Chapter 5 – Low Impact Development Site Planning and Design Strategies

Introduction

This chapter addresses the use of Low Impact Development (LID) site planning and design strategies to reduce stormwater runoff volumes and pollutant discharges. LID site planning and design is a non-structural approach for avoiding or reducing the impacts of development on natural site hydrology, which can minimize the need for structural stormwater Best Management Practices (BMPs).

What's New in this Chapter?

- Replaces and integrates the 2011 Low Impact Development Appendix into the revised Manual
- Streamlines content to focus on non-structural LID site planning and design strategies (Chapters 7 through 13 address structural LID measures)
- Provides design guidance for impervious area (simple) disconnection
- Incorporates LID credits to help quantify the benefits and incentivize the use of certain non-structural site planning and design techniques for meeting the runoff volume and pollutant reduction standard in Chapter 4 - Stormwater Management Standards and Performance Criteria

Stormwater Management Standard 1, as described in Chapter 4 - Stormwater Management Standards and Performance Criteria of this Manual, requires project proponents to consider the use of LID site planning and design strategies, to the Maximum Extent Practicable, to reduce and disconnect post-development impervious areas on a site prior to consideration of structural stormwater BMPs. Once LID site planning and design techniques have been considered and applied appropriately, structural stormwater BMPs should be used to retain on-site or treat the remaining required post-development stormwater runoff volume. This approach incorporates LID as the industry standard for all sites and encourages the integration of non-structural LID techniques early in the site planning and design process, consistent with the CT DEEP stormwater general permits.

This chapter provides guidance on the use of LID site planning and design strategies, including LID credits for common impervious area reduction and disconnection techniques, to help project proponents use these measures to meet the runoff volume and pollutant reduction requirements of Standard 1. Local development regulations and ordinances often dictate the extent to which these strategies can be applied for a particular project. Therefore, communities may need to revise their local land use regulations and ordinances to allow the use of these strategies. This chapter also provides guidance to communities for revising local land use regulations to enable and encourage the use of LID site planning and design strategies.

What is LID?

Low Impact Development (LID) is a site design and stormwater management strategy that maintains, mimics, or replicates pre-development hydrology through the use of numerous site design principles and small-scale structural stormwater practices distributed throughout a site to manage runoff volume and water quality at the source. LID includes the use of both non-structural site planning and design techniques, which are addressed in this chapter, and the use of distributed, small-scale structural stormwater BMPs, which are addressed in Chapter 13 - Structural Stormwater BMP Design Guidance and other sections of this Manual.

The fundamental objective of LID is to *avoid*, *reduce*, and *manage* the adverse impacts of development or redevelopment sites while still enabling the intended use of the site and enhancing the development relative to conventional development. The over-arching goals of LID and associated principles for achieving these goals are as follows:[51]

1. **Avoid Impacts**
    a. Protect as much undisturbed open space as possible to maintain pre-development hydrology and allow precipitation to naturally infiltrate into the ground.
    b. Maximize the protection of natural drainage areas, streams, surface waters, wetlands, and jurisdictional wetland buffers.
    c. Minimize land disturbance, including clearing and grading, and avoid areas susceptible to erosion and sediment loss.
    d. Minimize soil compaction and restore soils that were compacted due to construction activities or prior development
    e. Preserve the natural water cycle.
2. **Reduce Impacts**
    a. Provide low-maintenance, native vegetation that encourages water retention and minimizes the use of lawns, fertilizers, and pesticides.
    b. Minimize new impervious surfaces.
    c. Match as closely as possible the pre-development or natural site runoff characteristics in terms of volume and timing of runoff (mimic the natural water cycle).
3. **Manage Impacts at the Source**
    a. Break up or disconnect the flow of runoff from impervious surfaces by directing it to adjacent pervious, vegetated surfaces (disconnect).
    b. Infiltrate precipitation as close as possible to the point it reaches the ground using multiple, small-scale structural stormwater BMPs distributed throughout a site (decentralize and distribute).

[51] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

c. Utilize less complex, non-structural methods for stormwater management that are lower cost and lower maintenance than conventional structural controls.
d. Provide source controls to prevent or minimize the use or exposure of pollutants into stormwater runoff at the site in order to prevent or minimize the release of those pollutants into stormwater runoff.

Benefits of LID

LID provides a number of benefits and advantages over traditional development and stormwater management approaches. Some of these benefits and advantages include:

Reduced consumption of land for stormwater management. LID practices rely upon the natural capacity of undisturbed land to absorb precipitation thus reducing the need for structural stormwater controls that often require significant land area. When structural controls are still needed, they are typically small, close to the source of runoff, and can be integrated into the areas of the site that are typically not used for stormwater management.

Reduced development costs. Traditional stormwater management can require substantial land clearing, earthwork, structural drainage systems, and structural stormwater controls. LID approaches involve more compact design with less land clearing and earthwork, less impervious area, and the use of natural flow paths and vegetated conveyances instead of catch basins and pipes. This results in reduced reliance on drainage infrastructure, smaller stormwater controls, and reduced need for excavation and construction materials, which translates into cost savings to developers.

Increased property values. In addition to reduced development costs, sites that employ LID can have increased property values by improving the quality of building lots and increasing their marketability (e.g., greater sense of community cohesion and character, more attractive landscape, and more open space for conservation and recreation).

More aesthetically pleasing development. Traditional stormwater management tends to incorporate the use of large, unnatural looking practices such as detention ponds that take up valuable space on a site. When neglected, these practices may present safety and mosquito concerns. LID can result in a more aesthetically pleasing and naturally attractive landscape.

Reduced maintenance. Most LID site planning and design techniques require little or no maintenance. LID structural practices generally require less maintenance and similar or lower maintenance costs that traditional drainage systems. Much of the maintenance that is required can be accomplished by the average landowner or contracted landscape maintenance companies.

Preserved site hydrology. LID management mimics natural site hydrology and relies on the ability of undisturbed land to retain and absorb runoff from impervious surface. Runoff that is absorbed recharges groundwater and stream baseflow and does not need to be managed or controlled by a structural stormwater practice.

Reduced pollutant loads and improved water quality. LID approaches reduce the loading of sediments, nutrients, and pathogens to streams and other waterbodies because. Landscapes that utilize LID practices minimize discharge and often retain all runoff from events smaller than the 2-year, 24-hour design storm. The runoff volume reduction benefits of LID result in significantly reduced pollutants loadings compared to structural stormwater BMPs that rely on pollutant removal through treatment alone.

Preservation of natural systems. LID preserves large portions of contiguous land in an undisturbed, natural state, which preserves the chemical, biological, and ecological integrity of natural systems.

Enhanced climate and community resilience. Improved land use strategies contribute to community resiliency and can help mitigate impacts from climate change. For example, LID can help avoid or reduce increases in runoff volumes and peak flows to existing urban infrastructure that is, in many cases, already undersized due to past development and vulnerable to more intense and frequent storms. Maintaining existing site vegetation, minimizing and disconnecting impervious surfaces, and using small-scale controls that rely on vegetation can also provide shading and cooling of runoff from impervious surfaces, mitigating increased temperatures.

LID Site Planning and Design Techniques

The remainder of this chapter focuses on non-structural LID site planning and design techniques, which should be applied to the MEA (see Standard 1 in Chapter 4 - Stormwater Management Standards and Performance Criteria) prior to consideration of structural stormwater BMPs. Once LID site planning and design techniques have been considered and applied appropriately, structural stormwater BMPs should be used to manage the remaining required post-development stormwater runoff volume (see Chapter 13 - Structural Stormwater BMP Design Guidance and other sections of this Manual).

Table 5- 1 summarizes and categorizes LID site planning and design techniques according to the three broad objectives described previously – avoiding, reducing, and managing impacts. The following sections describe each technique. Applications of these techniques and related LID site planning and design credits are described in later sections of this chapter.

Table 5- 1 LID Site Planning and Design Techniques

LID Objective	Site Planning and Design Technique
Avoid Impacts	➢ Minimizing Soil Compaction ➢ Minimizing Site Disturbance ➢ Protecting Sensitive Natural Areas ➢ Preserving Vegetated Buffers ➢ Avoiding Disturbance of Steep Slopes ➢ Siting on Permeable and Erodible Soils ➢ Protecting Natural Flow Pathways ➢ Conservation and Compact Development
Reduce Impacts	➢ Reducing Impervious Surfaces o Local Roads o Cul-de-sacs o Sidewalks o Driveways o Buildings o Parking Lots ➢ Preserving Pre-development Time of Concentration ➢ Use of Low Maintenance Landscaping
Manage Impacts at the Source	➢ Disconnecting Impervious Surfaces (DCIA reduction) o Impervious Area (Simple) Disconnection ▪ Building Roof Runoff ▪ Road, Driveway, and Parking Lot Runoff ▪ Stormwater Runoff from Solar Arrays o Disconnection Using Structural Stormwater BMPs ➢ Conversion of Impervious Areas to Pervious Areas ➢ Source Controls

Avoid Impacts

Minimizing Soil Compaction

Healthy soils, which have not been compacted, perform numerous valuable stormwater functions, including:

- Effectively cycling nutrients
- Minimizing runoff and erosion
- Maximizing infiltration of stormwater and water-holding capacity

- Absorbing and filtering excess nutrients, sediments, and pollutants to protect surface and groundwater
- Providing a healthy root environment
- Creating habitat for microbes, plants, and animals
- Reducing the resources needed to care for turf and landscape plantings.

