Building Community Resilience Through Local Regulations

Participant Guide to Massachusetts Bylaws & Best Practices

Module 2: Low Impact Development 101

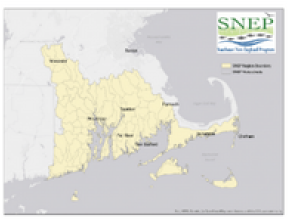
Context

This document is part of a comprehensive curriculum program, *Building Climate Resilience Through Local Regulations*, developed by Mass Audubon in collaboration with other nonprofit organizations and federal, state and regional agencies. The curriculum contains 8 modules, each of which guides the user through different components of improving community resilience through local regulations that support green designs and nature-based climate solutions. Each module includes a participant guide (e.g., this document) and a PowerPoint presentation.

The full curriculum, supplemental resources and additional information on bylaw review and best practices are available through: [Massachusetts Rivers Alliance]() and [Mass Audubon](). The [SNEP Network's website]() provides additional resources including an interactive virtual storymap and webinar recordings.

Acknowledgements

This bylaw curriculum has been developed by SNEP Network Partners Mass Audubon, Cape Cod Commission, the Southeast Regional Planning and Economic Development District, and the Blackstone Watershed Collaborative in partnership with the Massachusetts Rivers Alliance and the Citizen Planner Training Collaborative, with financial support from the SNEP Network. The Barrett Planning Group, LLC assisted with planning content.



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This product has been funded wholly or in part by the United States Environmental Protection Agency under Assistance Agreement SE- 00A00655-0 to the recipient. The contents of this document do not necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does the U.S. EPA endorse trade names or recommend the use of any products, services or enterprises mentioned in this document. This project also received funding from the Lookout Foundation.

The Southeast New England Program (SNEP) Network brings together local environmental organizations, academic institutions, regional planners, and consultants who collaborate to provide municipalities, tribes and organizations in Rhode Island and Southeast Massachusetts access to free training and technical assistance to advance stormwater management, ecological restoration, and sustainable financing goals across the region. The SNEP Network is administered through EPA's partnership with the New England Environmental Finance Center, a non-profit technical assistance provider for EPA Region 1. The SNEP Network supports this bylaw review curriculum as a key resource for communities to update their local regulations for improved nature-based climate solution implementation. Find out more about the SNEP Network at [www.snepnetwork.org]().

Module 2 | *Low Impact Development 101*

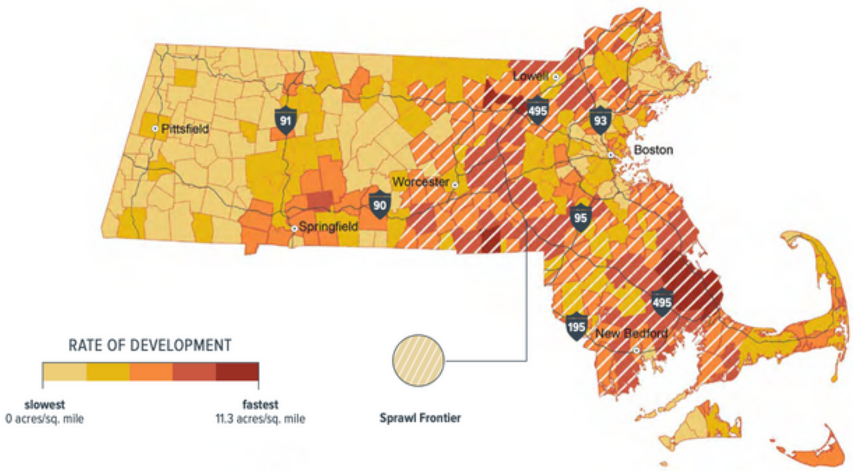

Figure 1. Sprawling developing trends in Massachusetts. *Source: Mass Audubon's Losing Ground Report (2020).*

Introduction

Conventional development disrupts the natural environment and ecosystem functions. Water moves faster across a developed site, characterized by open areas and impervious surfaces. Rather than infiltrating into the ground, it runs off, polluting local waterways and contributing to flooding. This module identifies problems caused by conventional development, and the nature-based alternatives — such as Low Impact Development (LID) techniques and stormwater best management practices (BMPs) — that help mitigate the impacts of these problems, in order to enhance community resilience.

