Low Impact Development strategies use careful site design and decentralized stormwater management to reduce the environmental footprint of new growth. This approach improves water quality, minimizes the need for expensive pipe-and-pond stormwater systems, and creates more attractive developments.

MASSACHUSETTS **LOW IMPACT DEVELOPMENT** TOOLKIT

FACT SHEET #1

LOW IMPACT SITE DESIGN

Overview

Conventional development strategies treat stormwater as a secondary component of site design, usually managed with "pipe-and-pond" systems that collect rainwater and discharge it off site. In contrast, Low Impact Development embraces hydrology as an integrating framework for site design, not a secondary consideration. Existing conditions influence the location of roadways, buildings, and parking areas, as well as the nature of the stormwater management system.

LID site design is a multi-step process that involves identifying important natural features, placing buildings and roadways in areas less sensitive to disturbance, and designing a stormwater management system that creates a relationship between development and natural hydrology. The attention to natural hydrology, stormwater "micromanagement," nonstructural approaches, and landscaping results in a more attractive, multifunctional landscape with development and maintenance costs comparable to or less than conventional strategies that rely on a pipe-and-pond approach.

Sensitive site landscaping is an important component of Low Impact Development. Ecological landscaping strategies seek to minimize the amount of lawn area and enhance the property with native, drought-resistant species; as a result, property owners use less water, pesticides, and fertilizers. The maintenance of vegetated buffers along waterways can also enhance the site and help protect water quality.

Applications and Design Principles

LID site planning is similar to Conservation Subdivision Design (CSD) process, though LID site planning can be applied to both residential and nonresidential development as well as redevelopment projects. The four step process of CSD (identify conservation areas; locate home sites; align streets and trails; draw in lot lines) provides a serviceable framework for the LID site design process, which involves designing a stormwater management system in conjunction with the second and third steps of the CSD process.

Management Objectives

- Develop a site plan that reflects natural hydrology.
- Minimize impervious surfaces.
- Treat stormwater in numerous small, decentralized structures.
- Use natural topopgraphy for drainageways and storage areas.
- Preserve portions of the site in undisturbed, natural conditions.
- Lengthen travel paths to increase time of concentration and attenuate peak rates.
- Use "end of pipe" treatment structures only for quantity/rate controls of large storms.

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Site Analysis

An LID site planning strategy will begin with an assessment of environmental and hydrologic conditions on a site and identification of important natural features such as streams and drainageways, floodplains, wetlands, recharge groundwater protection areas, high-permeability soils, steep slopes and erosion-prone soils, woodland conservation areas, farmland, and meadows. This investigation will help to determine what "conservation areas" should be protected from development and construction impacts, and what site features (such as natural swales) might be incorporated into the LID stormwater system.

The site analysis will also identify a "development envelope" where development can occur with minimal impact to hydrology and other ecologic, scenic, or historic features. In general, this will include upland areas, ridge lines and gently sloping hillsides, and slowly permeable soils outside of wetlands. The remainder of the site should be left in a natural undisturbed condition. It is important to protect mature trees and to limit clearing and grading to the minimum amount needed for buildings, access, and fire protection; lawn areas increase runoff that must be managed, whereas preservation of wooded areas reduces the volume of stormwater that must be treated. Construction activity, including stockpiles and storage areas, should be confined to those areas that will be permanently altered, and the construction fingerprint should be clearly delineated.

Locate Development and Roadways

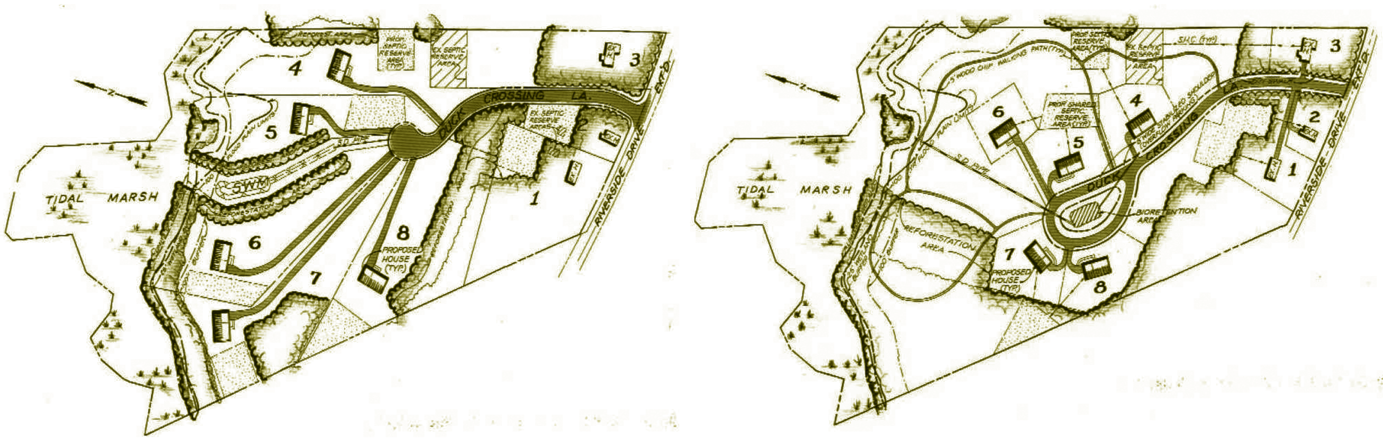
Based on the development envelope from the site analysis, developers and their consultants should prepare potential site development layouts. These layouts should minimize total impervious area; reflect the existing topography; and utilize existing drainageways, swales, depressions, and storage areas in their natural state. The goal is to minimize the amount of runoff that must be treated in a stormwater management system.

