Low Impact Development Guidebook

Produced by the Nashua Regional Planning Commission NRPC


www.wsud.org


Photo: LID Center


Photo: USDA, Natural Resources Conservation Service


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Introduction

Definitions and Description of LID

In short, Low Impact Development prescribes a system of site preparation and stormwater management designed to more closely mimic pre-development conditions. The term Low Impact Development encompasses broad considerations of where is development most appropriate, both on a watershed or individual site basis, as well as implementation of specific techniques or technologies designed specifically to handle stormwater volumes and pollutant loads. These specific LID technologies will be the focus of this Guidebook.

Low Impact Development as a concept continues to evolve and change as the technologies and uses mature. It now includes such broad practices as conserving natural areas, minimizing development impacts, maintaining site runoff rates, using integrated stormwater management practices, and implementing pollution prevention mechanisms with proper maintenance schedules and education programs. The goal of LID is to try to mimic predevelopment site hydrology and vegetation using site design techniques that store, infiltrate, treat, and evaporate stormwater runoff.

Nonpoint Source Pollution Causes and Effects

Nonpoint Source Pollution (NPS) is widespread overland stormwater runoff that does not originate from one specific location and represents the largest threat to surface water quality today. Point-source pollution was the first targeted source of pollution under the Clean Water Act and represented the nation's first serious attempt to control direct discharges into surface waterbodies. We are now in a new era where water pollution primarily comes from sources not so easy to see or even regulate. Land use practices, increased urbanization, and ever-increasing amounts of impervious surface are today's challenges. NPS can be classified into several different general types of pollutants that affect water quality in specific ways:

- Debris: Debris consists of everything from litter, cigarette butts, intentionally discarded solid waste, and leaf litter not endemic to shoreland areas. Debris is unsightly and can potentially contain toxic or hazardous materials detrimental to aquatic life.

- Sediment: Soil particles that are picked up by stormwater effluent can result in decreased light penetration into surface water bodies, thereby affecting the dissolved oxygen level at various levels within the water column. Excessive sediment loading can also alter the natural stream substrate when after sediments are deposited. Entrained sediments can also increase the rate at which channels are scoured and eroded, ultimately affecting the overall hydrology of the stream channel.

- Nutrients: While all natural systems require nutrient inputs to function and maintain all generative processes, too much of a good thing is too much! Stream systems are often limited by the amount of Nitrogen and Phosphorous that are naturally present, but when these nutrients are provided in excess of the amounts needed, such as through overfertilization of lawns or agricultural areas, the whole system can experience a productivity peak and subsequent crash that can be devastating to aquatic organisms.

- Toxics and Heavy Metals: Toxics and heavy metals can also be found in petroleum products and may also be present in improperly disposed household hazardous wastes. Many heavy metals can accumulate within the aquatic food chain and present problems for a number of ecologically important species.

- Petroleum Products: Petroleum products enter stream systems through runoff from parking and roadway surfaces and can poison waterbodies to the point where aquatic life is severely diminished and renders water unfit for human consumption.
- Salt: Salt also enters stream systems through runoff from parking and roadway surfaces due to winter maintenance practices. Salt is often expressed and measured as chloride in natural systems, where it can accumulate. Chloride is very difficult to remove from aquatic systems, particularly in ponds and lakes where flow output is minimal.

LID versus Traditional Development

Low Impact Development differs most notably from traditional storm sewer infrastructure in that LID devices tend to work with natural landforms and features on a small scale, often with many devices working separately but together to manage stormwater at the source of its origin. Traditional systems tend to focus on moving as much water as quickly as possible to large detention areas or storm sewer systems, which focus on moving as much water as quickly as possible to the closest surface waterbody. If stormwater were entirely clean and consisted only of rainwater, peak load volumes would be the only concern regarding these practices. Unfortunately, stormwater quickly picks up pesticides, fertilizers, automotive fluids, salt, sediment, and trash. In effect, the way we have typically handled stormwater causes us to be concerned with both volume and pollutant loads entering our surface waters.

Great strides have been made in many communities regarding performance standards for stormwater management. Many communities are requiring that developers show that stormwater volumes remain the same for both pre-construction and post-construction for certain sized storms. In these cases, LID can be another tool for achieving these standards, sometimes with decreased costs long term and increased aesthetic benefits. While LID may not be the answer on every site in every condition, it should be viewed as a viable and often cost-effective means of not only meeting existing performance standards, but also allowing the human environment to achieve the functions and processes that are readily available in the natural environment.

Opportunities and Benefits

Managing stormwater continues to be a challenged for financially stressed local economies within changing environmental climates. Rainfall depths of the average storm are increasing by 28 to 60 percent (UNHSCE 2007 Annual Report), which means that existing infrastructure is already undersized due to larger storm volumes. In other words, the 25-year storm of yesteryear is far smaller than the 25-year storm of today, and local governments simply lack the funds to entertain massive enlargements of storm sewer systems. In this situation, it is no wonder that we have stormwater infrastructure failures. Additionally, there is great concern about EPA-classified Impaired Waters where “no net increase” in pollutant loads is often required. In some more extreme cases, requirements for impaired waterbodies involve reducing pollutant loads by up to 60%, which might only be achievable by simultaneously reducing the volume of water that reaches these waterbodies through surface runoff.

