rights-of-way are required for BMPs that are to be operated by the Town. Easements and rights-of-way may also be required at the discretion of the Town Engineer for the purposes of ensuring proper BMP operation.

2.2 Applicability

2.2.1 General Applicability

The following table is intended to exemplify the general applicability of LID standards in accordance with Town policy.

Table 2.2
Example Applicability of Newington's Stormwater Standards

Type of Project	Example	Stormwater Management Standard
Development	Commercial, Institutional, Industrial	Standards 1 - 4
	Mixed-Use Development	
	Residential (e.g., residential subdivisions, multifamily residences, etc.)	
Redevelopment	Commercial, Institutional, Industrial Redevelopment	Standard 1 per Standard 5 Standards 2 - 4
	Mixed-Use	
	Change in Use that Increases Parking Demand per Town Zoning	
	Addition to a House (Single or Multifamily up to a Quadraplex)	Standard 1 per Standard 5 (Standard 5 may generally be met by addressing *Section 4.3* of this manual) Standards 2 - 4
	Addition of an Appurtenance (e.g., patio, walkway, driveway, etc.)	

2.2.2 New Development and Redevelopment

The stormwater management standards apply to new development and redevelopment activities in the Town of Newington, unless exempted. Two types of exemptions may apply:

1. Projects creating less than 600 square feet of new impervious or redeveloped surfaces provided that all of the following conditions are met:

    - The project drainage design will not have an adverse effect on offsite properties or offsite drainage infrastructure.
    - LID measures in accordance with the Town manual are implemented

Compliance with the stormwater standards (including use of LID to the maximum extent practicable) is required for all projects proposing to create 600 square feet or more of impervious surface. This standard allows the Town some flexibility and avoids the need for stormwater permitting on small projects such as walkways and patios.

on the site to the maximum extent practicable to mitigate the effects of site disturbance and new impervious cover.
- The project proponent submits an exemption request.

This exemption is available only until the cumulative addition of unreviewed impervious surface on a site reaches 600 square feet, regardless of ownership changes. Residential "teardowns" – demolition and reconstruction or replacement of an existing residential dwelling with another residence of any size – are not allowed to exercise this exemption.

2. Routine activities with low potential for adverse impacts to drainage or stormwater quality:

   - Resurfacing of an existing impervious area on a non-residential lot such as repaving an existing parking lot or drive with no increase in impervious cover.
   - Routine maintenance to existing town roads that is performed to maintain the original width, line, grade, hydraulic capacity, or original purpose of the roadway.
   - Repair or replacement of an existing roof of a single-family dwelling.
   - Construction of a second (or higher) floor addition on a single-family house.

2.2.3 Existing Development

Existing development includes those uses that have been previously permitted or grandfathered by the Town. The stormwater management standards do not apply to existing development, unless redevelopment or development activities are proposed on an existing developed site as described in the previous section. Retrofitting of existing developed sites with LID BMPs is voluntary, although encouraged to address existing water quality or drainage issues. *Section 4.5* of this manual discusses stormwater retrofits using LID techniques.

3 LID Planning and Design Process

LID represents a change in philosophy for stormwater management. Runoff is viewed as a resource, and hydrology is used as an organizing principle for site design – learning how to work with rain water in the landscape rather than just quickly disposing of it. LID is an ecologically-friendly approach to site development and stormwater management that aims not just to minimize development impacts (reduce impervious surfaces), but instead restore vital watershed ecological processes (natural hydrologic regime) necessary to restore and maintain the physical and biological integrity of waters.

LID uses management principles such as conservation of soils and drainage patterns; using integrated decentralized controls; uniform distribution of lot-level controls to increase runoff storage, contact time and time of travel; and, multifunction landscape features engineered to make the most cost effective use of space. The landscape is comprehensively engineered and optimized for stormwater controls. All of these principles are in direct contrast to conventional end-of-pipe treatment. *Figure 3.1* and *Figure 3.2* illustrate a comparison of conventional centralized controls and a LID decentralized approach.

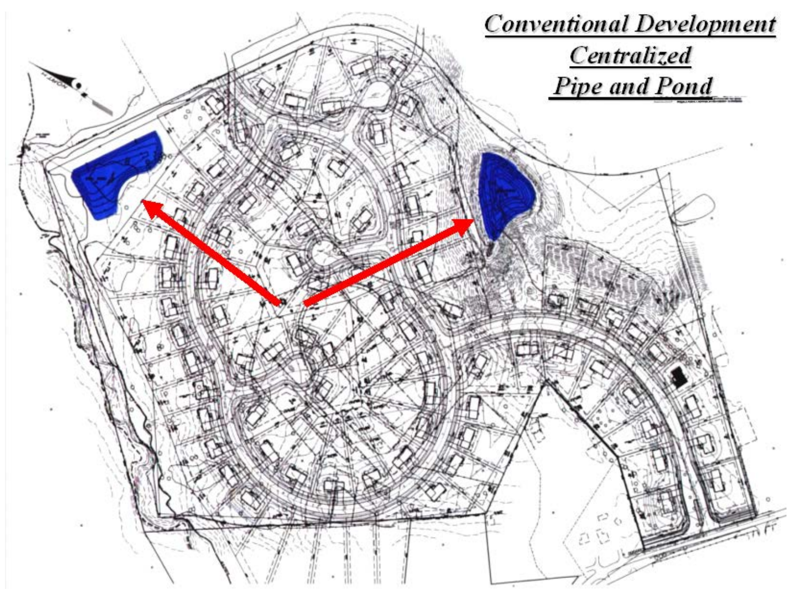

Figure 3.1 – Conventional Controls: A conventional approach requires clear cutting, mass grading and use impervious surfaces, gutters pipes and ponds to collect and treat runoff. This approach completely alters and destroys the natural hydrology and ability of the landscape to absorb rainwater and capture pollutants.

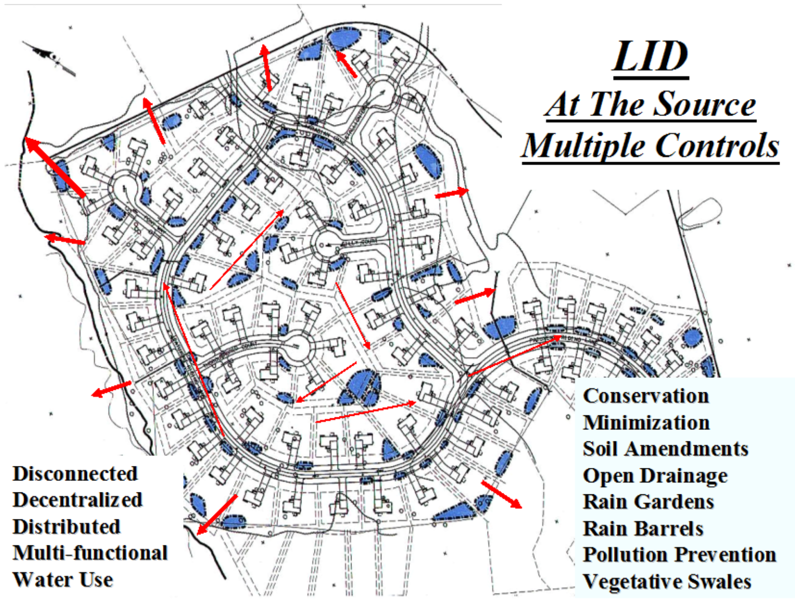

Figure 3.2 – LID Controls: A LID approach use a wide array of techniques that work with the landscape, soils, drainage patterns and vegetation to minimize impacts and integrated management controls to retain, detain, infiltrate and filter runoff. LID can provide better stormwater controls by mimicking the pre-development hydrology. Often LID designs increase lot yield and reduce infrastructure cost.

A specific site planning and design process is recommended to optimize the benefits of LID. This process includes optimizing conservation at the larger project level, minimizing impacts at site level, maintaining drainage features, and the use of engineered integrated management practices. Basic LID planning principles and the LID design processes are described below.

3.1 Basic Planning Principles

A well-designed integrated stormwater management system will minimize the volume of runoff generated and maximize the treatment capabilities of the landscape. LID design manages runoff as close to the source as possible. A well-designed system should also be easy to maintain, not interfere with the typical use of the property, and be aesthetically pleasing. To optimize a LID design, it is important to consider four fundamental concepts, from the project's inception through final design:

1. **Minimizing site disturbance**
   Undisturbed lands possess a natural capacity to store runoff. Development sites may include areas that are relatively sensitive to impacts from construction (e.g., erosion) or may have particularly rare or valuable environmental features. Protecting susceptible natural features provides the multiple benefits of preserving important resources, reducing development impacts, and preventing erosion.

   Generally, project proponents should inventory and map natural features, such as surface waters, wetlands and highly erodible soils, for preservation early in the site planning process. This helps to define a development envelope that avoids impacts to environmentally-sensitive site features.

2. **Working with site hydrology**
   Traditional stormwater management approaches seek to eliminate runoff by rapidly conveying it away from development, typically, via closed drainage systems such as storm sewers. This approach works efficiently to remove water from streets and sidewalks, but it is expensive and alters site hydrology. By contrast, LID techniques eliminate or reduce the generation of runoff, thereby maintaining site hydrology.

3. **Minimizing and disconnecting impervious surface**
   Runoff is generated primarily from impervious surfaces, such as rooftops, roadways or any hard surface that prevents water from infiltrating into the ground. Traditional development approaches have typically resulted in excessive impervious surfaces, which can be reduced through careful site planning. Techniques to limit impervious area include reducing road widths and lengths as well as the area of rooftops (e.g., preference for multi-story over single-story buildings).

   To the extent possible, project proponents should use pervious areas and vegetation to manage runoff. This can be accomplished by increasing a site's time of concentration – length of time required for runoff to concentrate and flow off site – and by reducing the runoff curve number.

4. **Applying small-scale controls at the source**
   Small-scale practices applied close to the source of runoff provides significant advantages over conventional stormwater systems such as detention ponds. They can reduce the need for costly underground drainage systems and large end-of-pipe controls. By using materials such as native plants and soil, these systems can be integrated into the landscape and appear more natural than large, engineered systems. The natural characteristics may also increase homeowner acceptance and willingness to adopt and maintain such systems. Small, distributed practices also offer a major technical advantage – one or more of the systems can fail without undermining the overall integrity of the site stormwater management strategy. Small-scale practices reduce safety concerns as they feature shallow basin depths and gentle side slopes.

Another important factor in LID design is that it is best applied by a multidisciplinary team of professionals. The contributions of soils scientist, biologists, landscape architects, urban planners, and engineers are all equally important. It is not just about meeting the volume storage and flow regulatory requirements, it is about professionals using their combined knowledge and skills to create and design ecologically-functional, economically-viable, aesthetically-pleasing sites.

The following LID planning principles should remain in the forefront throughout the various steps of the site planning and design process. These principles require a completely different way of thinking about site design than traditional design approaches.

- **Optimize Conservation –** Conserve natural resource areas, vegetation and soils to help reduce and treat runoff.
- **Mimic the Natural Water Balance –** Use LID techniques to maintain existing site hydrology. This requires careful evaluation of site soils in order to preserve and use permeable soils as part of the LID control strategy. Conserving natural drainage features and topography will also help to limit site disturbance and runoff generation.

- **Disconnect Impervious Surfaces –** Disconnect impervious surfaces. Site runoff characteristics are significantly changed when impervious surfaces are disconnected from the drainage system or receiving waters through the use of landscape features or engineered LID practices. This approach prevents the adverse cumulative effects of collecting and concentrating flows and helps to reduce erosion problems.
- **Decentralize and Distribute Controls –** LID is most efficient when multiple controls are distributed throughout the landscape close to the source of runoff. Increasing runoff time of travel significantly reduces flows and discharge frequencies. Increasing storage features decreases runoff volume and reduces annual pollutant loads. Utilizing landscape features for filtration increases its capacity to capture and cycle pollutants.
- **Multifunctional/Multipurpose Landscapes –** Landscape can be designed to either reduce or restore hydrologic functions. Landscape features should be optimized to provide beneficial hydrologic and water quality functions by preventing, storing, retaining, detaining, and treating runoff.
- **Outreach and Education –** An effective LID program includes public education and outreach to foster an understanding and appreciation of LID principles and practices by the public, including homeowners and others responsible for maintaining LID practices.

3.2 Site Planning and Design Process

The LID approach emphasizes the use of site planning and design techniques to conserve natural systems and hydrologic functions. The simplest and least costly LID technique is effective site planning, with the goal of preserving the predevelopment hydrology to the extent possible. To accomplish this, LID requires a thorough understanding of the site's soils, drainage patterns, and natural features. Early consideration of a site's natural features, hydrology, and soils as design elements can suggest areas that are best suited for development and conservation.

Step 1 – Define Basic Project Objectives and Goals

The first step in the LID site planning and design process is to identify applicable zoning, subdivision, and other local land use planning and regulatory requirements, which influence the density and geometry of the development, specifying roadway widths, parking, drainage, and other requirements.

Identifying the project objectives not only includes identifying regulatory requirements, but also ecological needs. Ecological needs include these fundamental aspects:

- Runoff volume to match predevelopment.
- Peak runoff rate to meet regulatory needs.
- Flow frequency and duration to match predevelopment.
- Water quality to meet regulatory requirements.
- Stream or wetland base flow needs.
- Recharge areas.
- Natural resource conservation requirements.

To ensure ecological needs receive appropriate attention, the project proponent should prioritize and rank objectives and determine the type of controls required to meet objectives such as infiltration,

filtration, discharge frequency, volume of discharges and groundwater recharge. Determine the feasibility for type and proper location of LID controls to best address volume, flows, discharge frequency, discharge duration and water quality.

Step 2 – Inventory and Evaluate Site Resources

Incorporating LID into site design requires a thorough assessment of the site and its natural systems. A site inventory and evaluation should be performed early in the site planning and design process to help identify challenges and/or opportunities for stormwater management and site development.

1. Conduct a detailed investigation of the site using available documents such as drainage maps, utilities information, soils maps, land use plans, and aerial photographs.

2. Evaluate site constraints such as available space, soil infiltration characteristics, water table, slope, rock outcrop, drainage patterns, sunlight and shade, wind, critical habitat, existing buildings, infill opportunities, circulation and underground utilities.

3. Identify protected areas, setbacks, easements, topographic features, sub drainage divides, and other site features that should be protected such as floodplains, steep slopes, and wetlands.

4. Delineate watershed and micro-watershed areas. Take into account previously modified drainage patterns, roads, infill opportunities, and stormwater conveyance systems.

Other unique site features may influence the site design including historical features, view sheds, climatic factors, energy conservation, noise, watershed goals, onsite wastewater disposal and off-site flows. All of these factors help to define the development area and natural features to be integrated into the LID design.

Step 3 – Conserve Natural Features

Successful LID design begins with understanding of the site's natural resources and how best to save these features and incorporate them into the stormwater management system. Natural features (wetlands, trees/vegetation, permeable soils) should be conserved and integrated into the overall site plan. The conservation features should continue to be used by directing runoff to the natural features in the same manner as the predevelopment conditions. The greater use of natural features generally reduces clearing and grading and associated costs.

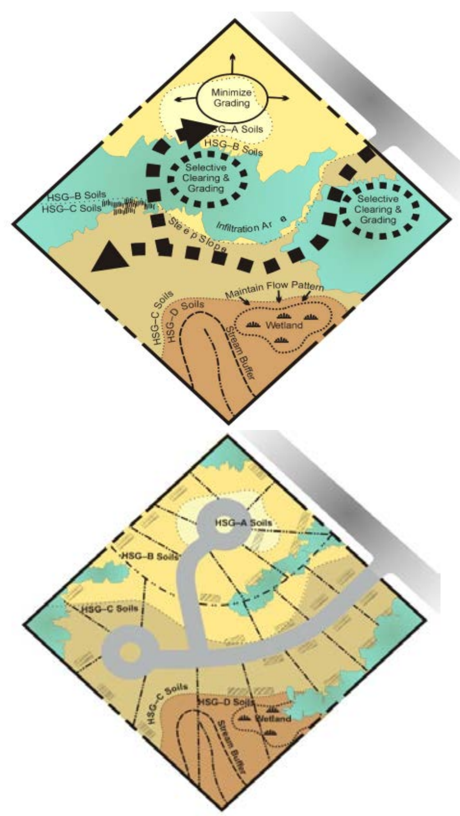

Figure 3.4 – Optimizing the use of green space.

Locating infrastructure to direct runoff to buffers, vegetative filters, and existing drainage features will help to reduce runoff quantity and improve water quality. This approach reduces disturbance of the natural soils and vegetation allowing more areas for infiltration and runoff contact with the landscape. To optimize the use of green space requires an ability to lay out the site infrastructure in a way that allows saving sensitive the natural features and their functions. The basic strategy is shown in *Figure 3.4*.

There are many techniques that should be considered including:

- Minimizing and properly stage grading and clearing for roadways and building pads as only necessary.
- Locating, saving and utilizing pervious soils.
- Locating treatment practices in pervious hydrologic soil groups A and B.
- *Where feasible*, constructing impervious surfaces on less pervious hydrologic soils groups C and D.
- Disconnecting impervious surfaces by draining them to natural features.
- Flattening slopes where possible.
- Re-vegetating cleared and graded areas.
- Utilizing existing drainage patterns.
- Routing flow over longer distances.
- Using overland sheet flow.
- Maximizing runoff storage in natural depressions.

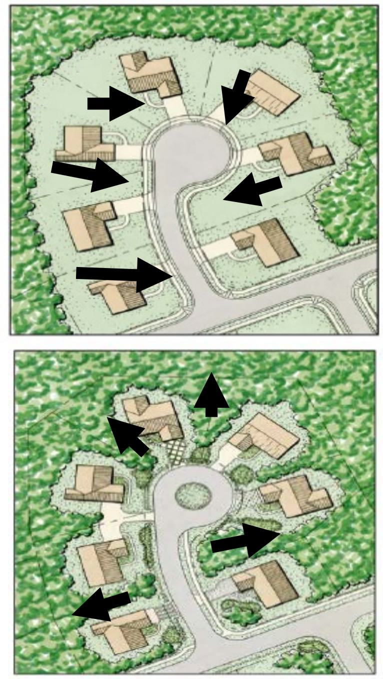

Figure 3.5 – Contrasting runoff patterns in conventional (top) and LID design (bottom).

Step 4 – Determine the Development Envelope

Determine the development envelope in which buildings, roads and other constructed features should be sited with minimal effect to site hydrology and other ecological, scenic, or historic features. Generally, the development envelope will include upland areas, ridge lines, gently sloping hillsides, and less permeable soils outside of wetlands. Setting the development envelope should also consider construction techniques, and make efforts to retain and protect mature trees, minimize clearing and grading for buildings, access and fire prevention, and other construction activities, including stockpiles and storage areas. The envelope should also be confined to areas to be permanently altered. Limiting the development envelope also reduces the amount of site disturbance and impervious cover, thereby generating less runoff and requiring smaller stormwater management systems.

In general, the following steps should be followed to determine the development envelope:

1. Determine those environmentally sensitive areas to be protected from development.

2. Delineate the different vegetative cover types on the site. Highlight those areas of special characteristics or environmental sensitivities. Areas with concentrations of large mature trees should be noted on the plan.

