Chapter 5

MANAGING STORMWATER

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5.0. INTRODUCTION: THE HISTORICAL REALITIES

The modern urban drainage system came into being soon after World War II. This generally consisted of a system of catch basins and pipes to prevent flooding and drainage problems by efficiently delivering runoff water to the nearest water body. However, as noted in **Chapter 4**, delivering the water too quickly often caused severe downstream flooding and streambank erosion in the receiving water. To prevent streambank erosion and provide more space for flood waters, some stream channels were enlarged and lined with concrete. While hardening and enlarging natural channels appeared to solve the erosion and flooding in the immediate vicinity, at some point the paved channels ended. The modified channels delivered increased peak flows to the unprotected receiving streams, often causing erosion and flooding further downstream and disturbing habitat necessary to support healthy aquatic ecosystems.

To control the quantity of water reaching the ends of pipes and channels during runoff events, on-site detention became the standard solution, requiring developers to reduce the peak flows of specified design storms. Detention can control peak flows directly below the point of discharge and at the property boundary. However, when designed on a site-by-site basis without taking other basins into account, they can lead to downstream flooding problems, because total flow volume is not reduced (McCuen, 1979; Ferguson, 1991; Traver and Chadderton, 1992; EPA, 2005d). In addition, in order to prevent clogging, openings in outlet structures for most basins are generally too large to hold back flows from smaller, more frequent storms – the storms that cause most of our water quality problems.

Because of the limitations of on-site detention, infiltration of urban runoff has become a recent goal of stormwater management, in order to control runoff volume. Without stormwater infiltration, Virginia communities can expect drops in local groundwater levels, declining stream base flows (Wang et al., 2003a), and flows diminished or stopped altogether from springs feeding wetlands and lakes (Leopold, 1968; Ferguson, 1994).

The need to provide volume control marked the beginning of Low Impact Development (LID) and Conservation Design (Prince George's County, 2000; Arendt, 1996), which were founded on the work of landscape architect Ian McHarg and associates decades earlier (McHarg and Sutton, 1975; McHarg and Steiner, 1998). The goal of LID is to allow for development of a site while maintaining as much of its natural hydrology as possible (e.g., infiltration, frequency and volume of discharges, and groundwater recharge). This is accomplished with infiltration practices, functional grading, open channels, disconnection of impervious areas, and the creation of less impervious surfaces. Much of the LID focus is to manage the stormwater as close as possible to its source – that is, on each individual lot rather, than conveying the runoff to a larger regional Best Management Practice (BMP). Individual practices include rain gardens, disconnected roof drains, permeable pavement, narrower streets, and grass swales. In some cases, LID site plans still must include a method for passing the larger storms safely from the site and through the downstream drainage system.

Evidence gathered in the 1970s and 1980s suggested that pollutants be added to the list of things in stormwater that need to be controlled (EPA, 1983). Damages caused by elevated flows, such as stream habitat destruction and floods, were relatively easy to document with something as simple as photographs. However, documentation of elevated concentrations of conventional and potentially toxic pollutants required intensive collection of water quality samples during runoff events. Early sampling efforts clearly showed the concentration of many pollutants, such as heavy metals and sediment, were elevated in urban runoff (Bannerman et al., 1979). Levels of heavy metals were especially high in industrial site runoff, and construction erosion was calculated to be a large source of sediment in watersheds. The National Urban Runoff Program added more evidence about the high levels of some pollutants found in urban runoff (Athayde et al., 1983; Bannerman et al., 1983).

With new development rapidly adding to the environmental impacts of existing urban areas, the need to develop effective stormwater management programs is more urgent than ever. Current day BMPs represent a radical departure from past practices, which focused on dealing with extreme flood events via large detention basins designed to reduce peak flows at the downstream property line. As described in this chapter, BMPs now include practices intended to meet broad watershed goals of protecting the biology and geomorphology of receiving waters in addition to flood peak protection. Effective stormwater management encompasses such diverse actions as using more conventional practices, like basins and wetlands, as well as installing stream buffers, reducing impervious surfaces, reducing runoff volume, removing pollutants, and educating the public.

5.1 TODAY'S STORMWATER MANAGEMENT GOALS

It is difficult to discuss methods of controlling stormwater without first considering the goals those methods are expected to meet. A broadly stated goal for stormwater management is as follows: *To reduce pollutant loads to water bodies and maintain, as much as is possible, the natural hydrology of a watershed.* This goal is translated more specifically in the Virginia Stormwater Management Law, as follows:

> ***. . . maintain after-development runoff rate of flow and characteristics that replicate, as nearly as practicable, the existing predevelopment runoff characteristics and site hydrology, or improve upon the contributing share of the existing predevelopment runoff characteristics and site hydrology if stream channel erosion or localized flooding is an existing predevelopment condition.*** (§ 62.1-44.15:28 A 7, Code of Virginia)

As is the case in numerous other states, Virginia relies on engineering criteria for BMP performance as the basis for more specific stormwater management goals. These criteria can be loosely categorized as:

Erosion and Sediment Control. This goal refers to the prevention of erosion and sedimentation from sites during construction and is focused at the site level. Criteria usually include a barrier plan to prevent sediment from leaving the site (e.g., silt fences, etc.), practices to minimize potential erosion of exposed soils (e.g., phased construction, timely stabilization, etc.), and facilities to capture and remove sediment from runoff (e.g., sediment basins, etc.). Because these measures are considered temporary, smaller storm events are designated as the design storms rather than those typically used if flood control is the goal.

Recharge Groundwater and Stream Base Flow. This goal focuses on sustaining the pre-construction hydrology of a site as it relates to stream base flow and groundwater recharge.

Water Quality Protection. This goal is usually crafted as a percent removal or a quantitative load limit for one or more specific target pollutants typically present in the stormwater discharge, and the goal is usually associated with a set volume ("Treatment Volume") of stormwater being treated by the BMPs. In Virginia, the target/indicator pollutant is Total Phosphorus.

Stream Channel Protection. This goal refers to protecting receiving stream channels from accelerated erosion during and immediately after storm events due to increased runoff. It is tied to the storm event that is presumed to be the typical "channel forming" storm event.

Frequent Flood Prevention. This goal addresses public safety and protection of property. It is applicable to storm events that exceed the carrying capacity of the receiving channel.

Extreme Flood Protection. This goal addresses public safety and protection of property in the event of an extreme or catastrophic storm event, such as the 100-year storm. In Virginia this goal addressed, as is typically done elsewhere, through flood plain management ordinances and BMP design criteria that provide for bypassing the extreme storm flow safely around stormwater control structures.

In Virginia, erosion and sediment control is the subject of a completely separate regulatory program. The other goals are discussed in more detail in **Chapter 10**, ***Unified Sizing Criteria***.

5.2 THE EMERGING SOLUTION

Some U.S. communities are already taking steps to successfully manage their land and develop using a more holistic, *green infrastructure* approach. Green infrastructure is our Commonwealth's life support system – an interconnected network of waterways, wetlands, woodlands, wildlife habitats and other natural areas such as greenways, parks and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces. This green network supports native species, maintains natural ecological processes, sustains air and water resources, and contributes to the health and quality of life for Virginia's communities and citizens (adapted from Benedict and McMahon, 2006). More simply, green infrastructure is a network of ecologically significant blocks of landscape, called cores or hubs, which connect to linear bands of green space, called corridors.

Green infrastructure planning is actually a comprehensive planning-scale approach that identifies these hubs and corridors, integrating outdoor recreation, open space, cultural resources and conservation lands. Strategically linking linear land corridors maximizes environmental, habitat and outdoor recreation resources to meet the needs of growing populations. Used prior to development, the planning model identifies and ranks vital natural resources in concert with other community needs and gray infrastructure (pipes, pavement, mechanical systems, etc. that support community functions. Land development and growth is then guided in ways that accommodate increased populations while protecting natural resources, thereby providing long-term economic viability and community sustainability.

While green infrastructure-type comprehensive planning is beyond the scope of this Handbook, it is important for site and stormwater designers to understand the natural linkages of this approach with site and stormwater design. Environmental Site Design practices, which are discussed in **Chapter 6** this Handbook, promote preserving open space and sensitive resources and minimizing impervious cover. The open spaces preserved on a site provide more impact when they are linked with identified green infrastructure hubs and corridors to strengthen the green system. At the scale of BMP selection and design, focusing on runoff reduction carries this approach even further, to the micro-site scale, helping to replicate existing site hydrology and runoff characteristics, while minimizing negative impacts on the natural stream system that is part of our green infrastructure.

Emerging green design techniques for managing stormwater present a new pollution control philosophy based on the known benefits of natural systems, which provide multimedia pollution reduction and use soil and vegetation for the trapping, treating, filtration, infiltration and evapotranspiration of stormwater. The communities already using these techniques are finding that they provide a viable alternative to traditional stormwater management methods.

In addition to removing pollution from runoff, this more holistic approach reduces and delays runoff volumes, enhances groundwater recharge, protects surface water from stormwater runoff, increases carbon sequestration, mitigates urban heat island effects, improves air quality, increases wildlife habitat, and results in better urban aesthetics. In other words, *this approach more closely replicates the pre-development hydrology and runoff characteristics of the site.*

Although used widely overseas, particularly in Germany and Japan, the use of this approach in the United States is still in its infancy. However, data indicate that it can effectively reduce stormwater runoff and remove stormwater pollutants. Communities that have implemented green design are already reaping the benefits.

The urban landscape, with its large areas of impermeable roadways and buildings (impervious surfaces) has significantly altered the movement of water through the environment. Over 100 million acres of land have been developed in the United States, and with development and sprawl increasing at a rate faster than population growth, urbanization’s negative impact on water quality is a problem that won’t be going away. To counteract the effects of urbanization, communities are beginning to promote site designs that intercept precipitation and allow it to infiltrate, rather than being collected on and conveyed from impervious surfaces.

Each year, the rain and snow that falls on urban areas in the United States results in billions of gallons of stormwater runoff and combined sewer overflows (CSOs). Green design techniques reduce the amount of pollution introduced into waterways and help to relieve the strain on stormwater and wastewater infrastructure. Efforts in many cities have shown that this approach can be used to reduce the amount of stormwater discharged or entering combined sewer systems and that it can be cost-competitive with conventional stormwater and CSO controls.

This new approach to site and stormwater design is also unique because it offers an alternative land development approach. New developments that incorporate these techniques often cost less to build because of decreased site development and conventional infrastructure costs. Furthermore, such developments are often more attractive to buyers because of environmental amenities. The flexible and decentralized qualities of this approach also allow it to be retrofitted into developed areas to provide stormwater control on a site-specific basis. The techniques can be integrated into redevelopment efforts ranging from a single lot to an entire citywide plan.

Nonetheless, wider adoption of this new design approach still faces obstacles. Among these is the economic investment that is required across the country for adequate stormwater and CSO control. Although these techniques are in many cases less costly than traditional methods of stormwater and sewer overflow control, some municipalities persist in investing only in existing conventional controls rather than trying an alternative approach. Local decision makers and organizations must take the lead in promoting a cleaner, more environmentally beneficial method of reducing the water pollution that affects their communities. The DEQ recommends that local decision makers institute the following policies to promote the use of green infrastructure:

1. **Develop with green design and pollution management in mind.** Build green space into new development plans and aim to preserve as much existing vegetation as is feasible.

2. **Incorporate green design into long- term control plans for managing combined sewer overflows.** Green techniques can be incorporated into plans for infrastructure repairs and upgrades.

3. **Revise local stormwater regulations to encourage green design.** A policy emphasis should be placed on reducing impervious surfaces, preserving vegetation, capturing runoff on-site, providing water quality improvements, and protecting receiving streams from runoff-related damage. *(NRDC – "Rooftops to Rivers")*

4. **Incorporate stormwater management, including environmental site design techniques that reduce imperviousness, in the early planning stages of development projects and community growth strategies.** Retrofitting existing development with BMPs is much more technically difficult and costly, because the space may not be available, other infrastructure is already installed, and/or utilities may interfere. There may also be easements dedicated to homeowner's associations or other entities that present regulatory limitations to what can be done. Because of these kinds of barriers, retrofitting existing urban areas often depends on the use of engineered or manufactured BMPs, which are more expensive for both construction and operation (NRC, 2008).

In support of these concepts, the Water Science and Technology Board of the National Research Council has recently recommended that "[f]uture development and water resource protection plans should consider reducing impervious cover in the potential expansion of communities" (NRC, 2008, pg. 119). Examples of this include encouraging residential cluster developments, building taller buildings, reducing the width of residential streets, creating one-side sidewalks, reducing the size of parking lots to satisfy average parking needs rather than peak requirements, and using permeable pavement in overflow parking lots. In so doing, traditional impervious cover could be reduced 10-50 percent (NRC, 2008, pg. 122).

5.2.1 What Is the Green Infrastructure Approach?

In the *green infrastructure* approach, centralized treatment and/or storage facilities located at the "end of pipe" discharge from developed sites are classified as structural BMPs. While structural BMPs such as stormwater ponds and wetlands can be effective in controlling peak flows from the site, current regulatory requirements for these structures do not address the frequent storms that erode stream banks, and do little or nothing to promote recharge. Furthermore, structural BMPs can contribute to downstream flooding when discharges from separate on-site structural BMPs overlap. Structural BMPs can be effective in pollutant removal; but since they generally omit groundwater recharge, consume space, and require extensive maintenance, they are less appropriate for the task. There is an emerging recognition that wet detention structural BMPs contribute to elevated stream temperatures, and discharge algae laden effluent, which can substantially degrade the benthic community in the receiving stream.

As a result, many progressive agencies are promoting the green infrastructure approach, which is designed to intercept runoff from rooftops, parking lots and roads as close as possible to its source, and direct it into vegetative recharge/filtration facilities incorporated into the overall site design and runoff conveyance system. Green infrastructure design techniques described in this Handbook include environmental site design, impervious area disconnection, conveyance of runoff through filter strips and swales, terraces, bioretention facilities, and recharge through infiltration facilities. These design techniques and BMPs form the basis of green infrastructure at the site engineering level.

Since these vegetated structures do not rely on detention, these BMPs are "Green". However, while green infrastructure BMPs may seem less complex than structural detention measures, procedures for their proper design require the same hydrologic and hydraulic methods used in designing structural BMPs. The use of green design also involves a quantitative approach for reducing runoff volume and estimating pollutant loads, as well as projecting how well a particular design will remove such pollutants. Hence it is a "Technology", capable of providing realistic estimates of pollutant loading and removal, while also addressing hydrologic and hydraulic parameters involved in urban site design.

5.2.2 The Treatment Train Approach

Many, if not most, development sites will need to employ multiple practices in order to satisfy the nutrient reduction requirements in the Regulations and adequately manage stormwater runoff. Under the treatment train approach, stormwater management begins at the site level with simple methods that (1) minimize the amount of runoff from the site, and (2) prevent pollution from accumulating on the land surface and becoming available for transport in site runoff. This approach relies heavily on Better/Environmental Site Design, pollution source controls, and non-structural SCMs). **Figure 5.1** below illustrates this "treatment train" approach.

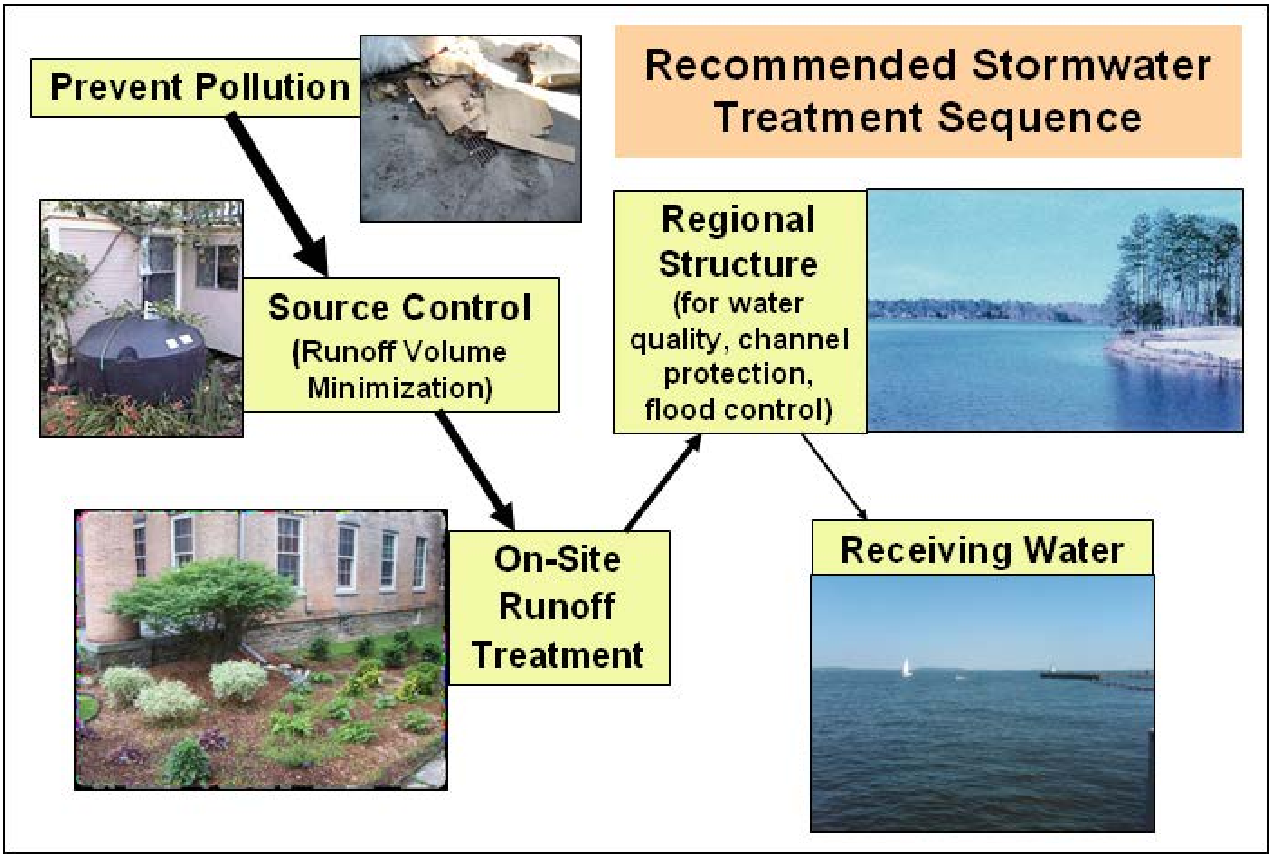

Figure 5.1: Treatment Train Approach for Stormwater Management (Adapted from MPCA, 2005)

As noted above, to be most effective and least costly, stormwater management plans should be conceived in the early planning stages of development projects. Most important, stormwater management plans using the green infrastructure approach organize the BMPs in a way that mimics the natural hydrology of the site. Thus, rainfall travels from the roof to the stream through a series of practices spread throughout the entire development site. **Table 5.1** lists groups of practices that reflect this order. No BMP should be considered for use without first considering those that precede it on this list. For example, environmental site design techniques, such as conserving or restoring open space and natural areas or minimizing impervious coverage through narrower streets, clustering, etc. are the first step. At this stage, pollution prevention practices are also applied to minimize the amount of pollutants that are available to wash off the site in stormwater runoff.

Then initial capture practices are applied, such as green roofs, rainwater harvesting (rain tanks and cisterns), or downspout disconnection are applied. Remaining runoff would then be directed to practices such as grass filters or dry swales, which might drain into bioretention or infiltration structures. This approach minimizes the amount of runoff generated and captures much of the runoff along the pathway to the development site outfall. If additional treatment or volume mitigation is needed, a pond or constructed wetland might be installed at the downstream end of the development site, as the final practice in the treatment train.