When soils are overly compacted, the soil pores are destroyed and permeability is drastically reduced. In fact, the runoff response of vegetated areas with highly compacted soils closely resembles that of impervious areas, especially during large storm events.[52]

Minimizing soil compaction is the practice of protecting and minimizing damage to existing soil quality caused by the land development process. Minimizing soil compaction is not only important for drainage of a site and the successful use of other LID site planning and design techniques and structural stormwater BMPs, but also for minimizing impacts to established vegetation. Heavy equipment used within the drip line of a tree can cause soil compaction, resulting in the death of tree roots. Damage done to a tree's root system may take 3 to 4 years after construction to become evident in a tree's canopy. Maintaining healthy soil can significantly reduce the cost of landscaping vegetation (higher survival rate, less replanting) and landscaping maintenance.

Specific techniques to minimize soil compaction include:

- Fencing off an area during construction ("no disturbance areas") to minimize unnecessary soil disturbance and compaction. Vehicle movement, storage, or equipment/material lay-down are not to be permitted in such areas.

- Use of the smallest (lightest) equipment possible and minimizing travel over areas that will be revegetated (e.g., lawn areas) or used for infiltration of stormwater runoff from impervious surfaces such as adjacent pervious areas.

- Prohibiting the use of excavation equipment within the limits of infiltration-based structural stormwater BMPs to avoid compaction of the bottom of the infiltration system. A hydraulic excavator or backhoe loader, operating outside the limits of the infiltration system, should be used to excavate and place materials in the excavation, which should then be raked by hand.

- Restoring soils compacted as a result of construction activities or prior development. This typically requires modification of the underlying soils to restore the pre-development infiltration rate and soil porosity and improve soil quality to support vegetation. The soil should be treated by scarification, ripping (tilling), or use of a shatter-type soil aerator to a depth of 9 to 12 inches or more depending on site and soil conditions. Amendment with 2

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[52] Schueler, T.R. 1995. *Site Planning for Urban Stream Protection*. Metropolitan Washington Council of Governments, Washington, D.C

to 4 inches of topsoil or organic material may be required to improve plant establishment based on soil testing results.

Minimizing Site Disturbance

Land disturbance, including clearing and grading, can dramatically alter the pre-development hydrology of a site, exposing soils to erosion, compacting the soils by heavy equipment, and altering the natural terrain and drainage patterns. The limits of clearing and grading refer to the part of the site where development will occur. This includes impervious areas such as roads, sidewalks, and buildings, as well as pervious areas such as lawn and open drainage systems. Limiting the land area disturbed by development (i.e., development footprint) is most effectively addressed at the site planning level.

Specific techniques for minimizing site disturbance include:

- Land disturbance activities should be limited to only those areas absolutely necessary for construction purposes. The disturbance limits should reflect reasonable construction techniques and equipment needs together with the physical constraints of the development site such as slopes, soils, and natural features to be avoided (including avoiding disturbing topsoil).

- At a minimum, the 100-year floodplain, wetlands and associated buffers, areas with erodible soils, forested areas and other natural open space to be protected, and areas designated for stormwater practices should be protected from disturbance and/or compaction.

- Limits of disturbance may vary by type of development, size of lot or site, and by the specific development feature involved. For example, for sites not previously developed or graded, limit site disturbance with the following recommendations:[53]

    - 40 feet beyond the building perimeter and parking garages

    - 10 feet beyond surface walkways, patios, surface parking and utilities less than 12 inches in diameter

    - 15 feet beyond primary roadway curbs and main utility branch trenches

    - 25 feet beyond constructed areas with permeable surfaces (such as permeable paving areas, infiltration-based stormwater BMPs, and playing fields) that require additional staging areas to limit compaction in the constructed area.

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[53] U.S. Green Building Council (USGBC). 2018. LEED Version 4 for Neighborhood Development. Updated July 2, 2018.

- Use of "site fingerprinting" to minimize land clearing and grading by establishing a limit on the percentage of a parcel that can be developed, ensuring that a minimum percentage of the parcel remains in a natural undisturbed state. This technique reduces clearing to the minimum area required for building and roadway footprints, construction access, and safety setbacks.
    - For example, on previously developed or graded sites, restore or protect a minimum of 50% of the site area (excluding the building footprint) or 20% of the total site area (including building footprint), whichever is greater, with native or adapted vegetation.[53]

- The limits of land disturbance (and no disturbance) should be depicted on the approved site plans and should be delineated in the field with tape, signs, or orange construction fence prior to commencing land disturbance activities. These limits should be reviewed and modified as necessary during a mandatory on-site preconstruction meeting.

- Maintain the area outside the limits of disturbance at natural grade and retain existing, mature vegetated cover.

- As described in the Connecticut Soil Erosion and Sediment Control Guidelines, implement proper construction sequencing to reduce the duration of soil exposure. Construction sequencing is a site-specific work schedule that coordinates the timing of site development related land-disturbance activities and the implementation of temporary and permanent erosion and sediment control measures during any particular phase to minimize soil erosion and sedimentation. Wherever practicable, site construction activities should be phased, with each phase having its own construction sequence and erosion and sediment control measures, to avoid the disturbance of over 5 acres at one time or 3 acres for sites that discharge directly to impaired waters consistent with the requirements of the CT DEEP Construction Stormwater General Permit.

- Existing topsoil should be stored on-site and reused during final grading to the maximum extent practicable. Stockpile areas should be clearly identified on the site plan.

- As-built topographic surveys should be required for site compliance to prevent more cut and/or fill than shown on an approved site plan.

- Existing stands of forest should be identified and protected before construction activity begins to the maximum extent possible.

- Individual large trees (i.e., trees with a Diameter at Breast Height or DBH of 24 inches or greater measured 4.5 ft from the ground surface) should be retained whenever feasible; the area within the drip line, or crown of the tree, should be fenced or roped off to protect trees and their roots from construction equipment.

- Performance bonds should be required to ensure that sites are cleared and graded according to the approved site plan and to cover the replacement cost of trees and other vegetation earmarked for preservation when damaged by construction activities (up to two years after completion of construction).
- Developments that are designed to “fit the terrain” of the site require significantly less grading and soil disturbance than those that are designed without regard for the existing topography. Road patterns should match the landform by placing roadways parallel to contour lines where possible. In doing so, natural drainageways can be constructed along street rights-of-way, thereby reducing the need for storm pipes.

Protecting Sensitive Natural Areas

Sensitive natural areas include woodlands, significant tree species, wetlands and watercourses, floodplains, and other hydrologically sensitive and naturally vegetated areas. Preserving and avoiding land disturbance activities in close proximity to these resources are important strategies for preserving predevelopment hydrology, water quality, important ecological functions, and the natural character and aesthetic value of a site.

Protecting sensitive natural areas involves delineating and defining sensitive natural areas before performing site layout and design. Once sensitive natural areas on a site are delineated, ensure that these areas and native vegetation are protected in an undisturbed state throughout the design, construction, and occupancy stages of a project.

If an area is permanently protected under a conservation easement or other legally enforceable deed restriction that ensures perpetual protection of the proposed area, the project proponent can subtract the conservation area from the total site area when calculating the applicable Water Quality Volume. The easement must clearly specify how the natural area vegetation shall be managed and boundaries will be marked. Managed turf (e.g., playgrounds, regularly maintained open areas) is not an acceptable form of vegetation management. Credits for protecting sensitive natural areas are described in the Section titled LID Site Planning and Design Credits.

Preserving Vegetated Buffers

Vegetated buffers are naturally vegetated areas between developed land and surface waterbodies and wetlands. Vegetated buffers protect water quality by providing shade for cooling, stabilizing banks, mitigating flow rates, and providing for pollutant removal by filtering runoff and promoting infiltration. Vegetated buffers also provide flood storage and wildlife habitat.

Preservation of vegetated buffers involves delineating and preserving naturally vegetated buffers and implementing measures to ensure that buffers and native vegetation are protected throughout planning, design, construction, and occupancy. General guidelines and standards for vegetated buffers include:

- A minimum buffer width of 100 feet as measured from the edge of a resource (wetland, top bank elevation of a stream, etc.) is recommended to preserve most buffer functions. Larger buffer widths (up to 300 feet or more) may be necessary for critical resources such as public drinking water supplies or based on site characteristics such as slope, soils, land use, vegetation type, and other factors.

- The minimum recommended buffer width may not be achievable on existing developed sites. The greatest buffer width that is practical should be maintained and restored and should not be reduced to less than 25 feet or below local or state regulatory requirements.

- Other environmental features important to water quality preservation and enhancement should be included within the buffer, such as the 100-year floodplain and steep slopes.

- Vegetated buffers should be protected during construction. Buffer zones and limits of disturbance should be shown on every drawing within every set of construction plans including, but not limited to, clearing and grading plans and sediment control plans. Buffer limits should be staked out in the field prior to any construction activity. Limits of disturbance should be marked with orange construction fence barriers with accompanying signs.