3. Determine and delineate steep slopes (slopes greater than 25% or 4 horizontal to 1 vertical slope as measured over a minimum distance of 50 feet).

4. Determine and delineate soils having moderate to high infiltration rates (HSG A and B soils).

5. These areas should be reserved for LID infiltration practices for post-development runoff.

6. Determine and define the pre-development runoff patterns on the site in order to provide a preliminary understanding of the site's drainage patterns and the ultimate discharge points.

7. Once the above areas have been clearly delineated on the site plan, the remaining areas would become the available development envelope. This is not to say that development cannot extend beyond the defined development envelope; it is however a starting point to develop environmentally sensitive site plans.

Step 5 – Minimize Impacts at the Lot Level

To the extent possible, conserve trees, natural drainage patterns, permeable soils and depressions on a lot or site, which will often result in less clearing and grading. *Figure 3.5* contrasts the conventional approach of draining runoff to the streets versus a LID design using site fingerprinting where runoff is directed to natural features.

The key to preventing excessive runoff from being generated is to slow down velocities by directing runoff toward areas where it can be infiltrated or stored. The use of many small measures throughout the site will serve this purpose better than a single larger control measure.

Figure 3.6 – LID techniques at the lot level.

Techniques that should be considered include:

- Directing flows to vegetated areas, including roof runoff.
- Directing flows from paved areas to stabilized vegetated areas.
- Breaking up flow directions from large paved surfaces.
- Encouraging sheet flow through vegetated areas.
- Locating impervious areas so that they drain to permeable areas.
- Maximizing overland sheet flow.
- Lengthening flow paths and increase the number of flow paths.
- Maximizing use of open swale systems.
- Increasing (or augmenting) the amount of vegetation on the site.
- Using site fingerprinting. Restricting ground disturbance to the smallest possible area.
- Reducing paving.
- Reducing compaction or disturbance of highly permeable soils.

- Avoiding removal of existing trees.
- Reducing the use of turf and use more natural land cover.
- Maintaining existing topography and drainage divides.
- Locating structures and roadways on Type C soils, where feasible.[1]

Various lot level techniques are illustrated in *Figure 3.6*.

[1] Because Type C and D soils tend to be poorly suited to construction, siting structures on them may be ineffective from a cost-benefit standpoint or technically impractical.

4 Use of LID Management Practices

LID management practices are generally small-scale structural stormwater Best Management Practices (BMPs) that can be used to manage the remaining stormwater runoff from a site after applying LID site planning and design techniques. LID BMPs are typically used in combination with LID site planning and design techniques to meet the stormwater management standards described in *Section 2* of this manual. These practices provide additional opportunities for runoff storage, detention, infiltration, and filtration on a site.

The remainder of this section focuses on the use of BMPs for common land uses settings in the Town of Newington:

- Low- to medium-density residential settings.
- Commercial, industrial and high-density residential settings.
- Roadways.
- Retrofits.

4.1 LID in Residential Settings

In addition to the many possible site planning techniques used, additional treatment can be provided using the following engineered practices listed below. *Figure 4.1* provides a schematic example of a combination of practices. Some potential applications of BMPs are discussed below.

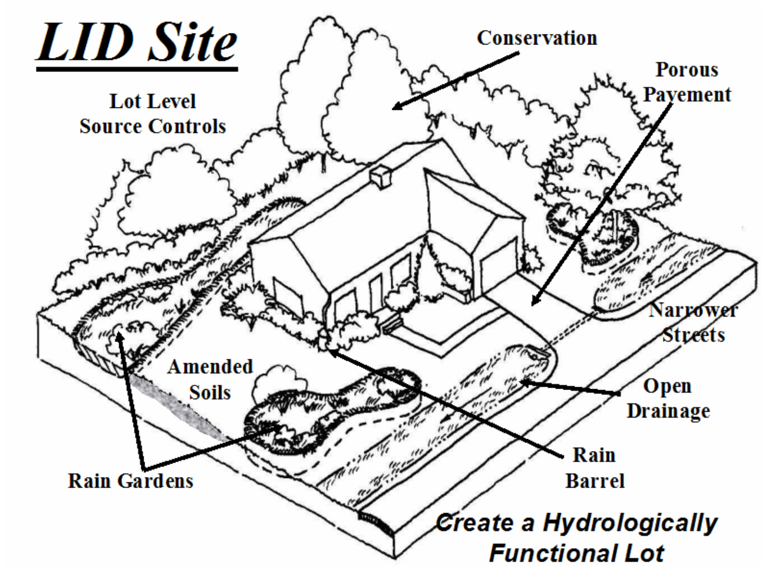

Figure 4.1 – Schematic of engineered LID practices.

- **Bioretention or Rain Gardens –** Vegetated depressions that collect runoff and either filter before discharge or infiltrate it into the ground.
- **Dry Wells –** Gravel- or stone-filled pits that are located to catch water from roof downspouts or paved areas.
- **Filter Strips –** Bands of dense vegetation planted immediately downstream of a runoff source designed to filter runoff before entering a receiving structure or water body.
- **Grass Swales –** Shallow channels lined with grass and used to convey and store runoff.
- **Infiltration Trenches –** Trenches filled with porous media such as bioretention material, sand, or aggregate that collect runoff and exfiltrate it into the ground.
- **Permeable Pavement –** Asphalt or concrete rendered porous by the aggregate structure.
- **Permeable Pavers** – Manufactured paving stones containing spaces where water can penetrate into the porous media placed underneath.
- **Rain Barrels and Cisterns –** Containers of various sizes that store the runoff delivered through building downspouts. Rain barrels are generally smaller structures, located above

ground. Cisterns are larger, are often buried underground, and may be connected to the building's plumbing or irrigation system.

- **Tree box filters –** Curbside containers placed below grade, covered with a grate, filled with filter media and planted with a tree in the center.
- **Vegetated Buffers –** Natural or man-made vegetated areas adjacent to a waterbody, providing erosion control, filtering capability, and habitat.
- **Small detention features –** For example driveway culverts can be undersized to detain flow and encourage stormwater retention.
- **Infiltration Swales –** Swales designed with infiltration trenches.

4.2 LID for Existing Residential Areas

4.2.1 Residential Stormwater Management Overview

Stormwater pollutants commonly associated with residential lots include pesticides and fertilizers used in landscaping. Other pollutants may include sediment from erosion-prone areas, yard waste such as leaves and grass clippings, pet waste, and oil and gas from driveway surfaces. Even runoff from rooftops can contain pollutants known to occur in rainfall. These have the potential to be transported in stormwater to surface water bodies, posing risks to the environment and human health. While the contribution from an individual yard may seem small, the cumulative effects of stormwater runoff from hundreds or thousands of homes within a watershed can be significant. Reducing the amount of stormwater runoff from a site helps to address flooding and pollution of streams, lakes, and ponds. Just as importantly for many Newington residents, LID can reduce nuisance drainage problems in residential areas since LID practices typically retain stormwater on site or recharge it to the ground.

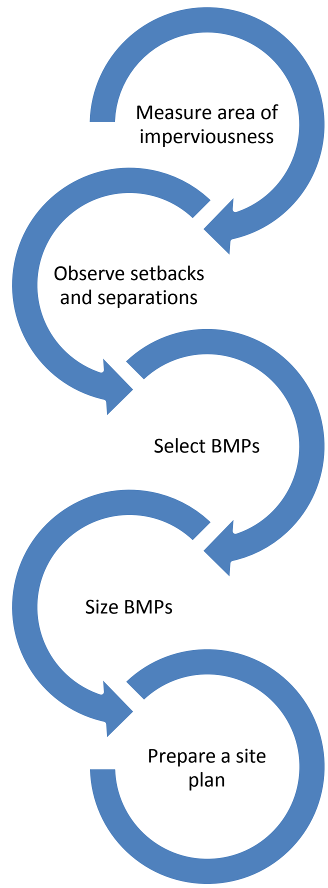

Figure 4.2 – Five steps for siting retrofit BMPs on individual residential lots.

This section of the Newington LID Manual is intended for use by homeowners, who wish to improve existing onsite drainage conditions with LID and for owners of single- and multi-family homes (i.e., one to four dwelling-units), who are planning building additions or additions of appurtenances such as patios, walkways, pools, and decks. Homeowners may to hire design and construction professionals to help with residential projects as required; or homeowners may do the work themselves. This section is written to support either approach.

4.2.2 Avoid, Reduce, and Manage Stormwater Impacts

There are several steps to follow when managing stormwater on an existing residential lot. First, avoid the negative impacts of stormwater to the extent possible. Protect undisturbed open space and existing vegetation by minimizing land disturbance and making the construction footprint as small as possible on the parcel.

Avoid impacts to natural drainage areas and limit soil compaction to the structural footprint only. Next, reduce impacts by minimizing the amount of stormwater runoff that flows off the lot. Eliminating or reducing the size of rooftops, driveways and other paved surfaces will reduce the amount of stormwater runoff that is generated from these impervious surfaces. Plant native shrubs and trees and low maintenance, drought-resistant turf grasses that require less irrigation, fertilizers, and pesticides. Use sustainable landscaping practices to promote plant health and limit the amount of chemicals applied to the landscape. For more information on planting, refer to the planting guidance in Appendix A of the *Connecticut Stormwater Quality Manual*.[2]

Finally, manage any stormwater runoff from the site that cannot be eliminated by directing it to pervious areas or stormwater management practices that will allow the water to infiltrate into the ground.

Five Steps for Siting BMPs on Existing Residential Lots

This manual recommends five key steps for siting BMPs on existing residential lots. They are as follows.

1. Measure the surface area of rooftop and driveway areas.
2. Observe setbacks for BMPs for other site features such as buildings and separation distances to groundwater.
3. Select BMPs based on site conditions.
4. Size the selected BMPs.
5. Prepare a site plan depicting location of all proposed BMPs.

[2] Appendix A of the Connecticut Stormwater Quality Manual is available on the internet at: http://www.ct.gov/deep/lib/deep/water_regulating_and_discharges/stormwater/manual/Apx_A_Plant_List.pdf.

A discussion of each of the five steps follows:

Step 1: Determine the surface area of new rooftop and driveway areas.
The purpose of this step is to calculate the surface area in square feet to be managed. This may include

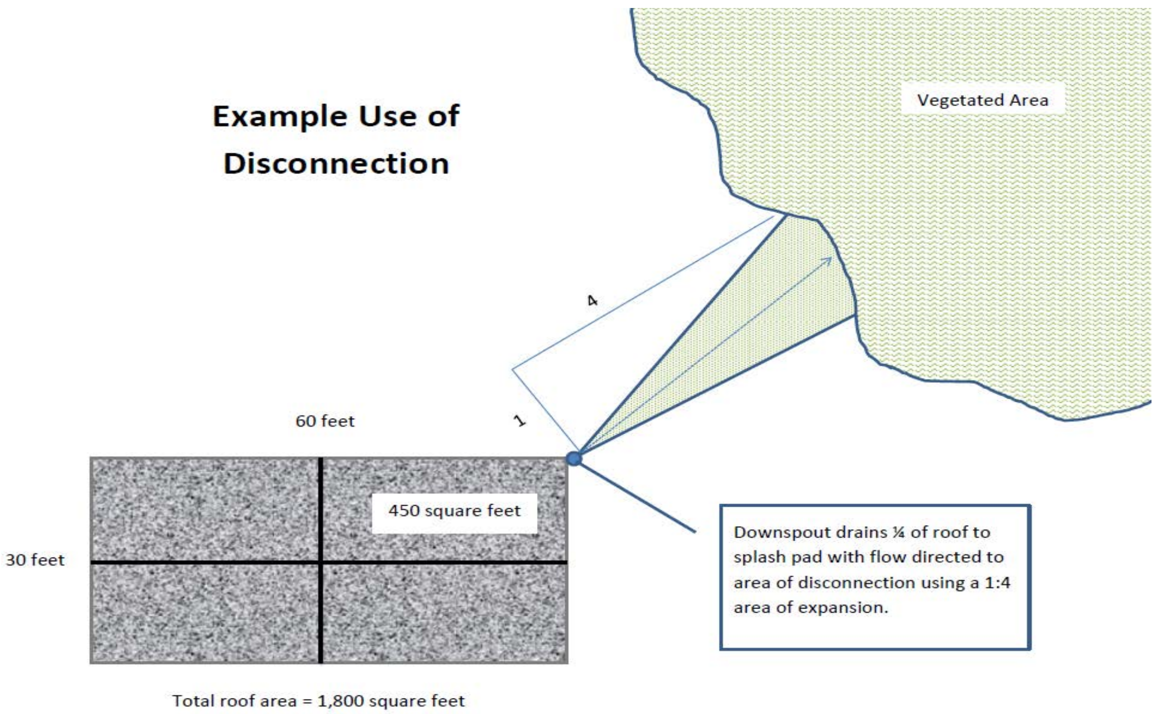

Figure 4.3 – Treating a rooftop with disconnection, adapted from "Rhode Stormwater Management Guidance for Individual Single-Family Residential Lot Development" (RIDEM, 2013)

existing, new, or added impervious surfaces. Determine the area of rooftops, driveways and parking areas by multiplying the length in feet times the width in feet. The resulting area will be in square feet. Alternatively, use the footprint area of the building as measured from the site plan. If the total area to be added is greater than 600 square feet, or if you are conducting this exercise for improving the management of existing area, then proceed to Step 2.

Step 2: Observe setbacks for BMPs for other site features such as buildings and separation distances to groundwater.
If needed, get a professional engineer or certified soil scientist to determine soil drainage and texture. When choosing locations for stormwater management practices, be sure to observe minimum separation distances and setbacks.

To ensure proper functioning of a stormwater management practice, make sure it is located in an area with adequate soil drainage. Improper siting of stormwater management practices can cause extended ponding or overall failure of the practice, which can lead to flooding and possibly mosquito breeding problems on the site. Private homeowners may test a potential site by digging a 6 to 8 inch deep hole, filling it with water, and observing infiltration. If the water does not drain within 12 hours, the location is not appropriate for an infiltrating stormwater management practice.

Potential stormwater practice locations can be inspected by a registered professional engineer or certified soil scientist. If planning to install an infiltration trench or dry well, determine the depth to the seasonal high groundwater table (SHGWT). This is especially advisable if there is a known or suspected shallow depth to SHGWT anywhere on the site. Determinations of depth to the SHGWT are best done by a professional engineer or certified soil scientist. Alternatively, refer to a prior determination of the depth to SHGWT such as may appear on a prior subsurface sewage disposal system (i.e., septic system) (SSDS) plan. The depth to SHGWT is not required for stormwater disconnection, vegetated swales, rain gardens or permeable pavement. Remember, state law requires notifying *Call before You Dig (811) at least two business days before you dig.*

Step 3: Select BMPs based on site conditions.
After identifying locations on the site that are appropriate for stormwater management practices, select the type of practice to be installed at each location. More than one practice may be selected to meet the stormwater management requirements. The Town of Newington strongly recommends that do-it-yourselfers rely on disconnection wherever practicable for the following reasons:

- Disconnection reduces runoff through vegetative uptake and groundwater recharge. Done properly, this helps to mitigate onsite ponding and optimizes pollution reduction benefits.
- It involves little or no construction. This makes installation relatively simple and reduces risks associated with excavation.
- It's generally the least expensive BMP.

Below are example sizing of BMPs for the do-it-yourselfer. This sizing is slightly conservative to simplify the calculations. Design professions should use the sizing standards provided in *Section 5*.

Table 4.1
Do-It-Yourself BMP Sizing Examples
(Approximate Sizing for BMPs in Different Soil Types per One Hundred Square Feet of Impervious Area)

BMP Type	Hydrologic Soil Group			
	A	B	C	D
Disconnection to a Grassy Area	50 square feet	400 square feet	Requires Design Professional	Not Acceptable
Bioretention	8.5 cubic feet (e.g., 17 square foot surface reservoir 6 inches deep)		Requires Design Professional	Not Acceptable
Dry Well	8.5 cubic feet (e.g., 3 feet x 3 feet x 3 feet rock-filled well)		Requires Design Professional	Not Acceptable
Rain Barrel[a]	65-gallon storage			Not Acceptable

Note
[a] Rain barrels may be used to manage flow from existing rooftops. Rain barrels are not acceptable for water quality treatment of redevelopment or development projects.

Step 4: Prepare a site plan depicting location of all proposed BMPs.
After selecting and sizing the appropriate BMPs for the previous steps, size each practice to accommodate the water quality volume, or the first one inch of runoff from the contributing impervious surface. To do this, determine the drainage area, which is the area of impervious surface that drains to each practice. For example, if a practice will receive runoff from a single downspout that drains ¼ of a rooftop, calculate the drainage area by dividing the entire roof area by 4 (*Figure 4.1*). To determine the water quality volume from each drainage area, multiply the drainage area in square feet by 0.083 (ft/in).

4.3 LID for High Density Industrial, Commercial and Residential Development

It is relatively easy to understand how LID principles and practices can be applied to single family residential development where there is ample space. High density development seems much more challenging with little green space available for LID practices. However, there is little difference in the application of LID site design principles and the use of small scale engineered practices for volume and water quality control. The only difference is LID practices must be designed to accommodate building architecture, sidewalks, parking lots, streets and landscaping.

It is still important to optimize the conservation and use of natural resources and soils on the larger project level and where feasible minimize impacts internal to the site.

The examples shown in *Figure 4.4* provide general LID design strategies for office buildings, small commercial buildings and big box sites. These site designs include a variety of techniques.

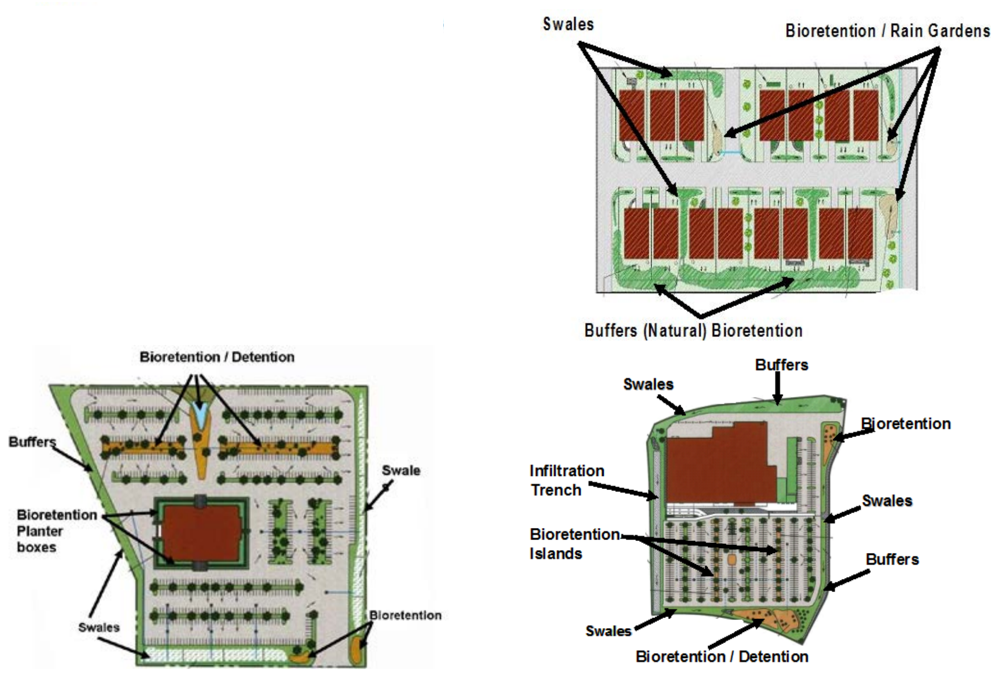

Figure 4.4 – LID design strategies for office buildings, small commercial buildings, and big box sites.