Table 5.1. Summary of Stormwater Control Measure (SCM) Categories

Stormwater Control Measure	When Used?[1]	Where Installed?[2]	Who Is Responsible?[3]	Hydrologic Control Objectives[4]	Water Quality Objectives[5]	Est. Maint. Protocols[6]
1. Product Substitution (lead-free gasoline, ethanol, P-free detergent, etc.) [7]	Continuous	State, regional	Regulatory agencies	NA[8]	Prevention	NA
2. Watershed and Land-Use Planning	Planning stage	Watershed	Local planning agencies	All objectives	Prevention	Yes
3. Conservation of Natural Areas	Site and watershed planning stage	Site, watershed	Developer, local planning agency	Prevention	Prevention	Yes
4. Impervious Cover Minimization	Site planning stage	Site	Developer, local review authority	Prevention & reduction	Prevention	No
5. Earthwork Minimization	Grading plan	Site	Developer, local review authority	Prevention	Prevention	Yes
6. Erosion and Sediment Control	Construction	Site	Developer, local review authority	Prevention & reduction	Prevention and removal	Yes
7. Reforestation and Soil Conservation[9]	Site planning and construction	Site	Developer, local review authority	Prevention & reduction	Prevention	No
8. Pollution Prevention SCMs for Stormwater Hotspots	Post-construction or retrofit	Site	Operators and local and state permitting agencies	NA	Prevention	No
9. Runoff Volume Reduction – Rainwater Harvesting	Post-construction or retrofit	Rooftop	Developer, local planning agency and review authority	Reduction	Removal	Yes
10. Runoff Volume Reduction – Vegetated (Green roofs, Bioretention, Bioinfiltration, Bioswales)	Post-construction or retrofit	Site	Developer, local planning agency and review authority	Reduction & some peak attenuation	Removal	Emerging
11. Runoff Volume Reduction – Subsurface (Infiltration Trenches, Permeable Pavement)	Post-construction or retrofit	Site	Developer, local planning agency and review authority	Reduction & some peak attenuation	Removal	Yes
12. Peak Reduction and Runoff Treatment (Stormwater Wetlands, Dry/E.D. Ponds)	Post-construction or retrofit	Site	Developer, local planning agency and review authority	Peak attenuation	Removal	Yes
13. Runoff Treatment (Sand Filters, Manufactured Treatment Devices)	Post-construction or retrofit	Site	Developer, local planning agency and review authority	None	Removal	Yes
14. Aquatic Buffers and Managed Floodplains	Planning, construction and post-construction	Stream corridor and sinkholes	Developer, local planning agency and review authority, landowners	NA	Prevention and removal	Emerging
15. Stream Rehabilitation	Post-development	Stream corridor	Local planning agency and review authority	NA	Prevention and removal	Unknown
16. Municipal Housekeeping (Street Sweeping, Storm Drain Cleanouts)	Post-development	Streets and stormwater infrastructure	MS4 permittee	NA	Removal	Emerging
17. Illicit Discharge Detection and Elimination	Post-development	Stormwater infrastructure	MS4 permittee	NA	Prevention and removal	No
18. Stormwater Education	Post-development	Stormwater infrastructure	MS4 permittee	Prevention	Prevention	Emerging
19. Residential Stewardship	Post-development	Stormwater infrastructure	MS4 permittee	Prevention	Prevention	No

TABLE NOTES:

[1] At which stage of the development cycle is the practice applied?

[2] Location/scale in the site/watershed where the practice is installed?

[3] Who is responsible for implementing the practice?

[4] Prevention = prevents generation of runoff; Reduction = reduces volume of runoff; Treatment = delays runoff delivery only; Peak Attenuation = reduction of peak flows through detention

[5] Prevention = prevents generation, accumulation, or wash-off of pollutants and/or reduces runoff volume; Removal = reduces pollutant concentrations in runoff by physical, chemical or biological means

[6] No = extremely limited understanding of procedures to maintain BMP in the future; Emerging = still learning about how to maintain the BMP; Yes = solid understanding of maintenance for future BMP needs

[7] Italics = Nonstructural BMPs

[8] NA = Not Applicable for the BMP

[9] Shaded rows correspond to Runoff Reduction Method and BMPs shown in **Table 5.5**

Source: Adapted from NRC, 2008

As noted above, these measures often result in significant cost savings for development projects, even when land costs are factored. Once efforts to minimize runoff volume and stormwater pollution are identified, the next step is to select structural stormwater BMPs, or groups of BMPs, aimed at collecting and treating the runoff that is generated.

The following provides additional information about each step in the treatment train approach to BMP selection. Included in the discussion are examples of some of the different structural and non-structural BMPs that can be employed during each step of the BMP selection process at a development site.

5.2.2.1 Pollution Prevention

The first step in effectively managing stormwater is to identify opportunities for stormwater pollution prevention. Stormwater pollution prevention is aimed at reducing and/or preventing the contamination of stormwater runoff at its source, *before* it has an opportunity to pollute the runoff flow and enter the conveyance system. Stormwater pollution prevention practices, also know as *"source controls,"* are an important way to prevent water quality problems in stormwater runoff from a variety of sources. The intent of source control practices is to prevent stormwater from coming in contact with pollutants in the first place rather than having to use downstream structural controls to treat the runoff and remove pollutants. Examples include keeping impervious surfaces clean and handling and storing chemicals properly.

The pollution prevention practices that can be used depend on whether the land use is residential, commercial, industrial, institutional, or municipal development. The nature and distribution of pollutant sources are different at every development site and, therefore, the practices that are used are unique to each site. **Table 5.2** below illustrates some of the common pollution prevention practices used in both residential and non-residential developments.

Promoting Pollution Prevention Management Practices

A community should actively promote the use of stormwater pollution prevention management practices by local businesses, industries, and institutions. This is ideally done through the adoption of a compendium of pollution prevention practices by communities. Both existing and new development can be required to prepare a stormwater pollution prevention plan (SWPPP) as a condition of a business or operation permit, or as part of an overall stormwater management site plan.

Table 5.2. Common Pollution Prevention Practices (Source Controls)

Residential Developments	Non-Residential Developments
• Product Substitution • Natural Landscaping • Tree Planting • Yard Waste Composting • Septic System Maintenance • Driveway/Parking Lot/Street Sweeping • Materials Management • Household Hazardous Waste Collection Programs • Car Fluid Collection and Recycling Programs • Downspout Disconnection • Pet Waste Pickup • Storm Drain Marking • Storm Drain Maintenance	• Covered Loading Areas • Fuel Containment Areas • Covered Vehicle Storage Areas • Removal of Illicit Storm Drain Connections • Catch Basin Cleanout • Downspout Disconnection • Covered Dumpsters • Prevention of Illegal Dumping • Covered Materials Storage Areas • Secondary Containment Structures • Spill Prevention and Response Plans • Signage • Employee Training

Brochures and fact sheets containing relevant pollution prevention practices as well as training programs and/or videos can be made available for specific commercial and industrial categories (such as restaurants, gas stations, or concrete operations) to provide business owners and employees with the necessary tools to preventing stormwater contamination in their activities and operations. More specific information about public information and education programs can be found in **Section 8.2.16** of **Chapter 8** in this Handbook.

Municipal Housekeeping

The first role of a local government is to prevent stormwater pollution by setting the example. A community should implement relevant pollution prevention practices in all areas of local government operations and activities. This can include such things as:

- Material Storage Practices
- Waste Reduction and Disposal
- Fleet Vehicle Maintenance
- Building and Grounds Maintenance
- Construction Activities

Though often associated with public works departments, housekeeping activities should be implemented across the entire spectrum of local agencies and entities, including locally-owned utilities (e.g. water and wastewater facilities and operations), parks and recreation departments, school districts, public hospitals, administrative offices, and other publicly-owned facilities.

Municipal facilities and operations should prepare a stormwater pollution prevention plan as well as a spill prevention plan, if applicable. These plans should include provisions for how a department or agency plans to reduce pollutant runoff from their site, including reducing exposure of potential pollutants and removing pollutants discharged from their site. Regular visits and inspections of each facility would be performed to insure compliance with these plans. A training program and/or video on stormwater issues and pollution prevention can be developed and provided for public employees.

Hazardous Household Waste Management

Household hazardous wastes can include a wide variety of materials used in the home, including paints, solvents, pesticides, herbicides and cleaners. Residents often dispose of the unused portion of these products down a drain (which goes to the wastewater treatment plan or septic tank), or they may dump them in their yard, a storm drain or a drainage ditch or stream. They may also put them in their trash can, for ultimate disposal in the local solid waste landfill. These faulty disposal strategies result in harm to bacteria in wastewater treatment plants or septic systems that digest or break down wastes, or direct pollution to streams, or the risk of long-term infusion of pollutants into the soil and, ultimately, the groundwater at landfill sites.

Ideally, a community should establish a collection center for household hazardous wastes. Citizens would be able to drop off their wastes, which can then be categorized and disposed of at an approved hazardous waste facility. An alternative is for the community to hold household hazardous waste drop-off days 2-4 times a year, where citizens can bring their waste materials to drop-off sites, and the community then categorizes and disposes of the materials. The cost of such operations can be borne through fees/per volume of material or absorbed into the fee structure of a local stormwater utility. A complementary option is to encourage the use of non-hazardous or less-hazardous alternatives for particular products.

Street Sweeping

Street and parking lot sweeping on a regular basis can remove sediment debris, litter and other pollutants from road and parking lot surfaces that are potential sources of stormwater pollution. Recent improvements in street sweeper technology have enhanced the ability of machines to pick up fine-grained sediment particles that carry a substantial portion of the stormwater pollutant load.

The frequency of and location of street sweeping is an important consideration for any program. How often and where to sweep are determined by the program budget and the level of pollutant removal the community wishes to achieve.

Dry Weather Outfall Screening / Illicit Connection Removal

A community should have an active dry weather outfall screening program to identify and eliminate illicit or illegal discharges from entering the stormwater drainage system. These discharges can include a variety of commercial, industrial or manufacturing process water discharges, floor drains from businesses or industrial locations, or even illicit sanitary sewer connections. They are generally characterized by continuous or periodic discharges which occur during dry and wet weather and contain pollutants that should not be discharged to surface waters.

A number of different procedures can be used to identify illicit connections and discharges into the stormwater drainage system. Once they have been identified, they should be eliminated under the authority of existing local ordinances or by referring the matter to the appropriate state agency. Information on what are appropriate connections to the stormwater drainage system should be provided to developers and contractors to prevent future illicit connections.

Sanitary Sewer Maintenance

Leaking sanitary sewer lines located near storm sewer pipes, paved channels and streams can add pathogens as well as nutrients such as nitrogen and phosphorus to stormwater and surface waters. Human waste also contributes to biological oxygen demand (BOD). Inspections and leak detection of sanitary sewer lines should be conducted on a regular basis as part of an operations and maintenance program for a local wastewater utility, public works department, or other responsible entity.

Septic Tank Maintenance

Effluent from poorly maintained or failing septic systems can rise to the surface and contaminate stormwater runoff. Improperly maintained septic systems can be potentially significant sources of pathogens and nutrients, especially nitrogen to stormwater runoff. In order to combat this problem, communities need to promote or require the regular maintenance of septic tank systems. A local jurisdiction can track septic tanks in a database, and send out notices at the required interval for septic tank inspections and maintenance. Septic tanks can also be permitted by a local jurisdiction, with permit renewal contingent on certification of septic tank maintenance.

Landfills

Improperly maintained landfills can allow litter, nutrients, pathogens and toxic contaminants to reach or stay on the surface of the landfill, allowing runoff to carry these pollutants to nearby water bodies. Therefore, it is important that a community regulate landfills to require the appropriate management measures to keep contaminated runoff from leaving the landfill site.

Pollution Reporting Hotline / Spill Response

Local citizens can be helpful eyes and ears by reporting water quality problems and polluting activities. A community should have procedures for reporting stormwater polluters and promptly responding to emergencies such as hazardous materials spills. A telephone hotline could be established for receiving calls about water pollution, polluters and spills. It would be preferable for this number to be manned 24 hours a day or at least for extended daily hours.

More guidance for establishing an effective local stormwater pollution prevention program can be found in **Chapter 8** of this Handbook. Even more detailed guidance about pollution prevention measures can be found in Manual #9 of the Center for Watershed Protection's *Urban Subwatershed Restoration Manual Series*, entitled ***Municipal Pollution Prevention / Good Housekeeping Practices*** (June 2008). The USEPA web site is also a good source for guidance on many of these source control types of practices, at:

http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=min_measure&min_measure_id=6

5.2.2.2 Runoff Volume Reduction

The next step in effectively managing stormwater is to identify opportunities for runoff volume reduction and/or groundwater recharge at the development site, which can reduce the generation of stormwater runoff. These BMPs typically have the effect of reducing the amount of impervious cover and the amount of stormwater runoff that must be controlled, which can save space and reduce the cost of BMPs at the site. **Table 5.3** lists some of the common BMPs used to reduce runoff volumes at development sites. **Figure 5.2** is a cluster development that conserves natural open space for common use and reduces the amount of streets and utilities needed to serve the community. **Figure 5.3** is an example of a Green Street design, incorporating several of these concepts. This location, part of the Natural Drainage Systems Project in Seattle, Washington, exhibits several elements of impervious cover reduction. In particular, vegetated swales were installed and curbs and gutters removed. There are sidewalks on only one side of the street, and they are separated from the road by the swales. The residences' rooftops have been disconnected from the storm drain systems and are redirected into the swales.

Table 5.3.Common ESD Techniques and BMPs Used to Reduce Runoff Volume

Runoff Reduction Measures	
• Natural Area Conservation • Site Reforestation • Prairie/Meadow Restoration • Stream and Shoreline Buffers • Soil Amendments • Impervious Cover Disconnection • Downspout Disconnection • Open Space Subdivision • Design Grass Channels • Bioretention	• Filtration • Infiltration • Dry Swales • Filter Strips (Sheet Flow to Open Space) • Reduced Street Width • Reduced Sidewalks • Smaller and/or Vegetated Cul-de-sacs • Shorter Driveways • Green Parking Lots and Driveways • Shared Parking Lots and Driveways

Figure 5.2. Cluster Development

Figure 5.3. Green Street Design for 110th Street, Seattle, WA
(Source: Seattle Public Utilities)

In the past, using these kinds of site design techniques, such as preserving open space to reduce runoff volume, did not translate into any kind of economically tangible credit for developers in Virginia. However, that is no longer true. Runoff volume calculations using the new Runoff Reduction Method (discussed below) will generate smaller amounts of site runoff where land cover is preserved that produces less runoff. This will translate into fewer and/or smaller BMPs needed on the site to manage the runoff. **Chapter 6** will provide more specific guidance about Environmental Site Design techniques.

5.2.2.3 On-Site and Off-Site Structural Stormwater Treatment

The final step in managing site stormwater effectively is to select individual structural stormwater BMPs, or groups of structural BMPs, aimed at collecting and treating runoff either on-site or off-site. These structural BMPs include:

- Runoff Volume Reduction (including Vegetated Roofs and Rainwater Harvesting)
- Grass Swales or Open Channels (including Dry Swales and Wet Swales)
- Filtration (including Filters and Biofiltration)
- Infiltration (including Permeable Pavement and Bioinfiltration)
- Stormwater Basins (Constructed Wetlands, Wet ponds, and Extended Detention)

5.2.2.4 Use of Proprietary BMPs

There is a plethora of proprietary and experimental stormwater technologies on the market. Adding these practices to the list provides designers with more flexibility to comply with stormwater requirements in difficult development situations. The performance of some of these products still remains largely unproven for pollutants of concern in Virginia – nutrients in particular. The DEQ, in cooperation with the Virginia Water Resource Research Center at Virginia Tech, has established a process for evaluating and certifying both public domain and manufactured treatment devices (MTDs) for use in the state. A list of approved MTDs is provided on the Virginia Stormwater BMP Clearinghouse web site, at http://www.vwrrc.vt.edu/swc/ DEQ expects this list to be expanded by July 2014..

5.3 THE VIRGINIA APPROACH

5.3.1 Site-Based Nutrient Load Limits

The Runoff Reduction Method for Virginia is focused on site compliance to meet a site-based load limit for Total Phosphorus (TP) of 0.41 lbs./acre/year. This means that the proposed Virginia stormwater regulations are aimed at limiting the total load of Phosphorus leaving a new development site. This is a departure from water quality computations of the past, in which the analysis focused on comparing the post-development site condition to the pre-development condition, or an average land cover condition. The chief objective of instituting a site-based load limit is so that land, as it develops, can still meet the nutrient reduction goals outlined in the Chesapeake Bay Tributary Nutrient Reduction Strategies.

With the site-based limit, newly-developed land will maintain loadings that replicate existing loading from agricultural, forested and mixed-open land uses, where there is no impervious cover. This is not to say that all developing parcels will maintain the pre-development loading rates, but that the rates, averaged across all development sites, will not increase when compared with loading rates from non-urban land.

An operational advantage to using site-based load limits is that it simplifies computations by focusing on the post-development condition. This should reduce time-consuming conflict between site designers and local government plan reviewers by eliminating disagreements about how to characterize the pre-development condition for a particular site.

Stakeholders participating on Advisory Committee's for the Stormwater Management Regulation revision process advised that Virginia should continue to use Total Phosphorus (TP) as the "indicator" pollutant of choice for stormwater regulation purposes. There are numerous practical and scientific reasons for this choice, but stakeholders also acknowledged that developers and consultants in Virginia are used to addressing TP, and continuing to use it would avoid unnecessary confusion. The load limit decided upon for Total Phosphorus is based on the TP load associated with an imperviousness threshold of 10 percent across a small watershed (as opposed to a river basin). Using the Center for Watershed Protection's *Impervious Cover Model* (see **Appendix 5-A** of this chapter), 10 percent is the upper limit of the range of imperviousness that results in stream degradation. So the goal would be to keep watershed imperviousness below 10 percent to avoid degradation of local streams and, subsequently, the Chesapeake Bay or other rivers fed by those streams.

5.3.2 Runoff Coefficients – Moving Beyond Impervious Cover

The negative impacts of increased impervious cover (IC) on receiving water bodies have been well documented (CWP 2003, Walsh et al. 2004; Shuster et al. 2005; Bilkovic et al. 2006). Due to widespread acceptance of this relationship, IC has frequently been used in watershed and site design efforts as a chief indicator of stormwater impacts.

More recent research, however, indicates that other land covers, such as disturbed soils and managed turf, also impact stormwater quality (Law et al, 2008). Numerous studies have documented the impact of grading and construction on the compaction of soils, as measured by increase in bulk density, declines in soil permeability, and increases in the runoff coefficient (OCSCD et al, 2001; Pitt et al, 2002; Schueler and Holland, 2000). These areas of compacted pervious cover (lawn or turf) have a much greater hydrologic response to rainfall than forest or pasture.

Further, highly managed turf can contribute to elevated nutrient loads. Typical turf management activities include mowing, active recreational use, and fertilizer and pesticide applications (Robbins and Birkenholtz 2003). An analysis of Virginia-specific data from the National Stormwater Quality Database (Pitt et al. 2004) found that runoff from monitoring residential sites with relatively low IC contained significantly higher nutrient concentrations than sites with higher IC non-residential uses (CWP & VA DCR, 2007). This suggests that residential areas with relatively low IC can have disturbed and intensively managed pervious areas that contribute to elevated nutrient levels.