- The vegetative species should reflect the predevelopment, natural vegetative community present in the area. This can be achieved by either preserving the existing vegetation or managing a disturbed buffer. Disturbed areas should be either planted with native species or allowed to revert to the natural vegetation over time, with an invasive species management plan. Some selective clearing may be allowed in the outer portion of a buffer to allow for removal of dead or diseased trees, especially those that pose a safety hazard.

- Although buffers should remain in a natural vegetated state, certain uses and activity restrictions are appropriate in different zones within the buffer depending on the width and density of vegetation. The inner half of the buffer along the shoreline or bordering wetland should remain as a "no touch" zone, with uses limited to passive recreation such as limited access paths for walking and canoe launches. The outer zone may be managed for heavier foot and bicycle traffic and may be acceptable for stormwater BMPs. Specific uses or activities within the upland review area associated with state jurisdictional wetlands also may be dictated by local inland wetlands and watercourses regulations.

- Design site runoff to enter the buffer as sheet flow. Where necessary, incorporate stormwater BMPs to retain and treat concentrated stormwater inflow to the buffer.

Avoiding Disturbance of Steep Slopes

The potential for soil erosion is significantly increased on slopes of 25% (4H:1V slope) or greater. Development on steep slopes also results in a larger disturbance footprint than development on flatter slopes. Development (clearing, grading, or other soil disturbance) on slopes of 25% or greater should be avoided.

Siting on Permeable and Erodible Soils

Whenever possible, highly erodible soils should be left undisturbed and protected from disturbance during site construction. Gravel soils tend to be the least erodible. As clay and organic matter increase, soil erodibility tends to decrease. Infiltration-based structural stormwater BMPs and pervious areas used for infiltration of runoff from adjacent impervious surfaces should be located on those portions of the site with the most permeable soils.

Protecting Natural Flow Pathways

Natural drainage features such as vegetated swales and channels and natural micro-pools or depressions should be preserved or incorporated into the design of a site to take advantage of their ability to infiltrate and attenuate flows and filter pollutants. Site designs should use and/or improve natural drainage pathways whenever possible to reduce or eliminate the need for stormwater pipe networks. Natural drainage pathways should be protected from significantly increased runoff volumes and flow rates through the use of upstream stormwater BMPs that control runoff volume and flow rate. Level spreaders, erosion control matting, revegetation, outlet stabilization, and check dams can also be used to protect natural drainage features.

Conservation and Compact Development

Compact development is a site development strategy that incorporates smaller lot sizes to reduce overall impervious cover while providing more undisturbed open space and protection of water resources. The strategy relies on mixed-use development patterns, which generate less stormwater than the typical single-use suburban model. In addition to stormwater and water quality benefits, compact development also promotes livability, walkability, and transportation efficiency, including a reduction in greenhouse gas emissions. This approach is also consistent with State of Connecticut policies to promote compact, transit accessible, pedestrian-oriented, mixed use development patterns and land use.

In a residential setting, compact development is referred to as “conservation” or “open space” development. Conservation development concentrates density in one portion of the site while preserving a large percentage of the site as open space. The similar concept of “cluster zoning” was adopted by many communities in the 1980s but did not include clear rationale or objective analysis to determine what open space or natural resources were most important to protect on a site. Conservation development promotes the use of existing opportunities and constraints to shape the final site design.[54] Conservation development is most effective for reducing impervious cover when used in conjunction other LID site design strategies that reduce the impacts of development such as narrower streets and reduced parking. Conservation subdivisions have also been shown to have marketing and sales advantages, as buyers prefer

[54] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

lots close to or facing protected open space. Conservation subdivisions have also been shown to appreciate faster than counterparts in conventional developments.[55]

Municipal land use regulations dictate the extent to which compact development strategies are allowed. Although many communities in Connecticut allow various forms of compact development, communities may need to re-evaluate local zoning and subdivision regulations to effectively promote the use of compact development strategies. The information sources listed at the end of this chapter provide additional information on how communities can modify local land use regulations to promote the use of compact development and related LID site planning and design techniques.

Reduce Impacts

Once a site development strategy has been selected, sensitive resource areas have been identified and preserved, and other site constraints have been avoided, the next objective of the LID site planning and design process is to reduce the impacts of land alteration. This includes minimizing the creation of new impervious surfaces, preserving the timing of site runoff to approximate pre-development conditions (i.e., slowing the flow), and the use of low maintenance LID landscaping.

Similar to avoidance of impacts, the extent to which impacts can be reduced on a site is also often dictated by local land use regulations, which have the potential to facilitate or hinder the implementation of LID site planning and design strategies. Communities should review and update their local land use regulations to reduce unnecessary creation of new impervious surfaces, remove barriers to the use of LID practices, and promote the use of low maintenance landscaping. The following sections provide strategies for communities to modify local land use regulations to reduce development impacts. Additional information on these topics can be found in the information sources listed at the end of this chapter

Reducing Impervious Surfaces

Reducing impervious surfaces includes minimizing areas associated with roads, sidewalks, driveways, buildings, and parking lots. By reducing the amount of impervious cover on a site, increases in post-development stormwater runoff are reduced while infiltration and evapotranspiration are increased. Reducing the area covered by impervious surfaces also provides greater opportunity for conservation of natural features and more space for vegetated swales, bioretention systems, and other structural stormwater BMPs.

Local Roads. Many local roads are wider than necessary. Reducing the length and width of roads can reduce the creation of new impervious surfaces. Other benefits of narrower roads

[55] Nonpoint Education for Municipal Officials (NEMO). 1999. "Conservation Subdivisions: A Better Way to Protect Water Quality, Retain Wildlife, and Preserve Rural Character". NEMO Fact Sheet #9.

include reduced clearing and grading impacts, reduced vehicle speeds (i.e., “traffic calming”), lower maintenance costs, and enhanced neighborhood character.

- Design local roads for the minimum required pavement width needed to support travel lanes; on-street parking; and emergency, maintenance, and service vehicle access. These widths should be based on future traffic volumes without compromising safety. Table 5- 2 provides recommended minimum road width standards for local roads.

Table 5- 2 Recommended Minimum Road Widths for Local Roads

Rural Local Roads (1)			
Annual Average Daily Traffic (AADT)	Type of Roadside Development		
	Open (Rural)	Moderate Density	High Density
<400	22	N/A	N/A
400 – 1,500	24	24	N/A
1,500 – 2,000	26	26	26
>2,000	28	28	28
Urban Local Roads			
On-Street Parking	Type of Area		
	Suburban	Intermediate	Built-Up
None (2)	24	24	24
One Side (3)	29	29	29
Both Sides (4)	34	34	34

Source: Adapted from CTDOT Highway Design Manual (2003 Edition including Revisions to February 2013)

Notes:

(1) Includes two travel lanes (9 to 12 feet in width) and two 2-foot shoulders.
(2) Includes two 10-foot travel lanes and two 2-foot shoulders.
(3) Includes two 10-foot travel lanes, one 2-foot shoulder, and one 7-foot parking lane.
(4) Includes two 10-foot travel lanes and two 7-foot parking lanes.
(5) Table excludes bicycle facilities, which are typically 5 feet wide.

- Consider site and road layouts that reduce overall street length. Reduce total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length. Conservation (open space) development and other compact forms of development can reduce overall street length.

- Consider elimination of curbs and the use of roadside vegetated open channels or swales as an alternative to traditional curb and gutter drainage (i.e., curbing, catch basins, and pipes), especially in low or medium density developments and slopes where roadside erosion is not a concern (typically slopes of less than 8 percent). Open vegetated channels provide the potential for infiltration and filtering runoff from impervious surfaces, as well as groundwater recharge and reduced runoff volume. In addition to the water quality benefits that open vegetated channels provide, these systems are also significantly less expensive to construct than conventional storm drain systems. The use of vegetated drainage swales in lieu of conventional storm sewers may be limited by soils, slope, and development density.

- Use curb extensions or "bumpouts" at roadway intersections or mid-block locations to reduce impervious area, manage stormwater through bioretention or other structural stormwater BMPs, provide traffic calming, and improve pedestrian safety. These practices are most applicable in medium or high-density developments.

- Use permeable pavement for on-street parking stalls, sidewalks, and crosswalks.

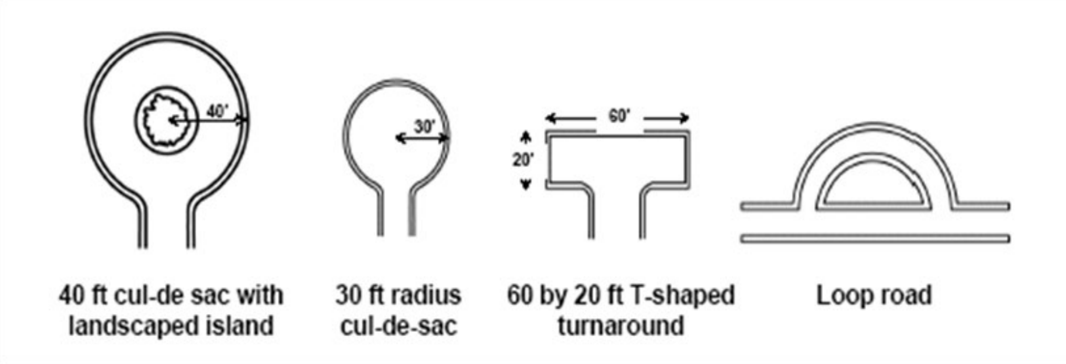
Cul-de-sacs. Cul-de-sacs are residential streets that are open at one end and have a dead-end at the other. Cul-de-sacs have a large "bulb" located at the closed end of the street to enable emergency and service vehicles to turn around without having to back up. Traditional cul-de-sacs utilize a large radius (50 to 60 feet or more), paved turnaround that can dramatically increase the imperviousness of a residential subdivision. Alternatives to this traditional design include turnaround bulbs with smaller radii and the use of a landscaped island (i.e., rain garden or bioretention area) in the center of the cul-de-sac to collect rainwater from the end of the roadway (Figure 5-1). The amount of pavement at cul-de-sac turnarounds can be reduced through the following techniques:

- Reduce the radius (and size) of the turnaround to the minimum required to accommodate emergency and maintenance vehicles, which is typically 30 to 40 feet. Consider the types of vehicles that may need to access a street. 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.