Typical LID techniques used for high-density developments include: perimeter buffers, swales and bioretention systems; parking lot bioretention/detention islands, planter boxes, green roofs, porous pavers/pavement and infiltration devices and underground storage. Runoff can be stored for use or controlled under buildings, parking lots and sidewalks using porous pavers and volume storage devices.

LID techniques can be integrated throughout the available green space using a range of bioretention techniques such as planter boxes, swales and street trees. In addition to the LID techniques previously listed, other engineered practices for high density development are included below. *Figure 4.5* provides a schematic example.

- **Planter Boxes** – Bioretention systems within containers designed for filtration and or infiltration.
- **Green Roofs** – Vegetated roofs designed for retention / detention storage and, filtration.
- **Underground Storage –** Use of cisterns, pipes, vaults or other storage devices for retention or detention storage.
- **Porous Pavers and Surfaces** – Porous surfaces design in combination gravel storage or other.
- **Manufactured Devices –** Numerous commercial devices are available for filtration, screening, storage and treatment that can be integrated in the high density development.
- **Building Architecture –** Buildings can be designed to capture hold and use more runoff with, cisterns, planter boxes and wall planting systems.

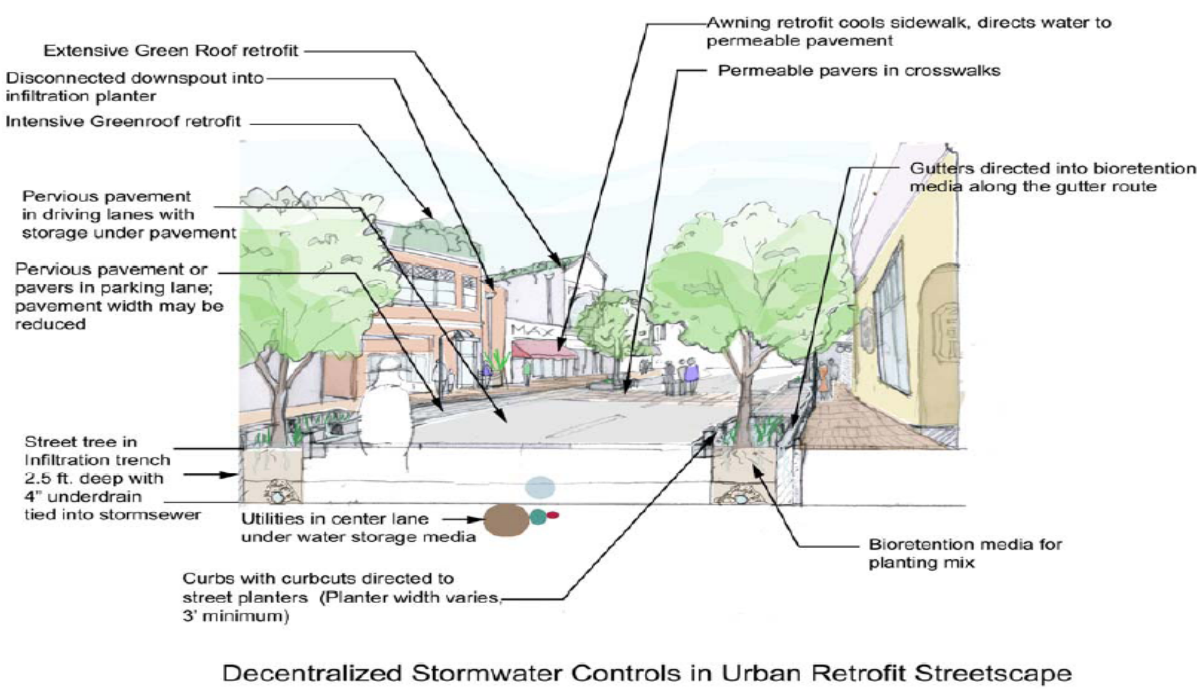

Figure 4.5 – Schematic example of engineered practices in an urban retrofit streetscape.

4.4 LID Roadway Designs

Roadways generate a major portion of runoff in urban areas and present significant engineering challenges in developing effective LID roadway controls. Despite the challenges there are effective LID design principles and engineering practices available for any roadway system to meet water quality objectives. However, use of some techniques may require modification roadway design standards. Further, in highly urbanized development, site constraints (limited space, poor soils and utility conflicts) often require more extensive engineering and use of more expensive structural LID practices.

A LID roadway design does not require reduction of impervious surface but rather optimizing the integration of LID practices by engineering the roadway itself or the surrounding landscape/streetscape to provide storage, detention or filtration as applicable. Reduction of the roadway surfaces is most useful in creating additional space for the use LID practices. Consider opportunities to hydrologically disconnect roadway surfaces by directing runoff to LID practices for storage, detention or infiltration.

4.4.1 Open Section Roadways

Open section roadways consist of a variable-width gravel or grass shoulder, usually wide enough to accommodate a parked car, and an adjoining grassed swale that conveys and treats runoff. When feasible, reducing road width provides greater opportunities to increase the width of grass shoulders and swales for treatment.

Street pavements width should be adjusted accordingly depending on off-street parking availability and shoulder requirements. Where feasible preserve existing vegetation and drainage features adjacent to the shoulder or swale. Also consider placing utilities under street pavements to eliminate conflicts with tree roots, grassed swales, and bioretention areas.

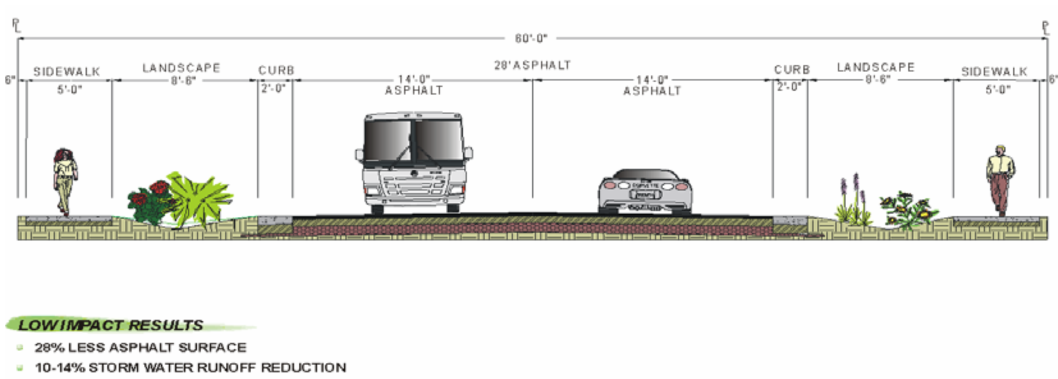

Figure 4.6 – Open section roadways.

A primary goal of LID is to work with landscape hydrology and make it more functional (i.e., to use the surrounding landscape to absorb and filter water). *Figure 4.6* shows a 60-foot roadway design with sidewalks on both sides. The important LID feature is the use of wider more functional swales for treatment and control. Notice that the swales are located between the road surface and sidewalks providing greater protection to pedestrians.

Figure 4.7 shows a narrow road section with sidewalks, shallow swale and porous pavement shoulders. The paver blocks provide a rough surface to alert drives if their tires leave the road surface. The pavers also protect the edge of the asphalt surface from breaking off. Generally, very shallow and broad swales are preferred as they provide more surface area to treat and absorb runoff. Swale performance can be greatly enhanced when you can take advantage of infiltration.

Figure 4.7 - Narrow low-volume road section with sidewalks, shallow swale and porous pavement shoulders.

Figure 4.8 shows an example of how to design a swale to enhance its ability to filter and infiltrate runoff. In this case several features have been incorporated into the design including using the culvert as a weir for detention control; check dams to increase ponding time and decrease velocities; trench drain along the bottom of the swale to encourage infiltration and increase runoff storage in the engineered soil. Road water quality treatment swales should be designed to be shallow with under drains if possible to encourage good drainage and discourage standing water and associated nuisance problems.

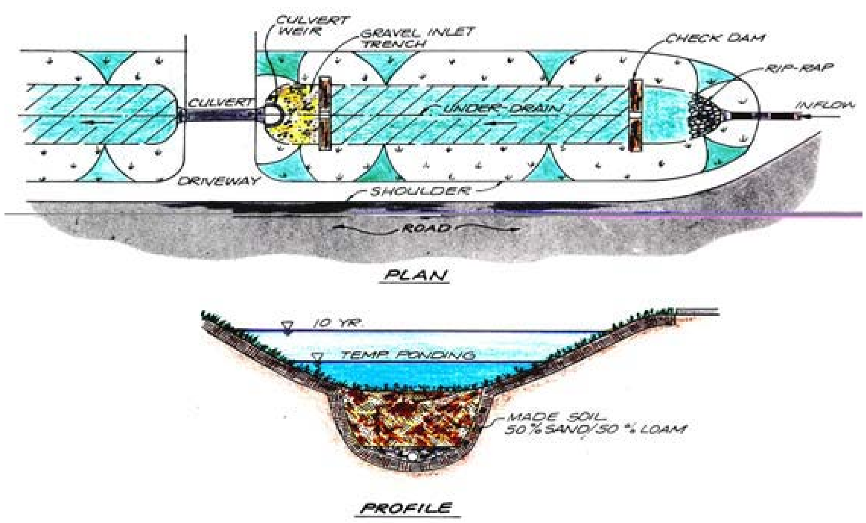

Figure 4.8 - Swale design to enhance its ability to filter and infiltrate runoff.

When it is possible to use narrower roadways, *Table 4.2* provides suggested general guidance. Even a narrow street width of 22 feet can still accommodate parking on one side of the roadway and leave ample room for a safe travel lane that is generous enough to accommodate most fire trucks, school buses, and garbage trucks.

Table 4.2
General Guidance for Narrower Roadways

Local Streets	
No On-Street Parking	18 feet
Parking on One Side	22 feet
Parking on Both Sides	28 feet

Adapted from *Designing Walkable Urban Thoroughfares (ITE, 2010).*

Local Streets are intended to provide access to individual lots. They should provide low-speed bicycle and vehicle routes and while accommodating pedestrians. In comparison to other types of streets, local streets should generally be short in total distance.

In residential areas, "yield" local streets provide the preferred cross-section to encourage equal priority among all users. These streets are characterized by a relatively narrow unstriped travelway shared by all vehicles, and also have comfortable pedestrian facilities. "Narrow" local streets may be used where most parking is handled off-street. This is typical in a traditional neighborhood design (TND) context. Where on-street parking is expected to be more heavily used, yield streets may not be appropriate.

Each local street type should feature a 14-foot minimum clear travel path so as to appropriately accommodate emergency vehicles.

4.4.2 Cul-De-Sac Designs

Homebuyers often prefer cul-de-sac properties for many reasons, and thus cul-de-sacs have become quite common. Depending on a subdivision's lot size and street frontage requirements, five to ten houses can usually be located around a standard cul-de-sac perimeter. The bulb shape allows vehicles up to a certain turning radius to navigate the circle. To allow emergency vehicles to turn around, cul-de-sac radii can vary from as narrow as 30 feet to upwards of 60 feet, with right-of-way widths usually extending ten feet beyond these lengths. *Figure 4.9* shows an open section roadway with on lot bioretention and a cul-de-sac with a bioretention area in the center for roadway runoff.

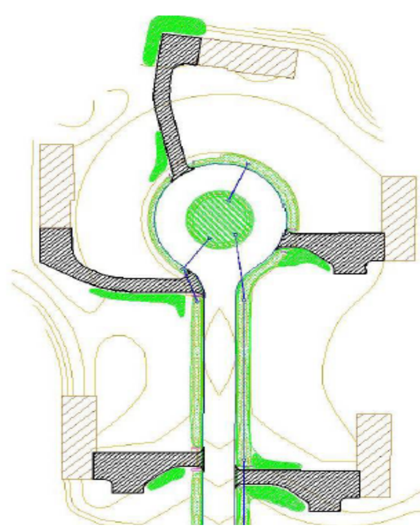

Figure 4.9 – Cul-de-sac designs.

4.4.3 Divided Highways

The wider right-of-ways of divided highways provide many opportunities for LID practices on the shoulders and in the median. *Figure 4.10* and *Figure 4.11* provide examples of these options.

Figure 4.10 – Examples of center median infiltration/filtration systems

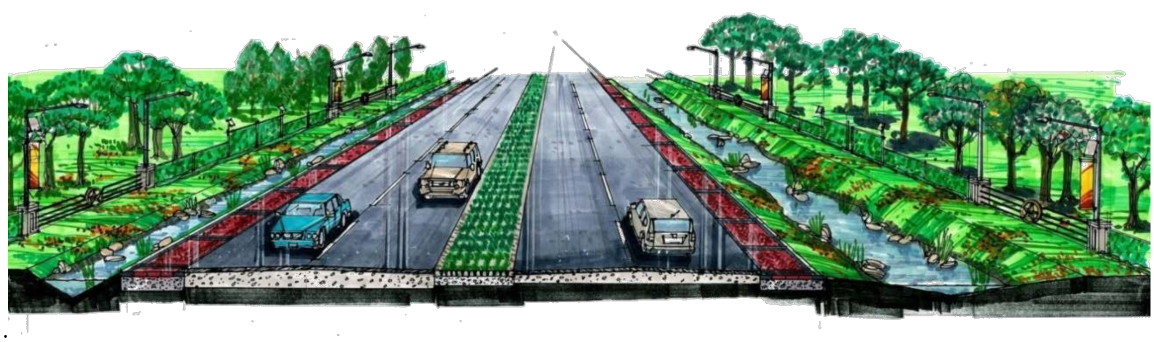

Figure 4.11- Shoulder Treatment Systems using detention and filtration design.

4.4.4 Highly Urbanized LID Street Design

Below are two examples of planter box designs in high density development (*Figure 4.12*). The image on the left is a slow flow system that requires very large surface areas to treat the water quality volume. The image on the right is a very high flow media system that has an extremely small foot print saving space reducing overall construction and maintenance costs. However, both provide the same water quality treatment benefits. Both systems can be designed with underground storage for detention infiltration or retention to be used for irrigation. There are many devices that can be used for underground storage ranging from metal, plastic or concrete pipes to a variety of plastic prefabricated storage devices.

Figure 4.12 – Examples of bioretention and planter box design in high density development in Connecticut.

4.4.5 Porous Surfaces

Porous pavers, asphalt and concrete are all other design options to provide a hard surface suitable for roadways that allow runoff to percolate into underground gravel beds or other storage devices for detention or infiltration. An example is provided below as *Figure 4.13*. To reduce the cost of these surfaces, they should not be placed over the entire roadway but rather strategically placed and sized to allow sufficient runoff volume to enter the underlying storage device.

Figure 4.13 – Porous surfaces.

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4.4.6 Other LID Roadway Design Considerations

- **Maximize natural drainage –** when planning streets, consider preserving natural drainage patterns and soil permeability by preserve natural drainage patterns and avoid locating streets in low areas or highly permeable soils.
- **Uncurbed roads –** where feasible, build uncurbed roads using vegetated swales as an alternative.
- **Urban curb/swale system –** runoff runs along a curb and enters a surface swale via a curb cut, instead of entering a catch basin to the storm drain system.
- **Dual drainage system –** a pair of catch basins with the first sized to capture the water quality volume into a swale while the second collects the overflow into a storm drain.
- **Concave medians –** median is depressed below the adjacent pavement and designed to receive runoff by curb inlets or sheet flow. Can be designed as a landscaped swale or a biofilter.
- **Street Length –** Reduce the length of residential streets by reviewing minimum lot widths and exploring alternative street layouts.
- **Access –** Consider access for large vehicles, equipment, and emergency vehicles when designing alternative street layouts and widths.
- **Right-of-way –** should reflect the minimum required to accommodate the travel lane, parking, sidewalk, and vegetation, if present.
- **Permeable materials –** use in alleys and on-street parking, particularly pull out areas.

4.5 Retrofit Case Studies

The impaired status of many of our surface waters can be linked directly to increased runoff volume and pollution loads from existing development. If impaired receiving waters are to be restored the impacts from existing development must be addressed. LID practices allow for retrofit of developed areas by integrating small-scale management techniques into the urban landscape (roads, sidewalks, parking areas, buildings, etc.). In most cases existing landscape features can simply be converted into bioretention systems for filtration, detention and infiltration. In more difficult cases storage can be provided under sidewalks and parking lots or on rooftops.

The most economical way to retrofit existing development is to ensure that all infill development, redevelopment and reconstruction projects include the LID practices. Over time as urban areas are redeveloped and rebuilt with LID practices much of the urban runoff can be treated greatly reducing water quality impacts and reducing flooding potential. The City of Portland, OR has evaluated such an urban retrofit program and has found over a 50-year period much of the City's runoff can be controlled and treated by green roofs and bioretention streetscape systems for roadway and parking lot runoff.

When selecting the most appropriate retrofit techniques it is important to select LID practices that can best address receiving water quality and volume needs. For example, where receiving waters are impaired by heavy metals or bacteria bioretention filtration and/or infiltration techniques would be most appropriate. Where volume control is necessary for detention porous surfaces or filtration devices in combination with underground storage detention and/or infiltration practices are best.

4.5.1 LID Retrofits in Connecticut

Retrofit and redevelopment projects utilizing LID techniques have been implemented throughout the country in recent years. Multiple projects have occurred in Connecticut. For example, a traffic-control project calling for access management adjacent to North Main Street in the City of Bridgeport, CT, incorporated rain gardens/bioretention and permeable pavement into project design. Specifically, North Main Street was narrowed and permeable pavement was installed alongside portions of the roadway to accommodate vehicular parking and treat stormwater runoff. Additionally, series of rain gardens were installed along the sidewalk to receive and treat stormwater runoff. Photographs of the LID techniques implemented along Main Street are provided as *Figure 4.14*.

Figure 4.14 – Permeable pavement (left photograph) and rain garden/bioretention (right photograph) retrofits along North Main Street in Bridgeport, CT.

Another example of green infrastructure retrofit project is the Hartford Green Capitols project. This project focused on Connecticut's capitol building in Harford, CT and included installation of porous pavement, green roofs, and rain gardens, as well as rain harvesting techniques. Such techniques served to mprove water quality and educate state residents about green infrastructure. Photographs of the LID techniques implemented as part of the Hartford Green Capitols Project are provided as *Figures 4.15-4.17*.

Figure 4.15 – Bioretention retrofit.

Figure 4.16 – Construction of a rain garden at Hartford Green Capitols Project. Source: Camp Dresser & McKee.

Figure 4.17 – Permeable pavement at Hartford Green Capitols Project. Source: Camp Dresser & McKee.

Additional examples of techniques used in Connecticut for both retrofit and redevelopment projects are provided as *Figure 4.18*.

Bioretention area at University of Connecticut Storrs Campus.

Roads are narrowed and permeable pavement is installed along roadways to provide additional parking and treat runoff.

Figure 4.18 – Retrofit and redevelopment techniques in Connecticut. Source: Connecticut Department of Energy and Environmental Protection.

