# Merrimack Valley Stormwater Collaborative

## MassDEP MS4 Municipal Assistance Grant Report

JUNE 30, 2021

Merrimack Valley Planning Commission

## Table of Contents

# Introduction

Merrimack Valley Planning Commission (MVPC) is comprised of fifteen cities and towns in northeastern Massachusetts. Created through an act of the State Legislature in 1959, MVPC's mission is to promote the orderly growth and development of the region. As such, through its Environmental Program, MVPC created the Merrimack Valley Stormwater Collaborative. The fifteen communities of the Merrimack Valley Stormwater Collaborative are subject to the 2016 Massachusetts Small Municipal Separate Storm Sewer System (MS4) Permit issued by the U.S. Environmental Protection Agency (effective July 1, 2018). In Year 4 of the permit, permittees are required to meet the following requirement:

"Four (4) years from the effective date of this permit, the permittee shall identify a minimum of 5 permittee-owned properties that could potentially be modified or retrofitted with BMPs designed to reduce the frequency, volume, and pollutant loads of stormwater discharges to and from its MS4 through the reduction of impervious area. Properties and infrastructure for consideration shall include those with the potential for reduction of on-site impervious area (IA) as well as those that could provide reduction of off-site IA. At a minimum, the permittee shall consider municipal properties with significant impervious cover (including parking lots, buildings, and maintenance yards) that could be modified or retrofitted. MS4 infrastructure to be considered includes existing street right-of-ways, outfalls and conventional stormwater conveyances and controls (including swales and detention practices) that could be readily modified or retrofitted to provide reduction in frequency, volume or pollutant loads of such discharges through reduction of impervious cover." (See Section 2.3.6.d of the MS4 Permit)

Working in its capacity as the coordinator for the Merrimack Valley Stormwater Collaborative, MVPC worked with each community in the Collaborative to select 5 municipal-owned properties where implementation of Best Management Practices (BMPs) would both reduce the overall volume of stormwater discharge and are logistically and fiscally feasible to implement by the municipality. MVPC developed a process to prioritize sites based on multiple factors including likelihood of redevelopment, proximity to impaired receiving waters, site soils and depth to groundwater, and location of site for ease of maintenance and visibility to the public (for education and outreach purposes). In communities with environmental justice (EJ) Census blocks, priority was given to sites within EJ areas.

MVPC then utilized Geographic Information Systems (GIS) to map and provide characteristics for each of the 5 sites within each community. This data was then shared with MVPC municipalities by adding it to their web-based GIS viewer, MIMAP, and by deploying it to those communities operating MVPC's Stormwater Inspector mobile application. Going forward, MVPC plans to track implemented projects and will integrate the data collected through this project with MIMAP and with the Greenscapes Northshore Low Impact Development (LID) viewer (https://greenscapes.org/lid-toolkit ).

# Prioritization Process

Year 2 of the MS4 permit required each community to implement operations and maintenance programs for permittee owned buildings and facilities and parks and open spaces. Part of this requirement included each community creating an inventory of these municipal-owned parcels. After collecting and reviewing the community developed property lists, MVPC met with each municipality to discuss prioritization. Each community was asked to prioritize properties where redevelopment might occur within the next 5 years, properties that were in watersheds with impaired waters, and/or properties where LID might have a co-benefit such as reducing flooding or temperatures in urban heat islands. Communities with state-identified Environmental Justice Census blocks were asked to prioritize properties in those Census blocks. Locations that are easily accessible for maintenance and highly visible for public education benefits were also prioritized.

A further description of each of the criteria on each community's BMP site identification spreadsheet is explained below (see spreadsheets in Appendix A).

## Waterbody or Watershed Area

For each BMP retrofit site, MVPC identified the associated watershed area. MVPC then used the *MassDEP Integrated List of Waters (December 2019)* to determine if the waterbody or waterway to which the site drains is listed as impaired or having Total Maximum Daily Load (TMDL) status. This list identifies waterbodies that do not meet state water quality standards with respect to certain uses including habitat for fish, other aquatic life and wildlife, fish and shellfish consumption, and primary (e.g., swimming) and secondary (e.g., boating) contact-recreation. The list makes a distinction between "pollutants" such as nutrients, metals, pesticides, solids, and pathogens that all require TMDLs and "pollution" such as low flow, habitat alterations or non-native species infestations that do not require TMDLs. Appendix F and H of the MS4 permit list specific requirements for those waterbodies and waterways with TMDL or impaired status.

As such, priority was given to sites that drain to impaired waters as BMP retrofits and/or reduction in impervious cover at these sites can be designed to reduce the frequency, volume, and pollutant loads of stormwater discharges.

## Soils

Many Green Infrastructure (GI)[1] BMPs rely on soil infiltration for treatment of pollutants, meaning soil permeability and the location of seasonal high groundwater may affect BMP function. Having information regarding the soil conditions in the area of the chosen municipal sites, helped prioritize the locations and informed the BMP retrofit recommendations.

[1] https://www.epa.gov/green-infrastructure/what-green-infrastructure

MVPC used the NRCS Web Soil Survey application (https://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) to create and download the soil map and accompanying Soil Resource Report for each municipal site. These maps provide some understanding of what site conditions may be like, however, the mapping is done at a scale that does not ensure accuracy and all soils should be verified before proceeding with design. In many urbanized areas, where fill has often been used, the mapping is only able to indicate "urban fill" with no additional detail on permeability or depth to groundwater is provided. The downloaded Soils Maps and Reports are included as attachments within the data associated with the mapped locations in each communities MIMAP.

## Operation and Maintenance and Public Education

The goal of locating Green Infrastructure BMPs in high visibility locations is two-fold. The most important is ease of maintenance. Many BMPs decrease in functionality if not maintained. Installing BMPs in locations that are easily accessible (for people, equipment, etc.) and can serve as a visual reminder, increases the likelihood that operation and maintenance (O&M) procedures will be followed. For each BMP recommended, the appropriate BMP installation fact sheet, including O&M, is included as an attachment in the mapped location within MIMAP. BMP fact sheets are also included in Appendix B of this report.

Locating Green Infrastructure BMPs in highly visible locations can also have education and outreach benefits. With signage, BMPs located at parks, schools, town/city halls will inform the public about the benefits of GI and its potential to improve water quantity and quality in Merrimack Valley communities. Additional benefits such as flood reduction and cooling could also be detailed where these co-benefits are achieved.

## Environmental Justice

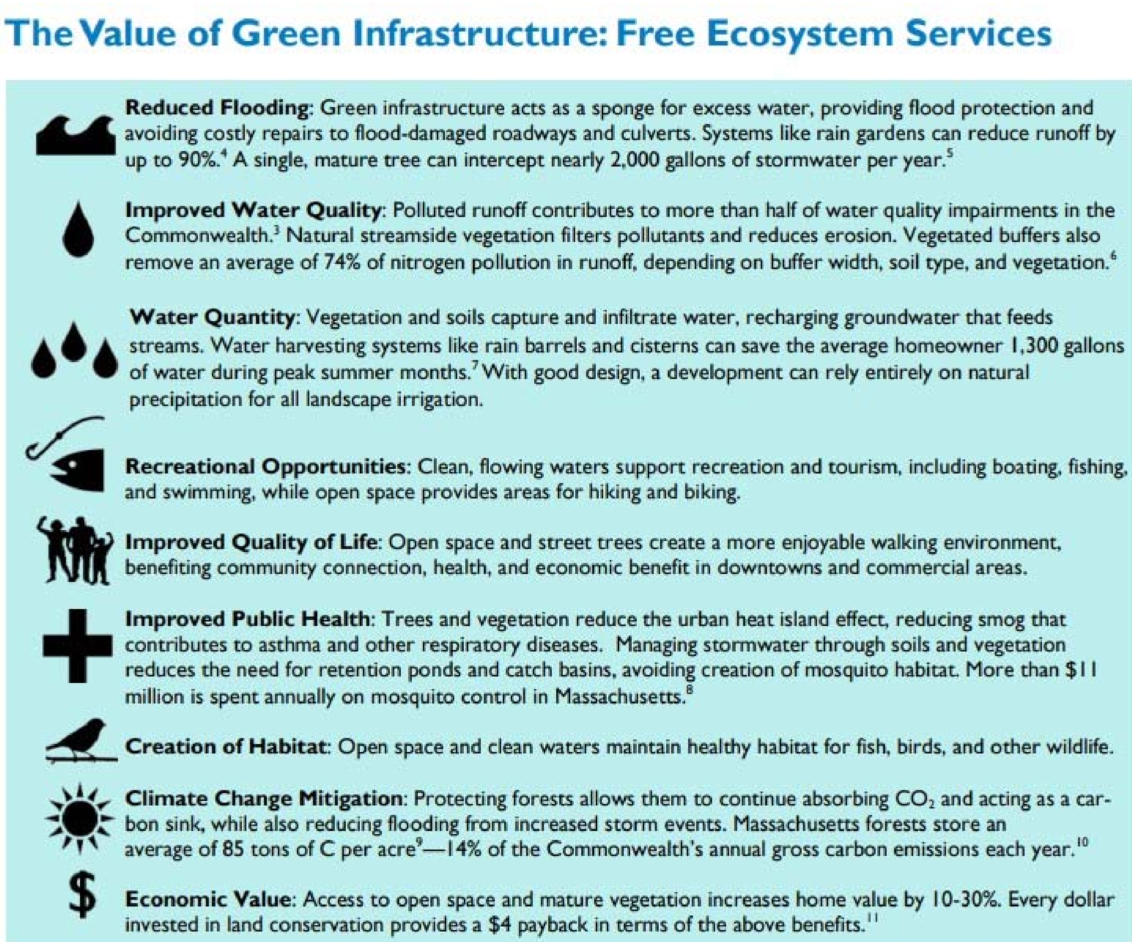
As detailed on the Mass.Gov website, Environmental Justice (EJ) "is based on the principle that all people have a right to be protected from environmental pollution, and to live in and enjoy a clean and healthful environment. Environmental justice is the equal protection and meaningful involvement of all people with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies and the equitable distribution of environmental benefits." Portions of a community are considered to have an EJ population if they meet the following criteria:

- Block group whose annual median household income is equal to or less than 65 percent of the statewide median ($62,072 in 2010); or
- 25% or more of the residents identify as a race other than white; or
- 25% or more of households have no one over the age of 14 who speaks English only or very well - English Isolation

Within the Merrimack Valley, the entire City of Lawrence, and portions of Haverhill, Methuen, Andover, and North Andover meet these criteria. For these communities, sites within EJ neighborhoods were given higher priority for installation of Green Infrastructure BMPs to help address the disproportionate environmental burdens experienced by lower-income people and communities of color and improve protection from environmental pollution. In addition, many EJ neighborhoods contain more impervious area and lower canopy cover resulting in a heat island effect resulting in higher temperatures in these urban areas as compared to suburban neighborhoods. With the Merrimack Valley experiencing more 90-degree days during the summer months due to climate change, mitigating the "heat island effect" is a high priority. BMP retrofits, including the removal of pavement and installation of GI, can be one method to begin to address this issue.

### Co-benefits of Green Infrastructure

In addition to stormwater volume and pollution attenuation, GI can provide additional ecosystem services that can benefit communities struggling to address other environmental issues. These are outlined in the following graphic from Mass Audubon's LID Factsheet (1 of 5)[2]:



**The Value of Green Infrastructure: Free Ecosystem Services**

**Reduced Flooding**: Green infrastructure acts as a sponge for excess water, providing flood protection and avoiding costly repairs to flood-damaged roadways and culverts. Systems like rain gardens can reduce runoff by up to 90%.[4] A single, mature tree can intercept nearly 2,000 gallons of stormwater per year.[5]

**Improved Water Quality**: Polluted runoff contributes to more than half of water quality impairments in the Commonwealth.[3] Natural streamside vegetation filters pollutants and reduces erosion. Vegetated buffers also remove an average of 74% of nitrogen pollution in runoff, depending on buffer width, soil type, and vegetation.[6]

**Water Quantity**: Vegetation and soils capture and infiltrate water, recharging groundwater that feeds streams. Water harvesting systems like rain barrels and cisterns can save the average homeowner 1,300 gallons of water during peak summer months.[7] With good design, a development can rely entirely on natural precipitation for all landscape irrigation.

**Recreational Opportunities**: Clean, flowing waters support recreation and tourism, including boating, fishing, and swimming, while open space provides areas for hiking and biking.

**Improved Quality of Life**: Open space and street trees create a more enjoyable walking environment, benefiting community connection, health, and economic benefit in downtowns and commercial areas.

**Improved Public Health**: Trees and vegetation reduce the urban heat island effect, reducing smog that contributes to asthma and other respiratory diseases. Managing stormwater through soils and vegetation reduces the need for retention ponds and catch basins, avoiding creation of mosquito habitat. More than $11 million is spent annually on mosquito control in Massachusetts.[8]

**Creation of Habitat**: Open space and clean waters maintain healthy habitat for fish, birds, and other wildlife.

**Climate Change Mitigation**: Protecting forests allows them to continue absorbing $CO_2$ and acting as a carbon sink, while also reducing flooding from increased storm events. Massachusetts forests store an average of 85 tons of C per acre[9]—14% of the Commonwealth's annual gross carbon emissions each year.[10]

**Economic Value**: Access to open space and mature vegetation increases home value by 10-30%. Every dollar invested in land conservation provides a $4 payback in terms of the above benefits.[11]

[2] https://www.massaudubon.org/our-conservation-work/advocacy/shaping-climate-resilient-communities/saving-land-water-money-with-lid/lid-fact-sheets

Communities were asked to identify additional issues that may need to be addressed on municipal sites (flooding, erosion, heat, etc.). Although few were identified by municipal staff, this information will be incorporated into the GIS data available for each municipal site and can be updated by communities in the future.

### Other Considerations

Municipal staff were asked to provide additional information to assist MVPC with prioritizing BMP retrofit sites.  These factors included plans for redevelopment and site plan availability. Sites already planned for updates would increase the likelihood of Green Infrastructure retrofit installation. Additionally, site plans might aid in identify existing site conditions conducive to BMP installation. MVPC received good feedback on sites where communities are planning redevelopment but did not receive robust response to site plan requests. As a result, this field will be included in the MIMAP data layer and can be updated by communities at a later date. MVPC also planned to include site photos for the top two sites where BMP retrofits might be installed in each community, but COVID related delays made this infeasible.

## Catchment Areas

Once MVPC and each community finalized the 5 municipally owned sites, MVPC's GIS team utilized GIS tools to create catchment area delineations for each of the 5 sites within each municipality. Utilizing topography and LiDAR data, initial catchment areas were defined. During the catchment area delineation process, MVPC observed that the GIS tools did not always capture the total surface area contributing to the proposed BMP locations. The catchment areas do reflect the general direction of surface area flow on site and that, combined with additional work that would be done prior to BMP construction, provide reliability in using this as preliminary information to inform future design and engineering.  These observations suggest that the mapped catchment areas provide value beyond the calculated square footage of each drainage area thus both  sets of information have been made available to the communities.

## Green Infrastructure (GI) Considered

Section 502 of the Clean Water Act defines Green Infrastructure as "...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters." The GI practices considered for the Merrimack Valley Region consisted of the following (descriptions taken from the resources uploaded to each community's identified BMP retrofit sites and found in Appendix B):

### Bioretention Areas including Rain Gardens

A bioretention system manages and treats stormwater runoff using conditioned soils and native plantings to filter, store and more slowly release the runoff. The system generally consists of an inflow component, a pretreatment element, an overflow structure, a shallow ponding area (less than 9" deep), a surface layer of mulch or other organic matter, a planting soil bed, plant materials, and an underdrain system to convey treated runoff to a downstream facility. "Rain gardens" are a type of bioretention system.[3] In very porous soils bioretention areas can be designed as "off-line" but in most instances will need to be a component of the stormwater management system, connected to downstream treatment structures through an overflow outlet or drop inlet. Ideally, overflow outlets should be located as far as possible from runoff inlets to maximize residence time and treatment.[4]

### Porous Pavement

Since impervious pavement is the primary source of stormwater runoff, Low Impact Development strategies recommend permeable paving for parking areas and other hard surfaces. Permeable paving allows rainwater to percolate through the paving and into the ground before it runs off. This approach reduces stormwater runoff volumes and minimizes the pollutants introduced into stormwater runoff from parking areas. All permeable paving systems consist of a durable, load bearing, pervious surface overlying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete (not recommended in cold climates), paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, parking stalls, and overflow parking areas. Permeable paving is not ideal for high traffic/high speed areas because it has lower load-bearing capacity than conventional pavement. Nor should it be used on stormwater "hotspots" with high pollutant loads because stormwater cannot be pretreated prior to infiltration. Heavy winter sanding may clog joints and void spaces.[5]

### Tree Box Filters

Tree box filters are a proprietary biotreatment device that is designed to mimic natural systems such as bioretention areas by incorporating plants, soil, and microbes. Tree box filters are installed at curb level and consist of an open bottom concrete barrel filled with a porous soil media, an underdrain in crushed grave, and a tree. Tree box filters are highly adaptable solutions that can be sued in all types of development and in all types of soils but are especially applicable to ultra-urban areas.[6]

### Vegetated Filter Strips

Vegetated filter strips are uniformly graded vegetated surfaces (i.e. grass or close growing native vegetation) that receives runoff from adjacent impervious areas. Vegetated filter strips typically treat sheet flow or small concentrated flows that can be distributed along the width of the strip using a level spreader. Vegetated filter strips are designed to slow runoff velocities, trap sediment, and promote infiltration, thereby reducing runoff volumes. They can also serve as an effective

---

[3] https://greenscapes.org/lid-toolkit/
[4] Massachusetts Low Impact Development Toolkit, Fact Sheet #4: Bioretention Areas, MAPC
[5] Massachusetts Low Impact Development Toolkit, Fact Sheet #6 Permeable Paving, MAPC
[6] Boston Water and Sewer Commission Stormwater BMP Fact Sheet

pretreatment for bioretention cells and are were recommended at all sites where bioretention is proposed.[7]

### Catch Basin Infiltration Trench Retrofit

The Town of Arlington recently piloted a catch basin retrofit that provides infiltration through a trench added onto an existing basin. An article highlighting the design was published in the Winter 2020 edition of the NEWEA Journal.[8] A copy of the article will be included with the mapped BMP retrofit site information.

### Water Quality Swale

Water quality swales are vegetated open channels designed to treat the required water quality volume and to convey runoff from the 10-year storm without causing erosion. Swales may be designed to be either dry or wet. Dry swales are created with permanent check dams to create pools that temporarily hold water. The soil bed consists of native soils or highly permeable fill material underlaid by an underdrain system. Wet swales are constructed in existing soils and rely on sedimentation, adsorption, and microbial breakdown to treat stormwater.[9]

### Maintenance

Like conventional stormwater infrastructure, Green Infrastructure requires regular inspection and maintenance to function as intended. Maintenance of Green Infrastructure generally requires more labor and less heavy equipment than traditional gray infrastructure. All fact sheets included in each community's mapped sites (and in Appendix B) include proper operation and maintenance of the recommended BMPs.

[7] Structural BMPs – Volume 2, Chapter 2 Massachusetts Stormwater Handbook
[8] https://www.unh.edu/unhsc/sites/default/files/media/newea_arlington.pdf
[9] https://megamanual.geosyntec.com/npsmanual/waterqualityswales.aspx

## Proposed BMP Retrofit Sites by Community

### Amesbury

**Amesbury Elementary School**

The parking lot and access drive at the Amesbury Elementary school could be retrofitted with bioretention areas between the parking lot and Southampton Road and between the access drive and parking area. Additional pavement could be removed to add bioretention swales/areas[10]. Porous pavement could also replace parking spaces on the eastern side of the lot closest to Southampton Road where the site appears to drain. Well drained A soils are indicated by the soils map. Education and outreach could be incorporated into school curriculum and enhanced by signage.

**Amesbury Town Park**

The various parking areas at Amesbury Town Park could be retrofitted with bioretention areas to capture stormwater runoff. Catchment maps show some street drainage may also be captured. Soil maps indicate well drained soils. Flows from this site eventually drain to the e. coli impaired Powow River. Public education opportunities exist for all sectors of the population given the many age groups served by Town Park.

### Andover

**Pomps Pond**

Pomps Pond was chosen for BMP retrofits to protect water quality at this swimming beach and given prioritization for its location within an Andover EJ block. Bioretention areas with pretreatment filter strips are recommended in areas between the parking and the beach. Porous pavers could also be used within some of the parking spaces to replace the traditional pavement. Retrofitting is only recommended in the parking spaces because there is less potential for damage to the system.

**Town Parking Lot (51 Park Street)**

The Town Parking Lot was prioritized because redevelopment plans are already in progress. This large area of impervious pavement drains to Rogers Brook which is impaired for E. coli and Fecal Coliform. While not in the towns EJ block, the lot is frequented by residents and visitors and would provide an excellent location for stormwater related education and outreach. Bioretention areas between parking rows are proposed. Soils are identified as urban fill so soil testing will be required to confirm infiltration capacity. Tree box filters are an additional option.

### Boxford

**Harry Cole School**

The Town of Boxford is currently planning parking lot redevelopment at the Harry Cole School and Green Infrastructure retrofits will be incorporated. The recommendation is to include bioretention

[10] Bioretention areas work best if designed with some pretreatment, either in the form of swales or a narrow filter strip

areas in landscaped portions of the site including to the west of the Main Street access drive and in other landscape islands as feasible. Incorporating Green Infrastructure education into the school curriculum would be an added benefit. Signage for education and outreach should also be considered.

**East Library/Cummings House**
Boxford also prioritized this site because redevelopment is in the planning stages. The current proposal would retrofit the site with catch basin pretreatment piped to a bioretention/infiltration area to the east of the existing building. Existing drainage flows into the street and the piped stormwater system

## Georgetown

**Town Hall & Public Safety Building (and additional lots – 2 sites)**
Georgetown prioritized two sites adjacent to each other based on their large impervious area and existing stormwater related runoff/flooding issues in that area of Town. Town Hall has limited parking area. Parking spaces could be reduced to add bioretention or parking spaces could be retrofitted with porous pavement to reduce stormwater flows. It is recommended that only the parking spaces are retrofitted because there is less potential for damage to the system.

Much of the Public Safety site is also needed for equipment maneuvering and parking. A large unpaved area which appears to be compacted and not permeable, could be retrofitted with grid pavers filled with either grass or gravel to provide a more porous area that could absorb a portion of the site stormwater. Adjacent areas should be kept free of sediment to avoid clogging the paver system. Soils map indicate well drained A soils.