Objectives

After completing this module, participants will be able to answer the following questions:

- What are some common LID techniques for stormwater management?
- Why should communities implement LID practices?
- How can LID be made suitable and cost-effective for communities?

Low Impact Development (LID)

Module 1 introduced the concept of green infrastructure and identified multiple nature-based solutions, such as natural resource conservation, open space preservation, and ecosystem restoration. Ecosystem services provided by forests, wetlands, trees, and other vegetated features are highly effective in mitigating environmental impacts from both climate change and sprawl development (Figure 1). Despite admirable conservation efforts, new and redevelopment across the Commonwealth continues to disrupt the natural water cycle, especially how water moves through communities.

Low Impact Development (LID) is a design strategy that minimizes pollution from stormwater runoff by reducing paved or impervious areas, preventing stormwater pollution, keeping stormwater close to the source, and treating it as a resource rather than a waste product. An easy moniker to remember LID principles is "slow it, spread it, sink it." Slow the flow of water down, spread it out over a larger area, and allow it to sink into the ground. Green infrastructure can be integrated into LID for stormwater management by preserving the natural landscape and relying on natural plant and soil processes to filter pollutants out of stormwater. Where natural green infrastructure has already been destroyed, or is diminished due to site constraints, constructed green infrastructure features like rain gardens and tree plantings can help minimize impacts.

Figure 2 below illustrates how development changes the hydrology of a site, reducing groundwater recharge. In natural areas, roughly 50% percent of precipitation infiltrates into the ground, 40% evapo-transpires (water used by plants is re-released into the atmosphere along with oxygen produced by the plant), and the remaining 10% runs off the land. Clearing trees and other vegetation from a site reduces water uptake by plants; replacing natural areas with impervious cover reduces water infiltration into the ground. Runoff drastically increases with greater impervious area: up to 30% of precipitation runs off a lot with one half impervious surface, and up to 55% when a lot is completely developed. Impervious surfaces also exacerbate the urban heat island effect; in the absence of plants, the sun still evaporates up to 30% of precipitation, but the natural cooling effect and oxygen production is lost.

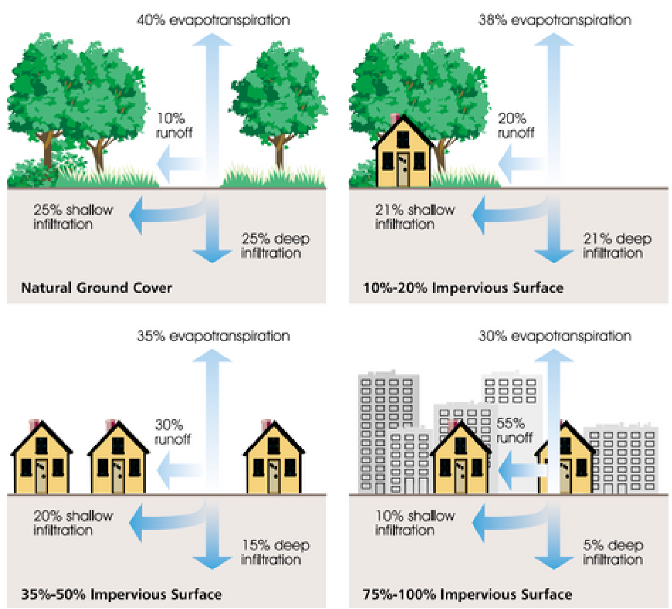

Figure 2. Impacts of development on hydrologic processes, such as groundwater infiltration, runoff, and evapotranspiration. *Source: US EPA.*

LID Techniques

A brief summary of the most common LID techniques is included below. Communities often cite cost concerns as the primary barrier to LID implementation, but in many communities and contexts, LID measures can be cost saving. For more information on each of these, including their costs and savings opportunities, see Mass Audubon's LID Fact Sheets. Fact Sheet #2 covers conservation design; Fact Sheet #3 includes: rain gardens and bioswales, green roofs, permeable paving, paving reductions, and rain barrels and cisterns.