4.5.2 Water Quality LID Retrofits in Urbanized Residential Areas

LID retrofits are often used for the purposes of addressing water quality issues such as impairments due pathogens and nutrients from stormwater. For example, the Town of Warren Rhode Island is using a combination of bioswales and permeable pavement along Water Street as a part of infrastructure improvements to address beach closures at its town beach.

Figure 4.19 – Before-and-after rendering of a green street retrofit for Water Street in Warren, Rhode Island.

The Warren Town Beach is located adjacent to the Warren River, west of Water Street, in the Town of Warren, Rhode Island. Water Street is developed for mixed uses including high-density residential, recreation, commerce, industry, marinas and the town's wastewater treatment facility. Historically, this beach experiences frequent beach closures due to elevated levels of bacteria. A 2008 study identified urban runoff and leaking sanitary sewers as a source of bacteria loadings to the Town Beach and Warren River. This project demonstrates the versatility of LID for solving water quality problems in complex and challenging settings.

4.5.3 Flood Management with LID

Commonly, green infrastructure is used to solve stormwater quality (i.e., pollution) problems; however, it also presents enormous utility for control of stormwater quantity (i.e., flooding) problems. The Shandon-Rosewood Watershed in Columbia, South Carolina is more than 750 acres in size. This urbanized, residential area experiences severe flooding at five intersections during moderate and large storm events.

Figure 4.20—Storm drains in the Shandon Neighborhood are undersized to handle significant rain events.

Initial analysis of area infrastructure showed the flooding was due to large expanses of hardscape (roads, sidewalks, roofs, etc.) served by a storm drain network that is undersized for the need. Storm drains surcharge as they are overloaded with large volumes of runoff and flood onto the road (*Figure 4.20*).

Implementing a conventional drainage approach to solve this problem presents several disadvantages. The list below notes some of the more significant disadvantages:

- Conventional retrofits can be quite costly. The initial estimate for conventional retrofits was more than $11 million.
- Replacement of buried drain lines would have conflicted with other existing buried utilities, which would likely create inconvenience for neighborhood residents and add cost to the overall project.
- Discharge of additional flows of stormwater would have created flooding or other problems in down-gradient areas. Conventional fixes would need to be continued through such areas to avoid simply pushing flood water backups downstream.

An alternative to conventional improvements is to use a green infrastructure. Use of green infrastructure in this instance relied on an innovative use of pervious pavement draining to subsurface infiltration chambers. This approach limited disturbance of the existing landscape while using infiltration to mimic conditions of undeveloped land and abate flooding that was resulting from intensive development.

The selected approach provides a number of useful advantages:

- It is more cost effective than constructing conventional drainage infrastructure as it avoids more/larger pipes. Total cost will be approximately half of the traditional approach.
- By imitating natural hydrology, selected approach improves base flow and eliminates potential for increased downstream flooding.
- Infiltration provides stormwater treatment and mitigates stormwater pollution problems, which might otherwise require control via expensive treatment practices.
- Unlike conventional infrastructure retrofits, green infrastructure improvements can be installed in incrementally, as opportunity presents across the watershed.

5 Design Standards for Low Impact Development Controls

This section discusses design standards for LID controls. It provides a general description of each control, its advantages, general use, and standards for its application. These standards are intended to elaborate on the narrative description of LID best management practices provided in chapter 4 of the *Connecticut Stormwater Quality Manual*.

- Approaches that Optimize Conservation
    - Limits of Clearing and Grading
    - Preserving Natural Areas
    - Avoid Disturbing Long, Steep Slopes
    - Minimize Siting on Porous and Erodible Soils

- Approaches that Mimic Natural Water Balance

- Approaches that Minimize and Disconnect Impervious Surface
    - Roadways
    - Buildings
    - Parking Footprints
    - Parking Lot Islands
    - Permeable Pavement
    - Disconnecting Impervious Area

- Integrated Management Practices at the Source
    - Vegetated Filter Strips
    - Natural Drainage Ways
    - Green Roofs and Façade
    - Rain Barrels and Cisterns
    - Dry Wells
    - Bioretention and Rain Gardens
    - Infiltration

5.1 Approaches that Optimize Conservation

5.1.1 Limits of Clearing and Grading

Perhaps the most potentially destructive stage in land development is the preparation of a site for building—clearing of vegetation and soil grading (Schueler, 1995). The limits of clearing and grading refer to the part of the site where development will occur. This includes all impervious areas such as roads, sidewalks, rooftops, as well as areas such as lawn and open drainage systems.

To minimize impacts, the area of development should be located in the least sensitive areas available. At a minimum, developers should avoid streams, floodplains, wetlands, and steep slopes. Where practicable, developers should also avoid soils with high infiltration rates as these will aid in reducing runoff volumes.

Advantages

- Preserves more undisturbed natural areas on a development site.
- Uses techniques to help protect natural conservation areas and other site features.
- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Helps to demonstrate compliance with regulatory standards (e.g., freshwater wetlands, coastal resources, water quality, wildlife, local environmental protection, etc.) for avoidance and minimization as well as setbacks from sensitive features.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.
- Promotes stable soils.
- May reduce landscaping costs.

Use

Establishing a limit of disturbance based on maximum disturbance zone radii/lengths.
These maximum distances should reflect reasonable construction techniques and equipment needs together with the physical situation of the development site such as slopes or soils. Limits of disturbance may vary by type of development, size of lot or site, and by the specific development feature involved.

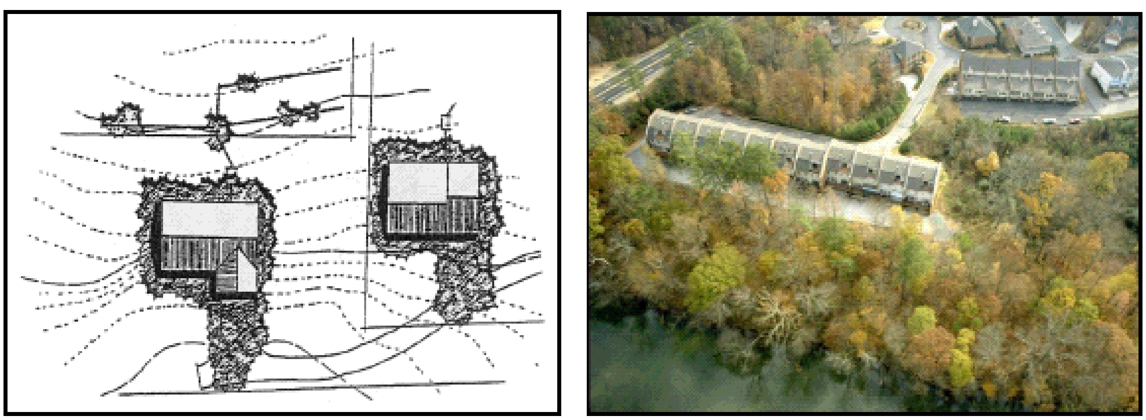

Figure 5.1 - Reduced limits of disturbance minimize water quality impacts. Source: Atlanta Regional Commission, 2001.

Standards

Generally speaking, limits of disturbance are recommended to be not more than:

a) Area of the building pad and utilities (e.g., onsite wastewater treatment systems and wells) plus 25 feet.

b) Area of a roadbed and shoulder plus 9 feet. (This is not intended to limit lawn areas.)

5.1.2 Preserving Natural Areas

Natural areas include woodlands, riparian corridors, areas contiguous to wetlands and other hydrologically sensitive and naturally vegetated areas. To the extent practicable these areas should be preserved.

Natural areas can be one of the most important components within a development scheme, not only from a stormwater management perspective, but in reducing noise pollution and providing valuable wildlife habitat and scenic values. New development tends to fragment large tracts of undisturbed areas and displace plant and animal species; therefore it is essential to maintain these buffers in order to minimize impacts. Areas adjacent to waterbodies (both freshwater and coastal) are protected under state law and cannot be altered without a state agency permit.

Advantages

- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Helps to demonstrate compliance with regulatory standards (e.g., freshwater wetlands, coastal resources, water quality, wildlife, local environmental protection, etc.) for avoidance and minimization as well as setbacks from sensitive features.
- Reduces safety and property-damage risks where flood hazard areas are incorporated into preservation.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase market value.
- Promotes stable soils.
- Establishes and maintains open space corridors.

Use

a) Check all federal, state and local enforceable policy to ensure proper setbacks and identification of preservation areas. Identify areas for preservation through site analysis using maps and aerial or satellite photography or by conducting a site visit.
b) Delineate areas for preservation via limits of disturbance before any clearing or construction begins and should be used to set the development envelope as well as guide site layout. Clearly mark areas for preservation on all construction and grading plans to ensure that equipment is kept out of these areas and that native vegetation is kept in an undisturbed state.
c) Protect preservation areas in perpetuity by legally enforceable deed restrictions, conservation easements and maintenance agreements.

Figure 5.2 shows a site map with undisturbed natural areas delineated.

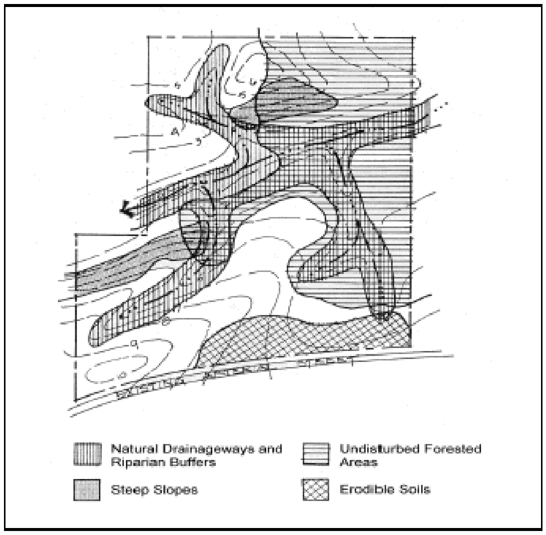

Figure 5.2 – Site map with natural areas delineated. Source: Atlanta Regional Commission, 2001.

Special Considerations

Riparian Buffers

A riparian buffer is a special type of preserved area along a watercourse where development is restricted or prohibited. Buffers protect and physically separate a watercourse from development. Riparian buffers also provide stormwater control flood storage and habitat values. An example of a riparian buffer is shown in *Figure 5.3*. Wherever possible, riparian buffers should be sized to include the 100-year floodplain as well as steep banks and freshwater wetlands.

Figure 5.3 – Riparian buffer along the French River, in Thompson, CT.
Source: Connecticut Department of Energy and Environmental Protection.

Riparian buffers consist of three zones (*Figure 5.4*):

- The inner zone consists of the jurisdictional riverbank wetland and should be sized accordingly. In addition to runoff protection, this zone provides bank stabilization as well as shading and protection for the stream. This zone should also include wetlands and any critical habitats, and its width should be adjusted accordingly. Permits should be sought for activities in the inner zone. Generally speaking, structural best management practices (BMPs) are not allowed in the inner zone.
- The middle zone provides a transition between upland development and the inner zone and should consist of managed woodland that allows for infiltration and filtration of runoff. A 25-foot width is recommended for this zone at a minimum. Forested riparian buffers should be maintained and reforestation should be encouraged where no wooded buffer exists. Proper restoration should include all layers of the forest plant community, including understory, shrubs and groundcover, not just trees.
- An outer zone allows more clearing and acts as a further setback for impervious surfaces. It also functions to prevent encroachment and filter runoff. A 25-foot width is recommended for this zone.

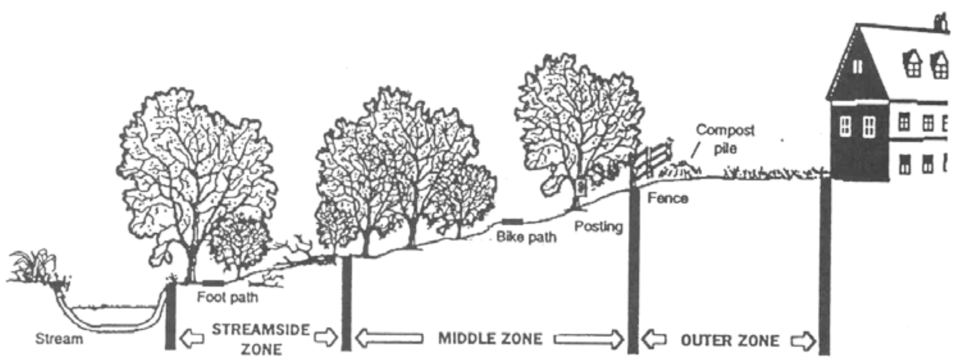

Figure 5.4 – Three-zone riparian buffer. Source: Atlanta Regional Commission, 2001.

Ideally, all three zones of the riparian buffer should remain in their natural state. However, some maintenance is periodically necessary, such as planting to minimize concentrated flow, the removal of exotic plant species when these species are detrimental to the vegetated buffer and the removal of diseased or damaged trees.

Floodplains
Floodplains are the low-lying flatlands that border streams and rivers. When a stream reaches its capacity and overflows its channel after storm events, the floodplain provides for storage and conveyance of these excess flows. In their natural state they reduce flood velocities and peak flow rates by the passage of flows through dense vegetation. Floodplains also play an important role in reducing sedimentation and filtering runoff, and provide habitat for both aquatic and terrestrial life. Development in floodplain areas can reduce the ability of the floodplain to convey stormwater, potentially causing safety problems or significant damage to the site in question, as well as to both upstream and downstream properties.

As such, floodplain areas should be avoided on a development site. Ideally, the entire 100-year floodplain at full buildout should be avoided for clearing or building activities, and should be preserved in a natural undisturbed state where possible. Maps of the 100-year floodplain can typically be obtained through the local review authority.

Standards

General

a) No disturbance shall occur to preservation areas during project construction.

b) Preserved areas shall be protected by limits of disturbance clearly shown on all construction drawings and clearly marked on site.

c) Preservation areas shall be located within an acceptable conservation easement instrument that ensures perpetual protection of the proposed area. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked. [Note: managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management.]

d) Preservation areas shall have a minimum contiguous area of 10,000 square feet or in the case of stream buffers should maintain a 50-foot set back from the jurisdictional wetland edge along the entire length of stream through the property of concern. Areas of smaller size may be incorporated for disconnection of impervious surface, but will be considered as open space in good condition.

e) Incorporate level spreaders or other dispersion devices, where practicable, to ensure sheet flow. See *Figure 5.5*, which depicts a level spreader. (Please note that the level spreader shown here is for dispersion of low flows only.

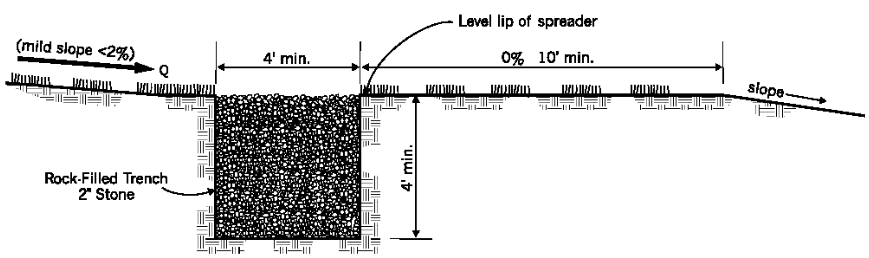

Figure 5.5 – Rock trench level spreader for low flows. Source: Prince George's County, Maryland, 2000.

f) Include bypass mechanisms for higher flow events to prevent erosion or damage to a buffer or undisturbed natural area.

g) Consider incorporating constructed berms around natural depressions and below undisturbed vegetated areas to provide for additional runoff storage and infiltration. Proper use of berms is discussed in the section entitled vegetated filter strips.

h) Where no berms are provided in Hydrologic Soil Group (HSG) type A and B soils, buffers may be used to attenuate and treat flows up to the water quality volume (i.e., volume equal to one inch over the impervious surface) in the following ratios:

Table 5.1
Ratio of Forested Buffer to Impervious Surface Required to Attenuate Runoff for Precipitation between 0.5 and 1.0 Inches[a, b]

	HSG Soil Type			
Runoff (inches)	A	B	C	D
1.0	1:3	2:1	N/A	N/A
0.9	1:4	1:1	N/A	N/A
0.8	1:6	2:3	N/A	N/A
0.7	1:9	2:5	N/A	N/A
0.6	1:15	1:4	1:1	N/A
0.5	1:25	1:8	1:2	N/A

Notes:
[a]Buffer size calculations based on TR-55. Calculations for precipitation depths less than 0.5 inches are not included as the empirical equations of TR-55 become less accurate for storms less than 0.5 inches.
[b]Standards for buffer width, area and length of contributing flow path, etc. must be met regardless of soil's capacity to attenuate flow.

i) Land cover in buffers will be assumed to be woods in good condition (i.e., Curve number (CN) equal to 32 in type A soil and 55 in type B soil). Type C and D may not be used for this purpose as woods on these soil types cannot abstract the depth of rainfall associated with one inch of runoff from the impervious surface.

j) Runoff must enter the buffer as overland sheet flow. The average contributing slope should be no less than 1% and no more 3%. Maximum average slope may be increased to 5% if a flow spreader is installed across the entire contributing length followed by a flat (i.e., 0% slope) 10-foot shelf across the length.

Streambank Areas

a) The minimum undisturbed buffer width should be at least the wetland jurisdictional setback plus 50 feet.

Maintenance

Except for routine debris removal, buffers shall remain in a natural and unmanaged condition.

5.2 Approaches that Mimic Natural Water Balance

LID controls mimic natural predevelopment hydrology in order to retain and attenuate stormwater runoff in upland areas. This reduces the amount of stormwater and intensity of flow at points of discharge. Flow attenuation prevents physical damage to waterways and reduces nonpoint source pollution. The remainder of *Section 5.2* discusses approaches for mimicking a site's natural water balance or predevelopment hydrology as a LID control.

Advantages

- Decreased need for constructed BMPs.
- Maintain predevelopment hydrology and thus reduces generation of stormwater and associated pollution.
- Encourage groundwater recharge.

Use

Mimicking predevelopment site hydrology involves a process of comparing and evaluating pre- and postdevelopment conditions that takes place in all stages of site planning. There are many methods of hydrologic analysis. This section of the manual relies on the use of the USDA-SCS Technical Release-55 (TR-55), entitled *Urban Hydrology for Small Watersheds* (1986).

Time of Concentration and Time of Travel

TR-55 focuses on the time of concentration (Tc) as a primary influence in the shape and peak of runoff hydrographs. TR-55 defines time of concentration as the "time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed."

Tc is calculated as follows:

$$t_c = t_t(1) + t_t(2) + t_t(3) \ldots + t_t(n)$$

Where:

Tt (travel time) = time it takes runoff to move across a segment of the watershed.
n = total number of travel segments in a watershed

Tt is mathematically defined by TR-55 as being directly influenced by two factors velocity of runoff (V) and length of runoff flow path (L). Velocity is further defined as a function of slope (s) and surface roughness (i.e., Manning's roughness coefficient for sheet flow) (n).

