Chapter 1
The Three Components of Stormwater Management

The most effective stormwater management plans include a comprehensive program of activities and controls, including prudent site design, aggressive pollution prevention, source control measures, and well-designed structural BMPs keyed to meeting a particular stormwater management standard, along with regular operation and maintenance of the BMPs. The best stormwater management plans are those that simulate natural hydrologic conditions, by gradually recharging groundwater and slowing runoff that flows to collection systems and receiving waters. To meet the Stormwater Management Standards, a project proponent needs to consider the following three stormwater management components in this order of priority:

- **Site Planning: Design the development using environmentally sensitive site design and low impact development techniques to preserve natural vegetation, minimize impervious surfaces, slow down times of concentration, and reduce runoff;**
- **Source Controls, Pollution Prevention, and Construction Period Erosion and Sediment Control:** Implement nonstructural measures to prevent pollution or control it at its source; and
- **Structural BMPs: Design, construct and maintain structural BMPs to attenuate peak flows, capture and treat runoff, and provide recharge to groundwater.**

Applicants select the best combination of control measures to meet the Stormwater Management Standards. The most cost-effective approach relies on the site planning and the nonstructural approaches discussed in this chapter. Maintaining pre-development hydrologic conditions through proper site planning and nonstructural approaches that preserve natural vegetation and prevent erosion and sedimentation is a highly effective pollution prevention strategy. By reducing or eliminating the need for structural BMPs, this approach results in a well-designed development with a stormwater management system that suits the land and minimizes costs.

A. Site Planning

Integrating comprehensive stormwater management into the site development process from the outset is the most effective approach for reducing and preventing potential pollution and flooding problems. Early stormwater management planning will generally minimize the size and cost of structural solutions. Stormwater management efforts which incorporate structural BMPs into the site design at the final stages frequently result in the construction of unnecessarily large and costly facilities, which may fail due to improper design, siting, engineering, operation or maintenance.

Who Does Site Planning for Stormwater?

Site planning is the responsibility of the project proponent. Certain components of site planning may require technical expertise (e.g., hydrology, engineering, landscaping), and in such cases, professional consultants and/or design engineers should do comprehensive site planning. Before and during the permit review process, collaborative efforts among various parties, including developers, consultants, technical staff, planning boards, and conservation commissions, frequently lead to final design plans that meet mutual goals.

Who Reviews Site Plans for Stormwater Management?
In most cases, site plan review, including review of the stormwater management system, is conducted at the local level by planning boards under the authority of the Subdivision Control Act or local regulations. Local zoning bylaws, for example, may establish special requirements for additional review through zoning districts or special permits that may require more stringent protection than the Stormwater Management Standards. If the project involves activity within a wetland resource area or associated Buffer Zone, the site design is subject to review by the conservation commission. If the Order of Conditions issued by the conservation commission is appealed, MassDEP reviews the project. The *Massachusetts Nonpoint Pollution Source Management Manual* (http://www.mass.gov/eea/agencies/massdep/water/watersheds/nonpoint-source-pollution.html#2) published by MassDEP (2006) provides additional information on site plan review and stormwater planning.

Careful site designs minimize the size and related material, construction, and maintenance costs of structural stormwater controls. Site planning should include the preparation of accurate and complete site plan maps and narratives. Stormwater controls must be developed for both construction activities and post-construction conditions. If the project is subject to review under the Wetlands Protection Act, the construction and post-construction controls should be addressed separately in the plans and narrative descriptions provided with the Notice of Intent under the Wetlands Protection Act.

What is Environmentally Sensitive Site Design?
Conventional development strategies treat stormwater as a secondary component of site design, usually managed with “pipe-and-basin” systems that collect rainwater and discharge it off-site. In contrast, environmentally sensitive site design embraces hydrology as an integrating framework for site design, not a secondary consideration. Existing conditions influence the location of roadways, buildings, and parking areas, as well as the nature of the stormwater management system. Environmentally sensitive site design is a multi-step process that involves identifying important natural features, placing buildings and roadways in areas less sensitive to disturbance, and designing stormwater management systems that create relationships between development and natural hydrology. The attention to natural hydrology, stormwater “micromanagement,” nonstructural approaches, and vegetation results in a more attractive, multifunctional landscape with development and maintenance costs comparable to or less than conventional strategies that rely on pipe-and-basin approaches.

Landscaping is an important component of environmentally sensitive site design. Ecological landscaping strategies seek to minimize the amount of lawn area and enhance the property with native, drought-resistant species; as a result, property owners use less water, pesticides, and fertilizers.[1] The maintenance of vegetated buffers along waterways can also enhance the site and help protect water quality.

What Types of Development Can Accommodate Environmentally Sensitive Site Design?
Environmentally sensitive site design can be applied to both residential and nonresidential developments as well as redevelopment projects. Environmentally sensitive site design begins with assessing the environmental and hydrologic conditions of a site and identifying important natural features such as streams and drainage ways, floodplains, wetlands, water supply

[1] See More Than Just a Yard Ecological Landscape Tools for Massachusetts Homeowners. See http://www.mass.gov/envir/mwrc/pdf/More_Than_Just_Yard.pdf.

protection areas, high-permeability soils, steep slopes, erosion-prone soils, woodland conservation areas, farmland, and meadows. This investigation helps to determine which "conservation areas" should be protected from development and construction impacts, and which site features (such as natural swales) should be incorporated into the stormwater management system.

The site analysis also identifies a "development envelope" where development can occur with minimal impact to hydrology and other ecologic, scenic, or historic features. In general, the development envelope includes upland areas, ridge lines and gently sloping hillsides, and slowly permeable soils outside of wetlands, leaving the remainder of the site in a natural undisturbed condition. It is important to protect mature trees and to limit clearing and grading to the minimum amount needed for buildings, access, and fire protection. Converting wooded areas to lawns increases the volume of runoff that must be managed.[2] The design should confine construction activity, including stockpiles and storage areas, to those areas that will be permanently altered, and clearly delineate the construction fingerprint.

What are the Most Common Environmentally Sensitive Site Design Techniques?
Specific environmentally sensitive site design techniques that minimize the creation of new runoff, enhance groundwater recharge, and remove suspended solids include minimizing impervious surfaces, fitting the development to the terrain, preserving and capitalizing on natural drainage systems, and reproducing pre-development hydrologic conditions. Each technique is discussed in detail below.

Minimize Impervious Surfaces
Replacing natural cover and soils with impervious surfaces leads to increased runoff volume and velocity, larger pollutant loads, and may adversely affect long-term hydrology and natural systems through flooding and channel erosion. Research demonstrates a marked drop in fish, amphibian, and insect species when the percent imperviousness within a watershed exceeds 15%.

Careful site planning can reduce the impervious area created by pavement and roofs and the volume of runoff and pollutant loading requiring control. Moreover, as the impervious surface area of a development increases, the size and expense of the stormwater control facilities also increase. Minimizing impervious surfaces mitigates this problem. Local zoning codes and development standards, such as those addressing road widths or cluster zoning, affect the amount of runoff generated by projects. Development practices that fail to minimize impervious surfaces rely on extensive conveyance networks to discharge stormwater runoff into receiving waters and adversely impact water quality.

[Note: To ensure a reliable source of safe drinking water, it is essential that impervious areas be minimized in certain recharge areas. To further that goal, the Massachusetts Drinking Water Regulations (310 CMR 22.00) require that municipalities proposing new groundwater sources for the public water system enact land use controls that prohibit land uses within the Zone II that render impervious more than 15% square feet of a lot, or 2,500 square feet, whichever is greater, unless a system for artificial recharge of precipitation is provided that will not result in the

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[2] Converting wooded areas to lawns increases the peak volume of runoff that must be attenuated in accordance with Standard 2. Standard 4 requires proponents that convert wooded areas to lawns to include proper management of fertilizers, herbicides, and pesticides in their pollution prevention plan. The EPA lists urban forestry as a stormwater management BMP. See http://cfpub1.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=min_measure&min_measure_id=5

degradation of groundwater quality. The Drinking Water Regulations impose a similar requirement on municipalities proposing new surface water sources.]

Common approaches that proponents can take to minimize impervious surfaces include:

- *Maintain as much of the pre-development vegetation as possible*, especially larger trees that may be on site. Vegetation absorbs water and reduces the amount of stormwater runoff. Proponents should locate structures to minimize shading effects on vegetation and roots and protect them from damage during the construction phase.
- *Maintain natural buffers and drainage ways.* Natural buffers located between development sites and wetlands infiltrate runoff, reduce runoff velocity, and remove some suspended solids. Natural depressions and channels act to slow and store water, promote sheet flow and infiltration, and filter pollutants.
- *Minimize the creation of steep slopes.* Steep slopes have significant potential for erosion and increase sediment loading. Avoid using slopes greater than 2:1.
- *Minimize placement of new structures or roads over porous or erodible soils:* Porous soils provide the best and most inexpensive mechanism for infiltrating stormwater, reducing runoff volume and peak discharges, and providing groundwater recharge and treatment by infiltration and adsorption through the soil strata. Proponents should avoid disturbing unstable soils that are likely to erode.
- *Reduce frontage and other setbacks.*
- *Modify Zoning to Allow Planned Unit Developments* that limit the density of development while maximizing the amount of undisturbed open space and *Cluster Developments* that cluster or group buildings closer together to maximize the amount of undisturbed open space.
- *Reduce the horizontal footprint of buildings and parking areas.* Footprint size can be reduced by constructing a taller building, including parking facilities within the building itself, while maintaining the same floor to area (FAR) ratio.
- *Reduce to one lane*, or eliminate if practical, on-street parking lanes on local access roads.
- *Limit sidewalks to one side*, or eliminate if practical, on local low-traffic roads.
- *Use shallow grass channels or water quality swales with check dams to manage runoff and snowmelt from roads and parking lots.* Guidelines for the use of grass channels and water quality swales are found in Chapter 2 of this Volume.
- *Use porous pavement* when possible for sidewalks, driveways, transition areas between pavement edge and swales, or overflow parking areas.

<u>Fit the Development to the Terrain</u>
Match road patterns to land forms. For example, in rolling terrain, local streets should branch from collector streets, ending in short loops or cul-de-sacs along ridgelines. Grids may be more appropriate in areas where the topography is characteristically flat. Preserve natural drainage ways by interrupting and bending the road grid around them. Grass channels or water quality swales can be constructed along street right-of-ways or on the back of lots to convey runoff without abrupt changes in the direction of flow.

<u>Preserve and Use Natural Drainage Systems</u>
The standard approach of using curbing on streets and parking areas impairs natural drainage systems. Curbs are widely held to be the signature of quality development; they provide a neat, “improved” appearance and also help delineate roadway edges. Because curb-and-gutter streets

trap runoff in the roadbed, storm inlets and drains are logical solutions to providing good drainage for the roadbed.

Unfortunately, a requirement for curb-and-gutter streets can create significant stormwater management problems. Because storm drains operate on gravity flow, their efficiency is maximized if they are located in the lowest areas of the site. Storm drain pipes are usually located in valleys and low areas, destroying natural drainage ways. Natural filtration and infiltration capacities are lost in the most strategic locations.

Further, in most instances, storm drains are designed for short-duration, high-frequency storms (1-hour duration with 2, 5, or 10-year return periods) and not for flood flows (24-hour duration, 50 and 100-year return period), which are handled by street and gutter flows after the storm drain capacity is exceeded. The result is that the natural drainage ways are converted from slow moving, permeable, absorptive, vegetated waterways to fast moving, impervious, self-cleaning, paved waterways, thereby increasing hydraulic efficiency, peak discharges and flood volumes.