## Groveland

**Washington Park**
The Washington Park parcel encompasses a parking area, ball fields and playground on the northwest side of the site and a fire station, second building (Washington Hall), access drives and parking on the southeast portion of the parcel. On the northwest lot, parking spaces could be reduced to add bioretention or parking spaces could be retrofitted with porous pavement to reduce stormwater flows. It is recommended that only the parking spaces are retrofitted because there is less potential for damage to the system. Tree box filters would be another option to consider where space is limited. The park and ball fields provide an opportunity for public education. Soils are well drained on this portion of the site.

On the southeast side of the parcel, similar BMPs could be employed although soils are more limited. For areas that are not frequently used, pavement could be reduced, and a grassed or gravel paver system installed. Bioretention in existing landscaped areas would also be an option but more soil testing would be needed to determine infiltration capacity.

**Pines Recreation Area/Town Hall**
Town Hall and the Pines Recreation Area contain large impervious areas that drain to the Merrimack River which is impaired for bacteria. These sites are frequently used and present an ideal location for educational signage related to Green Infrastructure. Soils are well drained throughout most of the site. Where feasible, drainage could be redirected to bioretention/raingardens within existing grassed areas or curbing removed and bioretention areas installed. Parking could also be reconfigured to add bioretention areas (either off-line or on-line) with overflows to existing drainage structures. Infrequently used parking areas could be converted to grid paver systems filled with either grass or gravel.

## Haverhill

Haverhill worked with CDM Smith on a report to assess City-owned property for Green Infrastructure retrofits for CSO control. MVPC reviewed that report and prioritized sites from the report within Haverhill's Environmental Justice (EJ) neighborhoods. The Green Infrastructure retrofit possibilities are taken directly from the CDM report.

**Tilton Elementary School**
Tilton Elementary School is located between Grove Street and Hancock Street (within a minority EJ neighborhood). Existing drainage patterns on this site allow stormwater runoff to flow toward Grove Street and to Hancock Street. Impervious areas on the site include the school's roof and paved walkways, drive aisles, and parking.

In order to reduce flows to Grove Street and Hancock Street, runoff could be collected from the existing roof by redirecting roof drains to new bioretention areas located in existing lawn areas on the northwest and southeast corners of the site. An additional bioretention area could be located adjacent to Grove Street in a lawn area and collect runoff from Grove Street on the uphill side of an existing catch basin. Porous pavement could replace parking spaces on the downhill side of the southern parking area. It would not be required to replace the entire parking area with porous pavement because the quantity of stormwater could be contained in the area of parking spaces.[11]

Schools provide an opportunity to integrate stormwater education into school curriculum and additional outreach through signage. The site also drains to the Little River which is impaired for E. coli and Total Phosphorous.

**City Hall**
City Hall is located between Main Street, Summer Street, and Newcomb Street and has a large flat roof. Existing drainage patterns on this site allow stormwater to flow toward catch basins on the surrounding streets, which are all connected to the combined sewer system. Impervious areas on the site include the roof, pedestrian walkways, drive aisles and parking spaces as well as a large parking lot north of the building.

[11] "Green Assessment for CSO Control." CDM Smith, January 24, 2017.

In order to reduce flows to the combined system, runoff could be collected from the existing roof by redirecting roof drains to new vegetated bioretention areas located in existing lawn areas on the south side of the building. This could be a demonstration area and provide a viewing area to pedestrians on the adjacent walkway. Paved parking spaces on site and connected to Newcomb Street could be replaced with porous pavement and collect water flowing downhill on the street. Flows entering the combined system from the large parking lot located north of City Hall could be reduced by installing a vegetated bioretention area at one of the lot's three entrances. Parking space markings would need to be manipulated to reconfigure the traffic patterns through the lot if a bioretention area was installed. Another option is to replace parking spaces with porous pavement."[3]

City Hall is located within and Income and Minority EJ neighborhood in a densely developed portion of the City. GI would also have the potential to promote cooling and reduce "heat island" effects. The site drains to the Merrimack River which is impaired for bacteria (Enterococcus) in this segment.

## Lawrence

### Rowell Park

The City is looking at redevelopment of Rowell Park and is exploring removing pavement to make a better pedestrian connection between the neighborhood and the park. Removing pavement and replacing it with landscaping will improve infiltration and reduce runoff. The pedestrian access should be constructed of permeable materials. Bioretention areas/raingardens could also be added along existing paths and sidewalks within the park. The park drains to the Spicket River which is impaired for E. coli. Rowell Park is located within an EJ neighborhood that is minority, low income, and experiences English isolation. Educational signage should be posted in both English and Spanish. Ideally the neighborhood will be involved in the planning and design of the proposed changes to the park.

### Mt. Vernon Park

This recreation area composed of ball fields and parking areas is within an EJ minority neighborhood. Mt. Vernon Park drains to a segment of the Merrimack River which is impaired for E. coli and Total Phosphorous. Well drained A and B soils are mapped for the park. Proposed Green Infrastructure retrofits could include installation of bioretention areas/swales, with pretreatment filter strips, within existing lawn adjacent to parking areas. Landscape islands could also be retrofitted as raingardens. Catchment mapping shows drainage flowing north to south across the site. A second option would be to infiltrate stormwater within downgradient parking spaces using porous pavement.

## Merrimac

### Wastewater Treatment Plant

The Wastewater Treatment Plant is located to the east of Cobbler Brook and is comprised of wastewater treatment structures, a building, and paved parking and access drives. To increase infiltration and reduce stormwater flows to the adjacent Cobbler Brook watershed, curbing could be removed and bioretention area/raingardens installed in maintained lawn areas. Parking spaces could also be retrofitted with porous pavers/pavement to infiltrate runoff. Pavement could be removed in infrequently used portions of the site and grass or gravel filled grid pavers installed. The majority of the site is mapped as a former gravel pit.

**Sweetsir School**

The Sweetsir School site includes several large paved parking areas with grassed islands. Lawn areas also abut the access drives. Well drained A and B soils are mapped on the Sweetsir School site making the islands and lawn areas ideal locations for stormwater infiltration using bioretention and rain gardens. A pretreatment filter strip should be added for pretreatment where space allows. Porous pavement is also an option in parking rows. School programs could use onsite Green Infrastructure as part of the curriculum. Educational signage would enhance outreach to the community.

## Methuen

**Methuen High School**

Methuen High School was chosen for its education and outreach potential with students (and the public) as well as its large impervious area. Although the soil report indicates poor soils in the tiered parking area, the islands between each level might still be used as bioretention areas. The parking islands on the Pleasant View Street side of the school would also be possible locations for these BMPs. Where feasible, vegetated filter strips should be installed as pretreatment for the bioretention. Information is provided on use of bioretention in clay/low infiltration soils. Ideally students could be involved in all stages of design, planting, and maintenance of the bioretention areas.

**Forest Lake**

Forest Lake Recreation Area was chosen to protect water quality at this swimming and boating area. Directing flows away from the pond and infiltrating within bioretention areas is the recommended Green Infrastructure BMP. Soils maps indicate well drained soils within the beach parking area. This site also has potential for education and outreach with signage about Green Infrastructure and its ability to protect water quality.

## Newbury

**Newbury Elementary School**

The Newbury Elementary School is one of the largest municipally owned parcels of impervious area. The site also drains to the Little River which is impaired for fecal coliform. Well drained A and B soils are mapped on the Elementary School site making the islands and lawn areas ideal locations for stormwater infiltration using bioretention and rain gardens. Bioretention could also be added between parking aisles if spaces could be reconfigured. Filter strips should be added as pretreatment to bioretention where feasible. Porous pavement in the parking spaces would be another BMP retrofit option. The project could be integrated into school curriculum regarding the water cycle, stormwater, and water quality. Signage at Green Infrastructure locations would provide additional community outreach.

**Library**
The Newbury Library has multiple locations within the parking area where bioretention could be added to increase infiltration of stormwater. Soils are mapped as well drained. Porous pavement within the parking spaces would be another BMP retrofit that could be undertaken when the parking lot is repaved. Areas of overflow parking could also be retrofitted with grid pavers filled with either gravel or grass. Signage at the Library would be an ideal opportunity for stormwater education and outreach to the community. The site drains to the Parker River which recently received a TMDL for bacteria (fecal coliform).

## Newburyport

**Knock Middle School**
Soils at the Middle School are mapped as hydrologic soil group C and C/D and primarily silt loams with areas of clay. Where feasible, drainage could be redirected to bioretention/raingardens installed within existing grassed areas. Parking could also be reconfigured to add bioretention areas (either off-line or on-line with overflows or underdrains to existing drainage structures). Another option is to replace parking spaces with porous pavement.

**Cashman Park**
Stormwater at this municipal park and boat launch area currently drains to catch basins and is piped to a stormwater basin. Possible Green Infrastructure retrofits include replacing parking space asphalt with porous pavement to infiltrate stormwater before it reaches the basins. The goal would be not to eliminate any parking spaces at this frequently used recreational site. Soils are mapped as “urban land” so additional testing will need to be conducted to confirm infiltration capacity of the soils. Retrofitting catch basins with an infiltration trench is another possibility. This work was recently piloted in Arlington, MA. The design is included as an attachment in the Park’s mapped catchment points and in Appendix B of this report.

## North Andover

**North Andover High School**
Landscaped lawn areas adjacent to access drives and parking areas are ideal areas for bioretention. Landscape islands between parking areas might also be retrofitted with rain gardens/bioretention cells. Mapped soils vary across the high school site so some bioretention many need to be “on-line” with overflows/underdrains to the existing stormwater system. Installation of filter strips as pretreatment for bioretention areas is recommended where feasible. Installation of porous pavement in parking spaces would be another Green Infrastructure option. Schools provide an opportunity to integrate stormwater education into school curriculum. Additional outreach through signage is also possible. North Andover has an active Environmental Club that might also be engaged in the design, installation, and maintenance processes.

**Town Hall Parking**
The North Andover Town Hall Parking has limited space for bioretention and drops off steeply beyond the paved area to Cochichewick Brook. Tree box filters would be one retrofit option. Retrofitting

catch basins with infiltration trenches might also be considered. If a major redevelopment of the parking lot is planned, regrading and installing porous pavement in parking aisles would be another Green Infrastructure option.

## Rowley

**Rowley Municipal Light Department**

Impervious areas at the Light Department drain to Ox Pasture Brook. The majority of the site is mapped as well drained soils (hydrologic soil class A). Some portions of the site are used as storage areas and removal of existing pavement and installation of grid pavers or other permeable pavement would be one opportunity to increase infiltration.

**Highway Department**

The Highway Department site supports multiple uses including material and heavy equipment storage. There is also a septic system within the one maintained lawn area. This site may prove challenging for Green Infrastructure. Currently there is one leaching catch basin located on site. Water quality swales might be installed on the perimeter of the site to provide some storage and infiltration. The spaces reserved for visitor parking could be repaved with permeable pavement or porous pavers.

## Salisbury

**Fire/Hilton Center/DPW/Playground**

Soils at this multi-use site are mapped as hydrologic soil class C & D and additional soil testing may be needed to understand the capacity for infiltration. Green Infrastructure retrofits might include bioretention areas within existing landscape islands and installation of additional bioretention between parking rows. Filter strips should be added for pretreatment to bioretention where feasible. Porous pavement could replace parking spaces on the site.

**Public Library**

The Public Library is mapped as having well drained soils and has landscaped areas that could be retrofitted with bioretention/rain gardens (with filter strip pretreatment). Another retrofit option would be to have porous pavement replace parking spaces. Installing signage at this location to highlight the benefits of Green Infrastructure could be a successful component of the Town's stormwater education and outreach.

## West Newbury

**Ferry Park**

The Town of West Newbury is discussing removing a portion of Church Street, adjacent to Ferry Park, between Ferry Lane and the intersection with Bridge Street to the northwest. Once pavement is removed a portion of the former roadway would be revegetated to be contiguous with Ferry Park. The remaining portion would be a small parking area where porous or grid pavers could be installed. A pedestrian path through the area, constructed of similar pervious materials, might also be considered. Education and outreach regarding stormwater and its effects on water quality would be especially impactful at this site adjacent to the Merrimack River (Enterococcus impaired). This site is within the 100-year floodplain of the Merrimack River. Restoration of this area would increase resiliency to more frequent flooding anticipated with sea level rise and more intense storm events.

**Town Hall and Town Hall Parking**

The parking areas around town hall are traditional pavement with gray stormwater infrastructure that discharges to nearby vegetated wetlands within the Merrimack River watershed. The parking area between Town Hall and the adjacent ball fields needs repaving. When this is undertaken the Town may wish to use landscaped islands within the parking lot to install bioretention (with filter strip pretreatment if feasible), potentially with an under drain to the existing drainage system (on-line). There is an overflow lot at the Housing Authority property that could benefit from infiltration if grid pavers (either grass or gravel) were installed. Soils at the site are hydrologic soil class B and well drained. Porous pavement in parking rows might also be considered. Town Hall and the adjacent parking areas would be an excellent location for stormwater education and outreach through signage.

# Appendix A

## BMP Site Identification Spreadsheets

Community: Amesbury

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Site Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (S.F.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 4 | Amesbury Elementary School | 24 S Hampton Rd | Amesbury | 01913 | DPW | Parking Lot, Access Drive, Paved and Grass Recreation Areas, Playground, Building | Unnamed Trib to Back River (MA84A-30) | Escherichia Coli (E. Coli) | | | Considering | No | A | 48,243.14 - AME07 | Bioretention areas (in existing lawn/add), porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation - Power wash/vacuum sweep porous pavement |
| 64 | 1 | Amesbury Town Park | 140 Friend Street | Amesbury | 01913 | DPW | Building, Parking, Ball Fields, Basketball Court, Skate Park, Playground, 2 small ponds and wooded area | Unknown trib to Pattens Pond to Powow River (MA84A-08) | Escherichia Coli (E. Coli) | | | No | No | A (majority of site) | 11,140.25 - AME13<br>18,271 - AME10<br>7,572 - AME11<br>13,025.7 - AME12 | Bioretention areas in existing lawn | Inspect & remove trash, remove/replace vegetation |
| 37 | 4 | Woodsom Farm Learning Center Parking Lot | 219 Lions Mouth Rd #RR | Amesbury | 01913 | DPW | Access Rd, Paved and Dirt Parking, Buildg, Agricultural Fields | Powow River (MA84A-28) | Fecal Coliform Total Suspended Solids (TSS) Turbidity | | | No | No | B | 28,134.4 - AME03<br>59,028 - AME16<br>34,604.4 - AME17 | | |
| 36 | 10 | Woodsom Farm Parking Lot | 222 Lions Mouth Rd | Amesbury | 01913 | DPW | Unpaved Parking | Unnamed Trib to Powow River (MA84A-28) | Fecal Coliform Total Suspended Solids (TSS) Turbidity | | | No | No | A,B, C | 4,981.9 - AME04 | | |
| 60 | 5 | Amesbury Town Forest Parking Lot | 54 Kimball Rd #RR | Amesbury | 01913 | DPW | Parking, Forest | Unnamed Trib to Lake Attitash | Harmful Algal Blooms Mercury in Fish Tissue | | | No | No | A | 33,880.45 - AME05 | | |

Community: Andover

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Site Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (S.F.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 118 | 7 | Pomps Pond | 147 163 Abbot Street | Andover | 01810 | | Parking Lot, Access Drive, Building, Beach Area | Pomps Pond to Shawsheen River MA83-19 | (Non-Native Aquatic Plants*) Mercury in Fish Tissue | Escherichia Coli (E. Coli), Fecal Coliform, TMDL 2587 - Shawseen | | No | Yes | A (Parking Lot Area) | AND01 - 37,7001.77<br>AND08 - 37,026.57 | Bioretention areas | Inspect & remove trash, remove/replace vegetation |
| 192 | 6 | Town Parking Lot | 51 Park St | Andover | 01841 | | Parking Lot | Rogers Brook (MA83-04) | (Physical substrate habitat alterations*) Escherichia Coli (E. Coli), Fecal Coliform, TMDL 2587 | | | Yes | No | Urban Land | AND16 - 52,600.97<br>AND17 - 27,123.33<br>AND18 - 7,992.61 | Bioretention areas/tree box filters | Inspect & remove trash, remove/replace vegetation - check tree annually, rake for permeability, remove trash and debris (replace tree and media every 5-10 years) |
| 118 | 2 | Recreation Park | 9 Woburn Street | Andover | 01810 | | Access Drive, Parking, Ball Field, Building | Pomps Pond to Shawsheen River MA83-19 | (Non-Native Aquatic Plants*) Mercury in Fish Tissue | Escherichia Coli (E. Coli), Fecal Coliform, TMDL 2587 - Shawseen | | No | Yes | A & Gravel Pit (Parking Lot Area) | Not calculated | | |
| 192 | 6 | High Plain Elementary School/Wood Middle School | 11 Cross Street | Andover | 01841 | | Buildings, Access Drives, Parking Lots, Ball Courts, Playground Area | Unnamed Tributary to Fish Brook (MA84A-40) | Chloride Escherichia Coli (E. Coli) | | | No | Yes | B | AND04 - 35,313<br>AND07 - 200,961.67<br>AND12 - 75,684.81<br>AND14 - 26,940.94<br>AND15 - 262,503.89 | | |
| 147 | 1 | West Andover Fire Station | 200 Greenwood Road | Andover | 01841 | | Building, Parking, Access Drives | Hussey Brook | Non-Native Aquatic Plants* | | | Yes | Yes | C | AND06-50,786.73 | | |

Community: Boxford

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Hydrologic Soil Group | Catchment Area (s.f.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 32 | 01-21 | Harry Cole School | 28 Middleton Road | Boxford | 01921 | School/DPW | Building, Access Drives, Parking, Paved Play Areas, Playground, Ball Fields | Fish Brook | E.Coli | | Yes | Yes | No | A - Front parking, B-Building and other parts of site | BOX05 - 40,998.92<br>BOX07 - 23,548<br>BOX13 - 31,412.95<br>BOX15 - 77,401.3 | Bioretention Areas | Inspect & remove trash, remove/replace vegetation |
| 29 | 2-1 | East Library/Cummings House | 10 Elm Street | Boxford | 01921 | DPW | Building, Parking, Access Drive | Fish Brook | E.Coli | | Yes | Yes | No | B | BOX04 - 15,241.15<br>BOX09 - 6,907.37<br>BOX14 - delete<br>BOX16 - 7,986.56 | Bioretention Areas | Inspect & remove trash, remove/replace vegetation |
| 12 | 1-2 | Intersection of Washington Street and Essex Street | adjacent to 4 Essex Street | Boxford | 01921 | DPW | Roadway Island | Parker River | Dewatering | | No | Yes | No | B | BOX01 - 12,263.72<br>BOX10 - 2,559.71 | | |
| 33 | 2-6 | Boy Scout Park (12 Cahoon Road) | Topsfield Road | Boxford | 01921 | DPW | Parking Lot, Ball Fields | Fish Brook | E.Coli | | No | No | No | A-at entrance Parking Lot & Fields - former gravel pit | BOX02 - 22,453.56<br>BOX18 - 208,659.81<br>BOX19 - 89,018.84 | | |
| 9 | 1-13 | Old Library | 188 Washington Street | Boxford | 01921 | Library/DPW | Building, Parking Lot, Bandstand, Basketball Court, Ball Fields | Parker River | Dewatering | | No | No | No | A | BOX03 - 15,740.78<br>BOX11 - 5,045.88<br>BOX12 - 2,930.75 | | |

Community: Georgetown

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Site Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (S.F.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11A | 58 | Town Hall/Public Safety Complex | 1 Library Street | Georgetown | 01833 | DPW | Parking, Access Drives, Buildings, Lawn Areas | Penn Brook | None | | | Considering | No | A, B(forested area & outer edge of PS parking) | GEO01 - 217,503.44 | Porous pavement in parking areas/remove spaces to add bioretention areas | Power wash/vacuum sweep porous pavement - Inspect & remove trash, remove/replace vegetation for bioretention |
| 10B | 1, 2 | Public Safety Complex_Other Lots | 45, 47 Central Street | Georgetown | 01833 | DPW | Paved and compacted soil parking, Access Drive | Penn Brook | None | Intense rain event road flooding | | Considering | No | A | GEO02 - 324,517.11<br>GEO07 - 10,838.16<br>GEO08 - 50,396 | Grid paver system with either grass or gravel | Periodically reseed/add gravel (plows must be raised when clearing) |
| 11A | 125 | Perley School | 51 North Street | Georgetown | 01833 | Schools | Building, Paved Parking, Access Drives, Sidewalks, Ball Field, Playgroung Area | Penn Brook | None | | | Considering | No | A, B (southwestern parking) | GEO033 - 11,615.19<br>GEO09 - 4,677.91<br>GEO10 - 95,510.62 | | |
| 11A | 89 | Georgetown High School | 9 Winter Street | Georgetown | 01833 | Schools | Building, Paved Parking, Access Drives, Sidewalks, Ball Fields, Forested Areas | Penn Brook | None | | | No | No | Urban Land, A, B | GEO04 - 7,788.23<br>GEO12 - 58,966.22<br>GEO13 - 31,906.69 | | |
| 10 | 45 | DPW_Highway Complex | 203 E Main Street | Georgetown | 01833 | DPW | Buildings, Material Storage, Parking, Paved access drives, unpaved/dirt areas, Lawn | Penn Brook | None | | | Considering | No | Udorthents, refuse substratum | Not calculated | | |
| 10A | 45 | Penn Brook School | 68 Elm Street | Georgetown | 01833 | Schools | Buildings, Access Drives, Sidewalks, Paved Parking, Ball Fields, Forested Areas | Unnamed Trib to Penn Brook | None | | | No | No | A (developed areas) | Not in MS4 | | |

ommunity: Groveland

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (s.f.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | 124 | Washington Park | 107 Washington Street | Groveland | 01834 | Highway Departme | Ball Field, Playground and Parking | Johnson's Creek | Impairment for e.coli removed | | | | No | A | GROV15 - 35,535.43<br>GROV16 - 217,300.68<br>GROV19 - 22,805.3 | Bioretention areas (in existing lawn/add), porous pavement in parking spaces, tree box filters | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 6 | 1 | Town Hall/Recreation Complex | 183 Main Street | Groveland | 01834 | Highway Departme | Town Hall, Parking, Access Drives, Courts, Boat Ramp | Merrimack River | Enterococcus, PCBs in Fish Tissue | | | | No | A | GROV03 - 40,591.7<br>GROV07 - 46,560.42<br>GROV10 - 18,953.88<br>GROV11 - 43,374.37<br>GROV13 - 28,344.06<br>GROV14 - 30,903.32 | Bioretention areas (in existing lawn/add), porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 11 | 15 | Pines Reccreation Area | 235 Main Street | Groveland | 01834 | Highway Departme | Dog Park, Ball Field, Parking | Merrimack River | Enterococcus, PCBs in Fish Tissue | | | | No | A | GROV08 - 264,106.48<br>GROV09 - 59,904.48 | Remove pavement in less trafficed areas and install grid pavers (gravel/grass) | Periodically reseed/add gravel (plows must be raised when clearing) |
| 39 | 124 | Washington Hall (101 Washington) | 107 Washington Street | Groveland | 01834 | Highway Departme | Buildings, Parking, Access Drives, Forest | Johnson's Creek | Impairment for e.coli removed | | | | No | C | GROV17 - 31,015.24<br>GROV18 - 43,715.89 | Remove pavement in less trafficed areas and install grid pavers (gravel/grass), Bioretention areas (in existing lawn/add), | Periodically reseed/add gravel for grid pavers (plows must be raised when clearing), Inspect & remove trash, remove/replace vegetation for bioretention |
| 2 | 8 | Pentucket School | Main Street | Groveland | | School District | Access Drive, School Building, Track | Merrimack River | Enterococcus, PCBs in Fish Tissue | | Yes | | No | A/D some B to rear of site | GROV05 - 339,465.51 | | |
| 16 | 4 | Shanahan Field | 423 Main Street | Groveland | 01834 | Highway Department/Historical Society | Ball Field, Building, Parking, Access Drive | Merrimack River | Enterococcus, PCBs in Fish Tissue | | | | No | A (Udorthents - fill) | GROV06 - 3,420.59<br>GROV21 - 2,582.69<br>GROV22 - 1,324.08<br>GROV23 - 11,793.7 | | |

