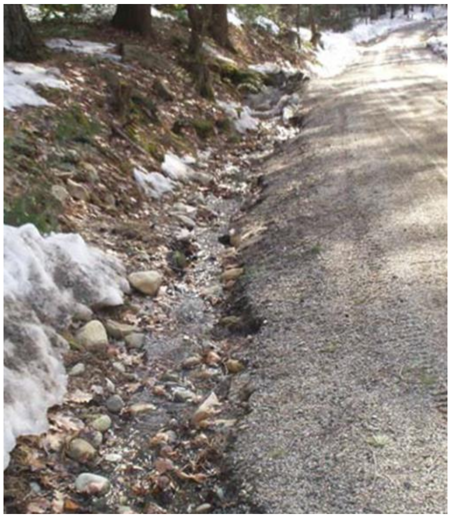

# Green Infrastructure Guide for Public Works Projects

Franklin Regional Council of Governments

September 2017

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## 1. Introduction to Green Infrastructure

Stormwater runoff from agricultural lands, roads, lawns, and other surfaces is now the most common source of water pollution in the U.S. At the same time, more extreme rainfall events and droughts due to climate change are resulting in greater flooding and increased stress on waterbodies and drinking water supplies. Traditionally, stormwater has been treated as a waste product to be collected and piped to centralized detention ponds or municipal storm sewers that drain into rivers and streams. Pollution, such as sediment, heavy metals, fertilizers, and oils picked up along the way, can end up in those rivers and streams.

A Green Infrastructure approach to stormwater management works with the natural features of a site to manage stormwater, reduce impervious surfaces, and use smaller, decentralized stormwater management techniques, that are often less costly than traditional stormwater systems. Keeping stormwater runoff close to where it falls reduces the amount of pollutants it can pick up from lawns and roadways. Green Infrastructure also helps maintain rural character in less developed areas, and provides green space in more urban areas.

*Stormwater can carry pollutants, such as oil, above, from roadways into rivers and streams.*

Green infrastructure treats stormwater as a resource rather than a waste product, and can complement or replace traditional pipe and pond, or "gray" stormwater infrastructure, which utilizes extensive underground systems. In many communities, existing stormwater infrastructure is aging, expensive to maintain, and inadequate to handle the heavier rainfalls our region is experiencing due to climate change. This leads to localized flooding and negative impacts to roads, bridges, property, and water quality. At the same time, many local roads and other public facilities are in need of upgrades. Integrating green infrastructure into public projects now and in the future can result in cost savings and provide a host of other public benefits.

## Gray vs. Green Stormwater Infrastructure

*Conventional "gray" stormwater infrastructure utilizes curbing, catch basins, and piping (below) to collect and convey stormwater runoff to centralized retention ponds (above right, credit UNH Stormwater Center) or to rivers and streams (below right).*

*Green infrastructure, such as swales and bioretention areas, manages stormwater runoff close to where it falls, providing for groundwater recharge. Photos, clockwise: Davis/Chapman Parking Lot in Greenfield; Pulaski Park in Northampton; roadside grass bioretention area in Dover, NH (credit UNH Stormwater Center)*

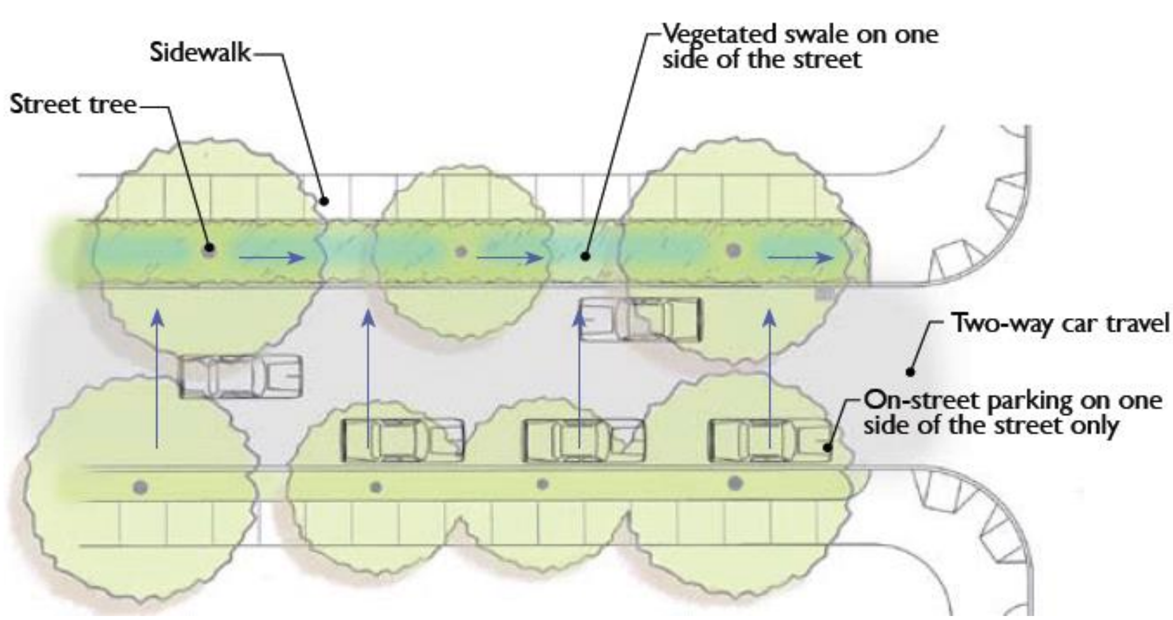
## Green Streets

Roads make up the majority of impervious surfaces in most communities. Green streets integrate green infrastructure into the public right-of-way to better manage and clean stormwater runoff from roads and sidewalks. Rain gardens, bio-retention areas, tree box filters or trenches, bio-swales, permeable pavement, and street trees are some of the techniques used to manage stormwater from roadways. New roads can be designed as green streets, and existing roads can be retrofitted to include green street practices.

*Green streets reduce the burden on the traditional stormwater infrastructure, in most cases complementing rather than replacing this infrastructure.*

Green streets reduce the burden on the traditional stormwater infrastructure, in most cases complementing rather than replacing this infrastructure. Green street practices may reduce the cost of a project by using less concrete or pavement than is typical, or by reducing the size of the "gray" infrastructure needed. Long term costs may also be less since most green infrastructure stormwater systems are on the surface, not underground, making maintenance easier.

Green streets improve the pedestrian environment and encourage walking and bicycling by providing more shade, slowing traffic, and improving air quality and streetscape aesthetics. Green streets can go hand in hand with Complete Streets, where all users of the right of way - pedestrians, bicyclists, and vehicles - are safely accommodated.




*Example of a green street. Source: U.S. EPA, 2009*

## Benefits of Using Green Infrastructure in Public Works Projects

There are a number of ways that incorporating green infrastructure into public works projects can benefit towns and cities. Following are several key reasons why communities may want to consider incorporating Green Infrastructure strategies in public projects.

### Water Quality

Clean water supports healthy environments and communities. In Franklin County, outdoor recreation is an important part of residents' quality of life and the local economy. In addition to the environmental benefits of clean water for wildlife, managing stormwater runoff to reduce pollution to streams, rivers, and waterbodies supports outdoor recreation such as boating, swimming, and fishing. In some areas of Franklin County, water quality testing has shown that after heavy rainfalls, waterbodies may not be suitable for recreation due to high levels of pollutants such as the bacteria E. coli. Preventing polluted stormwater runoff from entering waterbodies will support safe and healthy outdoor recreational opportunities for residents and visitors in the region.

*In 2011, flooding from Tropical Storm Irene caused massive damage to roads and infrastructure in western Franklin County, such as this road in Colrain.*

### Flooding

In Massachusetts, annual precipitation amounts have increased at a rate of over 1 inch per decade since the late 1800s, and are projected to continue to increase largely due to more intense precipitation events. The Northeast has experienced a greater increase in extreme precipitation events than the rest of the U.S. in the past several decades. Flood events have also increased due to these storms.[1] Flash flooding from intense rain can cause erosion and result in road and bridge washouts. In Franklin County, many roads are located along streams and rivers and are vulnerable to damage from flooding. Green infrastructure can help reduce the amount of stormwater entering streams and rivers, and delay peak flows to waterbodies, reducing the amount and velocity of flood water and the impact on infrastructure.