Bioretention: Rain Gardens and Bioswales

Rain gardens and bioswales are examples of bioretention (process for which sediments and contaminants are removed from stormwater runoff) areas engineered for water catchment and planted with native vegetation. Bioretention facilitates groundwater filtration and recharge, and are highly adaptable to specific site characteristics. The shape and size of a rain garden or bioswale depends in part on the impervious surface area being mitigated and soil type. Bioretention areas benefit driver and pedestrian safety by mitigating localized flooding of paved areas.

Rain gardens are often located along roads, in road medians, and near gutter downspouts on residential sites. Rain gardens look similar to other gardens with tall grasses or wildflowers, but are strategically located in natural or engineered depressions to maximize water collection. Figure 3 below diagrams the basic features of a rain garden.

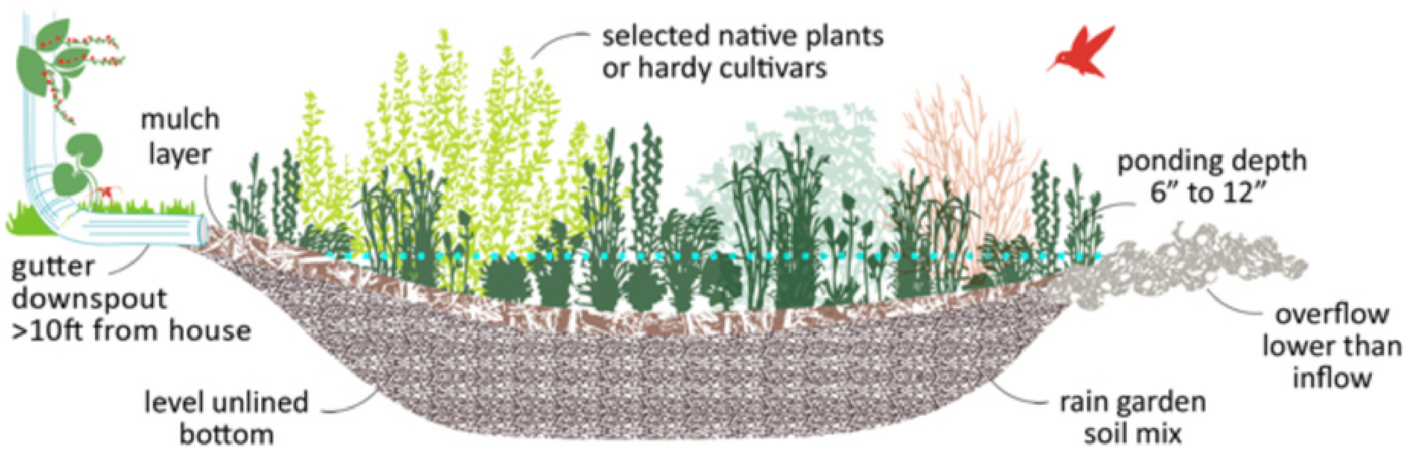

Figure 3. Diagram of a functional rain garden. *Source: "Build a Rain Garden," 12,000 Rain Gardens in Puget Sound, Washington State University.*

Bioswales are essentially just larger and deeper rain gardens. Bioswales are particularly useful in areas prone to flooding or near extensive impervious areas, such as parking lots. Bioswales are particularly valuable when located upstream from quality-impaired waterbodies; runoff collects significant pollutants as it travels across impervious surfaces; these contaminants are then filtered out in the bioswale, rather than flowing directly into the waterbody.

Cost Savings: Bioretention

Bioretention installation and maintenance costs are modest; in many instances they are less than the cost of installing a closed system with a catch basin and extensive piping. The savings potential from the benefits bioretention provides includes reduced water quality treatment costs (thanks to stormwater filtration) and avoided infrastructure and property damage (due to reduced flooding). As cost is unlikely to be prohibitive, the greatest barrier to implementing bioretention is the space required. If incorporated into the initial site design, large areas of impervious surface can be subdivided into smaller management areas, and treatment features like rain gardens and bioswales can be strategically dispersed throughout the site. Retrofitting a site with bioretention typically requires few, larger basins. This may not be possible in established urban contexts. Even reduced-scale nstallations of smaller, dispersed features improve groundwater recharge, stormwater filtration, and flood prevention; the cost savings and safety improvements provided by bioretention are a compelling incentive for property owners.

