Appendix L

Sample Details for Select Proposed Improvement Projects

New Jersey Stormwater Best Management Practices Manual

February 2004

C H A P T E R 9 . 1 0

Standard for Vegetative Filters

Definition

A vegetative filter is an area designed to remove suspended solids and other pollutants from stormwater runoff flowing through a length of vegetation called a vegetated filter strip. The vegetation in a filter strip can range from turf and native grasses to herbaceous and woody vegetation, all of which can either be planted or indigenous. It is important to note that all runoff to a vegetated filter strip must both enter and flow through the strip as sheet flow. Failure to do so can severely reduce and even eliminate the filter strip's pollutant removal capabilities.

The total suspended solid (TSS) removal rate for vegetative filters will depend upon the vegetated cover in the filter strip. Table 9.10-1 below presents the adopted TSS removal rates for various vegetated covers.

Table 9.10-1: Adopted TSS Removal Rates for Vegetated Filter Strips

Vegetated Cover	Adopted TSS Removal Rate
Turf grass	60 %
Native Grasses, Meadow, and Planted Woods	70 %
Indigenous woods	80 %

For filter strips with multiple vegetated covers, the final TSS removal rate should be based upon a weighted average of the adopted rates shown above in Table 9.10-1. This weighted average removal rate should be based upon the relative flow lengths through each cover type. For example, a 50-foot long vegetated filter strip (measured in the direction of flow) that has turf grass in the upper 25 feet and native grasses in the lower 25 feet would have a TSS removal rate of (25/50)(60%) + (25/50)(70%) or 65 percent.

Purpose

A vegetative filter is intended to remove pollutants from runoff flowing through it. Vegetated filter strips can be effective in reducing sediment and other solids and particulates, as well as associated pollutants such as hydrocarbons, heavy metals, and nutrients. The pollutant removal mechanisms include sedimentation, filtration, adsorption, infiltration, biological uptake, and microbacterial activity.

Vegetated filter strips with planted or indigenous woods may also create shade along water bodies that lower aquatic temperatures, provide a source of detritus and large woody debris for fish and other aquatic organisms, and provide habitat and corridors for wildlife.

Condition Where Practice Applies

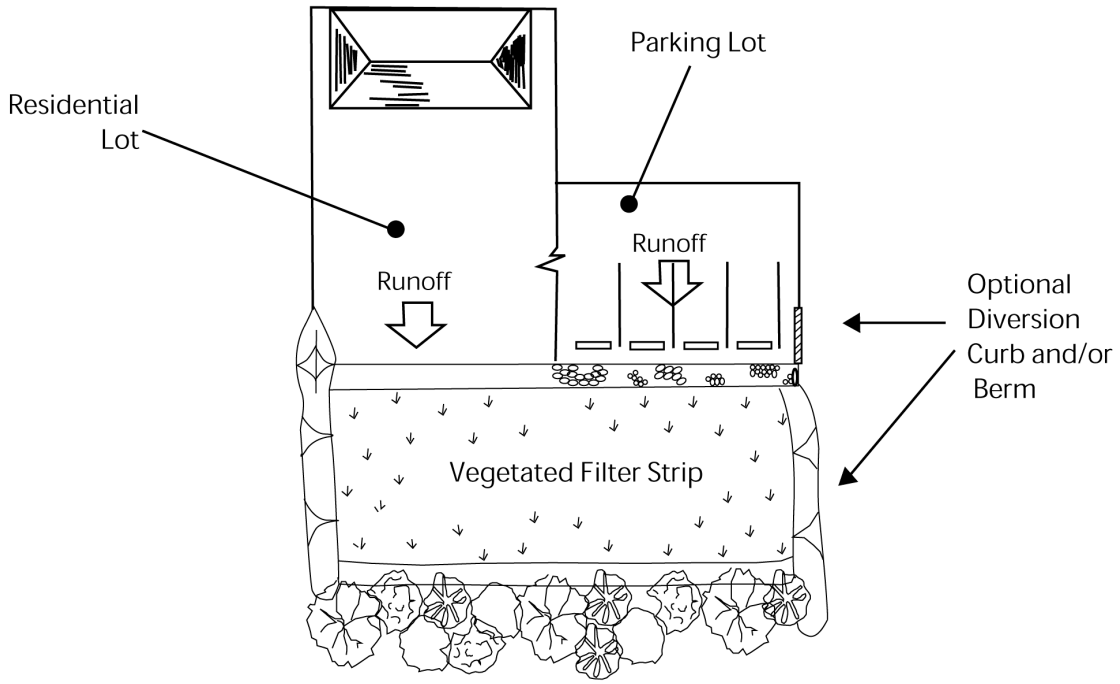
A vegetative filter can be effective only where the runoff entering and flowing through the strip remains as sheet flow and does not concentrate. This sheet flow requirement limits the use of vegetated filter strips in two ways. First, the area used for the filter strip itself must be mildly sloped and uniformly graded to maintain sheet flow or, in the case of indigenous areas, have surface features that retard, pond, and/or disperse runoff generally over the entire filter width. Second, since the runoff to a filter strip must enter the strip as sheet flow, the drainage area to the strip must also be uniformly graded and have a relatively horizontal downstream edge where it meets the upstream end of the filter strip. Such drainage areas may include yards, parking lots, and driveways where runoff flows as sheet flow. As a result, an area with irregular grading and other surface features that cause runoff to concentrate could neither be used as a vegetated filter strip nor have its runoff treated by one. For the same reasons, vegetated filter strips are also not intended to treat concentrated discharges from storm sewers, swales, and channels.

As detailed below in *Design Criteria*, additional factors must be considered. First, the vegetation in all filter strips must be dense and remain healthy and, in the case of planted or indigenous woods, have an effective mulch or duff layer. In addition, a vegetated filter strip must have a maintenance plan and be protected by an easement, deed restriction, or other legal measure that guarantees its existence and effectiveness in the future. Depending upon their TSS removal rate, vegetated filter strips can be used separately or in conjunction with other stormwater quality practices to achieve an overall pollutant removal goal.

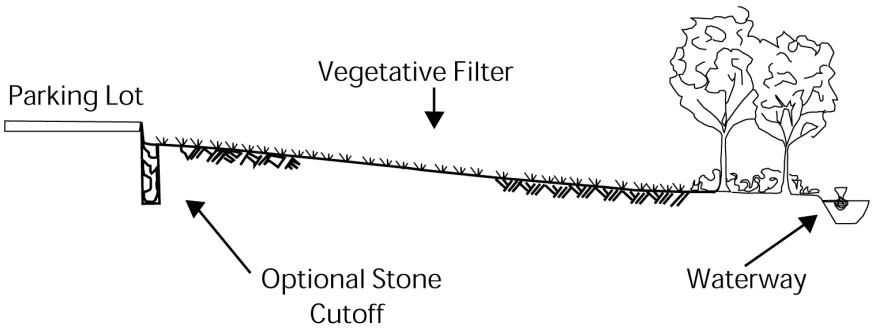
Design Criteria

The primary design parameters for a vegetated filter strip are its slope, type of vegetated cover, and the type of soils within its drainage area. These three parameters are then used to determine the standard filter strip length required to achieve the adopted TSS removal rates shown above in Table 9.10-1. In addition, since runoff from the stormwater quality design storm must enter and continue as sheet flow over this length, the peak runoff rate must be sufficiently low and uniformly distributed to ensure such conditions. This peak runoff rate is achieved by limiting the sheet flow length that runoff will flow before entering the filter strip. This length limitation, in turn, limits the size of the drainage area to the filter strip and, consequently, the peak runoff rate. Details of these and other design parameters are presented below. The components of a typical vegetated filter strip are shown in Figure 9.10-1.

Figure 9.10-1 Vegetative Filter Components



Plan View



Profile View

Source: Adapted from Schueler and Claytor 1996.

A. Drainage Area and Runoff Characteristics

As noted above, runoff from a drainage area may be directed to flow through a filter strip provided it enters the filter strip and continues through it as sheet flow. In addition, the peak rate and maximum depth of runoff entering the filter strip must be low enough to allow the strip's vegetated cover to serve as an effective filter. As such, the maximum drainage area to a vegetated filter strip will be limited to an area 100 feet long for impervious surfaces and 150 feet long for pervious surfaces. These lengths are to be measured in the direction of flow to the upstream edge of the filter strip.

In addition, the interface of the drainage area and the upstream edge of the filter strip must be as horizontal as possible (perpendicular to the flow direction) so that runoff will be evenly distributed along the upstream edge of the strip. As shown in Figure 9.10-1, a stone cutoff trench, recessed curb, or other measure may be used along the filter's upstream edge to help distribute the runoff and dissipate some of its energy as it enters the filter strip.

As noted above, the required strip lengths are based in part upon the type of soils within the filter strip's drainage area. Table 9.10-2 below lists the various types of soils and their associated Hydrologic Soil Groups that will affect the strip's required length. County Soil Surveys and onsite soil investigations can be used to determine these soil types. Where more than one type of soil exists in a drainage area, the soil with the smallest particle size (and, consequently, the longest filter strip length) should be used in the filter strip's design.

B. Filter Strip Cover

As noted above, the vegetation in a filter strip can range from turf and native grasses to herbaceous and woody vegetation, all of which can either be planted or indigenous. The type of vegetation used in the filter strip can be very broad, although the best performance is associated with those with dense growth patterns such as turf-forming grasses and dense forest floor vegetation. All vegetation must be dense and healthy. In addition, planted woods must have a mulch layer with a minimum thickness of 3 inches, while indigenous woods must have at least a 1 inch thick natural duff layer.

Further information and references are presented in *Chapter 7: Landscaping*.