### Drinking Water

Many residents and businesses in Franklin County rely on groundwater for their drinking water supply. Infiltrating rainwater is critical to maintaining underground aquifers and adequate water

[1] Massachusetts Wildlife Climate Action Tool: https://climateactiontool.org/content/precipitation-changes. Accessed December 27, 2017.

supply for the region. Although overall precipitation is increasing in Massachusetts, more droughts are expected in the future too, as much of the increase in precipitation is occurring in short intense rainfalls that may be separated by long dry periods. It is important for communities to consider stormwater as a resource, and not a nuisance to pipe away. Using green infrastructure to infiltrate more stormwater close to where it falls will help maintain healthy aquifers.

### Cost and Maintenance of Green Infrastructure

The upfront cost and long-term maintenance of green infrastructure stormwater systems is understandably a concern for communities. In some cases, GI techniques cost more upfront than conventional stormwater systems. However, upfront costs may be recouped due to lower maintenance costs over time. A five-year study conducted by the University of New Hampshire Stormwater Center found that in most cases, GI stormwater techniques had higher capital costs but lower annual maintenance costs when compared to conventional pipe and pond systems.[2] Utilizing GI may also reduce the amount and size of gray infrastructure needed in a project, resulting in overall project cost savings. In Franklin, MA, a project that reduced the width of paved roadway from 32 to 26 feet and removed a sidewalk from one side of the road (while leaving a sidewalk on the other side of the road) in a residential neighborhood eliminated almost 90,000 square feet of impervious surface and saved the town $195,000 in asphalt costs.[3]

Ultimately each community will need to determine the green infrastructure techniques that make sense for them based on local site conditions but also the skills, equipment, and capacity of the DPW to install and

### A Focus on Maintenance

In 2007 the University of New Hampshire (UNH) Stormwater Center partnered with the Dover, NH DPW to begin tackling water quality issues in the Berry Brook watershed. In the last 10 years, 25 GI stormwater retrofits have been installed, resulting in significant water quality benefits.

From the outset, the DPW Director was concerned about maintenance. Cleaning catch basins and mowing grass were maintenance activities that the department could easily handle, so rain gardens were outfitted with catch basins to collect silt, grass is used instead of plants for bioretention swales, and infiltration under paved surfaces is accomplished using catch basins with perforated piping instead of porous asphalt.

Using Berry Brook as a pilot, the DPW has built the skills and knowledge to now implement GI techniques in other roadway and public works projects in the city.

*Source: "Going the Distance Along Dover's Berry Brook," James Houle, Ph.D., CP- SWQ, CPESC, & Dolores Jalbert-Leonard. Land and Water, March/April 2017*
https://www.unh.edu/unhsc/sites/default/files/media/going_the_distance.pdf

[2] Houle, James J., and Robert M. Roseen, Thomas B. Ballestero, Timothy A. Puls, James Sherrard Jr. "Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management." Journal of Environmental Engineering, Vol. 139, No. 7, July 1, 2013.

[3] "Green Infrastructure as Standard Operating Procedure: Town of Franklin." Resilient Taunton Watershed Network, accessed December 28, 2017.
http://www.srpedd.org/manager/external/ckfinder/userfiles/resources/Environment/FRANKLIN%20DPW%20GI%20CASE%20STUDY.pdf

maintain them. In some communities, the cost of maintaining and cleaning catch basins is cumbersome, but weeding and mowing rain gardens and swales is doable. In other communities, it may be the opposite. A key lesson that communities have learned is to adapt systems to work for them, and to design each system with maintenance in mind. Green infrastructure systems that are easy to maintain are more likely to be successful over the long term.

## 2. Green Infrastructure Techniques

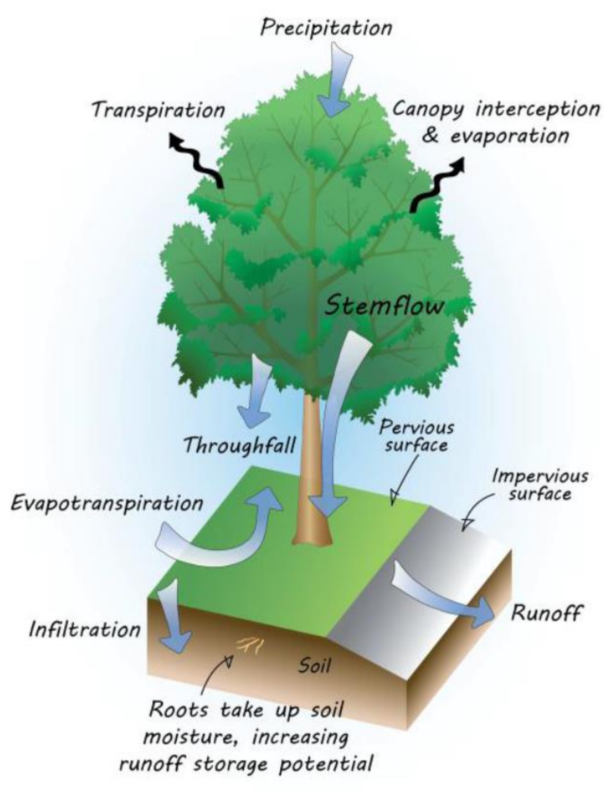
This section introduces different Green Infrastructure stormwater management techniques and how they might be applied in a transportation project. Information on design and maintenance, benefits, limitations, and cost is included, as well as links to additional resources.

### Street Trees

The value of street trees goes well beyond simple aesthetics. Trees in the built landscape offer many environmental and economic benefits, including cleaner air, traffic calming, noise reduction, and increased property values. Trees shade pavement and buildings, reducing the urban heat island effect and the costs and energy associated with cooling buildings.  Neighborhoods with mature street trees are attractive places to walk, bike, and be outside, improving public health and helping to build a sense of community.

Trees also serve an important stormwater management role. Trees intercept rain on leaves, branches, and trunks, delaying and reducing peak flows. Trees absorb groundwater through roots, increasing runoff storage capacity. Tree roots also promote stormwater infiltration into the soil, reducing the amount of runoff and helping to recharge groundwater resources. Finally, trees also remove pollutants from the soil, including metals, organic compounds, fuels, and solvents.

Trees need adequate soil and space to grow to full size and thrive. The larger the tree, the more




*Trees serve an important role in stormwater management by intercepting, infiltrating, and absorbing stormwater at the source, thereby reducing runoff. Source: U.S. EPA, 2013* stormwater benefits it can provide. In downtowns and village centers, planning and design is needed to ensure healthy tree growth. Impervious surfaces and compacted soil inhibit healthy tree growth in more urban settings, and can lead to upheavals in pavement and sidewalks from tree roots seeking oxygen and water.

### Benefits

- ✓ Reduce stormwater runoff
- ✓ Delay peak flows
- ✓ Increase groundwater recharge
- ✓ Pollutant removal
- ✓ Reduce urban heat island effect
- ✓ Improve livability/quality of life

### Considerations

- ✓ Space constraints within existing ROWs may limit the ability to plant trees. Reducing pavement widths on excessively wide streets provides an opportunity to add a tree belt or planted curb extension.
- ✓ Overhead and underground utility placement can interfere with tree and root growth. Plant smaller trees under overhead wires, and require underground utilities be placed under sidewalks or the roadway when possible.
- ✓ Trees can be susceptible to damage from road salt, snow plows, and foot traffic. Consider barriers, such as fencing, bollards, or parking blocks, to protect new trees in high traffic areas.
- ✓ Plant a diversity of salt-tolerant, non-invasive species to increase resilience to disease.
- ✓ Tree roots can heave pavement and sidewalks when space and soil conditions are not adequate. Consider using structural soils to provide more root space for trees in constrained areas such as parking lots and downtowns.