Green Roofs

Impervious surfaces are not limited to pavement; buildings similarly prevent groundwater infiltration and generate runoff from rooftops. Incorporating vegetation into a living or green roof can capture precipitation and mitigate runoff. Green roofs can also support pollinators, such as artificial beehives, especially in urban environments with taller buildings. Figure 4 below depicts four different types of green roofs.

Green roofs originated on buildings with large footprints and flat roof structures, such as schools, universities, museums, and some commercial and industrial buildings. But green roofs no longer need to be flat. While roofs with a steep pitch are less conducive due to uneven water distribution and increased erosion, roofs with slight pitch are a "happy-medium" because they're less vulnerable to pooling and leakage than flat roofs. This medium slope is the preferred strategy for smaller-scale and residential green roofs. Green roofs contribute other benefits, including cleaner air due to plant processes, and additional insulation from the heat-retention of the planting

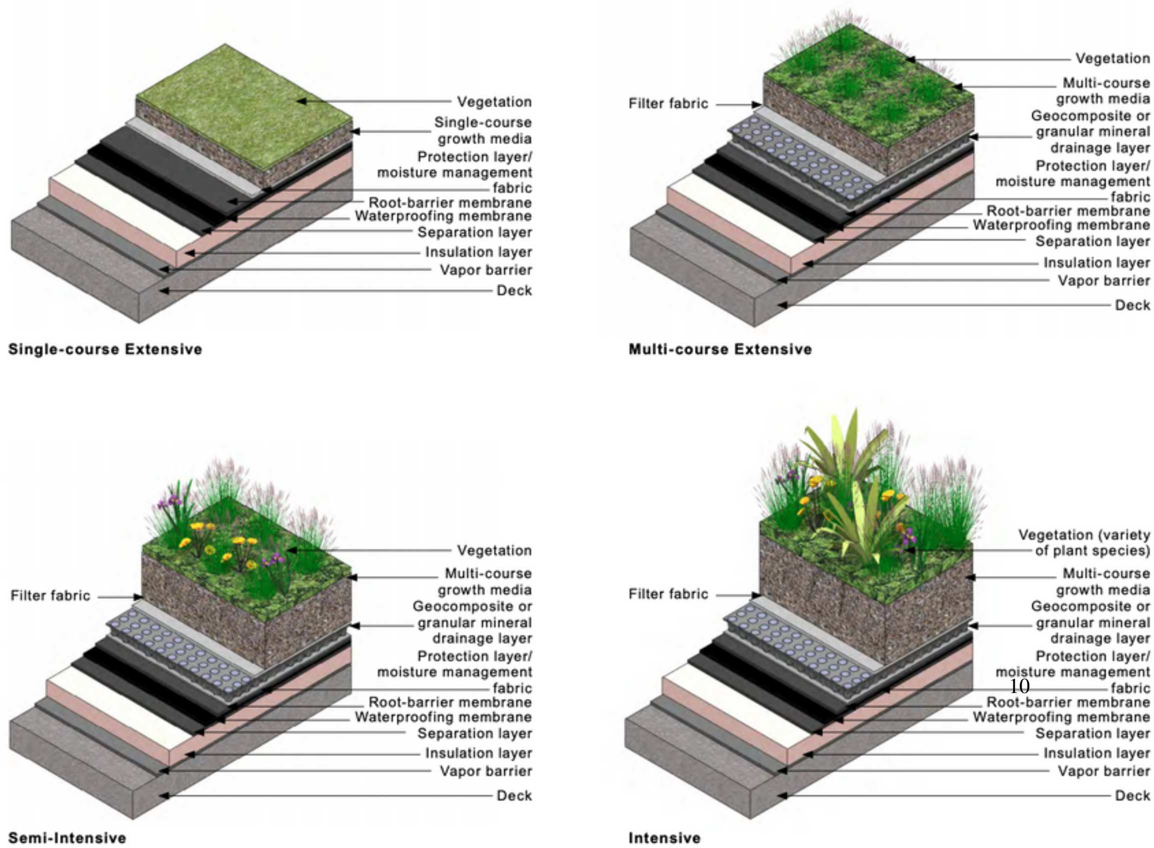

Figure 4. Diagram of green roof types. *Source: "The Benefits and Challenges of Green Roofs on Public and Commercial Buildings." (2011) US General Services Administration.*

medium and vegetation layer. As long as they are planted with hardy, native perennial plants, green roofs are low maintenance (limited to weeding and pruning), and virtually self-sustaining: rainwater contains all the nutrients needed to sustain plant life.