Tt is calculated as follows:

$$t_t = \frac{L}{3600V}$$

Where:

t_t = travel time in hours
L = flow length in feet
V = average velocity in feet per second
3600 = conversion factor for seconds to hours

Total Volume and Peak Discharge

TR-55 also notes that total runoff volume (Q) and peak runoff discharge (q_p) tend to increase as a result of urbanization. Peak discharge is defined as a factor of Q and can be calculated using as follows:

$$q_p = q_u A_m Q F_p$$

Where:

q_p = peak discharge in cubic feet per second

q_u = unit peak discharge
A_m = drainage area in square miles
Q = runoff in inches
F_p = pond and swamp adjustment factor

Q is derived as a factor of initial abstraction (Ia) and retention (S) and is calculated as follows:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

Where:

Q = runoff in inches
P = rainfall in inches
S = retention
I_a = initial abstraction

Initial abstraction is a measure of rainfall held in surface depressions, interception by vegetation, evapotranspiration and infiltration prior to the occurrence of runoff and is calculated as follows:

$$I_a = 0.02S$$

Where:

Ia = initial abstraction
S = retention

Retention is a measure of total capacity for rainwater storage in a watershed during a rain event. In small agricultural watersheds retention is typically about 5 times greater than initial abstraction.

Retention is calculated as follows:

$$S = \frac{1000}{CN} - 10$$

Where:

S = retention
CN = curve number

Curve number is a coefficient ranging from 0 - 100, which is used to represent the conversion of rainfall to runoff. For example, an impervious surface such as concrete has a CN of 98, which is analogous to representing that 98% of rain that falls on concrete runs off.

Identifying Hydrologic Benefits

All nonstructural and distributed BMPs have one or more hydrologic benefits in relationship to TR-55. *Table 5.2*) summarizes key hydrologic benefits of nonstructural and distributed BMPs recommended in this manual.

Table 5.2
Hydrologic Benefits of
Nonstructural and Distributed Techniques and Controls

Techniques & Controls	Decrease Curve Number	Reduce Slope	Lengthen Flow Path	Increase Roughness	Increase Initial Abstraction	Increase Total Retention
Reduce Limits of Clearing and Grading	●[a]		◖[b]	●	●	
Preserve Natural Features	●		●	●	●	
Avoid Long, Steep Slopes		●	◖		●	
Avoid Erodible Soils				●	●	
Avoid Porous Soils	◖			●	●	
Minimize Roadways	●		◖	●	●	
Minimize Buildings	●		●	●	●	
Minimize Parking	●		●	●	●	
Disconnect Impervious Area	●		◖	◖	●	
Buffers and Undisturbed Areas	●		●	●	●	●
Infiltration Swales	●	◖	◖	●	●	●
Vegetative Filter Strips	●			●	●	●
Bioretention	●				●	●
Nonstructural Conveyances	●		◖	●	●	
Drain Rooftop Runoff to Pervious Areas			●	●	●	
Rain Barrels and Cisterns					●	●
Dry Wells					●	●
Green Roofs and Walls					●	●

Notes
[a] Benefit always occurs.
[b] Benefit occurs sometimes.

Standards

Time of Concentration
The postdevelopment time of concentration (T_c) should approximate the predevelopment T_c.

Travel Time
The travel time (T_t) throughout individual lots and areas should be approximately constant.

Flow Velocity
Flow velocity in areas that are graded to natural drainage patterns should be kept as low as possible to avoid soil erosion.

Flows can be disbursed by installing a level spreader along the upland ledge of the natural drainage way buffer, and creating a flat grassy area about 30 feet wide on the upland side of the buffer where runoff can spread out. This grassy area can be incorporated into the buffer itself.

Figure 5.6– Alternative roadway design in Waterford, CT. Source: Tom Walsh, Shoreline Aerial Photography.

5.3 Approaches to Minimizing and Disconnecting Impervious Surface

A key concept of LID is the minimization and disconnection of impervious surface. For the purposes of stormwater management, impervious surfaces are commonly considered to include roads, parking lots, and buildings.

5.3.1 Roadways

The greatest share of impervious cover in most communities is from paved surface such as roads and sidewalks. Roadway lengths and widths should be minimized on a development site where possible to reduce overall impervious surface.

Numerous alternatives create less impervious cover than the traditional 40-foot cul-de-sac. These alternatives include reducing cul-de-sacs to a 30-foot radius and creating hammerheads, loop roads, and pervious islands in the cul-de-sac center (*Figures 5.7 through 5.9*).

Advantages
- Reduces the amount of impervious cover and associated runoff and pollutants generated.
- Reduces the costs associated with road construction and maintenance.

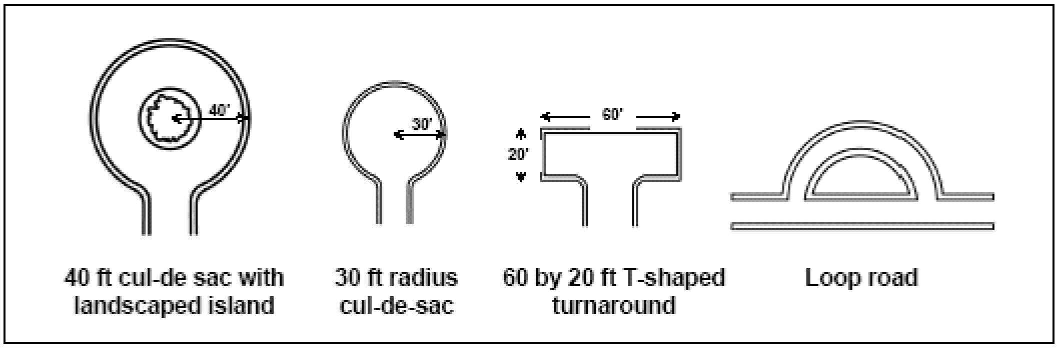

Figure 5.7 – Different styles of turnarounds. Source: Atlanta Regional Commission, 2001.

Figure 5.8 – Cul-de-sac infiltration island accepts stormwater from surrounding pavement. Note flat curb. Source: Connecticut, 2005.

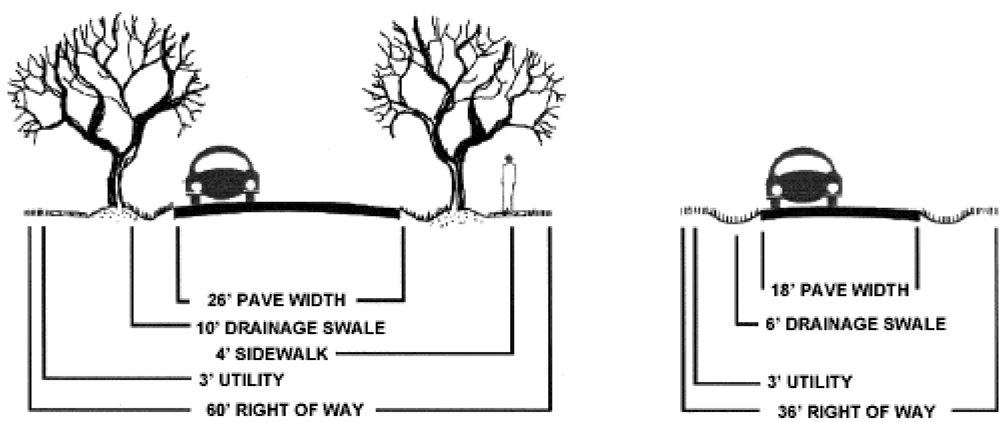

Figure 5.9 – Reduced road widths. Source: Atlanta Regional Commission, 2001.

Use

Examine local ordinances and other requirements to determine standards and degree of flexibility available. Communities may have specific standards for setbacks and frontages or criteria for cul-de-sacs and other alternative turnarounds.

Reduce Roadway Lengths and Widths

1. Consider site and road layouts that reduce overall street length.
2. Minimize street width by using narrower street designs as appropriate. Issues to consider include design speed, number of average daily trips (ADT), peak usage, need for on-street parking, sidewalks, design speed and right of way (see *Table 5.3*).

Reduce Surface Area of End-of-Street Turnarounds

1. Consider types of vehicles that may need to access a street. Sufficient turnaround area is a significant factor to consider in the design of cul-de-sacs. Fire trucks, service vehicles and school buses are often cited as needing large turning radii. However, some fire trucks are designed for smaller turning radii. In addition, many newer large service vehicles are designed with a tri-axle (requiring a smaller turning radius) and school buses usually do not enter individual cul-de-sacs.
2. Minimize pavement at end-of-street turnarounds. Incorporate landscaped areas and consider alternatives to cul-de-sacs wherever practicable.

Standards

Reduce Roadway Lengths and Widths

Table 5.3 shows a recommended standard for five categories of street. Streets are categorized based on ADT and density of dwelling units (row 1 in the table).

Table 5.3
Roadway Design Standards for Five Street Types

Design Factor	Access	Local	Collector	Arterial
ADT	0 – 500	500 – 5,000	2,500 – 10,000	7,500 – 20,000+
Number of Lanes	2	2	2	2 – 4
Turn lanes	None	None	Left (when needed)	Left and Right (when needed)
Lane Width (feet)	9 – 10	10 – 11	10 – 12	11 – 12
On-Street Parking (feet)	None	7 (parallel)	8 (parallel) 16 – 18 (angle)	None except for CBD
Drainage	Swale or curb/gutter	Swale or curb/gutter	Swale or curb/gutter	Swale or curb/gutter
Target Speed (MPH)	15 – 20	25	25 – 35	30 – 45
Bicycle Lanes	None	Shared	Shared or separate	Yes
Sidewalks	None or one-side	Two side	Two side	One side
Frontage Lots	Yes (may be rear)	Yes	Yes	Some

Average Daily Trips (ADT) = 10 x Number of Dwelling Units
Peak Trips Per Hour = Number of Dwelling Units

Local zoning may supersede these recommendations. Although, these recommended standards are intended to account for safety and snow disposal, greater widths may be appropriate in some instances.

Reduce Surface Area of End-of-Street Turnarounds
Where cul-de-sacs are necessary, radii should be no more than 30 feet. Alternatives such as hammerheads, jug handles and donuts should also be considered.

5.3.2 Buildings

Imperviousness associated with buildings and accessories such as driveways can often be reduced with considerate planning in the early stages of site design. The techniques below should be considered and applied wherever practicable.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.

Discussion

Footprints
The building footprint is the surface area of ground covered by structure. The impervious footprint of commercial buildings and residences can be reduced by using multistory buildings. In comparison to single-story buildings, multistory buildings maintain floor area while covering less ground surface. Use alternate or taller building designs to reduce the impervious footprint of buildings. For example, in residential areas, consider colonial style homes instead of ranches.

Setbacks and Frontages
Driveways generally extend from a roadway to a house. Therefore, driveway length is typically determined by building setback requirements. Driveways are noted to contribute up to 30 percent of impervious cover in residential areas (Schueler, 1995). Setback requirements of up to 75 feet are not uncommon. Notwithstanding, a driveway length of 20 to 30 feet is generally adequate to meet parking needs. A driveway width of 18 feet is generally adequate for parking two cars side-by-side.

Further, reducing side-yard widths and using narrower frontages can reduce total street length, especially important in cluster and open space designs. *Figure 5.10* shows residential examples of reduced front and side yard setbacks and narrow frontages.

Figure 5.10 – Reduced side yards and frontage at a development in Connecticut.

Flexible lot shapes and setback and frontage distances allow site designers to create attractive and unique lots that provide homeowners with enough space while allowing for the preservation of natural areas in a residential subdivision. *Figure 5.11* illustrates various nontraditional lot designs.

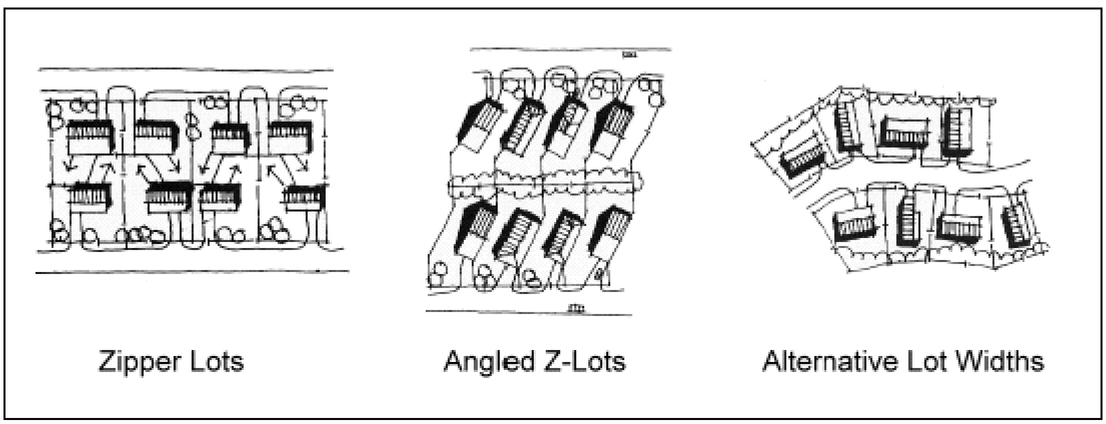

Figure 5.11 – Examples of nontraditional lot designs. *Source: Adapted from Atlanta Regional Commission, 2001.*

Use

Use smaller front and side setbacks and narrower frontages to reduce total road length and driveway lengths.

Reduce building and home front and side setbacks to allow for narrow frontages. Consider narrower frontages.

a) Consider alternative build styles that reduce ratio of footprint to floor area.
b) Review local regulations. Communities may have specific design criteria for setbacks and frontages.
c) Minimize setbacks and lot frontages.

Standards

a) Where practicable, reduce building setbacks to 20 - 30 feet and driveway widths to 18 feet.
b) Where practicable, reduce frontages to 60 feet.

5.3.3 Parking Footprints

Setting maximums for parking spaces, minimizing stall dimensions, using structured parking and encouraging shared parking and using alternative porous surfaces can reduce the overall parking footprint and site imperviousness.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.

Use and Standards

Apply the following approach:

Examine local ordinances and other requirements to determine standards and degree of flexibility available. Communities may have specific standards for parking stall size and number of parking spaces. There may also be prohibitions against shared parking.

Use Average Demand to Size Lots

a) Many parking lot designs result in far more spaces than actually required. This problem is exacerbated by a common practice of setting parking ratios to accommodate the highest hourly parking during the peak season. By determining average parking demand instead, a lower maximum number of parking spaces can be set to accommodate most of the demand.

b) If no local standards require a minimum number of spaces, apply the standards in *Table 5.4* as a maximum number of spaces.

Table 5.4
Recommended Maximum Number of Parking Spaces for Certain Land Uses

Land Use	Maximum Parking Spaces
Single Family House	2 per DU[a]
Shopping Center	5 per 1000 ft² GFA[b]
Convenience Store	3.3 per 1000 ft² GFA
Industrial	1 per 1000 ft² GFA
Medical Dental	5.7 per 1000 ft² GFA

Source: Georgia Stormwater Manual, 2002.
Notes:
[a] DU means dwelling unit.
[b] GFA means gross floor area.

Minimize Parking Stall Size
Another technique to reduce the parking footprint is to minimize the dimensions of the parking spaces. This can be accomplished by reducing both the length and width of the parking stall.

Parking stall dimensions can be further reduced if compact spaces are provided. While the trend toward larger sport utility vehicles (SUVs) is often cited as a barrier, stall width requirements in most local parking codes are much larger than the widest SUVs.

Figure 5.12 – Parking deck – New Haven, Connecticut.

Use Parking Decks
Structured parking decks can significantly reduce the overall parking footprint by minimizing surface parking. *Figure 5.12* shows a parking deck used for a commercial development.

Encourage Shared Parking
Shared parking in mixed-use areas and structured parking are techniques that can further reduce the conversion of land to impervious cover. For developments and blocks with a mix of land uses, perform a shared parking analysis in order to determine the peak demand for spaces for all uses rather than calculating each separately. Often mixed uses may be complimentary with regards to parking. For example, the peak demand for office buildings occurs during the period of minimal demand for residential buildings. The Urban Land Institute publication *Shared Parking,* Second Edition, 2005 provides a detailed methodology in order to determine the peak hour of parking demand and the overall number of spaces required for a mixed use development. This may reduce the number of spaces required by up to 20 percent.

5.3.4 Parking Lot Islands

A parking lot island is an area within a parking lot that can accommodate stormwater management practices and reduce impervious surfaces (*Figure 5.13*). Parking lot islands include small-scale management practices such as filter strips, dry swales, sand filters and bioretention.

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.
- Provides an opportunity for the siting of structural control facilities.
- Trees in parking lots provide shading for cars and are more visually appealing.

Use

- Break up expanses of parking with landscaped islands, which include shade trees and shrubs.
- Fewer large islands will sustain healthy trees better than more numerous very small islands.

Figure 5.13 – Bioretention in use as a parking lot island in Branford, CT. Source: Connecticut Department of Energy and Environmental Protection.

Structural control facilities such as filter strips, dry swales and bioretention areas can be incorporated into parking lot islands. Stormwater is directed into these landscaped areas and temporarily detained. The runoff then flows through or filters down through the bed of the facility and is infiltrated into the subsurface or collected for discharge into a stream or another stormwater facility. These facilities can be attractively integrated into landscaped areas and can be maintained by commercial landscaping firms.

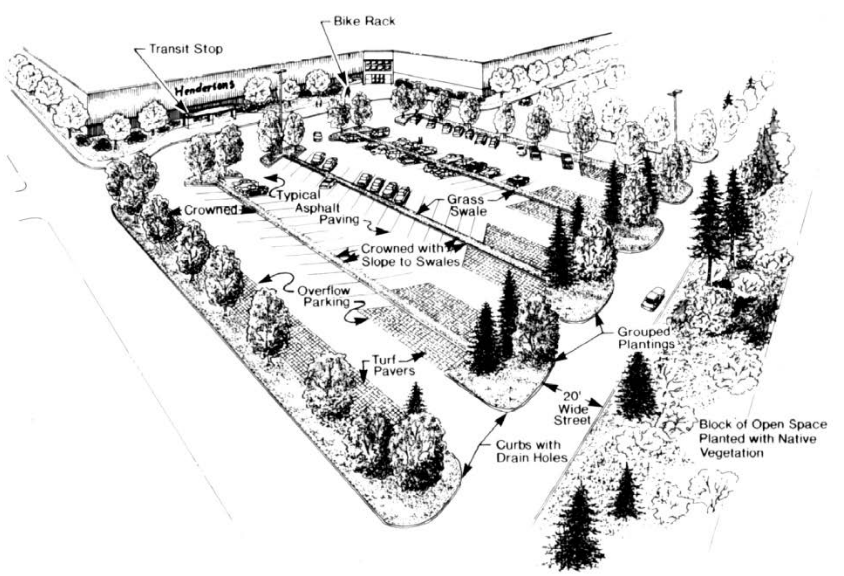

Figure 5.14 – Parking lot with integrated functional parking islands. Source: Connecticut, 2004.

Standards
Parking lot islands should:

a) Be at least 8 feet wide.
b) Be constructed with sub-surface drainage or an overflow to a storm drainage system to accommodate larger flows.
c) Incorporate compaction resistant soil.

5.3.5 Porous Surfaces

Figure 5.15 – Permeable pavement. Source: Connecticut Department of Energy and Environmental Protection, 2004.

Porous surfaces are designed to allow rain and snowmelt to pass through it, thereby reducing runoff, promoting groundwater recharge, and filtering pollutants. Common types of porous surfaces include:

- Porous asphalt or concrete
- Modular concrete paving blocks
- Modular concrete or plastic lattice
- Soil enhancement technologies
- Cast-in-place concrete grids
- Other materials such as gravel, cobbles, wood, mulch, brick, and natural stone.