C. Filter Strip Grading

As noted above, the area used for a vegetated filter strip itself must be mildly sloped and uniformly graded to maintain sheet flow or, in the case of indigenous areas, have surface features that retard, pond, and/or disperse runoff generally over the entire filter width. As such, indigenous areas such as meadows and woods under consideration as vegetated filter strips should be surveyed and inspected during runoff events to determine runoff flow patterns. Indigenous areas with surface features that obstruct or retard runoff flow, cause ponding, and/or disperse runoff are acceptable, while those with surface features that cause runoff to concentrate are not. It should be noted that such observations must be made with consideration for the proposed volume and peak rate of runoff that the area would receive as a vegetated filter strip.

D. Maximum Filter Strip Slope

In addition to the soils within a vegetated filter strip's drainage area, the soils within the filter strip itself are also important for determining filter strip's maximum allowable slope. Table 9.10-2 below presents maximum filter strip slopes for various vegetated covers and soil types within the filter strip. County Soil Surveys and onsite soil investigations can be used to determine the soil type within a filter strip.

Table 9.10-2: Maximum Filter Strip Slope

Filter Strip Soil Type	Hydrologic Soil Group	Maximum Filter Strip Slope (Percent)	
		Turf Grass, Native Grasses, and Meadows	Planted and Indigenous Woods
Sand	A	7	5
Sandy Loam	B	8	7
Loam, Silt Loam	B	8	8
Sandy Clay Loam	C	8	8
Clay Loam, Silty Clay, Clay	D	8	8

E. Required Filter Strip Length

To achieve the adopted TSS removal rates shown above in Table 9.10-1, the required filter strip length can be determined from Figures 9.10-2 to 6 below based upon the filter strip's slope, vegetated cover, and the soil within its drainage area. As shown in the figures, the minimum length for all vegetated filter strips is 25 feet.

Figure 9.10-2: Vegetated Filter Strip Length
Drainage Area Soil: Sand HSG: A

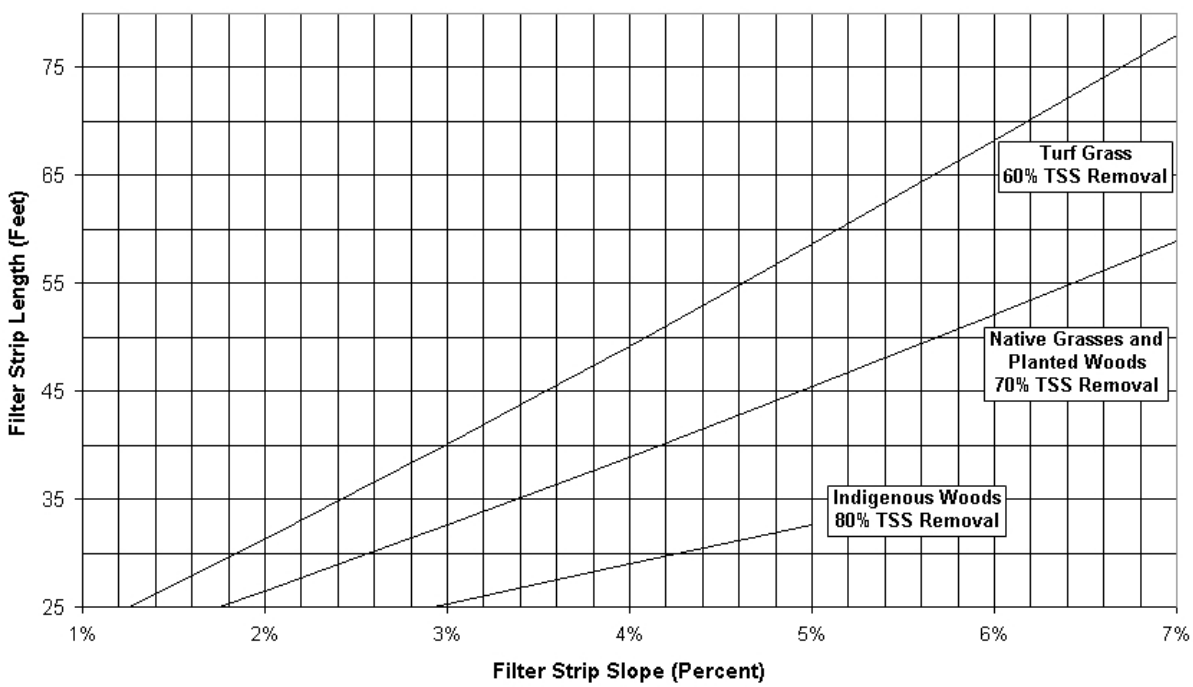


Figure 9.10-3: Vegetated Filter Strip Length
Drainage Area Soil: Sandy Loam HSG: B

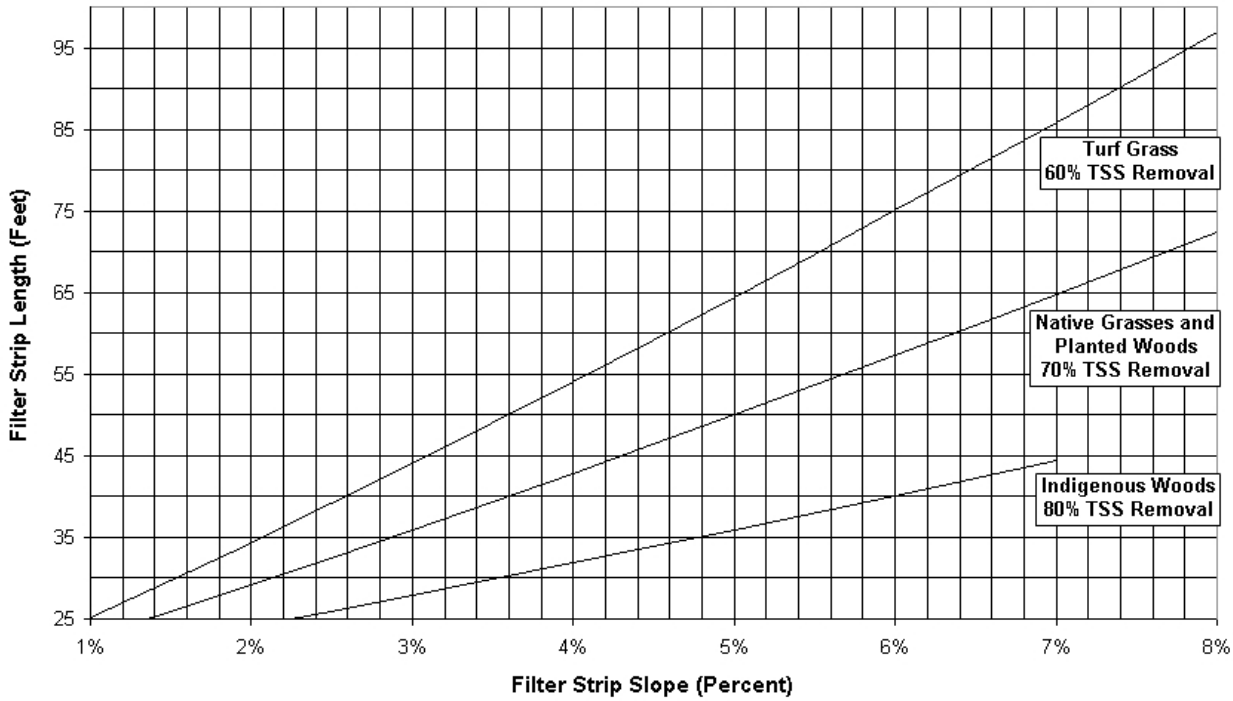


Figure 9.10-4: Vegetated Filter Strip Length
Drainage Area Soil: Loam, Silt Loam HSG: B

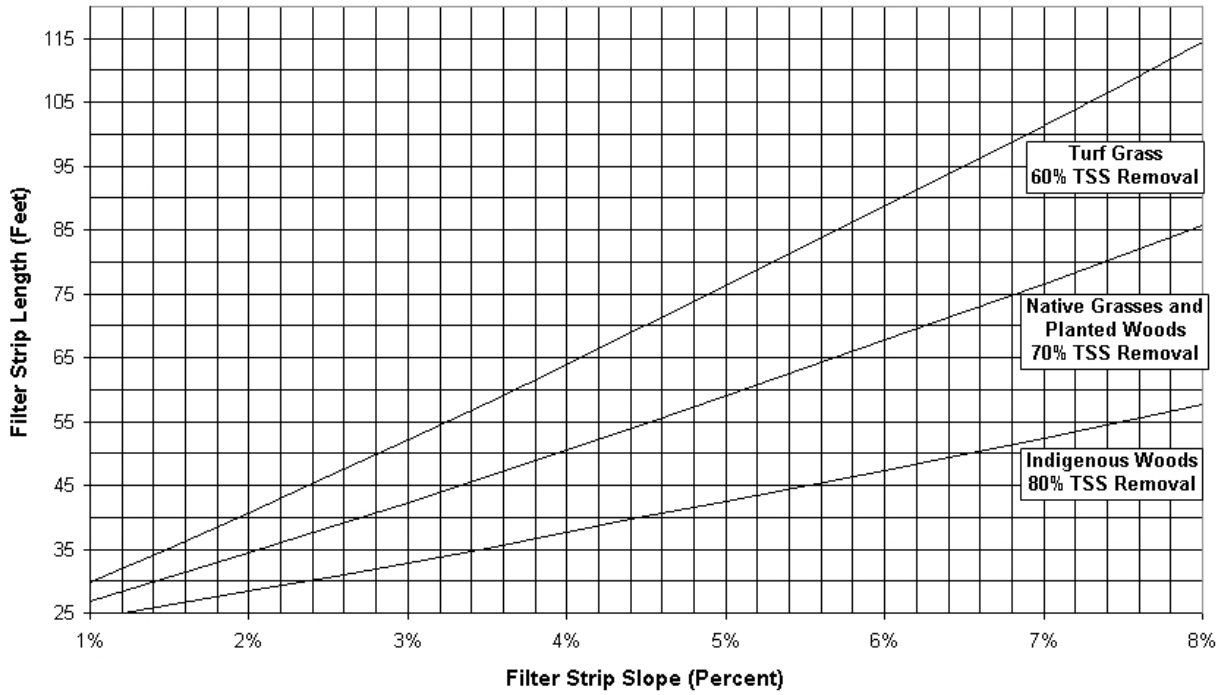


Figure 9.10-5: Vegetated Filter Strip Length
Drainage Area Soil: Sandy Clay Loam HSG: C