The failure to account for the altered characteristics of disturbed urban soils and managed turf can result in an underestimation of stormwater runoff and pollutant loads generated from urban pervious areas. Therefore, Virginia's new Runoff Reduction Method, the computation procedure for complying with the nutrient reduction requirements in the regulations, accounts for both impervious cover and other important land cover types. The runoff coefficients provided in **Table 5.4** were derived from research by Pitt et al (2005), Lichter and Lindsey (1994), Schueler (2001a), Schueler, (2001b), Legg et al (1996), Pitt et al (1999), Schueler (1987) and Cappiella et al (2005). As shown in this table, the effect of grading, site disturbance, and soil compaction greatly increases the runoff coefficient compared to forested areas.

Table 5.4. Site Cover Runoff Coefficients (R_V)

Soil Condition	Runoff Coefficient
Forest Cover	0.02 to 0.05*
Disturbed Soils/Managed Turf	0.15 to 0.25*
Impervious Cover	0.95
*Range dependent on original Hydrologic Soil Group (HSG), as follows: For Forest: A = 0.02; B = 0.03; C = 0.04; and D = 0.05 For Disturbed Soils: A = 0.15; B = 0.20; C = 0.22; and D = 0.25	

5.3.3 Treatment Volume – The Common Currency for Site Compliance

Treatment Volume (T_v) is the central component of the Runoff Reduction method. By applying site design, structural, and nonstructural practices, the designer can reduce the treatment volume by reducing the overall volume of runoff leaving a site. In this regard, the Treatment Volume is the main "currency" for site compliance.

As explained more fully in **Chapter 10** (***Unified Sizing Criteria***), Treatment Volume is a variation of the 90% capture rule that is based on a regional analysis of the mid-Atlantic rainfall frequency spectrum. In Virginia, the 90th percentile rainfall event is defined approximately as 1-inch of rainfall.

The rationale for using the 90th percentile event is that it represents the majority of runoff volume on an annual basis. Larger events would be very difficult and costly to control for the same level of water quality protection (as indicated by the upward inflection at 90%). However, by controlling the 1-inch rainfall event, these larger storm events would also receive partial treatment for water quality, as well as storage for channel protection and flood control.

The proposed Treatment Volume (T_v) has several distinct advantages when it comes to evaluating runoff reduction practices and sizing BMPs:

- The T_v provides effective stormwater treatment for approximately 90% of the annual runoff volume from the site, and larger storms will be partially treated.

- Storage is a direct function of impervious cover and disturbed soils, which provides designers incentives to minimize the area of both at a site.

- Using the 90% storm event to define the T_v is widely accepted and is consistent with other state stormwater manuals (MDE, 2000; ARC, 2002; NYDEC, 2001; VTDEC, 2002; OME, 2003; MPCA, 2005).

- The T_v approach provides adequate storage to treat pollutants for a range of storm events. This is important since the first flush effect has been found to be modest for many pollutants (Pitt et al, 2005).

- T_v provides an objective measure to gage the aggregate performance of environmental site design, LID and other innovative practices, and conventional BMPs together using a common currency (runoff volume).

- Calculating the T_v explicitly acknowledges the difference between forest and turf cover and disturbed and undisturbed soils. This creates incentives to conserve forests and reduce mass grading and provides a defensible basis for computing runoff reduction volumes for these actions.

5.3.4 The Runoff Reduction Method

At the core of Virginia's green infrastructure approach to stormwater management is a new *Runoff Reduction (RR) Method*, developed with assistance from the Center for Watershed Protection and the Chesapeake Stormwater Network. This methodology was developed in order to promote better stormwater design and as a tool for compliance with the Virginia Stormwater Management Regulations and is explained more thoroughly in **Chapter 12** of this Handbook. There are several shortcomings to existing stormwater design practices that the Runoff Reduction Method seeks to overcome, as follows:

- **Leveling the BMP Playing Field.** The suite of BMPs that has been available up to now in Virginia has been somewhat limited. There are many new and innovative practices that have proven effective at reducing runoff volumes and pollutant loads. In particular, good site design practices, that reduce stormwater impacts through design techniques, are not "credited" in the existing system. The RR Method puts traditional and innovative BMPs on a level playing field in terms of BMP selection and site compliance.

- **Meeting the Big-Picture Goals.** The existing stormwater compliance system does not meet Chesapeake Bay Tributary Strategy nutrient reduction goals for urban land. As sites are developed, the nutrient loads from urban land increase at a rate that exceeds urban land targets. The RR Method uses better science and improved BMP specifications to help with the job of incrementally attaining the Tributary Strategy goals for phosphorus and nitrogen.

- **Moving Beyond Addressing Only Impervious Cover.** Previous computation procedures used impervious cover as the sole indicator of a site's water quality impacts. More recent research indicates that a broad range of land covers – including forest, disturbed soils, and managed turf – are significant indicators of water quality and the health of receiving streams. The RR Method accounts for these land covers and provides built-in incentives – those credits that were not previously available – to protect or restore forest cover and reduce impervious cover and disturbed soils.

- **Moving Towards Total BMP Performance.** The previous system for measuring BMP effectiveness was based solely on the pollutant removal functions of the BMP, but did not account for the BMP's ability to reduce the overall volume of runoff. Recent research has shown that BMPs are quite variable in terms of providing runoff reduction, and some achieve very positive results. Runoff reduction has benefits beyond pollutant load reductions. BMPs that reduce runoff volumes can do a better job of replicating pre-development hydrologic conditions, protecting downstream channels, recharging groundwater, and, in some cases, reducing overbank (or "nuisance") flooding conditions. The RR Method uses recent research on runoff reduction to better gage total BMP performance.

- **Providing Accountability for Design.** Previously, it could be difficult for site designers and plan reviewers to verify BMP design features – such as sizing, pretreatment, and vegetation – that should be included on stormwater plans in order to achieve a target level of pollutant removal. Clearly, certain BMP design features either enhance or diminish overall pollutant removal performance. The RR Method provides clear guidance that links design features with performance by distinguishing between "Level 1" and "Level 2" designs.

As noted above, the RR Method relies on a three-step compliance procedure, as follows:

- **Step 1: Apply Site Design Practices to Minimize Impervious Cover, Grading and Loss of Forest Cover.** This step focuses on implementing Environmental Site Design (ESD) practices during the early phases of site layout. The goal is to minimize impervious cover and mass grading, and to maximize retention of forest cover, natural areas and undisturbed soils (especially those most conducive to landscape-scale infiltration). The RR Method uses a spreadsheet to compute a composite runoff coefficient for forest, disturbed soils, and impervious cover and to calculate a site-specific target treatment volume and Phosphorus load reduction target, based on criteria in the Virginia Stormwater Management Regulations.

- **Step 2: Apply Runoff Reduction (RR) Practices.** In this step, the designer considers possible combinations of RR practices on the site. In each case, the designer estimates the area to be treated by each RR practice to incrementally reduce the required treatment volume for the site. The designer is encouraged to use RR practices in series (i.e., *treatment trains*) within individual drainage areas (e.g., rooftop disconnection to a grass swale to a bioretention area) in order to achieve a higher level of runoff reduction.

- **Step 3: Compute the Pollution Removal (PR) of the Selected BMPs.** In this step, the designer uses the spreadsheet tool to see whether the required phosphorus load reduction has been achieved by the application of RR practices.

- **Step 4:** If the target phosphorus load limit is not reached, the designer can select additional BMPs that provide no runoff reduction but only treatment (e.g., filtering practices, wet ponds, stormwater wetlands, etc.) to meet the remaining load reduction requirement.

In reality, the process is *iterative* for most sites. When compliance cannot be achieved on the first try, designers can return to prior steps to explore alternative combinations of Environmental Site Design, Runoff Reduction practices, and Pollutant Removal practices to achieve compliance. A **possible Step 5** would involve paying an offset fee (or fee-in-lieu payment) or providing off-site mitigation, where such options are provided for by the local stormwater management program, to compensate for any load that cannot feasibly be met on a particular site. If the local government or program authority has a watershed or regional planning structure for stormwater management, it will be easier to apply such offset options to project sites within the jurisdiction. The amount of the fee will typically be driven by the "market," based on the phosphorus "deficit" – that is, the difference between the target reduction and the actual site reduction after the designer makes his or her best effort to apply Runoff Reduction and Pollutant Removal practices.

Common sense indicates that well-maintained and high quality long-term records of precipitation are "vital and nontrivial" for effective stormwater management programs. A network of precipitation gauge data is available online from the National Climatic Data Center, at http://www.ncdc.noaa.gov/oa/ncdc.html, or the Cooperative Weather Observer Program, at http://www.nws.noaa.gov/om/coop/ . Additionally, the National Weather Service provides estimates of the return periods for a range of depth-duration storm events, available at http://www.nws.noaa.gov/om/coop/. Considering the implications of climate change discussed in **Chapter 4**, such that precipitation regimes are systematically being altered, it is paramount to update depth-duration-frequency curves in order to guarantee stormwater management facilities will be able to accommodate more intense precipitation.

Figure 5.4 is a flow chart illustrating the step-wise compliance process described above. **Table 5.5** includes a list of site design and stormwater practices that can be used for each step.

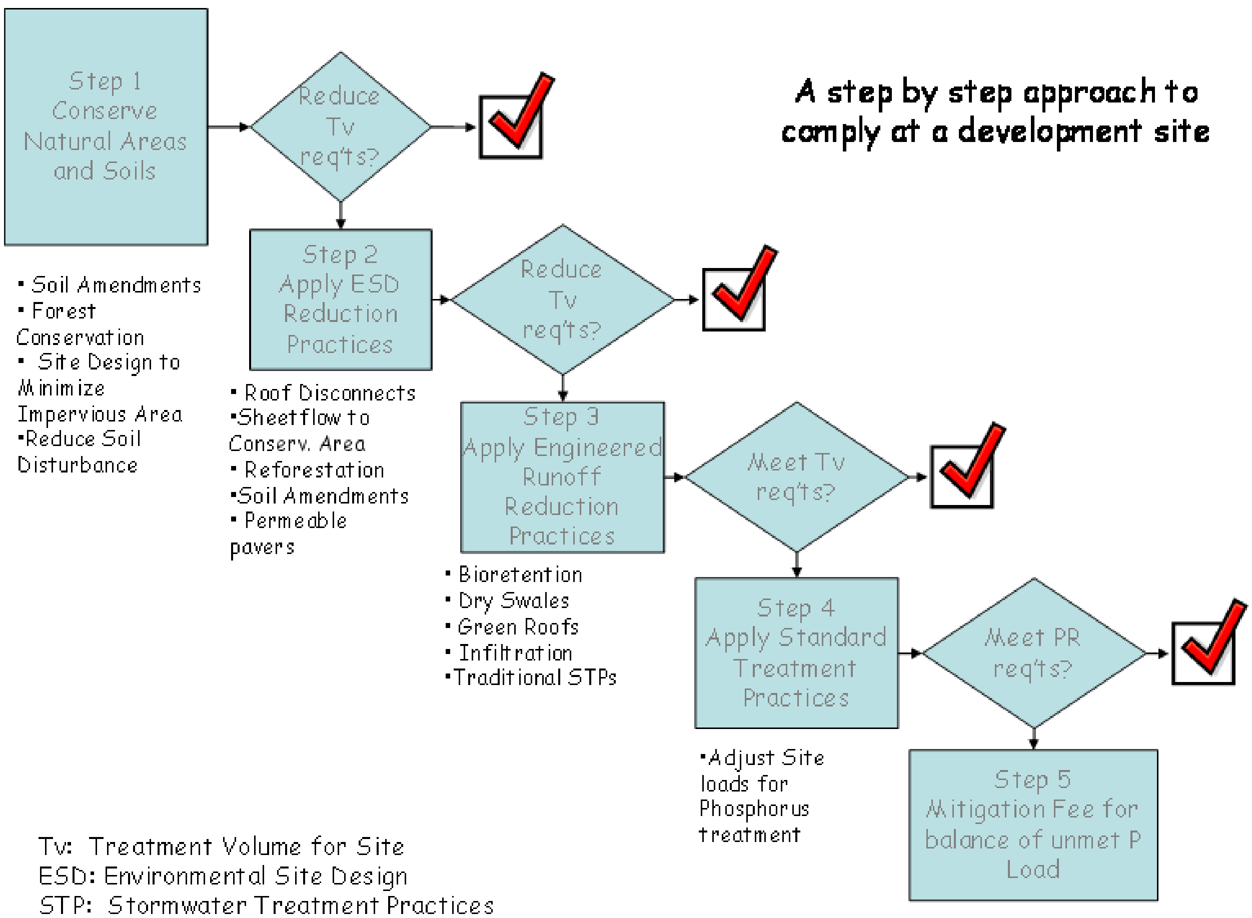

Figure 5.4. Step-Wise Process for Site Compliance

Table 5.5. Practices Included in the Runoff Reduction Method

Step 1: Environmental Site Design (ESD) Practices (see Control Measure #7 in Table 5.1)	Step 2: Runoff Reduction (RR) Practices (see Control Measures #s 9-11 in Table 5.1)	Step 3: Pollutant Removal (PR) Practices (see Control Measures #s 12-13 in Table 5.1)
Forest Conservation	Filter Strip (Sheet Flow to Conserved Open Space)	Filtering Practice
Site Reforestation	Rooftop Disconnection: • Simple • To Soil Amendments • To a Rain Garden or Dry Well • To a Rain Tank or Cistern	Constructed Wetland
Soil Restoration (combined with or separate from rooftop disconnection)		Wet Swale
		Wet Pond
Site Design to Minimize Impervious Cover and Soil Disturbance	Vegetated roof	
	Grass Channels	
	Permeable Pavement	
	Bioretention	
	Dry Swale (Water Quality Swale)	
	Infiltration	
	Extended Detention (ED) Pond	
NOTE: Practices in shaded cells achieve both Runoff Reduction (RR) and Pollutant Removal (PR) functions, and they can be used for Steps 3 and 4 depicted in **Figure 5.4**.		

5.4 THE CHALLENGES OF REDEVELOPMENT

Redevelopment is the process whereby an existing development is adaptively reused, rehabilitated, restored, renovated, and/or expanded, which results in disturbance or clearing of a defined footprint at the site. Redevelopment projects normally occur within dense urban watersheds that are served by existing water, sewer and other public infrastructure. When redevelopment is done properly, it is a key element of smart growth and sustainable development (USEPA, 2005b, 2006).

The potential for water quality improvements due to redevelopment stormwater requirements is significant. However, the challenges and constraints that the urban environment imposes on stormwater management at high intensity *redevelopment* projects are considerable. These challenges include physical, technological, economic and institutional impediments. To achieve effective stormwater management at redevelopment sites requires creative policy and engineering approaches at the state and local level.

Much of the confusion associated with redevelopment is generated by vague or ambiguous regulatory definitions of redevelopment and their associated stormwater treatment requirements. Redevelopment normally occurs within urban watersheds that are served by existing water, sewer and public infrastructure. When redevelopment is done properly, it is a key element of smart growth and sustainable development (CSN, 2011).

The Virginia Stormwater Management Regulation (9 VAC 25-870 et seq.) defines the term “prior developed lands” (rather than “redevelopment”) as follows:

> *Prior developed lands* means land that has been previously utilized for residential, commercial, industrial, institutional, recreation, transportation or utility facilities or structures, and that will have the impervious areas associated with those uses altered during a land-disturbing activity.

In the context of a local stormwater management program, it is useful to characterize what constitutes redevelopment in clear, measurable and operational terms, so that those who must comply with redevelopment requirements of the regulations can know exactly what is expected of them. The Virginia Stormwater Management Act allows localities the flexibility of establishing "more stringent" criteria, which might extend to clearer definitions of terms. Ideally, for a construction project to qualify as redevelopment, it should meet the criteria such as the following:

- *Minimum disturbance footprint:* This defines a minimum surface area of redevelopment activity that will be subject to stormwater requirements. In some jurisdictions around the Chesapeake Bay watershed, this threshold is as low as 250 square feet to as high as one acre.
- *Minimum amount of pre-existing impervious cover at the site:* A second threshold could be used to qualify a redevelopment project based on the existing impervious cover present at the site prior to construction (e.g., the site must have 40% or more existing impervious cover to be classified as redevelopment), while sites with less impervious cover are classified as new development. For example, this criterion might be applied to building sites only, and not to smaller VDOT roadway improvements.
- *Different treatment standards for existing impervious cover and new impervious cover created by the redevelopment project:* It is important to distinguish between these forms of total impervious cover at the site to ensure that higher treatment standards are in place for any new impervious cover that is created.
- *Less stringent stormwater performance standards as compared to new greenfield development projects:* This explicitly recognizes that redevelopment is desirable from the standpoint of smart growth.
- *Situations when it is permissible to shift from runoff reduction to water quality treatment:* The definition might specify the site conditions where full on-site infiltration or runoff reduction is not feasible or desirable at a redevelopment project. In these cases, designers would be allowed to shift to conventional stormwater practices to treat runoff quality. Examples might include brownfields, stormwater hotspots, and urban fill soils.

The Virginia Stormwater Management Regulations specify that stormwater treatment requirements only apply to the *disturbed area* of a redevelopment project, and not the entire property (e.g., if a strip shopping center is renovated but the parking lot is not disturbed, then stormwater requirements only apply to the building – in fact, if there is no *land* disturbance, then stormwater management requirements would not apply at all). The regulatory criteria make it easy to determine and verify what portion of a proposed redevelopment site will be subject to stormwater requirements, and which requirements will apply.

Virginia's requirements for redevelopment also clearly distinguish between *existing impervious cover* and *newly created impervious cover* at a redevelopment site. Stormwater treatment requirements are reduced for existing impervious cover (compared to green-fields. The situation reverses if the redevelopment project creates more impervious cover than the predevelopment condition. In this case, the new increment of impervious cover is subject to the higher stormwater treatment standards for new development (e.g., full water quality and channel protection). This creates a strong incentive to prevent creation of new or additional impervious cover at a redevelopment site.

Reflecting these concepts, the Virginia stormwater management regulatory criteria that apply to redevelopment projects are as follows:

- If the redevelopment project disturbs greater than or equal to 1 acre *and* there is *no increase* of total impervious cover from the pre-development condition, then the project must reduce the pre-development Total Phosphorus (TP) load by 20%.
- If the redevelopment project disturbs less than 1 acre *and* there is *no increase* of total impervious cover from the pre-development condition, then the project must reduce the pre-development TP load by 10%.
- If the redevelopment project results in a net increase in impervious cover over the pre-development condition, the design criteria for new development must be applied to the *increased* impervious area, while the appropriate redevelopment criteria above will apply to the existing impervious area, based on the size of the disturbed area.
- For linear redevelopment projects (e.g., VDOT roads), the TP load of the project occurring on prior developed land must be reduced 20% below the pre-development TP load.
- In any case, the TP load is *not* required to be reduced to below the standard for new development (0.41 lbs./acre/year of TP), *unless* a more stringent standard has been developed by the local stormwater management program.

Recognizing the many challenges regarding managing stormwater at redevelopment projects, stormwater managers and designers should not construe that stormwater treatment should be avoided at high intensity redevelopment sites. Rather, Virginia has crafted effective stormwater solutions that are specifically tailored to the unique conditions and economic realities found at redevelopment sites. **Appendix 5-C** of this chapter discusses the unique conditions at redevelopment projects and important considerations that apply to the management of stormwater on such sites.

5.5 STORMWATER CONTROL ON A WATERSHED SCALE

Implementing stormwater management on a site-by-site basis is the traditional mode of compliance in Virginia. This is largely due to the system of Land Use Law in Virginia, which vests authority for land use planning and decision-making with local governments. The reality is that few local governments have been willing to spend the money and perform the studies needed to support watershed-wide approaches to stormwater management, even though the Stormwater Management Law encourages and provides compliance incentives to do so. Comprehensive watershed-scale stormwater management plans provide the most efficient and flexible means of continuing to develop sensibly while still meeting stormwater regulatory criteria. The traditional site-by-site approach has created a large number of individual stormwater management systems and BMPs that are widely distributed and have become a substantial part of the contemporary urban and suburban landscape.