Permeable pavement is only recommended for sites that meet the following criteria:

- Low-traffic applications (generally 500 or fewer average daily trips or ADT).
- The underlying soils are sufficiently permeable (see Design Considerations below).
- Road sand is not applied.

Porous asphalt or concrete (i.e., porous pavement or gap-graded pavement), which looks similar to traditional pavement but is manufactured without fine materials and incorporates additional void spaces, are recommended for certain applications due to their potential for clogging and failure in cold climates.

Generally, runoff from adjacent areas should be directed away from permeable pavement by grading the surrounding landscape away from the site or by installing trenches to collect the runoff.

Regular maintenance is essential for long-term performance (sweeping, vacuum cleaning).

Advantages

- Reduces the amount of impervious cover and associated runoff and pollutants generated.
- Can reduce the cost associated with road and parking lot construction by eliminating or reducing the reliance on storm drainage infrastructure.

Use

a) Applicable to small drainage areas.
b) Low traffic (generally 500 ADT or less) areas of parking lots (i.e., overflow parking for malls and arenas), driveways for residential and light commercial use, walkways, bike paths, and patios.
c) Roadside right-of-ways and emergency access lanes.
d) Useful in stormwater retrofit applications where space is limited and where additional runoff control is required.
e) In areas where snow plowing is not required.

Standards

Chapter 11 of the *Connecticut Stormwater Quality Manual* includes specific design standards and considerations for permeable pavement. Addition design considerations include:

- **General Design** – Porous surface options include pavers, asphalt and other hard surfaces suitable for street and sidewalk design. The current Town specifications address porous asphalt; however, other forms of porous surfaces may be accepted by the Town at the discretion and approval of the Town Engineer. Generally, the Town anticipates that applications of porous surface, other than porous asphalt, will be designed and installed to the specification of their manufacturer. Installers shall have a minimum of three successful completions of comparably sized and type of projects within the last five years.

- **Porous Asphalt** – Porous asphalt shall be installed by a porous asphalt pavement installer with a minimum of three successful completions of comparably sized and type of projects within the last five years. Porous asphalt paving shall be provided according to materials, workmanship, testing, and other applicable requirements of the University of New Hampshire Stormwater Center "Design Specifications for Porous Asphalt Pavement and Infiltration Beds" (see *Appendix C*). Post-installation testing shall include application of clean water at the rate of at least five gallons per minute over the surface using a hose or other water distribution device. Water used shall be clean and free of suspended solids and deleterious liquids. Generally, tap water is appropriate for these purposes. All water applied shall infiltrate directly without the formation of large puddles and shall be observed and certified by the design engineer for the subject project.

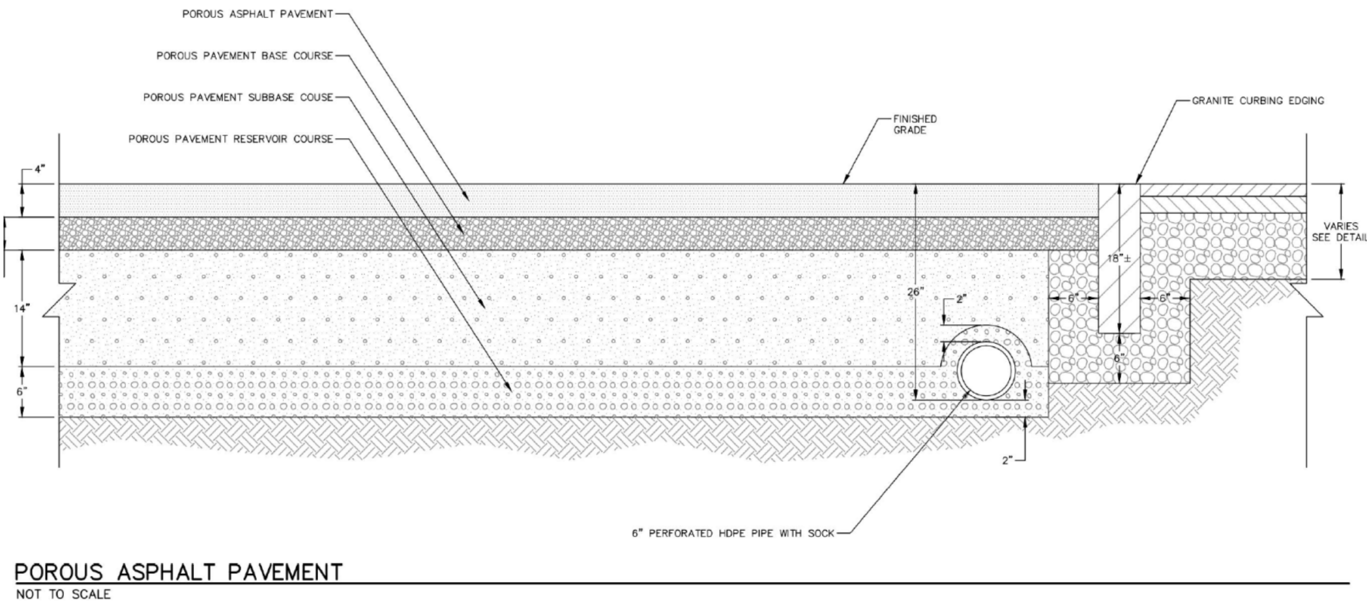

Figure 5.16 – Standard design for porous asphalt pavement.

5.3.6 Disconnecting Impervious Areas

Impervious surfaces that are separated from drainage collection systems by pervious surface or infiltration BMPs contribute less runoff and reduced pollutant loading. Isolating impervious surfaces promotes infiltration and filtration of stormwater runoff.

Advantages

- Promotes evapotranspiration and infiltration to reduce need for treatment and peak volume control at end-of-pipe.
- Reduces generation of stormwater.
- Maintains predevelopment hydrology, natural character and aesthetic features that may increase marketability and property values.

Use

Use the following techniques to disconnect impervious surfaces from stormwater collection systems:

a) Direct roof runoff and runoff from paved surfaces to stabilized vegetated areas such as buffers.
b) Direct runoff from large impervious surfaces (over 5000 square feet) to more than one receiving area.
c) Encourage sheet flow through vegetated areas.

Standards

General

a) Disconnect impervious surfaces to the extent practicable.
b) Up to the first inch of runoff from an impervious surface may be disconnected to a pervious surface such as a lawn.

Table 5.5
Ratio of Open Space: Pervious Area Necessary to Attenuate Surface Runoff for Runoff Between 0.5 and 1.0 Inches[a, b]

Runoff (inches)	HSG Soil Type			
	A	B	C	D
1.0	1:2	4:1	N/A	N/A
0.9	1:3	2:1	N/A	N/A
0.8	1:4	1:1	N/A	N/A
0.7	1:8	1:2	N/A	N/A
0.6	1:8	1:3	2:1	N/A
0.5	1:8	1:6	1:1	N/A

Notes:
[a]Buffer size calculations based on TR-55. Calculations for precipitation depths less than 0.5 inches are not included as the empirical equations of TR-55 become less accurate for storms less than 0.5 inches.
[b]Standards for buffer width and length of contributing flow path, etc. must be met regardless of soil's capacity to attenuate flow.

c) Relatively permeable soils (hydrologic soil groups A and B) must be present for disconnection. Assume that the pervious surface is open space in good condition (i.e., CN of 39 for HSG A and 61 for HSG B). (If a forested buffer is being used refer to "Preserving Natural Areas" for appropriate standards.) The following impervious to pervious area ratios should be used. Type C and D may not be used for this purpose as open space on these soil types does not abstract the rainfall required to generate one inch of runoff from the impervious surface.
d) The maximum contributing impervious flow path length should be no more than 75 feet.
e) The disconnected area should drain continuously through a vegetated channel, swale, or filter strip to the property line or structural stormwater control.
f) Flow from the impervious surface must enter the downstream pervious area as sheet flow.
g) The length of the disconnected area should be equal to or greater than the contributing length.
h) The entire disconnected area should maintain a slope less than or equal to 5 percent.
i) The surface of the contributing imperviousness area should not exceed 5,000 square feet.

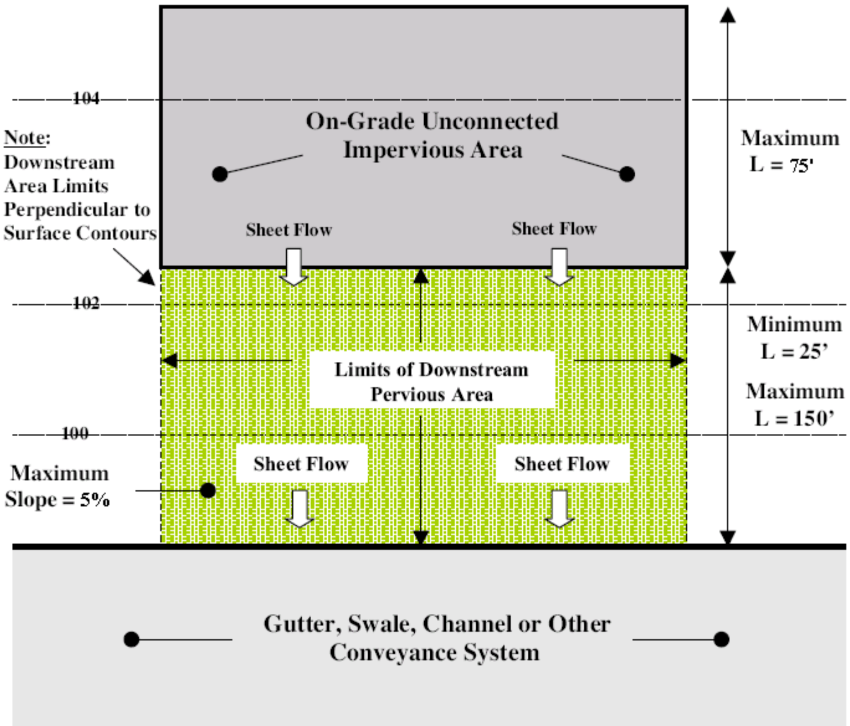

Figure 5.17 – Standards for disconnecting impervious surface via sheet flow. Source: New Jersey Department of Environmental Protection, 2004.

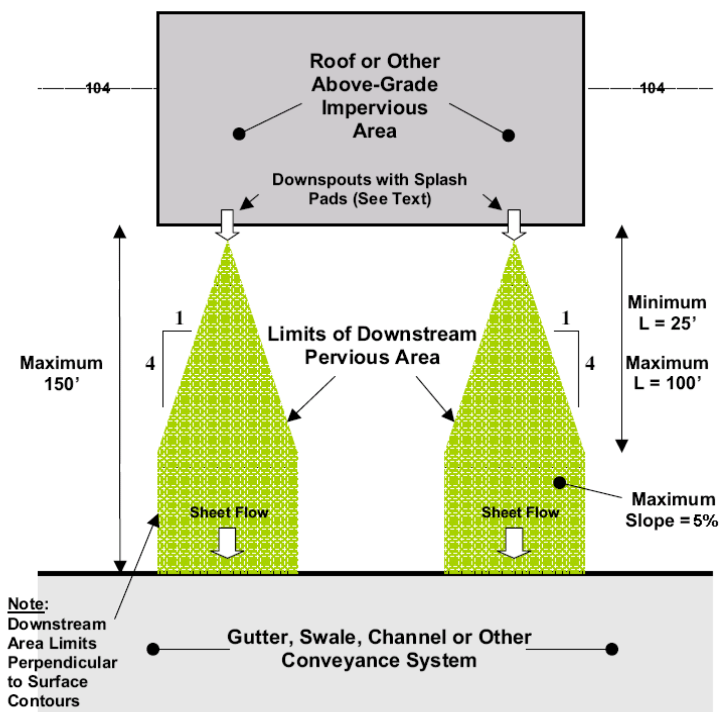

Figure 5.18 – Standards for disconnecting impervious surface via downspouts. Source: New Jrsey Department of Environmental Protection, 2005.

Downspouts

a) Downspout outfall expands in width at a rate of 1:4 for a maximum length of 100 feet and a minimum length of 25 feet.
b) No downspout may drain more than 600 square feet of roof.
c) Downspouts should be at least 10 feet away from the nearest impervious surface (e.g., driveways) to discourage reconnections to those surfaces.
d) Downspouts must be equipped with splash pads, level spreaders, or dispersion trenches that reduce flow velocity and induce sheet flow in the downstream pervious area.

5.4 Using Management Practices at the Source

5.4.1 Vegetated Filter Strips

A vegetated filter strip is an undisturbed densely vegetated area (e.g., well-tended lawn) contiguous with a developed area. These filter strips are most often located between a water resource and the developed portion of a site (*Figure 5.19*).

http://www.clemson.edu/extension/horticulture/nursery/remediation_technology/veg_buffer_strip.html.

Advantages
Filter strips serve to improve runoff water quality, add or maintain wildlife habitat, and provide a screening effect for homeowners. This type of BMP is best suited for complementing other structural methods utilized on-site for stormwater management.

Use
Filter strips can be composed of an undisturbed-forested area or created from disturbed land by proper seeding and plantings. Where grass is being used, the most effective pollutant removal filter strip is composed of dense grassy vegetation that is properly maintained

Channelization of runoff within the filter strip significantly reduces the amount of infiltration and subsequent pollutant removal. Filter strips must have a level-spreading device incorporated into the design. Caution must be used when installing level spreaders to ensure long-term even flow and distribution of runoff to the filter strip. *Figure 5.5* for an example of a level spreader. Low volume pedestrian pathways may be constructed through a buffer strip, provided they are no greater than 5 feet wide and take a winding course to reduce the potential for channelized runoff flow. Pesticides should not be applied in these areas, although minimal, fertilizer use is acceptable to help seeded areas become more quickly established. Incorporating organic material, such as mulch, into the topsoil is encouraged to promote better filter strip performance.

Soils with a high content of organic material will attenuate greater amounts of pollutants from stormwater runoff.

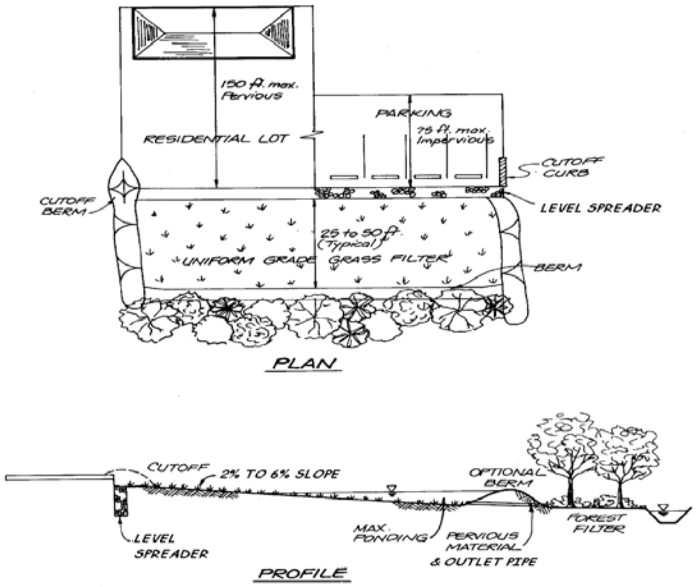

Figure 5.20 – Drawing of a vegetative filter strip. Source: Atlanta Regional Commission, 2001.

Standards

Chapter 11 of the *Connecticut Stormwater Quality Manual* includes specific design standards and considerations for vegetative filter strips, which should be followed when implementing these BMPs.

5.4.2 Natural and Vegetated Drainage Ways

Structural drainage systems and storm sewers are designed to be hydraulically efficient for removing stormwater from a site. However, in doing so, these systems tend to increase peak runoff discharges, flow velocities and the delivery of pollutants to downstream waters. An alternative is the use of natural drainage ways such as grass natural drainage systems (*Figure 5.21*).

The use of natural open channels allows for more storage of stormwater flows on-site, lower stormwater peak flows, a reduction in erosive runoff velocities, infiltration of a portion of the runoff volume, and the capture and treatment of stormwater pollutants.

Figure 5.21 – Vegetated drainage way. Photograph courtesy of the University of Connecticut NEMO program, Kara Bonsack

Advantages

- Reduces or eliminates the cost of constructing storm sewers or other conveyances, and may reduce the need for land disturbance and grading.
- Increases travel times and lower peak discharges.
- Can be combined with buffer systems to enhance stormwater filtration and infiltration.

Use

a) Use vegetated open channels in the street right-of-way to convey and treat stormwater runoff from roadways, particularly for low-density development and residential subdivisions where density, topography, soils, slope, and safety issues permit.
b) Use vegetated open channels in place of curb and gutter to convey and treat stormwater runoff.
c) Design drainage systems and open channels to:
    i. Increase surface roughness to retard velocity.
    ii. Include wide and flat channels to reduce velocity of flow and encourage sheet flow if possible.
    iii. Increase channel flow path to increase time of concentration and travel time.

Standards

Chapter 11 of the *Connecticut Stormwater Quality Manual* includes specific design standards and considerations for grass drainage channels, which should be followed when implementing these BMPs.

5.4.3 Green Roofs and Facades

Figure 5.22 – Aetna Building, Hartford, CT. Source: Connecticut Department of Energy and Environmental Protection.

Rooftop runoff management structures are modifications to conventional building design that attenuate runoff originating from roofs. The modifications include:

- Vegetated roof covers
- Roof gardens
- Vegetated building facades
- Roof ponding areas (e.g., blue roofs)

Roofs are significant sources of runoff from developed sites. If runoff is controlled at the source, the size of other BMPs throughout the site can be reduced. Rooftop runoff management practices influence the runoff hydrograph in two ways:

- Intercept rainfall during the early part of a storm.
- Limit the maximum release rate.

In addition to achieving specific stormwater runoff management objectives, rooftop runoff management can also be aesthetically and socially beneficial.

Advantages

- Rooftop runoff management techniques can be retrofitted to most conventionally constructed buildings.
- Reduces energy consumption for heating and cooling.
- Conserves space.
- Reduces wear on roofs caused by UV damage, wind, and extremes of temperature. Vegetative roof covers can reduce bare roof temperatures in summer by as much as 40 percent.
- Roof gardens, vegetated roof covers, and vegetated facades add aesthetic value to residential and commercial property that attract songbirds, bees, and butterflies.
- Benefit water quality by reducing the acidity of runoff and trapping airborne particulates.
- May reduce the size of onsite runoff attenuation BMPs.

Use

a) Use vegetative roofs on residential, commercial and light industrial buildings.
b) Vegetative roof systems are most appropriate on roofs with slopes of 12:1 to 4:1.
c) Vegetative roofs may be used on flatter slopes if an underdrain is installed.

Design Variations

- **Vegetated roof cover** – Vegetated roof covers, also called green roofs and extensive roof gardens, involve blanketing roofs with a veneer of living vegetation. Vegetative roof covers are particularly effective when applied to extensive roofs, such as those that typify commercial and institutional buildings. The filtering effect of vegetated roof covers results in a roof discharge that is free of leaves and roof litter. Therefore, it is recommended where roof runoff will be directed to infiltration devices (see Standards for Infiltration Practices and Dry Wells.)