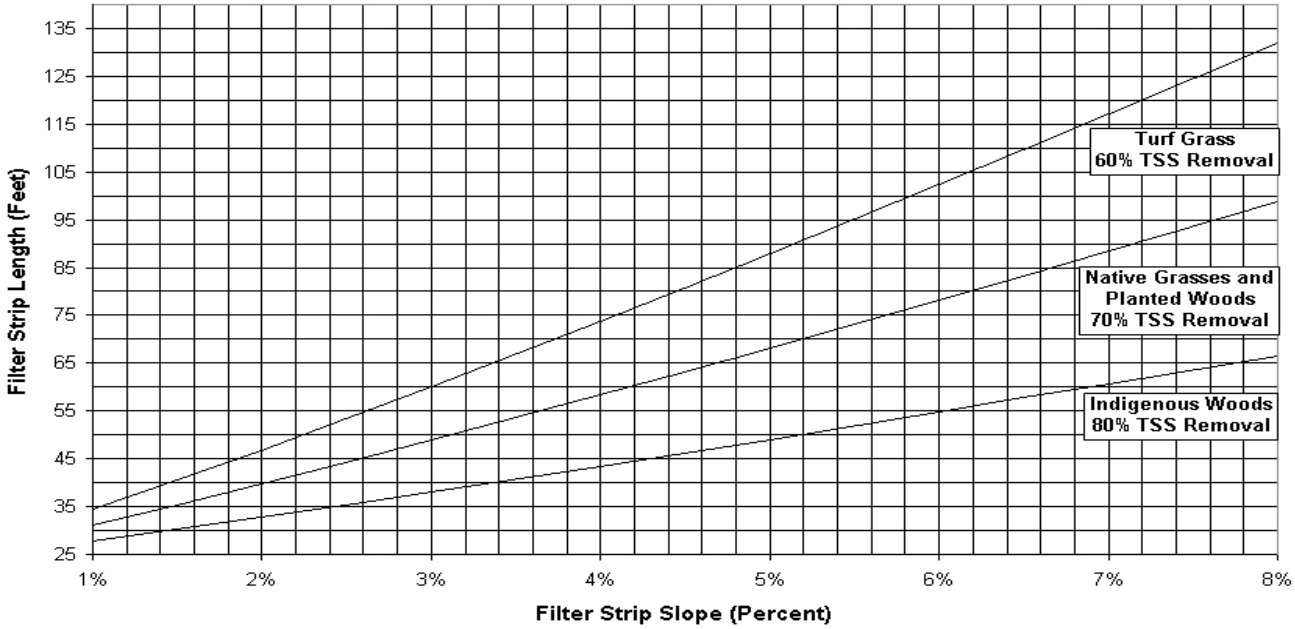
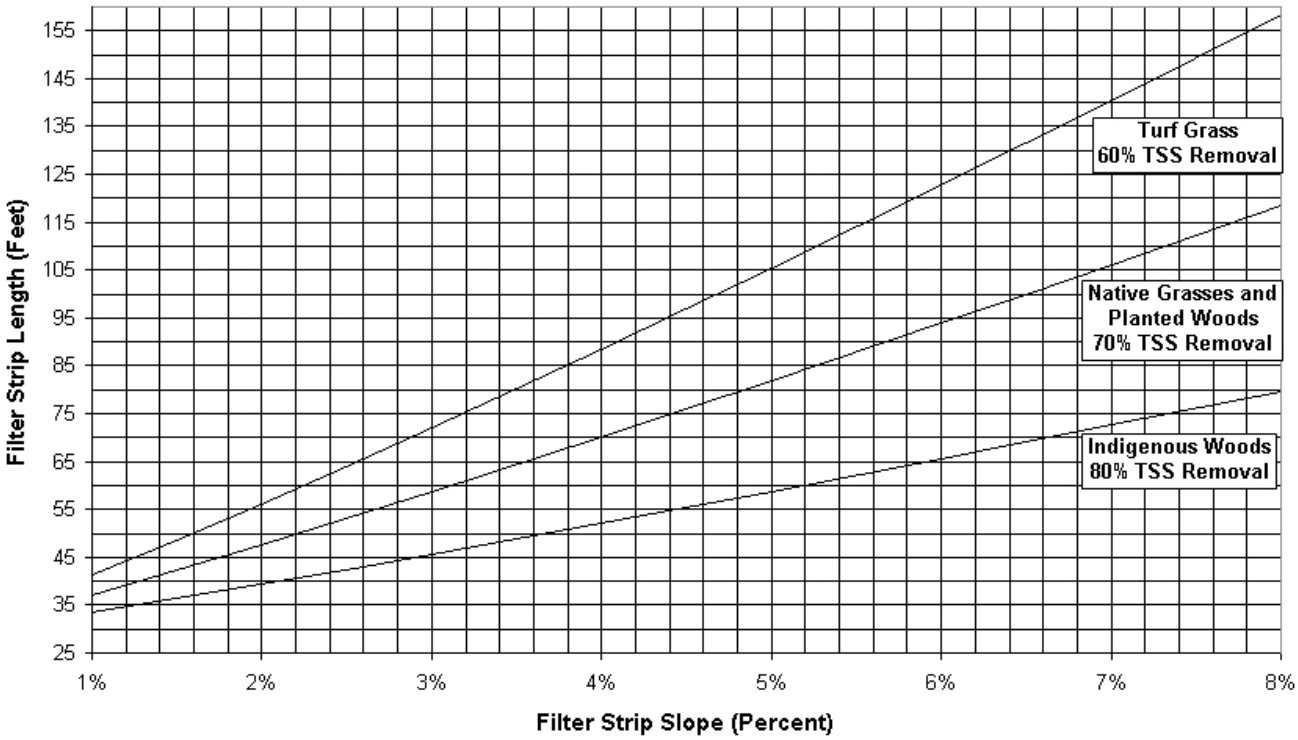


Figure 9.10-6: Vegetated Filter Strip Length
Drainage Area Soil: Clay Loam, Silty Clay, Clay HSG: D



Example 9.10-1: Computing Required Vegetated Filter Strip Length

A vegetated filter strip is to be installed at a uniform 5 percent slope to treat the runoff from a drainage area consisting of a paved parking lot and turf grass lawn. Runoff from the parking lot and lawn will enter the filter strip as sheet flow. The maximum sheet flow lengths across the parking lot and lawn do not exceed 100 and 150 feet, respectively. The soil in the drainage area is a silt loam. Compute the required filter strip length if the strip is to be vegetated with turf grass.

1. Determine the Hydrologic Soil Group of the drainage area soil. From Table 9.10-2, a silt loam is in Hydrologic Soil Group B.
2. Determine the maximum slope of the filter strip. Also from Table 9.10-2, the maximum slope of a turf grass filter strip with Hydrologic Soil Group B soils is 8 percent, which is greater than the 5 percent slope of the proposed filter strip.
3. Determine the required length of the filter strip. From Figure 9.10-4 for silt loam soils, the required length of a turf grass filter strip with a 5 percent slope is approximately 76 feet. The resultant TSS removal rate for the turf grass filter strip will be 60 percent.

Maintenance

Effective vegetated filter strip performance requires regular and effective maintenance. *Chapter 8: Maintenance and Retrofit of Stormwater Management Practices* provides information and requirements for preparing a maintenance plan for stormwater management facilities, including vegetated filter strips. Specific maintenance requirements for vegetated filter strips are presented below. These requirements must be included in the filter strip's maintenance plan.

A. General Maintenance

All vegetated filter strip components expected to receive and/or trap debris and sediment must be inspected for clogging and excessive debris and sediment accumulation at least four times annually and after every storm exceeding 1 inch of rainfall. Such components may include vegetated areas and stone cutoffs and, in particular, the upstream edge of the filter strip where coarse sediment and/or debris accumulation could cause inflow to concentrate.

Sediment removal should take place when the filter strip is thoroughly dry. Disposal of debris and trash should be done only at suitable disposal/recycling sites and must comply with all applicable local, state, and federal waste regulations.

B. Vegetated Areas

Mowing and/or trimming of vegetation must be performed on a regular schedule based on specific site conditions. Grass should be mowed at least once a month during the growing season. Vegetated areas must be inspected at least annually for erosion and scour. Vegetated areas should also be inspected at least annually for unwanted growth, which should be removed with minimum disruption to the planting soil bed and remaining vegetation.

When establishing or restoring vegetation, biweekly inspections of vegetation health should be performed during the first growing season or until the vegetation is established. Once established, inspections of vegetation health, density, and diversity should be performed during both the growing and non-growing season at least twice annually. The vegetative cover should be maintained at 85 percent. If

vegetation has greater than 50 percent damage, the area should be reestablished in accordance with the original specifications and the inspection requirements presented above.

All use of fertilizers, mechanical treatments, pesticides and other means to assure optimum vegetation health must not compromise the intended purpose of the vegetative filter. All vegetation deficiencies should be addressed without the use of fertilizers and pesticides whenever possible.

All areas of the filter strip should be inspected for excess ponding after significant storm events. Corrective measures should be taken when excessive ponding occurs.

C. Other Maintenance Criteria

The maintenance plan must indicate the approximate time it would normally take for the filter strip to drain the maximum design storm runoff volume and begin to dry. This normal drain time should then be used to evaluate the filter's actual performance. If significant increases or decreases in the normal drain time are observed or if the 72 hour maximum is exceeded, the filter strip's planting soil bed, vegetation, and groundwater levels must be evaluated and appropriate measures taken to comply with the maximum drain time requirements and maintain the proper functioning of the filter strip.