### Applicability

Trees can be used in many situations, including:

- ✓ Along roads, streets, and multi-use paths
- ✓ Surrounding parking lots and within parking lot islands or medians
- ✓ In parks, playgrounds, and plazas

Trees work well in conjunction with many other GI techniques:

- ✓ Vegetated swales
- ✓ Structural soils
- ✓ Porous asphalt/permeable pavement
- ✓ Bio-retention areas
- ✓ Reduce impervious surfaces

### Design and Maintenance

Trees need adequate space and uncompacted soil. A general rule of thumb is that a large tree (16" diameter at breast height and 30 foot canopy) needs at least 1,000 cubic feet of uncompacted soil. In open spaces and along rural roads, this space requirement typically isn't a problem. In villages, downtowns, and along some neighborhood streets, it can be challenging to find enough space to support healthy trees that, in turn, are effective at managing stormwater. In these locations, tree planting areas can be designed to collect and infiltrate stormwater while also supporting healthy tree growth. See Structural Soils (page 15) and Porous Asphalt/Permeable Pavement (page 13) for more information. New street trees will need regular watering in the first two years after planting. Beyond the first several years, trees will need occasional trimming or pruning.

### Additional Resources

*Stormwater to Street Trees: Engineering Urban Forests for Stormwater Management.* U.S. EPA, 2013 https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf

*Climate Resilient Trees for Streetside Tree Belt Planting*. Franklin Regional Council of Governments, 2018. https://frcog.org/wp-content/uploads/2018/06/Climate-resilient-trees.pdf

Cornell University Urban Horticulture Institute Recommended Urban Trees Site Assessment and Tree Selection for Stress Tolerance: http://www.hort.cornell.edu/uhi/outreach/recurbtree/index.html

## Vegetated Swales

Vegetated swales are open channels that collect runoff from adjacent roadways, sidewalks, or parking lots. The purpose of vegetated swales is to slow the flow of runoff using vegetation, reduce the amount of runoff through infiltration, and filter out pollutants and sediment.

Roadside grass swales are common along rural roads with no curbing. The function of roadside grass swales can be enhanced through tree and vegetation planting, and by amending soils for greater infiltration and bioretention. In locations where maintenance of vegetation is a concern, a properly designed grass swale with bioretention soils can be effective. Check dams may also be used within swales in locations with steeper slopes in order to help slow down and infiltrate the runoff.

*A roadside swale on a residential street collects and infiltrates stormwater runoff from the roadway. Source: MA Smart Growth / Smart Energy Toolkit* *https://www.mass.gov/smart-growth-smart-energy-toolkit-module-slideshows*

Vegetated swales in suburban and urban settings collect runoff from sidewalks, streets, and parking lots. They can be designed with perforated underdrains to convey excess flow to gray stormwater infrastructure.

*Vegetated swales can be used in conjunction with Complete Streets techniques, such as a side path. Graphic source: MA DOT Separated Bike Lane Planning and Design Guide, 2015* *[https://www.mass.gov/lists/separated-bike-lane-planning-design-guide](https://www.mass.gov/lists/separated-bike-lane-planning-design-guide)*

### Benefits

- ✓ Reduce stormwater runoff
- ✓ Delay peak flows
- ✓ Increase groundwater recharge
- ✓ Pollutant removal

### Considerations

- ✓ On slopes, check dams may be needed
- ✓ Soils may need to be amended to promote infiltration and limit ponding
- ✓ Vegetation must be tolerant to wet conditions, road salt, and snow storage

### Applicability

- ✓ Adjacent to streets, roads, and multi-use paths
- ✓ In parking lots
- ✓ Combine with street trees, bioretention, and reduced impervious surfaces

### Design and Maintenance

Pretreatment is needed to remove sediment and protect the functioning of the swale, either through a sediment forebay when runoff is piped to a swale, or a vegetated filter strip or "pea gravel diaphragm" for sheet flow. Initial maintenance includes inspection to ensure successful establishment of vegetation. Ongoing maintenance may include mowing (for grass swales), weeding, re-seeding/planting, and removal of sediment and trash (at least once a year).

### Additional Resources

Massachusetts Clean Water Toolkit: http://prj.geosyntec.com/npsmanual/waterqualityswales.aspx

Cornell University Urban Horticulture Institute's *Woody Shrubs for Stormwater Retention Practices* guide: http://www.hort.cornell.edu/uhi/outreach/pdfs/woody_shrubs_stormwater.pdf

## Bioretention Areas

Bioretention areas, also known as rain gardens, are shallow planted areas that collect, clean, and infiltrate stormwater from roads, parking lots, driveways, sidewalks, and roofs. Plants and sandy bioretention soils filter out pollutants before water is recharged to the ground. Bioretention areas often are designed to allow for temporary ponding of water. In areas with highly permeable soils, bioretention areas may not need to be connected to a storm drain. In slowly permeable soils a perforated underdrain may be installed at the bottom of the excavation to prevent excessive ponding. Bioretention areas can also be used in conjunction with existing gray infrastructure as part of a road retrofit project.

Native plants and trees tolerant of drought and intermittent wet conditions, and occasional salt from paved surfaces, should be used (see Additional Resources on page 12 for more information on plants for bioretention areas). Routine maintenance is similar to a traditional garden, and can be handled by homeowners or landscaping companies with proper direction. Bioretention areas can also be designed with grass, instead of plants, to allow for easy maintenance (see Vegetated Swales on page 9).

*A stone pre-settling zone at the inlet to a bio-retention swale allows sediment to settle out before runoff enters the swale. Image source: NACTO Urban Street Stormwater Guide*

### Benefits

- ✓ Reduce stormwater runoff
- ✓ Increase groundwater recharge
- ✓ Pollutant removal
- ✓ Habitat and aesthetic value

### Considerations

- ✓ Not suitable for slopes
- ✓ Not suitable in areas with high groundwater
- ✓ Should be designed with pre-treatment, such as a grass filter strip or stone pre-settling zone
- ✓ Requires careful maintenance (unless grass is used for vegetation)
- ✓ Vegetation must be tolerant of drought and wet conditions, as well as road salt

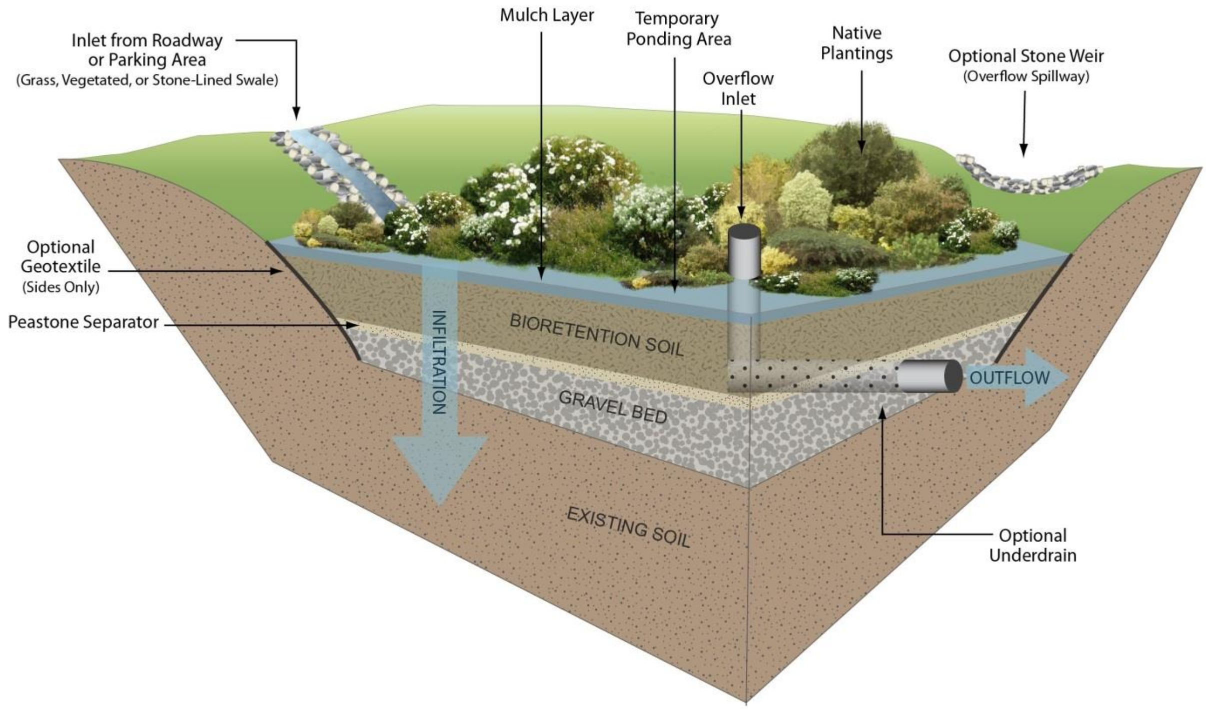
### Applicability

- ✓ Between sidewalks and streets and in curb extensions/bump-outs
- ✓ In parking lot islands and medians
- ✓ In parks, playgrounds, and plazas
- ✓ Adjacent to Town-owned buildings to treat roof runoff