In order to reduce site coverage but not square footage, site development layouts may include buildings clustered together, parking structures (instead of lots), or taller buildings with a smaller footprint relative to floor area. However, these strategies may conflict with local land use regulations that address density, height, frontages, and lot coverage, so consultation with local officials is critical to help them

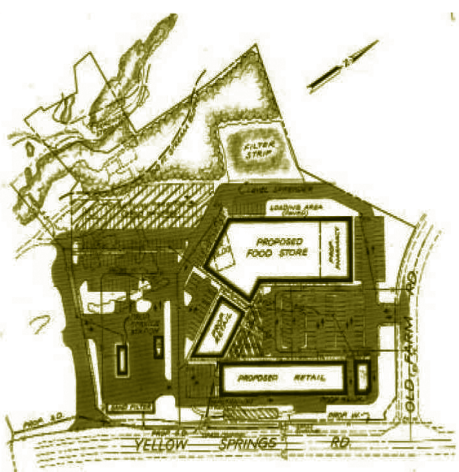
Conventional development strategies (above) concentrate stormwater runoff in storm sewers and deliver it to a few large ponds for treatment at the end of the pipe. Low Impact Development (right) seeks to create multiple small "sub-watersheds" on a site and treats runoff close to the source in smaller structures.

Cover, top: A clustered subdivision with smaller setbacks and preserved natural areas (left) contrasts with a conventional subdivision where all the trees have been removed.

Cover, bottom: A schematic diagram of a conservation subdivision design plan.



Above: Two alternative designs for an eight-lot subdivision. The low-impact on the right uses shared driveways and a one-way loop road to minimize impervious surfaces. The preservation of natural areas and the creation of trails adds value to the properties. *Images: Center for Watershed Protection*



Above: A commercial site design that uses clustering and multiple parking areas to protect water resources and provide opportunities for low impact stormwater management techniques. This design provides the same square footage and parking spaces as a conventional design that encroaches on a nearby marsh (at top). *Image: Center for Watershed Protection*

understand the rationale for the proposed development plan. Other strategies for minimizing impervious surfaces include reduced road widths, smaller parking areas, permeable paving, and green roofs, all of which are described in greater detail in other LID fact sheets.

Once approximate building locations are known, general roads alignments can be identified. Roads should not cross steep slopes, where cutting and filling will unnecessarily disturb drainage patterns; instead, roadways should follow existing grades and run along existing ridge lines or high points. As a rule of thumb, roadways should run parallel to contours on gentle slopes, and perpendicular to the contours on steeper slopes. Large expanses of parking should be broken up into multiple smaller parking lots; this will help to reduce grading on hilly sites, since separate parking areas can be placed at different elevations.

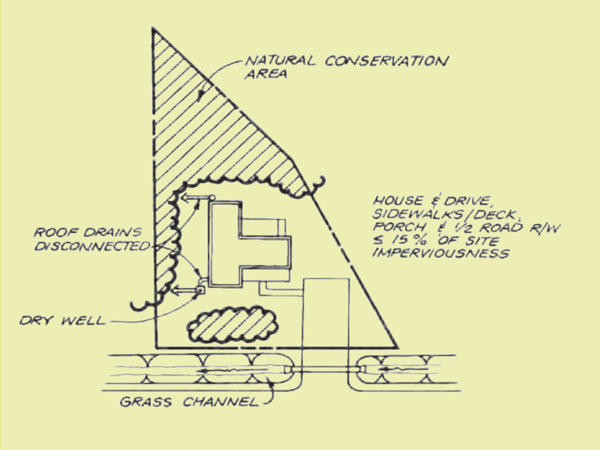
Create a Decentralized Stormwater System

The actual location of buildings and the alignment of roadways should be determined in conjunction with the design of the stormwater management system. The goal of this process is to minimize "directly connected impervious area"—those impervious areas that drain directly into a pipe-and-pond stormwater system. Designers should seek to maintain or create small sub-watersheds on the site and "micromanage" the runoff from these sub-watersheds in small decentralized structures, such as swales, bioretention areas, infiltration structures, and filter strips. Paved surfaces should be graded and crowned so that they form multiple "mini-watersheds;" the runoff from each small drainage area should to a different bioretention area, swale, or filter strip. Roof runoff should be sent to rain barrels, cisterns, dry wells, and vegetated areas via level spreaders.