Considerations

A number of factors should be considered when utilizing a vegetated filter strip to treat stormwater runoff. Most importantly, an adequate filter area and length of flow must be provided to achieve the desired treatment. Slopes of less than 5 percent are more effective; steeper slopes require a greater area and length of flow to achieve the same effectiveness. Good surface and subsurface drainage is necessary to ensure satisfactory performance. The designer should also be aware of potential ponding factors during the planning stage. Dry period between flows should be achieved in order to reestablish aerobic soil conditions.

Filter strip vegetation must be fully established before incoming stormwater flow is allowed. At least one full growing season should have elapsed prior to strip functioning as part of the stormwater management system. Further information and references on filter strip vegetation are presented in *Chapter 7*. Species must be appropriate for the region, soil, and shade condition. Mulching is required for both seeded and planted filter strips.

Perhaps the most common, naturally occurring filter strips are those upland vegetative stands associated with floodplains or found adjacent to natural watercourses. In some cases, preservation of these upland areas will allow them to continue to function as filter strips. To help ensure the longevity of these natural areas under altered and perhaps increased pollutant loading, a top dressing of fertilizer and supplemental plantings may be necessary.

References

Abu-Zreig, M. October 2000. Factors Affecting Sediment Trapping in Vegetated Filter Strips: SimulationStudy Using VFSMOD. Hydrological Processes, Volume 15, 1477–1488.

Abu-Zreig, M., R.P. Rudra, and H.R. Whiteley. 2001. Validation of a Vegetated Filter Strip Model (VFSMOD). Hydrological Processes 15, 729-742.

Castelle, A.J. and Johnson, A.W. February 2000. Riparian Vegetation Effectiveness – Technical Bulletin No. 799. National Council for Air and Stream Improvement.

Claytor, R. and T. Schueler. December 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection. Ellicott City, MD.

Desbonnet, A., P. Pogue, V. Lee and N. Wolff. July 1994. Vegetated Buffers in the Coastal Zone. Coastal Resources Center. University of Rhode Island.

Horner, R.R., J.J. Skupien, E.H. Livingston and H.E. Shaver. August 1994. Fundamentals of Urban Runoff Management: Technical and Institutional Issues. In cooperation with U.S. Environmental Protection Agency. Terrene Institute, Washington, D.C.

Livingston E.H., H.E. Shaver, J.J. Skupien and R.R. Horner. August 1997. Operation, Maintenance, & Management of Stormwater Management Systems. In cooperation with U.S. Environmental Protection Agency. Watershed Management Institute. Crawfordville, FL.

McCuen, R.H. and S.L. Wong. 1982. The Design of Vegetative Buffer Strips for Runoff and Sediment Control. Maryland Department of Natural Resources.

Munoz-Carpena, R., J.E. Parsons, and J.W. Gilliam. 1999. Modeling Hydrology and Sediment Transport in Vegetative Filter Strips. Journal of Hydrology 214 111-129.

New Jersey Department of Agriculture. November 1999. Standards for Soil Erosion and Sediment Control in New Jersey. State Soil Conservation Committee. Trenton, NJ.

New Jersey Department of Environmental Protection and Department of Agriculture. December 1994. Stormwater and Nonpoint Source Pollution Control Best Management Practices.

Ocean County Planning and Engineering Departments and Killam Associates. June 1989. Stormwater Management Facilities Maintenance Manual. New Jersey Department of Environmental Protection. Trenton, NJ.

Schueler, T.R. July 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Washington, D.C.

Schueler, T.R., P.A. Kumble and M. Heraty. March 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments. Washington, D.C.

Tollner, E.W., B.J. Barfield, C.T. Hann and T.Y. Kao. 1976. Suspended Sediment Filtration Capacity of Simulated Vegetation. Transactions of the ASAE. 10(11). pp. 678-682.

Walsh, P.M., M.E. Barrett, J.F. Malina and R.J. Charbeneau. October 1997. Use of Vegetative Controls for Treatment of Highway Runoff. Center for Research in Water Resources. University of Texas at Austin.

Wenger, S. A. March 1999. Review of the Scientific Literature on Riparian Buffer Width, Extent, and Vegetation. Institute of Ecology. University of Georgia.

VEGETATED BUFFER STRIPS

GENERAL

Buffer strips are densely vegetated areas that collect and slow runoff, filtering out sediments and insoluble pollutants and encourage infiltration. Stormwater flows into a buffer strip over a level spreader, a device that converts concentrated flow into sheet flow. As the runoff flows through the vegetation, its velocity is reduced, releasing its load of suspended solids and promoting infiltration.

Buffer strips are uniformly graded and are located down slope from disturbed or impervious areas or adjacent to waterways. Buffer strips are best used in conjunction with other management practices, however, as they do not significantly reduce peak flows or the volume of runoff.

ADVANTAGES

- Relatively low cost
- Easy to construct and maintain
- Can be aesthetically pleasing if designed properly
- Remove sediment and insoluble pollutants
- Increase the infiltration of runoff
- Can provide habitat for wildlife
- Can help stabilize stream banks

DISADVANTAGES

- Ineffective in areas with high velocity runoff
- Require a large amount of land area
- Ineffective for large drainage areas
- Reduced effectiveness with large storm events
- Best used in conjunction with other management practices

DESIGN

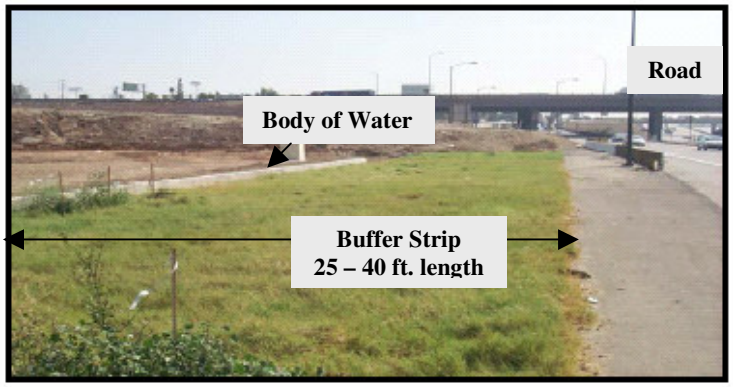
LEVEL SPREADERS AND BERMS

Maintaining sheet flow is critical to the proper operation of buffer strips. To ensure that concentrated flow is eliminated before runoff enters the buffer strip, a level spreader may be constructed at the top of the buffer strip. These devices disperse flows over a wide area, dissipating the energy of the runoff and creating sheet flow.

Common types of level spreaders are curb cuts, concrete weirs, and stone weepers or trenches.

LENGTH, WIDTH, AND SLOPE

Each buffer strip should be sized according to the individual characteristics of the site, taking into account the size of the area to be drained and the slope of the land that they are located on.



An Example of a Vegetated Buffer Strip, Source: Adapted from California Stormwater Quality Association

Buffer strips that border impervious surfaces should stretch the entire width of the surface and have a minimum flow length of at least 25 feet, with a 20-minute detention time. Increased lengths enhance the treatment ability of the practice by increasing detention time. However, lengths greater than 40 feet generally result in channelized flow and require additional flow dissipaters. Regardless of the length, each buffer strip should not drain an area larger than ½ acre. Sites that border bodies of water may have additional requirements beyond this ordinance. For length requirements on this type of site, please contact your local WDNR office.

The length of buffer strips is dependent upon the slope of the site. Slopes of 1-2 percent are recommended and may not exceed 6%. Steeper slopes encourage concentrated flow and may lead to channelization, while slopes flatter than 1 percent may result in ponding. Runoff velocities are determined by the detention time.

VEGETATION

Buffer strips only provide effective erosion control once the vegetation is densely established. "Dense" is defined as a stand of 6-8 inch sod-forming vegetation that uniformly covers at least 90% of a representative 1 square yard plot. As a result, until vegetation is firmly established, it shall under no circumstances be relied upon to prevent soil loss from the site.

Plant species selected for buffer strips should meet the following criteria:

- Native species may be used with careful selection (refer to the Native Grasses section of this Appendix)
- Species should be tolerant to frequent inundation as well as extended dry periods
- Species should be resistant to matting
- Species should form a dense cover
- Avoid exotic, noxious, and invasive species

CONSTRUCTION

- Buffer strips must be established before construction activity begins
- In order to be effective, buffer strips must be densely established

MAINTENANCE

- Grassed vegetation should be cut and removed at least once per year
- Mowing should only be performed during dry periods using lightweight equipment to prevent soil compaction and damage to vegetation
- Buffer strips should be inspected weekly and after all major storm events to ensure they are operating properly and to check for any potential problems, such as the formation of rills and gullies, bare spots, and sediment accumulation
- Buffer strips should be inspected for the accumulation of sediment after all major storm events

METHOD TO DETERMINE PRACTICE EFFICIENCY

Buffer strips filter out sediment and other particles by reducing the flow velocity of runoff. The trapping efficiency of this practice is dependant upon the particle size and the flow length of buffer strip. RUSLE2, when available, has the ability to calculate the approximate efficiency of vegetative buffer strips.

Buffer strips help remove suspended sediment from runoff by reducing the flow velocity. As the runoff velocity decreases, the sediment settles out. Buffer strips also help with reducing the amount of pollutants in the runoff since many pollutants are associated with the sediment. Studies have shown a suspended solid removal rate ranging between 40%-90%, with the efficiency of the buffer strip being dependent upon the quantity of runoff, length and steepness of the slope, as well as the vegetation used in the strip and the ability of the soil to infiltrate. Due to the number of variables affecting the performance of buffer strips, it is difficult to determine the exact efficiency of sediment removal for this practice.