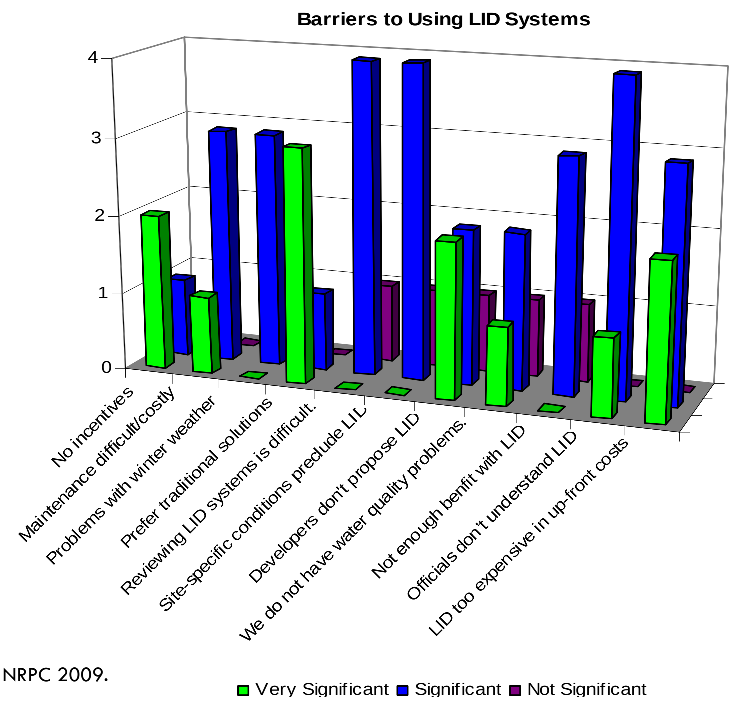
LID could be one of the answers to this problem. Many LID techniques, including conservation of natural areas and allowing waterbody buffers to remain intact and vegetated, promote infiltration with simultaneous nutrient removal. Especially in systems where vegetation is part of the technical design, water quality can be both improved and sometimes completely retained on site, achieving both volume reductions and diminished pollutant loading goals.

Barriers to Using LID

Using Low Impact Development techniques represents a shift in the way that developers, contractors, and local officials evaluate stormwater management systems. While the designs can be sometimes relatively simple, they are dramatically different from traditional storm sewer system infrastructure, which may make LID initially uncomfortable as a new technology. Developers and consultants should keep this in mind when proposing LID systems, and allow local officials the time and information necessary in order to learn about these sometimes unfamiliar technologies. Like any new way of doing things, there will be a learning curve that all involved parties need to scale before LID systems become accepted forms of development practice.

In a survey distributed to local permitting officials, the preference for doing things the "old way," expense of LID systems in their up-front costs, and problems with officials understanding LID were identified as the most significant barriers to using LID technologies. Additionally, the simple fact that developers themselves are not proposing LID systems in the first place was also a barrier.

Somewhat surprisingly, winter performance of LID designs, including porous pavement, was not as significant a concern as perhaps expressed in relatively recent years. The University of New Hampshire Stormwater Center may be able to take a large portion of credit for this new wave of acceptance of permeable pavements due to the Center's continuing research and outreach on the effectiveness of LID technologies during winter seasons in New England.



NRPC 2009.

Several other challenges related to LID in practice involve changing the way we look at stormwater management from a more holistic perspective. Local ordinances may not easily allow LID technologies and may actually discourage their use when permitting reviews are held up due to inconsistencies within regulations. This problem becomes even more difficult when these technologies require special attention and complicated construction methods which are unfamiliar or significantly different from traditional construction methods. LID techniques also often involve post-construction maintenance and long-term monitoring, often by a disconnected Home Owner's Association.

While none of these challenges is inherent to the technology itself, each can be discouraging enough not to attempt LID, or not to attempt LID in future developments. It will take diligence on the part of developers, project consultants, and municipal staff to allow and even encourage the development of LID systems if they are to become a part of the realm of accepted development practice. Throughout, it is important to remember that LID came about due to the simple fact that traditional engineered systems have not been proven to be similar to natural stormwater abatement, and we need to be doing things differently if we expect to maintain or improve surface water quality in our community waterways.

Bioretenion

What is a Bioretention Area?

Bioretention areas function as soil and plant-based filtration devices that remove pollutants through a variety of physical, biological, and chemical treatment processes. The reduction of pollutant loads to receiving waters is necessary for achieving regulatory water quality goals. Bioretention cells typically consist of a landscaped depression where water is gathered, ponded, and then infiltrated downward into the soil column. The can be complex in design with additional "bays" that perform sedimentation and chemical treatment functions.

Water Resource Benefits

Bioretention cells are dynamic, living, micro-ecological systems. They demonstrate how the landscape can be used to protect ecosystem integrity. The design of bioretention cells involves the hydrologic cycle, nonpoint pollutant treatment, resource conservation, habitat creation, nutrient cycles, soil chemistry, horticulture, landscape architecture, and ecology. As a result, bioretion cells demonstrate a multitude of benefits. Beyond its use for stormwater control, the bioretention cell provides attractive landscaping and a natural habitat for birds and butterflies. The increased soil moisture, evapotranspiration, and vegetation coverage creates a more comfortable local climate. Bioretention cells can also be used to reduce problems with on-site erosion and high levels of flow energy.

Properly designed and constructed bioretention cells are able to achieve excellent removal of heavy metals. Users of this technique can expect typical copper (Cu), zinc (Zn), and lead (Pb) reductions of greater than 90%. Removal efficiencies as high as 98% and 99% have been achieved for Pb and Zn. The mulch layer is credited with playing the greatest role in this uptake, with nearly all of the metal removal occurring within the top few inches of the bioretention system. Heavy metals affiliate strongly with the organic matter in this layer.

Phosphorous removal appears to increase linearly with depth of the bioretention cell, reaching a maximum of approximately 80% removal at about 2 to 3 feet depth. The likely mechanism for the removal of the phosphorus is its sorption onto aluminum, iron, and clay minerals in the soil. TKN (nitrogen) removal also appears to depend on depth but showed more variability in removal efficiencies between studies. An average removal efficiency for cell effluent is around 60%.

Generally 70 to 80% reduction in ammonia was achieved in the lower levels of sampled bioretention cells. Finally, nitrate removal is quite variable, with the bioretention cells demonstrating a production of nitrate in some cases due to nitrification reactions. Currently, the University of Maryland research group is looking at the possibility of incorporating into the bioretention cell design a fluctuating aerobic/anaerobic zone below a raised underdrain pipe in order to facilitate denitrification and thus nitrate removal.