The problem with the traditional approach is that the facilities are not designed to work as a *system* on a watershed scale. As a watershed is gradually built out, an unplanned system of site-based BMPs can actually increase flooding and channel erosion on a watershed scale, due to the effect of many facilities discharging into a receiving water body in an uncoordinated manner – often causing or aggravating the very problems the individual BMPs were built to prevent.

Stormwater management is most effectively undertaken in the context of a watershed management plan, with lower life-cycle costs to all involved. A watershed management plan is a comprehensive framework for applying management tools in a manner that achieves the water resource goals for the watershed as a whole (CWP, 1998a). Typically, watershed management plans are developed from watershed studies undertaken by one or more municipalities located within the watershed. The watershed approach has emerged over the past decade as the recommended approach for addressing nonpoint source pollution problems, including polluted stormwater runoff. Watershed planning offers the best means to:

- Address cumulative impacts derived from a number of new land development projects;
- Plan for mitigation to address cumulative impacts from existing developments;
- Focus efforts and resources on identified priority water bodies and pollutant sources in a watershed; and
- Achieve noticeable improvements to impaired waters or waters threatened with impairment.

In this context, the term "watershed scale" typically refers to a small local watershed to which the individual site drains (i.e., a few square miles within a single municipality). Ideally, stormwater management should occur on a watershed scale to prevent flow control problems from occurring or reducing the chances that they might become worse.

The watershed approach is built on **three main principles**:

- First, the target watersheds should be those where stormwater impacts pose the greatest risk to human health, ecological resources, desirable uses of the water, or a combination of these issues – typical watersheds where growth and development are occurring.
- Second, parties with a stake in the specific local situation (i.e., stakeholders) should participate in the analysis of problems and the creation of solutions, creating significant "buy in" from those affected.
- Third, the actions undertaken should draw on the full range of methods and tools available, integrating them into a coordinated, multi-organization attack on the problems.

Watershed stormwater design can optimize the number, size and location of BMPs and result in more manageable long-term operation and maintenance of these facilities. Such an approach allows the developer, designer, plan reviewer, owners and the municipality to jointly participate in master planning and installation and operation of a linked and shared system of distributed practices across multiple sites that achieve small watershed-specific objectives, such as flood protection, stream protection and restoration, and water quality.

Furthermore, stormwater systems designed on a watershed basis are more likely to be perceived by local citizens as a multi-functional resource that can contribute to the overall quality of the urban environment. Potential even exists to make the stormwater system a primary component of the civic framework of the community – elements of the public realm that serve to enhance a community's quality of life , such as public spaces, greenways and parks. A more detailed discussion of watershed-scale stormwater management planning is provided in **Appendix 5-B** of this chapter.

5.6 SUMMARY

Taking all of the elements above into consideration, ***the emerging goal of stormwater management is to mimic, as much as possible, the hydrological and water quality processes of natural systems as rain travels from the roof to the stream, through combined application of a series of practices throughout the entire development site and extending to the stream corridor***. The series of BMPs incrementally reduces the volume of stormwater on its way to the stream, thereby reducing the amount of conventional stormwater infrastructure required.

There is no single BMP prescription that can be applied to each kind of development; rather, a combination of interacting practices must be used for full and effective treatment. For a low-density residential Greenfield setting, a combination of BMPs that might be implemented is illustrated in **Table 5.6**. There are many successful examples of BMPs in this context and at different scales. By contrast, **Tables 5.7 and 5.8** outline how the general "roof-to-stream" stormwater approach is adapted for intense industrial operations and urban redevelopment sites, respectively. As can be seen, these development situations require a different combination of BMPs and practices to address the unique design challenges of dense urban environments. The tables are meant to be illustrative of certain situations; other scenarios, such as commercial development, would likely required additional tables.

***In summary, a watershed approach for organizing site-based stormwater decisions is generally superior to making site-based decisions in isolation*.** Communities that adopt the preceding watershed elements not only can maximize the performance of the entire system of BMPs to meet local watershed objectives, but also can maximize other urban functions, reduce total costs, and reduce future maintenance burdens.

Table 5.6. From the Roof to the Stream: BMPs in a Residential Greenfield

BMP	What It Is	What It Replaces	How It Works
Land-Use Planning	Early Site assessment	Doing SWM design after site layout	Map and plan submitted at earliest stage of development review showing environmental, drainage, and soil features
Conservation of Natural Areas	Maximize forest canopy	Mass clearing	Preservation of priority forests and reforestation of turf areas to intercept rainfall
Earthwork Minimization	Conserve soils and contours	Mass grading and soil compaction	Construction practices to conserve soil structure and only disturb a small site footprint
Impervious Cover Minimization	Better (Environmental) Site Design	Large streets, lots and cul-de-sacs	Narrower streets, permeable driveways, clustering lots, and other actions to reduce site IC
Runoff Volume Reduction – Rainwater Harvesting	Utilize rooftop runoff	Direct connected roof leaders	A series of practices to capture, disconnect, store, infiltrate, or harvest rooftop runoff
Runoff Volume Reduction – Vegetated	Front yard bioretention	Positive drainage from rooftop to road	Grading front yard to treat roof, lawn, and driveway runoff using shallow bioretention
	Dry Swales	Curb/gutter and storm drain pipes	Shallow, well-drained bioretention swales located in the street right-of-way
Peak Reduction and Runoff Treatment	Linear Wetlands (Wet Swales)	Large detention ponds	Long, multi-cell, forested wetlands located in the stormwater conveyance system
Aquatic Buffers and Managed Floodplains	Stream buffer management	Unmanaged stream buffers	Active reforestation of buffers and restoration of degraded streams
NOTE: BMPs are applied in a series, although all of the above may not be needed at a given residential site. This “roof-to-stream” approach works best for low- to medium-density residential developments.			

Table 5.7. From the Roof to the Outfall: BMPs in an Industrial Context

BMP Category	What It Is	What It Replaces	How It Works
Pollution Prevention	Drainage mapping	No map	Analysis of the locations and connections of the stormwater and wastewater infrastructure from the site
	Hotspot site investigation	Visual inspection	Systematic assessment of runoff problems and pollution prevention opportunities at the site
	Rooftop management	Uncontrolled rooftop runoff	Use of alternative roof surfaces or coatings to reduce metal runoff, and disconnection of roof runoff for stormwater treatment
	Exterior maintenance practices	Routine plant maintenance	Special practices to reduce discharges during painting, power washing, cleaning, seal coating and sandblasting
	Extending roofs for no exposure	Exposed hotspot operations	Extending covers over susceptible loading/unloading, fueling, outdoor storage, and waste management operations
	Vehicular pollution prevention	Uncontrolled vehicle operations	Pollution prevention practices applied to vehicle repair, washing, fueling, and parking operations
	Outdoor pollution prevention practices	Outdoor materials storage	Prevent rainwater from contact with potential pollutants by covering, secondary containment, or diversion from the storm-drain system
	Waste management practices	Exposed dumpster or waste streams	Improved dumpster location, management, and treatment to prevent contact with rainwater or runoff
	Spill control plan and response	No plan	Develop and text response to spills to the storm drain system, train employees, and have spill control kits available on-site
	Greenscaping	Routine landscape and turf maintenance	Reduce use of pesticides, fertilization, and irrigation in pervious areas, and convert turf to forest cover
	Employee stewardship	Lack of stormwater awareness	Regular ongoing training of employees on stormwater problems and pollution prevention practices
	Site housekeeping and stormwater maintenance	Dirty site and unmaintained infrastructure	Regular sweeping, storm-drain cleanouts, litter pickup, and maintenance of stormwater infrastructure
Runoff Treatment	Stormwater retrofitting	No stormwater treatment	Filtering retrofits to remove pollutants from the most severe hotspot areas
IDDE	Outfall analysis	No monitoring	Monitoring of outfall quality to measure effectiveness
NOTE: While many BMPs are used at each individual industrial site, the exact combination depends on the specific configuration, operations, and footprint of each site.			

Table 5.8. From the Roof to the Street: BMPs in a Redevelopment Context

BMP Category	What It Is	What It Replaces	How It Works
Impervious Cover Minimization	Site design to prevent pollution	Conventional site design	Designing the redevelopment footprint to restore natural area remnants, minimize needless impervious cover, and reduce hotspot potential
Runoff Volume Reduction – Rainwater Harvesting and Vegetated Roofs	Treatment on the roof	Traditional rooftops	Use of green rooftops to reduce runoff generated from roof surfaces
	Rooftop runoff treatment	Directly connected roof leaders	Use of rain tanks, cisterns, and rooftop disconnection to capture, store, and treat runoff
	Runoff treatment in landscaping	Traditional landscaping	Use of foundation planters and bioretention areas to treat runoff from parking lots and rooftops
Soil Conservation and Restoration	Runoff reduction in pervious areas	Impervious areas or compacted soils	Reducing runoff from compacted soils through tilling and compost amendments, and in some cases, removal of unneeded impervious cover
	Increase urban tree canopy	Turf or landscaping	Providing adequate rooting volume to develop mature tree canopy to intercept rainfall
Runoff Reduction – Subsurface	Increase permeability of impervious cover	Hard asphalt or concrete	Use of permeable pavers, porous concrete, and similar products to decrease runoff generation from parking lots and other hard surfaces
Runoff Reduction – Vegetated	Runoff treatment in the street	Sidewalks, curb and gutter, and storm drains	Use of expanded tree pits, dry swales and street bioretention cells to further treat runoff in the street or its right-of-way
Runoff Treatment	Underground treatment	Catch basins and storm-drain pipes	Use of underground sand filters and other practices to treat hotspot runoff quality at the site
Municipal Housekeeping	Street Cleaning	Unswept streets	Targeted street cleaning on priority streets to remove trash and gross solids
Watershed Planning	Off-site stormwater treatment or mitigation	On-site waivers	Stormwater retrofits or restoration projects elsewhere in the watershed to compensate for stormwater requirements that cannot be met on-site
NOTE: BMPs are applied in series, although all of the above may not be needed at a given redevelopment site.			

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Appendix 5-A

THE IMPERVIOUS COVER MODEL: AN EMERGING FRAMEWORK FOR URBAN STORMWATER MANAGEMENT

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5-A.1 INTRODUCTION

Impervious cover (IC) has unique properties as a watershed metric in that it can be measured, tracked, forecasted, managed, priced, regulated, mitigated and, in some cases, even traded. In addition, IC is a common currency that is understood and applied by watershed planners, stormwater engineers, water quality regulators, economists and stream ecologists alike. IC can be accurately measured using either remote sensing or aerial photography (Goetz et al. 2003 and Jantz et al. 2005). IC is also strongly correlated with individual land use and zoning categories (Cappiella and Brown 2001; Slonecker and Tilley 2004) which allows planners to reliably forecast how it changes over time in response to future development. Consequently, watershed planners rely on IC (and other metrics) to predict changes in stream health as a consequence of future development (CWP 1998).

Schueler (2004) has utilized IC to classify and manage urban streams, and economists routinely use IC to set rates for stormwater utilities and off-site mitigation (Parikh et al. 2005). Regulators and engineers utilize IC as a key input variable to predict future downstream hydrology and design stormwater management practices (MPCA 2005). A number of localities have modified their zoning to establish site-based or watershed-based IC caps to protect streams or drinking water supplies. In recent years, IC has been used as a surrogate measure to ensure compliance with water quality standards in impaired urban waters (Bellucci 2007).

Another noteworthy aspect of IC has been its use as an index of the rapid growth in land development or sprawl at the watershed, regional and national scale. For example, Jantz et al. (2005) found that IC increased at a rate five times faster than population growth between 1990 and 2000 in the Chesapeake Bay watershed – over 76,000 acres of impervious cover and over 232,000 acres of turf cover are created each year, or nearly 1 percent of the watershed per year. At a national level, several recent estimates of IC creation underscore the dramatic changes in many of our nation’s watersheds as a result of recent or future growth. Elvidge et al. (2004) estimated that about 112,665 km^2 (43,500 mi^2) of IC had been created in the lower 48 states as of 2000. Forecasts by Beach (2002) indicate that IC may nearly double by the year 2025 to about 213,837 km^2 (82,563 mi^2), given current development trends. Although care must be taken when extrapolating from national estimates, it is clear that several hundred thousand stream miles are potentially at risk. For example, a detailed GIS analysis by Exum et al. (2006) indicates that 14% of the total watershed area in eight Southeastern states had exceeded 5% IC as of 2000.

Given growth in IC, watershed managers are keenly interested in the relationship between subwatershed IC and various indicators of stream quality. The Impervious Cover Model (ICM) was first proposed by Schueler (1994) as a management tool to diagnose the severity of future stream problems in urban subwatersheds. The ICM projects that hydrological, habitat, water quality and biotic indicators of stream health decline at around 10% total IC in small subwatersheds (i.e., 5 to 50 km^2) (CWP 2003). The ICM defines four categories of urban streams based on how much impervious cover exists in their subwatershed:

- Sensitive (high-quality) streams
- Impacted streams
- Non-supporting streams, and
- Urban drainage.

The ICM is then used to develop specific quantitative or narrative predictions for stream indicators within each stream category (see **Figure 5-A.1**). These predictions define the severity of current stream impacts and the prospects for their future restoration. Predictions are made for five kinds of urban stream impacts: changes in stream hydrology, alteration of the stream corridor, stream habitat degradation, declining water quality, and loss of aquatic diversity. The model is intended to predict the average behavior of this group of indicator responses over a range of IC, rather than predicting the precise score of an individual indicator.

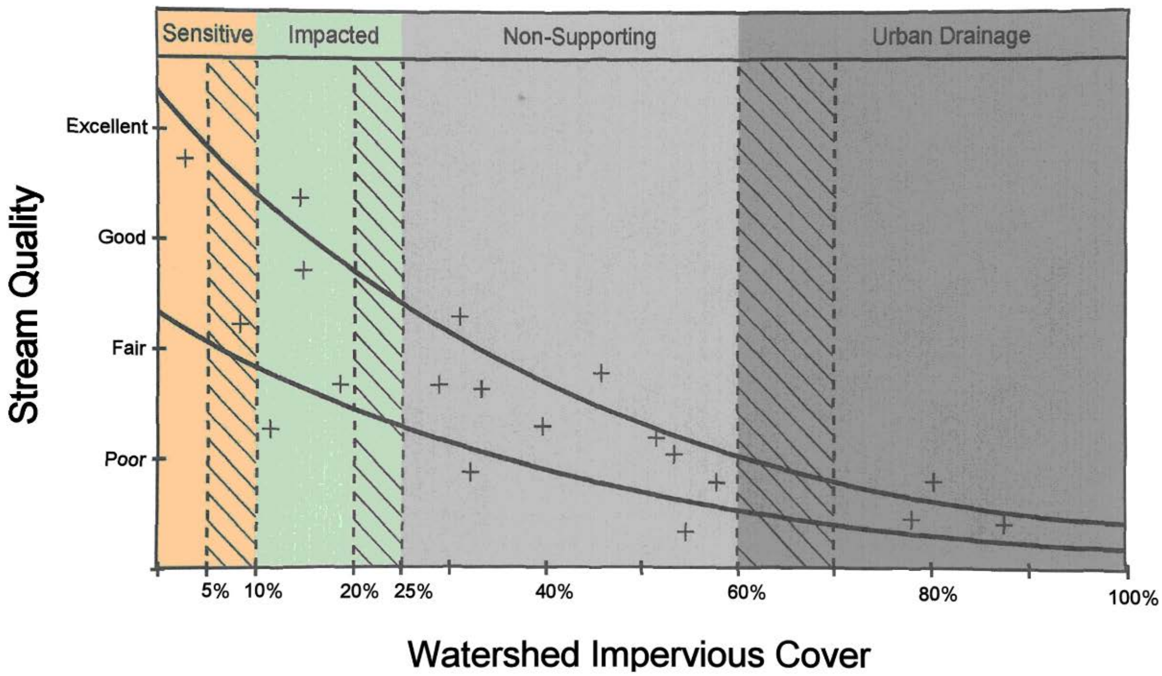

Figure 5-A.1. Reformulated Impervious Cover Model Reflecting Changes in Stream Quality in Response to Percent Impervious Cover in the Contributing Watershed.
(Source: Chesapeake Stormwater Network, 2008)

5-A.2 THE REFORMULATED IMPERVIOUS COVER MODEL

The reformulated ICM includes three important changes to the original conceptual model proposed by Schueler (1994). First, the IC/stream quality relationship is no longer expressed as a straight line, but rather as a "cone" that is widest at lower levels of IC and progressively narrows at higher IC. The cone represents the observed variability in the response of stream indicators to urban disturbance and also the typical range in expected improvement that could be attributed to subwatershed treatment. In addition, the use of a cone rather than a line is consistent with the findings that exact, sharply defined IC thresholds are rare, and that most regions show a generally continuous but variable gradient of stream degradation as IC increases.

Second, the cone width is greatest for IC values less than 10%, which reflects the wide variability in stream indicator scores observed for this range of streams. This modification prevents the misperception that streams with low subwatershed IC will automatically possess good or excellent quality. As noted earlier, the expected quality of streams in this range of IC is generally influenced more by other watershed metrics such as forest cover, road density, riparian continuity, and cropping practices. This modification suggests that IC should not be the sole metric used to predict stream quality when subwatershed IC is very low.

Third, the reformulated ICM now expresses the transition between stream quality classifications as a band rather than a fixed line (e.g., 5 to 10% IC for the transition from sensitive to impacted, 20 to 25% IC for the transition from impacted to non-supporting, and 60 to 70% IC for the transition from non-supporting to urban drainage). The band reflects the variability in the relationship between stream hydrologic, physical, chemical, and biological responses and the qualitative endpoints that determine stream quality classifications. It also suggests a watershed manager's choice for a specific threshold value to discriminate among stream categories should be based on actual monitoring data for their ecoregion, the stream indicators of greatest concern and the predominant predevelopment regional land cover (e.g., crops or forest).

5-A.3 GENERAL PREDICTIONS OF THE IMPERVIOUS COVER MODEL

The ICM is similar to other models that describe ecological response to stressors from urbanization in that the stream quality classifications are value judgments relative to some endpoint defined by society (e.g., water quality criteria). The ICM differs from most other models in that it provides a broader focus on a group of stream responses, yet focuses on only one stressor, impervious cover. The focus on IC allows watershed managers to use the ICM both to predict stream response and to manage future impacts by measuring and managing IC.

The general predictions of the ICM are as follows:

- Stream segments with less than 10 percent impervious cover (IC) in their contributing drainage area continue to function as Sensitive Streams, and are generally able to retain their hydrologic function and support good-to-excellent aquatic diversity.
- Stream segments that have 10-25 percent IC in their contributing drainage area behave as Impacted Streams and show clear signs of declining stream health. Most indications of stream health will fall in the fair range, although some segments may range from fair to good, as riparian cover improves. The decline in stream quality is greatest toward the higher end of the IC range.
- Stream segments with subwatershed IC that ranges from 25-60 percent are classified as non-supporting streams (i.e., no biological diversity). These stream segments become so degraded that any future stream restoration or riparian cover improvements are insufficient to fully recover stream function and diversity (i.e., the streams are so dominated by subwatershed IC that they cannot attain pre-development conditions).
- Stream segments whose subwatersheds exceed 60 percent IC are physically altered so that they merely function as a conduit for flood waters. These streams are classified as Urban Drainage and consistently have poor water quality, highly unstable channels, and very poor habitat and biodiversity scores. In many cases these urban stream segments are eliminated altogether by earthworks and/or storm drain enclosures. **Table 5-A.1** shows in greater detail how stream corridor indicators respond to greater subwatershed impervious cover.