- Use a pervious center island (i.e., native vegetation or structural stormwater BMP such as an infiltration basin or bioretention system). If a cul-de-sac island is used, the cul-de-sac radius should allow for a minimum 20-foot-wide road.

- Minimize the number of cul-de-sacs and consider alternative turnaround designs such as hammerheads (T-shaped turnaround) and loop roads (jug handles).

Figure 5-1. Reduced Cul-de-Sac Radius and Alternative Turnaround Designs



Source: Adapted from Atlanta Regional Commission, 2001.[56]

Sidewalks. Subdivision codes often require sidewalks on both sides of the street, as well as a minimum sidewalk width and distance from the street, which can create excess impervious cover and stormwater runoff.

- Adopt flexible design standards that are based on safe pedestrian movement and limiting impervious cover.
- Limit sidewalks to one side of the street. A sidewalk on one side of the street may suffice in low traffic areas where safety and pedestrian access would not be significantly affected.
- Reduce sidewalk widths (3 to 4 feet), separate them from the street with a vegetated area, and grade sidewalks to drain into front lawns and away from rather than towards the street.
- Consider alternative surfaces such as permeable pavement or gravel where appropriate. Consider removing sidewalks from the roadway right-of-way and provide access to natural features or connect other destinations, such as a playground, park, or adjacent development.

Driveways. Driveways account for significant amounts of impervious cover in suburban residential development. Generally, local subdivision regulations do not contain explicit driveway design standards regarding dimensions and surface materials. Subdivision regulations also indirectly influence the length of the driveway when excessive front yard setbacks, which dictate how far houses must be from the street, are required. Overall lot imperviousness can be reduced by minimizing driveway lengths, encouraging alternative pervious surfaces, and allowing shared driveways wherever possible.

- Consider the use of shared driveways that connect two or more homes together.
- Consider minimum driveway widths of 9 feet or less (one lane) and 18 feet or less (two lanes).

[56] https://atlantaregional.org/natural-resources/water/georgia-stormwater-management-manual/

- Reduce front yard setbacks (20 to 30 feet), resulting in shorter driveways and reduced driveway imperviousness. A 20- to 30-foot-long driveway is generally adequate to meet parking needs.
- Use alternative permeable driveway surfaces (e.g., grass, gravel, permeable pavement) or the use of "two track" design for residential driveways (i.e., hard surface for vehicle tires to drive on, with grass or other permeable surface in-between and outside the tracks).

Buildings. Reducing the footprints of buildings can reduce the impervious cover in certain residential and commercial settings. Residential and commercial building footprint area can be reduced by using alternate or taller buildings while maintaining the same floor-to-area ratio.

- Minimize building footprint area and building setbacks.
- Consider the use of green roofs and the use of rain barrels and cisterns for stormwater harvesting and reuse.
- Direct roof runoff to vegetated pervious areas and structural stormwater BMPs such as rain gardens/bioretention systems, dry wells, and other infiltration or filtering systems.

Parking Lots. Parking lots account for a large percentage of impervious cover in commercial, industrial, and institutional settings. The amount of parking and associated impervious area is dictated by local land use regulations. Reducing parking ratio requirements, allowing the use of shared parking and off-site parking allowances, providing compact car spaces, minimizing stall dimensions, incorporating efficient parking aisles, use of structured parking, and using pervious materials in spillover parking areas can serve to minimize the total impervious areas associated with parking lots.

- **Parking Ratios.** The number of parking spaces at a site is determined by local parking ratios which dictate the minimum number of spaces per square foot of building space, number of dwelling units, persons, or building occupancy. Parking ratios are typically set as minimums, not maximums, thereby allowing for excess parking. Parking ratios also typically represent the minimum number of spaces needed to accommodate the highest hourly parking at the site.

    - Establish both minimum and maximum parking ratios to provide adequate parking while reducing excess impervious cover. Parking demand ratios should be based upon project-specific parking studies, where feasible. Allow additional spaces above the maximum ratio only if project-specific parking studies indicate a need for additional capacity.

    - Incorporate mechanisms into local zoning regulations that tailor parking requirements to specific development projects. Allow flexibility within the regulations and require the developer to demonstrate the appropriate amount of parking needed.[57]

- Strategies for eliminating or reducing excess parking through parking demand ratios include but are not limited to: 1) setting minimum and maximum parking ratios (providing a range of values) based on a local parking study, 2) starting with industry standard values such as those developed by the Institute of Transportation Engineers (ITE) and the Urban Land Institute (ULI) and adjusting those values to reflect local characteristics, 3) consider using current minimum parking ratios as the new maximum requirements, and 4) eliminating minimum parking requirements for non-residential properties.

- **Shared Parking.** Shared parking is a strategy that reduces the number of parking spaces needed by allowing a parking facility to serve multiple users or destinations. This approach is most successful when the participating facilities are in close proximity to each other and have peak parking demands that occur at different times during the day or week or if they share patrons that can park at one facility and walk to multiple destinations. Parking ratios can be reduced if shared parking arrangements are in place, when multi-modal transit (e.g., mass transit, bike share, or car share programs) is provided, or when nearby on-street parking is available. Shared parking generally requires contractual agreements between two adjacent users or the use of parking management districts with multiple property owners.[58]

  A related strategy is to reserve sufficient land on the project site for projected future parking requirements (e.g., future buildout or redevelopment), but only construct a portion of the parking area at the outset of the project, maintaining the additional parking as green space and converting to parking on an as-needed basis.

- **Off-Site Parking Allowances.** Current land use regulations in many communities require new development and redevelopment projects to provide all parking on-site and do not allow off-site parking availability to be counted. Communities should increase the flexibility of parking requirements and include off-site parking allowances for certain types of development such as redevelopment sites and compact mixed-use centers given the difficulty of complying with conventional on-site parking demands in such settings. Design standards should specify a maximum distance (typical walking distance of 400-800 feet)

[57] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

[58] Capitol Region Council of Governments (CRCOG). 2002. Livable Communities Toolkit: A Best Practices Manual for Metropolitan Regions, Shared Parking Fact Sheet.

and requirements for well-marked safe pedestrian travel between the site and off-site parking lot.[59]

- **Structured Parking.** Vertical parking structures can reduce impervious cover by reducing the parking footprint. In urban areas or areas where land availability is limited or land costs are high, parking garages are generally more economical to build than purchasing additional land. In such areas, communities should consider using incentives (e.g., tax credits; stormwater waivers; or density, floor area, or height bonuses) to encourage the use of multi-level, underground, and under the building parking garages.[60]

- **Parking Stall and Aisle Geometry.** Local parking codes often require standard parking stall dimensions to accommodate larger vehicles. Reducing parking stall size and incorporating alternative internal geometry or traffic patterns through the use of one-way aisles and angled parking stalls can reduce parking lot size and impervious cover.

    - Reduce parking stall dimensions to 9 feet wide and 18 feet long.
    - Encourage one-way aisles used in conjunction with angled parking to reduce the amount of aisle space needed to access each stall, depending on the geometry of the parking lot.
    - Allow for a portion of parking lots to be comprised of compact car spaces (e.g., 8-foot by 16-foot stalls or smaller) including signage clearly designating compact car spaces.

- **Alternative Paving Materials.** Impervious cover can also be reduced through the use of alternative paving materials (e.g., permeable pavement) for parking stalls, parking aisles, and overflow parking. Local land use regulations should allow for the use of permeable pavement and promote the use of such materials in low traffic areas such as overflow parking areas. Chapter 13 - Permeable Pavement contains design guidance for permeable pavement systems including porous asphalt, pervious concrete, permeable interlocking concrete pavers, and other open course paver systems (plastic turf reinforcing grids, concrete grass pavers, etc.).

- **Parking Lot Landscaping.** Landscaped areas within and around parking lots can reduce the amount of impervious cover, allow for retention and treatment of parking lot runoff, provide tree canopy and shading, and enhance the appearance of a parking lot and associated development. Small-scale infiltration and treatment stormwater BMPs (e.g., bioretention, tree filters, vegetated filter strips, water quality swales, etc.) can be incorporated into parking islands and around the perimeter of parking lots.

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[59] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

[60] Center for Watershed Protection (CWP). 2017. Better Site Design Code and Ordinance Worksheet. December 2017.