## Design and Maintenance

Design of bioretention areas can be flexible in terms of size and shape to fit varying sites. Bioretention areas should be designed to drain within 72 hours, and may need an underdrain in slow draining soils. Bioretention areas are typically designed in layers as follows (from bottom of excavation to surface):

- Impermeable liner (optional)
- Gravel layer (approximately 12 inches) with optional underdrain
- Pea stone layer (approximately 4 inches)
- Bioretention soil media composed of 40% sand, 20-30% topsoil, 30-40% compost (between 24-48 inches)
- Fine-shredded hardwood mulch (approximately 3 inches)
- Ponding depth (varies with site conditions; usually between 6-9 inches)
- The planting plan typically includes herbaceous perennials and shrubs which can tolerant frequent ponding, saline conditions, and extended dry periods.




*Above – a diagram showing a typical design and elements of a bioretention area. Source: Massachusetts Clean Water Toolkit [http://prj.geosyntec.com/npsmanual/bioretentionareasandraingardens.aspx](http://prj.geosyntec.com/npsmanual/bioretentionareasandraingardens.aspx)*

### Additional Resources

Massachusetts Clean Water Toolkit:
http://prj.geosyntec.com/npsmanual/bioretentionareasandraingardens.aspx

UNH Stormwater Center Bioretention Soil Specification:
https://www.unh.edu/unhsc/sites/default/files/media/unhsc_bsm_spec_2-28-17_0.pdf

UNH Stormwater Center Bioretention Maintenance Guidelines and Checklist:
https://www.unh.edu/unhsc/maintenance

Cornell University Urban Horticulture Institute's *Woody Shrubs for Stormwater Retention Practices* guide: http://www.hort.cornell.edu/uhi/outreach/pdfs/woody_shrubs_stormwater.pdf

## Porous Asphalt / Permeable Paving

Porous asphalt and permeable paving, such as pervious concrete and pavers, allow water to filter through, recharging groundwater and reducing the amount of runoff on a site. Permeable pavement or porous asphalt is appropriate for low traffic areas such as parking stalls, overflow parking areas, sidewalks and walkways, and plazas. Maintenance varies depending on the type of pavement used, and may include periodic vacuum sweeping, reseeding of grass pavers, or refilling joint material. Porous asphalt and permeable paving can reduce the amount of traditional stormwater infrastructure required.

### Benefits

- ✓ Reduce stormwater runoff
- ✓ Delay peak flows
- ✓ Increase groundwater recharge
- ✓ Reduce need for additional stormwater infrastructure
- ✓ Does not require additional land for stormwater management
- ✓ Reduce winter salt and sand usage due to low/no black ice

### Considerations

- ✓ Not suitable for slopes over 5%
- ✓ Requires regular maintenance to avoid clogging
- ✓ Not suitable in Zone II or Zone A of public water supplies, or near critical resource areas

*Porous asphalt is used for the parking stalls at the Whately Park and Ride Lot. The travel lane is constructed of traditional asphalt. Note the lack of ponding in the parking stalls during a rain storm.*

✓ Requires soils with permeability of at least 0.25 inches per hour

## Applicability

✓ Low traffic areas including parking stalls, overflow parking areas, sidewalks, multi-use paths, plazas

✓ Combine with structural soils, street trees, and reduced impervious surfaces

## Design and Maintenance

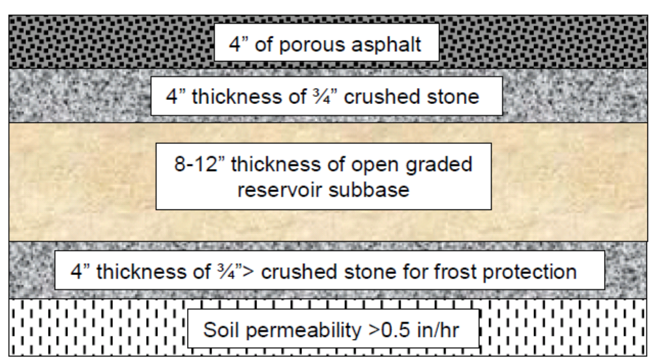
There are three major types of permeable paving, each constructed over a storage bed:

- **Porous asphalt and pervious concrete** appears to be the same as traditional asphalt or concrete pavement, but is mixed with a very low content of fine sand, so that it has from 10%-25% void space that allows for water to infiltrate through the material.
- **Paving stones** are impermeable blocks made of brick, stone, or concrete, set on a prepared sand base. The joints between the blocks are filled with sand or stone dust to allow water to percolate down into the subsurface. Some concrete paving stones have an open cell design to increase permeability.
- **Grass 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 material, distribute the weight of traffic and prevent compression of the underlying soil.

Porous asphalt/permeable paving performs well in cold climates. The major concern is the potential for frost heaving. The storage bed specifications prepared by the University of New Hampshire address this concern (see Additional Resources on page 15). Proper material preparation and installation are essential for success.

To keep the surface clean, frequent vacuum sweeping along with jet washing of asphalt and concrete pavement is required two-four times a year. During winter months, sand should not be applied to porous surfaces because it will clog the void spaces and reduce effectiveness.

TYPICAL POROUS ASPHALT CROSS-SECTION




*Source: Porous Asphalt Pavement for Stormwater Management fact sheet. The UNH Stormwater Center.* [https://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/porous_ashpalt_fact_sheet.pdf](https://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/porous_ashpalt_fact_sheet.pdf)

### Additional Resources

University of New Hampshire (UNH) Stormwater Center specification and fact sheets:

- Design Specifications for Porous Asphalt Pavement and Infiltration Beds: https://www.unh.edu/unhsc/sites/default/files/media/unhsc_pa_spec_-_feb-2014_-rev_9-16.pdf
- Permeable and Interlocking Concrete Pavement Fact Sheet: https://www.unh.edu/unhsc/sites/default/files/media/picp_unhsc_fact_sheet_rev2.pdf
- Pervious Concrete Pavement Fact Sheet: https://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/unhsc_pervious_concrete_fact_sheet_4_08.pdf
- Porous Asphalt Pavement Fact Sheet: https://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/porous_ashpalt_fact_sheet.pdf
- Pervious Pavement Maintenance Guidelines and Checklist: https://www.unh.edu/unhsc/maintenance

Massachusetts Clean Water Toolkit:
http://prj.geosyntec.com/npsmanual/porouspavement.aspx

Cornell University Urban Horticulture Institute Using Porous Asphalt and CU Structural Soil guide:
http://www.hort.cornell.edu/uhi/outreach/pdfs/cu_porous_asphalt.pdf

## Structural Soils

Structural soil is a mix of gravel and clay loam soil. The gravel provides load bearing support for pavement while also providing roughly 20% - 25% void space, which supports tree growth and stormwater infiltration. Typically, soils beneath pavement are compacted to meet engineering requirements to support vehicles and pavement. Plants and trees cannot survive in highly compacted soil, and stormwater cannot infiltrate into the ground. Roots from trees planted in narrow tree strips, islands, or planter boxes adjacent to paved areas often struggle to find adequate soil volume, and either die prematurely or cause heaving of pavement.