Cost Savings: Green Roofs

Similar to rain gardens and bioswales, green roofs provide cost avoidance by enhancing the longevity of neighborhood infrastructure and protecting nearby structures from stormwater damage. Their environmental benefits also reduce indirect costs associated with water quality impacts and urban heat island effects. Green roofs provide direct savings by reducing the building's energy costs. Rooftop plantings provide additional insulation; climate control inside these buildings requires less energy. Each square foot of green roof area pays for itself through energy cost savings in less than six years;[1] large buildings with extensive green roofs (over 10,000 square feet) yield direct cost savings even more quickly. Green roofs also protect a building's roof from environmental stress thanks to their waterproof membrane layer. While the useful life of a conventional roof is estimated around 17 years, green roofs can last more than twice as long, roughly 40 years.[2]

Permeable Pavement

Pavement is generally a barrier to groundwater infiltration, as it is typically impervious to water. Yet water-permeable pavement options are commercially available. Permeable pavement and concrete enable water to infiltrate through pores in the materials, recharging the groundwater below. These options improve public safety by reducing puddling and flooding. They can also mitigate pollutants in colder months, as they require significantly less salt to prevent freezing and icing.

Pavers are a good permeable option for smaller surfaces, such as patios and walkways: water infiltrates through the gaps between solid pavers. Some pavers are actually pervious (water infiltrates through the paver itself), while others are porous (water infiltrates through the pores in the cell or grid design of the pavers).[3] Permeable, pervious, and porous are often used interchangeably, but they each have distinct characteristics and varying ability to support vegetation. Porous pavers typically have sufficiently large cells to support grass growth, which may provide some water filtration. Porous and permeable pavers may provide sufficient infiltration to support tree root growth below the surface (depending on plant types and root structures). Figure 5 below shows various types of permeable pavement. (Note: like any paved areas, roots may lift and damage the solid surface.)

Cost Savings: Permeable Pavement

While permeable pavement may be more expensive than conventional materials at initial installation, their long term benefits quickly pay off. These LID strategies significantly reduce flood damage to buildings and infrastructure, which can increase property values and decrease insurance costs.[4] Financial benefits of permeable pavement are not limited to these indirect cost savings; meaningful direct costs savings result as well.

Permeable pavement reduces de-icing costs (both time and materials) as well as costs associated with ice-related accidents: it provides safer road conditions than conventional paving, while using 75% less salt.[5] Salt reduction is not only budget-friendly for municipalities and property owners; it is also good for the environment. Salt is very harmful to both soil and water quality, inhibiting plant growth and disrupting aquatic systems. Once salt enters an ecosystem, it is extremely difficult to remove. Reducing the amount of salt applied to paved areas will save money from expensive environmental remediation down the line.

Paving Reductions

Permeable paving is a useful mitigation strategy, but reducing the paved area outright is even more effective. Strategies for reducing impervious cover in a community include narrower roads, shared driveways, and alternative cul-de-sac layouts. Figure 6 below demonstrates one of these pavement reduction strategies.

In addition to improving stormwater management, these strategies provide multiple community benefits. Standard road widths in many communities exceed those required for road safety, parking, and incidental hazards (the minimum state standard is 20 ft wide, with two 10-foot travel lanes). Narrower roads actually increase road safety by encouraging slower speeds. Sidewalks protected from traffic by vegetated buffers improve neighborhood air quality. Shared driveways and alternative cul-de-sac layouts to minimize paved area devoted to individual residences also help preserve open space throughout the neighborhood, which provides further community benefits.