Natural waterways that are paved and specifically designed to be quickly drained by culverted stormwater management systems minimize channel storage times as well as reduce base flows and groundwater recharge. When examined in the context of environmentally sensitive site design, the net effect of the seemingly beneficial decision to use curbs can initiate a snowball effect that amplifies the extremes in the hydrologic cycle, increasing flood flows and reducing base flows.

Curb-and-gutter developments also affect water quality. Trace metals from automobile emissions and hydrocarbons from automobile crankcase oil and fuel spillage are directly deposited on paved surfaces. For the most frequent rainfalls, the first flush of stormwater runoff washes these deposits into the storm drain system, which is designed to keep in suspension the particles to which the pollutants adhere. The particles, together with their attached pollutants, are delivered via the runoff water to receiving waters where reductions in velocity permit them to settle out. Nutrient-rich runoff from surrounding lawns quickly moves through the paved system with no opportunity to come into contact with plant roots and soil surfaces. The result is rapid delivery of contaminants to lakes, streams, estuaries, and wetlands.

If natural vegetated drainage ways are preserved, flood volumes, peak discharges, and base flows can be maintained at pre-development levels. Trace metals, hydrocarbons, and other pollutants will bind to the underlying soils and organic matter. The infiltration process allows separation of the nutrients and other contaminants from the stormwater as it percolates through the subsurface soils.

<u>Reproduce Pre-development Hydrologic Conditions</u>

The goal of matching pre-development hydrologic conditions should be addressed at the site planning level. The full spectrum of hydrologic conditions, including peak discharge, runoff volume, infiltration capacity, base flow levels, groundwater recharge, and maintenance of water quality, can be examined through a comprehensive approach involving the entire site and even offsite areas contributing runoff to the site. Peak discharges, runoff volume, infiltration recharge, and water quality are directly related to the amount and location of impervious area required by development plans.

Past efforts focused on the reduction of the frequency and severity of flooding, primarily by lowering peak discharges to match pre-development levels with adequate storage (e.g., detention systems). Some waterways were deliberately designed to increase runoff removal with higher flow rates and smooth conveyances (e.g., storm drains, paved gutters, and waterways) so as to be self-cleaning, while ignoring infiltration and water quality issues. MassDEP does not recommend implementing these "solutions".

Standard 3 of the Stormwater Management Standards requires that proponents preserve infiltration at predevelopment levels in order to maintain base flow and groundwater recharge. Along with adequate pretreatment, infiltration of stormwater through the soil will generally remove pollutants and sediments and improve water quality.

Are there Limitations to Environmentally Sensitive Site Design?
Some environmentally sensitive site designs that seek to cluster development and reduce lot coverage may conflict with local land use regulations or public perceptions about what type of development is desirable.[3] For example, a compact multi-story building may be more visible than a single-story building with a larger footprint. To address this problem, developers, advocates and regulators who recognize the value of environmentally sensitive site design must educate the public.

Integrating Site Design, Pollution Prevention, and Structural BMPs
The time to integrate source controls and pollution prevention measures into the stormwater management system is during site design. During the planning process, a proponent should consider source control and pollution prevention measures, such as placing a roof over a fueling area or landscaping to minimize the need for fertilizers. These measures can reduce the requirements for stormwater control, prevent the discharge of pollutants to receiving waters, and result in substantial cost-savings.

During the site planning process, proponents should also consider the locations of structural BMPs and the need to provide ongoing access to those BMPs for maintenance. Some BMPs, such as infiltration basins, have specific site and construction requirements. The proponent should identify site constraints, such as depth to groundwater and nearby septic systems or wells, so the BMP will not fail or adversely affect on-site septic systems or wells.

Site planning can help identify the most appropriate points to direct discharges from BMPs. To avoid erosion and prevent system failure, proponents should locate discharge points on low slopes and stable soils away from the edges of wetlands. Where suitable, developers should use infiltration trenches for surface runoff and dry wells for uncontaminated runoff from non-metal roofs. The stormwater management system should be designed to separate the collection and treatment of contaminated and uncontaminated runoff.

The costs of rehabilitating or retrofitting failed stormwater management systems can be significant. These costs can be avoided by addressing stormwater runoff from the start. With careful planning, a proponent can design a stormwater management system that meets the Stormwater Management Standards, reduces the cost of stormwater management, facilitates long-term maintenance, and enhances the marketability and aesthetic qualities of the development.

Additional Resources and Links for Environmentally Sensitive Site Design:

[3] The Metropolitan Area Planning Council has developed a checklist that allows local communities to determine whether their local bylaws and ordinances prevent the use of environmentally sensitive design. See http://www.mapc.org/regional_planning/LID/LID_codes.html

Low Impact Development Design Strategies: An Integrated Design Approach; Prince George's County, Maryland, Department of Environmental Resources; June 1999. (available at http://www.epa.gov/owow/nps/lid/)

Better Site Design: A Handbook for Changing Development Rules in Your Community; Center for Watershed Protection; 1998. Site Planning for Urban Stream Protection; Thomas Schueler; Center for Watershed Protection; 1995.

Conservation Design for Subdivisions: A Practical Guide for Creating Open Space Networks; Randall Arendt; Island Press; 1996.

"Site Analysis." James A. LaGro, Jr.; John Wiley and Sons; 2001 *An Introduction to Better Site Design*; Article 45 from Watershed Protection Techniques; Center for Watershed Protection; 2000.

B. Nonstructural Approaches: Source Control and Pollution Prevention

Source controls can reduce the types and concentrations of contaminants in stormwater runoff and improve water quality. Source controls cover a wide range of practices including local bylaws and regulations, materials management at industrial sites, fertilizer and pest management in residential areas, reduced road salting in winter, erosion and sediment controls at construction sites, and comprehensive snow management.

Effective site planning is essential to source control and pollution prevention. Reducing impervious surfaces and runoff volumes prevents the transport of pollutants. The guiding principle for pollution prevention is to minimize the volume of runoff and the contact of stormwater with potential pollutants. Because nonstructural practices can reduce stormwater pollutant loads and quantities, the size and expense of structural BMPs (or in rare cases, even the need for structural BMPs) can be reduced, thereby affording substantial cost savings.

The *Massachusetts Nonpoint Pollution Source Management Manual* (http://www.mass.gov/eea/agencies/massdep/water/watersheds/nonpoint-source-pollution.html#2) published by MassDEP (2006) provides a detailed summary of the pollutants associated with specific land use activities. These summaries can be used to identify the potential pollutants at a site, so that suitable controls can be implemented.

Street and Parking Lot Sweeping

One effective nonstructural source control is street and parking lot sweeping. Many municipalities and some private entities (e.g., commercial shopping areas or office parks) have street sweeping programs. Although intended to provide important nonpoint source pollution control, many street sweeping programs are not effective at capturing the peak sediment loads.

The NURP study (EPA, 1983) indicates that sweeping streets once a year using rotary brush sweepers resulted in no TSS removal. A study conducted by the USGS (Smith, 2002) along the Southeast Expressway in Boston indicates that sweeping yielded a net increase in sediment, because the road shoulder was not stabilized and contributed more sediment to the Southeast Expressway than the sweepers could remove.

There are many reasons that some street sweeping programs are not effective.

- The period immediately following winter snowmelt, when road sand and other accumulated sediment and debris is washed off, is frequently missed by street sweeping programs.
- Larger particles of street dirt may prevent smaller particles from being collected.
- The entire width of roadway may not be swept.
- Sweepers may be driven too quickly to achieve maximum efficiency.
- Land surfaces along the paved surfaces may not be entirely stabilized.

Other studies have shown that if done properly, street sweeping can be highly effective. Breault 2005 indicates that sweepers can achieve high removal efficiencies. That study assessed total solids removal, and included large particles. Zarriello 2002 verified the effectiveness of high efficiency sweepers.

There are three factors in particular that can have a major influence on the effectiveness of a street sweeping program: **access, the type of sweeper, and the frequency of sweeping**.

Effective sweeping requires access to the areas to be swept. Parked cars impede street sweeping. Studies have shown that up to 95% of the solids on a paved surface accumulate within 40 inches of the curb, regardless of land use. It is essential that applicants or those responsible for stormwater maintenance have the ability to impose parking regulations to facilitate proper sweeping, particularly in densely populated or heavily traveled areas, so that sweepers can get as close to curbs as possible.

A good street sweeping program requires an efficient sweeper. There are three types of sweepers: Mechanical, Regenerative Air, and Vacuum Filter. Each has a different ability to remove TSS.

- Mechanical: Mechanical sweepers use brooms or rotary brushes to scour the pavement. Although most of the sweepers currently in use in Massachusetts are mechanical sweepers, they are not effective at removing TSS (from 0% to 20% removal). Mechanical sweepers are especially ineffective at picking up fine particles ("fines") (less than 100 microns).
- Regenerative Air: These sweepers blow air onto the road or parking lot surface, causing fines to rise where they are vacuumed. Regenerative air sweepers may blow fines off the vacuumed portion of the roadway or parking lot, where they contaminate stormwater when it rains.
- Vacuum filter: These sweepers remove fines along roads. Two general types of vacuum filter sweepers are available - wet and dry. The dry type uses a broom in combination with the vacuum. The wet type uses water for dust suppression. Research indicates vacuum sweepers are highly effective in removing TSS. The best ones (in terms of pollutant removal efficiencies) typically cost about $240,000 to $310,000.

Regardless of the type chosen, the efficiency of street sweeping is increased when sweepers are operated in tandem.

The frequency of sweeping is a major factor in determining efficiency. Unlike other stormwater treatment practices that function whenever it rains, street sweeping only picks up street dirt when streets and parking lots are actually swept. TSS removal efficiency is determined based on annual loading rates. If a road were swept only once a year with a sweeper that is 100% efficient, it would remove only a small fraction of the annual TSS load.

Street dirt accumulates on roads and parking lots and runs off in response to precipitation. The average interval between precipitation events in Massachusetts is approximately 3 days. Therefore, the hypothetical maximum effectiveness for street dirt removal requires sweeping at least once every 3 days, with a street sweeper with 100% efficiency at removing solids on paved surfaces before they become suspended. Modeling studies by Claytor (1999) in the Pacific Northwest suggest that optimum pollutant removal occurs when surfaces are swept every two weeks.

Because street sweeping may be an effective source reduction tool, a credit towards the 80% TSS removal standard *may* be available. ***At the discretion of the issuing authority**, a street sweeping program is eligible to receive credit towards the 80% TSS removal standard as set forth in the Table SS 1.*

TSS REMOVAL CREDITS FOR STREET SWEEPING

Table SS 1

TSS Removal Rate	High Efficiency Vacuum Sweeper – Frequency of Sweeping	Regenerative Air Sweeper – Frequency of Sweeping	Mechanical Sweeper (Rotary Broom)
10%	Monthly Average, with sweeping scheduled primarily in spring and fall.	Every 2 Weeks Average, with sweeping scheduled primarily in spring and fall.	Weekly Average, with sweeping scheduled primarily in spring and fall.
5%	Quarterly Average, with sweeping scheduled primarily in spring and fall.	Quarterly Average, with sweeping scheduled primarily in spring and fall.	Monthly Average, with sweeping scheduled primarily in spring and fall.
0%	Less than above	Less than above	Less than above

Street sweeping is not recommended as a practice to receive a TSS removal credit for post-construction period runoff, if the road or parking lot shoulders are not stabilized.