*Structural soil used under a sidewalk next to a narrow tree belt, provides a bridge, or "break-out" zone, for tree roots to access soil in the adjacent yard. Photo credit: Nina Bassuk, Urban Horticulture Institute, Cornell University.*

Structural soil works well in locations that require support for pavement, and where soil volume for healthy tree growth may be limited, such as downtown streetscapes, parking lots, sidewalks/ pathways, and plazas. It can also be used adjacent to narrow tree belts to provide a "break out" zone, or bridge, under the sidewalk, providing tree root access to neighboring lawns. Structural soil is particularly effective when combined with permeable pavement or porous asphalt, which allows for greater stormwater infiltration into the soil. A sub-drain may be needed in areas with highly compacted sub-soils to prevent standing water that could suffocate tree roots.

Structural soils should be tested to ensure effectiveness. Cornell University in Ithaca, New York, developed CU Structural Soil in the 1990s after extensive research and testing. CU Structural Soil uses a hydrogel as a tackifier to hold soil particles in place during and after installation. CU Structural Soil is only available from licensed CU providers. Currently there is only one licensed provider in Massachusetts, located in Wareham.

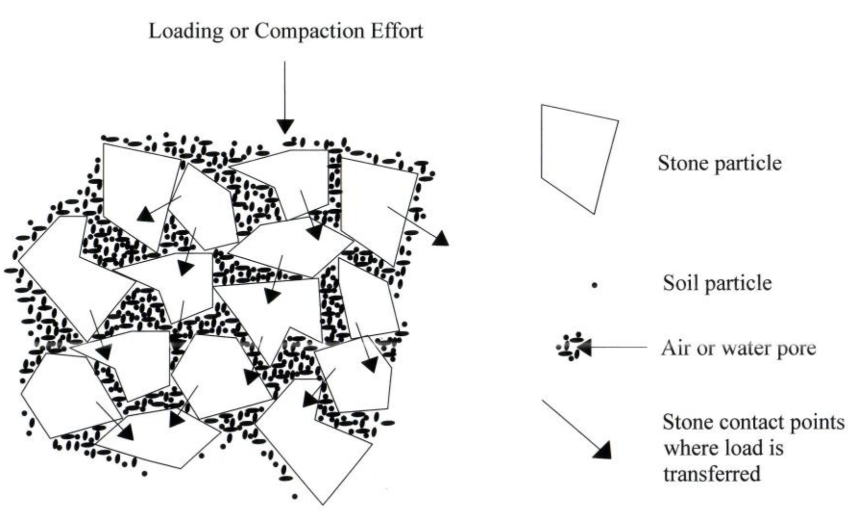
### Benefits

- ✓ Promotes healthy urban tree growth
- ✓ Reduces stormwater runoff
- ✓ Recharges groundwater
- ✓ Prevents heaving of sidewalks/pavement from tree roots

### Considerations

- ✓ In areas with poorly draining sub-soils, an underdrain may be needed to prevent ponding
- ✓ Not suitable for areas with high groundwater
- ✓ Not suitable for areas with high pollutant loads that could contaminate groundwater
- ✓ Lack of local providers of CU Structural Soil

Structural Soil Diagram




*Graphic credit: Nina Bassuk, Urban Horticulture Institute, Cornell University.*

### Applicability

- ✓ Urban streetscapes, parking lots, plazas, multi-use paths
- ✓ As a "break out" zone under a sidewalk adjacent to a narrow tree belt
- ✓ Combine with street trees and porous asphalt/permeable paving

### Design and Maintenance

Structural soil needs to be prepared according to specifications that ensure load bearing capabilities as well as adequate soil nutrients to support tree growth. The size of the structural soil reservoir is determined by runoff calculations and the desired rainfall storage amount, as well as the soil needs for trees (see Street Trees on page 7 for more information). Water can infiltrate into the reservoir through porous asphalt/permeable paving, through a swale along the edge of impervious surfaces, and through exposed planting areas around trees. Trees should be planted in a planting soil mix, with structural soil located in areas adjacent to the planting area where pavement is needed. An underdrain may be needed when subsoils are highly compacted or impermeable.

### Additional Resources

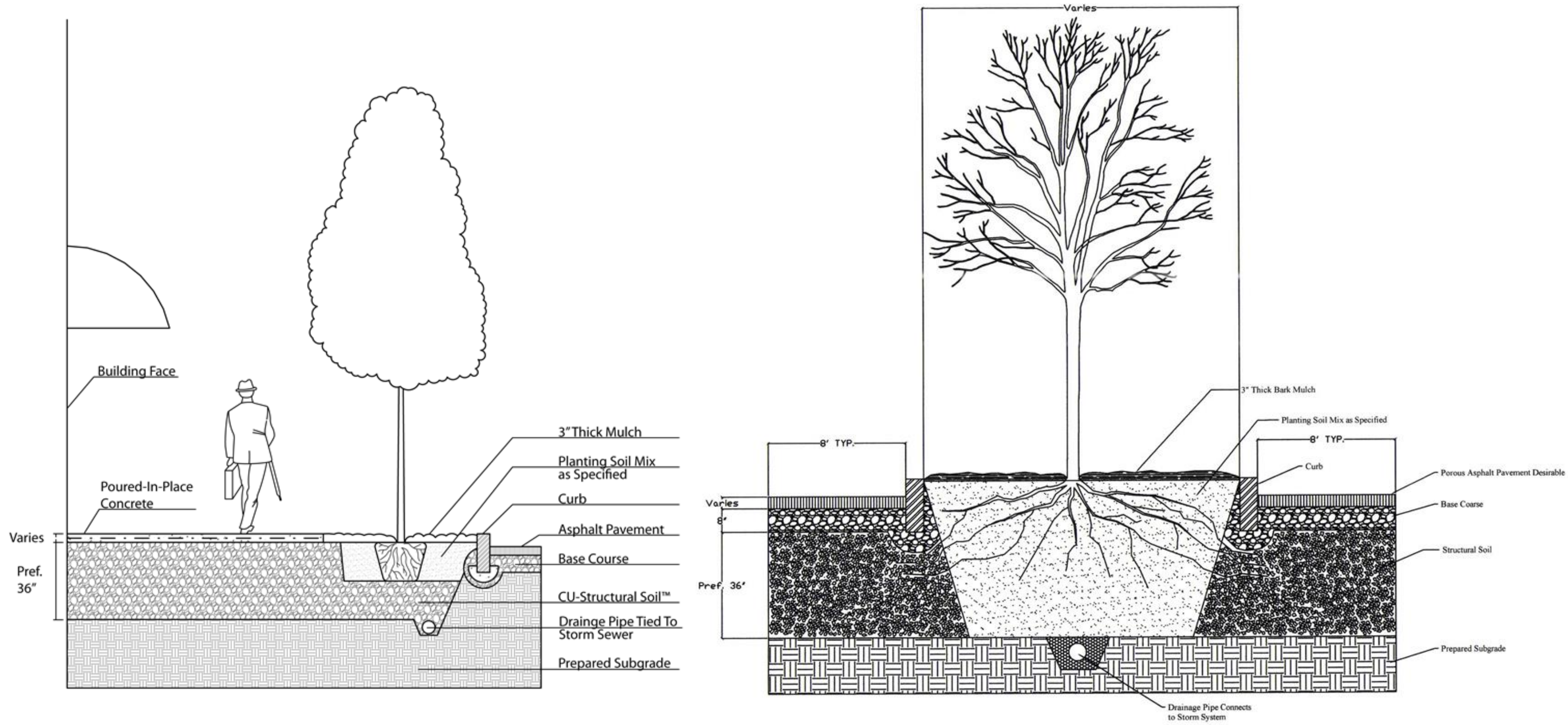
Cornell University Urban Horticulture Institute *CU-Structural Soil: A Comprehensive Guide*: http://www.hort.cornell.edu/uhi/outreach/pdfs/CU-Structural%20Soil%20-%20A%20Comprehensive%20Guide.pdf

Cornell University Urban Horticulture Institute CU Structural Soil website: http://www.hort.cornell.edu/uhi/outreach/index.htm#soil