- Require a minimum percentage of a parking lot to be landscaped.
- Allow the use of structural stormwater BMPs and open section drainage (via sheet flow and flush curbs or curb cuts) within landscaped areas, setbacks, or parking areas.
- Require landscaping within parking areas that "breaks up" pavement at fixed intervals and allow vegetated stormwater management areas to count toward required landscape minimums.
- Consider requiring a minimum amount of tree canopy coverage over on-site parking lots. A minimum landscape area width of 6 feet is recommended to support large, mature trees.

Preserving Pre-development Time of Concentration

The peak discharge rate and volume of stormwater runoff from a site are influenced by the runoff travel time and hydrologic characteristics of the site. Runoff travel time can be expressed in terms of "time of concentration" which is the time it takes for runoff to travel from the most distant point of the site or watershed to the downstream outlet or design point. Runoff flow paths, ground surface slope and roughness, and channel characteristics affect the time of concentration. Increasing the post-development time of concentration to match the time of concentration for pre-development conditions can substantially reduce development impacts in terms of peak rates of runoff and runoff volumes. Site design techniques that can modify or increase the runoff travel time and time of concentration include:

- Maximizing overland sheet flow.
- Maintaining pre-development flow paths on vegetated surfaces.
- Increasing the number of and lengthening flow paths on vegetated surfaces.
- Minimizing the number and length of flow paths on impervious surfaces.
- Maintaining overland flow across vegetated surfaces and areas with permeable soils.
- Maintaining pre-development infiltration rates by preserving those areas of the site. with high-permeability soils.
- Maximizing use of vegetated swales for the conveyance of stormwater instead of traditional curb/gutter and piped drainage systems.
- Maintaining or augmenting existing vegetation on the site.

Use of Low Maintenance Landscaping

As described in Chapter 6 - Source Control Practices and Pollution Prevention, lawns and other landscaped areas can contribute stormwater runoff pollution, resulting in adverse impacts to surface waters and groundwater, due to overfertilization, overwatering, overapplication of pesticides, and direct disposal of lawn clippings, leaves, and trimmings.

To reduce these potential impacts, low-maintenance, native vegetation should be used along with other LID landscaping techniques to minimize lawn area, irrigation needs, fertilizers, and pesticides. This approach can also help conserve water by reducing irrigation water demand and increase resilience of surface and groundwater resources during periods of drought. Chapter 6 -

Source Control Practices and Pollution Prevention contains links to additional sources of information on low maintenance and LID landscaping practices.

Communities should also develop or update their local land use regulations to reflect low maintenance or LID landscaping approaches that specifically address the link between a functional landscape and protection of water quality, water conservation, and resilience. LID landscape regulations should also be tailored to different land uses, densities, and locations.[61]

Manage Impacts at the Source

After all reasonable efforts to avoid and reduce impacts are exhausted, the final objective of the LID site planning and design process is to manage any remaining stormwater impacts including increases in runoff volume, pollutant loads, and peak flows. Techniques for managing stormwater impacts include disconnecting impervious surfaces by directing runoff to adjacent vegetated pervious areas (simple disconnection) or to structural stormwater BMPs located close to the source of runoff, conversion of impervious to pervious areas, and the use of source controls and pollution prevention.

Disconnecting Impervious Surfaces

As described in Chapter 2 - Stormwater Impacts, impervious surfaces with a direct hydraulic connection to a storm drainage system or a waterbody are considered "Directly Connected Impervious Area (DCIA)." Impervious surfaces that are separated from drainage systems or a waterbody by pervious surfaces or structural stormwater BMPs designed to retain the appropriate portion of the site's Water Quality Volume (WQV) are considered "disconnected" and contribute less runoff and reduced pollutant loading. Disconnecting impervious surfaces promotes infiltration and filtration of stormwater runoff and the reduction of DCIA. The two primary strategies for disconnecting impervious surfaces are described below.

Simple Disconnection. Impervious area disconnection, also called "simple disconnection," is a non-structural technique that involves directing stormwater runoff from impervious surfaces as sheet flow onto adjacent vegetated pervious surfaces where it has the opportunity for infiltration and treatment. Simple disconnection can be used to direct runoff from roofs, driveways, roads, parking lots, and solar arrays to vegetated pervious areas that meet specific characteristics (also called "Qualifying Pervious Areas") such that the appropriate portion of the site's WQV is dispersed and retained/infiltrated on-site without causing erosion or basement seepage. Key characteristics of the receiving pervious area include slope, soil infiltration capacity, dimensions and flow path length, size relative to the contributing area, and density of vegetation. Sites with flatter slopes, pervious soils, and a dense stand of vegetation are better

[61] Rhode Island Department of Environmental Management (RIDEM) and Coastal Resources Management Council (CRMC). 2011. Rhode Island Low Impact Development Site Planning and Design Guidance Manual.

suited for maintaining dispersed flow. Flows for larger storm events should bypass or exit the pervious area in a controlled manner.

Credits for the use of simple disconnection to meet the runoff volume and pollutant reduction requirements of Standard 1 (refer to Chapter 4 - Stormwater Management Standards and Performance Criteria) are described in LID Site Planning and Design Credits, including minimum criteria for receiving credit and restrictions on the use of simple disconnection.

Disconnection Using Structural Stormwater BMPs. Impervious areas that discharge runoff to structural stormwater BMPs designed to retain the appropriate portion of the Water Quality Volume (i.e., Infiltration BMPs or Stormwater Reuse BMPs) are also considered disconnected. Small-scale structural stormwater BMPs located close to the impervious areas where runoff is generated are generally preferred over large end-of-pipe controls. Chapters 8-13 of this Manual provide guidance on the selection, design, construction, and maintenance of structural stormwater BMPs to meet the stormwater management standards and performance criteria outlined in Chapter 4.

Conversion of Impervious to Pervious Areas

Impervious area conversion involves removing and replacing existing excess impervious surfaces (pavement, buildings, etc.) with pervious vegetated surfaces (lawn, meadow, woods) and restoring the pre-development infiltration rate and storage capacity (i.e., porosity) of the underlying soils. Conversion of the impervious surface to a vegetated pervious surface results in a reduction in runoff volume and pollutant loads and an increase in infiltration and groundwater recharge. This technique is applicable to redevelopment and retrofit situations. Credits for the use of impervious area conversion on redevelopment sites are described in LID Site Planning and Design Credits. Chapter 9 - Stormwater Retrofits provides additional guidance on impervious area conversion.

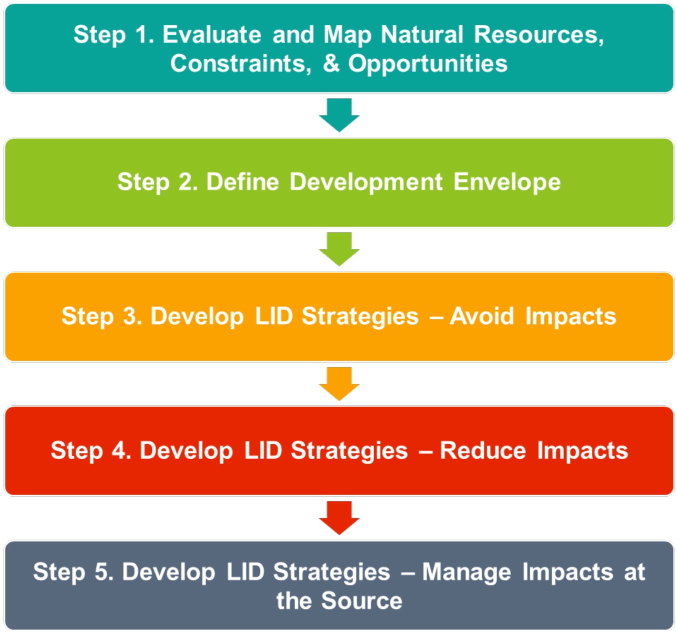
Source Controls and Pollution Prevention

Utilizing the source controls and pollution prevention measures described in Chapter 6 - Source Control Practices and Pollution Prevention can help minimize or prevent the discharge of pollutants in stormwater runoff. Source control practices and pollution prevention are operational practices (e.g., street and parking lot sweeping, catch basin cleaning and drainage system maintenance, and lawn and landscape management) that limit the generation of stormwater pollutants at their source and should be incorporated, to the maximum extent practicable, into the site design and operational aspects of all land development projects.

LID Site Planning and Design Process

Using LID successfully requires consideration of LID site planning and design strategies from the project's inception through final design. The LID site planning and design process focuses on the basic LID principles of preserving natural site characteristics and pre-development hydrology.

Figure 5-2. LID Site Planning and Design



The recommended LID site planning and design process is shown schematically in Figure 5-2. LID Site Planning and Design Process. This process is most applicable to new development, although the same principles and strategies can be applied to redevelopment projects and retrofits.

Once the local, state, and federal regulatory requirements and relevant stormwater management standards for a project are determined, the LID site planning and design process begins by evaluating and mapping existing natural resources as well as site constraints and opportunities for the use of LID techniques. The areas identified to be preserved in a natural state help define the remaining developable area or "development envelope" for the site. LID strategies are then applied within the development envelope to further avoid impacts, reduce impacts, and manage impacts at the source, in that order of priority, as described in the previous sections.