LID site design should also seek to maximize the travel time for stormwater runoff. Conventional pipe systems increase the speed of stormwater runoff, resulting in bigger peak discharge rates (and therefore bigger ponds) at the end of the pipe. In contrast, LID seeks to increase the time of concentration (the average travel time for rainfall) through a variety of techniques: retain stormwater in small structures close to the source (described above), provide as much overland or sheet flow as possible, use open drainage systems, provide long travel paths, and use vegetation to increase surface roughness.

Wherever possible, site design should use multifunctional open drainage systems such as vegetated swales or filter strips which also help to fulfill landscaping or green space requirements. Swales and conveyances can be designed to increase travel length (and time of concentration) with long flow paths that loop around parking lots or other features, rather than more direct routes. The result is increased infiltration and more attenuated peak discharge at the downstream end of the site—the peak comes later and is smaller.

LID stormwater structures (such as bioretention areas and infiltration trenches) should be sized to treat the stormwater from frequent, low intensity storms for



Above: A lot layout that uses infiltration, disconnection of rooftop runoff, conservation and vegetated swales to treat runoff.

water quality and infiltrate it into the ground or slowly release it; they should not be expected to completely manage the peak discharge rate or volume from large storms. Volume and rate controls at the downstream end of the site may still be necessary, but much smaller as a result of LID site design, decentralized stormwater management, and long travel paths.

Benefits and Effectiveness

- A comprehensive approach to site design is the most effective, cost-efficient means of minimizing stormwater runoff. A small investment in design at the outset of the project can reduce the expense associated with conventional stormwater systems.
- An LID site design approach based on natural hydrology will integrate the built space into the natural environment, giving the development integrity and an aesthetically pleasing relationship with the natural features of the site. Many LID stormwater management structures also serve as site landscaping.
- Developers who take a careful, comprehensive approach to site design—one that accommodates local development goals and protects important resources—run into less resistance from neighbors and local boards concerned about the aesthetic and environmental impacts of development.
- Site designs that involve a minimal amount of clearing, grading, and road/parking lot construction have lower overall site development costs.
- Small, distributed stormwater "micromanagement" techniques offer an advantage over centralized systems because one or more of the individual structures can fail without compromising the overall integrity of the stormwater management strategy for the site.
- Smaller decentralized facilities feature shallow basing depths and gentle side slopes, which reduce safety concerns as compared to deep ponds that must be fenced off.

Limitations

- The comprehensive LID site analysis and design process can rarely be conducted "in house" by developers; it requires the assistance of knowledgeable and qualified engineers and landscape architects.
- Some LID site designs that seek to cluster development and reduce lot coverage may conflict with local land use regulations or public perceptions about what type of development is desirable (a compact multistory building may be more visible than a single story building with a larger footprint.) Consequently, public education is necessary as well as cooperation among developers, advocates, and regulators who recognize the values of the LID site design approach.

Maintenance

There are no particular maintenance requirements associated with an LID site design, but by reducing the amount of stormwater runoff and associated stormwater management structures, LID can reduce the amount of maintenance required on a site.

Cost

The cost of an LID site design will vary depending on the site. The expertise necessary to create a comprehensive site plan may cost more than a simple engineering plan that ignores natural conditions and treats stormwater using a "pipe and pond" system; however, the resulting plans are commonly less expensive to construct and maintain, and the additional landscaping and aesthetic value of an LID development will add a premium to the sales price.

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This publication is one component of the Massachusetts Low Impact Development Toolkit, a production of the Metropolitan Area Planning Council, in coordination with the I-495 MetroWest Corridor Partnership, with financial support from US EPA. The Massachusetts Low Impact Development Interagency Working Group also provided valuable input and feedback on the LID Toolkit.

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FACT SHEET #2

ROADWAY AND PARKING LOT DESIGN

Overview

One of the simplest ways to cut down on stormwater runoff is to reduce the amount of impervious cover associated with roadways and parking lots. Careful design is the key to reducing pavement while still providing good site access and adequate parking. Good road and parking lot design can also create opportunities for decentralized stormwater management in bioretention areas, roadside swales, and infiltration structures. Basic strategies for roadway design include low-impact roadway layouts, narrow road widths, shared driveways, and open-section roadways. Parking lots designers should look at strategies to break up large parking lots, maximize shared parking, rethink parking requirements, and use permeable paving where appropriate.

Alternative road and parking designs may offer cost savings for developers, because there is less pavement to construct and less stormwater runoff to treat. In some cases, more compact parking may allow higher site densities. The primary impediment to these strategies may be resistance at the permitting stage. Many communities stringently enforce elaborate and often excessive roadway and parking standards in an effort to prevent development. Developers, advocates, and regulators who understand the benefits of Low Impact Development need to work together to point out that alternative designs can provide safe access and sufficient parking, as well as environmental and aesthetic benefits.