Table 5-A.1. General ICM Predictions Based on Urban Subwatershed Classification

Prediction	Impacted (IC = 11-25%) [8]	Non-Supporting (IC = 26-60%)	Urban Drainage (IC = ≥ 60%)
Runoff as a fraction of annual rainfall [1]	10 to 20%	25 to 60%	60 to 90%
Frequency of bankfull flow per year [2]	1.5 to 3 per year	3 to 7 per year	7 to 10 per year
Fraction of original stream network remaining	60 to 90%	25 to 60%	10 to 30%
Fraction of riparian forest buffer intact	50 to 70%	30 to 60%	Less than 30%
Crossings (roads/utilities, etc.) per stream mile	1 to 2	2 to 10	None left
Ultimate channel enlargement ratio [3]	1.5 to 2.5 times larger	2.5 to 6 times larger	6 to 12 times larger
Typical stream habitat score	Fair, but variable	Consistently poor	Poor, often absent
Increased stream warming [4]	2 to 4 °F	4 to 8 °F	8+ °F
Annual nutrient load [5]	1 to 2 times higher	2 to 4 times higher	4 to 6 times higher
Wet weather violations of bacteria standards	Frequent	Continuous	Ubiquitous
Fish advisories	Rare	Potential risk of accumulation	Should be presumed
Aquatic insect diversity [6]	Fair to good	Fair	Very poor
Fish diversity [7]	Fair to good	Poor	Very poor

[1] Based on annual storm runoff coefficient ranges from 2 to 5% for undeveloped systems.
[2] Predevelopment bankfull flood frequency is about 0.5 per year, or about one bankfull flood every two years.
[3] Ultimate stream channel cross-section compared to typical predevelopment channel cross section.
[4] Typical increase in mean summer stream temperature in degrees Fahrenheit compared with shaded rural stream.
[5] Annual unit area stormwater phosphorus and/or nitrogen load produced from a rural subwatershed.
[6] As measured by benthic index of biotic integrity. Scores for rural streams range from good to very good.
[7] As measured by fish index of biotic integrity. Scores for rural streams range from good to very good.
[8] IC is not the strongest indication of stream health below 10% IC, so the sensitive streams category is omitted from this table

Source: CWP, 2004

5-A.4 SCIENTIFIC SUPPORT FOR THE ICM

The ICM predicts that hydrological, habitat, water quality, and biotic indicators of stream health first begin to decline sharply at around 10 percent total IC in smaller catchments (Schueler, 1994). The ICM has since been extensively tested in ecoregions around the United States and elsewhere, with more than 200 different studies confirming the basic model for single stream indicators or groups of stream indicators (CWP, 2003; Schueler, 2004). Several recent research studies have reinforced the ICM as it is applied to 1st-to-3rd order streams (Coles et al., 2004; Horner et al., 2004; Deacon et al., 2005; Fitzpatrick et al., 2005; King et al., 2005; McBride and Booth, 2005; Cianfrina et al, 2006; Urban et al., 2006; Schueler et al., 2008).

Researchers have focused their efforts to define the specific thresholds where urban stream degradation first begins. There is robust debate as to whether there is a sharp initial threshold or merely a continuum of degradation as IC increases, although the latter view is more favored. There is much less debate, however, about the dominant role of IC in defining the hydrologic, habitat, water quality, and biodiversity expectations for streams with higher levels of IC (15 to 60 percent).

5-A.5 CAVEATS TO THE ICM

The ICM is a powerful predictor of urban stream quality when used appropriately. The first caveat is that subwatershed IC is defined as total impervious area (TIA, which includes *all* impervious cover) and *not* the effective impervious area (EIA, which is the portion of the TIA that is directly connected to the drainage collection system). Second, application of the ICM should be restricted to 1^{st}-to-3^{rd} order alluvial streams with moderate gradient and no major point sources of pollutant discharge. The ICM is most useful in projecting the behavior of numerous stream health indicators, and it is not intended to be accurate for every individual stream indicator. In addition, management practices in the contributing catchment or subwatershed must *not* be poor (e.g., no deforestation, acid mine drainage, intensive row crops, etc.); just because a subwatershed has less than 10 percent IC does not automatically mean that it will have good or excellent stream quality, if past catchment management practices were poor.

ICM predictions are general and may not apply to every stream within the proposed classifications. Urban streams are notoriously variable, and factors such as gradient, stream order, stream type, age of subwatershed development, and past land use can and will make some streams depart from these predictions. Indeed, these atypical streams are extremely interesting from the standpoint of restoration. In general, subwatershed IC causes a continuous but variable decline in most stream corridor indicators. Consequently, the severity of individual indicator impacts tends to be greater at the upper end of the IC range for each stream category.

5-A.6 EFFECTS OF CATCHMENT TREATMENT ON THE ICM

Most studies that investigated the ICM were done in communities with some degree of catchment treatment (e.g., stormwater management or stream buffers). Detecting the effect of catchment treatment on the ICM involves a very complex and difficult paired watershed design. Very few catchments meet the criteria for either full treatment or the lack of it; no two catchments are ever really identical, and individual catchments exhibit great variability from year to year. Not surprisingly, the first generation of research studies has produced ambiguous results. For example, seven research studies showed that ponds and wetlands are unable to prevent the degradation of aquatic life in downstream channels associated with higher levels of IC (Galli, 1990; Jones et al., 1996; Horner and May, 1999; Maxted, 1999; MNCPPC, 2000; Horner et al., 2001; Stribling et al., 2001). The primary reasons cited are stream warming (amplified by the presence of ponds), changes in organic matter processing, the increased runoff volumes delivered to downstream channels, and habitat degradation caused by channel enlargement.

Riparian forest cover is defined as canopy cover within 100 meters of the stream, and is measured as the percentage of the upstream network in this condition. Numerous researchers have evaluated the relative impact of riparian forest cover and IC on stream geomorphology, aquatic insects, fish assemblages, and various indices of biotic integrity. As a group, the studies suggest that indicator values for urban streams improve when riparian forest cover is retained over at least 50 to 75 percent of the length of the upstream network (Booth et al., 2002; Morley and Karr, 2002; Wang et al., 2003; Allan, 2004; Sweeney et al., 2004; Moore and Palmer, 2005; Cianfrina et al., 2006; Urban et al., 2006). The studies also indicate that downstream improvements in some stream quality indicators may still be observed when an unforested stream segment flows into a long segment of extensive riparian forest or wetland cover.

5-A.7 APPLICATION OF THE ICM TO OTHER RECEIVING WATERS

Recent research has focused on the potential value of the ICM in predicting the future quality of receiving waters such as tidal coves, lakes, wetlands and small estuaries. The primary work on small estuaries by Holland et al. (2004) [references cited in CWP (2003), Lerberg et al. (2000)] indicates that adverse changes in physical, sediment, and water quality variables can be detected at 10 to 20 percent subwatershed IC, with a clear biological response observed in the range of 20 to 30 percent IC. The primary physical changes involve greater salinity fluctuations, greater sedimentation, and greater pollutant contamination of sediments. The biological response includes declines in diversity of benthic macroinvertebrates, shrimp, and finfish.

More recent work by King et al. (2005) reported a biological response for coastal plain streams at around 21 to 32 percent urban development (which is usually about twice as high as IC). The thresholds for important water quality indicators, such as bacterial counts that exceed regulatory limits in shellfish beds and beaches, appears to begin at about 10 percent subwatershed IC, with chronic violations observed at 20 percent IC (Mallin et al., 2001). Algal blooms and anoxia resulting from nutrient enrichment by stormwater runoff also are routinely noted at 10 to 20 percent subwatershed IC (Mallin et al., 2004).

The primary conclusion to be drawn from the existing science is that the ICM does apply to tidal coves and streams, but the impervious levels associated with particular biological responses appear to be higher (20 to 30 percent IC for significant declines) than for freshwater streams, presumably due to their greater tidal mixing and inputs from near-shore ecosystems. The ICM may also apply to lakes (CWP, 2003) and freshwater wetlands (Wright et al., 2007) under carefully defined conditions. The initial conclusion is that the application of the ICM shows promise under special conditions, but more controlled research is needed to determine if IC (or other watershed metrics) is useful in forecasting receiving water quality conditions.

5-A.8 UTILITY OF THE ICM IN URBAN STREAM CLASSIFICATION AND WATERSHED MANAGEMENT

The ICM is best used as an urban stream classification tool to set reasonable expectations for the range of likely stream quality indicators (e.g., physical, hydrologic, water quality, habitat, and biological diversity) over broad ranges of subwatershed IC. In particular, it helps define general thresholds where water quality standards or biological narrative conditions cannot be consistently met during wet weather conditions (**Table 5-A.2**). These predictions help stormwater managers and regulators to devise appropriate and geographically explicit stormwater management and subwatershed restoration strategies for their catchments as part of MS4 permit compliance. More specifically, assuming that local monitoring data are available to confirm the general predictions of the ICM, it enables managers to manage stormwater within the context of current and future watershed conditions.

Table 5-A.2. Expectations for Different Urban Subwatershed Classes

Condition	Expectation
Sensitive Streams (2 to 10% IC) [1]	• Maintain or restore ecological structure, function and diversity so streams provide a "rural" benchmark with which to compare other stream categories • Specific stream quality indicators for sensitive streams should be compared to streams whose entire subwatersheds are fully protected (e.g., national parks, etc.)
Impacted Subwatersheds (11 to 25% IC)	• Consistently attain "good" stream quality indicator scores to ensure enough stream function to adequately protect downstream receiving waters from degradation. • Function is defined in terms of flood storage, in-stream nutrient processing, biological corridors, stable stream channels, and other factors.
Non-Supporting Subwatersheds (26 to 59% IC)	• Consistently attain "fair to good" stream quality indicator scores. • Meet bacteria standards during dry weather and trash limits during wet weather. • Maintain existing stream corridor to allow for safe passage of fish and floodwaters.
Urban Drainage Subwatersheds (60 to 100% IC)	• Maintain "good" water quality conditions in downstream receiving waters. • Consistently attain "fair" water quality scores during wet weather and "good" water quality scores during dry weather. • Provide clean "plumbing" in upland land uses such that discharges of sewage and toxics do not occur.

[1] The specific ranges in IC that define each management category should always be derived from local or regional monitoring data.

5-A.9 REVIEW OF MANAGEMENT RESPONSES TO THE ICM

The diversity in management responses to the ICM is fairly impressive. **Table 5-A.3** classifies the nearly 20 different planning, engineering, regulatory and economic tools that have been used (or proposed) to respond to the ICM. In general, each of these individual professional disciplines has adopted their own tools and methods to mitigate the effect of land development on water quality, and has rarely coordinated with other disciplines. This section reviews the strengths and weaknesses of the many different approaches to managing IC at the watershed and community scale.

5-A.9.1 Planning and Zoning Responses to the ICM

Planning responses are handicapped by the fact that that nearly all rural and suburban zoning categories produce more than 10% IC. This can be seen in **Figure 5-A.2,** which portrays data from Cappiella and Brown (2001) on the IC produced by different rural and suburban zones in four Chesapeake Bay communities. Only agricultural preservation zones and open urban land (e.g., parks, cemeteries and golf courses) produced less than 10% IC. This suggests that even low levels of new land development in a subwatershed will degrade streams and receiving waters to some degree.

Table 5-A.3. Range of Management Responses to the ICM

Planning and Zoning Tools	Engineering Tools
• Better (Environmental) Site Design • Large-Lot Zoning • Site-Based IC Caps • Watershed-Based IC Caps • Development Intensification • Watershed-Based Zoning • Watershed Planning	• Traditional Stormwater Treatment Requirements • Runoff Volume Reduction Practices • Special Subwatershed Stormwater Criteria • Watershed Restoration Plans
Regulatory Tools	**Economic Tools**
• Anti-Degradation Provisions • IC-Based TMDLs • Watershed-Based Permitting	• IC-Based Stormwater Utilities • Excess IC Fees • IC Mitigation Fees • Subwatershed IC Trading

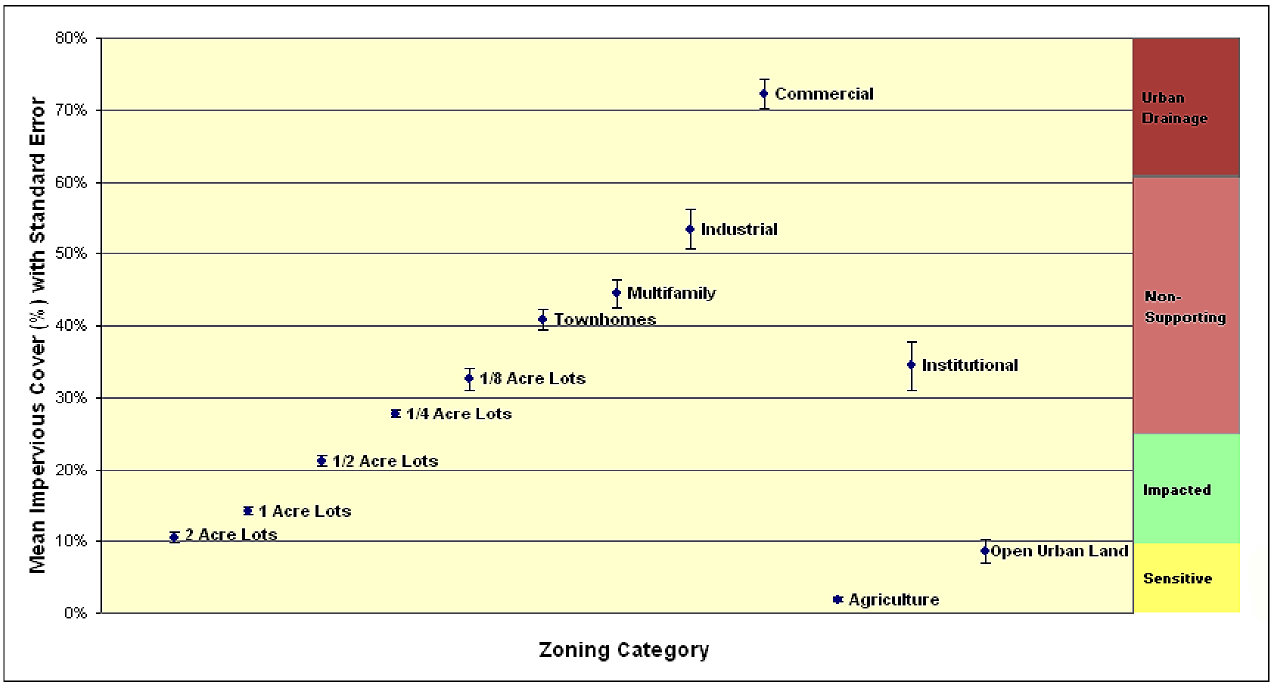

Figure 5-A.2. Relationship between impervious cover and zoning category
(Adapted from Cappiella and Brown, 2001)

This creates a difficult choice for land planners. On one hand, low density development reduces the extent of stream damage but spreads it out over a wider geographic area and thereby accentuates sprawl. More intense development, on the other hand, greatly increases local stream degradation to the point that many urban communities cannot meet water quality standards and may be subject to an uncertain future restoration liability. Communities have responded to this dilemma by pursuing several planning and zoning responses, as described below.

Environmental Site Design. This strategy relies on the fact that nearly 65% of new impervious cover can be classified as car habitat (Cappiella and Brown 2001) and focuses on changing local development codes to minimize the geometry of roads, parking lots, sidewalks, cul-de-sacs and other new development infrastructure. These techniques, which are collectively referred to as Environmental Site Design (ESD) or Better Site Design (BSD), can also include greater use of swales, relaxed lot geometry, natural area conservation, open-space subdivisions, pervious paving and other site design techniques (CWP 1998a). Several dozen communities across the country have changed their local codes and ordinances to promote ESD through a roundtable process to gain consensus among development stakeholders. The strength of the ESD approach is that numerous modeling studies have demonstrated it can reduce IC, pollutants and development costs by as much as 10 to 40% at individual development sites (Kloss and Calarusse 2006; CWP 1998b). The weakness of ESD is that it lacks a watershed context and therefore reductions in site IC may not be enough to meet subwatershed objectives.

Extremely Large Lot Zoning. Several communities have adopted extremely large lot zoning to protect sensitive streams in designated planning areas. Often, these zones are accompanied by decisions to restrict or exclude public water and sewer service. This form of very low-density residential development often involves densities ranging from 0.5 to 0.05 dwelling units per acre, and may also involve conservation easements to protect existing forests, buffers and other natural areas. Large lot zoning has been most frequently applied to protect drinking water reservoirs and trout streams, or generally maintain rural character.

The strength of large lot zoning is that it is relatively easy to implement in the context of existing zoning, and provides some measure of permanent protection for sensitive watersheds. The weakness is that the extensive road networks used to connect individual lots produce more IC area per dwelling unit than any other zoning category. When growth pressures are high, large lots tend to spread development over a wide geographic area and contribute to regional sprawl (U.S. EPA 2006). In addition, large lot zoning does not regulate how future property owners will manage their land, which can result in tree clearing, extensive turf or high density hobby farms. Lastly, large lot zoning obviously has no application in the more urban subwatersheds where the impacts of IC are the greatest.

Site-based IC Caps. Several communities have established IC caps within the context of a comprehensive land use plan or functional master plan for the express purpose of protecting drinking water or sensitive streams. Numerical IC caps are imposed on individual residential lots in order to stay below a designated IC threshold for the watershed as a whole. Individual development proposals are closely scrutinized to ensure the development footprint is below the IC cap, or is otherwise mitigated, disconnected or treated. For example, Montgomery County, MD has designated four sensitive watersheds as special protection areas that have an 8 to 10% IC cap for all new development (MCDEP, 2003). The strengths and weaknesses of IC caps are generally similar to those for large lot zoning. IC caps also have the added weakness that they require frequent monitoring to ensure that individual owners do not add more IC in the post-construction phase.

Watershed IC Caps. Direct watershed IC caps have been considered in a number of communities but seldom have been implemented. The caps can be used to protect both sensitive and impacted watersheds. The main drawback is the difficulty in measuring the aggregate change in a subwatershed IC cap over time as a result of many individual zoning and development decisions. A more indirect way to implement a watershed IC cap is through the watershed-based zoning approach.

Development Intensification. Higher density development generates less runoff and pollution per capita, per household or per increment of job growth (U.S. EPA 2006). Therefore, many urban planners and smart growth advocates have suggested that density be intensified within certain subwatersheds or designated planning areas in order to reduce development pressure in sensitive subwatersheds elsewhere. Intensification often involves high rise development, parking garages, mass transit, mixed uses and other features to decrease per-capita IC creation. Intensification is often created by drawing urban growth boundaries and then using incentives and public infrastructure investments to attract redevelopment. Portland (OR) and Toronto (ONT) are two well-known examples where urban growth boundaries were used to promote intensification.

The strength of intensification is that it confers numerous social, community and economic benefits and should result in less dramatic change to stream quality if the area is already developed (e.g., shifting from non-supporting to urban drainage). The weakness of intensification is that it cannot directly protect sensitive or impacted watersheds when multiple communities are involved. At the regional scale, it is often possible for both intensification and low density sprawl to occur at the same time, in response to different market forces and consumer preferences (e.g. land prices, affordable housing, commuting distances, employment centers and the like).

Watershed-based Zoning. Watershed-based zoning is a planning technique that directly ties comprehensive planning or zoning to the ICM. Local planners evaluate current zoning within individual subwatersheds present in their community (Schueler 1994). Current and future IC are forecasted for each subwatershed as a result of build-out of existing zoning. Land is then rezoned within each subwatershed to either increase or decrease IC to achieve the desired ICM classification, which is then incorporated into the local land use master plan or comprehensive plan. The process may also involve special overlay zones that set forth more specific buffer, stormwater and land conservation requirements within each subwatershed management category. To date, several communities have directly or indirectly utilized elements of watershed-based zoning, but none have fully implemented the entire process. The primary reason has been the inherent disconnect between local watershed planning and comprehensive land use planning in most communities.