All TSS Removal Credits shown in Table SS 1 assume that the sweeping program gives special attention to sweeping paved surfaces in March/April before spring rains wash residual sand from winter applications into streams. If this assumption is not correct, the issuing authority should reduce the TSS removal credit by 50%.

Planning Considerations

In deciding whether street sweeping is an effective option, consider factors such as whether road and parking lot shoulders are stabilized, the speed at which the sweepers will need to be driven (safety factor such as along a highway), whether access is available to the curb (whether vehicles parked along the curb line will preclude sweeping of the curb line), the type of sweepers, and whether the sweepers will be operated in tandem. Municipalities or private developers that are planning to purchase a new street sweeper should consider vacuum sweepers, because they are most consistently effective.

Maintenance

Reuse and Disposal of Street Sweepings

Once removed from paved surfaces, the sweeping must be handled and disposed of properly. MassDEP's Bureau of Waste Prevention has issued a written policy regarding the reuse and disposal of street sweepings. These sweepings are regulated as a solid waste, and can be used in three ways:

- In one of the ways already approved by MassDEP (e.g., daily cover in a landfill, additive to compost, fill in a public way)
- If approved under a Beneficial Use Determination
- Disposed in a landfill

MassDEP provides guidance and standards for handling, reusing, and disposing of street sweepings. (For more information, go to: http://www.mass.gov/eea/docs/dep/recycle/laws/stsweep.pdf)

Sources:

- American Sweeper Magazine. Non-peer review magazine. Link: http://www.nasweeper.com/
- Bannerman, Roger, 1999, Sweeping Water Clean, American Sweeper Magazine, Volume 7, Number 1.
- Breault, Robert F., Smith, Kirk P. and Sorenson, Jason R., 2005, Residential Street-Dirt Accumulation Rates and Chemical Composition, and Removal Efficiencies by Mechanical-and Vacuum-Type Sweepers, New Bedford, Massachusetts, 2003–04
- U.S. Geological Survey, Scientific Investigations Report 2005-5184, http://pubs.usgs.gov/sir/2005/5184/
- Brinkmann et al, 1999, Chemical and Physical Characteristics of Street Sweeping Sediments in Tampa, Florida, http://www.hinkleycenter.com/publications/characteristics_of_street_sweeping_98-12.pdf
- California Department of Transportation, Fact Sheet SC-7, 2003: http://www.dot.ca.gov/hq/construc/stormwater/SC-07.pdf
- Center for Watershed Protection, Pollution Prevention Fact Sheet: Parking Lot and Street Cleaning, http://www.stormwatercenter.net/Pollution_Prevention_Factsheets/ParkingLotandStreetCleaning.htm
- Fitz, D.R., 1998, Evaluation of Street Sweeping as a PM10 Control Method. *Other Documents and Presentations.* Final Report to the South Coast Air Quality Management District under Contract 96018, January. 98-AP-RT4H-005-FR.
- Hamilton, City of, Ontario, Canada, 1998, unpublished study, http://www.cleanair.hamilton.ca/about/sweeping.asp
- Keating, Janis, 2002, Street Sweepers, Picking Up Speed and Quieting Down, Keating, Stormwater - The Journal for Surface Water Quality Professionals, http://www.forester.net/sw_0207_street.html
- Martinelli, Thomas J., Waschbusch, R.J., Bannerman, R.T., Wisner, A., 2002, Pollutant Loadings to Stormwater Run-off from Highways: the Impact of a Freeway Sweeping Program, Wisconsin Department of Transportation, Research Project ID # 0092-45-82, Report WI-11-01, http://www.dot.wisconsin.gov/library/research/docs/finalreports/45-82sweeping-f.pdf and http://www.dot.wisconsin.gov/library/research/docs/briefs/45-82freewaysweeping-b.pdf
- Metropolitan Council, 1999, Best Practices for Street Sweeping, American Sweeper Magazine, Volume 7, Number 1: http://www.worldsweeper.com/Street/BestPractices/bestpract.html

- Massachusetts Department of Environmental Protection, DEP Policy BWP 94-092 - Reuse and Disposal of Street Sweepings, http://www.mass.gov/eea/docs/dep/recycle/laws/stsweep.pdf
- Partland, J.P., 2001, A Clean Swipe to Sweep Pollutants, Stormwater - The Journal for Surface Water Quality Professionals
- Selbig, W.R. et al, anticipated publication date 2007, Evaluation of Street Sweeping as a Water-Quality Management Tool in Residential Basins in Madison, USGS
- Smith, Kirk P., 2002, Effectiveness of Three Best Management Practices for High-Runoff Quality along the Southeast Expressway, Boston, Massachusetts, USGS, Water-Resources Investigations Report 02-4059, http://water.usgs.gov/pubs/wri/wri024059/
- Stidger, Ruth W., 2002, The Pros and Cons of Municipal Street Sweeping, Better Roads, April 2003, http://www.betterroads.com/articles/apr03b.htm
- Tiefenthaler, L. L.; Schiff, K. C.; Bay, S. M. 2001, *Characteristics of Parking Lot Runoff Produced by Simulated Rainfall*, Appendix F of the City of Long Beach Stormwater Monitoring Report 2000-2001, prepared by the Southern California Coastal Water Research Project, July 2001, ftp://ftp.sccwrp.org/pub/download/PDFs/characteristics_of_parkinglot_runoff.pdf
- United States Environmental Protection Agency (US EPA). 1983. *Results of the Nationwide Urban Runoff Program*. Vol. 1. Final Report. Office of Water, US EPA. Washington, DC.
- Waschbusch, R.J., 2003, Data and Methods of a 1999-2000 Street Sweeping Study on an Urban Freeway in Milwaukee County, Wisconsin, USGS, Open File Report 03-93, http://wi.water.usgs.gov/pubs/ofr-03-93/ofr-03-93.pdf
- Waschbusch, R.J., Selbig, W.R., and Bannerman, R.T., 1999. Sources of Phosphorus in Stormwater and Street Dirt from Two Residential Basins in Madison, Wisconsin, 1994-1995. USGS, Water Resources Investigations Report 99-4021.
- Zarriello, Phillip J., Robert F. Breault, and Peter K. Weiskel, 2002, Potential Effects of Structural Controls and Street Sweeping on Stormwater Loads to the Lower Charles River, Massachusetts, USGS, Water Resources Investigation Report 02-4220, http://water.usgs.gov/pubs/wri/wri024220/

Additional research underway in Wisconsin by the USGS, anticipated to be published in 2008, should provide additional information regarding removal efficiencies.

Pollution Prevention Plans

One of the most important undertakings for identifying potential pollutant sources and associated control requirements at a site is to prepare the source control and pollution prevention plan required by Standard 4. It is important for businesses, industries and municipalities to take a fresh look at their current management practices to reduce pollution at its source and ensure that they are meeting their environmental legal obligations. Businesses and towns can save money by preventing pollution, rather than cleaning up after the fact.

Industrial dischargers that are covered by the NPDES Multi-Sector General Permit are required to prepare a Stormwater Pollution Prevention Plan (SWPPP). A SWPPP prepared in accordance with the requirements of the Multi-Sector General Permit can be used to fulfill the source control and pollution prevention plan requirements of Standards 4, 5, and 6.

Likewise, many state agencies and municipalities are covered by the NPDES General Permit for Municipal Separate Storm Sewer Systems (MS4 Permit) that requires the implementation of good housekeeping and pollution prevention. State and local agencies subject to the MS4 Permit may be able to develop one plan that fulfills the source control and pollution prevention requirements of the Stormwater Management Standards and the MS4 Permit.

The source control and pollution prevention plan required by Standard 4 is intended to:

- **Identify potential sources of pollution that may affect the quality of stormwater discharges, and**
- **Describe and ensure the implementation of practices to reduce the pollutants in stormwater discharges.**

A source control and pollution prevention plan must describe all potential sources of pollutants and identify methods to eliminate and reduce those sources, including minimizing the use of hazardous materials or oil including pesticides, herbicides, fertilizers, and deicing chemicals; diverting stormwater from potential pollutant sources; keeping all hazardous materials or oil inside or under cover; implementing good housekeeping, preventive maintenance, snow and snowmelt management; and spill prevention and response procedures.

Certain land uses with higher potential pollutant loads located within the Zone II of a public water supply area require additional pollution prevention measures. These land uses include:

- landfills and open dumps,
- landfills handling wastewater residuals and/or septage,
- automobile graveyards and junkyards,
- stockpiling and disposal of snow or ice removed from highways,
- petroleum fuel oil and heating oil bulk stations and terminals,
- wastewater treatment plants permitted pursuant to 314 CMR 5.00,
- hazardous waste facilities subject to regulation under 310 CMR 30.00,
- waste oil retention facilities,
- treatment works for the remediation of contaminated ground or surface waters,
- floor drainage systems,
- storage of any of the following materials: sludge, septage, sodium chloride, chemically treated abrasives or other chemicals used for the removal of ice or snow, chemical fertilizers, animal manures, liquid hazardous materials or petroleum products.

For all such land uses that commence or are expanded on or after January 2, 2008, the source control and pollution prevention plan must include measures to prevent the land use from coming into contact with rain, snow, snowmelt and runoff.

Construction Period Erosion and Sedimentation Control

Construction period erosion and sedimentation control is an essential component of pollution prevention and environmentally sensitive site design. Construction period activities increase the potential for erosion and sedimentation at a site. Erosion is the wearing away of the land surface by running water, wind, ice, or other causes. Soil erosion is usually caused by the force of water falling as raindrops and by the force of water flowing in rills and streams. Raindrops falling on bare or sparsely vegetated soil detach soil particles. Water running along the surface of the ground picks up these particles and carries them along as it flows downhill towards a stream system.

Sedimentation is the deposition of soil particles that have been transported by water and wind. The quantity and size of the material transported increases with the velocity. Sedimentation occurs when the medium, air or water, in which the soil particles are carried, is slowed long enough to allow particles to settle out. Heavier particles, such as gravel and sand, settle out sooner than finer particles, such as clay.

There are four principal factors that influence the potential for erosion: soil type, surface cover, topography, and climate. These factors are interrelated in their effect on erosion potential. Variability in terrain, soils, and vegetation makes erosion control unique to each development. Erosion and resulting sedimentation generally occur in Massachusetts only when the soil is disturbed. The seriousness of the problem is a function of the topography and size of the disturbed area, the characteristics of the soils, the climate, and the vegetative cover.

As a rule of thumb:

- The more fine-grained material there is in a soil, the greater the amount of material that will be picked up by water flowing across its surface;
- The steeper the slope, the faster the water will move, thus being able to carry more soil; and,
- The larger the unprotected surface, the larger the potential for problems.

Topographic features distinctly influence erosion potential. Watershed size and shape, for example, affect runoff rates and volumes. Slope length and steepness are key elements in determining the volume and velocity of runoff and erosion risks. As both slope length and gradient increase, the rate of runoff increases and the potential for erosion is magnified. Swales and channels concentrate surface flow, which results in higher velocities. Exposed south-facing soils are hotter and drier, which makes vegetation more difficult to establish.

Where storms are frequent, intense, or of long duration, erosion risks increase. The high erosion risk period of the year results from seasonal changes in temperature, as well as variations in rainfall. When precipitation falls as snow, no erosion will take place immediately. In the spring, however, the hazards will be high. Most plants are still dormant. The existing vegetative cover is less able to buffer the raindrops. The ground is still partially frozen, or else saturated from melting snow, and its absorptive capacity is reduced. That is why it is necessary to stabilize exposed areas in the fall, before the period of high erosion risk in the spring.