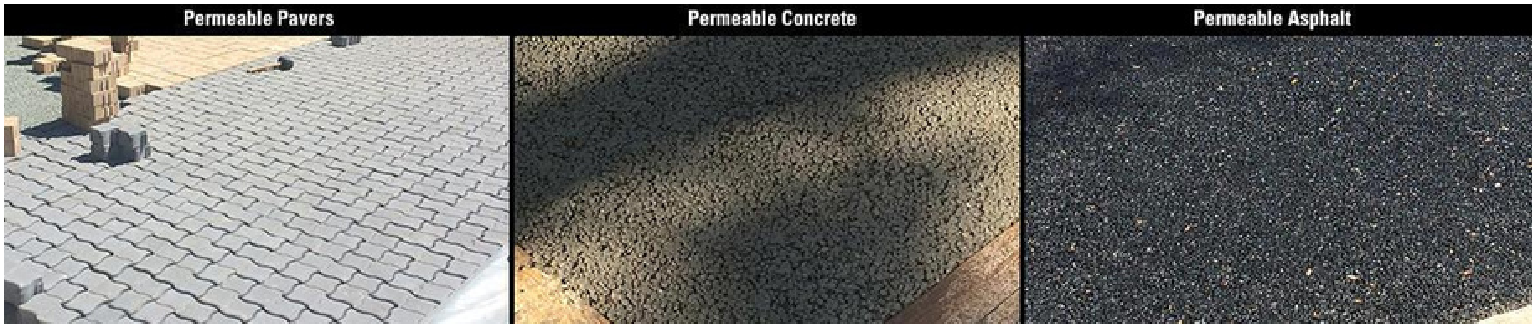

Figure 5. Images of some permeable paving types. *Source: USGS Wisconsin Water Science Center. Public domain.*

Cost Savings: Paving Reductions

Paving (and repaving) — even with conventional materials — is expensive; this cost burden often results in communities deferring maintenance, leading to poor road conditions. Decreasing the total paved area of a community, whether permeable or conventional, is a significant cost saving strategy. Narrowing roads from 28 ft to 20 ft in a small neighborhood with only one centerline mile of roadway saves $250,000 at installation, not to mention the long-term maintenance savings (e.g., plowing, salting, sweeping, etc.) throughout the life of the road. Additional indirect savings result from the mitigated flood damages and improved water quality associated with reductions in stormwater runoff.

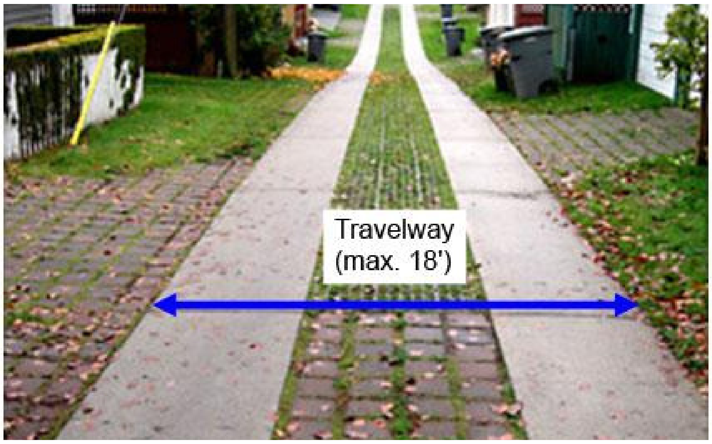

Figure 6. Image of a paving reduction strategy in an alley in Devens, MA. *Source: Devens Enterprise Commission, Subdivision Rules and Regulations, Street and Road Design Standards, 2013.*

Rain Barrels and Cisterns

Rainwater capture is perhaps the most intuitive strategy to reducing stormwater runoff and reusing it close to its source. Rain barrels (shown below in Figure 7) and cisterns can collect up to 100% of precipitation running off a roof; and collection mechanisms are simple and straightforward. Much of the necessary infrastructure for rainwater harvesting is already in place: many homes have gutters and downspouts that collect and direct rainwater away from the foundations: these can be easily adapted to fill a rain barrel or cistern. Rain barrels can store up to 50 gallons of water, and only require a simple modification to a

Figure 7. Image of a rain barrel. *Source: Town of Hanover, MA, Department of Public Works, April 30, 2020.*

home's downspout redirecting outflow into the barrel. Rainwater cisterns have even larger storage capacity, sometimes thousands of gallons, and also use existing downspouts. Installation of these larger structures is slightly more involved, especially for those stored underground. Without additional treatment or filtration, rainwater is not potable. It is ideal for watering lawns and indoor and outdoor plants, especially in summer months when many communities must restrict water use. Viewing rainwater as a resource for onsite reuse, rather than a waste product contributing to floods and sewer overflows, is yet another way to bolster community sustainability.