Community: Haverhill

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (s.f.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 520 | 312-2 | Tilton Elementary School | 70 Grove Street | Haverhill | 01832 | School Department | School Bldg, Parking and Access Drives, Walkways, Playground | Little River, Merrimack River | Escherichia Coli (E. Coli), PCBs In Fish Tissue, Phosphorus, Total | Combined Sewer Overflows | | | Yes | C, Urban Land | HAV01 - 27,039.9<br>HAV10 - 9,241.42 | Bioretention in existing lawn areas, Porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 202 | 37-1 | Haverhill City Hall | 4 Summer Street | Haverhill | 01830 | | Building, walkways | Merrimack River | Enterococcus PCBs In Fish Tissue | Combined Sewer Overflows | | | Yes | Urban Land | HAV02 - 2,005.1<br>HAV11 - 1,287.47 | Bioretention in existing lawn areas, Porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 202 | 37-5, 5B | Haverhill City Hall - Parking | Main Street | Haverhill | 01830 | | Parking Lot | Merrimack River | Enterococcus PCBs In Fish Tissue | Combined Sewer Overflows | | | Yes | Urban Land | HAV03 - 1,018,938 | Bioretention in existing lawn areas, Porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 200 | 1-3 | Haverhill Library Parking | 99 Main Street | Haverhill | 01830 | | Parking Lot | Merrimack River | Enterococcus PCBs In Fish Tissue | Combined Sewer Overflows | | | Yes | Urban Land | HAV04 - 16,611.41<br>HAV13 - 9,856.48<br>HAV14 - 33,128.98 | | |
| 107 | 4-1 | G.A.R. Park | 92 Main Street | Haverhill | 01830 | | Park, Walkways | Merrimack River | Enterococcus PCBs In Fish Tissue | Combined Sewer Overflows | | | Yes | Urban Land | HAV12 - 71,501.52 | | |
| 514 | 287-1 | Wysocki Park | Tremont Street | Haverhill | 01832 | | Park, Walkways | Merrimack River | Escherichia Coli (E. Coli), PCBs In Fish Tissue, Phosphorus, Total | Combined Sewer Overflows | | | Yes | A | HAV07 - 35,153.52 | | |
| | | Ginty Blvd | Ginty Blvd | Haverhill | 01830 | | Road, Sidewalk | Merrimack River | Enterococcus PCBs In Fish Tissue | Combined Sewer Overflows | | | Yes | Urban Land, C | HAV08 - 1,207,305<br>HAV15 - 14,203.98 | | |

Community: Lawrence

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Site Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (S.F.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 169 | 46 | Rowell Park | Hampshire St & Auburn St | Lawrence | 01841 | Recreation | Lawn, Sidewalks | Spicket River | (Debris*) (Physical substrate habitat alterations*) (Trash*) Benthic Macroinvertebrates Copper Escherichia Coli (E. Coli) Nutrients | Neighborhood connection to park | | Yes | Yes | None (Urban Land) | LAW06 - 411,216.07 | Remove pavement (possibly section of Auburn Street) to create pedestrian access only, use grid pavers or other permeable surface | Periodically reseed/add gravel (plows must be raised when clearing) |
| 134 | 23 | Mt. Vernon Park | Mt. Vernon Street (next to 160) | Lawrence | 01843 | Recreation | Parking, Access Drives, Ball Fields, Building, Walkways | Merrimack River (MA84-03) | Escherichia Coli (E. Coli) Mercury in Fish Tissue PCBs In Fish Tissue Phosphorus, Total | | | Yes | Yes | North Parking B, Rest of Site A | LAW05 - 46,596.05<br>LAW07 - 55,216.66<br>LAW08 - 36,039.16 | Bioretention in existing lawn areas, Porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 63 | 67 | Costello Park | Shawsheen Road | Lawrence | 01843 | Recreation | Parking, Walkways, Paved Courts, Community Gardens) | Shawsheen River (MA 83-19) | Escherichia Coli (E. Coli), Fecal Coliform (TMDL) | | | Considering | Yes | Parking Areas A & B | LAW04 - 282,446.83 | | |
| 186 | 104 | Guilmette School/Mullaney Park/Lawrence Fire Dept. | 66 Bodwell Street | Lawrence | 01841 | School | Buildings, Parking, Paved Areas, Acess Drives, Ball Fields | Merrimack River (MA84-03) | Escherichia Coli (E. Coli) Mercury in Fish Tissue PCBs In Fish Tissue Phosphorus, Total | | | No | Yes | A, Most of site | LAW01 - 208553.23<br>LAW10 - 67178<br>LAW11 - 35,761.7<br>LAW12 - 27,366.6 | | |
| 136 | 64 | Robert Frost Elementary School | 33 Hamlet Street | Lawrence | 01843 | School | Walkways, Access Drives, Buildings, Parking, Paved Play Areas, Playground, Ball Field | Merrimack River (MA84-03) | Escherichia Coli (E. Coli) Mercury in Fish Tissue PCBs In Fish Tissue Phosphorus, Total | | | No | Yes | A (developed areas_ | LAW02 - 96,142.68<br>LAW13 - 46,863.24<br>LAW14 - 12,286.02<br>LAW17 - 119,145.96 | | |
| 208 | 3 | Bruce School | 135 Butler Street | Lawrence | 01841 | School | Building, Parking, Paved Play Areas, Acess Drives, Ball Fields | Merrimack River (MA84-03) | Escherichia Coli (E. Coli) Mercury in Fish Tissue PCBs In Fish Tissue Phosphorus, Total | | | No | Yes | A (C on west end of site | LAW22 - 578,823.05 | | |

Community: Merrimac

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (s.f.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 39 | 1-2.A | Wastewater Treatment Plant | 50 FEDERAL WY | Merrimac | 01860 | Wastewater Department | Water Treatement, Building, Access Drives, Parking | Cobbler Brook | Debris, Floatables, Trash | | Yes | No | No | A, Gravel Pit | MERR09 - 2,185.29<br>MERR10 - 6,076.27 | Bioretention in existing lawn areas (with stone or grass filter strip), Porous pavement in parking spaces. Remove pavement and install grid pavers in low use areas. | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement. Periodically reseed/add gravel for grid pavers (plows must be raised when clearing) |
| 59 | 2-1.A | Sweetsir School | 104 CHURCH ST | Merrimac | 01860 | School Department | School Bldg, Access Drives, Parking, Play yard | Cobbler Brook | Debris, Floatables, Trash | | No | No | No | A (majority of site), B (southeast corner) | MERR02 - 5,473.19<br>MERR13 - 34,274.42<br>MERR14 - 43,042.38<br>MERR15 - 28,540.82<br>MERR17 - 12,825.11 | Bioretention areas/ rain gardens in lawn areas and in parking islands. Include stone filter strips for pretreatment. | Inspect & remove trash, remove/replace vegetation for bioretention |
| 17 | 1-1 | Fire / Highway Municipal Building | 16 EAST MAIN ST | Merrimac | 01860 | Fire Department / Highway Department | Building, Parking, Material Storage | Cobbler Brook | Debris, Floatables, Trash | | Yes | No | No | B, Urban Land (fill) | MERR03 - 19,891.65<br>MERR18 - 426,650.41 | Tree Box Filters | check tree annually, rake for permeability, remove trash and debris (replace tree and media every 5-10 years) |
| 47 | 1-2.A | Police Station | 2 JANA WAY | Merrimac | 01860 | Police Department | Building, Parking, Access Drive | Unnamed Trib to Merrimack River | Enterococcus PCBs In Fish Tissue | | Yes | No | No | C, C/D | MERR05 - 44,927.61<br>MERR21 - 9,256.45 | | |
| 42 | 1-3 | Senior Center | 100 EAST MAIN ST | Merrimac | 01860 | Senior Center | Building, Parking, Access Drive | Unnamed Trib to Cobblers Brook | Debris, Floatables, Trash | | Yes | No | No | A | MERR22 -132,362.88<br>MERR23 -30,7758.36 | | |
| 22 | 1-1 | Donaghue School | 24 UNION ST EX | Merrimac | 01860 | School Department | Building, Parking, Access Drive, Fields, Tennis Courts | Unnamed Trib to Cobblers Brook | Debris, Floatables, Trash | | Yes | No | No | B (Building Area), B/D (Fields) | MERR24 - 382,397.99<br>MERR26 - 3,564.33<br>MERR27 - 59,937.63 | | |

Community: Methuen

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (s.f.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 112 | 128-129 | Forest Lake | VP Ridgewood Lane | Methuen | 01844 | Parks & Recreation | Beach, Boat Ramp & Recreation Area | Forest Lake | Mercury in fish tissue | | | Yes | No | Parking - A<br>Boat Launch - B | METH07 - 197,616.07<br>METH10 - 5,946.6 | Bioretention Areas & Rain Gardens | Inspect & remove trash, remove/replace vegetation |
| 814 | 41-102A | Methuen High School | 1 Ranger Road | Methuen | 01844 | Schools | School, fields, parking | Searles Pond | | | | No | No | Parking Lots - C | METH08 - 230,022.25<br>METH11 - 10,879.33<br>METH13 - 75,571.32<br>METH14 - 22,384.82<br>METH15 - 154,626.12<br>METH16 - 60,692.57 | Bioretention Areas & Rain Gardens* | Inspect & remove trash, remove/replace vegetation |
| 612 | 53-4 | Charles Street (retaining wall project) | Charles St/Lawrence St | Methuen | 01844 | City | Parking | Spicket River | Benthic Macroinvertebrates, Copper, Escherichia Coli (E. Coli), Nutrients* | | Yes | Yes | Yes | Parking Lot - C<br>Main Bldg - Fill<br>Adj. Bldg and Field - A | METH18 - 38,658.2 | | |
| 512 | 146-20 | DPW/Highway Yard | 33 Lingberg Ave. | Methuen | 01844 | DPW | Highway Garage/Material Storage | Mystic Pond to Spicket River | Benthic Macroinvertebrates, Copper, Escherichia Coli (E. Coli), Nutrients* | | | No | Yes | Urban Land | METH04 - 188,425.99<br>METH20 - 16,844.37 | | |
| 912 | 82-23 | Veteran's Park | Milk Street | Methuen | 01844 | Parks & Recreation | Ball Fields, Parking | Bare Meadow Brook | Escherichia Coli (E. Coli)<br>Sedimentation/Siltation<br>Turbidity | | | No | No | Parking Lot A & A/D | METH05 - 6,876.65<br>METH21 - 1,931.05<br>METH22 - 1,412.48<br>METH23 - 2,061.06<br>METH24 - 4,970.18<br>METH25 - 1,708.86 | | |
| 410 | 126A-1 | Water Department | 124 Cross Street | Methuen | 01844 | Water Department | Water Dept. Offices, Garage and Material Storage | Spicket River | Benthic Macroinvertebrates, Copper, Escherichia Coli (E. Coli), Nutrients* | | | No | No | A | METH06 - 35,913.29<br>METH26 - 17,448.25<br>METH28 - 29,250.06 | | |
| | | | | | | | | | | | | | | | | *Possible poor soils | |

Community: Newbury

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Site Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (S.F.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R47 | 1 | Newbury Elementary School Complex | 63 Hanover Street | Newbury | 01951 | School Dept. | Building, Parking, Access Drives, Fields, Playground, Paved Play Area | Little River (MA91-11) | Fecal Coliform | | | | No | A, B, D | NEW06 - 33,009.14<br>NEW07 - 50,300.19<br>NEW09 - 6,718.26<br>NEW11 - 3,390.07<br>NEW12 - 7,507.26 | Bioretention areas/ rain gardens in lawn areas and in parking islands. Include stone filter strips for pretreatment. Porous Pavement | Inspect & remove trash, remove/replace vegetation for bioretention. Power wash/vacuum sweep porous pavement. |
| U14 | 17 | Library | 0 Lunt Street | Newbury | 01922 | Public Works | Building, Parking, Ball Field | Parker River | Fecal Coliform | | | | No | B (Building, some parking), A (Parking, ball field) | NEW02 - 28,357.5 | Bioretention areas/ rain gardens in lawn areas and in parking islands. Include stone filter strips for pretreatment. Porous Pavement | Inspect & remove trash, remove/replace vegetation for bioretention. Power wash/vacuum sweep porous pavement. |
| U06 | 31 | Town Hall (future) | 25 High Road | Newbury | 01951 | Public Works | Building, Parking | Unnamed Tributary to Merrimack River | Enterococcus, Fecal Coliform, PCBs In Fish Tissue | | | Yes | No | C/D Building and front parking<br>A Northern parking area | NEW15 - 3,185.77<br>NEW16 - 86,231.67 | | |
| | | Lunt Street Right of Way | 0 Lunt Street@ Intersection with Main Street | Byfield | 01922 | Public Works | ROW | Parker River | Fecal Coliform | | | | No | A | NEW04 - 34,3041.26 | | |
| | | Boston Road Right of Way | Boston Road @ Intersection with Middle Road | Newbury | 01951 | Public Works | ROW | Parker River | Fecal Coliform | | | | No | C/D | NEW05 - 2,523.81<br>NEW17 - 2,226.86 | | |

Community: Newburyport

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (s.f.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | 1 | Nock Middle School | 70 Low Street | Newburyport | 01950 | School | School | Little River (Parker River Tributary) (MA91-11) | Fecal Coliform | Education/Outreach | Yes | No | No | C | NBPT01 -87,148.32<br>NBPT08 -90,368.36<br>NBPT09-154,538.9 | Bioretention/raingardens in existing lawn areas and islands. Add bioretention between parking. Install filter strips as pretreatment where feasible. Add Porous Pavement to parking areas. | Inspect & remove trash, remove/replace vegetation for bioretention. Power wash/vacuum sweep porous pavement. |
| 52 | 83 | Cashman Park | 244 Merrimac Street | Newburyport | 01950 | Parks | Boat Ramp, Park, Parking | Merrimack River (MA84A-06) | Enterococcus, Fecal Coliform, PCBs In Fish Tissue | | Yes | No | No | Urban Land | NBPT13-135,305.6<br>NBPT14 -18,150.58 | Porous Pavement in parking spaces, Catch basin retrofits | Power wash/vacuum sweep porous pavement |
| 23 | 11 | Sewer Treatment Plant | 157 Water Street | Newburyport | 01950 | Sewer | Sewer Treatment/Parking/Roadways | Merrimack River (MA84A-06) | Fecal Coliform, PCB in Fish Tissue, Enterococcus | | Yes | No | No | Urban Land (some A toward road) | NBPT03-148,835.76 | | |
| 20 | 8 | Auixillary Building (Sewer) | 115 Water Street | Newburyport | 01950 | Sewer | Building, Parking, Access Drive | Merrimack River (MA84A-06) | Fecal Coliform, PCB in Fish Tissue, Enterococcus | | Yes | No | No | Urban Land (some A toward road) | NBPT15 -16,595.87<br>NBPT17 -7,612.48<br>NBPT18 -18,918.91 | | |
| | | Cross Streets between High and Merrimac | Oakland, Tyng, Kent | Newburyport | 01950 | DPS | Roads | Merrimack River (MA84A-06) | Fecal Coliform, PCB in Fish Tissue, Enterococcus | Identified in MVP | https://newburyportlivablestreets.org/2021/01/26/green-streets-combining-traffic-calming-and-stormwater-management-for-a-healthier-city/ | No | No | Mostly A and B (some urban land) | NBPT05 -19,658.51<br>NBPT19 -327,561.2 | | |
| 83 | 8A | DPS Facility and Administration | 16A Perry Way | Newburyport | 01950 | DPS | Building, Parking, Material Storage | Little River (Parker River Tributary) (MA91-11) | Fecal Coliform | | Yes | No | No | B | NBPT06 -85,227.54<br>NBPT20 -38,990.16<br>NBPT22 -13,893.46 | | |

Community: North Andover

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Site Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (S.F.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 092.0 | 0003 | North Andover High School | 0 Chickering Road | North Andover | 01845 | School Dept. | Building, Parking, Access Drives, Fields, Track, Tennis Courts | Cochichewick Brook | None | | Yes | No | No | A, B (some area of parking C/D) | NAND01 - 100,016.06 NAND09 - 6,279.28 NAND10 - 4,633.29 | Bioretention in existing lawn areas and landscape islands, filter strips for pretreatment. Porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 094.0 | 0003 | North Andover High School | 0 High School | North Andover | 01845 | School Dept. | Parking | Cochichewick Brook | None | | | No | No | A, B, C | NAND02 - 21,877 NAND11 - 29,759.62 NAND12 - 133,862.87 NAND13 - 129,992.96 NAND14 - 51,531.94 | Bioretention in existing lawn areas and landscape islands, filter strips for pretreatment. Porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 029.0 | 0034 | Town Hall | 120 Main Street | North Andover | 01845 | Public Works | Building, Parking | Sutton Pond | None | | Yes | Yes | No | C/D Building and front parking A Northern parking area | NAND03 - 13,687.7 NAND18 - 6,791.9 NAND19 - 18,667.71 | Tree box filter, catch basin infiltration trench, porous pavement in parking spaces | Power wash/vacuum sweep porous pavement, check tree annually, rake for permeability, remove trash and debris (replace tree and media every 5-10 years) |
| 029.0 | 0035 | Town Hall Parking | 120 Main Street | North Andover | 01845 | Public Works | Parking | Sutton Pond | None | | Maybe | No | No | B | NAND20 - 16,695.88 | Tree box filter, catch basin infiltration trench, porous pavement in parking spaces | Power wash/vacuum sweep porous pavement, check tree annually, rake for permeability, remove trash and debris (replace tree and media every 5-10 years) |
| 040.0 | 0014 | Town Hall Parking | 0 Rear Main Street | North Andover | 01845 | Public Works | Parking | Sutton Pond | None | | Maybe | No | No | B | NAND16 - 13,319.55 NAND17 - 28,568.45 | Tree box filter, catch basin infiltration trench, porous pavement in parking spaces | Power wash/vacuum sweep porous pavement, check tree annually, rake for permeability, remove trash and debris (replace tree and media every 5-10 years) |
| 057.0 | 0022 | Atkinson School | 0 Middle School | North Andover | 01845 | School Dept. | School Buildings, Parking, Access Drives, Walkways | Shawsheen River (MA83-19) | Escherichia Coli (E. Coli), Fecal Coliform, TMDL 2587 | | | Yes | No | A | NAND06 - 2,515.89 NAND22 - 36,613.65 NAND23 - 12,576.73 | | |
| 057.0 | 0022 | North Andover Middle School | 0 Middle School | North Andover | 01845 | School Dept. | School Buildings, Parking, Access Drives, Walkways | Cochichewick Brook | None | | | Yes | No | A | NAND07 - 194,732.06 NAND24 - 21,730.05 NAND26 - 120,848.06 | | |
| 043.0 | 0007 | North Andover Library | 345 Main Street | North Andover | 01845 | Public Works | Building, Walkways, Parking | Cochichewick Brook | None | | | No | No | C | NAND08 - 20,014.75 | | |

Community: Rowley

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (s.f.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 16 | Municipal Light Department | 47 Summer Street | Rowley | 01969 | Light Department | Office Building, Maintenance Garage, Parking | Ox Pasture Brook | none assessed | | | | No | A (B/D Stream and Buffer Area) | ROW01 - 67,776.2 | Grid pavers, porous pavers | Periodically reseed/add gravel (plows must be raised when clearing). Power wash/vacuum sweep porous pavement. |
| 15 | 3 | Highway Department | 40 Independent Street | Rowley | 01969 | Highway Departme | Maintenance Garage, Office, Material Stockpiles, Salt Shed, Storage Building, Parking | Ox Pasture Brook | none assessed | | | | No | A (B/D Stream and Buffer Area) | ROW02 - 98,418.74 | Water Quality Swales | Inspect swales, mow as needed, remove sediment and debris. Re-seed as necessary |
| 24 | 131 | Town Hall Annex | 39 Central Street | Rowley | 01969 | Town Administratio | Office Building, Parking | Ox Pasture Brook | none assessed | | | | No | A | ROW03 -13,005.83 ROW06 - 7,657.01 | | |
| 25 | 83 | Town Hall | 139 Main Street | Rowley | 01969 | Town Administratio | Office Building, Parking | Ox Pasture Brook | none assessed | | | | No | A | ROW04 - 12,605.62 | | |
| 25 | 82 | Library | 141 Main Street | Rowley | 01969 | Library | Building, Parking | Ox Pasture Brook | none assessed | | | | No | A | ROW05-195,327.54 | | |

Community: Salisbury

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Site Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (S.F.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 71 | Fire/Hilton Center/DPW/Playground | 39 Lafayette Road | Salisbury | 01952 | DPW | Buildings, Parking, Access Drives, Ball Fields, Ball Couts, Playground Area, Material Storage | Meader Brook | None | | | | No | C, C/D | SAL01 - 17,942.05<br>SAL16 - 19,470.43<br>SAL17 - 18,164.33<br>SAL18 - 16,934.46<br>SAL20 - 10,641.94 | Bioretention in existing lawn areas and landscape islands, filter strips for pretreatment. Porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 6 | 12 | Public Library | 17 Elm Street | Salisbury | 01952 | DPW | Building, Parking, Sidewalks, Access Drive | Town Creek | None | | Yes | No | No | A | SAL02 - 9,139.76<br>SAL13 - 2,369.02<br>SAL15 - 12,307.59 | Bioretention in existing lawn areas and landscape islands, filter strips for pretreatment. Porous pavement in parking spaces | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement |
| 6 | 135 | Town Common | 15 Elm Street | Salisbury | 01952 | DPW | Sidewalks, lawn areas, sitting areas | Town Creek | None | | | No | No | A | SAL03 - 94,605.15 | | |
| 6 | 38 | Memeorial Schhool | 18 Maple Street | Salisbury | 01952 | Schools | Building, Parking, Sidewalks, Access Drive, Ball Field | Town Creek | None | | | | No | Urban land | SAL05 - 5,645.45<br>SAL09 - 10,552.04<br>SAL10 - 5,087.69<br>SAL11 - 25,056 | | |
| 22 | 13 | Elementary School | 100 Lafayette Road | Salisbury | 01952 | Schools | Buidling, Access Drives, Parking, Ball Field, Forested Areas | Smallpox Brook | None | | | | No | A (Main School Bldg), C (Parking Areas) | SAL06 - 700.51<br>SAL07 - 13,207.33<br>SAL24 - 5,380.21<br>SAL25 - 6,724.47<br>SAL26 - 934.77<br>SAL27 - 4,590.03<br>SAL28 - 15,734.3<br>SAL30 - 19,364.13 | | |