Appendix E contains a checklist for use by project proponents, designers, and reviewers to help document the consideration and use of LID site planning and design techniques to the "Maximum Extent Practicable," as described in Chapter 4 - Stormwater Management Standards and Performance Criteria.

Step 1. Evaluate and Map Natural Resources, Constraints, & Opportunities

The following natural resources, potential site development constraints, and opportunities for the use of LID techniques should be evaluated and shown on an existing conditions base map of the project site (also referred to as a "LID Site Planning and Design Opportunities and Constraints Plan").

Soils. Determine and map the major soil type(s) on the site and associated infiltration rates, erodibility, and other characteristics. General soils information can be obtained from the online USDA NRCS Web Soil Survey.

Wetlands, Rivers, and Streams. Show the boundaries of inland wetlands and watercourses (intermittent and perennial) on the site as delineated in the field by a Certified Soil Scientist or Professional Wetland Scientist. Assess the quality of each wetland system (functions and values) on the site using methodologies established by the U.S. Army Corp of Engineers. Field-verify upland soil types on the site during the field delineation. Show regulatory buffers such as upland review areas and applicable stream or riparian buffer requirements. Since regulatory buffers vary by municipality, it is important to consult with the municipal wetland staff early in the development of the site plan. Also, field-delineate and show unique or significant wetland types such as vernal pools and associated upland protection buffer areas.

Natural Drainage Patterns and Hydrologic Features. Map prominent hydrologic features such as seeps, springs, drainage swales, and isolated depression storage areas. Show existing drainage patterns on the base map, as verified in the field.

Vegetation. Identify and show the existing vegetation types (deciduous forest, coniferous forest, meadow, etc.) and patterns on the site including tree lines. Features such as tree clusters, grassy areas, tidal and/or inland wetlands vegetation, and unique vegetation should be shown. Include all significant tree species with a Diameter at Breast Height (DBH) of 24 inches and greater measured at 4.5' above ground surface.

Flood Hazard Zones. Delineate the limits of the 1 percent annual chance (100-year) flood on the site based on surveyed site topography and the base flood elevation shown on available flood insurance mapping and flood studies by the Federal Emergency Management Agency (FEMA).

Bedrock. Identify areas of shallow bedrock or ledge based on soils mapping, test pits or soil borings, and visible rock outcrops.

Topography and Steep Slopes. Show site topography at 2-foot contour intervals obtained from traditional field survey or aerial survey methods by a licensed land surveyor. For sites with slopes less than 2%, include spot elevations and 1-foot contours. Determine and show areas of steep slopes, which are defined as slopes of 25% (4H:1V slope) or greater as measured over a minimum distance of 50 feet.

Coastal Resources. Identify and show coastal resources on or adjacent to the site including tidal wetlands, beach soils, dunes, bluffs, escarpments, coastal flood hazard areas, coastal waters, estuarine embayments, intertidal flats, submerged aquatic vegetation, and shellfish concentration areas. If applicable, identify and show the location of the Connecticut Coastal Jurisdiction Line (CJL), which is the jurisdictional limit for tidal, coastal, and navigable waters.

Other Sensitive Areas. Identify and map other sensitive areas on or near the project site including but not limited to watercourses supporting cold water fisheries, waters with identified water quality impairments or approved Total Maximum Daily Loads (TMDLs), state and federal listed species and significant natural communities identified by the CT DEEP Natural Diversity

Database, terrace escarpments located in the Connecticut River valley, agricultural land (prime farmland, unique farmland, and farmland of statewide or local importance), and stone walls.

Step 2. Define Development Envelope

Determine the development envelope in which buildings, roads and other constructed features may be sited with minimal impacts to natural resources and site hydrology. 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 define the development envelope:

1. Determine those environmentally sensitive areas to be protected from development such as wetlands, watercourses, vernal pools, and their associated buffer areas (see Step 1).
2. Delineate the different vegetative cover types on the site. Highlight those areas of special characteristics or environmental sensitivities. Areas with concentrations of trees with a diameter at breast height (DBH) of 24 inches or greater should be noted on the plan.
3. Determine and delineate steep slopes (slopes greater than 25% or 4H:1V slope as measured over a minimum distance of 50 feet).
4. Determine and delineate those soil areas which have moderate to high infiltration rates (A and B soils). These areas should be reserved for impervious area disconnection or infiltration systems.
5. Once the above areas have been clearly delineated on the base plan, the remaining areas generally define the development envelope. Determine and define the pre-development runoff patterns on the site in order to provide a preliminary understanding of the sites' drainage patterns and the ultimate discharge points.

Step 3. Develop LID Strategies – Avoid Impacts

Once the development envelope is defined, utilize other LID strategies to further avoid impacts including minimizing soil compaction, minimizing site disturbance, and conservation or other compact development approaches, as described in the section titled Avoid Impacts.

Step 4. Develop LID Strategies – Reduce Impacts

Implement LID strategies to further reduce development impacts, such as minimizing the creation of new impervious surfaces, preserving the timing of site runoff to approximate pre-development conditions, and using low maintenance LID landscaping, as described in the section titled Reduce Impacts.

Step 5. Develop LID Strategies – Manage Impacts at the Source

Finally, after all reasonable efforts to avoid and reduce impacts are exhausted, manage any remaining stormwater impacts by disconnecting impervious surfaces (direct runoff to adjacent vegetated pervious areas or to structural stormwater BMPs), converting impervious areas to pervious surfaces, and implementing source controls and pollution prevention measures, as described in the section titled Manage Impacts at the Source.

LID Site Planning and Design Applications

LID site planning and design strategies can be applied in a variety of land use settings for new development and redevelopment projects. The following sections provide common applications of LID site planning and design techniques for residential development and commercial/industrial/institutional development. The use of LID site planning and design strategies for retrofits, including parcel-based and roadway or right-of-way retrofit applications, are addressed in Chapter 9 - Stormwater Retrofits.

Residential Development

Compact Development

For new development, implement conservation or open space design strategies as much as possible to avoid impacts as described in the Section titled Avoid Impacts (e.g., minimize soil compaction and site disturbance; protect sensitive natural areas, vegetated buffers, and flow paths; and permanently set aside open space for multiple objectives including stormwater management).

House Lots

- Orient lots and buildings to maximize opportunities for simple disconnection, use of infiltration-based structural stormwater BMPs, and conveyance of stormwater through the use of vegetated open channels including linear bioretention and water quality swales.
- Convey stormwater from lots not adjacent to pervious vegetated areas using swales or dispersed as low velocity sheet flow to areas more conducive to infiltration.
- Locate lots adjacent to preserved open space to improve aesthetics and privacy.
- Orient lots to use shared driveways to access houses along common lot lines.

Roads

- Lay out roads and lots to minimize grading. Road alignments should follow existing grades to the extent possible.
- Consider reduced driveway widths and reduced front yard setbacks to limit driveway lengths.

- Use roadside vegetated open channels or swales as an alternative to traditional curb and gutter drainage (i.e., curbing, catch basins, and pipes) in low or medium density developments and where roadside erosion is not a concern (typically slopes of less than 8 percent).

- Use swales on one side of the road where roads with a cross slope are allowed. Otherwise, use a crowned road cross section and swales on both sides of the road.

- Completely eliminate curbing to promote sheet flow to roadside swales or use curb openings to convey gutter flow to roadside swales.

- For roads with grades generally greater than 8%, use catch basins and curb/gutter drainage, with catch basin outlets connected to roadside swales or other structural stormwater BMPs within the road right-of-way.

Driveways

- Grade driveways to adjacent open space and lawn areas (simple disconnection), rain gardens, or water quality swales to retain and infiltrate runoff on the lot and prevent driveway runoff from reaching the road.

- Consider use of driveway infiltration trenches, which are stone-filled trenches along the edge of a driveway to collect water from the driveway, allowing it to soak into the ground and reducing erosion along the edge of the driveway.

- Consider use of permeable surfaces such as porous asphalt, porous concrete, permeable concrete pavers, grass pavers, plastic turf reinforcing grids, and geocells (cellular confinement systems).

Roofs

- Direct roof downspouts to pervious vegetated areas (simple disconnection), dry wells or other small-scale infiltration systems (i.e., rain gardens), or to rain barrels for non-potable reuse such as lawn, landscape, or garden watering.

Lawns

- Use low-maintenance LID landscaping techniques to minimize lawn area and maintenance needs (e.g., irrigation, fertilizers, and pesticides).

- Use diverse selection of native vegetation species.

- Create shade by maintaining existing tree canopy and preserving natural/wild areas.

- Maintain pre-development flow path lengths in natural drainage patterns.

Commercial, Industrial, and Institutional Development

This section addresses LID site planning and design strategies for new development and redevelopment sites in commercial (office buildings, small commercial buildings, and big box retail), industrial, and institutional settings. These sites typically have larger building footprints and parking facilities, which can result in greater impervious cover and stormwater impacts. Such sites also present opportunities to reduce and manage stormwater impacts by minimizing and disconnecting impervious surfaces.

Compact Development

- For new development, implement conservation or open space design strategies as much as possible to avoid impacts as described in the Section titled Avoid Impacts (e.g., minimize soil compaction and site disturbance; protect sensitive natural areas, vegetated buffers, and flow paths; and permanently set aside open space for multiple objectives including stormwater management).