Applications and Design Principles

Roadway Width

Excessively wide streets are the greatest source of impervious cover (and stormwater runoff) in most residential developments. Some local codes require streets up to 40 feet wide in subdivisions with only a dozen houses. These inappropriate standards result from blanket application of high volume/high speed road design criteria, overestimates of on-street parking demand, and the perception that wide streets result in faster emergency response times.

Narrower road sections and alternative road profiles can reduce stormwater runoff and mitigate its impacts, while still allowing safe travel, emergency

Design Objectives

- Reduce total impervious surface.
- Reduce road/parking construction costs.
- Provide safe access and adequate parking.
- Minimize disturbance to natural site hydrology.
- Create opportunities for stormwater treatment and infiltration.
- Improve site appearance.

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Above: Excessively wide streets (top) with conventional curb-and-gutter profiles create large volumes of runoff and concentrate it in storm sewers. Low-impact roadways (bottom) use a narrower, more traditional design that enhances neighborhood character. Less runoff is created and it is directed to roadside swales for treatment and conveyance.

Cover, top: A narrow roadway design can allow for on-street parking as well as plenty of room for safe travel and emergency vehicle access.

Cover, bottom: This photo shows a perforated curb that directs runoff into a roadside bioretention area with a drop overflow inlet into the storm drain system. This approach treats the "first flush" of runoff using a low-impact technique and directs the remaining stormwater to conventional practices. *Photo: Lower Columbia River Estuary Partnership*

Right: A schematic diagram of an open-section roadway, with permeable paving parking lanes and roadside swales. Swales should be located between the roadway and a sidewalk, where present. *Image: Valley Branch (MN) Watershed District*

vehicle access, and adequate parking. For most low-traffic roads, a 24' road width is sufficient to accommodate two way traffic, and even narrower widths should be used in very low traffic conditions (e.g., a six-lot subdivision.) The National Fire Protection Administration Uniform Fire Code (2003) recommends a minimum unobstructed width of just 20 feet, with the recognition that local authorities can set lower standards if turnouts or alternate exits are available.

Recommended Minimum Street Widths

Source	Width (feet)
National Fire Protection Administration	20
Massachusetts State Fire Marshall	18 (minimum)
AASHTO	22
Institute of Transportation Engineers	22
Prince George's County, Maryland	20
Portland, Oregon	18 (on-street parking on one side) 26 (parking both sides)

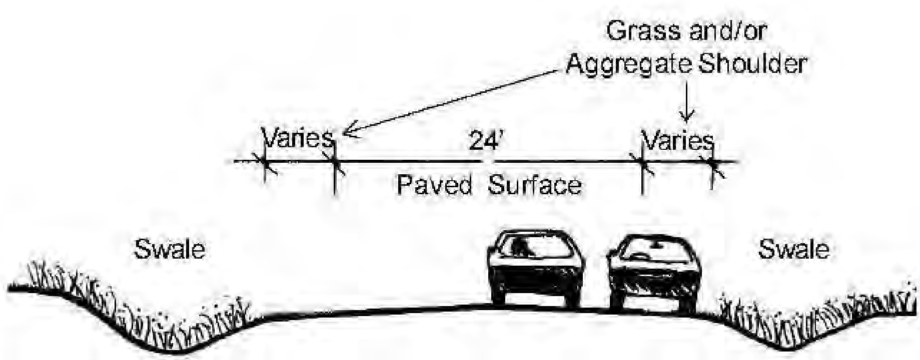
Source: Center for Watershed Protection

In order to achieve the environmental benefits of narrower street widths, regulators must make clear that they are willing to adjust site design standards to provide developers with the opportunity to try alternative designs. One preliminary step is to require parking on one side of the street only. This is appropriate where most houses have off–street parking. Design standards can also allow parking lanes or road shoulders made of permeable paving, such as grass pavers or paving blocks.

Some communities are moving to roadways that us a single travel lane and one or two "queuing lanes," which can be used for either parking or travel. This strategy can reduce street width by a third, and it does not affect travel except when two cars need to pass each other at the spot where a third car is parked, in which case one car pulls into the queuing lane until the oncoming car has passed. Research indicates that "tight streets" actually improve traffic safety by encouraging vehicles to slow down in residential neighborhoods. Throughout Massachusetts, many older neighborhoods built before current standards were enacted have narrow streets that function well, calm traffic, and lend character to the community.

Roadway Profile

Curbs and gutters concentrate stormwater runoff and increase its velocity, impeding decentralized treatment and infiltration. LID strategies recommend open-section roadways flanked by filter strips and swales instead of curbs and gutters. These LID techniques, built on the model of "country drainage," help to filter roadway runoff, promote infiltration, and reduce runoff velocity, resulting in lower peak discharge rates. If properly designed, open section roadways will be no more prone



to flooding than conventional roadway profiles. If curbs are deemed necessary to stabilize the roadway edge, the design can use invisible curbs (same level as the road surface), periodic curb cuts, or perforated curbs to allow stormwater to run off the roadway edge.