Community: West Newbury

| Map | Lot | Property Name | Property Address | Town/City | Zip Code | Responsible Department | Current Site Use | Waterbody or Watershed Site Drains To | Waterbody Impairment (if any)? | Other Reason for Retrofit (flooding, erosion, etc.)? | Site Plans Available? | Site Redevelopment Planned? | Environmental Justice (EJ) Area? | Soil Type | Catchment Area (S.F.) | Recommended BMP | Maintenance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R12 | 20 | Ferry Park | 0 Bridge Street | West Newbury | 01985 | DPW | Green Space and on-street parking | Merrimack River | Enterococcus, PCBs in Fish Tissue | Site in 100-year floodplain | No | No | No | B | WNE05 - 14,479.92<br>WNE09 - 2,534.99<br>WNE10 - 1,240.15 | Remove pavement, revegetate, new parking to use porous or grid pavers | Periodically reseed/add gravel (plows must be raised when clearing). |
| R14 | 6 | Town Offices Complex | 381 Main Street | West Newbury | 01985 | DPW | Building and Parking | Merrimack River | Enterococcus, PCBs in Fish Tissue | | Maybe | No | No | B | WNE01 - 48,852.91<br>WNE06 - 40,328 | Bioretention in existing lawn areas and landscape islands, filter strips for pretreatment. Porous pavement in parking spaces. Grid pavers for overflow areas | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement. Periodically reseed/add gravel (plows must be raised when clearing). |
| R14 | 4A | Parking | 0 Main Street | West Newbury | 01985 | DPW | Parking Lot | Millpond/Indian River | No uses assessed | | No | Considering | No | B | WNE02 - 10,645.51<br>WNE07 - 9,601.1 | Bioretention in existing lawn areas and landscape islands, filter strips for pretreatment. Porous pavement in parking spaces. Grid pavers for overflow areas | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement. Periodically reseed/add gravel (plows must be raised when clearing). |
| R14 | 3 | Public Safety Complex | 401 Main Street | West Newbury | 01985 | DPW | Building and Parking | Merrimack River/Millpond/Indian River | No uses assessed | | Yes | No | No | B | WNE03 - 5,842.07<br>WNE08 - 12,073.12 | | |
| R14 | 3B | Burham Field/Action Cove | 0 Bachelor Street | West Newbury | 01985 | DPW | Fields, Playground and Parking | Millpond/Indian River | No uses assessed | | No | No | No | B/D | WNE04 - 11,169.22 | Bioretention in existing lawn areas and landscape islands, filter strips for pretreatment. Porous pavement in parking spaces. | Inspect & remove trash, remove/replace vegetation for bioretention - Power wash/vacuum sweep porous pavement. |

# Appendix B

## BMP Fact Sheets

# Bioretention Areas & Rain Gardens

***Description:*** Bioretention is a technique that uses soils, plants, and microbes to treat stormwater before it is infiltrated and/or discharged. Bioretention cells (also called rain gardens in residential applications) are shallow depressions filled with sandy soil topped with a thick layer of mulch and planted with dense native vegetation. Stormwater runoff is directed into the cell via piped or sheet flow. The runoff percolates through the soil media that acts as a filter.

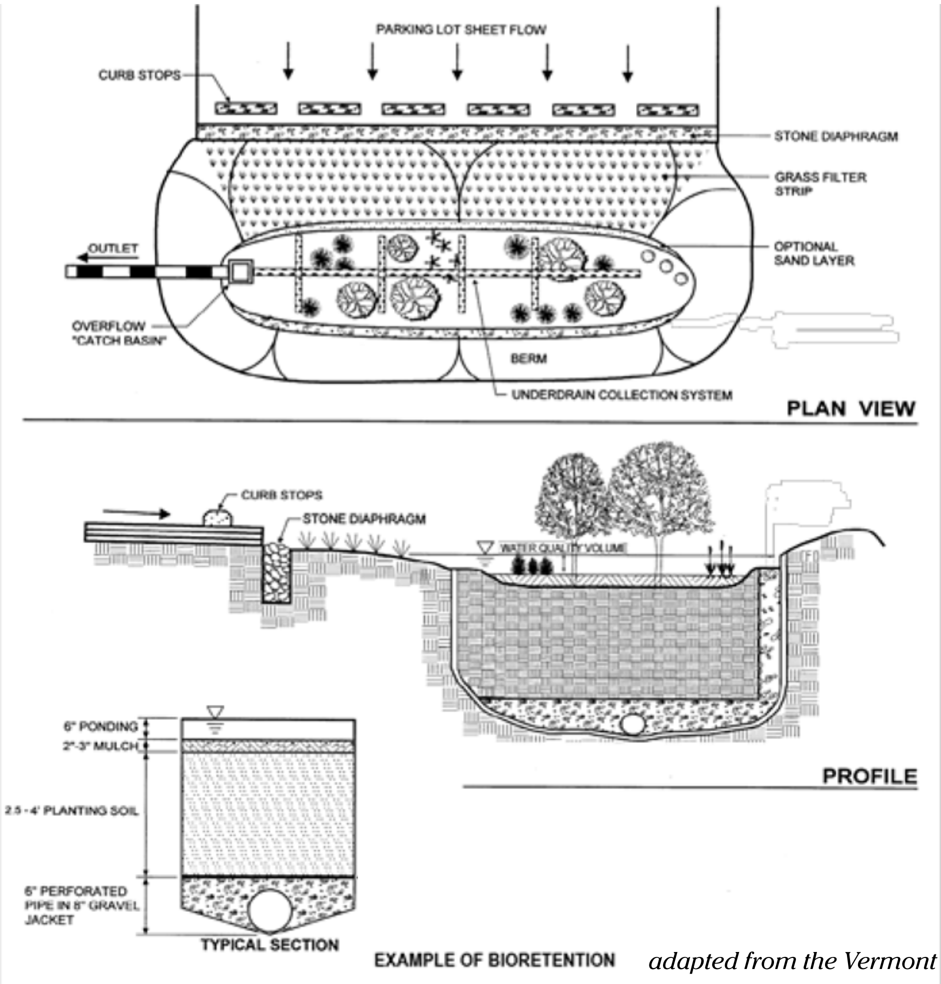
There are two types of bioretention cells: those that are designed solely as an organic filter filtering bioretention areas and those configured to recharge groundwater in addition to acting as a filter exfiltrating bioretention areas. A filtering bioretention area includes an impermeable liner and underdrain that intercepts the runoff before it reaches the water table so that it may be conveyed to a discharge outlet, other best management practices, or the municipal storm drain system. An exfiltrating bioretention area has an underdrain that is designed to enhance exfiltration of runoff into the groundwater.

## Ability to meet specific standards

| Standard | Description |
|---|---|
| **2 - Peak Flow** | N/A |
| **3 - Recharge** | An exfiltrating bioretention area provides groundwater recharge. |
| **4 - TSS Removal** | 90% TSS removal credit with adequate pretreatment |
| **5 - Higher Pollutant Loading** | Can be used for certain land uses with higher potential pollutant loads if lined and sealed until adequate pretreatment is provided. Adequate pretreatment must include 44% TSS removal prior to infiltration. For land uses that have the potential to generate runoff with high concentrations of oil and grease such as high intensity use parking lots and gas stations, adequate pretreatment may also include an oil grit separator, sand filter or equivalent. In lieu of an oil grit separator or sand filter, a filtering bioretention area also may be used as a pretreatment device for infiltration practices exfiltrating runoff from land uses with a potential to generate runoff with high concentrations of oil and grease. |
| **6 - Discharges near or to Critical Areas** | Good option for discharges near cold-water fisheries. Should not be used near bathing beaches and shellfish growing areas. |
| **7 - Redevelopment** | Suitable with appropriate pretreatment |

**Pollutant Removal Efficiencies**

| | |
|---|---|
| • Total Suspended Solids (TSS) | 90% with vegetated filter strip or equivalent |
| • Total Nitrogen | 30% to 50% if soil media at least 30 inches |
| • Total Phosphorus | 30% to 90% |
| • Metals (copper, lead, zinc, cadmium) | 40% to 90% |
| • Pathogens (coliform, e coli) | Insufficient data |



*adapted from the Vermont Stormwater Manual*

**Special Features:**
- Can be lined and sealed to prevent recharge where appropriate
- Adequate pretreatment is essential
- Not recommended in areas with steep slope
- Depth of soil media depends on type of vegetation that is proposed
- Soil media must be 30 inches deep to achieve removal of nitrogen

**Advantages/Benefits:**
- Can be designed to provide groundwater recharge and preserves the natural water balance of the site
- Can be designed to prevent recharge where appropriate
- Supplies shade, absorbs noise, and provides windbreaks
- Can remove other pollutants besides TSS including phosphorus, nitrogen and metals
- Can be used as a stormwater retrofit by modifying existing landscape or if a parking lot is being resurfaced
- Can be used on small lots with space constraints
- Small rain gardens are mosquito death traps
- Little or no hazard for amphibians or other small animals

**Disadvantages/Limitations:**
- Requires careful landscaping and maintenance
- Not suitable for large drainage areas

## Maintenance

| Activity | Frequency |
|---|---|
| Inspect and remove trash | Monthly |
| Mow | 2 to 12 times per year |
| Mulch | Annually |
| Fertilize | Annually |
| Remove dead vegetation | Annually |
| Prune | Annually |

# Bioretention Areas & Rain Gardens

*Not all bioretention cells are designed to exfiltrate. Only the infiltration requirements are applicable to bioretention cells intended to exfiltrate.*

## Applicability

Bioretention areas can provide excellent pollutant removal for the "first flush" of stormwater runoff. Properly designed and maintained cells remove suspended solids, metals, and nutrients, and can infiltrate an inch or more of rainfall. Distributed around a property, vegetated bioretention areas can enhance site aesthetics. In residential developments they are often described as "rain gardens" and marketed as property amenities. Routine maintenance is simple and can be handled by homeowners or conventional landscaping companies, with proper direction.

Bioretention systems can be applied to a wide range of commercial, residential, and industrial developments in many geologic conditions; they work well on small sites and on large sites divided into multiple small drainage areas. Bioretention systems are often well suited for ultra-urban settings where little pervious area exists. Although they require significant space (approximately 5% to 7% of the area that drains to them), they can be integrated into parking lots, parking lot islands, median strips, and traffic islands. Sites can be retrofitted with bioretention areas by replacing existing parking lot islands or by re-configuring a parking lot during resurfacing. On residential sites, they are commonly used for rooftop and driveway runoff.

## Effectiveness

Bioretention areas remove pollutants through filtration, microbe activity, and uptake by plants; contact with soil and roots provides water quality treatment better than conventional infiltration structures. Studies indicate that bioretention areas can remove from 80% to 90% of TSS. If properly designed and installed, bioretention areas remove phosphorus, nitrogen, metals, organics, and bacteria to varying degrees.

Bioretention areas help reduce stress in watersheds that experience severe low flows due to excessive impervious cover. Low-tech, decentralized bioretention areas are also less costly to design, install, and maintain than conventional stormwater technologies that treat runoff at the end of the pipe. Decentralized bioretention cells can also reduce the size of storm drain pipes, a major component of stormwater treatment costs. Bioretention areas enhance the landscape in a variety of ways: they improve the appearance of developed sites, provide windbreaks, absorb noise, provide wildlife habitat, and reduce the urban heat island effect.

## Planning Considerations

Filtering bioretention areas are designed with an impermeable liner and underdrain so that the stormwater may be transported to additional BMPs for treatment and/or discharge. Exfiltrating bioretention areas are designed so that following treatment by the bioretention area the stormwater may recharge the groundwater.

Both types of bioretention areas may be used to treat runoff from land uses with higher potential pollutant loads. However, exfiltrating bioretention areas may be used to treat runoff from land uses with higher potential pollutant loads, only if pretreatment has been provided to achieve TSS removal of at least 44%. If the land use has the potential to generate runoff with high concentrations of oil and grease, other types of pretreatment, i.e., a deep sump catch basin and oil grit separator or a sand filter, is required prior to discharge of runoff to an exfiltrating bioretention area. A filtering bioretention area may also be used as a pretreatment device for an exfiltrating bioretention area or other infiltration practice that exfiltrates runoff from land uses with a potential to generate runoff with high concentrations of oil and grease.

To receive 90% TSS removal credit, adequate pretreatment must be provided. If the flow is piped to the bioretention area a deep sump catch catch basin and sediment forebay should be used to provide pretreatment. For sheet flow, there are a number or pretreatment options. These options include:

- A vegetated filter strip, grass channel or water quality swale designed in accordance with the specifications set forth in Chapter 2.
- A grass and gravel combination. This should consist of at least 8 inches of gravel followed by 3 to 5 feet of sod. (source: North Carolina Stormwater Manual, 2007, http://h2o.enr.state.nc.us/su/documents/Ch12-Bioretention_001.pdf)
- Pea diaphragm combined with a vegetated filter strip specially designed to provide pretreatment for a bioretention area as set forth in the following table. (source: Georgia Stormwater Manual and Claytor and Schuler 1996)

**Dimensions for Filter Strip Designed Specially to Provide Pretreatment for Bioretention Area**

| Parameter | Impervious Area | | | | Pervious Areas (lawns, etc.) | | | |
|---|---|---|---|---|---|---|---|---|
| Maximum inflow approach length (feet) | 35 | | 75 | | 75 | | 100 | |
| Filter strip slope (max=6%) | <2% | >2% | <2% | >2% | <2% | >2% | <2% | >2% |
| Filter strip minimum length (feet) | 10 | 15 | 20 | 25 | 10 | 12 | 15 | 18 |

Bioretention areas must not be located on slopes greater than 20%. When the bioretention area is designed to exfiltrate, the design must ensure vertical separation of at least 2 feet from the seasonal high groundwater table to the bottom of the bioretention cell.

For residential rain gardens, pick a low spot on the property, and route water from a downspout or sump pump into it. It is best to choose a location with full sun, but if that is not possible, make sure it gets at least a half-day of sunlight.

Do not excavate an extensive rain garden under large trees. Digging up shallow feeder roots can weaken or kill a tree. If the tree is not a species that prefers moisture, the additional groundwater could damage it. Size the bioretention area using the methodology set forth in Volume 3.

## Design

Size the bioretention area to be 5% to 7% of the area draining to it. Determine the infiltrative capacity of the underlying native soil by performing a soil evaluation in accordance with Volume 3. Do not use a standard septic system (i.e., Title 5) percolation test to determine soil permeability.

The depth of the soil media must be between 2 and 4 feet. This range reflects the fact that most of the pollutant removal occurs within the first 2 feet of soil and that excavations deeper than 4 feet become expensive. The depth selected should accommodate the vegetation. If the minimum depth is used, only shallow rooted plants and grasses my be used. If there is a Total Maximum Daily Load that requires nitrogen to be removed from the stormwater dischrges, the bioretention area should have a soil media with a depth of at least 30 inches, because nitrogen removal takes place 30 inches below the ground surface. If trees and shrubs are to be planted, the soil media should be at least 3 feet.

Size the cells (based on void space and ponding area) at a minimum to capture and treat the required water quality volume (the first 0.5 inch or 1 inch of runoff) if intended to be used for water quality treatment (Stormwater Standard No. 4), the required recharge volume if used for recharge (Stormwater Standard No. 3), or the larger of the two volumes if used to achieve compliance with both Stormwater Standards 3 and 4.

Cover the bottom of the excavation with coarse gravel, over pea gravel, over sand. Earlier designs used filter fabric as a bottom blanket, but more recent experiences show that filter fabric is prone to clogging. Consequently, do not use fabric filters or sand curtains. Use the Engineered Soil Mix below.

*Engineered Soil Mix for Bioretention Systems Designed to Exfiltrate*

- The soil mix for bioretention areas should be a mixture of sand compost and soil.
  - o 40 % sand,
  - o 20-30% topsoil, and
  - o 30-40% compost.

- The soil mix must be uniform, free of stones, stumps, roots or similar objects larger than 2 inches. Clay content should not exceed 5%.
- Soil pH should generally be between 5.5-6.5, a range that is optimal for microbial activity and adsorption of nitrogen, phosphorus, and other pollutants.
- Use soils with 1.5% to 3% organic content and maximum 500-ppm soluble salts.
- The sand component should be gravelly sand that meets ASTM D 422.

| **Sieve Size** | **Percent Passing** |
|---|---|
| 2-inch | 100 |
| ¾-inch | 70-100 |
| ¼-inch | 50-80 |
| U.S. No. 40 | 15-40 |
| U.S. No. 200 | 0-3 |

- The topsoil component shall be a sandy loam, loamy sand or loam texture.
- The compost component must be processed from yard waste in accordance with MassDEP Guidelines (see http://www.mass.gov/dep/recycle/reduce/leafguid.doc). The compost shall not contain biosolids.

On-site soil mixing or placement is not allowed if soil is saturated or subject to water within 48 hours. Cover and store soil to prevent wetting or saturation.

Test soil for fertility and micro-nutrients and, only if necessary, amend mixture to create optimum conditions for plant establishment and early growth.

Grade the area to allow a ponding depth of 6 to 8 inches; depending on site conditions, more or less ponding may be appropriate.

Cover the soil with 2 to 3 inches of fine-shredded hardwood mulch.

The planting plan shall include a mix of herbaceous perennials, shrubs, and (if conditions permit) understory trees that can tolerate intermittent ponding, occasional saline conditions due to road salt, and extended dry periods. A list of plants that are suitable for bioretention areas can be found at the end of this section. To avoid a monoculture, it is a good practice to include one tree or shrub per 50 square feet of bioretention area, and at least 3 species each of herbaceous perennials and shrubs. Invasive and exotic species are prohibited. The planting plan should also meet any applicable local landscaping requirements.

All exfiltrating bioretention areas must be designed to drain within 72 hours. However, rain gardens are typically designed to drain water within a day and are thus unlikely to breed mosquitoes.

Bioretention cells, including rain gardens, require pretreatment, such as a vegetated filter strip. A stone or pea gravel diaphragm or, even better, a concrete level spreader upstream of a filter strip will enhance sheet flow and sediment removal.
Bioretention cells can be dosed with sheet flow, a surface inlet, or pipe flow. When using a surface inlet, first direct the flow to a sediment forebay. Alternatively, piped flow may be introduced to the bioretention system via an underdrain.

For bioretention cells dosed via sheet flow or surface inlets, include a ponding area to allow water to pond and be stored temporarily while stormwater is exfiltrating through the cell. Where bioretention areas are adjacent to parking areas, allow three inches of freeboard above the ponding depth to prevent flooding.

Most bioretention cells have an overflow drain that allows ponded water above the selected ponding depth to be dosed to an underdrain. If the bioretention system is designed to exfiltrate, the underdrain is not connected to an outlet, but instead terminates in the bioretention cell. If the bioretention area is not designed to exfiltrate, the underdrain is connected to an outlet for discharge or conveyance to additional best management practices.

### Construction
During construction, avoid excessively compacting soils around the bioretention areas and accumulating silt around the drain field. To minimize sediment loading in the treatment area, direct runoff to the bioretention area only from areas that are stabilized; always divert construction runoff elsewhere.

To avoid compaction of the parent material, work from the edge of the area proposed as the location of an exfiltrationg bioretention cell. Never direct runoff to the cell until the cell and the contributing drainage areas are fully stabilized.

Place planting soils in 1-foot to 2-foot lifts and compact them with minimal pressure until the desired elevation is reached. Some engineers suggest flooding the cell between each lift placement in lieu of compaction.

### Maintenance
Premature failure of bioretention areas is a significant issue caused by lack of regular maintenance. Ensuring long-term maintenance involves sustained public education and deed restrictions or covenants for privately owned cells. Bioretention areas require careful attention while plants are being established

**Bioretention Maintenance Schedule**

| *Activity* | *Time of Year* | *Frequency* |
|---|---|---|
| Inspect & remove trash | Year round | Monthly |
| Mulch | Spring | Annually |
| Remove dead vegetation | Fall or Spring | Annually |
| Replace dead vegetation | Spring | Annually |
| Prune | Spring or Fall | Annually |
| Replace entire media & all vegetation | Late Spring/early Summer | As needed* |

** Paying careful attention to pretreatment and operation & maintenance can extend the life of the soil media* and seasonal landscaping maintenance thereafter.

In many cases, a landscaping contractor working elsewhere on the site can complete maintenance tasks. Inspect pretreatment devices and bioretention cells regularly for sediment build-up, structural damage, and standing water.

Inspect soil and repair eroded areas monthly. Re-mulch void areas as needed. Remove litter and debris monthly. Treat diseased vegetation as needed. Remove and replace dead vegetation twice per year (spring and fall).

Proper selection of plant species and support during establishment of vegetation should minimize—if not eliminate—the need for fertilizers and pesticides. Remove invasive species as needed to prevent these species from spreading into the bioretention area. Replace mulch every two years, in the early spring. Upon failure, excavate bioretention area, scarify bottom and sides, replace filter fabric and soil, replant, and mulch. A summary of maintenance activities can be found on the previous page.

Because the soil medium filters contaminants from runoff, the cation exchange capacity of the soil media will eventually be exhausted. When the cation exchange capacity of the soil media decreases, change the soil media to prevent contaminants from migrating to the groundwater, or from being discharged via an underdrain outlet. Using small shrubs and plants instead of larger trees will make it easier to replace the media with clean material when needed.

Plant maintenance is critical. Concentrated salts in roadway runoff may kill plants, necessitating removal of dead vegetation each spring and replanting. The operation and maintenance plan must include measures to make sure the plants are maintained. This is particularly true in residential subdivisions, where the operation and maintenance plan may assign each homeowner the legal responsibility to maintain a bioretention cell or rain garden on his or her property. Including the requirement in the property deed for new subdivisions may alert residential property owners to their legal responsibilities regarding the bioretention cells constructed on their lot.