SOURCES

1. *California Stormwater BMP Handbook*: Vegetated Buffer Strip. California Stormwater Quality Association. January 2003. *Massachusetts Low Impact Development Fact Sheet: Grassed Filter Strips*. Boston Metropolitan Area Planning Council. August 2006.
2. Leeds, R, Brown, L. C., Sulc, M. R., and VanLieshout, L. *Vegetative Filter Strips: Application, Installation and Maintenance*. (AEX-467-94) Ohio State University Extension. Columbus.
3. *Minnesota Urban Small Sites BMP Manual*. Metropolitan Council. Minneapolis. 2000.
4. Schueler, T. R. *The Architecture of Urban Stream Buffers*. Watershed Protection Techniques. Center for Watershed Protection, Terrene Institute, Washington, D.C. 1995.
5. *Urban Storm Water Best Practices Study*. United States Environmental Protection Agency, Office of Water. Washington, D.C. 1999.
6. *Vegetative Buffer*. Conservation Practice Standard. Wisconsin Department of Natural Resources. November 2006.
7. *Water Related Best Management Practices in the Landscape*. U.S. Department of Agriculture, Natural Resources Conservation Service and Center for Sustainable Design at Mississippi State University. Washington, D.C. 1999.
8. *Wisconsin Field Office Technical Guide*. U.S. Department of Agriculture, Natural Resources Conservation Service. Washington D.C. 1993.
9. Wong, S.L. and R.H. McCuen. 1982. *The Design of Vegetative Buffer Strips for Runoff and Sediment Control*. Civ. Eng. Dep., Univ. of Maryland, College Park, MD.

The Chicago Center for Green Technology uses filter strips to convey runoff on-site.

A Citizen's Guide to Permeable Reactive Barriers

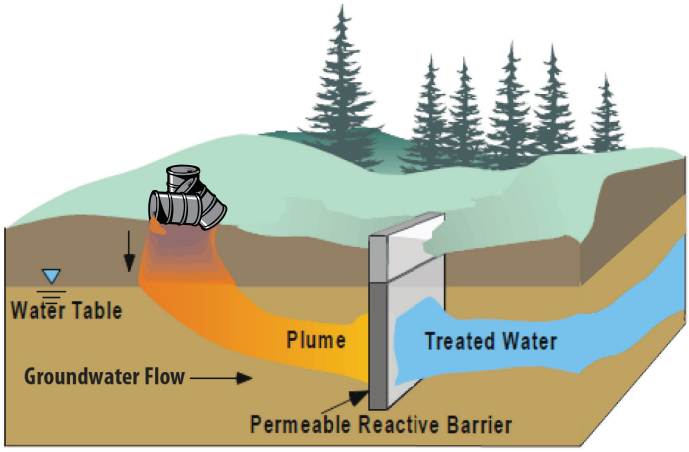
What Are Permeable Reactive Barriers?

A permeable reactive barrier, or "PRB," is a wall created below ground to clean up contaminated groundwater. The wall is "permeable," which means that groundwater can flow through it. Water must flow through the PRB to be treated. The "reactive" materials that make up the wall either trap harmful contaminants or make them less harmful. The treated groundwater flows out the other side of the wall.

How Do They Work?

A PRB is usually built by digging a long, narrow trench in the path of contaminated groundwater flow. The trench is filled with a reactive material, such as iron, limestone, carbon, or mulch, to clean up contamination. Due to limitations of excavation equipment, walls typically can be no deeper than 50 feet. However, a deeper but usually shorter PRB can be built by drilling a row of large-diameter holes or by using fracturing (See *A Citizen's Guide to Fracturing* [EPA 542-12-008]) and other new techniques.

The reactive material selected for the PRB will depend on the types of contaminants present in the groundwater. The material may be mixed with sand to make the wall more permeable so that it is easier for groundwater to flow through it, rather than around it. Side walls filled with an impermeable material such as clay may be constructed at an angle to the PRB to help funnel the flow of contaminated groundwater toward the reactive materials. The filled trench is covered with soil, and is not usually visible at the ground surface.



PRB treats a plume of groundwater contaminants.

Depending on the reactive material, contaminants are removed through different processes:

- Contaminants *sorb* (stick) to the surface of the reactive material. For example, carbon particles have a surface onto which contaminants, such as petroleum products, sorb as groundwater passes through.
- Metals dissolved in groundwater *precipitate*, which means they settle out of the groundwater by forming solid particles that get trapped in the wall. For example, limestone and shell fragments can cause dissolved lead and copper to precipitate in a PRB.
- Contaminants *react* with the reactive material to form less harmful ones. For example, reactions between iron particles and certain industrial cleaning solvents can convert the solvents to less toxic or even harmless chemicals.
- Contaminants are *biodegraded* by microbes in the PRB. Microbes are very small organisms that live in soil and groundwater and eat certain contaminants. When microbes digest the contaminants, they change them into water and gases, such as carbon dioxide. (*A Citizen's Guide to Bioremediation* [EPA 542-F-12-003] describes how microbes work.) Organic mulch frequently is used as reactive media in this type of PRB. Mulch barriers consist of plant-based materials, such as compost or wood chips, and naturally contain many different microbes. Groundwater flow through the PRB also releases organic carbon from the mulch wall, creating another reactive zone for contaminants just beyond the wall.

Over time, reactive materials will fill up with contaminants or treatment products and become less effective at cleaning groundwater. When this occurs the contaminated reactive material may be excavated for disposal and replaced with fresh material.

How Long Will It Take?

PRBs may take many years to clean up contaminated groundwater. The cleanup time will depend on factors that vary from site to site. For example, cleanup may take longer where:

- The source of dissolved contaminants (for instance, a leaking drum of solvent) has not been removed.
- The contaminants remain in place because they are not easily dissolved by groundwater.
- Groundwater flow is slow.

Are PRBs Safe?

The reactive materials placed in PRBs are not harmful to groundwater or people. Contaminated groundwater is cleaned up underground so treatment does not expose workers or others onsite to contamination. Because some contaminated soil may be encountered when digging the trench, workers wear protective clothing. Workers also cover loose contaminated soil to keep dust and vapors out of the air before disposing of it. Groundwater is tested regularly to make sure the PRB is working.

How Might It Affect Me?

During construction of the PRB, nearby residents may see increased truck traffic when materials are hauled to the site or hear earth-moving equipment. However, when complete, PRBs require no noisy equipment. Cleanup workers will occasionally visit the site to collect groundwater and soil samples to ensure that the PRB is working. When the reactive materials need to be replaced, the old materials will have to be excavated and hauled to a landfill.

Why Use PRBs?

PRBs are a relatively inexpensive way to clean up groundwater. No energy is needed because PRBs rely on the natural flow of groundwater. The use of some materials, such as limestone, shell fragments, and mulch, can be very inexpensive, if locally available. No equipment needs to be above ground, so the property may continue its normal use, once the PRB is installed.

Construction of a PRB in Sunnyvale, CA

PRBs have been selected or are being used at more than 30 Superfund sites across the country.

Example

A PRB with iron as the reactive material was installed in 1995 to clean up groundwater at a former semiconductor manufacturing site in Sunnyvale, California. Concentrations of industrial solvents in the groundwater plume were extremely high.

Due to changing groundwater flow directions, low-permeability walls were installed below ground and perpendicular to the PRB to direct the flow of contaminated groundwater toward the PRB. The PRB itself is about 8-feet wide, 40-feet long and 20-feet deep. The objective of the PRB is to reduce solvent concentrations to below the cleanup standards set by the State of California. As of 2009, solvent concentrations in groundwater samples collected within the treatment zone remain below the cleanup standards. Use of a PRB has allowed the metals machining facility currently at the site to continue operating during cleanup.

For More Information

For more information on this and other technologies in the Citizen's Guide Series, contact:

U.S. EPA
Technology Innovation &
Field Services Division
Technology Assessment Branch
(703) 603-9910

Or visit:
http://www.cluin.org/prb

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United States
Environmental Protection
Agency

Office of Solid Waste and
Emergency Response
(5102G)

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September 2012
www.epa.gov/superfund/sites
www.cluin.org

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

MASSACHUSETTS **LOW IMPACT DEVELOPMENT** TOOLKIT

FACT SHEET #1

BIORETENTION AREAS

Overview

Bioretention is an important technique that uses soil, plants and microbes to treat stormwater before it is infiltrated or discharged. Bioretention "cells" are shallow depressions filled with sandy soil, topped with a thick layer of mulch, and planted with dense vegetation. Stormwater runoff flows into the cell and slowly percolates through the soil (which acts as a filter) and into the groundwater; some of the water is also taken up by the plants. Bioretention areas are usually designed to allow ponded water 6-8 inches deep, with an overflow outlet to prevent flooding during heavy storms. Where soils are tight or fast drainage is desired, designers may use a perforated underdrain, connected to the storm drain system.

Bioretention areas can provide excellent pollutant removal and recharge for the "first flush" of stormwater runoff. Properly designed 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.

Applications and Design Principles

Bioretention systems can be applied to a wide range of development in many climatic and geologic situations; they work well on small sites and on large sites divided into multiple small drainages. Common applications for bioretention areas include parking lot islands, median strips, and traffic islands. Bioretention is a feasible "retrofit" that can be accomplished 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.

Management Objectives

- Provide water quality treatment.
- Remove suspended solids, metals, nutrients.
- Increase groundwater recharge through infiltration.
- Reduce peak discharge rates.
- Reduce total runoff volume.
- Improve site landscaping.