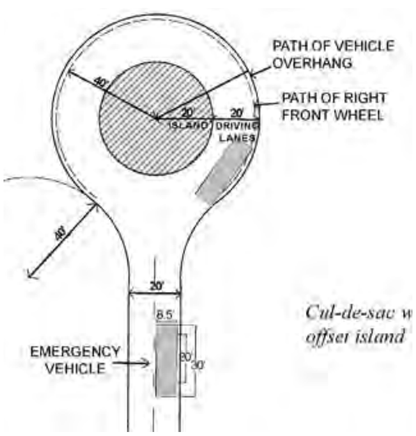
Roadway layout

The location and layout of roadways can also be modified to improve post-development hydrology. Roadways should be placed to avoid crossing steep slopes where significant cut and fill will be required. They should run parallel to contours on gentle slopes and perpendicular to contours on steeper slopes. Design of a roadway network may involve some give and take between reducing total roadway length and road layouts compatible with existing topography. On low-speed streets, clearing and grading should be limited to a small strip of land (5') on either side of the roadway and sidewalk.

In residential subdivisions, shared driveways can reduce site development costs as well as impervious surface coverage. Property owners will also realize some savings through shared snow plowing costs. Driveways can be limited to 9 feet in width. They should be sloped or crowned so that they drain evenly onto adjacent vegetated areas (not onto the street) where the runoff will infiltrate or travel via sheetflow.

Above: Periodic curb cuts in an urban setting allow for streetside infiltration. *Photo: Lower Columbia River Estuary Partnership*

Below: A 20-foot diameter land-scaped island in a cul-de-sac can reduce impervious surface by 25%. Cul-de-sac islands can also be designed to treat and infiltrate runoff through bioretention. *Image: Valley Branch (MN) Watershed District*



Turnarounds and Cul-de-Sacs

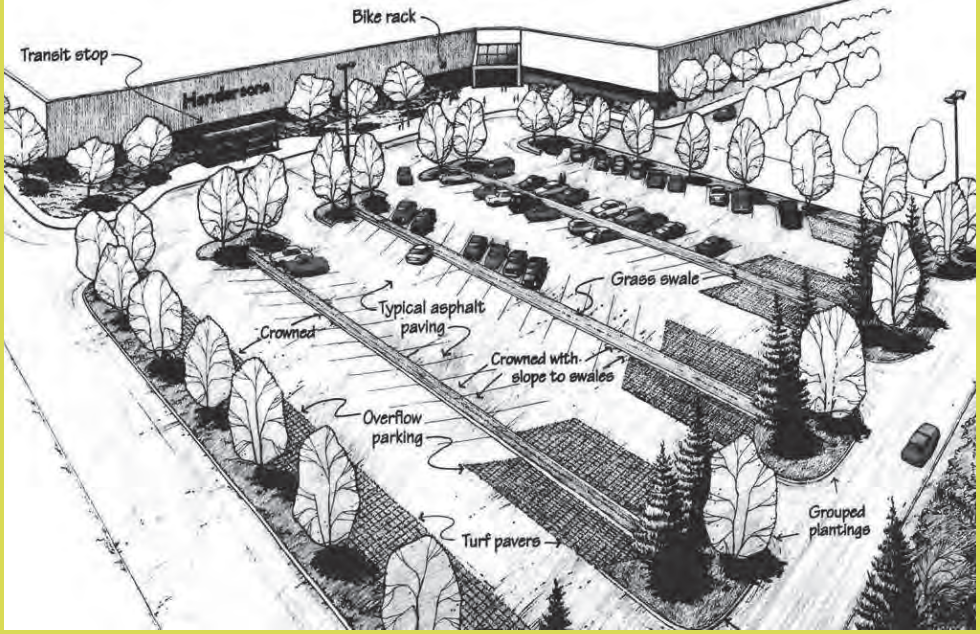
Many residential streets end in large cul-de-sacs up to 80 feet across, which generate large amounts of runoff during storms. Alternative designs can reduce runoff and improve neighborhood character, while still providing sufficient room for fire trucks and school buses to maneuver. One simple approach (applicable to both new construction and retrofits) is to create a landscaped island in the middle of a standard-size cul-de-sac. A 30-foot island in an 80-foot diameter cul-de-sac will reduce the impervious surface by 15%; if the island is designed and built as a bioretention area, and the roadway graded appropriately, this strategy can also treat roadway runoff.

Other design changes can produce even greater benefits. Reducing the radius of a cul-de-sac from 40 feet to 30 feet yields a 45% reduction in paved surface (5,000 sq. ft versus 2,800 sq. ft.) A T-shaped hammerhead occupies even less space but still provides sufficient room for turning vehicles and fire trucks (though it may require a 3-point turn.) Depending on the length of the street, designers should consider a one-way loop road with parking on one side. Cul-de-sac design is definitely one area where regulatory standards prevent creative designs; regulators should consider re-wording their regulations to replace geometric standards with performance standards.