## Cold Climate Considerations

Never store snow in bioretention areas. The Operation and Maintenance plan must specify where on-site snow will be stored. All snow dumps must comply with MassDEP's guidance. When bioretention areas are located along roads, care must be taken during plowing operations to prevent snow from being plowed into the bioretention areas. If snow is plowed into the cells, runoff may bypass the cell and drain into downgradient wetlands without first receiving the required water quality treatment, and without recharging the groundwater.

## References

Center for Watershed Protection, 2000, Bioretention as a Water Quality Best Management Practice, Article 110 from Watershed Protection Techniques; http://www.cwp.org/Downloads/ELC_PWP110.pdf
Federal Highway Administration , YEAR, Bioretention Fact Sheet, http://www.fhwa.dot.gov/environment/

Low Impact Development Center, 2003, Drainage – Bioretention Specification, http://www.lowimpactdevelopment.org/epa03/biospec.htm

Prince Georges County, 2002, Bioretention Manual, http://www.goprincegeorgescounty.com/der/bioretention.asp

Puget Sound Action Team, 2005, Low Impact Development, Pp. 174 - 184 http://www.psat.wa.gov/Publications/LID_tech_manual05/LID_manual2005.pdf

U.S. Environmental Protection Agency, 1999, Stormwater Technology Fact Sheet, Bioretention, EPA 832-F-99-012, http://www.epa.gov/owm/mtb/biortn.pdf

U.S. Environmental Protection Agency, 2005, National Management Measures to Control Nonpoint Source Pollution from Urban Areas, Publication Number EPA 841-B-05-004, Pp. 5-29 http://www.epa.gov/nps/urbanmm/

University of North Carolina,
www.bae.ncsu.edu/topic/bioretention
www.bae.ncsu.edu/stormwater/PublicationFiles/DesigningRainGardens2001.pdf

## Plant Species Suitable for Use in Bioretention - Herbaceous Species

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Scientific Name Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects/ Disease | Exposure | Form | Height | Root System | Native | Wildlife | |
| *Agrostis alba* redtop | FAC | Mesic-Xeric | 1-2 | H | – | H | H | Shade | Grass | 2-3' | Fiberous Shallow | Yes | High | – |
| *Andropogon gerardi* bluejoint | FAC | Dry Mesic-Mesic | 1-2 | – | – | – | – | Sun | Grass | 2-3' | Fiberous Shallow | Yes | High | – |
| *Andropogon virginicus* broomsedge | – | Wet meadow | 1-2 | L | – | | | Full sun | Grass | 1-3' | | Yes | High | Tolerant of fluctuating water levels and drought. |
| *Carex vulpinoidea* fox sedge | OBL | Freshwater marsh | 2-4 | L | – | | | Sun to partial sun | Grass | 2-3.5' | Rhizome | Yes | High | – |
| *Chelone glabra* | | | | | | | | | | | | | | |
| *Deschampsia caespitosa* tufted hairgrass | FACW | Mesic to wet Mesic | 2-4 | H | – | H | H | Sun | Grass | 2-3' | Fiberous Shallow | Yes | High | May become invasive. |
| *Glyceria striata* fowl mannagrass, nerved mannagrass | OBL | Freshwater marsh, seeps | 1-2 | L | – | | | Partial shade to full shade | Grass | 2-4' | Rhizome | Yes | High | – |
| *Hedera helix* English Ivy | FACU | Mesic | 1-2 | – | – | – | H | Sun | Evergreen ground cover | – | Fiberous Shallow | No | Low | – |
| *Hibiscus palustris* | | | | | | | | | | | | | | |
| *Iris kaempferi* | | | | | | | | | | | | | | |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FACU Facultative Upland - Usually occur in non-wetlands, however, occasionally found in wetlands.
FAC Facultative - Equally likely to occur in wetlands and non-wetlands.
FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Occur almost always in wetlands

***Adapted from the Prince George's County Design Manual &***
***the Center for Watershed Protection for the use of bioretention in Stormwater Management***

## Plant Species Suitable for Use in Bioretention - Herbaceous Species

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Scientific Name*** **Common Name** | **Indicator Status** | **Habitat** | **Ponding (days)** | **Salt** | **Oil/ Grease** | **Metals** | **Insects/ Disease** | **Exposure** | **Form** | **Height** | **Root System** | **Native** | **Wildlife** | |
| *Lobelia siphilitica* | | | | | | | | | | | | | | |
| *Lotus Corniculatus* birdsfoot-trefoil | FAC | Mesic-Xeric | 1-2 | H | L | H | H | Sun | Grass | 2-3' | Fiberous Shallow | Yes | High | Member of the legume family. |
| *Onoclea sensibilis* sensitive fern, beadfern | FACW | | | | | | | Shade | | 1-3.5' | | | H | |
| *Pachysandra terminalis* Japanese pachysandra | FACU | Mesic | 1-2 | – | – | – | M | Shade | Evergreen ground cover | – | Fiberous Shallow | No | Low | – |
| *Panicum virgatum* switch grass | FAC to FACU | Mesic | 2-4 | H | – | – | H | Sun or Shade | Grass | 4-5' | Fiberous Shallow | Yes | High | Can spread fast and reach height of 6'. |
| *Vinca major* large periwinkle | FACU | Mesic | 1-2 | – | – | – | H | Shade | Evergreen ground cover | – | Fiberous Shallow | No | Low | Sensitive to soil compaction and pH changes. |
| *Vinca minor* common periwinkle | FACU | Mesic | 1-2 | – | – | – | H | Shade | Evergreen ground cover | – | Fiberous Shallow | No | Low | – |
| Indian grass | | | | | | | | | | | | | | |
| Little bluestem | | | | | | | | | | | | | | |
| Deer tongue | | | | | | | | | | | | | | |
| Green coneflower | | | | | | | | | | | | | | |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FACU Facultative Upland - Usually occur in non-wetlands, however, occasionally found in wetlands.
FAC Facultative - Equally likely to occur in wetlands and non-wetlands.
FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Occur almost always in wetlands

***Adapted from the Prince George's County Design Manual &***
***the Center for Watershed Protection for the use of bioretention in Stormwater Management***

## Plant Species Suitable for Use in Bioretention - Herbaceous Species

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Scientific Name*** **Common Name** | **Indicator Status** | **Habitat** | **Ponding (days)** | **Salt** | **Oil/ Grease** | **Metals** | **Insects/ Disease** | **Exposure** | **Form** | **Height** | **Root System** | **Native** | **Wildlife** | |
| *Aronia arbutifolia (Pyrus arbutifolia)* red chokeberry | FACW | Mesic | 1-2 | H | – | H | M | Sun to partial sun | Deciduous shrub | 6-12' | – | Yes | High | Good bank stabilizer. Tolerates drought. |
| *Clethra alnifolia* sweet pepperbush | FAC | Mesic to wet Mesic | 2-4 | H | – | – | H | Sun to partial sun | Ovoid shrub | 6-12' | Shallow | Yes | Med | Coastal plain species. |
| *Cornus Stolonifera (Cornus sericea)* red osier dogwood | FACW | Mesic-Hydric | 2-4 | H | H | H | M | Sun or shade | Arching, spreading shrub | 8-10' | Shallow | Yes | High | Needs more consistent moisture levels. |
| *Cornus amomum* silky dogwood | FAC | Mesic | 1-2 | L | – | – | M | Sun to partial sun | Broad-leaved | 6-12' | – | Yes | High | Good bank stabilizer |
| *Euonymous europaeus* spindle-tree | FAC | Mesic | 1-2 | M | M | M | M | Sun to partial sun | Upright dense oval shrub | 10-12' | Shallow | No | No | – |
| *Hamamelis virginiana* witch hazel | FAC | Mesic | 2-4 | M | M | M | M | Sun or shade | Vase-like compact shrub | 4-6' | Shallow | Yes | Low | – |
| *Hypericum densiflorum* common St. John's wort | FAC | Mesic | 2-4 | H | M | M | H | Sun | Ovoid shrub | 3-6' | Shallow | Yes | Med | – |
| *Ilex glabra* inkberry | FACW | Mesic to wet Mesic | 2-4 | H | H | – | H | Sun to partial sun | Upright dense shrub | 6-12' | Shallow | Yes | High | Coastal plain species. |
| *Ilex verticillata* winterberry | FACW | Mesic to wet Mesic | 2-4 | L | M | – | H | Sun to partial sun | Spreading shrub | 6-12' | Shallow | Yes | High | – |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FACU Facultative Upland - Usually occur in non-wetlands, however, occasionally found in wetlands.
FAC Facultative - Equally likely to occur in non-wetlands and wetlands.
FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Almost always occur in wetlands.

***Adapted from the Prince George's County Design Manual & the Center for Watershed Protection for the use of bioretention in Stormwater Management***

## Plant Species Suitable for Use in Bioretention - Herbaceous Species

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Scientific Name*** **Common Name** | **Indicator Status** | **Habitat** | **Ponding (days)** | **Salt** | **Oil/ Grease** | **Metals** | **Insects/ Disease** | **Exposure** | **Form** | **Height** | **Root System** | **Native** | **Wildlife** | |
| *Itea virginica* tassel-white, Virginia sweetspire | OBL | Mesic | 1-2 | M | – | – | M | Sun or shade | Broad-leaved, deciduous shrub | 6-12' | – | Yes | Low | – |
| *Juniperus communis "compressa"* common juniper | FAC | Dry Mesic-Mesic | 1-2 | M | H | H | M-H | Sun | Mounded shrub | 3-6' | Deep taproot | No | High | Evergreen |
| *Juniperus horizontalis "Bar Harbor" creeping juniper* | FAC | Dry Mesic-Mesic | 1-2 | M | H | H | M-H | Sun | Matted shrub | 0-3' | Deep taproot | No | High | Evergreen |
| *Lindera benzoin* spicebush | FACW | Mesic to wet Mesic | 2-4 | H | – | – | H | Sun | Upright shrub | 6-12' | Deep | Yes | High | – |
| *Myrica pennsylvanica* bayberry | FAC | Mesic | 2-4 | H | M | M | H | Sun to partial sun | Rounded, compact shrub | 6-8' | Shallow | Yes | High | Coastal plain species. |
| *Physocarpus opulifolius* ninebark | FAC | Dry Mesic to wet Mesic | 2-4 | M | – | – | H | Sun | Upright shrub | 6-12' | Shallow | Yes | Med | May be difficult to locate. |
| *Viburnum cassinoides* northern wild raisin | FACW | Mesic | 2-4 | H | H | H | H | Sun to partial sun | Rounded, compacted shrub | 6-8' | Shallow | Yes | High | – |
| *Viburnum dentatum* arrow-wood | FAC | Mesic to wet | 2-4 | H | H | H | H | Sun to partial sun | Upright, multi-stemmed shrub | 8-10' | Shallow | Yes | High | – |
| *Viburnum lentago* nannyberry | FAC | Mesic | 2-4 | H | H | H | H | Sun to partial sun | Upright, mlti-stemmed shrub | 8-10' | Shallow | Yes | High | – |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FACU Facultative Upland - Usually occur in non-wetlands, however, occasionally found in wetlands.
FAC Facultative - Equally likely to occur in non-wetlands and wetlands.
FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Almost always occur in wetlands.

***Adapted from the Prince George's County Design Manual & the Center for Watershed Protection for the use of bioretention in Stormwater Management***

# Plant Species Suitable for Use in Bioretention - Herbaceous Species

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scientific Name* Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects/ Disease | Exposure | Form | Height | Root System | Native | Wildlife | |
| *Acer rubrum* red maple | FAC | Mesic-Hydric | 4-6 | H | H | H | H | Partial sun | Single to multi-stem tree | 50-70' | Shallow | Yes | High | – |
| *Amelanchier canadensis* shadbush | FAC | Mesic | 2-4 | H | M | – | H | Partial sun | Single to multi-stem tree | 35-50' | Shallow | Yes | High | Not recommended for full sun. |
| *Betula nigra* river birch | FACW | Mesic-Hydric | 4-6 | – | M | M | H | Partial sun | Single to multi-stem tree | 50-75' | Shallow | Yes | High | Not susceptible to bronze birch borer. |
| *Betula populifolia* gray birch | FAC | Xeric-Hydric | 4-6 | H | H | M | H | Partial sun | Single to multi-stem tree | 35-50' | Shallow to deep | No | High | Native to New England area. |
| *Fraxinus americana* white ash | FAC | Mesic | 2-4 | M | H | H | H | Sun | Large tree | 50-80' | Deep | Yes | Low | – |
| *Fraxinus Pennsylvanica* green ash | FACW | Mesic | 4-6 | M | H | H | H | Partial sun | Large tree | 40-65' | Shallow to deep | Yes | Low | – |
| *Ginko biloba* Maidenhair tree | FAC | Mesic | 2-4 | H | H | H | H | Sun | Large tree | 50-80' | Shallow to deep | No | Low | Avoid female species-offensive odor from fruit. |
| *Gleditsia triacanthos* honeylocust | FAC | Mesic | 2-4 | H | M | – | M | Sun | Small caopied large tree | 50-75' | Shallow to deep variable taproot | Yes | Low | Select thornless variety. |
| *Juniperus virginiana* eastern red cedar | FACU | Mesic-Xeric | 2-4 | H | H | – | H | Sun | Dense single stem tree | 50-75' | Taproot | Yes | Very high | Evergreen |
| *Liquidambar styraciflua* sweet gum | FAC | Mesic | 4-6 | H | H | H | M | Sun | Large tree | 50-70' | Deep taproot | Yes | High | Edge and perimeter; fruit is a maintenance problem. |
| *Nyssa sylvatica* black gum | FACW | Mesic-Hydric | 4-6 | H | H | H | H | Sun | Large tree | 40-70' | Shallow to deep taproot | Yes | High | – |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FACU Facultative Upland - Usually occur in non-wetlands, however, occasionally found in wetlands.
FAC Facultative - Equally likely to occur in non-wetlands and wetlands.
FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Almost always occur in wetlands.

***Adapted from the Prince George's County Design Manual &***
***the Center for Watershed Protection for the use of bioretention in Stormwater Management***

## Plant Species Suitable for Use in Bioretention - Herbaceous Species

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scientific Name* Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects/ Disease | Exposure | Form | Height | Root System | Native | Wildlife | |
| *Platanus acerifolia* London plane-tree | FACW | Mesic | 2-4 | H | – | – | M | Sun | Large tree | 70-80' | Shallow | No | Low | Tree roots can heave sidewalks. |
| *Platanus occidentalis* sycamore | FACW | Mesic-Hydric | 4-6 | M | M | M | M | Sun | Large tree | 70-80' | Shallow | Yes | Med | Edge and perimeter; fruit is a maintenance problem; tree is also prone to windthrow. |
| *Populus deltoides* eastern cottonnwood | FAC | Xeric-Mesic | 4-6 | H | H | H | L | Sun | Large tree with spreading branches | 75-100' | Shallow | Yes | High | Short lived. |
| *Quercus bicolor* Swamp white oak | FACW | Mesic to wet Mesic | 4-6 | H | – | H | H | Sun to partial sun | Large tree | 75-100' | Shallow | Yes | High | One of the faster growing oaks. |
| *Quercus coccinea* scarlet oak | FAC | Mesic | 1-2 | H | M | M | M | Sun | Large tree | 50-75' | Shallow to deep | Yes | High | – |
| *Quercus macrocarpa* bur oak | FAC | Mesic to wet Mesic | 2-4 | H | H | H | M | Sun | Large spreading tree | 75-100" | Taproot | No | High | Native to Midwest. |
| *Quercus palustris* pin oak | FACW | Mesic-Hydric | 4-6 | H | H | H | M | Sun | Large tree | 60-80' | Shallow to deep taproot | Yes | High | – |
| *Quercus phellos* willow oak | FACW | Mesic to wet Mesic | 4-6 | H | – | – | H | Sun | Large tree | 55-75' | Shallow | Yes | High | Fast growing oak. |
| *Quercus rubra* red oak | FAC | Mesic | 2-4 | M | H | M | M | Sun to partial sun | Large spreading tree | 60-80' | Deep taproot | Yes | High | – |
| *Quercus shumardii* Shumard's red oak | FAC | Mesic | 2-4 | H | H | H | M | Sun to partial sun | Large spreading tree | 60-80' | Deep taproot | No | High | Native to Southeast. |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FACU Facultative Upland - Usually occur in non-wetlands, however, occasionally found in wetlands.
FAC Facultative - Equally likely to occur in non-wetlands and wetlands.
FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Almost always occur in wetlands.

***Adapted from the Prince George's County Design Manual &***
***the Center for Watershed Protection for the use of bioretention in Stormwater Management***

## Plant Species Suitable for Use in Bioretention - Herbaceous Species

| Species | Moisture Regime | | Tolerance | | | | | | Morphology | | | General Characteristics | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scientific Name* Common Name | Indicator Status | Habitat | Ponding (days) | Salt | Oil/ Grease | Metals | Insects/ Disease | Exposure | Form | Height | Root System | Native | Wildlife | |
| *Sophora japonica* Japanese pagoda tree | FAC | Mesic | 1-2 | M | M | _ | M | Sun | Shade tree | 40-70' | Shallow | No | Low | Fruit stains sidewalk. |
| *Taxodium distichum* bald cypress | FACW | Mesic-Hydric | 4-6 | _ | _ | M | H | Sun to partial sun | Typically single stem tree | 75-100' | Shallow | Yes | Low | Not well documented for planting in urban areas. |
| *Thuja occidentalis* arborvitae | FACW | Mesic to wet Mesic | 2-4 | M | M | M | H | Sun to partial sun | Dense single stem tree | 50-75' | Shallow | No | Low | Evergreen |
| *Zelkova serrata* Japanese zelkova | FACU | Mesic | 1-2 | M | M | _ | H | Sun | Dense shade tree | 60-70' | Shallow | No | Low | Branches can split easily in storms. |

H High Tolerance
M Medium Tolerance
L Low Tolerance

FACU Facultative Upland - Usually occur in non-wetlands, however, occasionally found in wetlands.
FAC Facultative - Equally likely to occur in non-wetlands and wetlands.
FACW Facultative Wetland - Usually occur in wetlands, however, occasionally found in non-wetlands.
OBL Obligate Wetland - Almost always occur in wetlands.

***Adapted from the Prince George's County Design Manual &***
***the Center for Watershed Protection for the use of bioretention in Stormwater Management***

# Vegetated Filter Strips

***Description***: Vegetated filter strips, also known as filter strips, grass buffer strips and grass filters, are uniformly graded vegetated surfaces (i.e., grass or close-growing native vegetation) that receive runoff from adjacent impervious areas. Vegetated filter strips typically treat sheet flow or small concentrated flows that can be distributed along the width of the strip using a level spreader. Vegetated filter strips are designed to slow runoff velocities, trap sediment, and promote infiltration, thereby reducing runoff volumes.

## Ability to meet specific standards

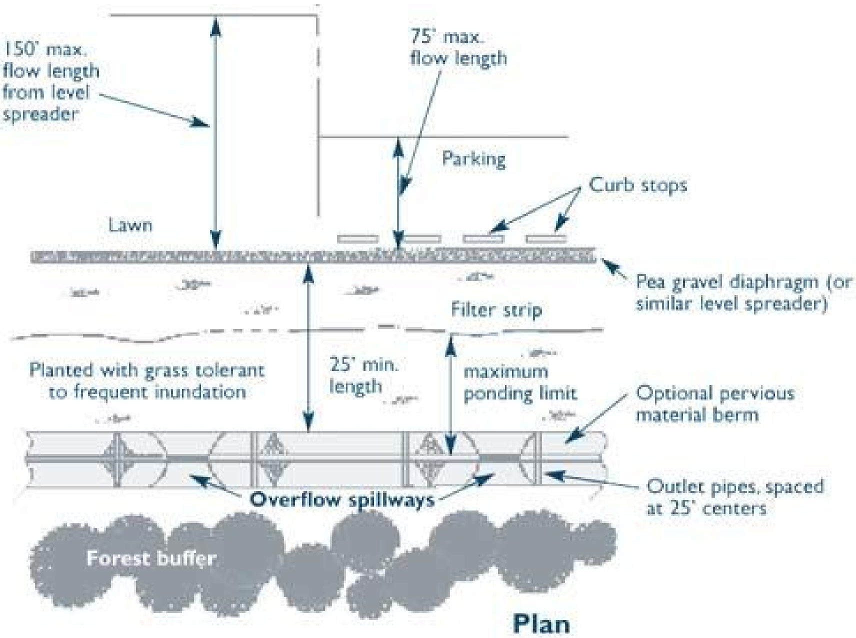
| Standard | Description |
|---|---|
| **2 - Peak Flow** | Provides some peak flow attenuation but usually not enough to achieve compliance with Standard 2 |
| **3 - Recharge** | No recharge credit |
| **4 - TSS Removal** | If greater than or equal to 25' and less than 50' wide, 10% TSS removal. If greater than or equal to 50' wide, 45% TSS removal. |
| **5 - Higher Pollutant Loading** | May be used as part of a pretreatment train if lined |
| **6 - Discharges near or to Critical Areas** | May be used as part of a pretreatment train if lined. May be used near cold-water fisheries. |
| **7 - Redevelopment** | Suitable for pretreatment or as a stand-alone practice if sufficient land is available. |

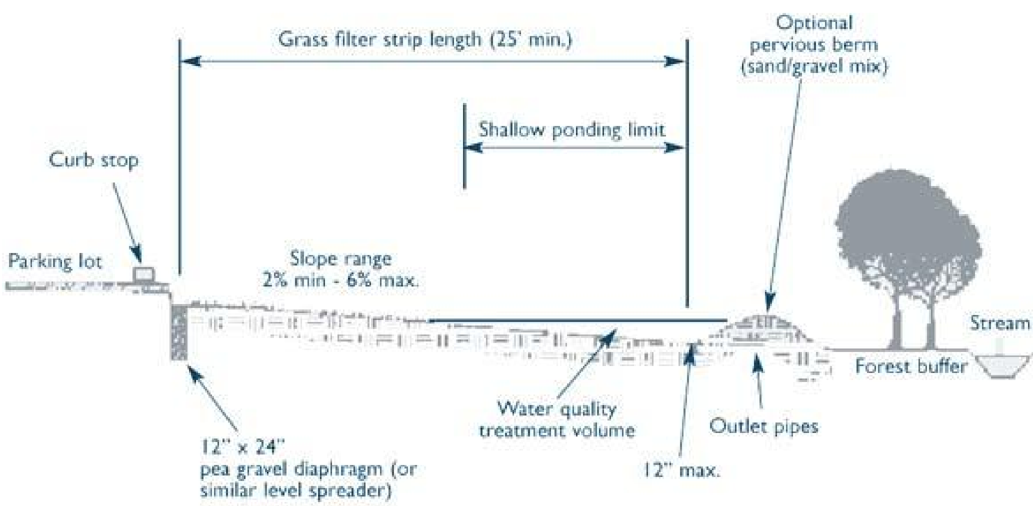
**Advantages/Benefits:**
- Reduces runoff volumes and peak flows.
- Slows runoff velocities and removes sediment.
- Low maintenance requirements.
- Serves as an effective pretreatment for bioretention cells
- Can mimic natural hydrology
- Small filter strips may be used in certain urban settings.
- Ideal for residential settings and to treat runoff from small parking lots and roads.
- Can be used as part of runoff conveyance system in combination with other BMPs
- Little or no entrapment hazard for amphibians or other small creatures

**Disadvantages/Limitations:**
- Variability in removal efficiencies, depending on design
- Little or no treatment is provided if the filter strip is short-circuited by concentrated flows.
- Often a poor retrofit option due to large land requirements.
- Effective only on drainage areas with gentle slopes (less than 6 percent).
- Improper grading can greatly diminish pollutant removal.