Sedimentation can occur in the ponding area as runoff velocity slows and solids fall out of suspension.

Site Suitability

For maximum effectiveness, bioretention cells must be constructed on soils that can accommodate high rates of infiltration (sands, loamy sands, or sandy loams). The site should also be analyzed in detail to determine where on the site a bioretention cell would be the most effective in relation to other techniques being employed on the site. Bioretention cells can be lined and fitted with subdrains to accommodate additional discharge during peak flow events.

Maintenance Needs

Bioretention cells are typically designed to require minimal maintenance. During the vegetation establishment period, plants will need to be tended, watered, and potentially fertilized to ensure continued growth and success.

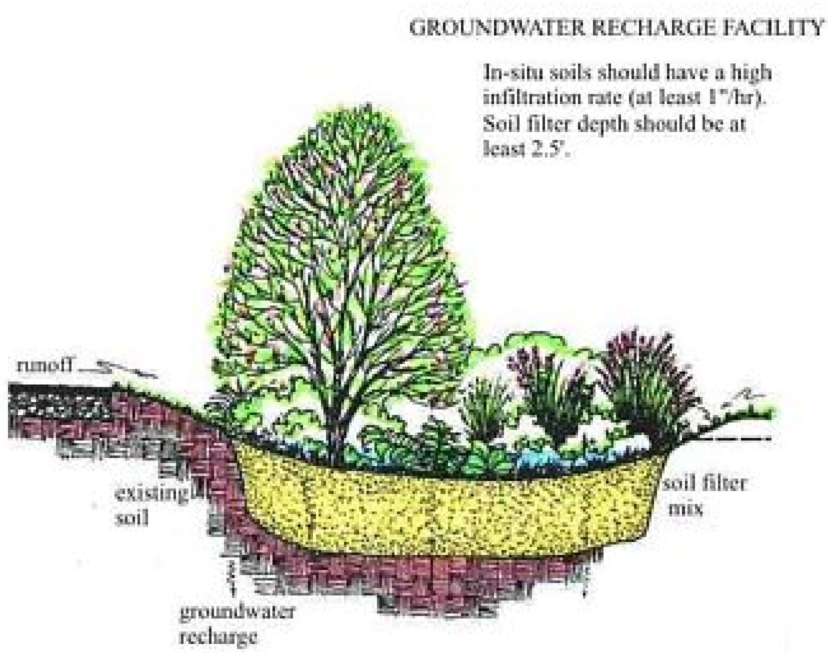


Image: lid-stormwater.net

Green Roofs

What are Green Roofs?

Green roofs, also known as vegetated roof covers, eco-roofs or nature roofs, are multi-beneficial structural components that help to mitigate the effects of urbanization on water quality by filtering, absorbing or detaining rainfall. They are constructed of a lightweight soil media, underlain by a drainage layer, and a high quality impermeable membrane that protects the building structure. The soil is planted with a specialized mix of plants that can thrive in the harsh, dry, high temperature conditions of the roof and tolerate short periods of inundation from storm events.

Water Resource Benefits

Green roofs provide stormwater management benefits through allowing plant materials and soil media to store and reduce flows of stormwater entering the storm drain system. Their primary benefit is to reduce peak flow discharge and attenuate the release of storm water during a storm event.

Additionally, green roofs are often quite aesthetically pleasing and can be novel additions to existing or planned infrastructure. Furthermore, green roofs can reduce urban "heat island" effects, reduce local concentrations of carbon dioxide, and reduce heating and air conditioning costs within their associated buildings.

Specifications

Green roofs can be generally classified as being extensive or intensive green roofs. Extensive green roofs are characterized by their low weight, low capital cost, and low maintenance. Intensive green roofs are characterized by their increased weight and capital cost, and their intensive planting and higher maintenance requirements. Extensive and intensive green roofs are either accessible or inaccessible but are always constructed to provide accessibility at least for roof maintenance activities.

Green roof top covers can vary from small-scale and simple designs that utilize a single plant species, to very large and extensive covers of landscaped gardens with numerous species. It is the desired function of the roof space that usually drives the green roof design, resulting in designs requiring different soil depths to accommodate various plants, shrubs, and/or trees. The additional structural support necessary to accommodate higher roof loads must also be taken into consideration.

Plant species are selected that have properties such as shallow root systems, good regenerative qualities, resistance to direct solar radiation, drought, frost, and wind. Vegetative cover can consist of a thin layer of moss and lichens to an assortment of native grasses, shrubs or even intricately landscaped gardens with multiple species and a soil substrate of 6 inches or more.

The waterproofing component of a green roof is by far the most important factor for the long-term success for the system. A typical green roof is a composite system of several layers of protective materials to achieve waterproofing and to convey water away from the roof deck. While the actual design specifications of a green roof will vary somewhat depending upon the manufacturer, a generalized, generic design consists of the following components:

- A waterproof membrane installed atop the existing roof, followed by a root barrier
- A drainage layer, applied over the entire roof area, must be present to carry away excess water.
- A filter fabric for fine soils
- The engineered growing medium or soil substrate (minimum of 2.5 to 3-inches to support a diverse and healthy plant community)
- Plant species that are capable of withstanding the harsh rooftop conditions of relatively extreme drought followed by saturated conditions during storm events.

Maintenance Needs

Once a properly installed green roof is well established, its maintenance requirements are usually minimal. Maintenance requirements include inspection of the roof membrane, the most crucial element of a green roof, as well as routine inspection and maintenance of the drainage layer flow paths. Initial watering and occasional fertilization are required until the plants have fully established themselves. Plants for green rooftops must be selected with care if the roof is expected to stay more or less maintenance free. Once the plants are healthy and well established, extensive green roofs no longer need to be irrigated except in cases of extreme drought. Regular fertilization with a slow release fertilizer twice a year will prevent acidification of the thin soil layer.