Metropolitan Area Planning Council
MAPC
arc of innovation

Above: This bioretention cell at a office park also helps to fulfill site landscaping requirements. *Photo: Low Impact Development Center*

Right: This schematic diagram shows parking lot runoff directed to a bioretention cell, with pretreatment by a grassed filter strip. *Image: Prince George's County (MD) Bioretention Manual*

Cover, top: A rain garden in a Connecticut Subdivision infiltrates rooftop and driveway runoff, and can be marketed as an extra amenity. *Photo: University of Connecticut, Jordan Cove Urban Monitoring Project*

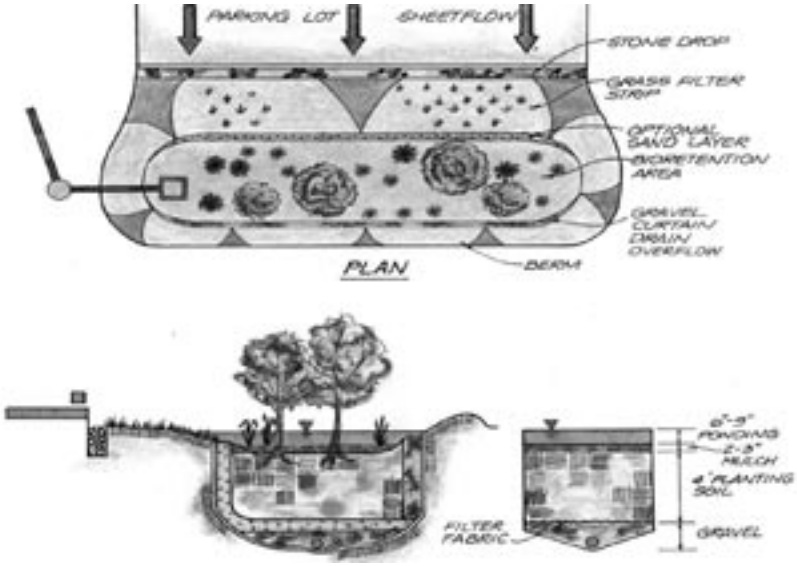
Cover, bottom: A narrow bioretention cell in a parking lot, planted with small trees to reduce the urban heat island effect. *Photo: Low Impact Development Center*

Bioretention cells are usually excavated to a depth of 4 feet, depending on local conditions. Generally, cells should be sized (based on void space and ponding area) to capture and treat the water quality volume (the first 0.5" or 1" of runoff, depending on local requirements.) Some manuals suggest a minimum width of 15', though much narrower bioretention cells have been installed in parking lot islands and are functioning well. Regardless of size, some type of filter should cover the bottom of the excavation. Filter fabric is commonly used but can be prone to clogging; consequently some engineers recommend a filter of coarse gravel, over pea gravel, over sand.

The cell should be filled with a soil mix of sandy loam or loamy sand. The area should be graded to allow a ponding depth of 6-8 inches; depending on site conditions, more or less ponding may be appropriate. The planting plan should include a mix of herbaceous perennials, shrubs, and (if conditions permit) understory trees that can tolerate intermittent ponding, occasionally saline conditions (due to road salt), and extended dry periods. The soil should be covered with 2-3" of fine-shredded hardwood mulch.

In very permeable soils, some bioretention areas can be designed as "off-line" treatment structures (no overflow necessary), but in most situations they will be an "on-line" component of the stormwater management system, connected to downstream treatment structures through an overflow outlet or an overflow drop inlet installed at the ponding depth and routed to the site's stormwater management system. Ideally, overflow outlets should be located as far as possible from runoff inlets to maximize residence time and treatment. In general, bioretention area should be designed to drain within 72 hours. In slowly permeable soils (less than 0.3 inches/hour) a perforated underdrain can be installed at the bottom of the excavation to prevent ponding.

Bioretention areas work best if designed with some pretreatment, either in the form of swales or a narrow filter strip. A stone or pea gravel diaphragm (or, better yet, a concrete level spreader) upstream of a filter strip will enhance sheet flow and better pre-treatment.



Benefits and Effectiveness

- Bioretention areas remove pollutants through filtration, microbes, 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 75% of phosphorus and nitrogen; 95% of metals; and 90% of organics,

Above, top: Bioretention cells are designed to allow ponded water six inches deep, which should infiltrate into the ground within 72 hours after a storm.

Above, middle: A large bioretention cell adjacent to a parking lot can reduce or eliminate expenses on storm sewers and detention basins. *Photo: Low Impact Development Center*

Above, bottom: Maintenance of rain gardens can generally be handled by homeowners. *Photo: Low Impact Development Center*

bacteria, and total suspended solids. Bioretention areas qualify as an organic filter according to the Massachusetts Stormwater Policy.

- In most applications, bioretention areas increase groundwater recharge as compared to a conventional "pipe and pond" approach. They can help to reduce stress in watersheds that experience severe low flows due to impervious coverage.
- 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. The use of decentralized bioretention cells can also reduce the size of storm drain pipes, a major driver of stormwater treatment costs.
- Bioretention areas enhance the landscape in a variety of ways: they improve the appearance of developed sites, provide wind breaks, absorb noise, provide wildlife habitat, and reduce the urban heat island effect.

Limitations

- Because bioretention areas infiltrate runoff to groundwater, they may be inappropriate for use at stormwater "hotspots" (such as gas stations) with higher potential pollutant loads. On these sites, the design should include adequate pretreatment so that runoff can be infiltrated, or else the filter bed should be built with an impermeable liner, so that all water is carried away by the underdrain to another location for additional treatment prior to discharge.
- Premature failure of bioretention areas is a significant issue that results from lack of regular maintenance. Ensuring long-term maintenance involves sustained public education and deed restrictions or covenants for privately-owned cells.
- Bioretention areas must be used carefully on slopes; terraces may be required for slopes >20%.
- The design should ensure vertical separation of at least 2' from the seasonal high water table.

This parking lot bioretention cell is being constructed with an impermeable liner and a perforated underdrain, to provide retention and treatment of runoff (but not infiltration).

Maintenance

- Bioretention requires careful attention while plants are being established and seasonal landscaping maintenance thereafter.
- In many cases, maintenance tasks can be completed by a landscaping contractor working elsewhere on the site.
- 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.

Cost

Bioretention areas require careful design and construction, the price of which will depend on site conditions and design objective. Generally, the cost of bioretention areas is less than or equal to that of a catch basin and underground chambers intended to treat the same area. Additionally, bioretention areas treat and recharge stormwater thereby reducing the amount/size of piping needed and the size of downstream basins and treatment structures.

Design Details

- Where bioretention areas are adjacent to parking areas, allow 3" of freeboard above ponding depth to prevent flooding.
- Determine the infiltrative capacity of the underlying native soil through an infiltration test using a double-ring infiltrometer. Do not use a standard septic system percolation test to determine soil permeability.
- Soil mix should be sandy loam or loamy sand with clay content less than 15%. Soil pH should generally be between 5.5-6.5, which is optimal for microbial activity and adsorption of nitrogen, phosphorus, and other pollutants. Planting soils should be 1.5-3% organic content and maximum 500ppm soluble salts.
- Planting soils should be placed in 1'-2' lifts, compacted with minimal pressure, until desired elevation is achieved. Some engineers suggest flooding the cell between each lift placement in lieu of compaction.
- Planting plan should generally include one tree or shrub per 50 s.f. of bioretention area, and at least 3 species each of herbaceous perennials, shrubs, and (if applicable) trees to avoid a monoculture.
- The bioretention landscaping plan should meet the requirements of any applicable local landscaping requirements.
- During construction, avoid excessive compaction of soils around the bioretention areas and accumulation of silt around the drainfield.
- In order to minimize sediment loading in the treatment area, only runoff from stabilized drainage areas should be directed to bioretention areas; construction runoff should be diverted elsewhere.

Additional References

Design Manual for Use of Bioretiention in Stormwater Management; Department of Environmental Resources, Prince George's County, MD; 1993.

Bioretention as a Water Quality Best Management Practice, Article 110 from Watershed Protection Techniques; Center for Watershed Protection; 2000 http://www.cwp.org/Downloads/ELC_PWP110.pdf

Storm Water Technology Fact Sheet, Bioretention, United States Environmental Protection Agency, Office of Water; 1999 http://www.lowimpactdevelopment.org/epa03/biospec. htm

Bioretention Fact Sheet, Federal Highway Administration www.fhwa.dot.gov/ environment/ultraurb/3fs3.html

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

United States
Environmental
Protection Agency

Constructed Treatment Wetlands

Natural wetland systems have often been described as the "earth's kidneys" because they filter pollutants from water that flows through on its way to receiving lakes, streams and oceans. Because these systems can improve water quality, engineers and scientists construct systems that replicate the functions of natural wetlands. Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality.

How do treatment wetlands work?

Natural wetlands perform many functions that are beneficial to both humans and wildlife. One of their most important functions is water filtration. As water flows through a wetland, it slows down and many of the suspended solids become trapped by vegetation and settle out. Other pollutants are transformed to less soluble forms taken up by plants or become inactive. Wetland plants also foster the necessary conditions for microorganisms to live there. Through a series of complex processes, these microrganisms also transform and remove pollutants from the water.

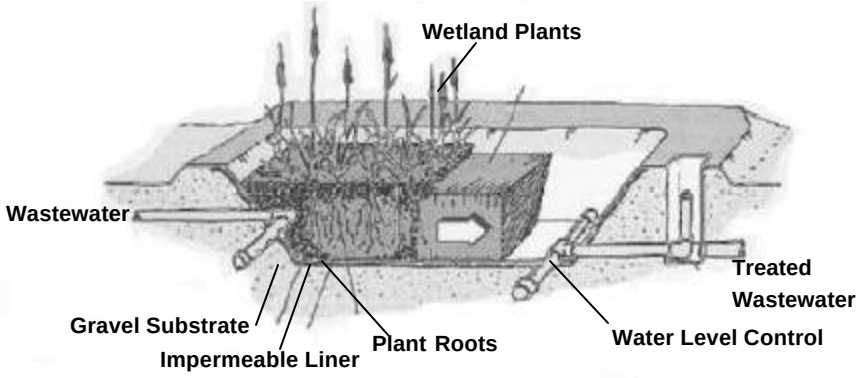
Nutrients, such as nitrogen and phosphorous, are deposited into wetlands from stormwater runoff, from areas where fertilizers or manure have been applied and from leaking septic fields. These excess nutrients are often absorbed by wetland soils and taken up by plants and microorganisms. For example, wetland microbes can convert organic nitrogen into useable, inorganic forms (NO_3 and NH_4) that are necessary for plant growth and into gasses that escape to the atmosphere.