Amereq, Inc., licensee of CU Structural Soil providers: http://www.amereq.com/pages/2/index.htm

Day, S.D, and S.B. Dickinson (Eds.) 2008. Managing Stormwater for Urban Sustainability using Trees and Structural Soils. Virginia Polytechnic Institute and State University, Blacksburg, VA: http://urbanforestry.frec.vt.edu/stormwater/Resources/TreesAndStructuralSoilsManual.pdf

Application of Structural Soils with Trees in a Streetscape and Parking Lot




*Structural soil applications in an urban streetscape (left) and parking lot island (right). Graphic credit: Nina Bassuk, Urban Horticulture Institute, Cornell University.*

## Reduce Impervious Surfaces

Roads make up a large percentage of impervious surfaces within a community. In 2011, the Massachusetts Chapter of the American Planning Association and the Home Builders Association of Massachusetts published the *Sustainable Neighborhood Road Design: A Guidebook for Massachusetts Cities and Towns*. This document addresses many of the issues that result from overbuilding neighborhood roads, and includes guidance for amending regulations for new roadway design. Recommendations include narrower paved widths of 20 – 24 feet, right-of-ways from 40 - 50 feet, and flexibility in road design that allows a road to follow the contours of the land more easily, and results in slower automobile speeds. The guidebook also encourages the use of green infrastructure, such as swales, rain gardens, and street trees, to manage stormwater from roads and sidewalks.

For existing roads, reducing pavement widths during roadway reconstruction projects results in less stormwater runoff and more roadside space for green infrastructure stormwater management techniques. Narrower paved widths also can result in significant savings. According to MassAudubon, reducing a short two-mile road from 28’ wide to 20’ equates to a savings of over $500,000 in pavement costs. Less pavement also means reduced maintenance costs, including plowing, salting, and sweeping. In addition to “road diets” that reduce overall pavement width along a street, methods to increase pedestrian safety and calm traffic on neighborhood roads such as bump outs and curb extensions, can also be utilized to reduce the amount of impervious surface and treat stormwater runoff.


*Examples of roadway narrowing and mid-block curb extensions that reduce impervious surface and treat stormwater. Source: U.S. EPA 2009*

Parking lots offer another opportunity to reduce impervious surface and add stormwater management features. Redesigns of municipal parking lots can incorporate more internal landscaping area that can treat stormwater and support shade trees.

### Benefits

- ✓ Reduces stormwater runoff
- ✓ Reduces cost of pavement and roadway maintenance
- ✓ Increases roadway safety

### Considerations

- ✓ On-street parking demand
- ✓ Existing or planned on-street bike facilities (bike lanes). If right-of-way is sufficient, narrowing the roadway and incorporating a separated bike lane or side path adjacent to the road may be preferable
- ✓ Amount of truck and bus traffic
- ✓ Emergency vehicle access. Typically a road width of 20 feet will accommodate emergency vehicles but the local fire department should be consulted
- ✓ Existing underground and overhead utility placement

### Applicability

- ✓ Existing roads with excessive paved widths
- ✓ Parking lots
- ✓ Combine with street trees, vegetated swales, bioretention areas, and porous asphalt/permeable paving

### Design and Maintenance

Design and maintenance of a reduced impervious area project would be the same for a typical roadway project, but would ideally incorporate green infrastructure stormwater techniques in areas where pavement is being removed. Utility placement must be considered and in some circumstances, existing utilities may need to be moved to accommodate stormwater techniques. For example, utilities may need to be relocated from under a tree belt to under the sidewalk or edge of roadway pavement.

### Additional Resources

MA APA and Homebuilders Association of Massachusetts *Sustainable Neighborhood Road Design: A Guidebook for Massachusetts Cities and Towns:* http://www.apa-ma.org/resources/publications/nrb-guidebook

U.S. EPA's Green Streets Handbook: https://www.epa.gov/green-infrastructure/green-street-handbook

U.S. EPA's Conceptual Guide to Effective Green Streets Design Solutions: https://www.epa.gov/G3/learn-about-green-streets

## Unpaved Roads

Unpaved roads are a part of our rural landscape and treasured by many residents. However, unpaved roads pose many challenges to highway departments. Water is the enemy of unpaved roads, and much of the work local road crews do involves controlling drainage. Water flowing too slowly deposits sediments and clogs channels and culverts. Standing water can weaken the sub-base and lead to surface failure. Water flowing too quickly can erode and washout sections of roadway.

When unpaved roads run alongside rivers and streams, which they often do, erosion and sediment from the roadway can cause significant water quality problems. Sediment in streams can smother habitat and transport pollutants. Best Management Practices (BMPs) for unpaved roads can improve water quality and potentially reduce maintenance costs by keeping more of the road bed on the road and not in adjacent streams.

*Unpaved roads are an integral part of Franklin County's rural character, but present unique stormwater management challenges.*

Good planning and use of non-structural BMPs is most cost effective. Maintaining existing drainage paths that are stable and well vegetated can be most effective in slowing, infiltrating and cleaning stormwater runoff. Vegetation absorbs water, which will reduce the amount of stormwater runoff the road drainage system needs to handle. Large trees are especially important because their roots help to hold soil in place, and should be protected from damage during any planned roadwork.

Structural BMPs may be needed to deal with drainage issues on an unpaved road. The purpose of structural BMPs is to control, slow, and filter road runoff. These may include:

- Vegetated or rock-lined channels and swales – conveys runoff from the roadway to a stable outlet
- Check dams – slows the speed of runoff in a channel or swale, reducing erosion and gullying
- Ditch turnouts – releases runoff to a stable natural vegetated area
- Pipe culverts with stone inlet and outlet protection – releases concentrated runoff into existing stable natural vegetated areas
- Natural stone headwall – supports the roadway at pipe openings, preventing erosion and supporting the road structure
- Level spreader – an excavated depression constructed at "zero percent" grade across a slope. The level spreader changes concentrated flow into sheet flow and then outlets it onto stable areas, reducing erosion potential and encouraging sedimentation

- Water bars – narrow channels excavated diagonally across the road to divert runoff and prevent erosion on long, sloping roads

*Above: Uncontrolled runoff scours and erodes an unpaved road. Below: A stabilized culvert inlet and rock drainage channel help slow and convey stormwater runoff away from the roadway.*

### Benefits

- ✓ Reduces sediment in waterbodies
- ✓ Increases roadway safety
- ✓ Reduces downstream flooding
- ✓ May reduce maintenance costs long term

### Considerations

- ✓ BMPs require on-going maintenance to function properly
- ✓ Some BMPs may not be appropriate on higher volume roads
- ✓ Use simple, flexible, and easy to maintain BMPs that fit within the road right-of-way

### Applicability

- ✓ Unpaved roads
- ✓ Combine with vegetated swales

### Design and Maintenance

The resources listed below provide information on designing different BMPs for unpaved roads. Maintenance is critical for long-term effectiveness of BMPs. Choosing BMPs that are easy to maintain will help make the task more realistic. For most BMP's, the maintenance requirements include visual tasks (e.g., inspection of sediment build up) and physical upkeep tasks (e.g., sediment removal and disposal, and mowing of grassed swales.) Proper maintenance can provide long-term cost savings in addition to water quality benefits. Often dealing with a washout or other major issue will be more expensive than maintaining stormwater BMPs.

### Additional Resources

*The Massachusetts Unpaved Roads BMP Manual: A Guidebook on How to Improve Water Quality While Addressing Common Problems*. Berkshire Regional Planning Commission, prepared for MA DEP, 2001: http://www.mass.gov/eea/docs/dep/water/resources/a-thru-m/dirtroad.pdf

MA Division of Ecological Restoration's 2012 *Massachusetts Stream Crossings Handbook:* http://www.mass.gov/eea/docs/dfg/der/pdf/stream-crossings-handbook.pdf

Massachusetts Clean Water Toolkit: http://prj.geosyntec.com/npsmanual/sectionintroroads.aspx

## 3. Green Infrastructure Case Studies

The following case studies illustrate green infrastructure stormwater management techniques implemented in Franklin County towns including lessons learned.