  Because of recent advances in synthetic drainage materials, vegetated covers now are feasible on most conventional flat roofs. An efficient drainage layer is placed between the growth media and the roof surface. This layer rapidly conveys water off of the roof surface and prevents water from "lying" on the roof. In fact, vegetated roof covers can be expected to protect roof materials and prolong their life.

  If materials are selected carefully to reduce the weight of the system, vegetated roof covers generally can be created on existing flat roofs without additional structural support. Drainage nets or sheet drains constructed from lightweight synthetic materials can be used as underlayments to carry away water and prevent ponding. The total load of a fully vegetated and saturated roof cover system can be less than the design load computed for gravel ballast on conventional tar roofs.

Although vegetative roof covers are most effective during the growing season, they also are beneficial during the winter months as additional insulation if the vegetative matter from the dead or dormant plants is left in place and intact.

- **Roof Gardens** – Vegetated roof covers blanket an entire roof area and, although presenting an attractive vista, generally are not intended to accommodate routine traffic by people. Roof gardens, on the other hand, are landscaped environments, which may include planters and potted shrubs and trees. Roof gardens can be tailor-made natural areas, designed for outdoor recreation, and perched above congested city streets. Because of the special requirements for access, structural support, and drainage, roof gardens are found most frequently in new construction.

  Roof gardens generally are designed to achieve specific architectural objectives. The load and hydraulic requirements for roof gardens will vary according to the intended use of the space. Intensive roof gardens typically include design elements such as planters filled with topsoil, decorative gravel or stone, and containers for trees and shrubs. Complete designs also may detain runoff ponding in the form of water gardens or storage in gravel beds. A wide range of hydrologic principles may be exploited to achieve stormwater management objectives, including runoff peak attenuation and runoff volume control.

- **Vegetated Building Facades** – Vegetated facades provide many of the same benefits as vegetated roof covers and roof gardens, including the interception of precipitation and the retardation of runoff. However, their effectiveness is limited to small rainfall events.

  Vertical facades and walls of houses can be covered with the foliage of self-climbing plants that are rooted in the ground and reach heights in excess of 80 feet. Vines can be evergreen or prolific deciduous flowering plants. As for roof gardens, the designer must be judicial in selecting plant species that will prosper in the constructed environment. Planters and trellises can be installed so that vegetation can be placed strategically.

- **Roof Ponding –** Roof ponding, also known as blue roofs, is applicable where the increased load of impounded water on a roof will not increase the building costs significantly or require extensive reinforcement. Roof ponding generally is not viable for large-area commercial buildings where clear spans are required. Special consideration must be given to ensuring that the roof will remain watertight under a range of adverse weather conditions. Low-cost plastic membranes can be used to construct an impermeable lining for the containment area.

Flat roofs can be converted to ponding areas by restricting the flow to downspouts. Even small ponding depths of 1 or 2 inches can attenuate stormwater runoff peak flows effectively for most storms.

Design Considerations

Rooftop measures are primarily peak runoff attenuation measures. The methods for evaluating the peak attenuation properties of these measures are based on approaches used for other peak runoff attenuation BMPs. The emphasis of the design should be promoting rapid roof drainage and minimizing the weight of the system. By using appropriate materials, the total weight of fully saturated vegetated roof covers can readily be maintained below 20 pounds per square foot (psf). Because of the many factors that may influence the design of vegetated roof covers, it is advisable to obtain the services of installers that specialize in this area.

Rainfall retention properties are related to field capacity and wilting point. Appropriate media for this application should be capable of retaining water at the rate of 40 percent by weight, or greater. The media must be uniformly screened and blended to achieve its rainfall retention potential. During the early phases of a storm, the media and root systems of the cover will intercept and retain most of the rainfall, up to the retention capacity. For instance, 3-inch cover with 40 percent retention potential will effectively control the first 1.2 inches of rainfall. Although some water will percolate through the cover during this period, this quantity generally will be negligible, compared to the direct runoff rate without the cover in place.

Once the field capacity of the cover is attained, water will drain freely through the media at a rate that is approximately equal to the saturated hydraulic conductivity for the media. Through the selection of the media, the maximum release rate from the roof can be controlled. The media is a mechanism for "buffering" or attenuating the peak runoff rates from roofed areas. Rooftop runoff management measures generally are more effective in controlling storms that generate 1 inch or less of runoff (i.e., 1.2-inch storm). However, because storms of this size constitute the majority of rainfall events, rooftop runoff measures can be important in planning for comprehensive stormwater management. These measures are particularly useful when linked to groundwater recharge BMPs such as infiltration trenches, dry wells, and permeable pavements. By retaining rainfall for evaporation or plant transpiration, some rooftop runoff management measures, such as vegetated roof covers, can also achieve significant reductions in total annual runoff. This attenuation of runoff peaks from larger storms should be taken into account when sizing related runoff peak attenuation at the site.

By using specific information about the hydraulic properties of the cover media, the effect of the roof cover system on the runoff hydrograph can be approximated with numerical modeling techniques. As appropriate, the predicted hydrographs can be added into site-wide runoff models to evaluate the effect of the vegetative roof covers on site runoff. The hydraulic analysis of roof covers will require the services of a professional engineer who is experienced with drainage design.

Impermeable Lining

a) In some instances, the impermeable lining can be the watertight tar surface, which is conventional for flat roof construction. However, where added protection is desired, a layer of plastic or rubber membrane can be installed immediately beneath the drainage net or sheet drain. This liner needs to be designed by a professional engineer to ensure proper function.
b) If membranes are used, their resistance to ultraviolet (UV) radiation, extremes of temperature, and puncture must be known. In most cases, covering the sealing material with a protective layer of gravel or geotextile is advisable.

Drainage

a) The drainage net or sheet drain is a continuous layer that underlies the entire cover system. A variety of lightweight, high-performance drainage products will function well in this environment. The product selected should be capable of conveying the discharge associated with the runoff peak attenuation storm without ponding water on top of the roof cover. When evaluating a drainage layer design, the roof topography should be evaluated to establish where the longest travel distances to a roof gutter, drain, or downspout occur. If flow converges near drains and gutters, the design unit-flow rate should be increased accordingly.
b) Drainage nets or sheet drains with transmissivities of 15 gallons per minute per foot, or larger, are recommended.
c) The drainage layer should be able to convey the design unit flow rate at the roof grade without water ponding on top of the cover media. For larger storms, direct roof runoff is permitted to occur. The design flow rates should be based on the largest runoff peak attenuation design storm considered in the design.
d) To prevent the growth media from penetrating and clogging the drainage layer and to prevent roots from penetrating the roof surface, a geotextile should be installed immediately over the drainage net or sheet drain. Many vendors will bond the geotextile to the upper surface of the drainage material.
e) Effective roof garden designs will ensure that all direct rainfall is cycled through one or more devices before being discharged to downspouts as runoff. For instance, rainfall collected on a raised tile patio can be directed to a media-filled planter where some water is retained in the root zone and some is detained and gradually discharged through an overflow to the downspout.
f) In the case of roof ponding, devices such as the one shown in *Figure 5.23*, are easily fabricated. However, some form of emergency overflow also is advisable. Emergency overflow can be as simple as a free overfall through a notch in the roof parapet wall.
g) In roof ponding systems, because the roof is impermeable, the runoff hydrograph is simply the rainfall distribution for the design storm multiplied by the area of the roof.

The depth to storage relationship can be computed from the topography of the roof. For perfectly flat roofs, the storage volume of a ponding level is equal to the roof area times the ponding level. The depth-discharge relationship in will be unique to the outlet device used. For simple ponding rings on flat roofs, the discharge rate will approximately equal:

$$q = 3.141\ CD\ (d - H)^{3/2}$$

Where:

q = outflow rate
C = discharge coefficient (Varies based on design) Typical: C = 3.0
D = diameter of the ring
d = depth of ponding
H = height of the ring

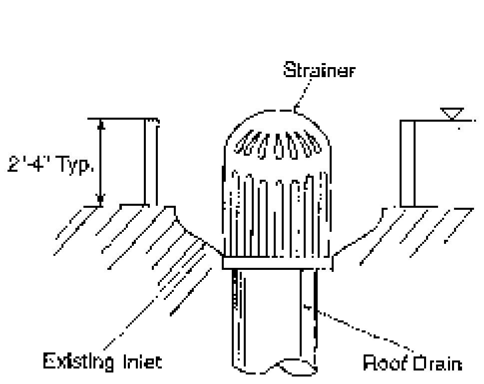

Figure 5.23 – Roof ponding rings. Source: Tourbier, 1974.

Roof Loading

The net weight of the fully vegetated roof cover should be compared against the design loads for the roof.

Lightweight Growth Media

a) The depth of the growth media should be kept as small as the cover vegetation will allow. Typically, a depth of 3 to 4 inches will be sufficient. Low-density substrate materials with good water-retention capacity should be specified. Examples are mixtures containing crushed pumice and terra cotta. Media that are appropriate for this application will retain 40 to 60 percent water by weight and have bulk dry densities of between 35 and 50 lb/cubic foot. Earth and topsoil are too heavy for most applications.
b) Hydrologic properties are specific to the growth medium. If the supplier does not provide information, prospective media should be laboratory tested to establish porosity, moisture content at field capacity, moisture content at the wilting point (nominally 0.33 bar), and saturated hydraulic conductivity.

Adapted Plants and Grasses

a) A limited number of plants can thrive in the roof environment where periodic rainfall alternates with periods that are hot and dry. Effective plant species must:

    i. Tolerate mildly acidic conditions and poor soil;
    ii. Prefer very-well-drained conditions and full sun;
    iii. Tolerate dry soil;
    iv. Be vigorous colonizers.

    Both annual and perennial plants can be used. Dozens of species have been successfully field-tested. Among these, some species of sedum (Sedum) have been shown to be particularly well adapted. Other candidates include hardy species of sedge (Carex), fescue (Festuca), feather grass (Stipa), and yarrow (Achillea).

b) Vegetative roof covers may include provisions for occasional watering during extended dry periods. Conventional lawn sprinklers work well.
c) The key to developing an effective vegetated facade is selecting plants that are well adapted to the conditions in which they must grow. For instance, depending on the location, plants may encounter shade or full sun. Plants that will provide thick foliage should be selected. Some plants with good climbing and foliage characteristics are ivy (Hedera), honeysuckle (Loniciera), wisteria (Wisteria), Virginia creeper (Part henocissus), trumpet creeper (Campsis), and hardy cultivars of clematis (e.g., Cleinatis paniculata). Some of these plants will require a trellis or lattice to firmly support the vines.

Inspection and Maintenance

a) Plans for water quality swales should identify detailed inspection and maintenance requirements, inspection and maintenance schedules, and those parties responsible for maintenance.
b) All rooftop runoff management measures must be inspected and maintained periodically. Furthermore, the vegetative measures require the same normal care and maintenance that a planted area does. The maintenance includes attending to plant nutritional needs, irrigating as required during dry periods, and occasionally weeding.
c) The cost of maintenance can be significantly reduced by judiciously selecting hardy plants that will outcompete weeds.
d) In general, fertilizers must be applied periodically. Fertilizing usually is not a problem on flat or gently sloping roofs where access is unimpeded and fertilizers can be uniformly broadcast.
e) Properly designed vegetated roof covers should not be damaged by treading on the cover system.
f) When retrofitting existing roofs, preserve easy access to gutters, drains, spouts, and other components of the roof drainage system.
g) It is good practice to thoroughly inspect the roof drainage system quarterly. Foreign matter, including leaves and litter, should be removed.

Table 5.6
Typical Maintenance Activities for Rooftop Runoff Structures

Activity	Schedule
• Inspect to ensure vegetative cover is established • Remove foreign matter, leaves, and litter	Quarterly
• Irrigate/Water • Weed	As necessary
• Apply fertilizers to flat or gently sloped roofs	As necessary
• Repair erosion on side slopes with seed or sod	As necessary

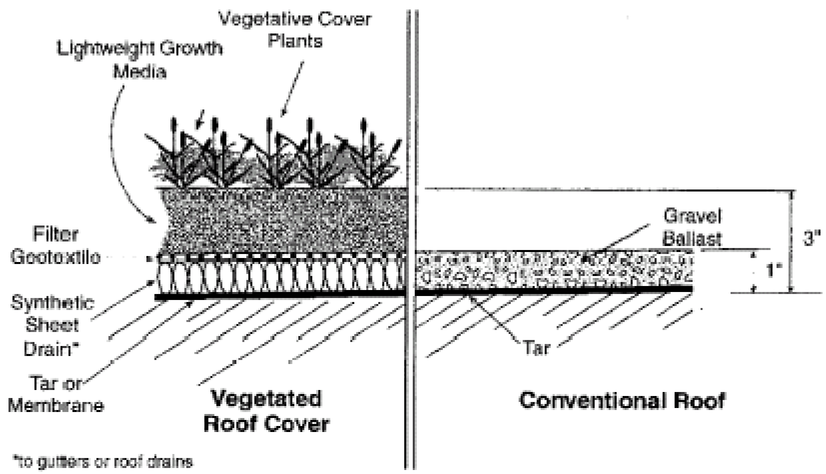

Figure 5.24 – Example of Vegetated Rooftop Cross-Section

5.4.4 Rainwater Harvesting

Rain barrels and cisterns are rainwater collection and storage devices (*Figure 5.25*). They are generally low-cost and easily maintainable. They are applicable, for purposes of retrofit, to residential, commercial and industrial sites to manage rooftop runoff. Rain barrels and cisterns are not generally given stormwater management credit on new development.

Cisterns are generally larger than rain barrels, with some underground cisterns having the capacity of 10,000 gallons or more. Water collected in cisterns is typically used for irrigation or in some instances as a potable supply.

Advantages

- Low cost.
- Applicable to a wide range of sites (e.g., residential, commercial industrial, etc.).
- Provide retention and detention of runoff from roofs.
- Can provide reuse of water for landscape irrigation.

Figure 5.25 – Example of a rain barrel. Source: Connecticut Department of Energy and Environmental Protection.

Use

a) Use rain barrels and cisterns in commercial, industrial and domestic settings.

b) Incorporate rain barrels and cisterns when a building is being designed so that they can be blended into the landscape. They can also be retrofitted.

c) Size rain barrels and cisterns based on roof area. The required capacity of a rain barrel is a function of the rooftop surface evaporative water losses and initial abstraction.

Rain barrel volume can be determined by calculating the roof top water yield for any given rainfall, using Equation 10. A general rule of thumb to utilize in the sizing of rain barrels is that 1 inch of rainfall on a 1000-square-foot roof will yield approximately 600 gallons.

$$V = A^2 \times R \times 0.90 \times 7.5 \ gals/ft^3$$

where:

V = volume of rain barrel (gallons)
A^2 = surface area roof (square feet)
R = rainfall (feet)
0.9 = 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.

$$60 \ gallons = 215 \ ft.^2 \times 0.042 \ ft. \times 0.90 \times 7.5 \ gallons/ft.^3$$

d) If collected water will be used as a drinking source, the system will generally require local authority review and approval.

e) Assure long-term function by establishing maintenance agreements.

Standards

Chapter 4 of the *Connecticut Stormwater Quality Manual* includes specific design standards and considerations for rain barrels and cisterns, which should be followed when implementing these BMPs.

5.4.5 Dry Wells

A dry well is a small, excavated pit, backfilled with stone aggregate. Dry wells function like infiltration systems to control roof runoff and are applicable for most types of buildings (*Figure 5.26*).

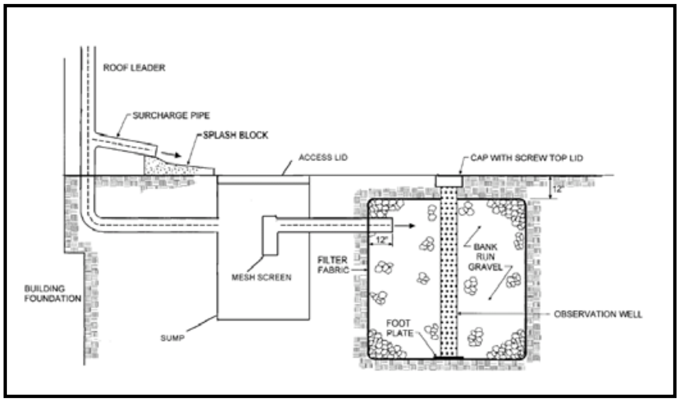

Figure 5.26 – Schematic of a drywell with optional sump to facilitate cleanout. Source: Adapted from New York, 2001.

Advantages

- Low cost.
- Applicable to a wide range of sites (e.g., residential, commercial industrial, etc.).
- Provides retention of runoff from roofs.
- Recharges groundwater.
- Reduces need for end-of-pipe treatment.

Use

a) Dry wells can be useful for disposing of roof runoff and reducing the overall runoff volume from a variety of building sites.

b) Infiltration of rooftop runoff from commercial or industrial buildings with pollution control, heating, cooling, or venting equipment may require UIC review and approval.

Standards

Chapter 4 and 11 of the *Connecticut Stormwater Quality Manual* include specific design standards and considerations for dry wells, which should be followed when implementing these BMPs.

5.4.6 Bioretention, Rain Gardens and Tree Box Filters

Figure 5.27 – Bioretention at University of Connecticut Storrs Campus, Mansfield. Source: Connecticut Department of Energy and Environmental Protection.

Bioretention and rain gardens are shallow landscaped depressions designed to manage and treat stormwater runoff. Bioretention systems are a variation of a surface sand filter, where the sand filtration media is replaced with a planted soil bed designed to remove pollutants through physical and biological processes (EPA, 2002). The concept of bioretention originated with the Prince George's County, Maryland, Department of Environmental Resources in the early 1990s as an alternative to more traditional management practices. Stormwater flows into the bioretention area, ponds on the surface, and gradually infiltrates into the soil bed. Treated water is allowed to infiltrate into the surrounding soils or is collected by an underdrain system and discharged to the storm drain system or receiving waters. Small-scale bioretention applications (i.e., residential yards, median strips, parking lot islands) are commonly referred to as rain gardens (*Figure 5.28*). Tree box filters (*Figure 5.29*) are essentially mini bioretention systems installed in concrete vaults. They are most often designed to fit in urban landscapes (e.g., sidewalks as part of street tree systems) where space is at a premium.

Advantages

- Applicable to small drainage areas, stormwater retrofits and highly developed sites.
- Can be applied to most sites due to relatively few constraints and many design variations (i.e., highly versatile).
- High solids, metals, and bacteria removal efficiency.
- Infiltrating bioretention can provide groundwater recharge.
- Helps to mimic predevelopment runoff conditions.
- Reduces need for end-of-pipe treatment.

Figure 5.28 – Rain garden. Source: Connecticut Department of Energy and Environmental Protection.