Parking Lots

Expansive parking lots that drain to just a few catch basins create large volumes and high velocities that require the use of pipe-and-pond stormwater techniques. The LID approach encourages designers to create multiple smaller parking lots separated by natural vegetation and bioretention areas. On hilly sites, the creation of multiple parking areas at different elevations can reduce the amount of grading necessary and preserve natural hydrology.

Permeable paving is rarely appropriate for use in high traffic parking lots, but some success has been found with hybrid parking lots, which use conventional paving for driveways and aisles, and permeable paving for stalls. Permeable paving may also be appropriate for overflow parking areas, which are generally used only a few weeks out of the year.



Above: A schematic drawing of a parking lot that uses a variety of low impact techniques. Parking areas are separated by vegetated swales that convey runoff to bioretention areas, and permeable paving is used for overflow parking at the periphery of the lot. A bike rack and transit stop help to reduce the number of auto trips to the site. *Image: Robert W. Droll, ASLA*

Other strategies include reducing the total number of parking spaces and reducing the size of some parking spaces. Many communities have provisions for shared parking, so that mixed use developments, or single-use developments near other uses, can share parking according to a formula based on the peak demand periods; residents use the parking spaces at night and customers or employees use the same spaces during the day. Parking spaces designed for compact cars can also help to limit impervious coverage.

Considering the aesthetic and environmental impacts of large parking areas, community boards might consider parking maximums, as well as parking minimums, in order to prevent oversized parking lots and ensure that supply is in line with demand.

Benefits and Effectiveness

- Narrower roadways, smaller parking areas, and smaller stormwater management systems result in lower site development costs.
- A hierarchy of streets sized according to daily needs yields a wide variety of benefits: lower average speeds, more room for trees and landscaping, improved aesthetics, and reduced heat island effect.
- Designs that reduce the amount of parking and break it up into multiple smaller lots separated by vegetation create more attractive developments.

Limitations

- Alternative roadway and parking designs may conflict with local codes, which often have strict requirements for road widths and drainage systems. However, many boards may be willing to adjust their standards if developers, advocates, and neighbors support the alternative design.
- Emergency service access is a common concern with reduced street widths. Where possible, these concerns can be addressed through education or multiple points of access to a site.

Cost

Narrower streets and smaller parking lots cost less than conventional streets because less grading, base material, and pavement is required. Open section roadways cost considerably less than standard designs due to the elimination of curbs and gutters.

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Shared Parking Guidelines; Institute of Transportation Engineers, Washington DC; 1995.

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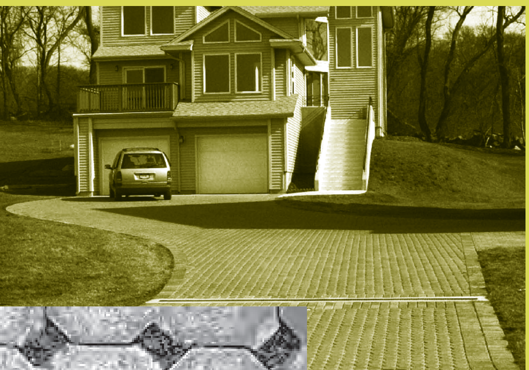
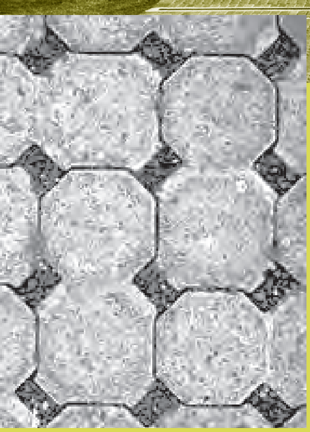
FACT SHEET #3

PERMEABLE PAVING





Overview

Since impervious pavement is the primary source of stormwater runoff, Low Impact Development strategies recommend permeable paving for parking areas and other hard surfaces. Permeable paving allows rainwater to percolate through the paving and into the ground before it runs off. This approach reduces stormwater runoff volumes and minimizes the pollutants introduced into stormwater runoff from parking areas.

All permeable paving systems consist of a durable, load bearing, pervious surface overlying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, parking stalls, and overflow parking areas.

Applications and Design Principles

Permeable paving is appropriate for pedestrian-only areas and for low- to medium-volume, low-speed areas such as overflow parking areas, residential driveways, alleys, and parking stalls. Underlying soils should have a permeability of at least 0.3" per hour; less permeable soils will require an underdrain. Permeable paving is an excellent technique for dense urban areas because it does not require any additional land. With proper design, cold climates are not a major limitation; porous pavement has been used successfully in Norway, incorporating design features to reduce frost heave.

Permeable paving is not ideal for high traffic/high speed areas because it generally has lower load-bearing capacity than conventional pavement. Nor should it be used on stormwater "hotspots" with high pollutant loads because stormwater cannot be pretreated prior to infiltration. Heavy winter sanding may clog joints and void spaces.

Management Objectives

- Reduce stormwater runoff volume from paved surfaces
- Reduce peak discharge rates.
- Increase recharge through infiltration.
- Reduce pollutant transport through direct infiltration.
- Improve site landscaping benefits (grass pavers only.)