Assess the Site

The first step in controlling erosion and sedimentation is to assess the site for possible erosion and sediment problems. Erosion and sedimentation hazards associated with site development include increased water runoff, soil movement, sediment accumulation, and higher peak flows caused by:

- Removal of plant cover and a large increase in soil exposed to erosion by wind and water
- Changes in drainage areas caused by regrading the terrain, diversions or road construction
- A decrease in the area of soil which can absorb water because of construction of streets, building, sidewalks or parking lots
- Changes in volume and duration of water concentrations caused by altering steepness, distance and surface roughness
- Soil compaction by heavy equipment, which can reduce water intake of soils to 1/20 or less of the original rate
- Prolonged exposure of unprotected sites and service areas to poor weather conditions

- Altering the groundwater regime in a way that may adversely affect drainage systems, slope stability, survival of existing vegetation and establishment of new plants
- Exposing subsurface materials that are too rocky, too acidic or otherwise unfavorable for establishing plants
- Obstructing streamflow by new buildings, dikes and landfills
- Inappropriate timing and sequencing of construction and development activities
- Abandonment of sites before construction is completed

Develop an Erosion and Sediment Control Plan

After this assessment is complete, a construction period erosion and sedimentation control plan must be prepared as required by Standard 8. Construction sites that disturb at least one acre of land are required to obtain coverage under the NPDES Construction General Permit and prepare a SWPPP. A SWPPP prepared in accordance with the Construction General Permit satisfies the erosion and sedimentation control plan requirement of Standard 8.[4]

At a minimum, the construction period erosion and sedimentation control plan required by Standard 8 must be prepared in accordance with the *Erosion and Sedimentation Guidelines: A Guide for Planners, Designers, and Municipal Officials* and shall include the following items:

- **Brief narrative**
- **Vicinity map**
- **Site topography map**
- **Site development plan**
- **Erosion and sedimentation control plan drawing**
- **Detail drawings and specifications**
- **Vegetation planning**

The erosion and sedimentation control plan must identify the party(ies) responsible for implementing the erosion and sedimentation control plan or any component(s) thereof. The Conservation Commission's Order of Conditions should require the responsible parties to implement the erosion and sedimentation control plan as approved by the Conservation Commission during land disturbance activities. Land disturbance activities include demolition, construction, clearing, excavation, grading, filling, and reconstruction. The requirement to implement the erosion and sedimentation control plan should end with the final stabilization of the site and the removal of the temporary erosion and sedimentation controls.

[4] For projects subject to jurisdiction under the Wetlands Protection Act, the construction period pollution prevention and erosion and sedimentation control plan should ordinarily be included in the Stormwater Report submitted with the Notice of Intent. For highly complex projects, where the proponent demonstrates that submission with the Notice of Intent is not possible, the issuing authority has the discretion to issue an Order of Conditions authorizing a project prior to submission of the construction period pollution prevention and erosion and sedimentation control plan. In any event, all Orders of Condition shall provide that no work, including site preparation and land disturbance, may commence unless and until a construction period pollution prevention plan that meets the requirements of Standard 8 as further elaborated by the Massachusetts Stormwater Handbook has been approved by the issuing authority.

Site Planning and Construction Sequencing

Because any modification of a site's drainage features or topography requires protection from erosion and sedimentation, the erosion and sedimentation control plan should include site planning and construction sequencing. Typically the staging of construction activities will depend upon these site factors:

- Existing soil limitations
- Existing slope and construction grading limitations
- Drainage problems
- Exposed soils during construction

The staging of construction activities to reduce sedimentation and the designation of areas to leave undisturbed during construction will reduce the size of construction BMPs, which reduces construction costs.

In developing a construction sequencing plan, the following factors should be considered:

- *Review and consider all existing conditions in the initial site selection for the project.* Select portions of the site that are suitable for the project rather than force the terrain to conform to development needs. Ensure that development features follow natural contours. Steep slopes, areas subject to flooding, and highly erodible soils severely limit a site's use, while level, well-drained areas offer few restrictions. Control seepage and high water table conditions. Any modification of a site's drainage features or topography requires protection from erosion and sedimentation.
- *Limit disturbance. Careful site selection will help on this point.* The site, or corridor, should be able to accommodate the development with a minimum of grading. The development plan should fit its topographic, soil, and vegetative characteristics with a minimum of clearing and grading. Natural cover should be retained and protected wherever possible. Critically erodible soil, steep slopes, stream banks, and drainage ways should be identified. The development can then be planned to disturb these vulnerable areas as little as possible.
- *Stabilize and Protect Disturbed Areas as Soon as Possible.* Two methods are available for stabilizing disturbed areas: mechanical (or structural) methods and vegetative methods. In some cases, both are combined in order to retard erosion.
- *Keep Stormwater Runoff Velocities Low*. The removal of existing vegetative cover during development and the resulting increase in impermeable surface area after development will increase both the volume and velocity of runoff. These increases must be taken into account when providing for erosion control.
- *Protect Disturbed Areas from Stormwater Runoff.* Best management practices can be utilized to prevent water from entering and running over the disturbed area. Diversions and other control practices intercept runoff from higher watershed areas, store or divert it away from vulnerable areas, and direct it toward stabilized outlets.
- *Retain Sediment within the Corridor or Site Area.* Sediment can be retained by two methods: filtering runoff as it flows and detaining sediment-laden runoff for a period of time so that the soil particles settle out. The best way to control sediment, however, is to prevent erosion.

Construction period erosion and sedimentation control and pollution prevention measures

In addition to construction sequencing, the erosion and sedimentation control plan must include source control and pollution prevention measures, construction period BMPs to address erosion and sedimentation, procedures for operating and maintaining the BMPs especially in response to wet weather events, actions to control mosquitoes during construction, and stabilization measures. Information on mosquito control is set forth in Chapter 5. Pollution prevention activities include storing construction materials away from wetland resource areas and catch basin inlets and preserving natural vegetation wherever possible.

The erosion and sedimentation control plan should specify the structural BMPs to be used during construction. The Massachusetts Erosion and Sediment Control Guidelines list 45 different kinds of Construction Period BMPs, from Brush Barriers, Check Dams and Dust Control to Inlet Protection, Outlet Protection and Stabilization to Sediment Fences. The BMPs selected for the project should reflect the needs identified in the project's erosion and sediment control plan. The erosion and sedimentation control plan must include design cross-sections and required freeboard for each construction period BMP. See Erosion and Sedimentation Guidelines, a Guide for Planners, Designers and Municipal Officials, http://www.mass.gov/eea/docs/dep/water/essec2.pdf. [5]

When considering which control measures to use, always evaluate the consequences of a measure failing. Failure of a practice may be hazardous or damaging to both people and property. For example, a large sediment basin failure can have disastrous results; low points in dikes can allow them to overflow and cause major gullies. The BMPs used during construction must be distinct from the BMPs that will be used to handle stormwater after construction is completed and the site is stabilized. Many stormwater technologies (infiltration technologies) are not designed to handle the high concentrations of sediments typically found in construction runoff, and thus must be protected from construction-related sediment loadings. All construction period BMPs must be properly designed, and sediment traps or basins must be sized to provide adequate capacity and retention time to allow for proper settling of fine-grained soils.

Operation, Inspection, and Maintenance of Construction Period Best Management Practices.

The erosion and sedimentation control plan shall include a schedule for implementing the stormwater management activities during land disturbance and construction that establishes a sequence in which these activities will be implemented as the project proceeds. The plan should also state when temporary practices will be removed and how disturbed areas and any areas designated for waste disposal will be stabilized.

The erosion and sedimentation control plan should specify who is responsible for maintenance of construction period BMPs, and when maintenance will be provided. The maintenance schedule should be based on site conditions, design safeguards, construction sequence, and anticipated weather conditions. For each construction period BMP, the erosion and sedimentation control plan must specify the amount of allowable sediment accumulation, and detail what will be done with the sediment removed.

Inspections

[5] The EPA has developed fact sheets for the BMPs that may be used to control erosion and sedimentation during construction. See http://cfpub1.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=min_measure&min_measure_id=4

The erosion and sedimentation control plan must also include a description of how the site will be inspected and maintained during land disturbance. Essential parts of the inspection program must include:

- Inspection during or immediately following initial installation of sediment controls.
- Inspection following severe rainstorms to check for damage to controls.
- Inspection prior to seeding deadlines, particularly in the fall.
- Final inspection of projects nearing completion to ensure that temporary controls have been removed, stabilization is complete, drainage ways are in proper condition, and the final contours agree with the proposed contours on the approved plan.

The erosion and sedimentation control plan should call for interim inspections as manpower and workload permit, giving particular attention to the maintenance of installed controls. The erosion and sedimentation control plan should require that all inspections be documented in a written report or log. These reports should contain the date and time of inspections, dates when land-disturbing activities begin, comments concerning compliance or noncompliance, and notes on any verbal communications concerning the project.

Additional information on preparing and implementing pollution prevention plans is contained in *Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices* (EPA-832-R-92-006) or *Stormwater Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices* (EPA-832-R-92-005), available through Office of Water Resource Center at 202- 566-1729, NTIS at 800-553-6847, or the Educational Resources Information Center/Clearinghouse at 800-538-3742.

Snow and Snowmelt Management

Snow Disposal

A pollution prevention plan must provide for proper management of snow and deicing materials. The application and storage of deicing materials, most commonly salts such as sodium chloride, can lead to water quality problems for surrounding areas. Salts, gravel, sand, and other materials are applied to highways and roads to reduce the amount of ice or to provide added traction during winter storm events. Salts lower the melting point of ice, allowing roadways to stay free of ice buildup during cold winters. Sand and gravel increase traction on the road, making travel safer.

Finding a place to dispose of snow contaminated with deicing materials poses a challenge to municipalities and businesses as they clear roads, parking lots, bridges, and sidewalks. While we are all aware of the threats to public safety caused by snow, collected snow that is contaminated with road salt, sand, litter, and automotive pollutants such as oil also threatens public health and the environment.

As snow melts, road salt, sand, litter, and other pollutants are transported into surface water or through the soil where they may eventually reach the groundwater. Road salt and other pollutants can contaminate water supplies and may be toxic to aquatic life. Sand washed into waterbodies can create sand bars or fill in wetlands and ponds, impacting aquatic life, causing flooding, and affecting our use of these resources. To avoid these impacts, private and public entities must plan how they will manage snow before winter begins.

Deicing Materials

To prevent increased pollutant concentrations in stormwater discharges, the amount of road salt applied should be reduced. Calibration devices for spreaders in trucks aid maintenance workers in the proper application of road salts. Many drinking water supply watersheds in Massachusetts use lower amounts of road salt to protect the resource. Reduced salt areas should be designated next to roads and wetlands. The amount of salt applied should be varied to reflect site-specific characteristics, such as road width and design, traffic concentration, and proximity to surface waters. Alternative materials, such as sand or gravel, calcium chloride, and calcium magnesium acetate may be used in especially sensitive areas. MassHighway is developing a Generic Environmental Impact Report on Snow and Ice Control that evaluates options for reducing the impact of deicing materials on water resources. Information about road deicing materials can also be found at the American Association of State Highway and Transportation Officials web site at: http://www.transportation.org/

Proper Storage of Deicing Materials

Proper snow management involves the proper storage of deicing materials. Covering stored road salts may be costly; however, the benefits are greater than the perceived costs. Storing road salts correctly prevents the salt from lumping together, which makes it easier to load and apply. In addition, covering salt storage piles reduces salt loss from stormwater runoff and potential contamination to streams, aquifers, and estuarine areas. Salt storage piles should be located outside the 100-year floodplain for further protection against surface water contamination.