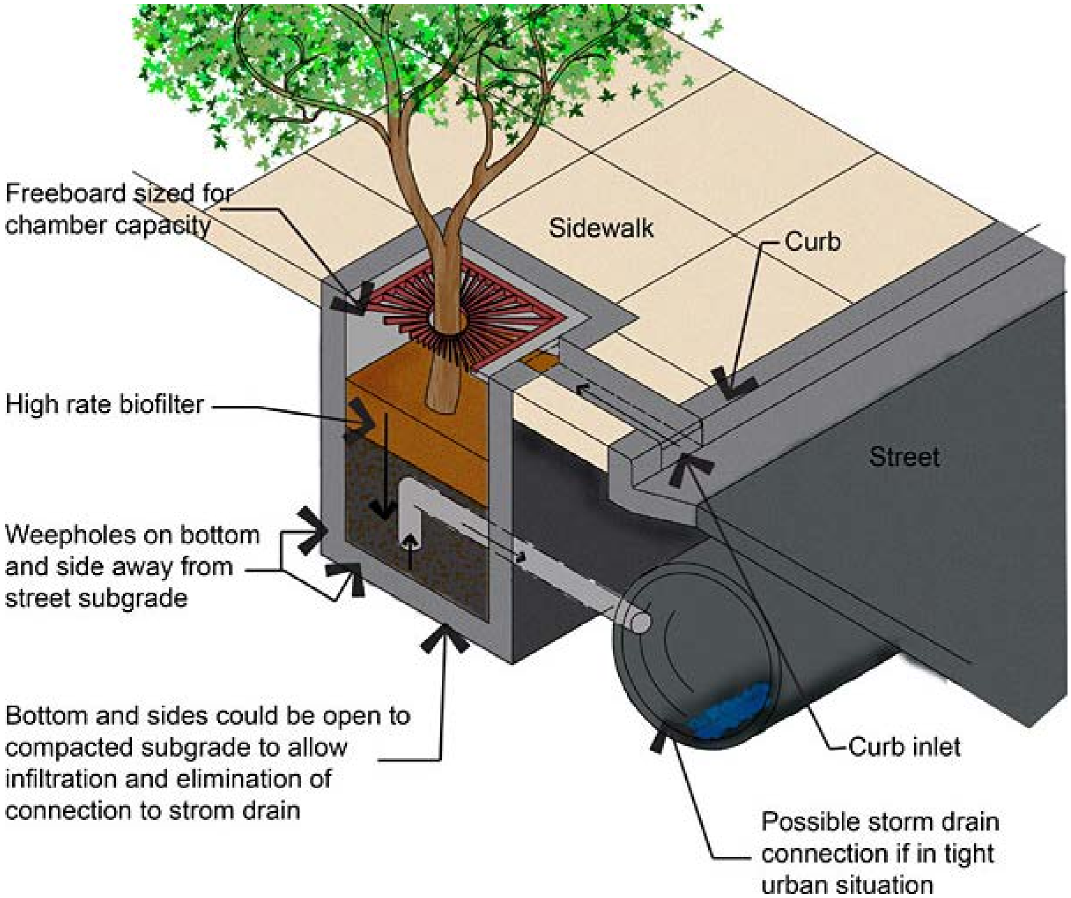

Figure 5.29 – Diagram of a tree box filter. Source: http://www.nashuarpc.org/publications/environmental/LID_guidebook.pdf

Use

a) Bioretention may be used in a wide variety of settings including residential, commercial, and industrial areas.
b) May be decentralized (e.g., as rain gardens on individual lots) or centralized in common areas to manage multiple properties.
c) May be lined and underdrained; or designed to infiltrate and recharge groundwater.

Figure 5.30 – Photograph of a tree box filter.

Standards

Chapter 4 and 11 of the *Connecticut Stormwater Quality Manual* include specific design standards and considerations for bioretention, which should be followed when implementing these BMPs.

Tree box filters should use the same soil media as standard bioretention systems. Like bioretention the reservoir at the top of a tree box filter should be sized to manage the water quality volume and should include a bypass drain for large storm events. The vault may be either closed or open-drained at the bottom depending on the underlying soils and depth to groundwater. Vegetation species used in the tree box filter should be both drought and salt-tolerant with root systems that are not terribly aggressive.

5.4.7 Infiltration Trenches

An infiltration trench is an excavated trench that has been back-filled with stone to form a subsurface basin. Stormwater runoff is diverted into the trench and is stored until it can be infiltrated into the soil, unusually over a period of 1 – 2 days.

Figure 5.31 – Photograph of an infiltration trench.

Advantages

- Applicable to small drainage areas, stormwater retrofits and highly developed sites.
- High bacteria removal efficiency.
- Infiltration provides groundwater recharge.
- Helps to mimic predevelopment runoff conditions.
- Reduces need for end-of-pipe treatment.

Use

a) Infiltration may be useful for disposing of roof runoff (e.g., dry wells), or runoff from parking lots and roadways.
b) Infiltration trenches generally have a longer life cycle when hydrologically proceeded by pretreatment such as a vegetated filter strip.
c) Infiltration generally requires UIC review and approval.

Standards

Chapter 11 of the *Connecticut Stormwater Quality Manual* includes specific design standards and considerations for infiltration, which should be followed when implementing infiltration BMPs.

5.4.8 Subsurface Gravel Wetlands

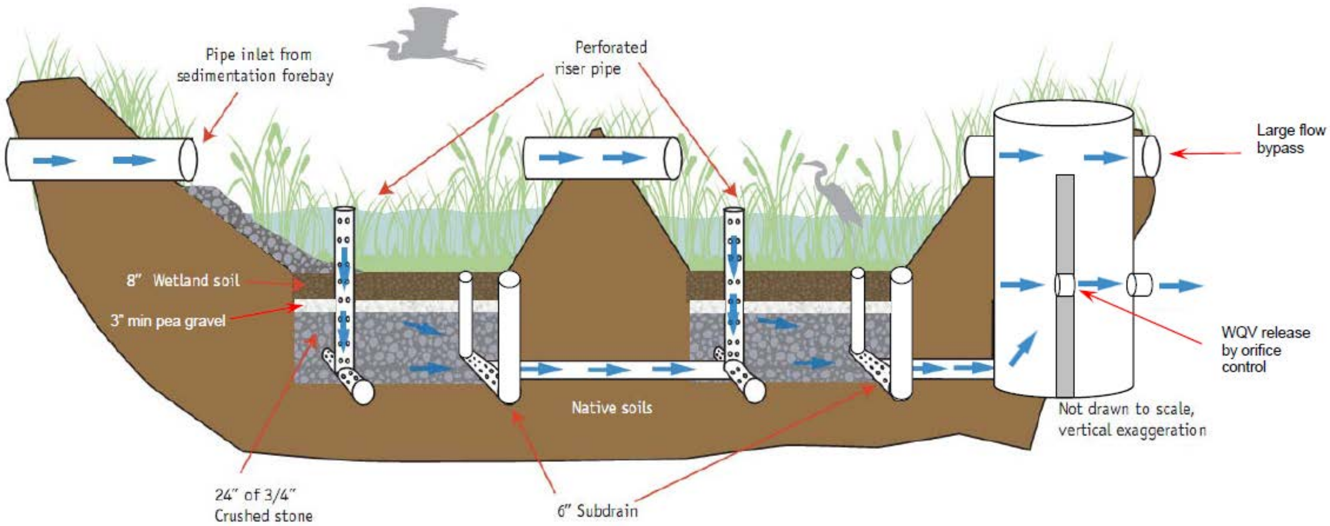

Figure 5.32 – Schematic of subsurface gravel wetland. Source: UNHSC

A subsurface gravel wetland (SGW) is a wet stormwater basin system designed to provide treatment primarily in a wet gravel bed with emergent vegetation. The SGW is designed as a series of horizontal flow-through treatment cells, preceded by a sedimentation basin (forebay) (*Figure 5.32*).

Advantages

- Applicable to small drainage areas, stormwater retrofits and highly developed sites.
- High bacteria removal and nutrient removal efficiency.
- Reduces need for end-of-pipe treatment.
- Well-suited for water quality retrofit of existing storm drainage systems and stormwater ponds.

Uses

a) Subsurface gravel wetlands may be used in a wide variety of settings including residential, commercial, and industrial areas; but are most commonly applied to commercial and industrial settings.
b) May be decentralized (e.g., bioretention) or centralized in common areas to manage multiple properties.
c) Must be lined and underdrained to ensure proper function.

Design Considerations

SGWs are designed to retain and filter the entire WQV using a forebay and two treatment cells. The two treatment cells are gravel reservoirs that act as permanent pools. These saturated gravel reservoirs support anaerobic microbial cultures, which provide water quality treatment of pathogens, nutrients, and other constituents. Water retained in the gravel reservoir is displaced by subsequent runoff events and thus receives flow-through filtering prior to being discharged.

Gravel wetlands may be constructed on-line or off-line. On-line systems receive upstream runoff from all storms, providing runoff treatment for the stormwater quality design storm and conveying the runoff from larger storms through an outlet or overflow. Multi-purpose on-line systems also store and attenuate these larger storms to provide runoff quantity control. In off-line gravel wetlands, the runoff from storms larger than the stormwater quality design storm bypasses the basin through an upstream diversion device. This not only reduces the size of the required basin storage volume, but reduces the basin's long-term pollutant loading and associated maintenance. In selecting an off-line design, the potential effects on wetland vegetation and ecology of diverting higher volume runoff events should be considered.

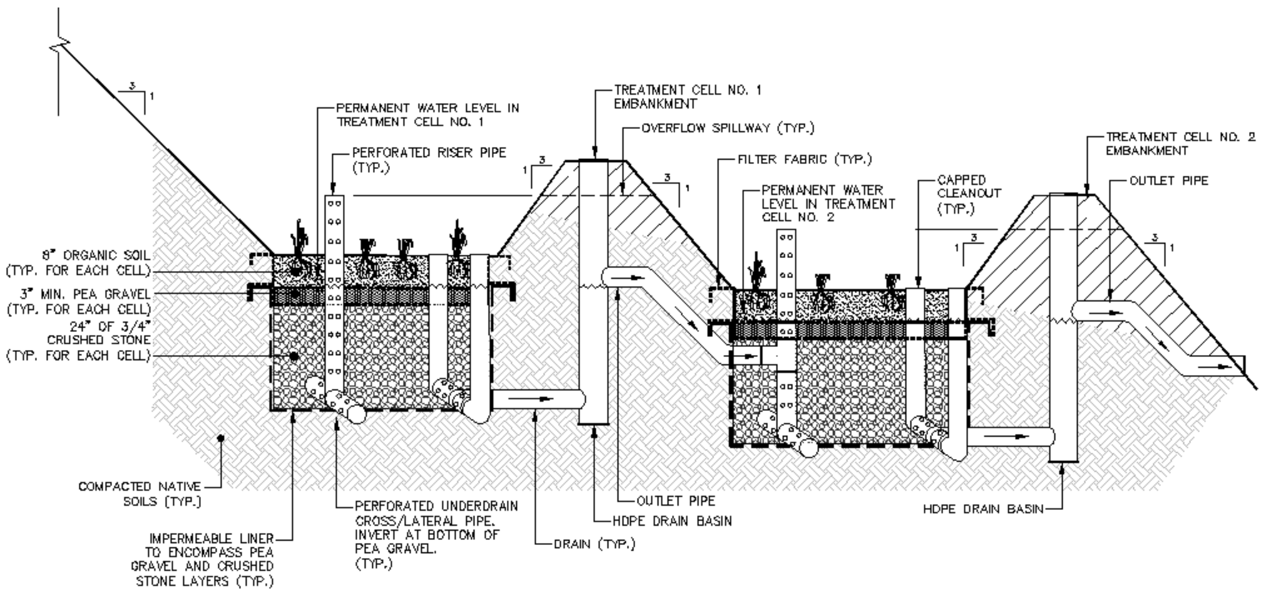

Figure 5.33 – Typical design of a subsurface gravel wetland.

Forebays

a. Forebays should be designed in accordance with the *Connecticut Stormwater Quality Manual* standards for constructed wetlands. Manufactured pretreatment systems may be used in lieu of forebays provided that they meet the *Connecticut Stormwater Quality Manual* standards.

General Treatment Cell Design

a. Subsurface gravel wetlands should generally include two treatment cells. Each treatment cell should include a volumetric capacity of 50% of the WQV and together should provide for 100% volumetric capacity of the WQV.
b. All surface basin (and forebay) side slopes are 3:1 or flatter for maintenance.
c. Gravel length to width ratio of 0.5. At a minimum, cells should be configured to create a 15-foot flow path across each treatment cell. The flow once again passes through 15 feet of anaerobic gravel before discharging. The two cell system allows for storm events equal or less than the water quality storm to pass through 30 feet of gravel.
d. Berms and weirs separating the forebay and treatment cells should be constructed with clay, or non-conductive soils, and/or a fine geotextile, or some combination thereof, to avoid water seepage and soil piping through these earthen dividers.

Treatment Cell Wetlands Layers

a. A minimum soil depth of eight inches must be provided for the vegetation. The soil mix must provide sufficient growing media and have low permeability rates since the flow into the gravel media must pass through the pipe and not through the wetlands soil.

b. The surface infiltration rates of the gravel wetland soil should be similar to a low hydraulic conductivity wetland soil (0.1-0.01 ft/day = 3.5 x 10-5 cm/sec to 3.5 x 10-6 cm/sec)). The wetlands soils must have low hydraulic conductivity to support continuously wet conditions in the treatment cells. Soils should be mixed using a combination of compost, sand, silt, and clay, with the clay component not exceeding 15% by volume. The soil should be a silt loam with 10% to 20% organic content by mass. The organic matter should consist of leaf compost or peat. Leaf compost should be properly matured and at least one year old. The leaf compost should be made exclusively of fallen deciduous leaves with less than 5% dry weight of woody or green yard debris or other materials. The compost should be generally free of trash and other debris. Leaf mulch, composted mixed yard debris, wood chips, biosolids, mushroom compost or composted animal manures are not acceptable sources of organic matter.

c. A three inch pea gravel layer is required between the wetland soil and the subsurface gravel cells. The transition between the planting bed and the crushed stone may be also composed of a combination of sand and washed pea gravel. This transition layer is necessary to prevent the finer portion of the wetland soil from migrating down into the gravel cells. The transition area must be designed to ensure that the wetland soil does not migrate to the gravel cell below. Pea gravel/sand must be used instead of filter fabric because the fine components of the wetland soil may clog the filter fabric and restrict root growth. The portion of the pipes that pass through the wetlands planting media and through the berm between the cells must be solid as shown above.

Table 5.7
Design Criteria for Gravel Wetlands

Wetland Design Feature	Size
Minimum wetland soil depth	8 inches
Minimum pea gravel depth	3 inches
Minimum crushed stone depth	24 inches
Minimum distance flow length in gravel substrate cell	15 ft (for each cell)
Drain time of wetlands cells	30 to 48 hours
Forebay Volume	10% of WQV
Temporary Wetlands Volume (Per Cell)	50% of WQV
Distance of outlet invert above bottom of wetland soil	4 inches

Submerged Gravel Beds

a. The gravel cells must be a minimum of 24 inches deep filled with ¾-inch crushed stone. It is essential that the gravel cells remain submerged in order for denitrification to occur.

b. The bottom of the gravel wetlands does not require a separation from the seasonal high groundwater table; however, the bottom of the gravel bed must be enclosed with a liner or other impervious material to ensure that the gravel bed remains saturated, and to prevent the migration of the stormwater into the adjacent groundwater table. The elevation of the outlet pipe and box, including bedding materials must be at or above the seasonal high groundwater table or lined.

Subdrains and Outlets

a. The SGW must be design to drain the water quality design storm between 24 to 48 hours. The drain time is controlled by an orifice at the outlet structure, placed four inches above the bottom of the wetland soil bed. If designs include flow through the subsurface gravel significantly greater than 30 feet, additional analysis should be performed to determine whether the orifice or the losses through the subsurface gravel system controls the drain time. In addition, the riser pipes or underdrains must be sized with sufficient capacity that that they do not control the drain time of the system.

b. The outlet structure must have an adjustable outlet to allow vegetation to initially establish. Once the vegetation is established, the outlet structure must maintain the water elevation at four (4) inches above the bottom of the wetlands soil.

c. Subsurface gravel wetlands should be equipped with a bottom drain pipe valve at an elevation a minimum of three (3) inches above the bottom of the gravel bed for maintenance. Maintenance plans must clearly indicate that all valves for maintenance are to remain closed except as necessary for specific maintenance activities, such as the temporary draindown or backflush of the subsurface wetlands cell if necessary. Such drains must be controlled by a lockable valve that is readily accessible from the outlet structure.

d. Care should be taken to not design a siphon that would drain the wetland: the primary outlet location must be open or vented.

Overflow Bypass

a. Subsurface gravel wetlands must be able to convey peak flows greater than the WQV to downstream drainage systems in a safe and stable manner. SGWs classified as dams by CTDEEP must also meet the overflow requirements of these Standards.

b. Vertical perforated or slotted riser pipes deliver water from the surface down to the subsurface, perforated or slotted distribution lines. These risers shall have a maximum spacing of 15 feet (4.6 m). Oversizing of the perforated or slotted vertical risers is useful to allow a margin of safety against clogging with a minimum recommended diameter of 12" (30 cm) for the central riser and 6" (15 cm) for end risers. The vertical risers shall not be capped, but rather covered with an inlet grate to allow for an overflow when the water level exceeds the WQV.

c. Vertical cleanouts connected to the distribution and collection subdrains, at each end, shall be perforated or slotted only within the gravel layer, and solid within the wetland soil and storage area above. This is important to prevent short-circuiting and soil piping.

Tailwater

a. The design of all hydraulic outlets must consider any significant tailwater effects of downstream waterways or facilities. This includes instances where the lowest invert in the outlet or overflow structure is below the flood hazard area design flood elevation of a receiving stream.

Maintenance

Effective subsurface gravel wetland performance requires regular and effective maintenance. Maintenance requirements for gravel wetlands are presented below. These requirements must be included in the maintenance plan.

General Maintenance

a. All subsurface gravel wetland components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least twice annually and as needed. The forebay must be cleaned when it accumulates to either six (6) inches or 10% of the forebay volume or if it remains wet nine hours after the end of a storm event.

b. The subsurface gravel wetland system has many components that allow portions of the system to drain for maintenance purposes or for the initial establishment of vegetation. The standard status of these valves or other controls must be clearly indicated in the maintenance plan to ensure that the hydraulics function as designed.

c. Disposal of debris, trash, sediment, and other waste material must be done at suitable disposal/recycling sites and in compliance with all applicable local, state, and federal waste regulations.

Vegetated Areas

a. The wetlands vegetation must be harvested at least once every three years and no more frequently than once a year.

b. When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed at least twice annually during both the growing and non-growing seasons. The vegetative cover must be maintained at 85 percent. If vegetation has greater than 50 percent damage, the area must be reestablished in accordance with the original specifications and the inspection requirements presented above.

c. The types and distribution of the dominant plants must also be assessed during the semi-annual wetland inspections described above. This assessment should be based on the health and relative extent of both the original species remaining and all volunteer species that have subsequently grown in the wetland. Appropriate steps must be taken to achieve and maintain an acceptable balance of original and volunteer species in accordance with the intent of the wetland's original design.

d. All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health should not compromise the intended purpose of the subsurface gravel wetland. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

Structural Components

a. All structural components must be inspected for cracking, subsidence, spalling, erosion, and deterioration at least annually.

Other Maintenance Criteria

a. The system must take between 24 hours and 72 hour to drain. If the drain time is significant longer than 72 hours or shorter than 24 hours for a storm event of one-inch or more, the wetland's outlet structure, perforated pipe performance, forebay, valves, and other components that may provide hydraulic controls must be evaluated and appropriate measures taken to comply with the minimum and maximum drain time requirements and maintain the proper functioning of the subsurface gravel wetland. All the components that must be checked in such cases must be listed in the maintenance plan for the system.

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