Why build them?

Wetlands are some of the most biologically diverse and productive natural ecosystems in the world. While not all constructed wetlands replicate natural ones, it makes sense to construct wetlands that improve water quality and support wildlife habitat. Constructed wetlands can also be a cost-effective and technically feasible approach to treating wastewater. Wetlands are often less expensive to build than traditional wastewater treatment options, have low operating and maintenance expenses and can handle fluctuating water levels. Additionally, they are aesthetically pleasing and can reduce or eliminate odors associated with wastewater.

A Popular Idea

Designing and building wetlands to treat wastewater is not a new concept. As many as 5,000 constructed wetlands have been built in Europe and about 1,000 are currently in operation in the United States. Constructed treatment wetlands, in some cases involving the maintenance of important wetland habitat, have become particularly popular in the Southwest, where the arid climate makes the wetland habitat supported by these projects an especially precious resource.



Wetland plants and associated microorganisms treat wastewater as it flows through a constructed wetland system.

How are they built?

Constructed wetlands are generally built on uplands and outside floodplains or floodways in order to avoid damage to natural wetlands and other aquatic resources. Wetlands are frequently constructed by excavating, backfilling, grading, diking and installing water control structures to establish desired hydraulic flow patterns. If the site has highly permeable soils, an impervious, compacted clay liner is usually installed and the original soil placed over the liner. Wetland vegetation is then planted or allowed to establish naturally.

Design and Planning Considerations:

If planned and maintained properly, treatment wetlands can provide wastewater treatment and also promote water reuse, wildlife habitat, and public use benefits. Potentially harmful environmental impacts, such as the alteration of natural hydrology, introduction of invasive species and the disruption of natural plant and animal communities can be avoided by following proper planning, design, construction and operating techniques. The following guidelines can help ensure a successful project:

- Construct treatment wetlands, as a rule, on uplands and outside floodplains in order to avoid damage to natural wetlands and other aquatic resources, unless pretreated effluent can be used to restore degraded systems.
- Consider the role of treatment wetlands within the watershed (e.g., potential water quality impacts, surrounding land uses and relation to local wildlife corridors).
- Closely examine site-specific factors, such as soil suitability, hydrology, vegetation, and presence of endangered species or critical habitat, when determining an appropriate location for the project in order to avoid unintended consequences, such as bioaccumulation or destruction of critical habitat.
- Use water control measures that will allow easy response to changes in water quantity, quality, depth and flow.
- Create and follow a long-term management plan that includes regular inspections, monitoring and maintenance.

USDA, Natural Resources Conservation Service

This hog operation in Taylor County, Iowa, uses a wetland system constructed on a series of hillside terraces to filter and purify wastewater. Water quality tests indicated that the effluent from the treatment wetland was cleaner than that required for wastewater treatment plants.

Tres Rios Project Improves Water Quality

In 1990, city managers in Phoenix, Arizona, needed to improve the performance of their 91st Avenue Wastewater Treatment Plant to meet new water quality standards issued by the Arizona Department of Environmental Quality. After learning that upgrading their treatment plant might cost as much as $635 million, the managers started to look for a more cost-effective way to polish the treatment plant's wastewater discharge into the Salt River. A preliminary study suggested that the city consider a constructed wetland system that would polish effluent, while supporting high-quality wetland habitat for migratory waterfowl and shorebirds, including endangered species, and protecting downstream residents from flooding at a lower cost than retrofitting their existing treatment plant. As a result, the 12-acre Tres Rios Demonstration Project began in 1993 with assistance from the U.S. Army Corps of Engineers, the Bureau of Reclamation and EPA's Environmental Technology Initiative and now receives about two million gallons of effluent per day. The demonstration project was so successful that the city and the Bureau of Reclamation asked EPA for help in expanding the project to a full-scale, 800-acre project. For more information on the Tres Rios Constructed Wetlands Project, visit, http://phoenix.gov/TRESRIOS/

EPA 843-F-03-013
Office of Water
August 2004

Wetland Resources

Treatment Wetlands (2004), Robert H. Kadlec and Robert L. Knight, Lewis Publishers, Boca Raton, Fl.

Guiding Principles for Constructed Treatment Wetlands: Providing for Water Quality and Wildlife Habitat (2000), United States Environmental Protection Agency, EPA 843-B-00-003. Available online at www.epa.gov/owow/wetlands/constructed/guide.html

Constructed Wetlands Handbooks (Volumes 1-5): A Guide to Creating Wetlands for Agricultural Wastewater, Domestic Wastewater, Coal Mine Drainage and Stormwater in the Mid-Atlantic Region (1993-2000), United States Environmental Protection Agency. Available online at www.epa.gov/owow/wetlands/pdf/hand.pdf

Handbook for Restoring Tidal Wetlands (2000), Joy B. Zedler, CRC Press, Boca Raton, FL.

Stormwater Retrofit Techniques for Restoring Urban Drainages in Massachusetts and New Hampshire

Small MS4 Permit Technical Support Document, April 2011

Draft NPDES Permits Call for Stormwater Retrofits

The 2010 draft NPDES Small MS4 general permits for Massachusetts and New Hampshire (herein referred to as the draft permits) may require the retrofitting of existing unmanaged and/or inadequately managed stormwater runoff in impaired watersheds as summarized in **Table 1**. While new development is required to manage stormwater on-site, older developments may have been constructed before stormwater management was required or modern criteria were established. Retrofits include new installations or upgrades to existing Best Management Practices (BMPs) in developed areas where there is a lack of adequate stormwater treatment (**Figure 1**). Stormwater retrofit goals may include, among other things, the correction of prior design or performance deficiencies, flood mitigation, disconnecting impervious areas, improving recharge and infiltration performance, addressing pollutants of concern, demonstrating new technologies, and supporting stream restoration activities.

Table 1. References to Retrofit Requirements in the MA and NH Draft NPDES Permits.

Stormwater Retrofit Requirements	Draft NPDES Permit Section	
	NH	MA*
MS4s discharging to impaired waters with an approved TMDL must implement specific BMPs to meet reduction targets**	2.2.1; Appendix F	2.2.1; Appendix G
MS4s discharging to impaired waters without an approved TMDL must identify and implement BMPs to address impairment as part of their Stormwater Management Program (SWMP)	2.2.2	2.2.2
Increased discharges to impaired waters must provide additional BMPs or enhanced control of an existing discharge	--	2.3.1
Inventory and rank MS4-owned properties and infrastructure based on retrofit potential	2.3.6.8(b)	2.4.6.9(c)
Report on MS4-owned properties and infrastructure that have been retrofitted with BMPs	2.3.6.8(d)	2.4.6.9(d)
Design and install stormwater controls at municipal facilities, where needed, as part of the Stormwater Pollution Prevention Plan (SWPPP)	2.3.7.2	2.4.7.2

* MA permit sections listed are from the draft North Coastal Small MS4 General Permit
**Appendices F and G identify waste load targets for those small MS4s for which there are approved TMDLs.

Figure 1. Structural retrofits such as the bioretention, bioswale, and sand filter shown here can be used to capture, treat, and/or infiltrate unmanaged runoff. Public open space and large parking lots are common retrofit locations.

Retrofitting to Meet Total Maximum Daily Load (TMDL) Reductions

MS4s discharging to impaired watersheds with approved TMDLs may now be required to retrofit existing development in order to meet pollutant reduction targets. Draft permit appendices F and G for New Hampshire and

Massachusetts, respectively, provide a listing of small MS4s subject to approved TMDLs and their respective load reduction targets and permit requirements.

Retrofitting the Charles River Watershed
(draft MA North Coastal permit, Section 2.2.1(d))

MS4s within the Charles River or within its tributary watershed must also develop Phosphorus Control Plans (PCPs) that identify, prioritize, and provide design/construction schedules for the structural and non-structural control measures necessary to reduce Total Phosphorous (TP). Structural control measures include practices that reduce or disconnect impervious cover, enhance infiltration, or otherwise treat stormwater. Non-structural measures include pollution prevention and source control activities (e.g., street sweeping). Permittees must also estimate costs and identify third party implementers in the PCP.

Progress on development of the PCP must be reported by the MS4 in the second year NPDES annual report. Implementation of the PCP must start no later than four years from the effective date of the NPDES permit and be completed within 10 years. Beginning one year after implementation of the PCP, the permittee must begin estimating annual TP load reductions based on implementation.

The Stormwater Retrofit Process

A widely accepted approach (Schueler et al., 2007) to stormwater retrofitting at the small watershed scale is summarized in brief below:

1 Evaluate local need and capacity for retrofitting in your MS4. Determine if your jurisdiction falls within the Charles River Watershed or other TMDL watersheds, and identify your pollutant reduction requirements. If there are redevelopment projects in the planning stage, identify any federal, state and local requirements for improving on-site stormwater management. Have you already conducted a retrofit inventory?

2 Using GIS, institutional knowledge and blueprints as appropriate, identify potential retrofit locations at publicly-owned properties (e.g., parks, schools, and municipal maintenance yards), street rights-of-way, culverts/outfalls, and existing detention practices. Target large parking lots, rooftops, or other impervious areas (public or privately-owned) that lack stormwater management and are considered directly connected to the MS4. Identify sites that are prone to flooding, chronic contamination, and/or have a high maintenance burden (**Figure 2**).

3 Conduct a retrofit investigation by visiting each location to verify current conditions and identify potential retrofit treatment options and constraints. Use this opportunity to verify if impervious cover on site is directly-connected to the MS4 or disconnected. Eliminate sites where retrofitting is infeasible or impractical due to existing constraints (e.g., land use, environmental conditions, presence of utilities, or other limitations).