Parking Lots

- Lay out and grade parking lots to direct runoff to structural stormwater BMPs (e.g., bioretention, tree filters, and water quality swales) in parking islands and around the perimeter of parking facilities to retain and infiltrate stormwater and convey it to other structural stormwater BMPs if necessary. Eliminate curbing or use curb cuts to direct sheet flow runoff into these features.
- Consider use of impervious area disconnection (simple disconnection) to direct runoff to adjacent vegetated areas if there is sufficient land area on the site.
- Where surface area is limited, use underground infiltration systems and underground detention below parking lots.
- Use permeable pavement for parking stalls, parking aisles, and overflow parking.
- Provide compact car spaces, minimize parking stall dimensions, and incorporating efficient parking aisles such as diagonal parking spaces with one-way aisles.
- Consider shared parking agreements with adjacent or nearby properties.
- Consider use of structured parking.
- Pretreatment is required for runoff from parking lots prior to entering a structural stormwater BMP (see Chapter 13 - Structural Stormwater BMP Design Guidance) or prior to discharge to adjacent vegetated areas through the use of impervious area disconnection (simple disconnection).
- Infiltration of stormwater from industrial and commercial facilities is restricted for certain Land Uses with Higher Potential Pollutant Loads (LUHPPLs) (see Chapter 10 - General

Design Guidance for Stormwater Infiltration Systems), in locations where contaminated soils exist, where the required vertical separation to SHGT cannot be met, or in locations with unacceptable horizontal setbacks for infiltration.

Roofs

- Direct roof downspouts to pervious vegetated areas (simple disconnection), dry wells or other infiltration systems, or to cisterns for non-potable reuse such as lawn or landscape irrigation.
- Consider use of green roofs to manage runoff from building roof areas.

Lawn and Landscaped Areas

- Use low-maintenance LID landscaping techniques to minimize lawn area and maintenance needs (e.g., irrigation, fertilizers, and pesticides).
- Use diverse selection of native vegetation species.
- Incorporate trees in bioretention systems within parking lot islands and around the perimeter of parking lots to provide shade and cooling of impervious surfaces and stormwater runoff during the summer.
- Maintain pre-development flow path lengths in natural drainage patterns.

LID Site Planning and Design Credits

Credits are a way of quantifying the benefits of LID site planning and design techniques, providing additional incentive to use non-structural approaches for meeting the runoff volume and pollutant reduction requirements of Standard 1, as described in Chapter 4 - Stormwater Management Standards and Performance Criteria. LID site planning and design credits may be used to reduce the required Water Quality Volume and Required Retention Volume, provided that the proposed measures meet specific minimum criteria. Implementing such LID site planning and design measures (i.e., those that meet the criteria to receive credits) can reduce or eliminate the need for structural stormwater BMPs.

This section presents credits for the following non-structural LID site planning and design techniques for managing impacts at the source:

- Impervious area conversion
- Impervious area (simple) disconnection
    - Roof runoff
    - Driveways, roads, and parking lot runoff
    - Stormwater runoff from solar arrays.

These techniques provide quantifiable runoff volume and pollutant reduction benefits. For each LID site planning and design technique, a description of the credit is provided along with the minimum criteria for receiving credit.

Credits are not provided for the LID site planning and design techniques described in this chapter that are designed to avoid or reduce impacts. Such techniques involve minimizing land disturbance and impervious area and conserving natural site features, all of which contribute to a reduction in runoff volume and pollutant loads. Standard 1 requires project proponents to consider the use of LID site planning and design strategies, to the MEA, prior to consideration of structural stormwater BMPs. Therefore, all of the LID strategies presented in this chapter should be considered for use, regardless of whether LID credits are available.

Impervious Area Conversion

Converting impervious surfaces (pavement, buildings, etc.) to pervious vegetated surfaces (lawn, meadow, woods) and restoring the pre-development infiltration rate and storage capacity (i.e., porosity) of the underlying soils can be an effective strategy for reducing existing impervious cover on redevelopment sites. Conversion of the impervious surface to a pervious vegetated surface results in a reduction in runoff volume and pollutant loads and an increase in infiltration and groundwater recharge.

The subgrade below pavement is often highly compacted, with low infiltration and water storage capacity, and lacking organic material in the soil structure to support vegetative growth. An important aspect of converting impervious surfaces to pervious vegetated surfaces is to ensure that the converted area has similar hydrologic functions and characteristics as a natural, undeveloped area in terms of runoff and infiltration. This typically requires modification of the underlying soils to restore the pre-development infiltration rate and soil porosity and improve soil quality to support vegetation.

Credit Description

An impervious area conversion credit is available when an existing impervious surface is converted to a pervious vegetated surface and the pre-development infiltration rate and storage capacity of the underlying soils is restored.

If the impervious area conversion meets the minimum criteria presented below, the converted area can be deducted from the total impervious area, reducing the required Water Quality Volume and Required Retention Volume and the size of the structural stormwater BMPs needed to meet the static storage volume and pollutant reduction requirements of Standard 1.

Minimum Criteria for Credit

The impervious area conversion credit is subject to the following minimum criteria and restrictions:

- The existing impervious surface must be replaced with a pervious vegetated surface (lawn, meadow, woods) to provide natural or enhanced hydrologic functioning.
- The soils beneath the previously paved surface, which are typically highly compacted, must be modified to restore the pre-development infiltration rate and porosity (similar to that of the native underlying soils) and improve the soil quality to support vegetation. The subgrade must be treated by scarification, ripping (tilling), or use of a shatter-type soil aerator to a depth of 9 to 12 inches or more depending on site and soil conditions.
- Soil testing is required (by the University of Connecticut Soil Testing Laboratory, another university soil testing laboratory, or a commercial soil testing laboratory) to determine the suitability of the soils for plant growth and to classify the permeability (in terms of Hydrologic Soil Group) of the restored pervious area. Amendment with 2 to 4 inches of topsoil or organic material may be required to improve plant establishment or restore soil permeability.
- Impervious area conversion should not be used where subsurface contamination is present from prior land use due to the increased threat of pollutant migration associated with increased hydraulic loading from stormwater infiltration, unless the contaminated soil is removed and the site is remediated, or if approved by CT DEEP on a case-by-case basis.

Impervious Area (Simple) Disconnection

Impervious area (simple) disconnection can be used to direct runoff from roofs, driveways, roads, parking lots, and solar arrays to natural or landscaped vegetated areas that are of sufficient size and with adequately permeable soils (also called "Qualifying Pervious Areas" or QPAs) to disperse and retained runoff without causing erosion, basement seepage, or negative impacts to adjacent downgradient properties. QPA's may also be referred to as Qualifying Natural Dispersion areas in other stormwater management guidance / manuals locally or nationally. QPAs with flatter slopes, pervious soils, and a dense stand of vegetation are better suited for maintaining dispersed flow. Level spreaders may also be used to disperse the discharge, enhance infiltration, and avoid flow concentration and short-circuiting through the pervious area.

Credit Description

An impervious area disconnection credit is available when runoff from rooftops, driveways, roads, parking lots, and solar arrays are directed to a QPA such that the appropriate portion of the site's WQV is dispersed and retained/infiltrated on-site without causing erosion, basement seepage, or negative impacts to adjacent downgradient properties. This technique involves grading the site to direct runoff as sheet flow to specially designed vegetated areas that can treat and infiltrate the runoff.

If stormwater runoff from an impervious area is directed to a QPA that meets the minimum criteria described below, the area can be deducted from the total impervious area, reducing the required Water Quality Volume and Required Retention Volume of the site and the size of the structural stormwater BMPs needed to meet the retention and treatment requirements of Standard 1.

Minimum Criteria for Credit

The impervious area disconnection credit is subject to the following general criteria and restrictions,[62] which apply to disconnection of runoff from all types of impervious surfaces.

General Criteria

- QPAs must be clearly shown and labeled as such on site plans.
- QPAs must be located outside of regulated wetland areas but may be used within the outer portion of wetland buffer areas (i.e., upland review areas) if allowed by the approving authority.
- Excessively fertilized lawn areas cannot be used as a QPA. For lawn areas to be considered as QPAs, they must consist of low-maintenance grasses adapted to the New England region (refer to Section 5.4.2 on the use of low-maintenance landscaping).
- QPAs can only receive runoff from land uses with higher potential pollutant loads (LUHPPLs), as defined in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems, provided that no runoff from the areas or activities that may generate runoff with a higher potential pollutant load is directed to a QPA.
- The QPA must be designed to not cause basement seepage. To prevent basement seepage, at a minimum, the QPA must be at least 10 feet away from any building foundation and must be directed away from any building foundation. This credit shall not be utilized in locations where there is a history of groundwater seepage and/or basement flooding.
- Construction vehicles must not be allowed to drive over the QPA to prevent compaction of the soil. If it becomes compacted, the soil must be amended, tilled, and re-vegetated once construction is complete to restore infiltration capacity.
- The QPA must have a minimum of 4 inches of topsoil or organic material. The QPA must sustain healthy vegetative cover (dense herbaceous vegetative ground cover) over the long term. Existing vegetation, grasses, and/or plantings are acceptable. Vegetation must

[62] These criteria have been adapted from the Rhode Island Stormwater Design and Installation Standards Manual (2015), MA MS4 General Permit Appendix F (2021), CTDOT Guidance for Natural Dispersion/Vegetative Filter Areas (2021), Trinkaus Engineering, LLC Morris, CT Low Impact Sustainable Development and Stormwater Management Design Manual (2018), CT DEEP Construction Stormwater General Permit Appendix I (Stormwater Management at Solar Array Construction Projects), and New Jersey Stormwater BMP Manual (2004).

cover 90% or more of the QPA. Forested areas used as QPAs must have dense herbaceous vegetative ground cover to effectively disperse flows and prevent soil erosion.