If properly designed and established, a typical green roof does not need to be cut. A thin soil layer does not support tall vertical growth, and the vegetation mat will tend to spread horizontally. Occasional weeding of the rooftop, especially in the establishment phase, may be necessary.

Because of the severe consequences of drainage backups, inspection of the drainage flow paths (or channels) is crucial, especially on extensive roofs. If drainage routes become blocked, green roofs can cause some flat roofs to leak due to continuous contact with water or wet soil. Roofs can leak from drainage backups or root puncture or if the correct water-proofing membrane system, root barrier, and/or drainage layer are not selected.

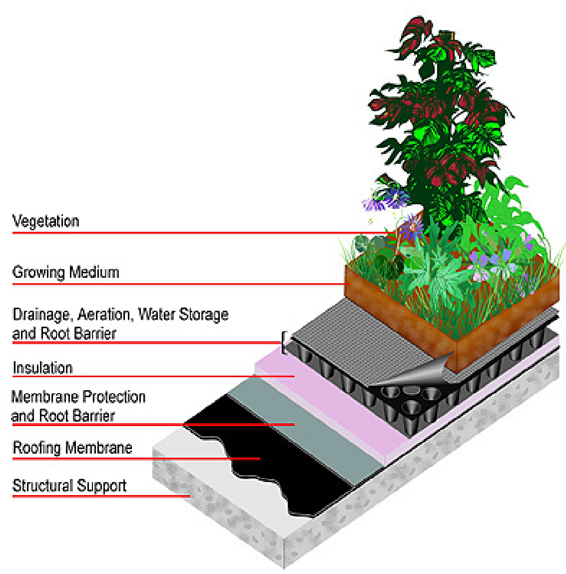
Initial / Long-term Costs

Costs for green roofs in the United States are estimated to average between $15 to $20 per square foot. By far the highest costs associated with green roof creation are the soil substrate/growth medium and the plant components associated with it. The cost of planting can also increase if plants are placed individually rather than pre-grown on vegetation mats.

Offsetting the initial capital and ongoing maintenance costs, green roofs provide a number of long-term cost savings. Rooftop vegetation moderates the temperature extremes of a roof surface and prevents it from being exposed to ultra-violet (UV) radiation and cold winds that could accelerate its breakdown. A vegetated roof, on average, can be expected to prolong the service of the life of a conventional roof by at least 20 years (ZVG, 1996). When the savings associated with deferred maintenance and reduced energy consumption are taken into account, vegetated rooftops are comparable in cost to conventional roofs.

Other long-term economic advantages to consider in the construction of green roofs, which can further offset their initial construction costs, include increased insulation value, resulting in savings on energy heating and cooling costs, potential for greenhouse gas emissions trading credits, provision of amenity space and aesthetic appeal, increasing the value of the property and the marketability of the city as a whole, and visual and environmental benefits that increase property value.

Cost savings in terms of environmental benefits to the community include cost savings from increased stormwater retention, attenuation of peak flows and urban flooding, through the reestablishment of predevelopment hydrology, decreased need to expand or rebuild separate storm sewer system infrastructure due to a decrease in total hydraulic loads, and reduction of pollutant loads to receiving waters by nonpoint source pollutant treatment through nutrient cycling of the plants and the soil chemistry of the rooftop matrix.



Images (left-right): re-nest.com, lakecountyil.gov

Porous Pavement

What is Porous Pavement?

Porous pavement is a type of roadway and parking area system that allows precipitation to directly infiltrate to the substrate below. Porous pavements can be either asphalt or concrete in structure and they are useful in achieving onsite stormwater management in areas with relatively low volume and low speed traffic conditions. Porous pavements are an exciting alternative to traditional paving mechanisms that create additional impervious surface and change the hydrologic function of a site. Porous pavements are quite pervious and allow precipitation to recharge onsite.

Water Resource Benefits

Unlike their traditional counterparts, porous pavements act to slow the flow of water once it reaches the land surface which can help attenuate peak flow discharges. Since pervious pavement is comprised of a large sand and gravel filter media, water quality can be significantly improved as runoff infiltrates downward through the system. Water quality benefits include dramatic reductions in total suspended solids, petroleum hydrocarbons, and metals due to both physical and microbial chemical filtration.

Specifications

Additionally, quality control of the asphalt or concrete production is critical to the success of a porous pavement project. The University of New Hampshire Stormwater Center provides detailed batch "recipes" for use in New England climates and locations. (http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_pa_spec_10_09.pdf) Researchers urge that individuals contract with trained applicators as this may be the most crucial stage of the process in determining success or failure of the ultimate project.

Site Suitability

Porous pavements are not suitable in all environments. They require the native soil permeability to be between 0.25 and 3.0 inches per hour with three to five feet of separation from the seasonal high groundwater level. They are also most appropriate where vehicle traffic is light and turning movements are few or at low speeds. Residential driveways and low-turnover commercial parking lots are appropriate locations for porous pavements.

Maintenance Needs

Porous pavements can be surprisingly resilient in the face of even no routine maintenance, though implementation of a proper maintenance schedule is sure to extend the life of the porous pavement and achieve the highest level of water quality benefits for the site. Porous pavements should be vacuumed two to four times per year, especially when sand, salt, and leaf debris builds up during the fall and at the conclusion of the winter months.

Initial / Long-term Cost

In general, material costs for porous pavements are approximately 20-25 percent higher than traditional pavements. However, since porous pavements do not require additional stormwater infrastructure, net cost for installing pervious pavement is comparable to conventional parking systems. Costs are generally between $2,000 and $2,300 per space for porous surface lots.

A Note on Performance of Porous Pavements in Cold Climates

Much of the debate on the effectiveness of porous pavements has focused on their use in cold, northern New England winter climates. Concerns about maintenance requirements, potential for the soil media to freeze and subsequently fail, and the effect of sand and salt applications on porous pavements have all been studied and addressed extensively at the University of New Hampshire Stormwater Center (UNHSC), where a porous asphalt parking lot has been in place since 2004.