**Pollutant Removal Efficiencies**

| | |
|---|---|
| • TSS (if filter strip is 25 feet wide) | 10% assumed (Regulatory) |
| • TSS (if filter strip is 50 feet wide) | 45% assumed (Regulatory) |
| • Nutrients (Nitrogen, phosphorus) | Insufficient data |
| • Metals (copper, lead, zinc, cadmium) | Insufficient data |
| • Pathogens (coliform, e coli) | Insufficient data |




*adapted from the "Design of Stormwater Systems" 1996*

## Maintenance

| Activity | Frequency |
|---|---|
| Inspect the level spreader for sediment buildup and the vegetation for signs of erosion, bare spots, and overall health. | Every six months during the first year. Annually thereafter. |
| Regularly mow the grass. | As needed |
| Remove sediment from the toe of slope or level spreader and reseed bare spots. | As needed |

## Special Features

Include an impermeable liner and underdrain for discharges from Land Use with Higher Potential Pollutant Loads and for discharges within Zone IIs and Interim Wellhead Protection Areas; for discharges near or to other critical areas or in soils with rapid infiltration rates greater than 2.4 inches per hour.

# Vegetated Filter Strips

### Applicability

Vegetated filter strips are used to pretreat sheet flow from roads, highways, and small parking lots. In residential settings, they are useful in pretreating sheet flow from driveways. They provide effective pretreatment, especially when combined with bioretention areas and stream buffers. Urban areas can sometimes accommodate small filter strips depending on available land area, making them potential retrofit options in certain urban settings. Vegetated filter strips can also be used as side slopes of grass channels or water quality swales to enhance infiltration and remove sediment.

### Effectiveness

Variable TSS removal efficiencies have been reported for filter strips, depending on the size of the contributing drainage area, the width of the filter strip, the underlying parent soil, the land slope, the type of vegetation, how well the vegetation is established, and maintenance practices. Vegetated filter strips may remove nutrients and metals depending on the length and slope of the filter, soil permeability, size and characteristics of the drainage area, type of vegetative cover, and runoff velocity.

### Planning Considerations

Vegetated filter strips may be used as a stand-alone practice for redevelopments, only where other practices are not feasible. Vegetated filter strips can be designed to fit within the open space and rights of way that are available along roads and highways. Do not design vegetated filter strips to accept runoff from land uses with higher potential pollutant loads (LUHHPL) without a liner. Vegetated filter strips function best for drainage areas of one acre or less with gentle slopes.

### Design

Do not locate vegetated filter strips in soils with high clay content that have limited infiltration or in soils that cannot sustain grass cover.

The filter strip cannot extend more than 50 feet into a Buffer Zone to a wetland resource area.

The contributing drainage area to a vegetated filter strip is limited to one acre of less.

Design vegetated filter strips with slopes between 2 and 6 percent. Steeper slopes tend to create concentrated flows. Flatter slopes can cause ponding and create mosquito-breeding habitat.

Design the top and toe of the slope to be as flat as possible. Use a level spreader at the top of the slope to evenly distribute overland flows or concentrated runoff across the entire length of the filter strip. Many variations of level spreader designs may be used including level trenches, curbing and concrete weirs. The key to any level spreader design is creating a continuous overflow elevation along the entire width of the filter strip.

Velocity dissipation (e.g. by using riprap) may be required for concentrated flows.

Design the filter strip to drain within 24 hours after a storm. The design flow depth must not exceed 0.5 inches.

To recieve TSS removal credit, make the filter strip at least 25 feet long and generally as wide as the area draining to the strip. To prevent high-velocity concentrated flows, the length of the flow path must be limited to 75 feet if the filter strip handles runoff from impervious surfaces, and 150 feet if the filter strip handles runoff from pervious surfaces. The minimum width of the filter strip must be 20% of the length of the flow path or 8 feet, whichever is greater.

To prevent groundwater contamination, the filter strip must be constructed at least 2 feet above seasonal high groundwater and 2 to 4 feet above bedrock.

The filter strip must be planted with grasses that are relatively salt-tolerant. Select grasses to withstand high flow velocities under wet weather conditions.

A vegetated filter strip may be used as a qualifying pervious area for purposes of the LID Site Design Credits for disconnecting rooftop and nonroof top runoff.

### Construction

Proper grading is essential to establish sheet flow from the level spreader and throughout the filter strip.

Implement soil stabilization measures until permanent vegetation is established.

Protect the area to be used for the filter strip by using upstream sediment traps.

Use as much of the existing topsoil on the site as possible to enhance plant growth.

### Maintenance

Regular maintenance is critical for filter strips to be effective and to ensure that flow does not short-circuit the system. Conduct semi-annual inspections during the first year (and annually thereafter). Inspect the level spreader for sediment buildup and the vegetation for signs of erosion, bare spots, and overall health. Regular, frequent mowing of the grass is required. Remove sediment from the toe of slope or level spreader, and reseed bare spots as necessary. Periodically, remove sediment that accumulates near the top of the strip to maintain the appropriate slope and prevent formation of a "berm" that could impede the distribution of runoff as sheet flow.

When the filter strip is located in the buffer zone to a wetland resource area, the operation and maintenance plan must include strict measures to ensure that maintenance operations do not alter the wetland resource areas. Please note, filter strips are restricted to the outer 50 feet of the buffer zone.

### Cold Climate Considerations

In cold climates such as Massachusetts, the depth of soil media that serves as the planting bed must extend below the frost line to minimize the effects of freezing. Avoid using peat and compost media, which retain water and freeze during the winter, and become impermeable and ineffective.

### References:

Center for Watershed Protection, Stormwater Management Fact Sheet: Grassed Filter Strip, http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Filtering%20Practice/Grassed%20Filter%20Strip.htm

Claytor, R.A. and T.R. Schueler. 1996. Design of Stormwater Filtering Systems. Center for Watershed Protection. Silver Spring, Maryland.

Connecticut Department of Environmental Protection. 2004. Connecticut Stormwater Quality Manual.

International Stormwater BMP Database, Biofilter – Grass Strip, http://www.bmpdatabase.org

Knox County, Stormwater Management Manual, Volume 2, Section 4.3.9, Filter Strip, Pp. 4-155 to 4-164, http://knoxcounty.org/stormwater/pdfs/vol2/4-3-9%20Filter%20Strip.pdf

Knoxville, City of, 2003, Knoxville BMP Manual Stormwater Treatment, Filter Strips and Swales, Practice No. ST – 05, http://www.ci.knoxville.tn.us/engineering/bmp_manual/ST-05.pdf

Maine Department of Environmental Protection. 2006, Maine Stormwater Best Management Practices Manual, Chapter 5, Pp. 5-1 to 5-18, http://www.maine.gov/dep/blwq//docstand/stormwater/stormwaterbmps/vol3/chapter5.pdf

Maryland Department of the Environment, 2000, Maryland Stormwater Design Manual, Volume I, Chapter 2, Unified Sizing Criteria, P. 2.39, http://www.mde.state.md.us/assets/document/chapter2.pdf

Massachusetts Highway Department. 2004. Storm Water Handbook for Highways and Bridges.

Metropolitan Council. 2001. Minnesota Urban Small Sites BMP Manual: Stormwater Best Management Practices for Cold Climates. Prepared by Barr Engineering Company. St. Paul, Minnesota.

New Jersey Department of Environmental Protection, 2004, Best Management Practice Manual, Chapter 9.10, Standard for Vegetated Filter Strip, Pp. 9.10-1 to 9.11-10, http://www.njstormwater.org/tier_A/pdf/NJ_SWBMP_9.10.pdf

New York State Department of Environmental Conservation (NYDEC). 2001. New York State Stormwater Management Design Manual. Prepared by Center for Watershed Protection. Albany, New York.

United States Environmental Protection Agency (EPA). 1999. Preliminary Data Summary of Urban Storm Water Best Management Practices. EPA 821-R99-012.

# Soil Constraints and Low Impact Development

## Careful Planning Helps LID Work in Clay Soils

LID Barrier Busters Fact Sheet Series

Low impact development (LID) practices, also referred to as green infrastructure, include natural or man-made swales, depressions and vegetated areas that are designed to capture, filter and infiltrate runoff using soils and vegetation. When selecting and designing LID practices, the type of soil underlying the area must be factored into the design process. Designers often incorrectly assume that LID practices should not be sited on clay soils because they are concerned that the clay soils lack sufficient infiltration capacity to manage the runoff and that ponding might occur.

LID practices can be sited on clay soils if the appropriate conditions are present and the infiltrative capacity of the soils has not been significantly altered. Drainage problems tend to occur when the pore spaces in clay soils have been disturbed and compacted by construction activities or previous land uses. In such situations, surficial ponding might occur if the infiltration rate of the clays is too low. Designers should anticipate the challenges that can occur in soils with high clay content. By analyzing the infiltration rates of soils on the site, designers can select the best locations for LID practices and/or identify specific areas that would need remediation (e.g., adding soil amendments) to ensure adequate infiltrative capacity. Compacted soils should be mechanically de-compacted and/or amended to provide the requisite infiltrative capacity that can retain the desired design volume.

### FAQ

Don't clay-rich soils prevent water infiltration needed for LID?

**Barrier Busted!**

LID practices can work in clay-rich soils when designed to ensure adequate infiltration.

EPA's LID Barrier Busters fact sheet series... helping to overcome misperceptions that can block adoption of LID in your community

Tetra Tech

Roof water drains to this rain garden.

## Practices That Work With Clay Soils

LID practices such as rain gardens, permeable pavements, and bioretention cells can perform well on sites with clay soils if the practices are sized appropriately, proper drainage is provided, and they are constructed and designed to minimize clogging. Suggested design elements include:

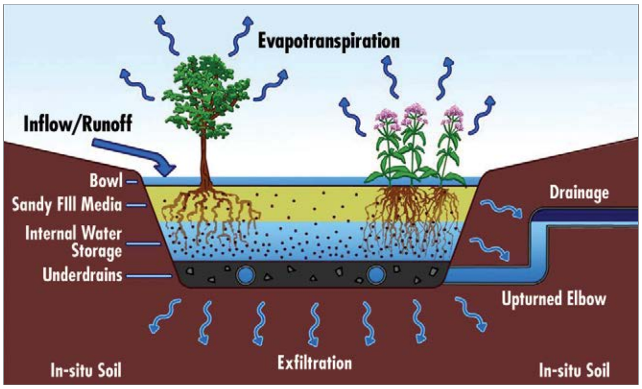
(1) Design the practice to retain a prescribed volume (e.g., 1 inch of rainfall) that can be infiltrated and/or evapotranspired within a given time frame (e.g., 48 hours) as determined by the capacity of the soils and plants.

(2) Use soil amendments where necessary to improve soil infiltration rates.

(3) Design and place overflow, bypass and underdrain systems to prevent ponding and clogging.

(4) Select plant species that facilitate ongoing infiltration through root structures.

(5) Include a margin of safety to ensure the system will perform as designed, even with some degree of clogging.




Shawn Kennedy, North Carolina State University Stormwater Group

This bioretention system has an underdrain with an upturned elbow.

Note: If a practice is designed as a retention/filter system that retains a design volume and filters excess volume, additional design elements such as underdrains, orifice controls and inverted elbows can be incorporated. In high-clay soils, rapid drying can cause the formation of linear cracks in the clay which can reduce the effective retention volume of the practice, especially in designs that include underdrains. Incorporating inverted or upturned elbows in the design of the discharge pipe, as depicted in the figure (above, right), helps to ensure that the requisite design volume is retained and infiltrated.

# Case Studies

## *Rain Gardens, Madison, Wisconsin*

In 2003 the U.S. Geological Survey (USGS) installed four rain gardens next to municipal buildings to test the effect of soil type and plant type on the rain gardens' ability to absorb stormwater. Two rain gardens were installed in sandy soils and two rain gardens were installed in clay soils. For each soil type, one rain garden was planted with turf, and the other with native prairie grasses. Each rain garden was sized to a ratio of approximately 5:1 contributing drainage area to receiving area, resulting in surface areas between 100 to 400 square feet with a 0.5-foot depth. The rain gardens were not equipped with underdrains. The USGS monitored the rain gardens for 4 years, observing inflows, outflows, rainfall amounts and evapotranspiration amounts.

USGS

Roof stormwater drains to these monitored rain gardens in Madison, Wisconsin.

### *Results*

- Regardless of vegetation or soil type, the rain gardens were able to store and infiltrate 96 to 100 percent of the stormwater they received over the 5-year study period.
- Under similar soil conditions, rain gardens planted with prairie species had significantly greater median infiltration rates than those planted with turf grass.
- Comparing soil types, the median infiltration for sand was nearly 5 to 9 times greater than the infiltration rates of clay, depending on vegetation type.

Estimated Median Infiltration Rates (Inches/Hour) for Each Garden across All Water Years (2004–2008)

| Rain Garden Type | Soil Texture Type | Median Infiltration Rate |
|---|---|---|
| Turf-sand | Silt loam, sandy clay loam and sandy loam | 2.50 |
| Prairie-sand | | 4.20 |
| Turf-clay | Sandy loam to clay-loam, heavily compacted | 0.28 |
| Prairie-clay | | 0.88 |

- Soil and root investigations indicate that clay soil planted with prairie grass had deeper root growth and appeared well-drained relative to the turf grass, which had limited root growth and a perched water table.

Source: Selbig, W.R., and Balster, Nicholas. 2010. Evaluation of turf-grass and prairie-vegetated rain gardens in a clay and sand soil, Madison, Wisconsin, water years 2004–08: U.S. Geological Survey Scientific Investigations

## *Roadside Bioretention, Toledo, Ohio*

In 2009 the city of Toledo installed nearly 800 feet of residential roadside bioretention areas and permeable sidewalks on a site with clay soils to help reduce the occurrence of combined sewer overflows during heavy rainfall events. The bioretention areas were designed with an engineered sandy loam soil and included underdrains to help drain the system if needed. Plants were chosen by the residents adjacent to the bioswales based on how much maintenance they were willing to do in front of their homes. Most chose turf grass, but some chose native plants. Underground water storage was provided beneath the permeable sidewalk. Flow monitors were installed before and after construction to assess the effectiveness of the system.

Tetra Tech

Stormwater from the road and sidewalks flows into this bioretention system on Maywood Avenue in Toledo.

### *Results*

- Monitoring results comparing pre-construction to post-construction LID implementation indicate greater reductions in peak and total volumes when the underdrain valve is closed as opposed to open (see table at right).
- Long-term modeling for the closed underdrain system indicates an annual average stormwater volume reduction of about 64 percent and peak flow reductions of 60–70 percent.

Average Percent Reductions between Pre-and Post-construction Flows (2010–2011)

| Underdrain Status | Open | Closed |
|---|---|---|
| Total Flow Volume | -10% | 57% |
| Peak Flow | 51% | 71% |

Source: Tetra Tech. 2009. City of Toledo, OH, Maywood Avenue Stormwater Volume Reduction Project Construction Plan Set. Table shows follow-up monitoring conducted in 2010–2011.

United States Environmental Protection Agency • Office of Wetlands, Oceans, and Watersheds
1200 Pennsylvania Avenue, NW, Washington, DC 20460
841-R-14-004A • October 2014

know where it goes

take simple steps to reduce STORMWATER POLLUTION

# Plastic Grid Pavers

## Flexible, open-cell designs for a variety of needs

## Description

Plastic grid pavers, also called grass pavers, gravel pavers, and reinforced turf, are a type of open-cell unit paver, the cells of which are filled with soil and planted with turf. They distribute the weight of traffic and prevent compression of the underlying soil.[1] They can be filled with either gravel or soil and grass, with the former being a better choice for more frequently used areas. These pavers are constructed primarily from recycled plastic materials. Plastic grid pavers can be found in the form of interlocking blocks or in rolls.

*Photo of Grasspave2 showing base course and sod courtesy of* Invisible Structures Inc.

*Photo of emergency vehicle parked safely on a fire lane paved with Grasspave2 courtesy of* Invisible Structures Inc.

# Description cont.

Due to their flexibility, plastic grid pavers can be used on sites with uneven terrain, but they do not have as much intrinsic strength as concrete pavers. They do not require drains, detention or retention ponds, or any other associated drainage facility. Grass pavers can improve site appearance by providing vegetation where there would otherwise be only pavement. [1]

*Grasspave installed as an emergency access road looks just like a lawn on the campus of St. Andrews school in Barrington.*

# Uses & Benefits

Plastic grid pavers are recommended for use in:

- Parking areas
- Residential driveways
- Fire lanes and emergency access roads
- Golf cart paths
- Sidewalks
- Bike paths

There are also plastic grid paver products that can be used for temporary soil stabilization during construction such as NDS Tuff-track™.

# Design Criteria

For grass pavers, chose a lawn grass type that has deep roots that can penetrate the reservoir base course, such as tall fescue. [2] Irrigation may be required but should be in the form of infrequent soakings so that the turf develops deep root systems. Plastic grid pavers come in rolls or in interlocking blocks and require some subgrade preparation depending on site conditions and the manufacturer guidelines. Information such as percolation rate and frost-heave potential of soil, and the depth to the high water table may be needed. The need for and design of a base course is determined by the maximum traffic load weight anticipated at the site. Plastic grid pavers have been shown to function best with stabilized shoulders in RI. [3]

# Maintenance

Plastic grid pavers will benefit from seasonal inspections to spot-check for issues, and those filled with gravel or stone may need the aggregate replenished at times. Grid pavers planted with turf are to be maintained like a lawn, with regular mowing and watering. Manufacturers usually supply recommendations for product maintenance, but the following maintenance suggestions are generally true:

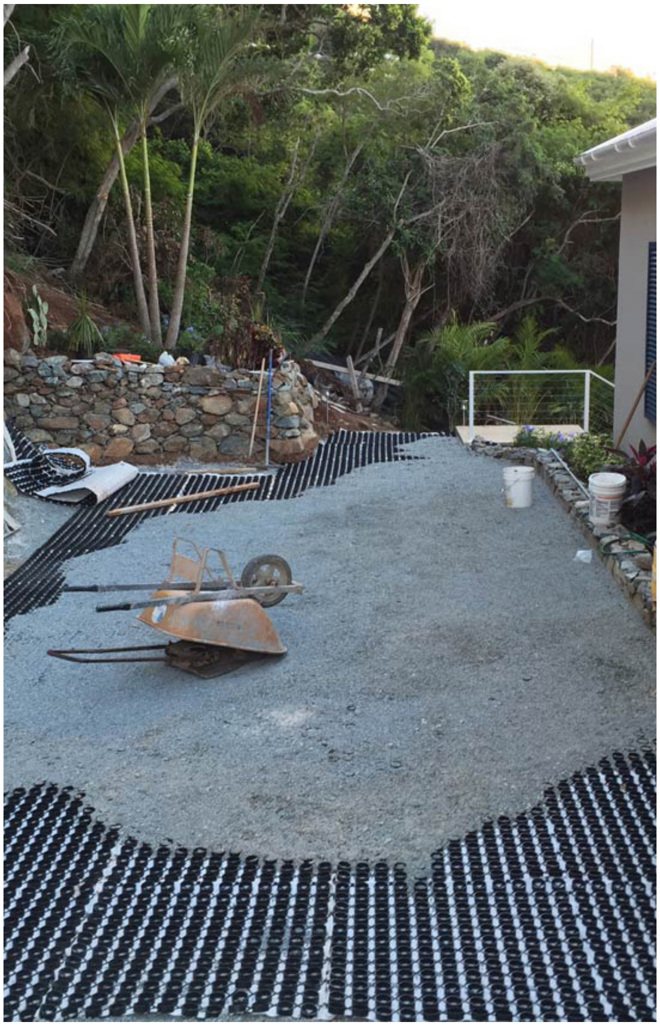
- Periodically reseed to fill in bare spots of grass pavers
- Periodically add gravel to gravel pavers
- Attach rollers to the bottom edge of a snowplow to prevent catching of edges of plastic grid pavers
- Do not allow large amounts of runoff from adjacent impervious surfaces onto grass or gravel paved areas as this may result in clogging
- Do not aerate turf as this will damage the pavers [4]

*Coventry Center Bike Path, paved with Netpave 50.*

# *Reducing Stormwater Runoff*

Impervious surfaces such as rooftops, driveways, roads, and parking lots change the flow of water over the land. Conventional stormwater management focuses on quickly removing runoff from a developed area, most often by using pipes to move water to sewers or directly to nearby waterways. Excessive stormwater runoff entering coastal waters can cause problems including harmful algal blooms and beach closures. Permeable pavement infrastructure provides necessary hard surfaces while simultaneously reducing the amount of stormwater exiting a developed area.

*Photo of overflow lot paved with Grasspave2 courtesy of PowellsWood Garden.*



*Photos showing Gravelpave2 driveway installation courtesy of* Seas the Day.

**Updated 2018**

# Limitations

Grass pavers are not suitable for everyday, all-day parking because the grass will get insufficient sunlight. Consider frequency of use before deciding whether to use turf or gravel fill for plastic grid pavers.[1]

# Estimating Cost

Plastic grid pavers range in cost depending on their application. NDS GrassPave, for medium-duty use such as a residential driveway or emergency vehicle access road, is $2.30 per square foot. NDS Tufftrack is $7.88 per square foot and highly versatile. Tufftrack can be used for a light-duty application such as a footpath by forgoing the subbase, or for heavy-duty applications such as construction entrance soil stabilization. Most other plastic grid paver options are under $4 per square foot and are for light- to medium-duty use. *Prices for NDS products found on [https://www.ndspro.com/](https://www.ndspro.com/). Many of the pictures used in this factsheet feature products by Invisible Structures Inc. To be directed to a local distributor call 800-233-1510.*

# Sources


1 Massachusetts Low Impact Development Toolkit. “Permeable Paving.” Fact sheet. Metropolitan Area Planning Council. Boston, MA. n.d. Web.

2 Center for Turfgrass Science. “Turfgrass Species for Pennsylvania.” PennState College of Agricultural Sciences. State College, PA. 2018.

3 Low Impact Development Inventory. “Coventry Center Greenway Bike Path.” Rhode Island Stormwater Solutions. Kingston, RI. 2018.