### Greenfield: Parking Lot and Roadside Infiltration/Reduce Impervious Surface

Stormwater entering storm drains in downtown Greenfield ends up in the Green River, which flows into the Deerfield River just west of its confluence with the Connecticut River. Greenfield has implemented several projects in recent years to help mitigate the amount of polluted stormwater entering storm drains in the downtown.

#### Town Hall Municipal Parking Lot

When the Greenfield DPW reconstructed the municipal parking lot behind the Town Hall, they used it as an opportunity to add trees and a bioretention swale to capture runoff from the parking area. A bioretention area is located within a parking lot median and captures runoff through gaps in the curbing along the uphill side of the median. Water filters into and through the median. During heavier rain, runoff may reach a catch basin at the bottom of the swale, allowing for overflow into the storm sewer system.

*Redesign of a municipal parking lot allowed for the addition of shade trees and a bioretention swale to capture runoff from a section of pavement. Pollutants filter out of the runoff before entering the storm drain.*

Lessons learned from previous green infrastructure projects helped the DPW make appropriate design decisions for this project. One example was to use hardwood mulch to reduce the chance that it would float away during heavy rains. Site constraints limited the size of the bioretention area, which captures runoff from only a portion of the parking lot. According to the Town Engineer at the time of the project, one thing he would have changed with the project would be to remove the curbing altogether on the uphill side to allow runoff to flow more easily into the median.

### Olive Street Tree Belt

The City of Greenfield planned to use Community Development Block Grant (CDBG) funds to replace a sidewalk and add a bump out on Olive Street, where the new JWO Transit Center had recently opened in 2013. The Town Engineer at the time was interested in including rain gardens as part of the project, and reached out to the Franklin Regional Council of Governments (FRCOG) for assistance. FRCOG was able to secure a MA DEP 319 grant to supplement the CDBG project and fund the rain gardens. The project was completed in 2015.

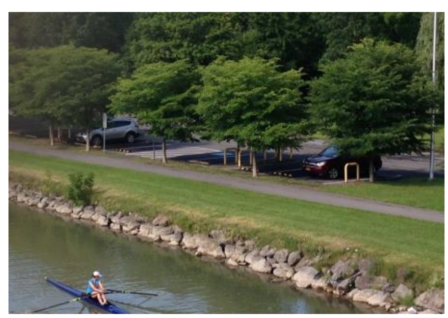
Prior to adding the tree belt, Olive Street had an excessively wide paved area and no street trees. Adding the tree belt reduced the amount of impervious surface and added a buffer between pedestrians on the sidewalk and the roadway. Stormwater from the sidewalk and roadway is directed to swales within the tree belt that filter and infiltrate water. The swales are connected to the storm sewer system for overflow.

Several lessons learned from the project can prove helpful for future roadside designs. The steep grade of the roadway means that water flowing into the swales has less time to infiltrate. In addition, after completion of the project, repaving of the street was needed to better direct stormwater into the swales, but subsequent construction projects in the area delayed these changes. A portion of the project also had to be temporarily moved during construction of a parking

### Porous Asphalt, Structural Soil, and Shade Trees

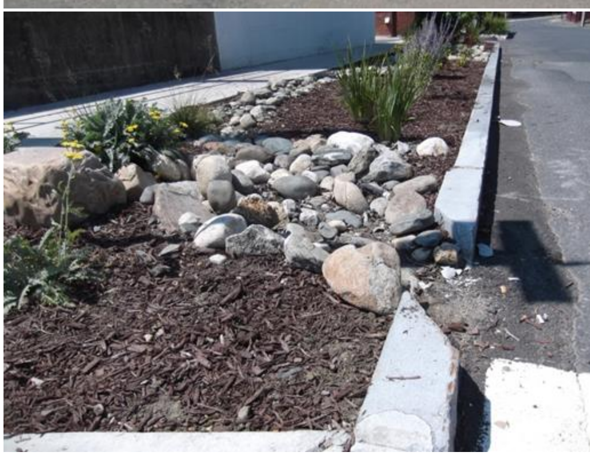
Pavement and trees *can* co-exist peacefully. A demonstration parking lot project in Ithaca, New York, used CU© Structural Soil as a base layer, covered with porous and non-porous asphalt. The structural soil provides additional root space under the pavement for shade trees, allowing hybrid elms to grow to full size, while reducing the size of the planting space needed. The system is designed to contain a 100-year rain event without the need for catch basins or pipes. After ten years, the porous asphalt continues to function well, despite minimum maintenance from the DPW.

*Parking space is maximized with the use of structural soil.*



*Ten years after planting, the elms shade most of the parking spaces.*

*Information and photos courtesy of Andrew Hillman, Davey Resource Group* garage. These lessons underline the importance of planning stormwater projects with a long-term consideration of other infrastructure upgrades. Nevertheless, the addition of the tree belt and trees will have positive stormwater and livability benefits over time.



*Top left: Olive Street before the tree belt was installed. Top right: Olive Street after the tree belt installation. The top photos are taken from the entrance to the JWO Transit Center. Bottom left: a curb cut allows stormwater from the roadway to enter the rock-lined swale which also traps sediment.*

## Whately Park and Ride: Porous Asphalt

The Whately Park & Ride lot was constructed by MassDOT in 2013. The completion of this facility fulfills a recommendation from the 2004 MassDOT Connecticut River Crossing Transportation Study that examined ways to reduce traffic over the region's Connecticut River bridges. The lot is well-used and serves commuters who are carpooling or parking and riding the bus to destinations such as UMass Amherst. The lot is located in the Town of Whately at the intersection of Route 116 and Route 5/10. It has approximately 45 spaces for vehicles and includes a bus shelter, bus pullout, and bicycle parking.

During the permitting for the park and ride lot, the Whately Conservation Commission requested that porous pavement be used to reduce stormwater runoff to an adjacent wetland. According to MassDOT, porous asphalt was used in the parking stalls at the park and ride, but not in the driveway and parking aisles due to concern over porous asphalt's ability to withstand bus and truck usage. In addition, porous asphalt was not used within 100 feet of the wetland, a recommendation from MA DEP for critical resource areas. The cost of the porous pavement was $135 / Ton compared with regular hot mix asphalt which was bid at $85 / Ton.

According to both MassDOT and the Chair of the Whately Conservation Commission, the porous asphalt appears to be working as designed. Mass DOT currently does not perform any special maintenance, such as vacuuming, for the asphalt, but may need to in the future to ensure continued functionality of the asphalt.

*Left: The Whately Park and Ride lot on a rainy day. The porous asphalt in the parking stalls allows stormwater to infiltrate through. In contrast, rain is ponding in the drive aisle where non-porous asphalt was used.*

## Montague: Unity Park Rain Gardens

In 2012 and 2013, the playground, ballfields, and parking lots at Unity Park were refurbished using Community Development Block Grant (CDBG) funds. A rain garden was added at each of two parking lots to collect and treat stormwater runoff. One of the rain gardens also serves as the drainage area for the park's popular water spray feature. The reason for adding green infrastructure elements to the project was three-fold, according to Jon Dobosz, Montague Director of Parks and Recreation: including sustainable elements was a goal of the project; the project's location next to the Connecticut River required mitigation by the Rivers Protection Act; and the third was aesthetics - "Who wouldn't like a flowering garden in a park?"

The Montague DPW Parks crew maintains the rain gardens. According to Dobosz, the only garden requiring significant maintenance is the rain garden adjacent to the playground with the water feature. The maintenance crew typically cleans out the garden, trims the bushes, and adds a load of mulch in the early spring. Around July, the crew conducts a mid-season clean-up.

*Top left: A rain garden adjacent to a parking lot at Unity Park. The Connecticut River can be seen in the background. Top right: A rain garden serves as the drainage area for the playground's popular water spray feature.*

## Northfield: Four Mile Brook Road

Four Mile Brook Road in Northfield is a 2.75 mile long gravel road. Much of the road lies within the Rivers Protection Act 200-foot riparian buffer of the Four Mile Brook, a cold water tributary to the Connecticut River that runs along the road. Steep slopes and a narrow valley create a high stream power during heavy rain events. The presence of the road contributes to the high stream flows by concentrating runoff and transporting it to the brook. Prior to stormwater improvements, significant amounts of sediment were carried from the road to the brook, causing erosion along the road and water quality issues in the brook.