4 Develop an inventory of potential retrofit candidates, with illustrative concept sketches, site photos, and basic drainage calculations (**Figure 3**).

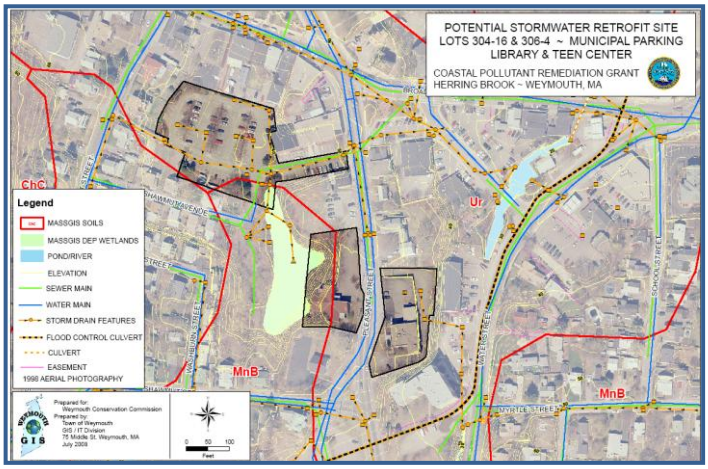


Figure 2. Mapping analysis used to identify potential locations for retrofits in Weymouth, MA showing aerial imagery, parcel ownership, stormwater infrastructure and utilities, topography, soils, and hydrology. The MassGIS and NH's GRANIT websites are good sources of GIS data and can be found at www.mass.gov/mgis/ and www.granit.unh.edu/, respectively.

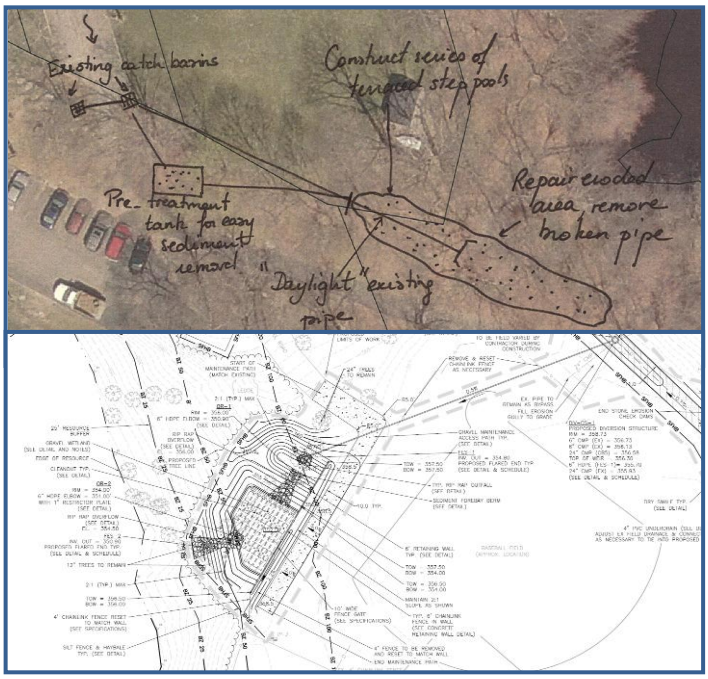


Figure 3. Concept sketches can be done by hand. Once priorities have been identified, concepts can be further advanced to engineering design and construction plans.

5 Evaluate and rank retrofit concepts based on predetermined factors such as pollutant reduction requirements, BMP feasibility and performance, impervious cover disconnection, cost, visibility, property ownership, and community support.

The draft permits require an inventory and ranking of all MS4-owned properties and infrastructure for retrofit potential within two years of the effective date of the permit.

6 Model watershed treatment benefits for various implementation scenarios to help determine the most cost-effective approaches to implementation. There are a number of existing public models that could be used to assist in the evaluation of implementation scenarios, such as the Center for Watershed Protection's Watershed Treatment Model (WTM), Pitt and Voorhees' Source Loading and Management Model (SLAMM), or EPA's new System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN) developed by TetraTech. These models can be uploaded at www.cwp.org; www.winslamm.com/; and www.epa.gov/ednnrmrl/models/sustain/index.html.

MS4s in the Charles River Watershed subject to Phosphorous Control Plans must establish 2010 baseline Total Phosphorous Loads, and report annual load reductions based on retrofit implementation pursuant to Sections 2.2.1(vi) and 2.2.1(x) of the draft MA North Coastal permit.

7 Take the top projects to final design and construction stages (**Figure 4**). Allow additional time to complete site surveys, necessary state and local permitting, contractor bidding and specifications, and, in some cases, generate public support. The time required to secure implementation funding will likely vary depending on the primary source of funds (i.e., stormwater utility, general or capital budgets, or grants).

Beginning with the third year annual report, permittees will be required to report on completed retrofit projects. Permittees are encouraged to also report non-MS4 and private sector retrofit projects.

8 Provide inspection and maintenance services for the life of the retrofit (**Figure 5**). MS4 programs should establish a BMP tracking system to ensure long-term maintenance of existing and retrofitted facilities.

Figure 4. As an example of a priority retrofit taken to final design and construction, this shows the installation of a bioretention facility at a nature center in Massachusetts.

Figure 5. Ensuring the long-term maintenance of sand filters, swales, bioretention facilities, and other BMPs is a critical component of a municipal stormwater management program.

Do the Performance Objectives for Retrofits and New Developments Differ?

Yes. In the draft small MS4 general permits for MA and NH, the primary objective for new development is to achieve a condition of pre-development hydrology. As a practical matter, this can be accomplished by preventing a discharge from the 90th percentile storm (about a one-inch rainfall event in Massachusetts and New Hampshire). In contrast, the primary objective for a retrofit is to improve the hydrology of an existing site and reduce the discharge of stormwater as much as possible. In many cases, retrofits provide an opportunity to remedy past design and/or performance deficiencies.

Are Certain Structural Practices Preferred?

Yes. While all retrofit sites are unique and no single solution fits all, in general, preferred practices are those that provide for increased infiltration, evapotranspiration and rainwater harvesting because these practices reduce stormwater runoff volume while also providing water quality benefits. Retrofits that provide for infiltration (e.g., infiltration basins and trenches, bioretention systems, rain gardens, and swales) where little or no infiltration currently exists are likely to improve site hydrology. Infiltration practices also help to recharge groundwater aquifers, although practices located near public drinking water sources should carefully consider the impact of infiltrating stormwater discharges on drinking water sources.

Depending on the water quality/TMDL goals for the watershed, permittees should also consider retrofitting existing BMPs to maximize pollutant removal. The retrofitting of dry detention ponds, for instance, may provide the most cost-effective approach to capture and treat large drainage areas.

Where Can We Find BMP Performance Efficiencies?

Both the Massachusetts and New Hampshire Stormwater manuals include pollutant removal efficiencies for various stormwater practices. These can be found at www.mass.gov/dep/water/laws/policies.htm#storm and des.nh.gov/organization/divisions/water/stormwater/manual.htm, respectively.

Other reliable sources of pollutant removal rates can be found in Appendix D of Schueler et al. (2007), the University of Massachusetts at Amherst, Stormwater Technologies Clearinghouse at www.mastep.net/, or the University of New Hampshire Stormwater Center at www.unh.edu/erg/cstev/.

Where Can I go for More Permit Information?

For more information regarding the new permit requirements for Massachusetts and New Hampshire, go to: www.epa.gov/ne/npdes/stormwater/index.html

Load reduction targets for small MS4s in Massachusetts and New Hampshire that are subject to approved TMDLs are available at:
www.epa.gov/ne/npdes/stormwater/ma/Appendix-G-Small-MS4-MA.pdf

www.epa.gov/ne/npdes/stormwater/nh/Appendix-F-Small-MS4-NH.pdf

Additional Retrofitting Resources

Charles River Watershed BMP Factsheets
www.crwa.org/projects/stormwater/stormwaterBMPs.html

Rhode Island Stormwater Design and Installation Manual. 2010.
www.dem.ri.gov/programs/benviron/water/permits/ripdes/stwater/pdfs/desgnmnl.pdf

Schueler, T., Hirschman, D., Novotney, M., and J. Zielinski. 2007. Urban Watershed Restoration Manual No. 3: Urban Stormwater Retrofit Practices.
www.cwp.org/

USEPA Webcast Series: The Art and Science of Stormwater Retrofitting.
www.epa.gov/npdes/outreach_files/webcast/apr0908/107156_od/107156_od.html

Municipal Retrofit Case Studies

Catskill Watershed Corporation- Stormwater Retrofit Grant Program
www.cwconline.org/programs/strm_wtr/strm_wtr1.html#retro

Center for Landuse Education and Research (CLEAR), University of Connecticut, Eagleville Brook TMDL and Retrofit Project website:
www.clear.uconn.edu/eagleville/Eagleville_TMDL/Home.html

Charlottesville, VA - Stormwater Stewardship on Public Lands Program
www.charlottesville.org/index.aspx?recordid=259&page=635

Massachusetts Institute of Technology (MA) - Stata Center web.mit.edu/environment/ehs/topic/stata.html

Montgomery County, MD - Rainscapes Program
www.montgomerycountymd.gov/dectmpl.asp?url=%5Ccontent%5Cdep%5Cwater%5Crainscapes.asp

Portland, OR - Clean River Rewards Program
www.portlandonline.com/BES/index.cfm?c=edeef

Portland, OR - Downspout Disconnection Program
www.portlandonline.com/BES/index.cfm?c=edaib

Sanitation District No. 1 of Northern Kentucky- Public Service Park. www.sd1.org/

Seattle, WA - Natural Drainage Systems Program
www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/GreenStormwaterInfrastructure/NaturalDrainageProjects/index.htm

Villanova University - Best Management Practice Demonstration Park www3.villanova.edu/VUSP/