4 “Rhode Island Stormwater Designs and Installations Standards Manual.” Coastal Resources Management Council & Rhode Island Department of Environmental Management. Rhode Island. 2015, pp. 5-33. Web.



Produced by URI Cooperative Extension with funding from the Rhode Island Department of Transportation and support from the Rhode Island Department of Environmental Management.

# Porous Pavement

From the [Massachusetts Stormwater Handbook]

## Description

Porous pavement is a paved surface with a higher than normal percentage of air voids to allow water to pass through it and infiltrate into the subsoil. This porous surface replaces traditional pavement, allowing parking lot, driveway, and roadway runoff to infiltrate directly into the soil and receive water quality treatment. All permeable paving systems consist of a durable, load-bearing, pervious surface overlying a stone bed that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways; parking stalls, and overflow parking areas.

## Ability to Meet Massachusetts Stormwater Management Standards

| Standard | Description |
|---|---|
| 2 - Peak Flow | Provides peak flow attenuation for small storms. |
| 3 - Recharge | Provides groundwater recharge. |
| 4 - TSS Removal | 80% TSS removal credit if storage bed is sized to hold ½-inch or 1-inch Water Quality Volume, and is designed to drain within 72 hours. |
| 5 - Higher Pollutant Loading | Not suitable. |
| 6 - Discharges near or to Critical Areas | Not suitable, especially within Zone II or Zone A of public water supplies. |
| 7 - Redevelopment | Suitable. |

## Advantages/Benefits

- Reduce stormwater runoff volume from paved surfaces
- Reduce peak discharge rates.
- Increase recharge through infiltration.
- Reduce pollutant transport through direct infiltration.
- Can last for decades in cold climates if properly designed, installed, and maintained
- Improved site landscaping benefits (grass pavers only).
- Can be used as a retrofit when parking lots are replaced.

## Disadvantages/Limitations

- Prone to clogging so aggressive maintenance with jet washing and vacuum street sweepers is required.
- No winter sanding is allowed.
- Winter road salt and deicer runoff concern near drinking water supplies for both porous pavements and impervious pavements.
- Soils need to have a permeability of at least 0.17 inches per hour.
- Special care is needed to avoid compacting underlying parent soils.

## Pollutant Removal Efficiencies

- Total Suspended Solids (TSS) 80%

- Nutrients (Nitrogen, phosphorus) Insufficient data
- Metals (copper, lead, zinc, cadmium) Insufficient data
- Pathogens (coliform, e coli) Insufficient data

## Maintenance

| Activity | Frequency |
|---|---|
| Monitor to ensure that the paving surface drains properly after storms | As needed |
| For porous asphalts and concretes, clean the surface using power washer to dislodge trapped particles and then vacuum sweep the area. For paving stones, add joint material (sand) to replace material that has been transported. | As needed |
| Inspect the surface annually for deterioration | Annually |
| Assess exfiltration capability at least once a year. When exfiltration capacity is found to decline, implement measures from the Operation and Maintenance Plan to restore original exfiltration capacity. | As needed, but at least once a year |
| Reseed grass pavers to fill in bare spots. | As needed |

## Special Features

Most appropriate for pedestrian-only areas and for low-volume, low-speed areas such as overflow parking areas, residential driveways, alleys, and parking stalls.

## Applicability

Porous pavement, also known as permeable paving, is appropriate for pedestrian-only areas and for low-volume, low-speed areas such as overflow parking areas, residential driveways, alleys, parking stalls, bikepaths, walkways, and patios. It can be constructed where the underlying soils have a permeability of at least 0.17 inches per hour. Porous paving is an excellent technique for dense urban areas, because it does not require any additional land. Porous pavement can be successfully installed in cold climates as long as the design includes features to reduce frost heaving.

Porous paving is not appropriate for high traffic/high speed areas, because it has lower load-bearing capacity than conventional pavement. Do not use porous pavement in areas of higher potential pollutant loads, because stormwater cannot be pretreated prior to infiltration. Heavy winter sanding will clog joints and void spaces. On some highways, MassHighway Department uses an Open Graded Friction Course (OGF) that has a permeable top coat but an impermeable base course. MassDEP provides no Water Quality or Recharge Credit for OGC, because it does not provide treatment or recharge. The primary benefit of OGF pavements is reductions in noise and hydroplaning.

## Effectiveness

Porous pavement provides groundwater recharge and reduces stormwater runoff volume. Depending on design, paving material, soil type, and rainfall, porous paving can infiltrate as much as 70% to 80% of annual rainfall. To qualify for the Water Quality and Recharge Credits, size the storage layer to hold the Required Water Quality or Required Recharge Volume, whichever is larger, using the Static Method, and design the system to dewater within 72 hours. Porous pavement may reduce peak discharge rates significantly by diverting stormwater into the ground and away from pipe-and-basin stormwater management systems, up to the volume housed in the storage layer. Grass pavers can improve site appearance by providing vegetation where there would otherwise be pavement. Porous paving can increase the effective developable area of a site, because the infiltration provided by permeable paving can significantly reduce the need for large stormwater management structures.

## Planning Considerations

Porous paving must not receive stormwater from other drainage areas, especially any areas that are not fully stabilized. Use porous paving only on gentle slopes (less than 5%). Do not use it in high-traffic areas or where it will be subject to heavy axle loads.

## Consider The Setback Requirements When Considering Porous Pavement

| Considerations | Setback Requirements |
|---|---|
| Slope | Less than 5% Septic system |
| Soil absorption system | 50 feet |
| Private well | 100 feet |
| Public well | Outside the Zone 1 |

| | |
|---|---|
| Public reservoir | Outside the Zone A |
| Surface Waters | 100 feet |
| Cellar Foundations | 20 feet |
| Slab Foundations | 10 feet |
| Property Lines | 10 feet |
| Minimum depth | 2 feet vertical separation above seasonal high groundwater from bottom of storage layer |
| Frost Line | Below frost line |

Bedrock As with any stormwater exfiltration system, determine if it is feasible in locations with high bedrock. Presence of bedrock near land surface reduces the ability of soils to exfiltrate to groundwater.

Porous paving reduces the need for other stormwater conveyances and treatment structures, resulting in cost savings.

Permeable paving also reduces the amount of land needed for stormwater management.

## Design

There are three major types of permeable paving:

- Porous asphalt and pervious concrete. Although it appears to be the same as traditional asphalt or concrete pavement, it is mixed with a very low content of fine sand, so that it has from 10%-25% void space.
- Paving stones (also known as unit pavers) 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 to the subsurface. Some concrete paving stones have an open cell design to increase permeability.
- Grass pavers (also known as turf blocks) 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.

Each of these products is constructed over a storage bed.

## Storage Bed Design

The University of New Hampshire has developed specifications for storage beds used in connection with porous asphalt or pervious concrete. According to UNH, the storage bed should be constructed as indicated in Figure PP 1 with the following components from top to bottom:

- a 4-inch choker course comprised of uniformly graded crushed stone,
- a filter course, at least 12 inches thick, of poorly graded sand or bankrun gravel to provide enhanced filtration and delayed infiltration
- a filter blanket, at least 3 inches thick, of pea stone gravel to prevent material from entering the reservoir course, and
- a reservoir course of uniformly graded crushed stone with a high void content to maximize the storage of infiltrated water and to create a capillary barrier to winter freeze thaw. The bottom of the stone reservoir must be completely flat so that runoff can infiltrate through the entire surface.

The size of the storage bed may have to be increased to accommodate the larger of the Required Water Quality and the Required Recharge Volume.

If paving stones or grass pavers are used, a top course of sand that is one inch thick should be placed above the choker coarse.

## Overflow Edge

Some designs incorporate an "overflow edge," which is a trench surrounding the edge of the pavement. The trench connects to the stone reservoir below the surface of the pavement and acts as a backup in case the surface clogs.

## Preparation Of Porous Asphalt

Care must be taken in batching and placing porous asphalt. Unless batched and installed properly, porous pavement may have a reduced exfiltration ability. At Walden Pond State Reservation, several of the areas paved with porous asphalt did not meet the target exfiltration rate. Cores were taken and it was found that the batches had more sand and/or asphalt than was specified, and those sections had to be removed and repaved.

It is critical to minimize the amount of asphalt binder. Using greater amounts of asphalt binder could lead to a greater likelihood of "binder" or asphalt drawdown and clogging of voids. Sun light heating can liquefy the asphalt. The liquefied asphalt then drains into the voids, clogging them. Such clogging is not remedied by power washing and vacuuming. The topcoat in such instances needs to be scarified and resurfaced. The University of New Hampshire has prepared detailed specifications for preparing and installing porous asphalt that are intended to prevent asphalt problems.

## Additional Design Considerations

- Provide an open-graded subbase with minimum 40% void space.
- Use surface and stone beds to accommodate design traffic loads
- Generally, do not use porous pavement for slopes greater than 5 %.
- Do not place bottom on compacted fill.
- Provide perforated pipe network along bed bottoms for distribution
- Provide a three-foot buffer between the bed bottom and the seasonal high groundwater elevation, and a two-foot buffer for bedrock.

## Cold Weather Design Considerations

Porous pavement performs well in cold climates. Porous pavement can reduce meltwater runoff and avoid excessive water on the road during the snowmelt period.

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.

## Maintenance

In most porous pavement designs, the pavement itself acts as pretreatment to the stone reservoir below. Consequently, frequent cleaning and maintenance of the pavement surface is critical to prevent clogging. To keep the surface clean, frequent vacuum sweeping along with jet washing of asphalt and concrete pavement is required. No winter sanding shall be conducted on the porous surface.

As discussed, designs that include an "overflow edge" provide a backup in case the surface clogs. If the surface clogs, stormwater will flow over the surface and into the trench, where some infiltration and treatment will occur. For proper maintenance:

- Post signs identifying porous pavement areas.
- Minimize salt use during winter months. If drinking water sources are located nearby (see setbacks), porous pavements may not be allowed.
- No winter sanding is allowed.
- Keep landscaped areas well maintained to prevent soil from being transported onto the pavement.
- Clean the surface using vacuum sweeping machines monthly. For paving stones, periodically add joint material (sand) to replace material that has been transported.
- Regularly monitor the paving surface to make sure it drains properly after storms.
- Never reseal or repave with impermeable materials.
- Inspect the surface annually for deterioration or spalling.
- Periodically reseed grass pavers to fill in bare spots.
- Attach rollers to the bottoms of snowplows to prevent them from catching on the edges of grass pavers and some paving stones.

University of New Hampshire Center for Stormwater Technology Evaluation and Verification; this research group tests and evaluates stormwater BMPs on the UNH campus.

- An article about the use of permeable pavers at the Westfarms Mall in Connecticut.
- Case Studies from Uni-Group USA, a block paver manufacturer.
- The Nonpoint Education For Municipal Officials program at the University of Connecticut has been involved in numerous permeable paving pilot projects.
- Permeable paver specifications courtesy of the Low Impact Development Center.
- Porous pavement design and operational criteria from the US Environmental Protection Agency, which also publishes a Low Impact Development Page. Also see this report on a Field Evaluation of Permeable Pavements for Stormwater Management (PDF.)

- New Jersey Stormwater Best Management Practices Manual February

Adapted from: MassDEP, Massachusetts Nonpoint Source Pollution Management Manual, 2006.

## References

Ferguson, Bruce, K., Porous Pavements, 2005, CRC Press. Taylor and Francis Group, Boca Raton UNH, 2007, UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds, Revised October 2007, http://www.unh.edu/erg/cstev/pubs_specs_info/unhsc_pa_apec_07_07_final.pdf

Asphalt Pavement for Stormwater Management, http://www.unh.edu/erg/cstev/pubs_specs_info/porous_ashpalt_fact_sheet.pdf

# TREE BOX FILTERS

(Adapted from Boston Water and Sewer Commission Stormwater BMP Fact Sheet)

## Description

Tree box filters are a proprietary biotreatment device that is designed to mimic natural systems such as bioretention areas by incorporating plants, soil, and microbes. Tree box filters are installed at curb level and consist of an open bottom concrete barrel filled with a porous soil media, an underdrain in crushed gravel, and a tree. Tree box filters are highly adaptable solutions that can be used in all types of development and in all types of soils but are especially applicable to ultra-urban areas.

## Applications

Commonly used in densely urbanized areas such as along roads, highways, sidewalks and parking lots.

## Advantages

- Reduces volume and rate of runoff
- Smaller footprint required
- May be used as pretreatment device
- Provides decentralized stormwater treatment
- Ideal for redevelopment or in ultra-urban setting

## Limitations

- Vegetative maintenance required
- Treats small volumes
- Treats small tributary areas

## Ability To Meet Massachusetts Stormwater Standards

Presumed to remove 80% of Total Suspended Solids (Stormwater Management Standard #4).

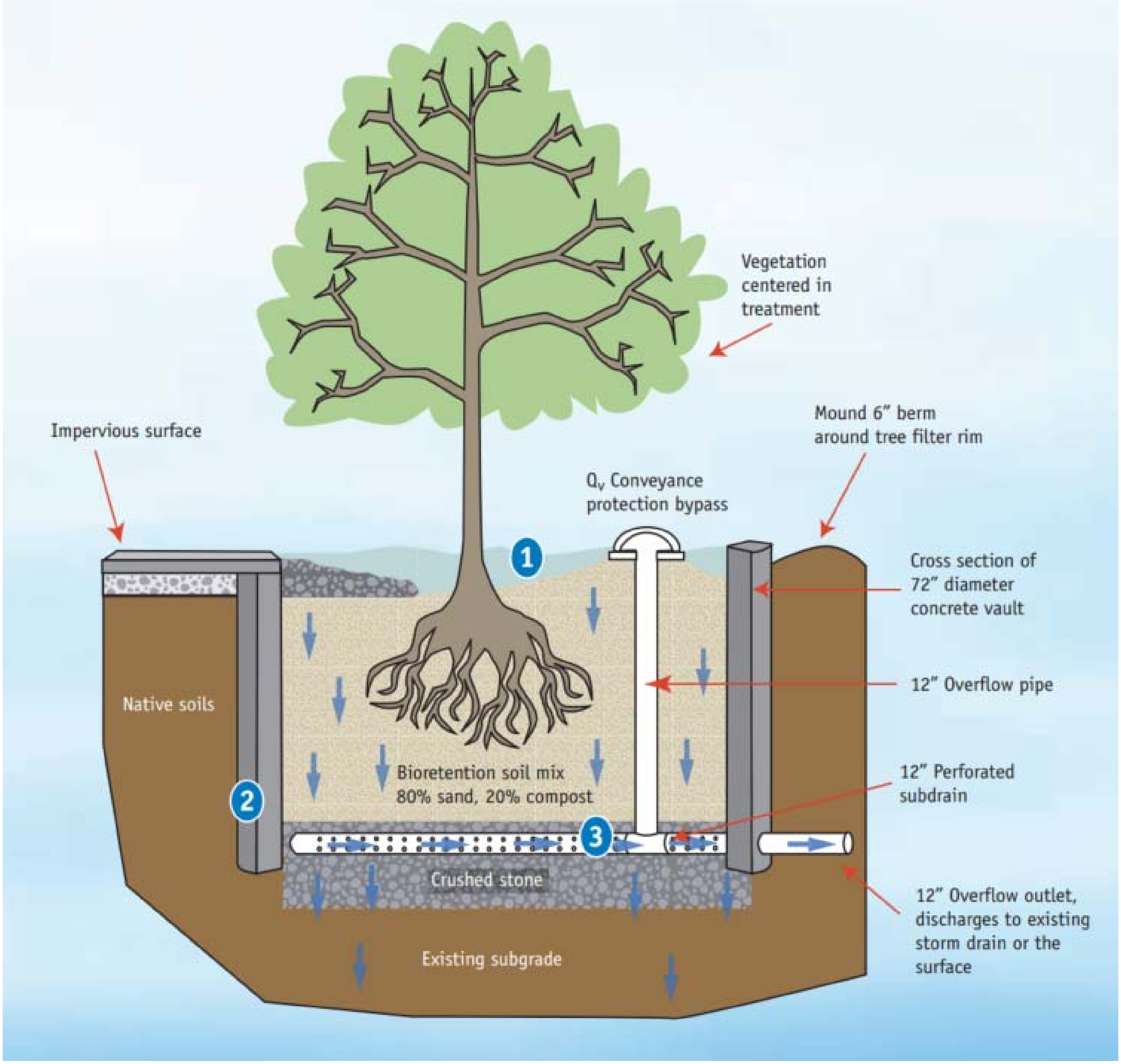
## General Cost Considerations

Estimated cost range of tree filters is $10,000 and $18,000.

## Design Considerations

Note: for more detailed design guidance refer to the Massachusetts Stormwater Handbook

- Design at a minimum to capture and treat the required water quality volume
- Design to drain in less than 72 hours
- Tree box filters are typically designed in layers as follows (bottom to top):
    - Line bottom of excavation with filter fabric
    - Install precast concrete barrel (minimum 6 feet in diameter), approximately 4 feet deep
    - Pack a perforated underdrain pipe in a clean, washed crushed stone layer (minimum 24-inch layer)
    - Minimum 1 to 2 feet of soil media (or per manufacturer specification)
    - Minimum 6 inches of ponding depth
    - Design an overflow riser pipe with grate, connected to perforated underdrain
    - Design curb cut to act as inlet to tree box filter, with rip rap pad at inlet for energy dissipation
    - Use a deciduous tree centered in the concrete barrel




**Tree Box Filter Cross-Section**
(Image Credit: University of New Hampshire, Stormwater Center. 2009 Biannual Report. p.22.)

## Construction Considerations

- Provide energy dissipation (e.g., rip rap) at each concentrated inlet point.
- Soil mix chosen should support growth of tree.
- Tree shall be selected carefully to blend in and enhance aesthetics of adjacent structures (buildings and sidewalks).

## Maintenance

- Annually check tree
- Rake media surface at least twice a year to maintain permeability
- Replace media when tree is replaced (every 5 to 10 years) to restore permeability and pollutant removal efficiency
- Remove accumulated trash and debris to restore permeability

# Water Quality Swale

## Description

Water quality swales are vegetated open channels designed to treat the required water quality volume and to convey runoff from the 10-year storm without causing erosion.

There are two different types of water quality swales that may be used to satisfy the Stormwater Management Standards:

- Dry Swales
- Wet Swales

Unlike drainage channels which are intended to be used only for conveyance, water quality swales and grass channels are designed to treat the required water quality volume and incorporate specific features to enhance their stormwater pollutant removal effectiveness. Water quality swales have higher pollutant removal efficiencies than grass channels.

## Ability to Meet Massachusetts Stormwater Management Standards

| Standard | Description |
|---|---|
| 2 - Peak Flow | With careful design may be able to reduce peak flow at small sites |
| 3 - Recharge | May not be used to satisfy Standard 3 |
| 4 - TSS Removal | Wet swales and dry swales achieve 70% TSS removal when provided with a pretreatment device such as a sediment forebay with a check dam. |
| 5 - Higher Pollutant Loading | Dry swale recommended as pretreatment BMP. Must be lined. For some land uses with higher potential pollutant load, an oil grit separator or equivalent may be required before discharge to the swale. |
| 6 - Discharges near or to Critical Areas | Dry and Wet Swales recommended as treatment BMPs for cold-water fisheries. Must be lined unless 44% TSS has been removed before discharge to swale. Should not be used near shellfish growing areas and bathing beaches. |
| 7 - Redevelopment | Recommended for redevelopments and urban applications if sufficient land is available. |

## Pollutant Removal Efficiencies

- Total Suspended Solids (TSS)
  - Dry Swale 70%
  - Wet Swale 70%
- Total Nitrogen - 10% to 90%
- Total Phosphorus 20% to 90%
- Metals (copper, lead, zinc, cadmium) Insufficient data
- Pathogens (coliform, e coli) Insufficient data

## Advantages/Benefits

- May be used to replace more expensive curb and gutter systems.
- Roadside swales provide water quality and quantity control benefits, while reducing driving hazards by keeping stormwater flows away from street surfaces.
- Accents natural landscape.
- Compatible with LID designs
- Can be used to retrofit drainage channels and grass channels
- Little or no entrapment hazard for amphibians or other small animals

## Disadvantages/Limitations

- Higher degree of maintenance required than for curb and gutter systems.
- Roadside swales are subject to damage from off-street parking, snow removal, and winter deicing.
- Subject to erosion during large storms
- Individual dry swales treat a relatively small area
- Impractical in areas with very flat grades, steep topography or poorly drained soils
- Wet swales can produce mosquito breeding habitat
- Should be set back from shellfish growing areas and bathing beaches

## Maintenance

| Activity | Frequency |
|---|---|
| Inspect swales to make sure vegetation is adequate and slopes are not eroding. Check for rilling and gullying. Repair eroded areas and revegetate. | The first few months after construction and twice a year thereafter. |
| Mow dry swales. Wet swales may not need to be mowed depending on vegetation. | As needed. |
| Remove sediment and debris manually | At least once a year |
| Re-seed | As necessary |

## Special Features

There are two types of swales that may be used to satisfy the Stormwater Management Standards – dry swales and wet swales.

## Dry Swale

Dry swales are designed to temporarily hold the water quality volume of a storm in a pool or series of pools created by permanent check dams at culverts or driveway crossings. The soil bed consists of native soils or highly permeable fill material, underlaid by an underdrain system.

## Wet Swale

Wet swales also temporarily store and treat the required water quality volume. However, unlike dry swales, wet swales are constructed directly within existing soils and are not underlaid by a soil filter bed or underdrain system. Wet swales store the water quality volume within a series of cells within the channel, which may be formed by berms or check dams and may contain wetland vegetation (Metropolitan Council, 2001). The pollutant removal mechanisms in wet swales are similar to those of stormwater wetlands, which rely on sedimentation, adsorption, and microbial breakdown.

## Water Swales

## Applicability

Use water quality swales

- As part of a treatment train
- As one of the best BMPs for areas discharging to cold-water fisheries if they are lined.
- As one of the best BMPs for redevelopments and urban applications.
- For residential and institutional settings (especially dry swales)

Water quality swales have many uses. Dry swales are most applicable to residential and institutional land uses of low to moderate density where the percentage of impervious cover in the contributing areas is relatively low. Wet swales may not be appropriate for some residential applications, such as frontage lots, because they contain standing water that may attract mosquitoes.

Water quality swales may also be used in parking lots to break up areas of impervious cover. Along the edge of small roadways, use water quality swales in place of curb and gutter systems. Water quality swales may not be suitable for sites with many driveway culverts or extensive sidewalk systems. When combining water quality swales with roadways and sidewalks, place the swale between the two impervious areas (e.g. between road and sidewalk or in-between north and south bound lanes of a roadway/highway).