Results of the UNHSC studies are promising in that seasonal performance appears to differ only minimally from winter to summer and that pavement pores remained open throughout the filter media, dispelling fears about freeze/thaw problems in porous pavements. Additionally, because the high level of drainage achieved during winter months, pervious pavements may actually be even more durable than traditional pavements, extending the lifespan of these lots beyond conventional surfaces.

Some winter guidelines are recommended in order to achieve the highest level of pervious pavement performance, and to reduce the potential for increased maintenance or lot failure:

- Plow after every storm totaling more than 2 inches of snowfall, with a slightly elevated blade to reduce pavement scarring
- Apply anti-icing treatments prior to storms, which can increase traffic safety at the lowest cost. Since meltwater drains directly through porous surfaces, contact time of de-icing chemicals is reduced. Correct for this loss in contact time through increased salt application.
- Sand application should be limited since it will increase the need for vacuuming
- Vacuum porous pavements a minimum of 2-4 times per year, especially after debris accumulation in the fall and winter months.

As a final reminder, researchers have observed that porous asphalt requires between zero and 25% of the salt routinely applied to traditional pavements to achieve equivalent or better deicing and traction. Over time, significant cost savings can be achieved through use of porous pavements and savings from sand and salt applications.

Images (left-right, pg 12): minnehahacreek.org, mandalaconcrete.com

Images (left-right, pg 13): alanizpaving.com, inhabitat.com

Rain Barrels

What are Rain Barrels?

Rain barrels are collection devices that are commonly used to store stormwater runoff from a specific location, generally a rooftop, for use at a later time. Rain barrels come in a variety of shapes, sizes, colors, and forms and vary in their level of sophistication for pumping capacity. The water can then be used for lawn and garden watering or other uses such as supplemental domestic water supply. Rain barrels can be connected to provide larger volumes of storage. Larger systems for commercial or industrial use can include pumps and filtration devices.

Water Resource Benefits

The primary benefit of employing a rain barrel or cistern to capture roof runoff is to attenuate the peak flow discharge of storm events. By storing and diverting runoff from impervious areas such as roofs, these devices reduce the undesirable impacts of runoff that would otherwise flow swiftly into receiving waters and contribute to flooding and erosion problems. No water quality treatment occurs with the use of a rain barrel, so some thought to the ultimate use of the stored water should be made. Generally speaking, rooftop runoff is a relatively clean source of water which can be used for a variety of purposes. Use of rain barrels also provides an opportunity for water conservation and the possibility of reducing water utility costs. Stored water can be used for lawn or garden irrigation representing a significant savings over the course of a year in volume of water used for residential purposes.

Specifications

For residential applications a typical rain barrel design will include a hole at the top to allow for flow from a downspout, a sealed lid, an overflow pipe and a spigot at or near the bottom of the barrel. The spigot can be left partially open to detain water or closed to fill the barrel. A screen is often included to control mosquitoes and other insects.

Site Suitability

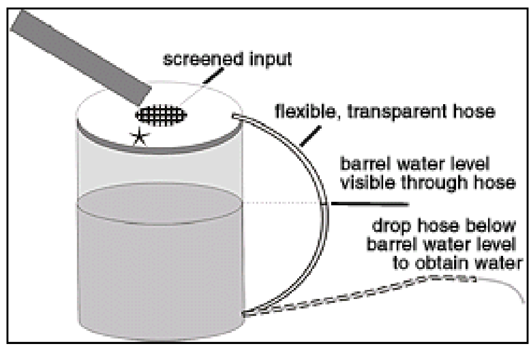
Rain barrels, or larger cisterns, are appropriate for almost all residential, commercial, or industrial rooftops. Some thought should be given to sizing the rain barrel appropriately, either for the amount of water to be contained or for the ultimate function that the water being stored will fulfill.

Maintenance Needs

Maintenance requirements for rain barrels are minimal and consist only of regular inspection of the unit as a whole and any of its constituent parts and accessories. The roof catchment, gutters, and downspouts should be inspected regularly to ensure that particulate matter does not enter or clog the barrel components.

Initial / Long-term Costs

Although costs vary somewhat between manufacturers, in general, the cost of a single, rain barrel roof top water catchment system averages about $120. More sophisticated rain barrels which include a pumping mechanism are more costly.



Images (clockwise): cityofdubuque.com, sustainstl.org, watershed activities.com, simplyrainbarrels.com

Rain Gardens

What is a Rain Garden?

A rain garden is a type of bioretention area that is designed specifically to serve both aesthetic and stormwater infiltration functions. Rain gardens are typically employed to capture and infiltrate rainwater from an individual structure or site, such as from a rooftop or driveway. The relative small size of these features makes them especially attractive for residential purposes where other large-scale or intensive systems may not be appropriate. They are often designed with plants that are attractive and inviting, yet require little maintenance after an initial establishment period. The rain garden itself is constructed as a shallow depression designed to capture and infiltrate water. During large storm events, water is allowed to pond on the surface of the depression, and in more sophisticated versions, an overflow pipe is installed to allow for excess flow to be diverted directly into the storm sewer system.

Water Resource Benefits

Rain gardens are biophysical systems that have the dual benefits of being able to remove chemical nutrients from stormwater effluent before delivering that water back to either a traditional storm sewer system or to groundwater, depending on whether the rain garden is under-drained or self-contained. Rain gardens are usually located close to the stormwater effluent source (perhaps a roof drain or adjacent to a parking area or driveway) which can also serve to slow stormwater, reducing its erosive power. As water slows, its capacity to carry sediments and fine particles is decreased, providing a further water quality benefit.