Watershed Planning. Watershed plans can guide land use decisions to change the location or quantity of IC created by new development. Numerous techniques exist to forecast future watershed impervious cover and its probable impact on the quality of aquatic resources (CWP, 1998 and MD DNR 2005). The level of control that can be achieved by watershed planning is theoretically high, but relatively few communities have aggressively exercised it. In particular, few communities have fully integrated their watershed planning efforts into their comprehensive planning and zoning process. Consequently, many watershed plans contain recommendations for implementation of watershed practices, but few substantive changes in zoning or land use decisions. Powerful consumer and market forces often drive low-density sprawl development, regardless of the recommendations of the watershed plan.

Even when land use is an explicit component of local watershed plans, these local decisions are reversible and often driven by other community concerns such as economic development, adequate infrastructure, and transportation. Schueler (1996) has explained the primary reasons why local watershed plans are not fully implemented. Many of these reasons still exist today. Consequently, many communities continue to struggle with how to influence the optimal location and intensity of subwatershed IC in their watershed plans. Furthermore, they often lack an effective accountability mechanism (such as a watershed-based permit) to fully implement these plans.

5-A.9.2 Engineering Responses to the ICM

Traditional Stormwater Treatment Requirements. Many communities have relied on engineering rather than planning solutions to address ICM impacts. The major trend has been to adopt stormwater management requirements to treat both the quality and quantity of runoff from individual development sites. The most common practice has been to pipe runoff into a stormwater detention or retention pond. Performance research studies indicate that ponds do have modest flood control and pollutant removal capability (ASCE, 2007 and CWP 2007). Traditional stormwater ponds, however, have not been shown to improve stream quality indicator scores. For example, seven research studies have concluded that stormwater ponds are incapable of preventing the degradation of aquatic life in downstream channels (MNCPPC 2000; Maxted 1999; Stribling et al. 2001; Galli 1990; Horner and May 1999; Horner et al. 2001; Jones et al. 1996). Given that current stormwater technology cannot fully mitigate land development impacts, the engineering community has explored new sizing criteria and stormwater technology to improve their performance.

Runoff Reduction Approach. The prevailing stormwater paradigm has recently shifted to what is known as the Runoff Reduction Approach (Schueler 2008). The goal is to mimic natural systems as rain travels from the roof to the stream through combined application of a series of small practices distributed throughout the entire development site. Runoff reduction is operationally defined as the total runoff volume reduced through canopy interception, soil infiltration, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapotranspiration. The overall site design objective is to replicate the runoff coefficient for all storms up to a certain design storm event for the native predevelopment land cover.

Runoff reduction practices include rain tanks, rain gardens, infiltration, bioretention, dry swales and linear wetlands, among others. The comparative runoff reduction rate achieved by various stormwater practices varies greatly, as shown in **Table 5-A.4**. Several traditional stormwater practices, such as ponds and sand filters have little or no capability to reduce incoming stormwater runoff volume (Strecker et al. 2004), whereas other practices can achieve annual runoff reduction rates ranging from 40 to 90%, depending on their design. Typically, multiple practices are needed at each site to incrementally reduce the total stormwater runoff volume delivered to the stream. The major challenge with runoff reduction is how to size and arrange the individual practices to meet the appropriate stream protection objective with a subwatershed. The most recent approach is to define a variable runoff reduction volume based on the subwatershed management designation. The shift to runoff reduction is quite recent, so monitoring efforts to demonstrate its effect on improving stream quality indicator scores at the subwatershed scale have yet to be completed. Several recent studies have shown that LID or runoff reduction approaches can be effective at the scale of the individual site (Phillips et al, 2003, Selbig and Bannerman, 2008).

Table 5-A.4. Comparative Runoff Volume Reduction Rates of Selected Stormwater Control Measures in the Chesapeake Bay Region

SCM	Level 1 RR [1]	Level 2 RR [1]
Infiltration	50	90
Bioretention	40	80
Soil Amendments	50	75
Permeable Pavement	45	75
Green Roof	45	60
Dry Swale	40	60
Rain Tanks/Cisterns	Actual holding volume x 0.75	
Filter Strip	25-50	50
Rooftop Disconnection	25	50
Grass Channel	10	20
Extended Detention Pond	0	15
Wet Pond	0	0
Constructed Wetland	0	0
Wet Swale (Linear Wetland)	0	0
Filters	0	0
[1] BMP Level 1 and Level 2 designs are explained in CWP/CSN (2008)		

Source: CWP/CSN (2008)

Special Subwatershed Stormwater Criteria. Another approach has been to define special subwatershed design criteria that govern the size, selection and location of the structural and non-structural practices needed to protect aquatic resources in sensitive subwatersheds. Several recent state stormwater manuals have established more prescriptive criteria to protect sensitive waters, such as wetlands, lakes, and trout streams (see Wenger at al 2008 and MPCA 2005) or to focus on increasing the removal of a specific pollutant of concern in a more developed situation (see Schueler 2008).

Watershed Restoration Practices. Stormwater retrofits, stream repair, riparian and upland reforestation, discharge prevention and pollution source controls have all been applied to restore stream quality in urban subwatersheds. A full description of their strengths and weaknesses can be found in the Small Watershed Restoration Manual Series produced by the Center for Watershed Protection. The individual and aggregate effectiveness of restoration techniques appears to be inversely related to the amount of IC present in a subwatershed (Schueler 2004). The best prospects for improving stream quality indicator scores occur in sensitive and impacted watersheds, whereas the cost and feasibility of restoration climbs rapidly in non-supporting and urban drainage subwatersheds (Schueler et al. 2007).

Most communities assemble individual restoration practices within the context of a larger watershed restoration plan to achieve defined stream quality objectives. The key problem of watershed planning tends to be one of implementation. Many communities have fine plans, but have only implemented a handful of actual restoration projects. The poor track record in implementation is created by the inherent difficulty of delivering dozens or hundreds of restoration projects over time, their high cost, and the lack of dedicated financing to build them. In addition, most local watershed restoration plans lack accountability mechanisms to ensure progress is maintained over the 10-15 years required for full implementation.

5-A.9.3 Regulatory Responses to the ICM

Beneficial uses and related water quality standards are frequently exceeded in most urban subwatersheds, so regulatory agencies continue to grapple with the ICM as it relates to the many complex provisions of the Clean Water Act. Some recent trends include the following:

Anti-Degradation, Tiered Uses and Wet Weather Standards. Several sections of the Clean Water Act could potentially protect sensitive and impacted streams, or allow greater flexibility in meeting standards in non-supporting streams. For example, anti-degradation provisions can protect waters that currently achieve or exceed water quality standards or their designated use, but are threatened by future watershed development. States such as Ohio and Maine have crafted anti-degradation rules to regulate discharges or activities by NPDES permittees in the watershed to protect healthy waters. States also have the capability to designate tiered uses and wet weather standards to set more realistic water quality goals for non-supporting and urban drainage subwatersheds, although, to date, few have exercised this option.

Impervious cover based TMDLs. Total Maximum Daily Loads or TMDLs are the primary tool to document how pollutant loads will be reduced to meet water quality standards. Maine, Vermont and Connecticut have recently issued TMDLs that are based on IC rather than individual pollutants of concern (Bellucci 2007). In an IC- based TMDL, IC is used as a surrogate for increased runoff and pollutant loads as a way to simplify the urban TMDL implementation process. IC-based TMDLs have been issued for small subwatersheds that have biological stream impairments associated with stormwater runoff but no specific pollutant listed as causing the impairment (in most cases, these subwatershed are classified as impacted according to the ICM).
A specific subwatershed threshold is set for effective IC, which means IC reductions are required through removal of IC, greater stormwater treatment for new development, offsets through stormwater retrofits or other means. Since IC-based TMDLs have only appeared in the last year, communities have little or no experience in actually implementing them. Traditional pollutant-based TMDLs continue to be appropriate for non-supporting and urban drainage subwatersheds, although they could be modified to focus compliance monitoring on priority urban source areas or subwatersheds that produce the greatest pollutant loads.

Watershed-Based Permitting. U.S. EPA (2007) has issued technical guidance to promote watershed-based permitting, which has the potential to integrate the many permits to improve water quality conditions in urban watersheds. States and localities, however, have yet to implement watershed-based permitting at the sub-watershed scale in the context of the ICM. This regulatory tool shows promise, and several recommendations for applying it to urban watersheds as part of the NPDES MS4 stormwater permit program are presented in the Watershed Planning section of **Chapter 5** and in **Appendix 5-B**.

5-A.9.4 Economic Responses to the ICM

Economists have been attracted to IC because it is easy to measure and can act as a common currency that spans and transcends the site and watershed scale. In recent years, economists have tried to value or price IC so as to better use market forces to improve urban watershed management. These efforts are mostly in their infancy and face the twin problems of defining the unit price of IC and how it varies among subwatersheds with different IC. Several economic approaches that utilize IC are described below.

IC-Based Utilities. Several hundred communities have adopted stormwater utilities that charge residents and businesses a monthly or quarterly charge based on their IC. Funds are used to operate stormwater programs, maintain stormwater infrastructure and comply with their stormwater permits. Utility charges typically range from $30 to $120/year/ residential unit and apply only to existing development. In most cases, an average unit IC charge is applied to all homes and businesses, since most communities lack enough GIS or political resolution to estimate IC and charge for individual parcels. The utility fee can be an incentive to reduce site IC by reducing charges for homeowners that install retrofits such as rain gardens.

IC Mitigation Fees. IC mitigation fees can be applied to new development to discourage the creation of excess IC or to pay for off-site restoration when on-site stormwater compliance is not possible. In the first case, communities establish a maximum IC cap within an individual zoning category or for the subwatershed as a whole. New development projects that exceed the cap are charged a unit fee used to finance restoration practices elsewhere in the subwatershed. In the second case, an IC-based fee-in-lieu is charged when an individual site cannot meet stormwater runoff reduction requirements in full or in part. The basic IC pricing mechanism is the same in both cases: the average per IC acre cost to provide an equivalent amount of restoration or stormwater treatment elsewhere in the watershed. The weakness of mitigation fees involves difficulty in accurately matching the fees collected to actual construction of cost-effective restoration projects in the desired subwatershed that needs restoration.

Subwatershed IC Trading and Offsets. Trading of IC among subwatersheds is still a novel concept although its theoretical elements have been outlined by Parikh et al. (2005). Like other water quality trading programs, development sites that face higher pollution control costs can meet their regulatory obligations by purchasing environmentally equivalent (or superior) pollution reductions or “credits” from another subwatershed at lower cost, thus achieving the same water quality improvement at lower marginal cost. IC is a logical currency for stormwater trading, and may be most efficient in shifting costs among different subwatersheds to produce the greatest water quality improvement. For example, the higher compliance cost in an urban drainage subwatershed might be traded to a sensitive subwatershed to provide greater protection by purchasing lower cost conservation easements.

5-A.10 SUMMARY

The preceding review suggests that no single planning, engineering, economic or regulatory tool appears capable of effectively protecting or restoring stream quality over the full range of subwatershed IC. Some individual tools work reasonably effectively across a narrow range of impervious cover, but most have significant weaknesses, particularly when it comes to implementation. In addition, most communities tend to use only one kind of tool to mitigate the impact of IC (i.e. planning approaches versus engineering solutions). As a result, most communities are unsatisfied with the outcomes of their urban watershed protection or restoration efforts to date.

The review also suggests some possible management remedies. The first is that many communities set unrealistically high expectations for stream quality given their development intensity. In this instance, it may be wise to set more realistic and achievable stream quality objectives (several recommendations are made in the ensuing section. Second, communities may wish to apply a combination of planning, engineering, economic or regulatory tools at the same time. Third, communities should classify their subwatersheds to make sure they are applying the most effective and appropriate tools within the prescribed range of subwatershed IC. Finally, communities may need to develop more stringent accountability mechanisms to ensure that the tools they use are fully implemented.

5-A.11 A SUGGESTED URBAN STREAM MANAGEMENT SYSTEM

Once realistic expectations have been set for a subwatershed, the specific combination of planning, engineering, economic and regulatory tools that are needed becomes more obvious. Some potential combinations for each subwatershed management category are detailed in **Tables 5-A.5 through 5-A.7** below. It should be strongly emphasized that these strategies provide a starting point for developing a local watershed management strategy, and that they will always need to be modified for local conditions.

5-A.11.1 Management Strategies to Protect High Quality Streams

One of the more troubling findings of the ICM, and much of the recent urban stream research, is that it does not take very much subwatershed development to degrade high quality streams – depending on the ecoregion, as little as 3 to 7% IC. Many high quality streams have evolved in response to the forest (or native cover) of their subwatersheds, and have unique habitat conditions that support trout, salmon or spawning of anadromous fish. Given the vulnerability of these streams, watershed managers must commit to an aggressive protection strategy to mitigate the impacts of land development (**Table 5-A.5**). The comprehensive strategy involves watershed zoning, land conservation, preservation of the riparian network and stormwater practices that create no net increase of runoff volume or velocity up to the two year design storm event.

Additional regulatory and economic tools are also needed to protect and maintain the quality of exceptional streams, as shown in **Table 5-A.5**. While the proposed strategy is much more stringent than what most communities currently allow, it is technically achievable, and provides greater reliability in meeting the objectives of maintaining exceptional stream biodiversity and function. From the standpoint of implementation, it is important to formally designate these subwatersheds as being exceptional, and then using the anti-degradation provisions of the Clean Water Act to provide regulatory support for the development restrictions.

Table 5-A.5. Management Strategies to Protect High-Quality Streams

Subwatershed Outcomes Need to Protect High Quality Streams
• Restrict subwatershed IC to less than 10% (or a regional IC threshold) • Retain more than 65% forest or native vegetative cover in the subwatershed • Ensure forest or native cover on at least 75% of the stream network • Do not allow more than one crossing per stream mile, and none that create a barrier to migration
Recommended Watershed Planning and Engineering Practices
• Require full runoff volume reduction up to the 2-year storm for all new IC by maximizing the use of runoff reduction practices and discouraging conventional detention ponds and large diameter storm drain pipes • Establish wide stream buffers (100-200 feet) for the entire drainage network, including zero-order streams • Apply conservation practices to all croplands and keep livestock out of streams • Use site or subwatershed IC caps, extremely large lot zoning, watershed-based zoning, farm preservation, or conservation easements to limit subwatershed IC • Use limited stream restoration to restore habitat, remove fish barriers, and correct past mistakes
Recommended Regulatory and Economic Measures
• Protect healthy streams using anti-degradation provisions of the Clean Water Act • Monitor the geomorphic stability and biological diversity of the streams to verify compliance • Reduce public infrastructure investments in the subwatershed to discourage growth • Increase technology and permit requirements for private water and sewer infrastructure • Designate these subwatersheds as receiving areas for IC mitigation fees to finance restoration and secure conservation easements

5-A.11.2 Management Strategies for Suburban Streams

Stream quality in suburban subwatersheds (10 to 25% IC) exhibits a great deal of variability or scatter. Indicator scores can range from poor to fair to good (but not excellent). A reasonable management objective is to achieve both good indicator scores and maximize stream function to adequately protect downstream receiving waters from degradation (e.g., flood storage, in-stream nutrient processing, biological corridors, stable stream channels, etc.). Given the relatively light development intensity of suburban watersheds, there is room to apply a broad range of management practices in the uplands and the stream corridor (**Table 5-A.6** below).

The basic upland management prescription for suburban streams is to maximize tree canopy and minimize both turf and impervious cover across the subwatershed. Stormwater practices that achieve full runoff reduction up to the two year storm event are applied in a roof to stream sequence to reduce channel erosion and maintain recharge. The prescription for the stream corridor is to protect and enhance buffers around streams, wetlands and floodplains, with special emphasis on minimizing the enclosure of zero order streams (i.e., maintaining them as an open stormwater treatment system). Some elements of the stream corridors may require stream repairs, reforestation or wetland creation.

Table 5-A.6 also outlines the regulatory and economic tools needed to implement and maintain watershed practices for suburban streams. The key management challenge is to prevent a gradual

"creep" in IC over time through rezoning, redevelopment and homeowner expansions. Consequently, watershed managers should set clear goals for maximum future IC, and track it over time to ensure it remains within prescribed limits.

Table 5-A.6. Management Strategies to Protect Impacted Suburban Subwatersheds

Recommended Watershed Planning and Engineering Practices
• Require full runoff reduction up to the one year storm for all new IC created in the subwatershed • Minimize subwatershed IC, maximize forest cover and conserve soil quality using runoff reduction practices from roof to stream • Conserve and protect stream buffers, floodplains, wetlands and river corridor in a natural state and in public ownership • Adjust zoning to limit IC to meet 20 to 25% subwatershed IC caps • Use Environmental Site Design roundtable process (CWP, 1998a) to seek 25% reduction in average IC and turf cover produced by each zoning category • Implement selected stream restoration and storage retrofits to mitigate effect of existing development in the watershed • Establish an ultimate subwatershed tree canopy goal of 40 to 45%
Recommended Regulatory and Economic Measures
• Utilize IC-based TMDLs to set specific targets for runoff reduction and removal of pollutants of concern • Invest in public infrastructure to enhance the quality of drinking water, wastewater and stormwater • Designate these subwatersheds as receiving areas for IC mitigation fees to finance retrofits and other restoration practices • Impose IC mitigation fees for both new and existing development to discourage creation of needless impervious cover, finance restoration and maintain stream protection and stormwater infrastructure

5-A.11.3 Strategies to Manage Highly Urban Streams

The quality of highly urban subwatersheds will be inevitably degraded by the combination of IC creation, soil compaction and stream alteration. Highly urban streams can have one of two management designations – non-supporting (25 to 60% IC) and urban drainage (60 to 100% IC). Urban drainage subwatersheds generally have little or no remaining surface stream network, whereas non-supporting streams still have some surface streams, although they are often highly degraded and fragmented. The management goal for both stream classes is to limit the extent of degradation, while at the same recognizing these subwatersheds are an intense human habitat, both in the uplands and the remaining stream corridor. The proposed management strategies for non-supporting and urban drainage subwatersheds are presented in **Table 5-A.7**.

The basic approach is to protect public health and safety through stormwater management, pollution prevention and discharge prevention practices in the uplands, and to use the stream corridor as a greenway and a conduit for floodwaters. While it is not possible to achieve high levels of aquatic diversity, the watershed practices can reduce pollutant export to downstream receiving waters, and ensure safe water contact during dry weather periods. The land use planning strategy for these subwatersheds encourages both intensification and redevelopment. The impacts from increased IC can be ameliorated by green buildings, expanded urban tree canopy, and selected stormwater retrofits and watershed restoration projects.