The Massachusetts General Laws, Chapter 85, Section 7A, forbid outside storage of salt in areas that would threaten groundwater and surface water sources for public water supplies or within 200 feet of an established river or estuary. Outside Zone IIs, Zone As and 200 feet of established rivers or estuaries, road salt and other deicing compounds must be stored on sheltered (protected from precipitation and wind), impervious pads. Internal flow within the shelter must be directed to a collection system and external flow directed around the shelter.

The Drinking Water Regulations require municipalities proposing new water sources to enact land use controls that prohibit the uncovered, uncontained storage of road deicing materials within:

- Wellhead Protection Areas (Zone I and Zone II) for public water supply wells and
- Zone A for both new public supply reservoirs

Road salt storage and loading areas are classified as Land Uses with Higher Potential Pollutant Loads. The pollution prevention plan for land uses involving the storage of deicing compounds should include plans to bring the storage into compliance with all applicable laws and regulations. Standard 5 of the Stormwater Management Standards provides that stormwater runoff from road salt storage areas requires the use of the specific structural BMPs determined to be suitable for runoff from land uses with higher potential pollutant loads, unless all salt storage areas are protected from exposure to rain, snow, snowmelt and runoff. MassDEP has issued Guidelines on Deicing Chemical (Road Salt) Storage (1997). See http://www.mass.gov/eea/agencies/massdep/water/regulations/guidelines-on-deicing-chemical-road-salt-storage.html.

Snow Disposal Sites

In addition to limiting the use of deicing materials, proper management of snow and snowmelt requires selection of proper sites for snow disposal. MassDEP has developed a guidance document for communities regarding snow disposal, available on the web at: http://www.mass.go v/eea/agencies/massdep/water/regulations/guidelines-on-deicing-chemical-road-salt-storage.html. This guidance document recommends the following procedures.

Site Selection

The key to selecting effective snow disposal sites is to locate them adjacent to or on pervious surfaces in upland areas away from water resources and wells. At these locations, the snowmelt water can filter into the soil, leaving behind sand and debris that can be removed in the springtime. As more fully set forth below, the following areas should be avoided:

- Avoid dumping snow into any waterbody, including rivers, the ocean, reservoirs, ponds, or wetlands. In addition to water quality impacts and flooding, snow disposed of in open water can cause navigational hazards when it freezes into ice blocks.
- Do not dump snow within a Zone II or Interim Wellhead Protection Area (IWPA) of a public water supply well or within 75 feet of a private well, where road salt may contaminate water supplies.
- Avoid dumping snow on high and medium yield aquifers where it may contaminate groundwater.
- Avoid dumping snow in sanitary landfills and gravel pits. Snowmelt water will create more contaminated leachate in landfills posing a greater risk to groundwater. In gravel pits, there is little opportunity for pollutants to be filtered out of the melt water, because groundwater is close to the land surface.
- Avoid disposing of snow on top of storm-drain catch-basins or in stormwater drainage channels or ditches. Snow combined with sand and debris may block a storm drainage system, causing localized flooding. A high volume of sand, sediment, and litter released from melting snow may be quickly transported through the system into surface water.

Site Maintenance

In addition to carefully selecting disposal sites before the winter begins, it is important to prepare and maintain these sites to maximize their effectiveness. The following maintenance measures should be undertaken at all snow disposal sites:

- A silt fence or equivalent barrier should be placed securely on the downgradient side of the snow disposal site.
- To filter pollutants out of the melt water, a 50-foot vegetative buffer strip should be maintained during the growth season between the disposal site and adjacent water bodies.
- Debris should be cleared from the site prior to using the site for snow disposal.
- Debris should be cleared from the site and properly disposed at the end of the snow season and no later than May 15.

References

American Association of State Highway and Transportation Officials. 2000. AASHTO: Transportation Center of Excellence. http://www.transportation.org/

Massachusetts Executive Office of Energy & Environmental Affairs. Adopt a Stream Program. Road Salt: Some Alternatives and Strategies.

MA-DEP Bureau of Resource Protection. 1997. Massachusetts Guidelines on Deicing Chemical (Road Salt) Storage. See http://www.mass.gov/eea/agencies/massdep/water/regulations/guidelines-on-deicing-chemical-road-salt-storage.html

USEPA. 1995. Planning Considerations for Roads, Highways and Bridges. U.S. Environmental Protection Agency, Office of Water, Washington, DC. www.epa.gov/OWOW/NPS/education/planroad.html

Koppelman, L.E., E. Tanenbaum, and C. Swick. 1984. Nonpoint Source Management Handbook. Long Island Regional Planning Board, Hauppauge, NY

Other Important Pollution Prevention and Source Control Measures

There are many other effective pollution control and source control measures that proponents, citizens and municipalities can undertake to reduce pollutant loads in stormwater, including the following[6]:

- ***Lawn and garden activities***, including application and disposal of lawn and garden care products, and proper disposal of leaves and yard trimmings. Effective measures include: applying pesticides and fertilizers properly, including: timing; application reduction; providing buffer areas (preferably natural vegetation) between surface waters and lawn and garden activities; limiting lawn watering and landscaping with climate-suitable vegetation; providing guidelines for what to expect from landscaping and lawn care professionals; and providing composting guidelines, if not covered elsewhere under solid waste efforts. <http://www.mass.gov/eea/agencies/massdep/water/watersheds/nonpoint-source-pollution.html#2> See "More than Just a Yard: Ecological Landscaping Tools for Massachusetts Homeowners." http://www.mass.gov/eea/docs/eea/wrc/morethanjustyard.pdf and Guide to Lawn and Landscape Water Conservation, http://www.mass.gov/eea/docs/eea/wrc/lawnguide.pdf**.**
- ***Turf management*** on golf courses, parks, and recreation areas. Many of the measures described above are applicable to turf management and need to be implemented by caretakers responsible for golf courses and parks and recreation areas (including municipal employees, in some cases).
- ***Pet waste management.*** Pooper-scooper laws for pets should be enacted and implemented. Public outreach is essential to the effectiveness of these laws. Priority resource areas, such as bathing beaches and shellfish growing areas, may need to exclude pets at least for the summer months or at other critical use times. Specific controls for horses and the control of manure may be needed. <http://www.mass.gov/eea/agencies/massdep/water/watersheds/nonpoint-source-pollution.html#2>
- ***Integrated Pest Management* (IPM)** effectively prevents and controls pests (including weeds) in a way that maximizes environmental benefits at a reduced cost to growers. IPM involves applying an array of techniques and control strategies for pest management – with a focus on using them in the proper amounts and determining when they are most needed. By choosing from all possible pest control methods (e.g., biological controls and beneficial organisms) and rotating methods, resistance to repeated chemical controls can

[6] Appendix A lists source control and pollution prevention measures for certain land uses .

be delayed or prevented. <http://www.mass.gov/eea/agencies/massdep/water/watersheds/nonpoint-source-pollution.html#2>

- ***Proper storage, use, and disposal of household hazardous chemicals,*** including automobile fluids, pesticides, paints, and solvents. Information should be provided on chemicals of concern, proper use, and disposal options. Household hazardous waste collection days should be sponsored whenever feasible. Recycling programs for used motor oil, antifreeze, and other products should be developed and promoted.
- ***Storm drain stenciling*** involves labeling storm drain inlets with painted messages warning citizens not to dump pollutants into the drains. The stenciled messages are generally a simple phrase to remind passersby that the storm drains connect to local waterbodies and that dumping pollutes those waters. Some storm drain stencils specify which waterbody the inlet drains to or name the particular river, lake, or bay. Commonly stenciled messages include: “No Dumping. Drains to Water Source,” “Drains to River,” and “You Dump it, You Drink it. No Waste Here.” Pictures can also be used to convey the message, including a shrimp, common game fish, or a graphic depiction of the path from drain to waterbody. Communities with a large Spanish-speaking population might wish to develop stencils in both English and Spanish, or use a graphic alone. <http://www.mass.gov/eea/agencies/massdep/water/watersheds/nonpoint-source-pollution.html#2>
- ***Proper operation and maintenance of septic systems.*** Knowledge of proper operation and maintenance of septic systems should be promoted to avoid serious failures.
- *Car Washing*. This management measure involves educating the general public, businesses, municipal fleets (public works, school buses, fire, police, and parks) on the water quality impacts of the outdoor washing of automobiles and how to avoid allowing polluted runoff to enter the storm drain system. Outdoor car washing has the potential to result in high loads of nutrients, metals, and hydrocarbons during dry weather conditions in many watersheds, as the detergent-rich water used to wash the grime off our cars flows down streets and into storm drains. Commercial car wash facilities often recycle their water or are required to treat their wash-water discharge prior to release to the sanitary sewer system. As a result, most stormwater impacts from car washing are from residents, businesses, and charity car wash fundraisers that discharge polluted wash water to the storm drain system. <http://www.mass.gov/eea/agencies/massdep/water/watersheds/nonpoint-source-pollution.html#2>
- ***Commercial operations and activities,*** including parking lots, gas stations, and other local businesses. Recycling, spill prevention and response plans, and proper material storage and disposal should be promoted. Using dry floor cleaners and absorbent materials and limiting the use of water to clean driveways and walkways should be encouraged. Care should be taken to avoid accidental disposal of hazardous materials down floor drains. Floor drains should be inventoried.
- ***Department of Public Works Facilities (DPWs)*****.** Because of the nature of the activities they perform, such as storing and managing sand, salt, and chemicals, and fueling and maintaining trucks and other equipment, DPWs are in a unique position to prevent a wide range of compounds from becoming stormwater pollutants. MassDEP has developed a Fact Sheet specifically for DPWs: <http://www.mass.gov/eea/agencies/massdep/water/watersheds/nonpoint-source-pollution.html#2>
- **Other efforts, including water conservation and litter control, can be tied to nonpoint source pollution control.**

Local Bylaws and Regulations

Local bylaws, ordinances, and regulations are among the best mechanisms to institute many of the nonstructural controls described above, because they can cover a wide range of pollution prevention issues that fall below federal thresholds or for which no threshold exists. These bylaws are generally proposed by planning boards or conservation commissions, in consultation with other local officials. Stormwater bylaws and earth removal or sediment and erosion control bylaws are among the most common types of local initiatives. Stormwater bylaws establish requirements for site planning and pollution prevention plans in conjunction with design and construction activities. Earth removal or erosion and sediment control bylaws focus specifically on construction activities and controlling soil erosion problems. Many local boards of health have adopted pet waste control bylaws.

MassDEP's *Nonpoint Pollution Source Management Manual* (2006) provides several general suggestions for developing various types of bylaws for nonpoint pollution control, including controlling erosion and sediment, limiting impervious surfaces (or lot clearing), specifying nutrient loading standards, and enhancing site plan review, wetlands protection, and road salt management.