Generally, rain gardens are most effective at removing Nitrogen and Phosphorous from stormwater effluent, as these are nutrients that can be absorbed and used by plant materials. Metals can also be removed from stormwater effluent, generally through physical deposition of sediments on the surface of the rain garden that contain heavy metals and metal oxide compounds.

Specifications

There are two basic types of rain gardens: self-contained and under-drained. Self-contained rain gardens allow stormwater runoff to infiltrate directly into the soil column and groundwater. In cases where infiltration is not desired, such as with high ground water tables or adjacent contaminated soils, an under-drained system can be constructed. In an under-drained rain garden, piping is provided beneath the rain garden to move excess water not absorbed in the planting or soil media into a conventional storm sewer system. Deciding on which type of rain garden to construct will depend on the volume of water to be treated, the existing soil conditions, space available for constructing the rain garden, and project budget.

In both types of rain gardens, the site is excavated and the re-filled with a minimum of 8 inches of porous planting media. Systems that allow for two to three foot depths of media are generally ideal. This construction essentially mimics the hydrologic action of a healthy forest, and allows water to collect in the rain garden, move rapidly down through the soil, reach saturated conditions after the peak of the rainfall or runoff event, and allow plants to slowly utilize the accumulated water and nutrients. Rain gardens with no underdrain typically hold moisture longer, particularly in the lower areas of the garden. Plants selected for rain gardens should be able to tolerate inundation, especially in the lower-lying areas. Plants that can thrive in extremes of both drought and saturated conditions are most desirable, and should also be able to withstand the slow accumulation of nutrients that results in a properly functioning rain garden.

Aside from plant selection, providing the right kind of porous soil mix is crucial to the success of a rain garden. In general, the following mix of materials should be used as the soil media:
50% (by volume) sand
15% (by volume) double-shredded hardwood mulch (15% by volume)
30% (by volume) weed-free topsoil
5% (by volume) peat moss or compost

Site Suitability

Rain gardens need to be constructed according to the runoff volumes that will be treated. As a general rule, the rain garden should be sized at approximately five to seven percent of the area being drained. For example, if a rain garden is to drain a 2,000 square foot roof, the garden should be approximately 100 square feet in size. Soils that are not naturally well-drained will require either a deeper porous media bed or will need to have subsurface drainage installed so that the garden does not flood beyond the designed surface ponding depth.

Maintenance Needs

In general, rain gardens are constructed to require little maintenance through proper plant selection and site preparation. Maintenance for rain gardens is similar to that required for most bioretention areas, and can be accomplished primarily by hand and does not require any special equipment. Over time and with highly contaminated runoff, the soil media of the rain garden may need to be replaced in order to achieve desired water quality benefits of runoff treatment as the soils accumulate nutrient materials.

Description	Method	Frequency
Plants		
Water plants during establishment period	By Hand	Immediately after Construction of Bioretention Area or Rain Garden
Treat diseased trees and shrubs	By Hand	As Needed
Remove and replace any dead or diseased vegetation not responding to treatment	By Hand	Twice Yearly
Organic Layer		
Remulch void areas	By Hand	As Needed
Remove existing mulch layer before applying new mulch layer (optional)	By Hand	Yearly
Soil		
Inspect and repair erosion pathways	By Hand	Monthly / As Needed
Soil testing	By Hand	Yearly
Replace soil	Mechanical	Approximately 5-10 years after construction upon evidence of reduced CEC.
Source: Prince George's County, Department of Environmental Resources, 1993.		

Initial / Long-term Costs

Initial costs of constructing a rain garden are estimated at between $3 and $15 per square foot, depending on the type of native soil and plant materials choices. Additionally, soil replacement for a system designed to drain one acre would cost between $1,000 and $2,000 over a one-day construction period.

Image: lowimpactdevelopment.org

Tree Box Filter

What is a Tree Box Filter?

A tree box filter is another type of bioretention area most often used to treat parking or driving surface effluents. Tree box filters are popular because of their aesthetic appeal and usefulness as stormwater device retrofits. The system consists of a container filled with a soil mixture, a mulch layer, under-drain system and a shrub or tree. Stormwater runoff drains directly from impervious surfaces into the tree box. Water is treated as it infiltrates downward through the tree box and then flows out through an under drain connected to a storm drainpipe or into the surrounding soil.

Water Resource Benefits

Like most bioretention devices, these filters shine in their ability to manage metals, Nitrogen, and Phosphorous due to the living plant materials being able to extract, remove, and utilize runoff nutirents. Tree box filters also have the added benefit of being able to capture sediments and suspended solids from parking lot or roadway runoff and therefore function similarly to a typical catch basin. Tree box filters can also be used to control runoff volumes or peak flows by adding storage volume beneath the filter box with an outlet control device.

Specifications

Tree box filters are in essence a concrete vault filled with a porous soil media and planted with vegetation species. Soil media that is generally 80 percent sand and 20 percent compost work well to allow for quick infiltration while being able to support vegetative growth. Tree box filters are sized according to the amount of impervious surface that they will be draining, and generally include a bypass drain for large storm events. The vault may be either closed or open-drained depending on the underlying soils and depth to groundwater. Vegetation species used in the tree box filter should be both drought and salt-tolerant with root systems that are not terribly aggressive.

Tree Box Filter Sizing and Pollutant Removal Guidelines					
Tree Box Filter Size	**Annual Volume Filtered**	**TP Removal**	**TN Removal**	**TSS Removal**	**Metal Removal**
	%	%	%	%	%
9 x 16	99.48%	81.57%	75.70%	94.50%	90.52%
9 x 12	98.55%	80.81%	74.99%	93.62%	89.68%
6 x 12	96.58%	79.19%	73.40%	91.75%	87.88%
*6 x 6	89.93%	73.74%	68.43%	85.43%	81.83%
3 x 6	69.26%	56.79%	52.70%	65.79%	63.02%
3 x 3	60.88%	49.75%	46.32%	57.83%	55.40%
One 6’ x 6’ tree box filter per ¼ acre of impervious surface is the optimum size for pollutant removal and cost effectiveness.					