In 2010, the Town received a grant from the MA DEP to implement stormwater Best Management Practices (BMPs) along Four Mile Brook Road. Six sites were identified for BMPs, with a goal to manage the runoff to protect the road and filter the road bed material (sediment) from the runoff before it is discharged to the ground surface or flows into the brook. The BMPs used include: riprap/rock lined channels and swales with and without rock check dams; pipe culverts with natural stone inlet and outlet protection; natural stone headwalls; ditch turnouts; and a level spreader with gabion outlet protection. Total project cost came to $225,000, with the town contributing 40% through in-kind staff time and Chapter 90 funds.

The BMPs were designed to be simple, low cost, and low maintenance. In a rural town that may have many miles of unpaved roads (Northfield and its neighboring towns have over 60 miles of unpaved roads), designing stormwater BMPs to be easy to maintain is critical to water quality and Town budgets. Implementing simple stormwater BMPs on unpaved roads can result in a reduction in maintenance costs by managing the runoff and keeping more of the road bed on the road and not in the stream.

*Above left: one of the sites on Four Mile Brook Road prior to the project. Above right: The same location after installation of a rock-lined swale that collects, slows, and filters stormwater runoff from the road, helping to keep the roadway edge intact.*


*Above left: A natural stone headwall at the inlet end of a road culvert on Four Mile Brook Road. Above right: A ditch turnout on Four Mile Brook Road. These BMPs slow, filter and convey stormwater runoff from the roadway, reducing erosion and removing sediment before it enters the brook.*

## 4. Funding Green Infrastructure

Green infrastructure stormwater management techniques may be funded in a variety of ways. GI can be incorporated into larger roadway or sidewalk construction/reconstruction projects, or could be pursued as standalone projects. Depending on the nature of the project, the following funding sources may be available to help cover the cost of implementing GI into public works projects.

### Transportation Improvement Program (MassDOT)

The Transportation Improvement Program (TIP) is a prioritized, multi-year listing of transportation projects in a region that are to receive Federal funding for implementation. Projects are limited to certain roadways and are constrained by available funding for each fiscal year. Any transportation project in Franklin County that is to receive federal funding must be listed on the TIP.

Projects are chosen and prioritized by the Franklin County Transportation Planning Organization (TPO), which is made up of state, regional, and local officials. Towns are responsible for paying for design and any Right of Way work, but construction is funded 80% by Federal funds, and 20% by State funds. The typical timeframe for a project listed on the TIP is ten years, but the payoff for a town is that the construction is paid for 100%.

### Chapter 90 Funding (MassDOT)

The Chapter 90 program is a State funding program that entitles municipalities to reimbursement for capital improvement projects for road construction, preservation, and improvement that create or extend the life of capital facilities. The funds can be used for maintaining, repairing, improving, or constructing town and county ways and bridges that qualify under the State Aid Highway Guidelines. Items eligible for Chapter 90 funding include project design, roadways, sidewalks, right-of-way acquisition, shoulders, landscaping and tree planting, roadside drainage, street lighting, and traffic control devices. Each municipality in Massachusetts is granted an annual allocation of Chapter 90 reimbursement funding that it is eligible for, and the municipality can choose among any eligible infrastructure investments.

### MassWorks Infrastructure Program (Executive Office of Housing & Economic Development)

The MassWorks Infrastructure Program is a State funding program that funds a range of publicly owned infrastructure projects, including but not limited to streets, roads, curb-cuts, parking facilities, site preparation and improvements on publicly owned land, and pedestrian walkways, in order to prepare communities for long-term strength and sustainability, with particular emphasis on projects that support multi-family housing in walkable mixed-use districts, or that support economic development in weak or distressed areas. Each year, at least ten percent of funds will be set aside for projects in small, rural communities with a population of 7,000 or less to support economic or community development and improvements to enhance safety.

### Complete Streets (MassDOT)

The Complete Streets Funding Program is a State funding program that provides technical assistance and construction funding to eligible municipalities for roadway construction, reconstruction, and some rehabilitation and resurfacing projects that increase safety and accessibility for all travel modes including walking, biking, transit, and vehicles, and for people of all ages and abilities. Eligible municipalities must pass a Complete Streets Policy and develop a Prioritization Plan.

### Hazard Mitigation Grant Program (Massachusetts Emergency Management Agency)

The Hazard Mitigation Grant Program, administered by the Massachusetts Emergency Management Agency, provides federal funds to states, territories, tribal governments, and other communities after a disaster to reduce or eliminate future risk to lives and property from natural hazards. State and local governments, tribal organizations, and certain private non-profits may be eligible to apply for funding to cover projects including stormwater upgrades, drainage and culvert improvements, property acquisition, slope stabilization, infrastructure protection, seismic and wind retrofits, structure elevations, etc.

### Pre-Disaster Mitigation (PDM) Grant Program (Massachusetts Emergency Management Agency)

The PDM Grant Program, administered by the Massachusetts Emergency Management Agency, provides Federal funds to states, territories, Indian tribal governments and communities for hazard mitigation planning and the implementation of mitigation projects prior to a disaster event. Federal funding for this nationally competitive grant program is generally an annual allocation (subject to Congressional appropriation).

### Municipal Vulnerability Preparedness (MVP) Grant Program (Executive Office of Energy and Environmental Affairs)

The MVP Grant Program provides State funding to support cities and towns across the state to begin the process of planning for climate change resiliency and implement priority projects. The state awards communities with funding to complete vulnerability assessments and develop action-oriented resiliency plans. Communities who complete the MVP program become certified as an MVP community, and are then eligible for MVP Action grant funding to advance priority actions that address climate change impacts resulting from extreme weather, sea level rise, inland and coastal flooding, severe heat, and other climate impacts. Projects that propose nature-based solutions or strategies that rely on green infrastructure or conservation and enhancement of natural systems to improve community resilience are given priority for funding.

## Section 319 Nonpoint Source Competitive Grant Program (Massachusetts Department of Environmental Protection)

This grant program is authorized under Section 319 of the Federal Clean Water Act for implementation projects that address the prevention, control, and abatement of nonpoint source (NPS) pollution. In general, eligible projects must: implement measures that address the prevention, control, and abatement of NPS pollution; target the major source(s) of nonpoint source pollution within a watershed/subwatershed; contain an appropriate method for evaluating the project results; and must address activities that are identified in the Massachusetts NPS Management Plan. Proposals may be submitted to MA DEP by any interested Massachusetts public or private organization. To be eligible to receive funding, a 40% non-federal match is required from the grantee.

## Federal 604b Water Quality Management Planning Grant Program (Massachusetts Department of Environmental Protection)

This Federal funding program, administered by the Massachusetts Department of Environmental Protection, is authorized under the Federal Clean Water Act Section 604(b) for water quality assessment and management planning. Eligible entities include: regional planning agencies, councils of governments, conservation districts, counties, cities and towns, and other state public planning agencies and interstate agencies. No local match is required.

## Clean Water State Revolving Fund (Massachusetts Department of Environmental Protection)

The State Revolving Fund (SRF), administered by the Massachusetts Department of Environmental Protection, offers affordable loan options to cities and towns to help protect water resources and drinking water. The Clean Water SRF Program helps municipalities comply with federal and state water quality requirements by focusing on watershed management priorities, stormwater management, and green infrastructure.

## Urban and Community Forestry Challenge Grants (Massachusetts Department of Conservation and Recreation)

This Federally-funded grant program helps develop, grow and sustain programs that plant, protect and maintain a community's public tree resources and develop partnerships with residents and community institutions. The Challenge program consists of 50-50 matching grants (projects serving environmental justice neighborhoods are 75-25 grant match) offered to municipalities and non-profit groups in Massachusetts communities of all sizes for the purpose of building local capacity for excellent urban and community forestry at the local and regional level. For the purpose of these grants, Urban and Community Forestry refers to professional management (planting, protection and maintenance) of a municipality's public tree resources in partnership with residents and community institutions.