EEA's SmartGrowth Tool Kit (http://www.mass.gov/envir/smart_growth_toolkit/), the EPA website (http://www.epa.gov/owow/nps/ordinance/mol6.htm) and the Stormwater Managers Resource Center website (http://www.stormwatercenter.net) include model bylaws for LID development. See also http://www.mapc.org/regional_planning/Developing_Local_Bylaw.pdf. Technical assistance with the development of local bylaws is available from the Massachusetts Coastal Zone Management Office, or the NRCS Community Assistance Program. Other groups such as regional planning agencies or nonprofit groups such as Massachusetts Association of Conservation Commissions or the Massachusetts Audubon Society may be able to provide assistance with bylaw development.

C. Structural Best Management Practices

This section of Chapter 1 presents information about the structural Best Management Practices (BMPs) that may be used to manage stormwater runoff in accordance with the Stormwater Management Standards. Proponents should consult this section when selecting and evaluating BMPs for a given development or redevelopment. Conservation commissions and other issuing authorities should become familiar with the information presented here to learn whether a BMP is appropriate for a project site, if a drainage system meets the Stormwater Management Standards, and what actions are required to operate and maintain the BMP.

This section of Chapter 1 groups individual BMP technologies according to the principal methods of stormwater management: pretreatment, treatment, conveyance, and infiltration. *Some BMPs fall into several categories, because they serve several functions*. For example, some bioretention areas are designed to act as a filter (hereinafter "filtering bioretention areas"), and others are designed to infiltrate (hereinafter "exfiltrating bioretention areas"). The next section describes the basic issues to consider when choosing a BMP to meet a particular Stormwater Management Standard, including site suitability, design specifications, construction methods, and maintenance requirements.

Note that the BMPs described in this chapter address *post-construction* stormwater management. There are many other BMPs focused expressly on mitigating stormwater impacts *during* construction. Detailed descriptions of these construction-specific BMPs can be found in

MassDEP's *Massachusetts Nonpoint Pollution Source Management Manual,* Chapter 6: "Erosion and Sediment Control." (2006), MassDEP's *Erosion and Sedimentation Control Guidelines: A Guide for Planners, Designers, and Municipal Officials* (May 2003), and MassHighway's *Stormwater Handbook for Highways and Bridges* (May 2004).

Chapter 2 contains detailed information on specific post-construction structural stormwater best management practices. For each BMP, there is a discussion of its purpose, advantages and disadvantages, applicability, expected range of pollutant removal effectiveness, planning considerations, design and construction issues and operation and maintenance requirements.

Volume 3 provides the basic calculations needed to design a BMP for conformance with each Standard, including how to determine:

- **The required water quality volume;**
- **The required recharge volume based on hydrologic soil classification; and**
- **The size of the BMP.**

Because increased awareness and attention to stormwater management have encouraged the research and development of new technologies for stormwater management, Chapter 4 provides additional information on innovative and emerging BMP technologies. Some of these technologies have been evaluated as part of EPA's Technology Acceptance Reciprocity Partnership (TARP) or Massachusetts' Strategic Envirotechnology Partnership (STEP). Chapter 4 provides information on the TARP and STEP programs.

The Classes of BMPs

MassDEP divides the stormwater BMPs into several basic classes as shown in Table 2-1. The table also lists manufactured BMPs such as proprietary separators. Each BMP varies to the extent that it conveys, treats, infiltrates, retains, attenuates, and stores stormwater runoff. *Note that some BMPs fit into more than one class because they serve more than one function.* The classes include:

Structural Pretreatment BMPs**: The first BMPs in a treatment train, these measures typically remove the coarse sediments that can clog other BMPs. The settling process generates sediment that must be routinely removed. Maintenance is especially critical for pretreatment BMPs, because they receive stormwater containing the greatest concentrations of suspended solids during the first flush. Some pretreatment devices such as the Oil Grit Separator are required to pretreat the runoff from certain land uses with higher potential pollutant loads, such as gas stations and high intensity use parking lots[7]. The most common pretreatment BMPs include:**

- **Deep Sump Catch Basins**
- **Oil Grit Separators**
- **Proprietary Separators**
- **Sediment Forebays**
- **Vegetated Filter Strips**

[7] For such land uses, it may be possible to use a filtering bioretention area, or a sand filter in lieu of an oil grit separator.

Pretreatment BMPs can be configured as on-line or off-line devices. On-line systems are designed to treat the entire water quality volume. Off-line practices are typically designed to receive a specified discharge rate or volume. A flow diversion structure or flow splitter is used to divert the design flow to the off-line practice. To receive TSS removal credit, oil grit separators and deep sump catch basins must be configured as off- line devices.

Treatment BMPs
There are three main types of Treatment BMPs:

- **Stormwater Treatment Basins**
- **Constructed Stormwater Wetlands**
- **Filtration BMPs**

They are more specifically described below**.**

Stormwater Treatment Basins: These BMPs provide peak rate attenuation by detaining stormwater and settling out suspended solids. The basins that are most effective at removing pollutants have either a permanent pool of water or a combination of a permanent pool and extended detention, and some elements of a shallow marsh. Stormwater basins include:

- **Extended Dry Detention Basins**
- **Wet Basins**

Constructed Wetlands: Constructed stormwater wetlands are designed to maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention and settling. Gravel wetlands remove pollutants by filtering stormwater through a gravel substrate.

- **Constructed Stormwater Wetland**
- **Gravel Wetland**

Filtration BMPs: Filtration systems use media to remove particulates from runoff. They are typically used when circumstances limit the use of other types of BMPs, such as where space is limited–particularly in a highly urbanized setting–or when it is necessary to capture particular industrial or commercial pollutants (e.g., hydrocarbons). In these circumstances, other BMPs might be cost-prohibitive or not as effective. Filtered runoff may be collected and returned to the conveyance system, or allowed to partially exfiltrate into the soil. Filtration BMPs include:

- **Filtering Bioretention Areas and Rain Gardens**
- **Proprietary Media Filter**
- **Sand Filters/Organic Filters**
- **Treebox Filter**

Conveyance BMPs: These BMPs collect and transport stormwater to BMPs for treatment and/or infiltration. These practices may also treat runoff through infiltration, filtration, or temporary storage. A water quality swale usually functions as a runoff conveyance channel and a filtration practice. The vegetation or turf also prevents erosion, filters sediment, and provides some nutrient uptake benefits. Conveyance BMPs include:

- **Drainage Channels**
- **Grass Channels**
- **Water Quality Swales**
    - **Dry**

- **Wet**

Infiltration BMPs: Infiltration systems are designed primarily to reduce the quantity of stormwater runoff from a particular site. Infiltration techniques reduce the amount of surface flow and direct the water back into the ground. Infiltration practices typically cannot provide channel protection and overbank or extreme flood detention storage. Infiltration BMPs include:

- **Exfiltrating Bioretention Areas and Rain Gardens**
- **Dry Wells**
- **Infiltration Basins**
- **Infiltration Trenches**
- **Leaching Catch Basins**
- **Subsurface Structures**

Other BMPs: Some BMPs do not fit into any of the categories set forth above. These BMPs include the following:

- **Dry Detention Basins**
- **Green Roofs**
- **Porous Pavement**
- **Rain Barrels and Cisterns**

Accessories: BMP accessories are devices that enable BMPs to operate as designed. BMP accessories include the following:

- **Check Dams**
- **Level Spreaders**
- **Outlet Structures**
- **Catch Basin Inserts**

Table 2.1		
BMPs for Controlling Stormwater Quantity		
	Pretreatment BMP	**BMP that requires pretreatment**
Pretreatment		
Deep Sump Catch Basin	**Yes**	**No**
Oil Grit Separators	**Yes**	**No**
Proprietary Separators	**Yes**	**No**
Sediment Forebays	**Yes**	**No**
Vegetated Filter Strips	**Yes**	**No**
Treatment		
Bioretention areas/rain gardens	**No**	**Yes**
Constructed stormwater wetlands	**No**	**Yes**
Extended Dry Detention Basins	**No**	**Yes**
Gravel Wetlands	**No**	**Yes**
Proprietary Media Filters	**No**	**Yes**
Sand/Organic Filters	**No**	**Yes**
Tree Box filters	**No**	**Yes**
Wet basins	**No**	**Yes**
Conveyance		
Grass Channels	**No**	**Yes**
Water Quality Swales – Dry	**No**	**Yes**
Water Quality Swales – wet	**No**	**Yes**
Infiltration BMPs		
Dry Wells	**No**	**No pretreatment required for runoff from non-metal roofs and metal roofs outside Zone II, IWPA and industrial site.**
Infiltration Basins	**No**	**Yes**
Infiltration Trenches	**No**	**Yes**
Leaching Catch Basins	**No**	**Yes**
Subsurface Structures	**No**	**Yes**
Other BMPs		
Dry Detention Basins	**No**	**No**
Green Roofs	**No**	**No**
Porous Pavements	**No**	**No**
Rain Barrels & Cisterns	**No**	**No**

The BMP Selection Process

Once site planning, pollution prevention, and source control measures have been implemented, applicants should integrate structural BMPs into the overall stormwater control system. For the most part, structural BMPs are engineered systems that are typically made of natural materials such as grass and plants, or manufactured materials like steel, fiberglass, and concrete. They act as the last line of defense in protecting the Commonwealth's waters from stormwater pollution. As such, these man-made structures can be highly effective in removing pollutants from stormwater if properly designed and maintained.

The following sections provide guidance for choosing the appropriate structural BMPs for a site by explaining the basic considerations for their use. Each BMP has certain limitations. When designing a stormwater management system for any site, the project proponent, working together with planners and design engineers, should ask the following questions:

- **How can the stormwater management system be designed to meet the standards for stormwater quantity and quality most effectively?**
- **What are the opportunities to meet the stormwater quality standards and the stormwater recharge and peak discharge standards simultaneously?**
- **What opportunities exist to use comprehensive site planning to minimize the need for structural controls?**
- **Are there Critical Areas on or adjacent to the project site?**
- **Does the project involve stormwater discharges from land uses with higher potential pollutant loads?**
- **What are the physical site constraints?**
- **Given the site conditions, which BMP types are most suitable?**
- **What type of development is being proposed and what pollutants does this land use typically generate?**
- **Is there an opportunity to receive the LID Site Design credits by incorporating environmentally sensitive design or low impact development techniques?**
- **Is the future maintenance reasonable and acceptable for this type of BMP?**
- **Has adequate access been provided for maintenance?**
- **Is the BMP option cost-effective?**
- **Does the stormwater discharge near or to an impaired surface water?**
- **Has a TMDL been developed?**
- **Are BMPs available to remove the pollutant of concern?**

The project proponent should consider whether a system of several BMPs is more appropriate for a site than a single BMP structure. Too often, stormwater controls are added to a site plan in its final stages. When planning for stormwater management is done as an afterthought, proponents are not likely to select the most environmentally appropriate and cost-effective practices for controlling runoff.

By engaging in early planning, the proponent can focus on the entire site and identify the best available locations for reducing, infiltrating and treating runoff. Early stormwater management planning can also allow the proponent to combine best management practices into treatment trains. With a treatment train, one or more of the measures can fail without undermining the integrity of the overall site control strategy.

Including stormwater management in the early stages of the planning process gives proponents the opportunity to consider whether a decentralized system comprised of BMPs scattered throughout the site may provide greater environmental benefits at less cost than a centralized system that transports all runoff to a single location for treatment and disposal. Through early planning, a proponent may discover that a decentralized system that uses dry wells for roof runoff, relies on water quality swales rather than curbs and gutters to convey street runoff to additional BMPs, and installs infiltration trenches in front of an extended dry detention basin, is the most cost-effective and environmentally protective approach to achieving compliance with the Stormwater Management Standards.