Site Suitability

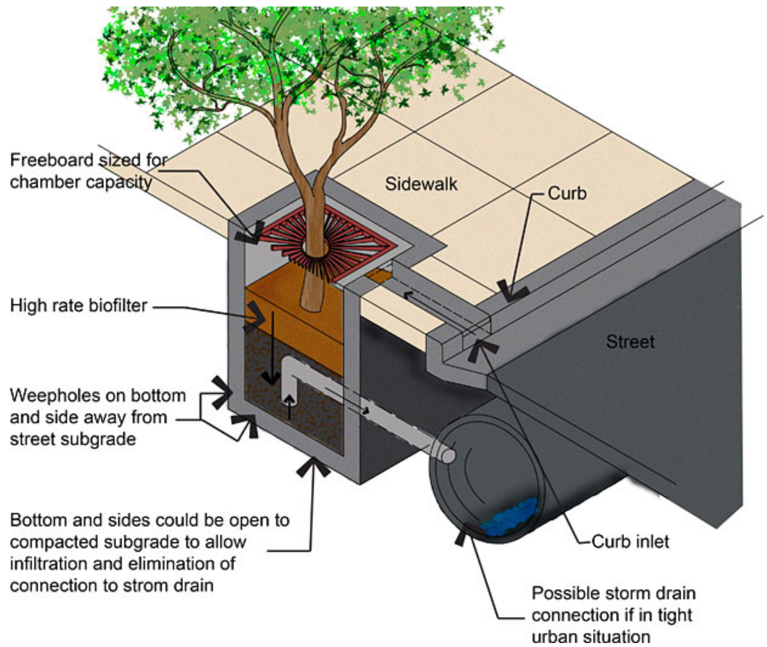
Tree box filters are especially valuable stormwater tools in locations where space is limited and are therefore suitable for both urban and residential applications. Tree box filters have the added benefit of providing an aesthetically pleasing yet functional amenity to streetscapes, parking lots, or other locations where locating trees might be either desirable or required. Tree box filters are available commercially through a number of

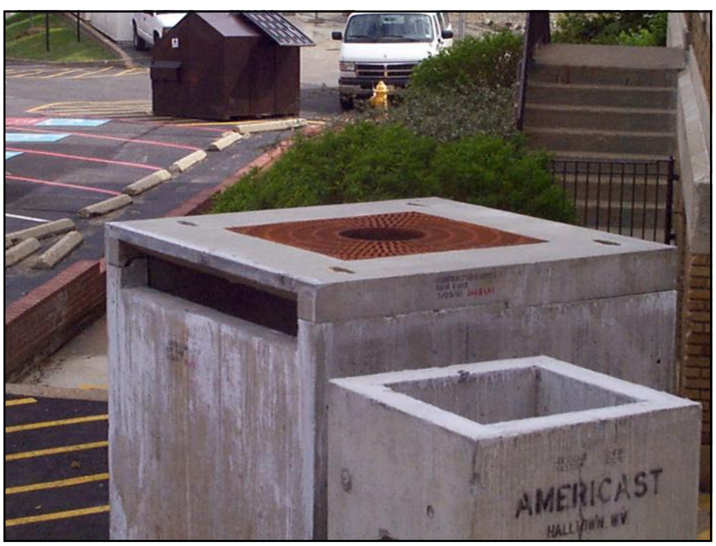
Maintenance Needs

Maintenance of tree box filters includes as needed removal of trash, debris, and sediment and replenishment of the top layer of mulch. Plants may need to be watered during drought events and potentially replaced if dead or dying. Tree box filters are relatively low maintenance, highly attractive, and versatile in terms of design and placement, contributing greatly to their utility as stormwater treatment and control devices.

Initial / Long-term Costs

A typical catch basin can be replaced or retrofitted with a tree box filter for approximately $2,500. Long-term maintenance costs are minimal since these systems are designed to be self-sustaining.





Images (top-bottom): filterra.com, ladstudios.com, lid-stormwater.net

LID Web Links & References

LID – General

University of New Hampshire Stormwater Center 2007 Annual Report
http://www.unh.edu/erg/cstev/2007_stormwater_annual_report.pdf

Rundown on Runoff: The UNH Stormwater Center's 2005 Data Report
http://www.unh.edu/erg/cstev/pubs_specs_info/annual_data_report_06.pdf
This UNH Stormwater Center report provides a comparison of findings for a variety of LID treatment methodologies for water quality performance, including sand filters, bioretention systems, hydrodynamic separators, gravel wetlands, and stone swales.

Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices
http://www.epa.gov/owow/NPS/lid/costs07/
This report provides information to cities, counties, states, private-sector developers and others on the costs and benefits of using Low Impact Development (LID) strategies and practices to help protect and restore water quality.

Low Impact Development (LID) Literature Review and Fact Sheets
http://www.epa.gov/owow/NPS/lid/lidlit.html
This report, which was developed by EPA in cooperation with the LID Center, contains a summary of the current monitoring and effectiveness data on LID practices. Fact sheets describing four LID case studies are also available.

Seasonal Performance Variations for Storm-Water Management Systems in Cold Climate Conditions
http://www.unh.edu/erg/cstev/pubs_specs_info/jee_3_09_unhsc_cold_climate.pdf
Article in the Journal of Environmental Engineering, March 2009 discussing the performance of several LID technology systems during the winter season.

LID Strategies and Tools for NPDES Phase II Communities
http://www.lowimpactdevelopment.org/lidphase2/
This site was developed through a Cooperative Assistance Agreement under the U.S. EPA Office of Water 104b(3) program in order to assist stormwater Phase II communities integrate low impact development (LID) strategies into their compliance programs. LID is a rapidly growing approach to stormwater management that offers the opportunity for Phase II communities to develop a comprehensive natural resource and water quality protection program.