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Cover: A driveway in Connecticut built with manufactured paving stones. Lower photo shows paving stone detail. P*hoto: University of Connecticut, Jordan Cove Urban Monitoring Project*

Above: A parking lot with concrete grass paver parking stalls. Lower photo shows grass paver detail. *Photos: Lower Columbia River Estuary Partnership*

Right: A schematic cross section of permeable paving. In some applications, the crushed stone reservoir below the paving is designed to store and infiltrate rooftop runoff as well. *Image: Cahill Associates, Inc. 2004*

Three Major Types of Permeable Paving

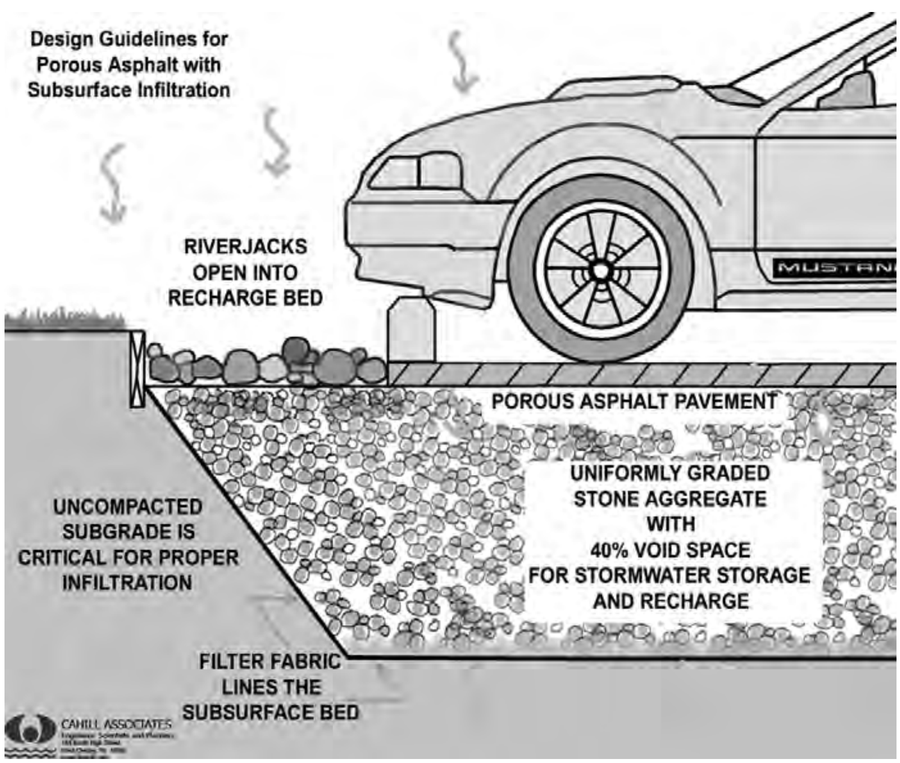
- Porous asphalt and pervious concrete appear to be the same as traditional asphalt or concrete pavement. However, they are mixed with a very low content of fine sand, so that they have 10%-25% void space and very low runoff coefficients.
- Paving stones (aka unit pavers) are impermeable blocks made of brick, stone, or concrete, set on a sand or crushed stone base. Joints are filled with stone or sand to allow water to percolate downward. Runoff coefficients range from 0.1 – 0.7, depending on rainfall intensity, joint width, materials, and base layer permeability. Open cell designs and coarse bed material can yield runoff coefficients less than 0.3.
- Grass pavers (aka turf blocks or grid pavers) are a type of open-cell unit paver in which the cells are filled with soil and planted with turf. The pavers, made of concrete or synthetic, distribute the weight of traffic and prevent compression of the underlying soil. Runoff coefficients are similar to grass, 0.15 to 0.6.

Each of these techniques is constructed over a base course that doubles as a reservoir for the stormwater before it infiltrates into the subsoil. The reservoir should consist of uniformly-sized crushed stone, with a depth sufficient to store all of the rainfall from the design storm. The bottom of the stone reservoir should be completely flat so that infiltrated runoff will be able to infiltrate through the entire surface. Some designs incorporate an "overflow edge," which is a trench surrounding the edge of the pavement. The trench connects to the stone reservoir below the surface of the pavement and acts as a backup in case the surface clogs.

Benefits and Effectiveness

Porous pavement provides groundwater recharge and reduces stormwater runoff volume. Depending on design, paving material, soil type, and rainfall, permeable paving can infiltrate as much as 70% to 80% of annual rainfall.

Porous pavement can reduce peak discharge rates significantly by diverting stormwater into the ground and away from the pipe-and-pond stormwater management system.