- The slope of the QPA shall be less than or equal to 8% for lawn and less than or equal to 15% for undisturbed meadow or forested areas. Full or partial credit for QPA's outside of this slope criteria may be given based on-site specific conditions and the design retention requirement as approved by the review authority.

- Flow from the impervious surface must enter the QPA as sheet flow. All discharges onto the QPA must be stable and non-erosive.

- Upon entering the QPA, all runoff must remain as sheet flow. The shape, slope, and vegetated cover in the QPA must be sufficient to maintain sheet flow throughout its length.

- A vegetated channel, swale, or structural stormwater BMP may be necessary downgradient of the QPA to manage stormwater from larger storm events that is not fully retained within the QPA for stormwater quantity control purposes.

- The flow path through the QPA should comply with the setbacks established for structural infiltration BMPs (refer to Chapter 10 - General Design Guidance for Stormwater Infiltration Systems).

- QPAs should have a depth to the seasonal high groundwater table shall be 18 inches or greater. HSG classification will influence infiltration rates see Chapter 10 for guidance regarding the classifications and expected rates. HSG classification and depth to seasonal high groundwater table must be field verified by a Qualified Professional through field evaluation (i.e., test pits or soil borings) (refer to soil evaluation guidance in Chapter 10 - General Design Guidance for Stormwater Infiltration Systems).

- The QPA must be included in the Operation and Maintenance (O&M) Plan required by Standard 4. The O&M Plan shall include measures to inspect the QPA at least annually to remove any deposited sediment (e.g., sand from winter sanding operations) and trash, address any ponding and erosion, and re-plant any vegetation that has died to maintain vegetative cover of 90% or greater.

- The QPA must be owned or controlled (e.g., drainage easement) by the property owner and must remain as a landscaped or natural vegetated area over the long term.

The following additional criteria and restrictions apply to disconnection of runoff from the specific types of impervious surfaces listed below.

Roof Runoff

- The rooftop area contributing runoff to any one downspout cannot exceed 1,000 ft^2.

- If designing for retention of the full WQV the length of the QPA (in feet) is recommended to be equal to or greater than the contributing rooftop area (in square feet) divided by 13.3 (e.g., for 1,000 ft^2 roof/13.3 = 75 ft). Treatment can be achieved at varying lengths and widths.

- If designing for retention of the full WQV the width of the QPA is recommended to be equal to or greater than the roof length. For example, if a roof section is 20 feet wide by 50 feet long (1,000 ft^2 roof), the width of the QPA shall be at least 50 feet. Treatment can be achieved at varying lengths and widths.

- Although they may abut, there shall be no overlap between QPAs. For example, the runoff from two 1,000 ft^2 sections of roof must be directed to separate QPAs. They shall not be directed to the same area.

- Where provided, downspouts must be at least 10 feet away from the nearest impervious surface (e.g., driveways) to prevent reconnection to the stormwater drainage system.

- Where provided, downspouts must have a splash pad, level spreader, or dispersion trench to reduce flow velocity and induce sheet flow in the QPA.

- Where a gutter/downspout system is not used, the rooftop runoff must be designed to sheet flow at low velocity away from the structure housing the roof using an infiltration trench or similar level spreader.

- To take credit for rooftop disconnection associated with a LUHPPL (for non-metal rooftops), the rooftop runoff must not commingle with runoff from any paved surfaces or activities or areas on the site that may generate higher pollutant loads.

Driveway, Road, and Parking Lot Runoff

- The maximum contributing flow path from driveway, road, and parking lot impervious areas shall be 75 feet.

- QPA Sizing (0-8% slope): The length of the QPA (i.e., the dimension parallel to the direction of flow) must be equal to or greater than the length of the contributing impervious area. The width of the QPA (i.e., the dimension perpendicular to the direction of flow) shall be no less than the width of the contributing impervious surface. For roads, the minimum QPA width is 25 feet.

- QPA Sizing (8-15% slope): The length of the QPA must be equal to or greater than the length of the contributing impervious area. The width of the QPA shall be no less than the twice the width of the contributing impervious surface. For roads, the minimum QPA width is 50 feet. Full or partial credit for QPA's outside of this slope criteria may be given based on site specific conditions and the design retention requirement as approved by the review authority.

- Although they may abut, there shall be no overlap between QPAs. For example, the runoff from two consecutive segments of road must be directed to separate QPAs. They shall not be directed to the same area.
- Runoff from driveways, roadways, and parking lots may be directed over soft shoulders, through curb cuts, or level spreaders to QPAs. Measures must be employed at the discharge point to the QPA to prevent erosion and promote sheet flow.
- The drainage design must account for snow shelf blocking runoff during winter months.
- Salt tolerant vegetation shall be chosen for all roadside applications.

Solar Array Runoff

Roadways, gravel surfaces, and transformer pads within the solar array are considered Directly Connected Impervious Area (DCIA) for the purposes of calculating WQV. Solar panels are considered unconnected and therefore eligible for the impervious area disconnection credit if all of the following criteria are met:

- Post-construction slopes below the solar panels are less than 15%.
    - For slopes less than or equal to 5%, appropriate vegetation shall be established that will ensure sheet flow conditions and that will provide sufficient ground cover throughout the site.
    - For slopes greater than 5% but less than 10%, practices including, but not limited to, level spreaders, terraces, or berms shall be used to ensure long term sheet flow conditions.
    - For slopes greater than or equal to 8%, use erosion control measures in accordance with solar array requirements contained in the CT DEEP Construction Stormwater General Permit and the Connecticut Soil Erosion and Sediment Control Guidelines, as amended.
    - For slopes equal to or greater than 10% and less than 15%, use engineered stormwater control measures[63] designed to provide permanent stabilization and non-erosive conveyance of runoff to the property line of the site or downgradient from the site.
- The vegetated area receiving runoff between rows of solar panels is equal to or greater than the average width of the row of solar panels draining to the vegetated area.

[63] Engineered stormwater control measures does not refer to exclusively implemented by engineers, but rather the consideration that natural solutions may not solely provide the benefit needed.

- Overall site conditions and solar panel configuration within the array are designed and constructed such that stormwater runoff remains as sheet flow across the entire site and flows towards the intended stormwater management controls.

- The solar panels shall be designed and constructed in such a manner as to allow the growth of native vegetation beneath and between the panels. Pollinator-friendly vegetation is strongly encouraged. Chemical fertilization, herbicides, or pesticides cannot be used except as necessary to initially establish the vegetation.

- The lowest vertical clearance of the solar panels above the ground shall not be greater than 10 feet. The panels shall, however, be at an adequate height to support vegetative growth and maintenance beneath and between the panels. If the lowest vertical clearance of the solar panels above the ground is greater than 10 feet, non-vegetative control measures are required to prevent/control erosion and scour along the drip line or otherwise provide energy dissipation from water running off the panels.

- Appropriate vegetated buffers and setback distances between solar panels and downgradient wetlands or waters and property boundaries are maintained consistent with the requirements of the CT DEEP Construction Stormwater General Permit.

Additional Information Sources

- Sustainable Land Use Regulation Project and Model Regulations (Capitol Region Council of Governments)
- Livable Communities Toolkit: A Best Practices Manual for Metropolitan Regions (Capitol Region Council of Governments)
- Smart Growth Guidelines for Sustainable Design & Development (EPA and Capitol Region Council of Governments, November 2009)
- Transit Oriented Development Toolkit for CT (Connecticut Fund for the Environment, Partnership for Strong Communities, Regional Plan Association, Tri-State Transportation Campaign)
- Transit-Oriented Development and Responsible Growth Website (Connecticut Department of Economic and Community Development)
- Rhode Island Low Impact Development Site Planning and Design Guidance Manual (Rhode Island Department of Environmental Management and Rhode Island Coastal Resources Management Council, March 2011)
- The Rhode Island Conservation Development Manual: A Ten Step Process for the Planning and Design of Creative Development Projects (Rhode Island Department of Environmental Management, June 2003)
- City Green: Innovative Green Infrastructure Solutions for Downtowns and Infill Locations (EPA, May 2016)
- Smart Growth/Smart Energy Toolkit Modules – Open Space Design (OSD)/Natural Resource Protection Zoning (NRPZ) (Massachusetts Executive Office of Energy and Environmental Affairs)
- Water Quality Scorecard: Incorporating Green Infrastructure Practices at the Municipal, Neighborhood, and Site Scales (EPA 2009)
- Better Site Design Code and Ordinance Worksheet – 2017 Update (Center for Watershed Protection (December 2017)
- EPA Smart Growth Publications
- Smart Growth Network
- Sustainable Sites Initiative