LID Standard Details and Specifications Technical Guidelines
http://www.lowimpactdevelopment.org/ewri_sds.htm
This web tool is being developed to help communities create better stormwater management programs through the advancement and implementation of sound technical solutions through the use of Low Impact Development (LID).

LID Clearinghouse
http://www.lid-stormwater.net/clearinghouse
The LID Clearinghouse is a forum that allows researchers, practitioners, and program managers to collaborate and efficiently disseminate and share information with local governments, states, builders, developers, stakeholders, and environmental groups. The administrative and technical information available through this clearinghouse will be useful to permit writers, local government officials, watershed managers, and stakeholders.

Low Impact Development Center
http://lowimpactdevelopment.org
The LID Center) has created a number of web-based resources available to assist in the design of LID projects and the development of LID programs.

LID for Big Box Retailers
http://lowimpactdevelopment.org/bigbox/
This effort was funded by an EPA Assistance Agreement through the EPA Office of Water. The recommendations or outcomes of this effort may or may not reflect the views or policies of EPA. The purpose of this project is to provide large building and site footprint high volume retailers with strategies that integrate innovative and highly effective Low Impact Development (LID) stormwater management techniques into their site designs for regulatory compliance and natural resource protection at the local levels.

Stormwater Management – General

Quality Assurance for Nonpoint Source Best Management Practices (BMPs)
http://www.lowimpactdevelopment.org/qapp/
This site was developed by the LID Center through a grant under the US EPA Region 1 in order to provide a web-based template that allows watershed stakeholders to address typical New England nonpoint source (NPS) concerns. The purpose of this website is to assist stakeholders in utilizing LID BMPs in their Quality Assurance Project Plans. The goal of this project is to provide sufficient information on the potential use and applicability of several LID best management practices (BMPs).

Managing Stormwater as a Valuable Resource
http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-01-13.pdf
This document discusses the need to preserve groundwater recharge and the NHDES policy of encouraging the use of natural filtration BMPs. It also discusses the importance of local programs to ensure the ongoing inspection and maintenance of infiltration BMPs permitted by DES and the proper sizing, design, and construction of BMPs that do not fall under DES review. The document encourages towns and water suppliers to manage stormwater as a resource.

Protecting Water Resources and Managing Stormwater: A Bird's Eye View for New Hampshire Communities
http://www.unh.edu/erg/cstev/pubs_specs_info/stormwater_guide.pdf
UNHSC, in partnership with the UNH Cooperative Extension, has produced a new guide focused on what local communities can do to protect water resources and manage stormwater runoff.

Stormwater Manager's Resource Center
http://www.stormwatercenter.net/
The Stormwater Manager's Resource Center (SMRC) is designed specifically for stormwater practitioners, local government officials and others that need technical assistance on stormwater management issues.

National Menu of Stormwater BMPs: Stormwater Management in New Development and Redevelopment
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=min_measure&min_measure_id=5
Includes fact sheets on best practices for mitigating stormwater impacts from existing urban areas.

Stormwater Management – Ordinances

New Hampshire Stormwater Manual Volume 1: Stormwater and Antidegredation
http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-08-20a.pdf
The NH Stormwater Manual provides developers, designers, and regulatory personnel with a reference guide for the selection, design, and application of measures to manage stormwater from newly developed and redeveloped properties. These measures include source controls, design techniques (including LID design approaches), structural practices, and construction practices designed to minimize water quality impacts and to protect and improve the functions of natural wetlands and waterways.

Bioretention

UNHSC Subsurface Gravel Wetland Design Specifications
http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_gravel_wetland_specs_6_09.pdf
Provides design components and specification of materials for a typical gravel wetland.

Bioretention Cell
http://www.lowimpactdevelopment.org/epa03/biospec.htm
Provides recommended materials and specifications for constructing a bioretention cell.

Porous Pavements

Pervious Pavements
http://stormh2o.com/september-2008/pervious-asphalt-concrete.aspx
Article in *Stormwater*, September 2008 regarding findings about functionality and performance of pervious pavements in cold climates.

Porous Asphalt Pavements for Stormwater Management
http://www.unh.edu/erg/cstev/pubs_specs_info/napa_pa_5_08_small.pdf
Article in Hot Mix Asphalt Technology, May/June 2008 describing the form, function, and water quality benefits of Porous Asphalt.

Pervious Concrete Pavement for Stormwater Management
http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_pervious_concrete_fact_sheet_4_08.pdf
UNH Stormwater Center factsheet on pervious concrete.

Porous Asphalt Pavement for Stormwater Management
http://www.unh.edu/erg/cstev/pubs_specs_info/porous_ashpalt_fact_sheet.pdf
UNH Stormwater Center factsheet on pervious asphalt.

Winter Maintenance Guidelines for Porous Pavements
http://www.unh.edu/erg/cstev/pubs_specs_info/winter_maintenance_fact_sheet.pdf
UNH Stormwater Center factsheet on winter maintenance of porous pavements.

UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds (Rev. 10/09)
http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_pa_spec_10_09.pdf
Provides design specifications for porous asphalt pavements in parking lot applications.

Rain Gardens

Rain Garden Design Templates
http://www.lowimpactdevelopment.org/raingarden_design/
This site has been developed through an NFWF grant to display a series of rain garden, or bioretention, design templates that can be used by landscape architects, landscape contractors, and garden clubs throughout the Bay. These designs will promote the use of rain gardens by providing a set of easily accessible high quality sustainable and maintainable designs for the landscape industry and citizens

10,000 Rain Gardens
http://www.rainkc.com/
This is a Kansas City metropolitan area initiative. 10,000 Rain Gardens is dedicated to educating the public about what citizens can do to improve water quality and manage stormwater on personal and community property. The site includes information on rain gardens, rain banks and other green solutions for managing stormwater.

Produced by the Nashua Regional Planning Commission
9 Executive Park Drive, Suite 201
Merrimack, NH 03054

603-424-2240 | www.nashuarpc.org