Stormwater Quantity Management

Approximating a site's pre-development hydrology, including the natural cover, is the primary goal of stormwater quantity management. A site's post-development hydrology can be controlled through a combination of stream bank/channel erosion control (2-year 24-hour storm events), flood control (10-year 24-hour and 100-year 24-hour storm events). Table 2-2 indicates the types of quantity controls provided by specific BMPs.

Table 2-2
BMPs for Controlling Peak Discharge Rates

	Peak Discharge Rate Control: 2-Yr. Storm	Peak Discharge Rate Control: 10-Yr. Storm	Peak Discharge Rate Control: 100-Yr. Storm
Pretreatment			
Deep sump catch basins	No	No	No
Oil grit separators	No	No	No
Proprietary separators	No	No	No
Sediment forebays	No	No	No
Vegetated filter strips	With careful design	No	No
Treatment			
Bioretention areas/rain gardens	No	No	No
Constructed stormwater wetlands	Yes	Yes	No
Extended dry detention basins	Yes	Yes	With careful design
Gravel wetlands	Yes	Yes	No
Proprietary media filters	No	No	No
Sand/Organic filters	No	No	No
Tree box filters	No	No	No
Wet Basins	Yes	Yes	With careful design
Conveyance			
Drainage channels	No	No	No
Grass Channels	No	No	No
Water Quality Swales	With careful design	With careful design	No
Infiltration BMPs			
Dry wells	No	No	No
Infiltration Basins	With careful design	With careful design for small sites	With careful design
Infiltration Trenches	Full exfiltration trench systems	Full exfiltration trench systems	Full exfiltration trench systems
Leaching catch basins	Only if sufficient leaching catch basins	Only if sufficient leaching catch basins	No
Subsurface structures	No	No	No
Other BMPs			
Dry detention basins	Yes	Yes	With careful design
Green Roofs	Yes with careful design	No	No
Porous Pavement	Yes with careful design	No	No
Rain barrels & Cisterns	Yes for cistern with careful design	No	No

Stormwater Quality Management

When designing stormwater management systems and screening BMP technologies to meet the water quality management standards, ask the following questions:

- **Does the project affect a sensitive resource?**

- **Based on existing and post-development conditions, what is the volume of stormwater to be treated for water quality?**
- **Is the water quality volume based on 0.5 inch or 1.0 inch of runoff times the impervious area?**
- **What is the best combination of BMP technologies and non-structural practices to achieve the 80% reduction of TSS loadings on an average annual basis?**
- **Does the stormwater discharge impact an impaired surface water? If so, what pollutants are the cause of that impairment? Which BMPs can remove that pollutant?**

Although the Stormwater Management Standards only require removal of TSS, a proponent must consider other pollutants, if the development or redevelopment will affect a surface water that is the subject of a Total Maximum Daily Load (TMDL) that indicates the concentrations of certain pollutants in stormwater runoff must be reduced. In that event, the proponents must design, construct, operate and maintain a stormwater management system that is consistent with the TMDL.

Stormwater Recharge

When designing stormwater management systems to meet the recharge standard, ask the following questions:

- **Based on existing and post-development conditions and soil types, what is the volume of stormwater to be recharged to groundwater?**
- **Will the infiltration BMP exfiltrate stormwater to the ground within a Zone II or Interim Wellhead Protection Area or an area with a rapid infiltration rate (greater than 2.4 inches per hour)?**
- **Is the infiltration BMP near a bathing beach, shellfish growing area, Outstanding Resource Area, Special Resource Area, or cold-water fishery?**
- **What pretreatment measures are needed to ensure that the infiltration BMP can continue to operate as designed?**

Site Suitability/BMP Suitability

In choosing an effective BMP system, it is necessary to determine the most suitable combinations of BMPs based on the characteristics of the site. The basic site requirements for each technology are included in Chapter 2. Site suitability is a major factor in choosing BMPs. Physical constraints at a site may include soil conditions, watershed size, depth to water table, depth to bedrock and slope. For redevelopment projects, physical constraints may include compacted soils or the presence of underground utilities. In some cases, a BMP may be eliminated as an option because of site constraints. Often, however, BMPs can be modified or combined with other BMPs and adapted to site conditions to create an efficient system capable of meeting the Stormwater Management Standards.

The following subsections briefly address the physical site conditions that affect BMP selection.

<u>Soil Suitability</u>
Generally, dry detention basins and extended dry detention basins are suitable in a broad range of soil conditions, but wet basins may have difficulty maintaining water levels in very sandy soils. Soil type is of particular importance to infiltration BMPs. Do not locate infiltration BMPs in areas

with low permeability soils. (This would exclude "D" soil groups, as defined by the Natural Resources Conservation Service.) Where infiltration technologies are planned, confirm that the soils have adequate permeability.

Drainage Area/Watershed To Be Served
The size of the contributing area may be a limiting factor in selecting the appropriate BMP technology. Recommendations for appropriate contributing watershed areas are included in the discussion for each technology. Proper site planning can often overcome area constraints. Basins typically require large contributing drainage areas in order to function properly, while infiltration BMPs require smaller drainage areas. For technologies that require large contributing watersheds, additional offsite runoff may be routed to the BMP to increase flows. Conversely, portions of the total runoff can be routed to smaller individual BMPs to allow for the use of lower capacity BMPs. Keep in mind that some BMPs may have more rigorous maintenance and inspection requirements.

Depth to Water Table
Depth to the seasonal high groundwater table is an important factor for stormwater technologies, especially infiltration BMPs. If the seasonal high groundwater table extends to within two feet of the bottom of an infiltration BMP, the site is seldom considered suitable. The groundwater table acts as an effective barrier to exfiltration through the BMP media and soils below and can prevent an infiltration BMP from draining properly. Depending on soil conditions, depth to the groundwater table is also an important factor in reducing the risk of microbial contamination. For constructed stormwater wetlands and wet basins, a groundwater table at or near the surface is desirable. Areas with high groundwater tables are generally more conducive to siting these types of BMPs.

Depth to Bedrock
The depth to bedrock (or other impermeable layers) is a consideration for siting facilities that rely upon infiltration. Bedrock impedes the downward exfiltration of stormwater and prevents infiltration BMPs from draining properly. An area is generally not suitable for infiltration BMPs, if bedrock is within two feet of the bottom of the BMP. Similarly, stormwater basin BMPs are not feasible if shallow bedrock lies beneath the area to be excavated.

Slopes
Site slopes restrict the types of BMP that can be used. Water quality swales and infiltration trenches are not practical when slopes exceed 20%. To achieve water quality benefits and credit for TSS removal, proponents may not site water quality swales or grass channels on slopes greater than 5%. Where there are steeper slopes, the stormwater management system must be carefully designed to prevent stormwater runoff from bypassing the treatment BMPs and causing erosion and off-site flooding.

Thermal Enhancement
The water in wet basins and constructed stormwater wetlands warms up rapidly in summer. Warm water released from BMPs can be lethal to cold-water aquatic organisms. Do not use these BMPs in areas adjacent to designated cold-water streams.

Proximity to Critical Animal Habitats or Endangered Species
Some BMPs can be lethal traps for small animals such as frogs, salamanders, and turtles. Sediment forebays and dry detention basins with excessively steep or vertical side slopes (e.g., concrete steps) or improperly located catch basins can prevent a trapped animal from escaping.

LID techniques may be more suitable for managing stormwater while at the same time, protecting indigenous animal populations as well as rare and endangered species.

Proximity to Septic Systems and Water Supplies
When evaluating the suitability of infiltration BMPs such as infiltration trenches, infiltration basins and dry wells, it is critical to consider setback requirements mandated under other state programs such as those addressing septic systems and drinking water supplies. Table 2.3 summarizes setback requirements for infiltration BMPs.

Table 2.3: Setbacks for Infiltration Structures
General Setback Requirements: **Soil Absorption Systems for Title 5 Systems:** 50ft. **Private wells**: 100 ft. **Public wells**: Outside Zone I **Public reservoir, surface water sources for public water systems and their tributaries**: Outside Zone A **Other surface waters**: 50 ft. **Property Line**: 10 feet **Building foundations**: >10 to 100 ft., depending on the specific type of infiltration BMP. See infiltration BMP for specific setback. **Specific BMPs have additional setback requirements**. See Chapter 2.

Proximity to Foundations
Infiltration of stormwater can cause seepage into foundations when BMPs are located too close to buildings; MassDEP requires a 10 to 100 foot setback depending on specific type of infiltration BMP.

Public Acceptance
Aesthetics are important in gaining acceptance of BMPs. BMPs can either enhance or degrade the amenities of the natural environment and the adjacent community. Careful planning, landscaping and maintenance can make a BMP an asset to a site. Frequently, ownership and maintenance responsibilities for BMPs in new developments fall on adjacent property owners. If adjacent residents will be expected to pay for maintenance, education and acceptance of the BMP are necessary.

BMP Treatment Trains
BMPs in series incorporate several stormwater treatment mechanisms in sequence to enhance the treatment of runoff. Known as "stormwater treatment trains," they consist of a combination of source control measures, natural features, and structural BMPs to maximize pollutant removal and subsurface recharge. Combining nonstructural and structural measures in series rather than using a single method of treatment improves the levels and reliability of pollutant removal. The effective life of a BMP can be extended by combining it with pretreatment BMPs, such as a vegetated filter strip or sediment forebay, to remove sediment prior to treatment in the downstream "units." Sequencing BMPs can also reduce the potential for re-suspension of settled sediments by reducing flow energy levels or providing longer flow paths for runoff.

The most suitable components for a treatment train depend on the pollutants to be removed. Pollutants in stormwater fall into two groups: suspended solids and dissolved pollutants. Particle sizes greater than 0.45 micron are considered suspended solids. Pretreatment BMPs (e.g.

sediment forebay, oil grit separator) are ordinarily designed to remove suspended solids that have larger particle sizes than the dissolved solids removed by treatment practices that rely on settling (e.g. extended dry detention basins and wet basins s) or filtration (e.g. sand filters and filtering bioretention areas).

There are many combinations of BMPs that can be placed in a treatment train to maximize suspended solids removal. According to Minton (2006), some of the more common ones include:

- **A sediment forebay discharging to a wet basin flowing into a constructed stormwater wetland**
- **A water quality swale flowing into a wet basin or a constructed stormwater wetland**
- **An oil grit separator connected to a sand or organic filter**
- **A sediment forebay discharging to an extended dry detention basin connected to a sand filter**
- **A water quality swale discharging to a vegetated filter strip connected to an infiltration trench.**

BMPs by Land Use

Certain BMPs are more suitable for some land uses than others[8]. Some types of urban land uses contribute higher than normal pollutant loadings of solvents, oils, lubricants, fertilizers, grease, and/or bacteria. Table LUHPPL presents the applicability and use of various BMPs for various land uses with higher potential pollutant loads.