Table 5-A.7. Strategies for Non-Supporting and Urban Drainage Subwatersheds [1]

Recommended Watershed Planning and Engineering Practices
• Encourage intensification and redevelopment • Require runoff reduction for the 90th percentile storm as part of the redevelopment process (NS subwatersheds) or a fraction thereof (UD subwatersheds) • Provide sufficient upland retrofit, discharge prevention, and pollution prevention practices to treat stormwater hotspots • Utilize street cleaning and storm drain inlet cleanouts to remove gross pollutants from the dirtiest source areas. • Maintain a forest canopy goal of at least 25% and 15% for NS and UD subwatersheds, respectively • Manage the remaining stream corridor as a greenway and protect/restore large natural area remnants
Recommended Regulatory and Economic Measures
• Utilize conventional TMDLs to reduce pollutants of concern at the most polluted subwatersheds and urban source areas. • Conduct dry weather water quality monitoring in streams (NS) or receiving waters (UD) to assure progress towards goals • Designate these subwatersheds as sending areas for IC mitigation fees to finance retrofits and other restoration practices in less dense subwatersheds • Impose IC mitigation fees for redevelopment when full site compliance with runoff reduction targets cannot be attained.
[1] For space purposes, the strategies for non-supporting (NS) and urban drainage (UD) have been combined together since they differ primarily in the scope or extent of treatment, except where noted

For some, this strategy sacrifices urban streams, and enables municipalities to violate existing water quality standards. The key point, however, is that IC and associated infrastructure has such a dominant influence on these streams that aquatic diversity and water quality standards could never be met, regardless of the investment. Implementation of the stringent measures outlined in **Table 5-A.7** can result in incremental improvements in local waters and substantial pollutant reduction to downstream waters.

5-A.12 CONCLUSIONS

The reformulated ICM organizes and simplifies a great deal of complex stream science into a model that can be readily understood by watershed planners, stormwater engineers, water quality regulators, economists and policy makers. More information is needed to extend the ICM as a method to classify and manage small urban watersheds and organize the optimum combination of best management practices to protect or restore streams within each subwatershed classification.

The challenge for scientists and watershed managers is no longer proving the hypothesis that increasing levels of land development will degrade stream quality along a reasonably predictable gradient – the majority of studies now support the ICM. Rather, researchers may shift to testing a hypothesis that widespread application of multiple management practices at the catchment level can improve the urban stream degradation gradient that has been repeatedly observed. The urgency for testing the catchment effect of implementing best management practices is underscored by the rapid and inexorable growth in IC across the country.

5-A.13 REFERENCES

** Denotes research papers that were included in the Center for Watershed Protection's ICM database. A list of additional papers that were reviewed, but did not meet the criteria for inclusion in the ICM database, is available upon request from the Center for Watershed Protection.*

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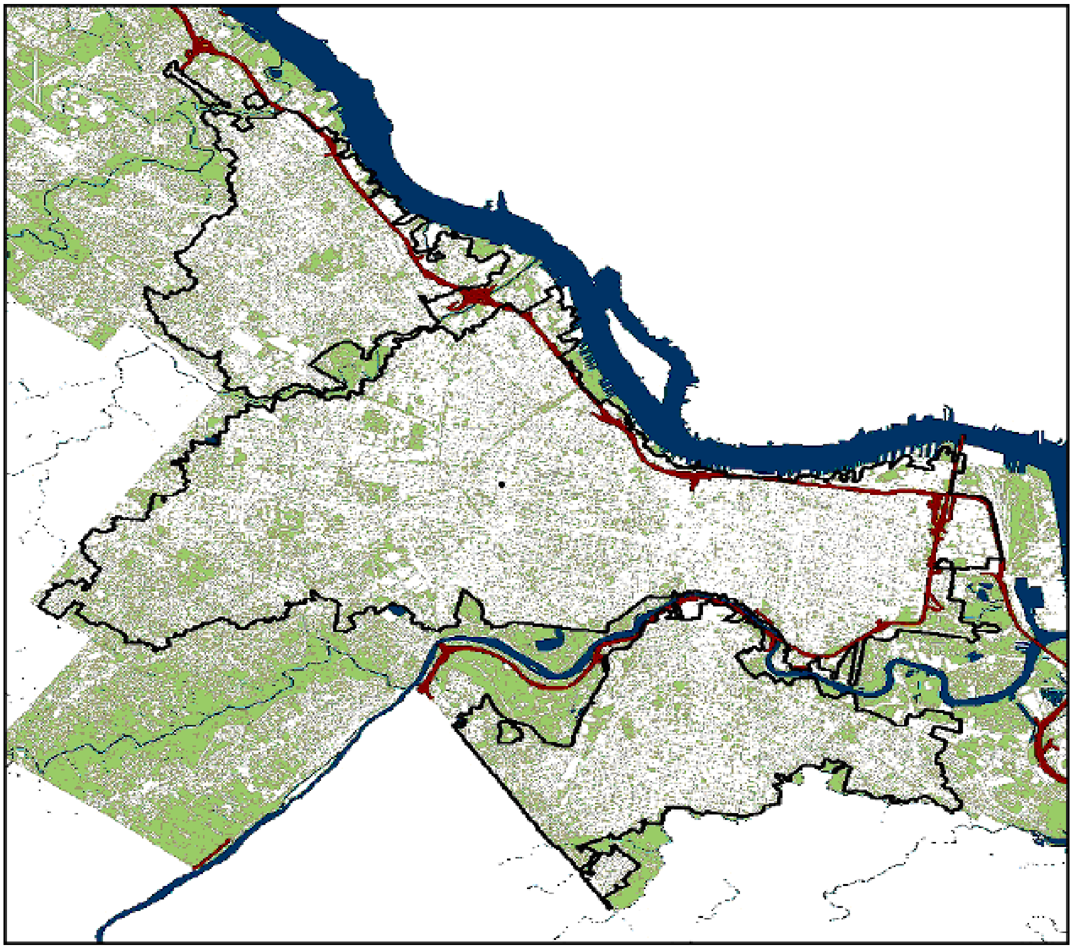
Appendix 5-B

Watershed-Based Stormwater Planning



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5-B.1.0 STORMWATER MASTER PLANNING

5-B.1.1 Introduction

Stormwater master planning is an important tool with which communities can assess and prioritize both existing and potential future stormwater problems, as well as use to consider alternative stormwater management solutions. A stormwater master plan is prepared to consider, in detail, what stormwater management practices and measures are to be provided for an urban drainage area or a large development project.

Stormwater master plans are most often used to address specific single functions such as drainage provision, flood mitigation, cost/benefit analysis, or risk assessment. These plans prescribe specific management alternatives and practices. Multi-objective stormwater master planning broadens this traditional approach to potentially include land use planning and zoning, water quality, habitat, recreation, and aesthetic considerations. The broadest application of stormwater master planning is the comprehensive watershed plan which is described in detail in this Appendix.

For any stormwater master plan, it is important at the outset to: (1) clearly identify and quantify the objectives and issues the plan will address; (2) recognize the constraints (technical, political, legal, financial, social, physical) that limit the possible solutions; and (3) develop a clear technical approach that will address the key issues and needs while staying within the constraints to potential solutions.

5-B.1.2 Watershed Planning Flexibilities in the Virginia Stormwater Management Regulations

Although site-by-site compliance with stormwater management requirements is much better than no stormwater management at all, evidence from across the nation indicates that individual controls on stormwater discharges are inadequate as the sole solution for stormwater in urban watersheds. Ideally, BMP implementation needs to be designed as a system, integrating structural and nonstructural BMPs and incorporating watershed goals, site characteristics, development land use, construction erosion and sediment controls, aesthetics, monitoring and maintenance. Stormwater cannot be adequately managed on a piecemeal basis due to the complexity of both the hydrologic and pollutant processes and their effect on habitat and stream quality.

Section 9 VAC 25-870-96 of the regulations allows local governments to develop comprehensive watershed-based stormwater management plans as an alternative way to comply with the water quality requirements, the water quantity requirements, or both. State and federal agencies intending to develop large tracts of land also may develop or participate in comprehensive watershed stormwater management plans where practicable. Section 9 VAC 25-870-76 also allows linear development projects, such as streets and highways, to achieve compliance in accordance with such a watershed plan, as an alternative to strict on-site compliance.

Those who develop such plans must demonstrate to DEQ and the State Water Control Board (Board) that the results of implementing the plan will be at least as good as, if not better than, those that would be achieved from straightforward implementation of the regulation requirements on a site-by-site basis. The Board must approve local watershed plans before they may be implemented.

The local program must document nutrient reductions achieved during the plan's implementation, in order to demonstrate the actual equivalence of compliance results. If the percent of impervious area upon which the plan was based changes or if any other amendments are deemed necessary by the local program, the local program must provide plan amendments to the Soil and Water Conservation Board for review and approval. For example, if the plan's target total nutrient removal for the watershed is based on an expected build-out resulting in a composite 53 percent impervious cover, and subsequently the locality approves comprehensive plan and zoning changes that will result in a composite 65 percent imperviousness at build-out, then the plan's original targets will no longer achieve results equivalent to those required in the regulations. The locality would need to amend the plan to achieve equivalence and submit the amendments to the Board for review and approval.

Section 9 VAC 25-870-63 of the regulations allows watershed plans to allow for compliance offsets (off-site mitigation, compliance trading, or fee-in-lieu options), where compliance is not feasible or cost-effective on the development site due to physical constraints, etc. In such cases, the chosen offset measure must ensure that the resulting stormwater control is equal to or greater than what would be required on each contributing land disturbing site. In fact, since the watershed planning process accounts for ultimate pollutant load reductions, such plans provide the best opportunity to optimize the most cost-effective strategy and mix of practices to achieve compliance. The regulations require that offsets must be achieved within the same Hydrologic Unit Code (HUC) watershed, or within HUCs established by the locality for this purpose. *Watershed plans also provide the best opportunity for communities to achieve an effective approach to encouraging and stimulating redevelopment and infill development and discourage continued sprawl into outlying areas.*

5-B.1.3 Advantages of the Watershed Approach to Stormwater Management

The watershed approach has the following significant advantages over traditional piecemeal approaches to stormwater management that require individual land developments to provide on-site stormwater management facilities

Lower capital and O&M Costs. Typically, comprehensive watershed management plans result in fewer and larger stormwater management facilities. Economies of scale are achievable in capital costs and especially in Operation and Maintenance costs. Strategic placement of regional facilities allows available funding to be concentrated on areas where the potential benefits are greatest. Cost sharing arrangements significantly reduce the net cost of stormwater management to the community as a whole.

Increased effectiveness on a watershed-wide basis. Often different portions of watersheds require different types of stormwater controls. Watershed planning permits the siting of a variety of on-site and regional facilities in locations where the greatest respective benefits are achieved.

Greater use of nonstructural measures. Often the most practical stormwater controls involve nonstructural measures such as land acquisition, floodplain zoning, subdivision drainage ordinances, and land use controls. Watershed planning provides a coordinated comprehensive framework and decision-making process to allow the effective implementation of these measures.

Less risk of negative "spillover" effects. The piecemeal approach may adequately solve localized drainage problems, but seldom addresses downstream impacts. Thus, the site-by-site approach raises the risk that dynamic interactions between upstream drainage improvements may actually increase downstream flooding. An objective of watershed planning is to account for these upstream interactions and achieve solutions for both localized and regional stormwater management concerns.

More flexibility in ways to satisfy regulatory criteria. Once a community has calculated the volume of water that must be "treated" to achieve the necessary reduction in pollutants, the total load to be reduced can be apportioned to a number of different kinds and scales of strategically located practices. For example, the mix of BMPs could include the following:

- Some on-site practices where this is feasible
- Fees-in-lieu of on-site practices, where achieving the required reduction is impractical or unachievable (or where development intensity – e.g., the central business district or corridor) is such that it is more cost-effective to achieve the reductions elsewhere in the watershed)
- Off-site mitigation, where the required pollutant reduction is achieved collectively on more than one site (provided applicable conditions are met)
- Regional-scale facilities
- Stormwater retrofits in previously developed areas
- Stream restoration to reduce sediment from bank erosion and bedload transport

This approach allows the community to make the best use of its land while still achieving the stormwater management goals established for the watershed.

5-B.1.4 Types of Stormwater Master Planning

There are several basic types of stormwater master plans that can be prepared. Below are descriptions of representative examples of master plans.

Flood assessment master plans. Flood assessment is the simplest form of stormwater master planning, where only the essential components, alignments, and functions of a drainage system are analyzed. The focus of these studies is on water quantity control and flood prevention and/or mitigation.

Frequently, a flood assessment study analyzes both existing conditions and projected future build-out conditions. The study is based upon estimates (usually modeled) of peak and total discharges for selected return frequency runoff events. The selected events should be based on local standards. Both the hydrology and hydraulics of the system are analyzed to determine water surface profiles and elevations. This, in turn, assists in determining probable locations where impacts can be expected to occur. Frequently, an alternatives analysis will be performed as part of the master plan to provide potential solutions to mitigating the flood impacts. This typically involves the modeling of proposed modifications or development scenarios.

Examples include examining the effects of detention on flooding and providing improved flood protection (e.g., flood proofing structures, levies, etc). A local community might develop HEC-1 and HEC-RAS models for the hydrology and hydraulics of a watershed for the purposes of estimating the full buildout floodplain and regulating new development on this basis rather than the ever-changing “existing conditions” approach.

Flood study cost/benefit analysis master plans. Another type of master planning builds on a flood assessment master plan to determine acceptable risks and the associated costs. Using information developed in the flood analysis, economic and/or environmental impacts can be assessed. This initially entails establishing a relation between water surface elevation and associated damage (often referred to as stage-damage curves). Based on this relationship, an acceptable level of risk is determined, from which design discharges and associated water surface profiles and elevations are established. Acceptable levels of risk might be based upon the likelihood of loss of human life, impacts to residences, impacts to non-residence structures, or damage to utilities. This information then helps determine the ultimate drainage infrastructure that will be needed to achieve the planning goals. Either a formal cost-benefit analysis or a more subjective “cost-effectiveness” approach could be used. Based on the design criteria, preliminary designs can be developed which in turn yield initial cost estimates for the infrastructure.

For example, a community might look at different flood protection strategies along a stream and estimate the costs and flood damage savings for each alternative in an effort to select the most appropriate solution(s) for that community.

Water quality master plans. Master planning for stormwater quality is becoming increasingly important, as nonpoint source loads are a critical component of watershed-wide water quality assessments. For many Georgia communities it is necessary to be able to estimate pollutant loads from stormwater runoff for TMDLs, as well as for the expansion of wastewater treatment facilities. A water quality master plan can provide the foundation from which to develop broader water quality assessments.

Stormwater quality studies will typically analyze water quality impacts to receiving waters (and groundwater, particularly in karst regions) and develop structural and nonstructural strategies to reduce or minimize the pollutant loads. Studies usually involve the development, calibration, and verification of a water quality model. The level of model sophistication can vary from simple to complex. Often, a cost/benefit analysis will be performed as a component of the water quality study to quantify the efficacy of various strategies.

For example, a community might develop a simple spreadsheet-based loading model to perform planning level analyses of loadings of pollutants, potential removal by stormwater controls, and the impacts of development strategies – or they use a more complex continuous simulation water quality model and supporting monitoring to develop a combination of point and non-point source loading estimates in support of a watershed assessment or TMDL.

Biological/habitat master plans. Biological/habitat master planning is similar to a water quality master plan. However, rather than focusing on water chemistry, the focus is on the aquatic biological communities and supporting habitats. Biological assessments are being implemented on a more frequent basis to assess overall water body health. Biological studies provide the ability to assess both acute and long-term effects of nonpoint source impacts to a receiving water in the absence of continuous monitoring data. The resulting data can be used in the design and development of habitat improvement and stream restoration projects, riparian buffers, structural control retrofits, etc.

For example, a community may desire to improve the quality and aesthetics of a stream. Biological monitoring and habitat assessment establishes the baseline health of the stream and can be compared to a reference stream in the area. This information is assessed to determine causes of impairment (often paired with chemical monitoring) and methods to reduce impairment are investigated. The plan might then include riparian corridor planning, land use zoning changes, and planned habitat restoration.

Comprehensive watershed master plans. The comprehensive watershed approach is the most general type of stormwater master planning as well as the most extensive. The intent of comprehensive watershed plan is to assess existing water resources health and to make informed land use and stormwater planning decisions based on the current and projected land use and development within the targeted watershed and its associated subwatersheds. Watershed-based water quantity and water quality goals are typically aimed at maintaining the pre-development hydrologic and water quality conditions to the extent practicable through peak discharge control, volume reduction, groundwater recharge, channel protection, and flood protection. In addition, watershed plans may also promote a wide range of additional goals include the streambank and stream corridor restoration, habitat protection, protection of historical and cultural resources, enhancement of recreational opportunities, and aesthetic and quality of life issues.

Watershed-based studies often involve a holistic approach to master planning, where hydrology, geomorphology, habitat, water quality, and biological community impacts are analyzed and solutions are developed. A detailed discussion of watershed-based master planning is provided below.

5-B.2.0 COMPREHENSIVE WATERSHED PLANNING FOR VIRGINIA COMMUNITIES

5-B.2.1 Introduction

Due to the realization that urban stormwater quantity and quality management need to be addressed at a larger scale, communities are increasingly turning towards the development of comprehensive watershed and subwatershed plans. These plans usually encompass broader management issues such as land use planning and zoning, recreational and aesthetic opportunities, water supply protection, and habitat management.

5-B.2.2 Scale of Watershed Management

Watersheds are typically defined according to the resource area or downstream water body of interest. Although there are no maximum size limits for defining a watershed, a manageable watershed for local planning efforts is usually no greater than 100,000 acres (~150 square miles). It is important to remember that larger watershed boundaries require the involvement of more jurisdictions and stakeholders.

Ideally, planning take place at both the watershed and smaller "subwatershed" scales. Typically, the broad, "big picture" planning takes place at the watershed level, and the more refined objectives and implementation plans are pursued at a subwatershed level (see **Table 5-B.1 and Figure 5-B.1** below). Finally, individual projects and controls are carried out at the project or catchment level.

Often times it may be more efficient to plan at the watershed scale and to assess the effectiveness of plan implementation at the subwatershed scale, where indicator response is more apparent. For example, many of the non-traditional goals of a multi-objective watershed master plan, such as establishment of inter-jurisdictional greenways, wildlife corridors, and forest conservation areas, are easier to conceptualize and implement at the watershed scale.

A community undertaking a watershed planning effort will need to determine whether the project area under consideration is part of a larger watershed or river basin with its own distinct management goals. If so, the community needs to ensure that the planned activities complement the broader-scale efforts. On the other end of the scale, a local government must also make sure that development and neighborhood level stormwater management projects and activities are incorporated into and complement the overall watershed plan.