Above: A parking lot with conventional asphalt aisles and paving stone parking stalls. Paving stones are most appropriate for low-speed, low-traffic areas. *Photo: Lower Columbia River Estuary Partnership*

- Grass pavers can improve site appearance by providing vegetation where there would otherwise be only pavement.
- Porous paving increases effective developable area on a site because portions of the stormwater management system are located underneath the paved areas, and the infiltration provided by permeable paving can significantly reduce the need for large stormwater management structures on a site.

Limitations

- Permeable paving can be prone to clogging from sand and fine sediments that fill void spaces and the joints between pavers. As a result, it should be used carefully where frequent winter sanding is necessary because the sand may clog the surface of the material. Periodic maintenance is critical, and surfaces should be cleaned with a vacuum sweeper at least three times per year.
- In cold climates, the potential for frost is minimized with 24-hour design times for the reservoir. Some design manuals recommend excavating the base course to below the frost line, but this may not be necessary in rapidly permeable soils. In addition, the dead air and void spaces in the base course provide insulation so that the frost line is closer to the surface.
- Permeable paving should not receive stormwater from other drainage areas, especially any areas that are not fully stabilized.
- Permeable paving can only be used on gentle slopes (<5%). It should be used judiciously in high-traffic areas or where it will be subject to heavy axle loads.
- Snow plows can catch the edge of grass pavers and some paving stones. Rollers can be attached to the bottom edge of a snowplow to prevent this problem.

Above: A handicap-accessible park pathway made of permeable paving stones.
Photo: GeoSyntec Consultants, Inc.

Maintenance

- Post signs identifying porous pavement areas.
- Minimize use of salt or sand during winter months
- Keep landscaped areas well-maintained and prevent soil from being transported onto the pavement.
- Clean the surface using vacuum sweeping machines. Paving stones may require periodic addition of joint material to replace material that has been transported.
- Monitor regularly to ensure that the paving surface drains properly after storms.
- Do not reseal or repave with impermeable materials.
- Inspect the surface annually for deterioration.
- Grass pavers may require periodic reseeding to fill in bare spots.

Design Details

- For all permeable paving, base course is a reservoir layer of 1”-2” crushed stone; depth to be determined by storage required and frost penetration.
- Permeable paving require a single-size grading of base material in order to provide voids for rainwater storage; choice of materials is a compromise between stiffness, permeability, and storage capacity. Use angular crushed rock material with a high surface friction to prevent traffic compaction and rutting.
- The design may also include a 2” thick filter course of 0.5” crushed stone, applied over the base course. A geotextile fabric may be laid at the top of the filter layer to trap sediment and pollutants.
- For grass pavers, use deep-rooted grass species whose roots can penetrate the reservoir base course. Irrigation may be required but should be infrequent soakings so that the turf develops deep root systems. Grass pavers are not suitable for every day, all day parking because the grass will get insufficient sunlight. Better for use as occasional overflow parking.
- The introduction of dirt or sand onto the paving surface, whether transported by runoff from elsewhere or carried by vehicles, will contribute to premature clogging and failure of the paving. Consequently, permeable paving should be one of the last items to be built on a development site, after most heavy construction vehicles are finished and after the majority of the landscaping work is completed.

Cost

On most sites, permeable paving costs more than conventional asphalt or concrete paving techniques. In the case of porous asphalt and pervious concrete, construction costs may be 50% more than conventional asphalt and concrete. Construction costs of paving stones and grass pavers varies considerably and will depend on the application. As with any site improvement or stormwater management structure, property owners should provide a budget for maintenance of permeable paving, at an annual rate of 1%-2% of construction costs.

Permeable paving reduces the need for stormwater conveyances and treatment structures, resulting in cost savings elsewhere. Permeable paving also reduces the amount of land needed for stormwater management and may satisfy requirements for greenspace, allowing more development on a site.

Local Case Study

West Farms Mall – West Hartford, CT

Grass pavers were installed at the West Farms Mall off of I-84 at exit 40, to handle peak-season overflow parking associated with a mall expansion. Over four acres of reinforced turf was designed to accommodate 700 spaces of overflow parking for the peak shopping seasons. There are a few drains installed in the reinforced turf but are only used during very heavy storms. Because the reinforced turf works so well the existing storm drainage system did not have to be enlarged for the additional parking. The overflow parking area needs to be mowed on a regular basis and treated like a regular lawn. The area also needs to be plowed as any parking would be. Rollers were fit to the bottom of the snow plow so the reinforced turf would not be damaged. The manager of the Westfarms facility is satisfied with the turf.

Websites

www.unh.edu/erg/cstev/index.htm (University of NH)
www.invisiblestructures.com/GP2/whole_lotof_turf.htm
www.uni-groupusa.org/case.htm
www.nemo.uconn.edu/ (University of CT)
www.lowimpactdevelopment.org/epa03/pavespec.htm
www.epa.gov/ednnrmrl/repository/abstrac2/abstra2.htm
www.forester.net/sw_0503_advances.html
www.icpi.org (Interlocking Concrete Pavement Institute)

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FOR MORE INFORMATION, VISIT: WWW.MAPC.ORG/LID AND WWW.ARC-OF-INNOVATION.ORG.