Cost Savings: Rain Barrels and Cisterns

Rain barrels are very affordable, often sold at even lower cost from municipalities, water suppliers, and local nonprofit organizations; and they can be self-installed. Cisterns are slightly more costly, due to their larger size and more involved installation. Direct savings from rainwater capture are reflected on a property's water bill, from using less water outdoors, as well as avoiding the need to replace landscaping, because harvested rainwater can keep plants alive during summer water restrictions.

Aside from these examples, most savings from rain barrels and cisterns are those indirect (but still valuable) benefits associated with many LID techniques. Reducing and capturing roof runoff offsets the impact of its impervious surface on other stormwater management systems (green or gray), prolonging the useful life of the system. Less stormwater volume results in a correlative reduction in flooding, erosion, and their associated property damage and water quality impairments.

Conservation Design

Module 1 explained the value of ecosystem services provided by the green infrastructure of natural landscapes. Conventional development typically fails to recognize or protect these nature-based sustainability solutions, sacrificing them in favor of larger lot sizes and extensive lot clearing. Reimagining neighborhood design to conserve natural features and leverage the important functions they provide is critical to the long-term sustainability and climate resilience of our communities.

Costs & Savings: Conservation Design

Conservation design reduces stormwater runoff more than any of the other aforementioned techniques because it preserves free ecosystem services on a larger scale, letting nature do the work![6] Conservation subdivisions are less expensive to build than conventional subdivisions, as they require less clearing, grading, and paving. Once built, property values in conservation subdivisions tend to be higher than their conventional alternatives, despite smaller lot sizes. These communities are highly desirable for their conserved natural land, recreation space, and neighborhood walkability. Energy bills tend to be lower as well, due to the natural climate-moderating benefits of trees: reducing wind that causes heat loss in cooler months, and providing cooling effects from shade in the summer. Subdivisions constructed for conservation following LID principles also require less engineered gray stormwater infrastructure, thanks to these strategies working holistically with one another. For more information on each of these LID techniques, including their relative costs and savings opportunities, see Mass Audubon's LID Fact Sheets. Conservation Design is covered in Fact Sheets #2, and the other techniques (rain gardens and bioswales, green roofs, permeable paving, paving reductions, rain barrels and cisterns) are included in Fact Sheet #3.

Conclusion

This module presented LID and stormwater BMPs, which provide numerous environmental and community benefits, in addition to cost-savings opportunities for municipalities, developers, and property owners alike. From small-scale and single-property implementation to community-wide adoption, these measures protect community members, their built environment, and natural resources. LID maintenance may differ from conventional stormwater management systems, but their ongoing costs are typically equivalent to or less than their conventional counterparts, and are quite modest compared to the costs avoided by having these protections in place. Any community — rural or urban, large or small — can implement LID in ways that protect and leverage the value of natural systems. Module 3 will build on the principles of LID, exploring how to incorporate LID strategies into local regulations.

End Notes

1. www.massaudubon.org/valueofnature
2. https://www.mass.gov/doc/water-infrastructure-finance-commission-final-report/download
3. Losing Ground: Nature's Value in a Changing Climate, Mass Audubon, 2020. www.massaudubon.org/losingground
4. de la Cretaz, A. et al. 2010. "An Assessment of the Forest Resources of Massachusetts." UMass Amherst Department of Natural Resource Conservation and MA DCR. 91 pp.
5. McLeod, E. et al. 2011. "A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2." Frontiers in Ecology and the Environment. 9(10), pp. 552-560.
6. Mitsch, W. J. and Gosselink, J. G. 2008. Wetlands. Van Nostrand Reinhold, New York, NY: Van Nostrand Reinhold. via Barbier, E.B, et al. 2011. "The Value of Estuarine and Coastal Resources." Ecological Monographs. 81(2), pp. 169-193.