The topography and soils on the site will determine what is appropriate. The topography should provide sufficient slope and cross-sectional area to maintain non-erosive flow velocities. Porous soils are best suited to dry swales, while soils with poor drainage or high groundwater conditions are more suited to wet swales. Design water quality swales to retain and treat the required water quality volume. Because they must also be designed to convey the 2-year and 10-year 24-hour storms, they may have to convey additional runoff volume to other downgradient BMPs.

## Planning Considerations

The primary factors to consider when designing a water quality swale are soil characteristics, flow capacity, erosion resistance, and vegetation. Site conditions and design specifications limit the use of water quality swales.

Swale storage capacity should be based on the maximum expected reduction in velocity that occurs during the annual peak growth period. Usually the maximum expected drop in velocity occurs when vegetation is at its maximum growth for the year. Use the minimum level when checking velocity through the swale or the ability of the swale to convey the 2-year 24-hour storm without erosion. This usually occurs during the early growing season and dormant periods.

Other important factors to consider are land availability, maintenance requirements and soil characteristics. The topography of the site should allow for the design of a swale with sufficient slope and cross-sectional area to maintain a non-erosive flow rate, and to retain or detain the required water quality volume. The longitudinal slope of the swale should be as close to zero as possible and not greater than 5%. The grass or vegetation types used in swales should be suited to the soil and water conditions. Wetland hydrophytes (plants adapted to grow in water) or obligate species (i.e., species that occur 99% of the time under natural conditions in wetlands) are generally more water-tolerant than facultative species (i.e., species that occur 67% to 99% of the time under natural conditions in wetlands) and are good selections for wet swales, while dry swales should be planted with species that produce fine and dense cover and are adapted to varying moisture conditions.

## Design

See the following for complete design references: Site Planning for Urban Stream Protection. 1995. Schueler. Center for Watershed Protection.

Watershed Protection Techniques, Volume 2, Number 2, 1996. Center for Watershed Protection. Biofiltration swale performance, recommendations, and design considerations. 1992. Metro Seattle: Water Pollution Control Department, Seattle, WA.

Access for maintenance must be incorporated into both designs. The maintenance access way must be a minimum of 15 feet wide on at least one longitudinal side of the swale to enable a maintenance truck to drive along the swale and gain access to any one point. When constructed along a highway, the breakdown lane can be used as the access. When constructed in a residential subdivision, an on-street parking lane may double as the maintenance access, provided signs are posted indicating no parking is allowed during periods when the swales are being maintained.

**Dry Swales**

- Size dry swales to provide adequate residence time for the required water quality volume. Hydraulic Residence Time (HRT) must be a minimum of 9 minutes. Use Manning's Equation to determine the HRT.
- Dry swales should have a soil bed that is a minimum of 18 inches deep and composed of approximately 50% sand and 50% loam.
- Pretreatment is required to protect the filtering and infiltration capacity of the swale bed. Pretreatment of piped flows is generally a sediment forebay behind a check dam with a pipe inlet. For lateral inflows (sheet flow), use a vegetated filter strip on a gentle slope or a "pea gravel diaphragm."
- Design dry swales to completely empty between storms. Where soils do not permit full dewatering between storms, place a longitudinal perforated underpipe on the bottom of the swale bed. The inter-event period used in design to dewater the swale must be no more than 72 hours.
- Dry swales must have parabolic or trapezoidal cross-sections, with side slopes no greater than 3:1 (horizontal: vertical) and bottom widths ranging from 2 to 8 feet.
- Size dry swales to convey the 10-year storm and design swale slopes and backs to prevent erosion during the 2-year event. At least one foot of freeboard must be provided above the volume expected for the 10-year storm.
- Make sure that the seasonal high water table is not within 2 to 4 feet of the dry swale bottom.
- Use outlet protection at any discharge point from a dry swale to prevent scour at the outlet.

**Wet Swales**

- Size wet swales to retain the required water quality volume.
- Use wet swales only where the water table is at or near the soil surface or where soil types are poorly drained. When the swale is excavated, keep the swale bed soils.
- Pretreatment is required to protect the filtering and infiltration capacity of the wet swale bed. Pretreatment is generally a sediment forebay behind a check dam with a pipe inlet. For lateral inflows, use gentle slopes or a pea gravel diaphragm.
- Use check dams in wet swales to achieve multiple cells. Use V-notched weirs in the check dams to direct low flow volumes.

- Plant emergent vegetation or place wetland soils on the wet swale bottom for seed stock.
- Wet swales are parabolic or trapezoidal in cross- section, with side slopes no greater than 3:1 (horizontal: vertical) and bottom widths ranging from 2 to 8 feet.
- Size wet swales to convey the 10-year 24-hour storm and design wet swale slopes to prevent erosion during the 2-year 24-hour event.
- Use outlet protection at any discharge point from wet swales to prevent scour at the outlet.

## Construction

Use temporary erosion and sediment controls during construction. Select the vegetation mix to suit the characteristics of the site. Seeding will require mulching with appropriate materials, such as mulch matting, straw, and wood chips. Anchor the mulch immediately after seeding. Water new seedlings well until they are established. Refer to "Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers, and Municipal Officials" for information on seeding and mulching.

## Maintenance

Incorporate a maintenance and inspection schedule into the design to ensure the effectiveness of water quality swales. Inspect swales during the first few months after installation to make sure that the vegetation in the swales becomes adequately established. Thereafter, inspect swales twice a year. During the inspections, check the swales for slope integrity, soil moisture, vegetative health, soil stability, soil compaction, soil erosion, ponding and sedimentation.

Regular maintenance includes mowing, fertilizing, liming, watering, pruning, and weed and pest control. Mow swales at least once per year. Do not cut the grass shorter than three to four inches, otherwise the effectiveness of the vegetation in reducing flow velocity and removing pollutants may be reduced. Do not let grass height exceed 6 inches.

Manually remove sediment and debris at least once per year, and periodically re-seed, if necessary, to maintain a dense growth of vegetation. Take care to protect water quality swales from snow removal and disposal practices and off-street parking. When grass water quality swales are located on private residential property, the operation and maintenance plan must clearly identify the property owner who is responsible for carrying out the required maintenance. If the operation and maintenance plan calls for maintenance of water quality swales on private properties to be accomplished by a public entity or an association (e.g. homeowners association), maintenance easements must be secured.

# Tackling stormwater pollution from contemplation to implementation—doing the right thing

JAMES HOULE, PhD, CPSWQ, CPESC, Univ. of New Hampshire Stormwater Center, Durham, New Hampshire
DOLORES JALBERT LEONARD, ROCA COMMUNICATIONS, South Berwick, Maine

**ABSTRACT** | Town of Arlington Town Engineer Wayne Chouinard's leadership is advancing a new standard of stormwater practice for small-scale, affordable stormwater controls in Massachusetts. By collaborating with EPA, the University of New Hampshire Stormwater Center, and the Mystic River Watershed Association, Mr. Chouinard has developed a new standard detail for an innovative infiltration trench retrofit. Since 2014, Arlington has installed 31 of these systems and plans to install 20 more next year. Nutrient removal performance curves show that these systems can significantly remove phosphorus in the appropriate context. The work has sparked collaborations with surrounding communities that are focused on advancing green infrastructure throughout the watershed and revitalizing the Mystic River, considered impaired by phosphorus since 2007.

**KEYWORDS** | Stormwater, infiltration, nutrient removal, performance curves, Arlington, MS4, Mystic River watershed, green infrastructure

Wayne Chouinard, Arlington town engineer, inspects an infiltration trench chamber

### DOING THE RIGHT THING

"They're really just holes in the ground." Wayne Chouinard is being both accurate and modest as he describes the infiltration trenches that helped earn him an Environmental Merit Award from EPA Region 1 this fall.

It is true that "Wayne's drains," as they are known among his colleagues, are just ditches, some open and vegetated, some beneath the surface. To focus on the simple structure, however, is to overlook the art, one that Chouinard has honed since he became the town engineer of Arlington, Massachusetts, in 2011.

Under his leadership, infiltration trenches have become a new standard of practice for Arlington. The design and installation of each is informed by the ones that came before. As a result, this network of cost-effective, small-scale stormwater controls is reducing the flow of phosphorus and other pollutants off the landscape, helping Arlington comply with its new Municipal Separate Storm Sewer System (MS4) permit and contributing to a revitalization of the Mystic River and its watershed.

"This approach is only workable when you have local champions like Wayne who collaborate and innovate to solve problems," says Newton Tedder, senior permit writer, EPA Region 1. "His environmental leadership has provided a cleaner, healthier environment for the town's citizens and the watershed as a whole."

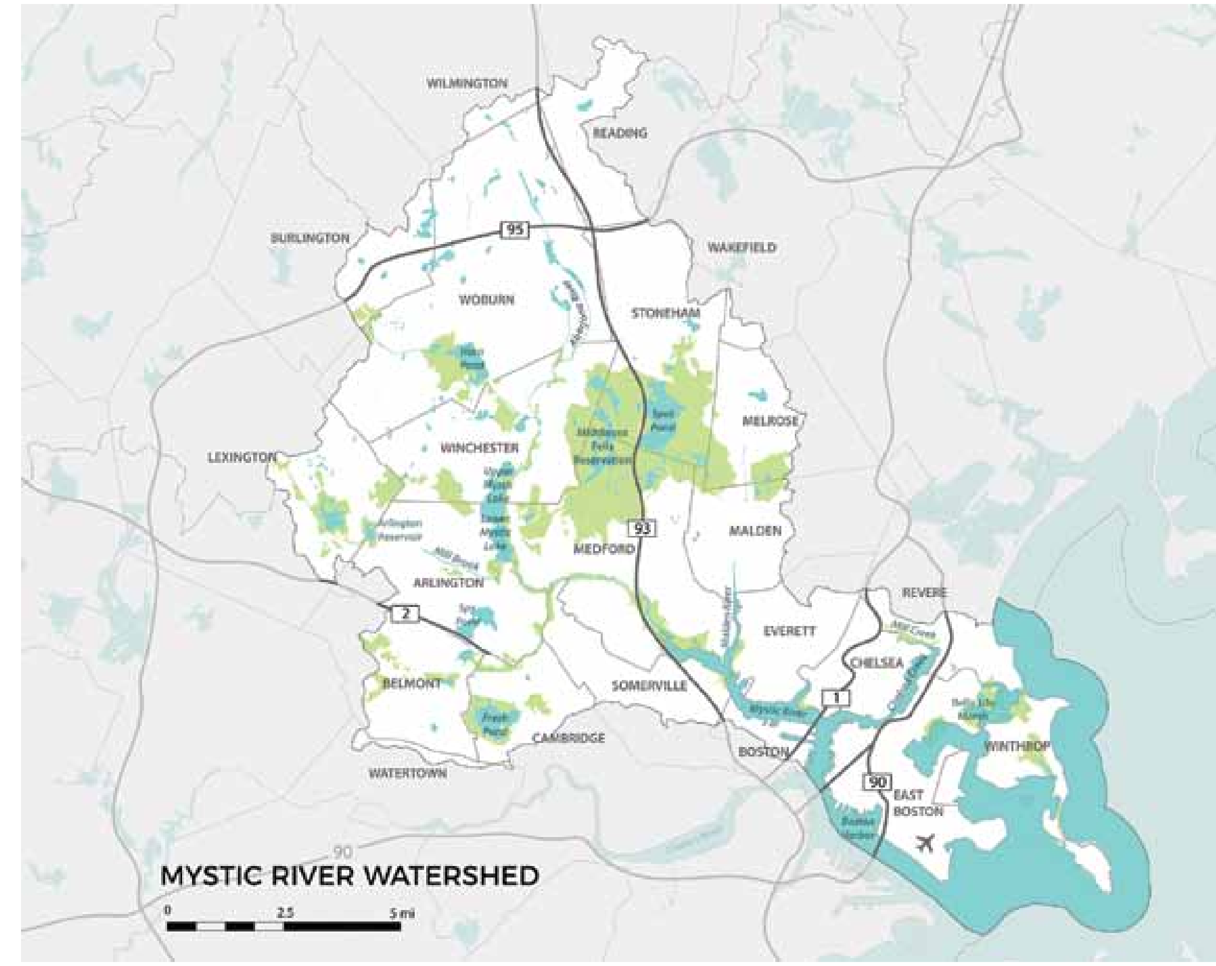



**Figure 1. Overview of the Mystic River Watershed—one of the great urban rivers of New England, the Mystic has become the focus of a federal, state, municipal, and non-profit partnership committed to improving water quality and environmental conditions and creating open space and public access**

### New Career, New Partners

Mr. Chouinard began his career in home construction in the 1990s. From there, he transitioned into consulting, reviewing site plans for municipalities. Moving from building to plan review and from the private sector to the public, there has been one constant in his career.

"The hobby part of engineering for me has always been hydrology—I'm fascinated by runoff calculations," laughs the Natick, Massachusetts native. "When I came to Arlington, I wanted to know, How can I do more of that stuff?"

At the time, little was being done with stormwater at the municipal level. Old regulations were driving the standard of practice and contributing to municipal projects that, as Mr. Chouinard describes it, "went awry." There was opportunity for change, but in Arlington's compact urban landscape, there was not much space or money for new ideas.

The best advice Mr. Chouinard received at the time was to educate other people and himself. He started an informal series of talks on stormwater, inviting others to give presentations. He began to collaborate with the Mystic River Watershed Association (MyRWA), a non-profit that promotes water quality and environmental preservation, and he eventually joined the Mystic River Watershed Steering Committee.

Together with his new colleagues, he began to write grants to pay for some of the ideas they generated. Several of these were funded by EPA. This enabled Mr. Chouinard to meet people in the association, who quickly transitioned from being "those regulators" to becoming "my co-workers."

"Once I started working with all of these groups, I could see that we were all peers in the Mystic River," Mr. Chouinard says. "They probably could see my passion for all of this, and I liked theirs. Before I knew it, it had flourished into a great working relationship."

### Small-scale, Affordable, and Effective

Mr. Chouinard's connections eventually led him to work with the University of New Hampshire Stormwater Center (UNHSC), a research, testing, and educational facility that serves as a technical resource for water managers, planners, and design engineers around the country. Together, they collaborated with EPA on a pilot project to explore

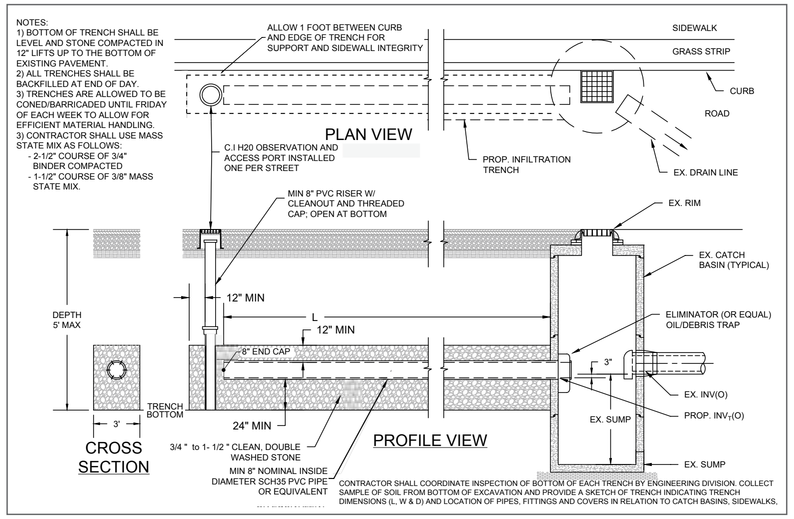



Figure 2. Design detail and specifications for the infiltration trenches

**Table 1. Modeled costs and infiltration trench performance***

| Unit | Cost ($) |
|---|---|
| System | 2,200 |
| IC treated per acre (per ha) | 18,857 (44,000) |
| TP per lb (per kg) | 24,750 (55,000) |
| TN per lb (per kg) | 3,930 (8,609) |
| TSS per lb (per kg) | 86 (190) |
| Volume eliminated per cf (per $m^3$) | 0.11 (4) |

*Based on the EPA's cost memo and the Massachusetts MS4 permit Appendix F

how Arlington and neighboring Winchester could reduce nutrient pollution, specifically phosphorus, in stormwater discharges.

"We put our heads together to see what we could do that was small scale and affordable," Mr. Chouinard explains. In Arlington's urban landscape, infiltration trench retrofits made sense (see Figure 2).

UNHSC scientists provided performance curves for pollutant load reductions for the proposed trenches; these turned out to be essential for tracking their effectiveness. UNHSC scientists continue to monitor one of the installation sites to refine the curves (see Figure 3).

"Before they formalized the nutrient removal numbers, I didn't know how much these designs could achieve," says Mr. Chouinard. "Having that spreadsheet gives us something to point to, to show we are making progress and can track it. People don't question it because it's from the UNH Stormwater Center."

Since 2014, Arlington has installed 31 infiltration trenches. In 2019 alone, the town installed nine systems for less than $20,000 (Table 1), with an annual reduction of nearly 1 lb (0.45 kg) of phosphorus and 1,296 gal (4,906 L) of runoff across the nine 2019 installations.

"Working with Wayne was effortless," observes UNHSC Director Dr. James Houle. "Stormwater management is increasingly focused on expensive, high-yield engineered controls. Wayne knew there was another option—an 'everyday' approach in which the town could make improved stormwater management part of the culture. Now, infrastructure improvements routinely include stormwater improvements. This do-it-yourself attitude will not only save the river but also will help the town and taxpayers avoid higher costs in the future."

### New Standard of Practice for the Watershed

Over six years, Mr. Chouinard has adjusted the trench detail to incorporate what they learn and adapt it to new sites. They have found that connecting the trenches to existing catch basins lowers installation costs. The first systems were installed under pavement, but they determined it was more practical to sometimes divert the flow into open grassy areas. Sandier subgrade soils are more likely to increase phosphorus uptake and being selective about where the trenches are installed can significantly increase the impact of the investment.

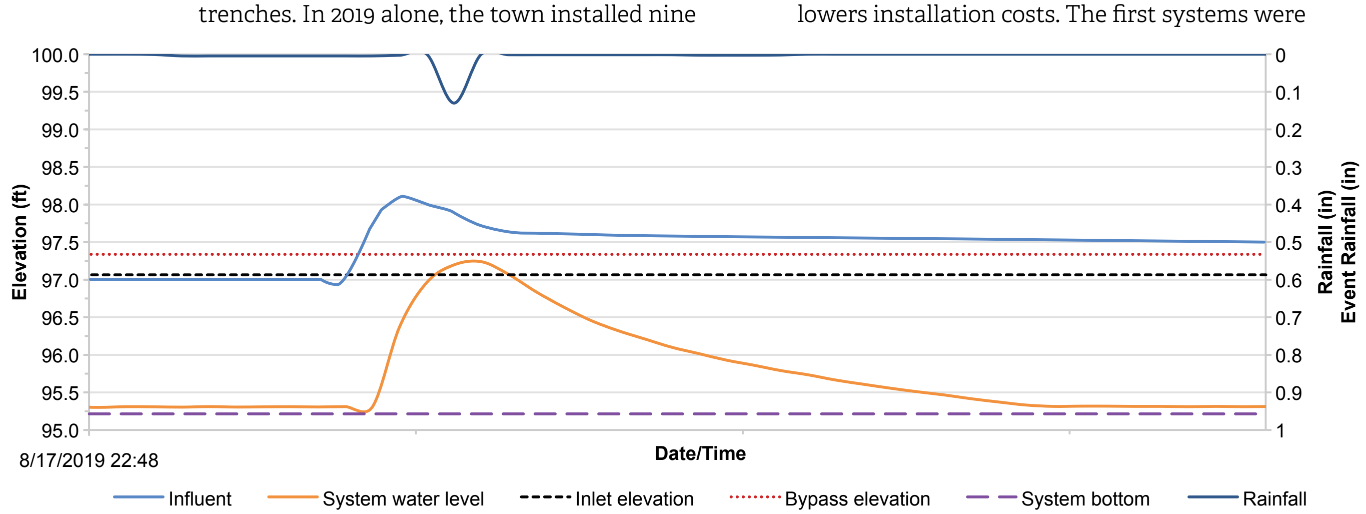



Figure 3. Monitoring results from one of the installed trenches: water level (blue) entering the system; small peaks above the bypass (red-dotted line) indicate overflow. Everything below the bypass line indicates infiltration into the ground, yielding volume and pollutant reductions.





Alongside infiltration trenches, Arlington has employed other small-scale stormwater control systems, including (left to right) porous pavement, rain gardens, and updated outfalls

Nuances like these are contributing to a new standard of practice for Arlington, the bar for which keeps getting a little higher.

"Every year we have another collaboration that pushes us forward, and every single year we learn something new," says Mr. Chouinard. "I try to document it all so anyone can pick this up. I wanted to make this scalable and easy for a young engineer and other communities to implement."

This approach has prompted neighboring towns to learn more and incorporate some of the low-cost nutrient reduction strategies used in Arlington. Mr. Chouinard is often called on to give presentations for other communities and national webinars, and he is happy to do so, even though "the most fun is when I get to put something in the ground. I just really love my job."

"Wayne jumped into this work with enormous creativity, energy, and enthusiasm," says Andy Hrycyna, watershed scientist with MyRWA. "The designs he worked to develop are being rolled out across the watershed. It's a great testament to what can happen when agencies and municipal officials engage in collaborative conversation."

It is also a testament to how one great idea can attract significant funding for watershed improvement. MyRWA recently received a $498,715 grant from the Massachusetts Department of Environmental Protection to build 50 more trenches in Arlington and in nearby Medford and Winchester in the coming years.

The end game? A revitalized Mystic River where people can enjoy boating and fishing, one with healthy wetlands that support wildlife and provide other benefits. Mr. Chouinard sees the path for this laid out in the town's MS4 permit as the way to get there.

He predicts that "over the next 20 years, we will see progress and it will all be steered by the permit. We need to keep putting in these systems, tracking their effectiveness, and changing our approach based on what we learn. We can't just keep repeating the past; we need to do the right thing."

## ACKNOWLEDGMENTS

The authors are indebted to the insights and photo contributions of Newton Tedder, senior permit writer, EPA Region 1, and Andy Hrycyna, watershed scientist, Mystic River Watershed Association.

## ABOUT THE AUTHORS

- Dr. James Houle is the director of the University of New Hampshire Stormwater Center, where he leads the center's growing body of research projects. His expertise includes the diffusion of innovative stormwater management solutions; the design and implementation of green infrastructure and low-impact development strategies; system operations and maintenance; and water resource monitoring.
- Dolores Jalbert Leonard is founder of Roca Communications, a woman-owned, strategic communications firm dedicated to positive social and environmental change. She delivers communications solutions and facilitates co-learning experiences for organizations focused on advancing clean water, healthy ecosystems, and resilient communities.

## REFERENCES

EPA. (2016), Massachusetts Small Municipal Separate Storm Sewer Systems (MS4) General Permit. from https://www.epa.gov/npdes-permits/massachusetts-small-ms4-general-permit.