Table LUHPPL: Best Management Practices for Land Uses with Higher Potential Pollutant Loads	
• Discharges from certain land uses with higher potential pollutant loads may be subject to additional requirements, including the need to obtain an individual or general discharge permit pursuant to the MA Clean Waters Act or Federal Clean Water Act. • All proponents must implement source control and pollution prevention. • All BMPs shall be designed in accordance with specifications and procedures in the Massachusetts Stormwater Handbook Volumes 2 and 3. • The required water quality volume equals 1inch times the total impervious area of the post-development site. • Many land uses have the potential to generate higher potential pollutant loads of oil and grease. These land uses include, without limitation, industrial machinery and equipment and railroad equipment maintenance, log storage and sorting yards, aircraft maintenance areas, railroad yards, fueling stations, vehicle maintenance and repair, construction businesses, paving, heavy equipment storage and/or maintenance, the storage of petroleum products, high-intensity-use parking lots, and fleet storage areas. To treat the runoff from such land uses, the following BMPs must be used to pretreat the runoff prior to discharge to an infiltration structure: an oil grit separator, a sand filter, organic filter, filtering bioretention area or equivalent. • 44% TSS removal is required prior to discharge to an infiltration device. • Until they complete the STEP or TARP verification process outlined in Volume 2, proprietary BMPs may not be used as a terminal treatment device for runoff from land uses with higher potential pollutant loads. For the purpose of this requirement, subsurface structures, even those that have a storage chamber that has been manufactured are not proprietary BMPs, since the pretreatment occurs in the soil below the structure, not in the structure itself.	
Pretreatment	
	Deep Sump Catch Basin
	Oil Grit Separator
	Proprietary Separators - See Volume 2
	Sediment Forebays
	Vegetated Filter Strip (*must be lined*)
Treatment	
Sand Filters, Organic Filters, Proprietary Media Filters, Wet Basins, Filtering Bioretention Areas, and Extended Dry Detention Basins must be lined and sealed unless 44% of the TSS has been removed prior to discharge to the BMP.	Filtering Bioretention Areas including rain gardens
	Constructed Stormwater Wetlands
	Dry Water Quality Swales
	Extended Dry Detention Basins
	Gravel Wetlands
	Proprietary Media Filter (Does not include catch basin

[8] The MassHighway Stormwater Handbook provides information on the information to consider when selecting BMPs for highway projects.

Redevelopment Projects

There are fewer stormwater BMP options for heavily urbanized areas (often called *ultra-urban* areas) compared to less congested areas, because of the restrictions inherent in building in urbanized areas. The primary barrier is space, or more precisely, lack of space. This limitation eliminates many space-intensive options (e.g., extended dry detention basins) and makes BMPs that can be used on a micro-scale and that have smaller "footprints" more attractive. Other considerations that can take the shape of barriers include:

Engineering Concerns

If the discharge point of a BMP is to a storm drain or an underdrain connecting to a storm drain, proponents should avoid overloading the existing system. The BMP will not work if the discharge cannot be efficiently moved off-site or out of manufactured systems like proprietary separators or oil grit separators. BMP selection must include engineering considerations such as available head, hydraulic grade lines, and the presence of pipeline bottlenecks that may worsen flooding.

Underground Utilities

The presence of underground utilities, including gas and water mains, sewer pipes and electric cable conduits in urban areas, can greatly reduce the amount of land available for redevelopment BMPs. Utility conduits can limit the ability to excavate, making BMP siting and sizing difficult.

Given these constraints, the most suitable BMPs for redevelopment include:

- Bioretention Areas/Rain Gardens
- Grass Channels
- Green Roofs
- Subsurface Structures
- Leaching Catch Basins
- Porous Pavement
- Sand Filters/Organic Filters
- Water Quality Swales (Dry)
- Deep Sump Catch Basins
- Dry Wells
- Proprietary Separators
- Infiltration Trenches
- Other Proprietary Technologies
- Rain Barrels and Cisterns
- Vegetated Filter Strips

Table SSR summarizes the ability of each of these redevelopment BMPs to provide groundwater recharge, improve water quality, and attenuate peak flows. Redevelopment projects are required to meet Standard 2, Standard 3, and the structural best management practice requirements of Standards 4, 5 and 6 *to the maximum extent practicable*.

Redevelopment projects must meet all other requirements of the Stormwater Management Standards *and* improve existing conditions using one or more of the above techniques. Chapter 3 provides a detailed checklist to help conservation commissions and applicants determine which BMPs are most appropriate in each case and what types of improvements they provide.

Table SSR

Stormwater Standards and Redevelopment				
BMPs	**Standard 7: Is BMP Suitable for Redevelopment?**	**Standard 2: Does BMP Attenuate Peak Flows?**	**Standard 3: Does BMP Provide Recharge?**	**Standard 4: Does BMP Remove TSS?**
Pretreatment				
Deep sump catch basin	Yes	No	No	Yes
Oil grit separator	Yes	No	No	Yes
Proprietary separators	Yes	No	No	Yes
Sediment forebay	Yes	No	No	Yes
Vegetated filter strip	Yes	Some with careful design	No	Yes
Treatment				
Bioretention area/rain gardens	Yes	No	Depends on design	Yes
Constructed stormwater wetlands	As retrofit for dry detention basin	Yes	No	Yes
Extended dry detention basin	As retrofit for dry detention basin	Yes	No	Yes
Gravel wetlands	As retrofit for dry detention basin	Yes	No	Yes
Proprietary media filters	Yes	No	No	Yes
Sand/Organic filters	Yes	No	No	Yes
Tree box filters	Yes	No	No	Yes
Wet basins	As retrofit for dry detention basin	Yes	No	Yes
Conveyance				
Drainage channels	Yes	No	No	No
Grass channels	Yes	No	No	Yes
Water quality swale-dry	Yes	With careful design	No	Yes
Water quality swale-wet	May not be practicable because of site constraints	N/A	N/A	N/A
Infiltration				
Dry wells	Yes, runoff from nonmetal roofs and metal roofs outside Zone II, IWPA, and industrial sites	No	Yes	Yes
Infiltration basins	May not be practicable because of site constraints	N/A	N/A	N/A
Infiltration trenches	Yes, w/pretreatment	Yes Full Exfiltration System Trenches	Yes	Yes
Leaching catch basins	Yes, w/pretreatment	Yes if sufficient catch basins	Yes	Yes
Subsurface structures	Yes w/pretreatment	No	Yes	Yes
Other BMPs				
Dry detention basin	May not be practicable because of site constraints	N/A	N/A	N/A
Green roofs	Yes	Some with careful design	No	No

Porous pavement	Yes	Some with careful design	Yes	Yes
Rain barrels & cisterns	Yes	Some for cisterns with careful design	No	No

Additional references and links for Redevelopment Projects:
U.S. Department of Transportation, Federal Highway Administration
Stormwater BMPs in an Ultra-Urban Setting: Selection and Monitoring:
www.fhwa.dot.gov/environment/ultraurb/uubmp6p2.htm
California Stormwater Quality Association
www.cabmphandbooks.com/Development.asp
Center for Watershed Protection, Urban Stormwater Retrofit Manual
http://www.cwp.org/PublicationStore/USRM.htm#usrm3

Retrofitting Existing Stormwater Management Measures
MassDEP defines retrofitting as expanding, modifying, or otherwise upgrading existing stormwater management measures. As such, retrofitting stormwater management measures can reduce some of the adverse stormwater quantity and quality impacts caused by existing land developments. In many instances, existing stormwater management measures can be dramatically improved, and downstream water bodies protected, through effective retrofitting.

Beginning in the 1970s, many new developments were constructed with dry detention basins. Many of these facilities were built to attenuate the peak flow impacts of the 10-year, 25-year, and/or 100-year 24-hour storms. Because smaller storms are typically responsible for degrading water quality and eroding stream banks, it makes sense to retrofit such facilities to control these smaller storm events.

Another important benefit of retrofitting stormwater management facilities is the opportunity to correct site nuisances, maintenance problems, and aesthetic concerns. Retrofitting also allows a community to keep pace with new stormwater management regulations and objectives. It can help a community address a particular stormwater quantity or quality problem that has developed as a result of deficiencies in existing stormwater management facilities, or a basin-wide problem that has been identified in a TMDL. Constructing new stormwater management systems at future land development sites will not be sufficient to bring all the waters of the Commonwealth into compliance with the state's water quality standards. To assure that all the state's surface waters meet their existing and designated uses, previously constructed stormwater management facilities located at redeveloped sites must be retrofitted and improved.

In addition to such basic considerations as need and cost, two important factors must be considered when evaluating retrofit possibilities:

1. Health and safety; and
2. Effectiveness.

Review these factors thoroughly before undertaking a stormwater management measure retrofit to justify the cost and effort and ensure the retrofit's long-term success.

<u>Health and Safety</u>
A retrofit must not increase health and safety risks in any way. For example, the storage volume in an existing dry detention basin presently used for stormwater quantity control must not be reduced to provide new stormwater quality enhancement without ensuring that the lost quantity

storage will not adversely increase peak basin outflows and cause downstream flooding or erosion.

Effectiveness

In many retrofit situations, it may not be possible to upgrade the stormwater management measure to meet all current groundwater recharge and stormwater quality and quantity standards. This means that relative performance improvements for a range of retrofits must be evaluated to determine which one represents the optimum combination of effectiveness, viability, and cost. As a result, the final retrofit selected for an existing stormwater measure will have to be based on its relative rather than absolute effectiveness. In such relative determinations, both the costs and benefits of the evaluated retrofits become more influential factors than when an absolute performance standard is used. Chapter 3 provides guidance on the BMPs most suitable for retrofitting.

Maintenance Requirements

Too often, BMPs are constructed without plans or obligations for long-term maintenance. Chapter 2 includes the basic maintenance requirements for each structural control. The maintenance requirements for BMPs must be considered during the selection process. Because maintenance is mandatory, it is logical that BMP selection should gravitate toward measures that are more easily maintained. In general, BMPs installed *above ground* are easier to maintain than ones placed *underground.* Further, BMPs that incorporate *natural vegetation* as part of the pollutant removal process, such as bioretention areas, require less maintenance than *engineered and pre-fabricated systems*.

For most BMPs, the maintenance requirements include visual inspections (e.g., inspection of sediment forebays) and physical upkeep (e.g., removing and disposing of sediment, and mowing water quality swales). Whatever the maintenance requirements, the Stormwater Management Standards mandate that all stormwater management facilities have an Operation and Maintenance Plan. The Operation and Maintenance Plan must clearly address the following BMP maintenance issues:

- How and when maintenance is to be performed,
- How and when inspections will be performed, and
- How these tasks will be financed.

The Operations and Maintenance Plan must provide that best practical measures be implemented to conduct maintenance activities in a manner that avoids, minimizes and mitigates adverse impacts to wetland resource areas. BMPs should be designed to minimize maintenance needs wherever possible. Proponents should anticipate future maintenance problems and develop plans to alleviate them as much as possible. Preventative design measures, such as using forebays to trap incoming first-flush sediment, can reduce the future maintenance costs and requirements.

At a minimum, the Operation and Maintenance Plan must also identify:

(1) Stormwater management system owners
(2) The party or parties responsible for operation and maintenance
(3) The routine and non-routine maintenance tasks to be undertaken after construction is complete and a schedule for implementing those tasks
(4) Plan showing the location of all stormwater BMPs

(5) Description and delineation of public safety features
(6) Estimated operations and maintenance budget

For the developer, the most difficult part of preparing a maintenance plan may be identifying the party that is responsible for performing and paying for the long-term maintenance of the BMP. The Order of Conditions should require the responsible party to: (1) implement the Operation and Maintenance Plan; (2) maintain a log of all operation and maintenance activities including without limitation inspections, repairs, replacement and disposal (for disposal, the log shall indicate the type of material and the disposal location); (3) make this log available to the MassDEP and the Conservation Commission; (4) allow the MassDEP and the Conservation Commission to inspect each BMP to determine whether the responsible party is implementing the Operation and Maintenance Plan; and (5) submit the O & M Compliance Statement when requesting a Certificate of Compliance.