More specific information about the correlation of Virginia hydrologic unit geography with the USGS watershed mapping can be found on the Virginia Department of Conservation and Recreation website at:

http://www.dcr.virginia.gov/soil_and_water/hu.shtml

Table 5-B.1. Description of New USGS Hydrologic Mapping System Units

Order	No. Digits in New ID#	New Name	Unit Size	Sample Management Measures
1	2	Region	Avg. 177,560 sq. mi.	
2	4	Subregion	Avg. 16,800 sq. mi.	
3	6	(River) Basin	Avg. 10,596 sq. mi.	
4	8	Sub-basin	Avg. 703 sq. mi.	Basin-wide planning
5	10	Watershed [1]	Range: 40,000 acres (62.5 sq. mi.) to 250,000 acres (390+ sq. mi.)	Basin-wide planning combined with watershed-based development standards
6	12	Subwatershed	Range: 10,000 acres (15+ sq. mi.) to 40,000 acres (62.5 sq. mi.)	Watershed-based development standards combined with stream classification and management
		Catchment [2]	Avg. Range: 5 - 15 sq. mi.	Stream classification and management
		Subcatchment [2]	Avg. Range: 0 - 5 sq. mi.	Site design measures and structural controls

NOTES:
[1] 100,000 acres or 150 sq. mi. may be the upper practical local planning limit
[2] These terms are not part of the new USGS classification system, but they may help local planners develop more discrete planning units

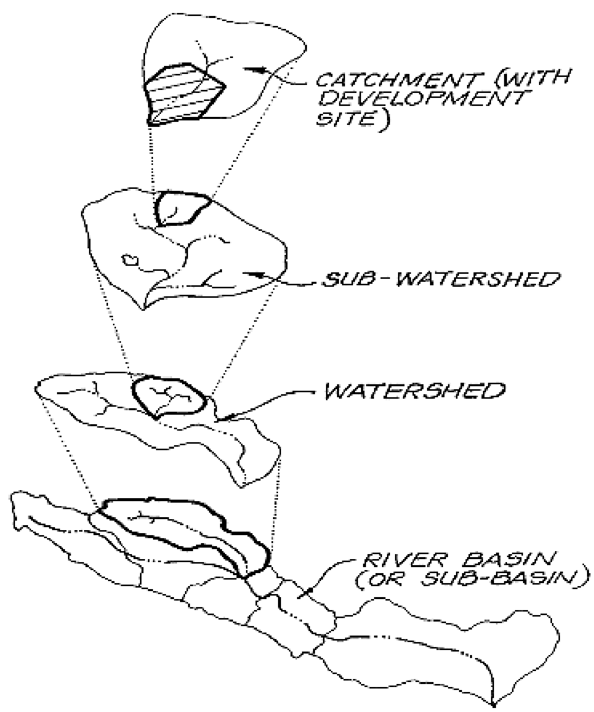

Figure 5-B.1. Watershed Management Units

Source: Center for Watershed Protection (1998)

5-B.2.3 Elements of a Watershed Management Plan

Watershed management plans should include recommended criteria for stormwater source controls and treatment practices in the watershed. These criteria are based on watershed-specific factors such as physical attributes, land use, pollution sources, and sensitive receptors. The criteria are the basis for selecting and locating stormwater controls in the watershed. At a minimum, a watershed management plan should contain the following elements to address stormwater-related issues:

- Watershed delineation and identification of watershed characteristics such as topography, soils, surficial geology, impervious cover, and land use (current and projected)
- Inventory of flood hazard areas as identified by FEMA Flood Insurance Studies or the Virginia Department of Conservation and Recreation (DCR), plus historic floods and damages
- An evaluation of streams/watercourses, including areas of limited flow capacity, bank or bed erosion, sediment deposition, water quality, principle water uses and users, recreation areas, morphology classification, and channel stability
- An inventory and evaluation of hydraulic structures, including culverts, bridges, dams and dikes, with information on their flow capacity and physical condition
- An inventory of significant water storage areas, including principal impoundments, floodplains, and wetlands
- Identification of sensitive and impaired wetlands and water bodies
- Evaluation of functional value of wetlands to identify sensitive and high quality wetland resources
- Sensitive groundwater recharge or aquifer protection areas
- Identification of existing problem land uses and impacts on water quality
- Land use restrictions in sensitive areas
- Inventory of local wetlands, conservation, planning and zoning, and subdivision regulations of the watershed municipalities to identify potential regulatory changes for addressing stormwater impacts
- A runoff hydrograph analysis of the watershed for floods of an appropriate duration, including a 24-hour event, with average return frequencies of 2, 10, 25, and 100 years for existing and future land uses
- The relationship between the computed peak flow rates and gauging station data, with modification or calibration of the hydrographs to obtain a reasonable fit where necessary
- Identification of the peak rate of runoff at various key points in the watershed, and the relative timing of the peak flows
- Identification of points in the watershed where hydraulic structures or watercourses are inadequate under existing or anticipated future conditions
- Recommendations on how the subwatershed's runoff can be managed to minimize any harmful downstream (flooding) impacts
- Existing and projected future pollutant loads, impacts of these loads, and pollution reduction goals
- Existing and projected aquatic habitat disturbances and goals for habitat restoration
- Recommendations for watershed-specific stormwater treatment controls, conceptual design, and operation and maintenance (O&M) needs and responsibilities

- Water quality monitoring program
- Prioritized implementation plan for recommendations
- Identification of public water supply watershed areas and identified aquifer recharge areas

The watershed management plan should address integrating flood control and stormwater management controls with community needs, including open space, aesthetics, and other environmental objectives, such as habitat and stream restoration. This synchronization with other programs can create better funding opportunities and enhance the overall benefit of the stormwater management practices in the watershed.

5-B.2.4 The Watershed Planning Process

Watershed and subwatershed plans provide a framework for managers and decision-makers to determine what the goals and strategies of the plan should be and how and where various management and protection tools need to be implemented to achieve the goals and strategies. Developing watershed and subwatershed plans should ideally occur in a rapid, cost effective manner. A 18-step approach to watershed planning is presented below. It is important to remember throughout the process that it is critical to have public involvement and "buy in." Without community support, it may be difficult to implement a plan.

5-B.2.4.1 Identify Initial Goals and Establish a Baseline

Prior to initiating a watershed plan, some broad goals should be identified that define the purpose of the plan initiative. For example, a goal of a plan may be to preserve and maintain a high quality segment of stream in a community, protect drinking water quality in a water supply watershed, or meet a water quality TMDL. Other goals may be a response to negative impacts being observed within a watershed, such as property flooding or channel erosion and degradation.

Prior to addressing the initial goals, it is necessary to gather basic information to determine a starting point to develop the plan. Information about possible stakeholders, current land use and impervious cover, technical studies (e.g., previous hydrologic/hydraulic studies, floodplain studies, water quality studies, etc.), staffing, and financial resources can help guide the first steps of the plan. Once the broad goals have been identified and defined, specific tasks that may need to be performed include the following.

Task 1: Define Watershed and Sub-Watershed Boundaries

Defining the watershed and subwatershed boundaries sets the stage for completing the rest of the watershed baseline. The product of this task is a simple map that outlines the boundaries of the watershed and each of its sub-watersheds. Producing this map (**Figure 5-B.2** below is an example) is a necessary first step to answering questions such as "Which political jurisdictions and citizens should participate in this watershed planning effort?" and "What are the land use patterns in the watershed and each of its sub-watersheds?" This establishes the scale of watershed planning, discussed in **Section 5-B.2.2** above.

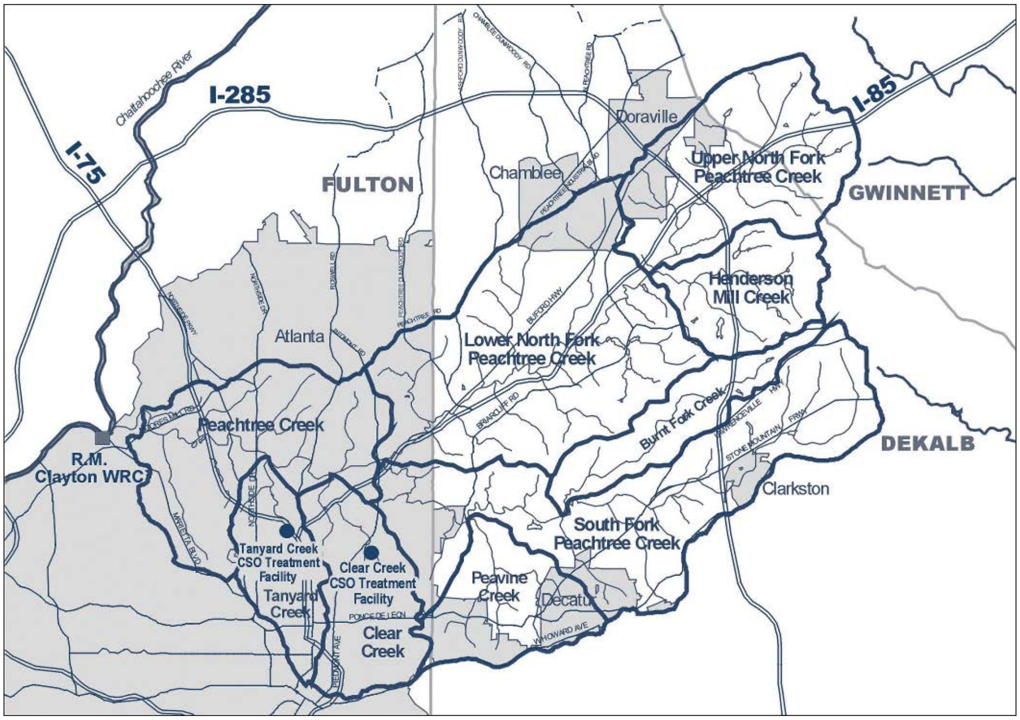

Figure 5-B.2. Example of a Watershed Map with Subwatersheds Delineated
Source: ARC (2001)

Task 2: Identify Possible Stakeholders

Early on, it is important to identify the partners, or stakeholders, that will be involved in some way to make watershed plans happen. Stakeholder involvement is discussed in more detail in **Chapter 3** of this Handbook, pertaining to development of a local stormwater management program.

Early stakeholder involvement guides the development of the watershed plan to incorporate the needs of the community and promote resource protection. By involving possible stakeholders early on in the process, managers can gage who wants to participate in developing the plan, what they can offer to the process, or what obstacles participants may present. Stakeholders might include other government agencies, businesses and industry, regulated entities, nonprofits, and neighborhood leaders and interested citizens. To effectively achieve local/regional water quality goals, it is best to take a coordinated, structured and collaborative approach, coordinating across sectors and creating alignment in policies, funding and programs to achieve a Collective Impact (Hanleybrown et al, 2012).

The watershed and subwatershed boundaries delineated in *Task 1* are a good place to start identifying possible stakeholders. A quick review of the map helps determine which jurisdictions and neighborhoods fall within the watershed boundaries. Direct outreach to citizens living within the watershed boundaries can also spark interest within the community. Stakeholders can provide resources, expertise, or knowledge to guide the development of the plan. Also, it is important to include stakeholders from the local development community since some decisions of the plan, such as new ordinances or zoning, will directly impact them. It is also wise at this time to look beyond the boundaries of the watershed under study to see how the plan may help achieve the broad water resource goals of larger river basins.

Task 3: Estimate Existing Land Use and Impervious Cover

Estimating existing subwatershed land cover is a recommended baseline task in preparing a watershed plan, since this data can be used in modeling stormwater runoff and estimating pollutant loadings. Existing impervious cover provides an estimate of current conditions in each sub-watershed and serves as an important benchmark to assess future land use changes. Land use and impervious cover percentages can be used to initially categorize sub-watersheds, help managers set expectations about what can be achieved in each sub-watershed, and guide decisions in the watershed. The Impervious Cover Model, presented in **Appendix 5-A**, may be useful in this analysis. If the analysis indicates that impervious cover will increase to such an extent that it will likely cause subwatershed quality to decline, the management plan should include provisions to mitigate these future impacts.

Task 4: Assemble Historical Monitoring Data in the Watershed

Good monitoring data that accurately characterizes the resource quality in a sub-watershed are needed throughout the watershed planning process. Historical monitoring or modeling data are often available from past efforts. Collecting historical data may significantly reduce the costs of initial baseline monitoring. Historical data may also provide information about the response of the water resource to land use change over time. This record can help managers evaluate current decisions in the context of the impacts of past decisions on the resource.

Task 5: Assess Existing Mapping Resources

Maps depicting current conditions—including land use, potential pollution sources, problem areas, etc.—in each sub-watershed, as well as management decisions made during the planning process, are an integral part of the watershed plan. The effort to produce these maps depends on what data are already mapped, and in what form. Also, some field measurements may not be required if recent maps of these features already exist.

Regional development authorities, state agencies, universities or environmental agencies may already have some maps, either in paper or digital form. The Virginia Geographic Information Network (VGIN) website (http://gisdata.virginia.gov/Portal/) is a good source of existing digital GIS data. Stakeholders are also a source to find existing mapping resources. Assigning one individual or a small group the task of assembling and manipulating mapping data is an effective way to set this baseline.

Task 6: Conduct an Audit of Local Watershed Protection Capability

The final element of the watershed baseline is a critical evaluation of the local capability to implement watershed protection tools and management alternatives. This evaluation or audit examines whether existing local programs, regulations, and staff resources are capable of implementing the watershed plan. If not, it identifies key areas that need to be improved. The scope of the audit can include an analysis of local master plans, ordinances, the development review process, performance criteria for stormwater controls and management practices, program funding, and staffing levels. The effort needed for the watershed audit depends to a great extent on the size and complexity of the local program(s), the number of staff employed, and the pace of development activity.

5-B.2.4.2 Set Up a Watershed Management Structure

Establish the institutional organization responsible for the overall management and implementation of the watershed plan. Choosing the most effective watershed management structure to guide the development of the watershed and subwatershed plans is one of the more complex decisions a community or watershed planning team confronts. Successful watershed planning requires a strong organization to act as the driving force to focus the resources of a diverse group of stakeholders to implement the plan.

It is crucial to choose a watershed management structure that can be sustained over the life of the watershed planning and implementation process, as well as to revisit and update the plan as project goals are achieved or circumstances change.

A core set of features are needed to make watershed management structures effective:
- Adequate permanent staff to perform facilitation and administrative duties
- A consistent, reliable, long-term funding source to ensure a sustainable organization
- Including all stakeholders in planning efforts
- A core group of individuals dedicated to the project who have the support of local governmental agencies
- Local ownership of the watershed plan fostered throughout the process
- A process for monitoring and evaluating implementation strategies
- Open communication channels to increase cooperation between organization members

The first two features, permanent staffing and adequate long-term funding to support them, are probably the most important. Regardless of the size, a successful management structure should define inter-agency and governmental partnerships and agreements needed to support the organization over the long term.

5-B.2.4.3 Determine Budgetary Resources Available for Planning

Conduct an analysis to determine what level of staffing, financial and other resources are available to develop and implement the plan. Balance the available resources against the estimated cost of developing the plan.

One of the most important challenges confronting a community or watershed planning group is how to develop watershed and subwatershed plans within existing budget constraints. The watershed planning team needs to identify what sources of funding are available and to develop budgets for the subwatershed and watershed plans. Several current and future revenue sources may be available to finance the development of a watershed plan. This revenue may include both staff time and general funds. In early meetings, it is important to get clear commitments from each involved agency or group as to what resources they can commit to the watershed planning effort. Substantial savings can be realized if volunteers are available to conduct some of the analyses, if existing staff time is reallocated to work on the plan, or if the plan is part of a larger planning effort where some costs can be shared. Also, keep in mind that grants from local professional and business organizations may be feasible, since those entities may ultimately benefit from more comprehensive and flexible implementation of stormwater management at the watershed scale.

5-B.2.4.4 Forecast the Type of Current and Future Development in the Watershed and Its Subwatersheds

Forecasting the type of current and future development within the local watershed will ultimately influence how individual BMPs will be implemented at each individual site. The broad development categories that are generally thought of include (1) *Greenfield Development* (small and large scales), which changes pristine or agricultural land to urban or suburban land uses (frequently low-density residential housing); (2) *Redevelopment* within established communities and on Brownfield sites, which changes an existing urban land use to another, usually of higher density; and (3) *Retrofitting*, which is not truly a development type, but rather an opportunity to upgrade stormwater management within an existing urban land use and drainage infrastructure to meet higher stormwater management standards. Forecast future development, land use, and impervious cover in each subwatershed. This analysis will influence the goal setting process in *Step 8*

As previously mentioned, land use in a watershed and its individual subwatersheds has a strong influence on water quality and aquatic ecosystems. In this step, it is recommended that the community forecast future land use and impervious cover based on available planning information, such as future land use plans or master plans. In Virginia, such a forecast will typically be associated with the community's comprehensive land use plan.

Greenfield Development. Greenfield development requires new infrastructure designed according to contemporary design standards for roads, utilities, and related infrastructure. At the largest scale, Greenfield development refers to planned communities at the developing edge of metropolitan areas, ranging from several hundred acres to tens of thousands of acres with long build-out schedules. They often include the trunk (primary) stormwater system as well as open stream and river corridors. The most progressive communities of this type incorporate a significant portion of the area to stormwater systems that exist as surface elements. Such stormwater system elements are typically at the subwatershed scale and provide for consolidated conveyance, detention, and water quality treatment. These elements of the infrastructure can be multi-functional in nature, providing for wildlife habitat, trail corridors, and open-space amenities.

Greenfield development can also occur on a small scale – neighborhoods or individual sites within newly developing areas that are served by the larger public and smaller site-by-site stormwater systems. This smaller scale, incremental expansion of existing urban patterns is a more typical way for cities to grow. A more limited range of BMPs and innovative stormwater management practices is available on smaller projects of this type, including what are referred to as LID practices.

Redevelopment. Redevelopment refers to developed areas undergoing land use change. In contrast to Greenfields, infrastructure in previously developed areas is often in poor condition, was not built to current design standards, and is inadequate for the new land uses proposed. Furthermore, the existing infrastructure is often fixed in space in a manner that limits the site layout of the redevelopment project. Redevelopment within established communities is typically at the scale of individual sites and occasionally the scale of a small district. The area is usually served by private, on-site systems that convey larger storm events into pre-existing stormwater systems that were developed decades ago, either in historic city centers or in “first ring,” post-World War II suburbs adjacent to historic city centers. Redevelopment in these areas is typically much denser than the original use. The resulting increase in impervious area, and typically the inadequacy of existing stormwater infrastructure serving the site often results in significant development costs for on-site detention and water quality treatment. Elaborate vaults or related structures, or land area that could be used for development, must often be committed to on-site stormwater management to comply with current stormwater requirements.

Brownfields are redevelopments of industrial and often contaminated property at the scale of an individual site, neighborhood, or district. Secondary public systems and private stormwater systems on individual sites typically serve these areas. In many cases, especially in outdated industrial areas, little or no stormwater infrastructure exists, or it is so inadequate as to require replacement. Water quality treatment on contaminated sites may also be necessary. For these reasons, stormwater management in such developments presents special challenges. For example, the most common methods of remediation of contaminated sites involve capping of contaminated soils or treatment of contaminants in situ, especially where removal of contaminated soils from the site is cost-prohibitive. Given that contaminants are still often in place on redeveloped Brownfield sites and must not be disturbed, installing certain BMPs (e.g., infiltration of stormwater into site soils) or excavating for stormwater piping and other utilities presents special challenges.

Each type of development has a different characteristic footprint, level of impervious cover, amount of open space, land cost, and existing stormwater infrastructure. Consequently, BMPs that are ideally suited for one type of development may be impractical or infeasible for another. As might be expected, there are more options available for managing stormwater in Greenfield development than at redevelopment sites, and more options in redevelopment than for retrofitting existing urban areas.

Table 5-B.2 below shows which broad BMP categories (from **Table 5.1 of Chapter 5**) are best suited for Greenfield development (particularly low-density residential), redevelopment of urban areas, and intense industrial redevelopment, which requires a substantially different suite of BMPs than for urban development.

Table 5-B.2. Applicability of Stormwater Control Categories by Type of Development

Stormwater Control Category	Low-Density Greenfield Development	Urban Redevelopment	Intense Industrial Redevelopment
1. Product Substitution	Sometimes	Often	Often
2. Watershed and Land-Use Planning	Always	Always	Sometimes
3. Conservation of Natural Areas	Always	Rarely	Sometimes
4. Impervious Cover Minimization	Always	Rarely	Rarely
5. Earthwork Minimization	Always	Rarely	Rarely
6. Erosion and Sediment Control	Always	Always	Always
7. Reforestation and Soil Conservation	Always	Often	Often
8. Pollution Prevention SCMs for Hotspots	Rarely	Often	Always
9. Runoff Volume Reduction – Rainwater Harvesting	Always	Always	Often
10. Runoff Volume Reduction – Vegetated	Always	Sometimes	Often
11. Runoff Volume Reduction – Subsurface	Always	Sometimes	Rarely
12. Peak Reduction and Runoff Treatment	Always	Rarely	Sometimes
13. Runoff Treatment	Sometimes	Sometimes	Always
14. Aquatic Buffers and Managed Floodplains	Often	Rarely	Sometimes
15. Stream Rehabilitation	Sometimes	Rarely	Rarely
16. Municipal Housekeeping	Sometimes	Sometimes	NA
17. Illicit Discharge Detection and Elimination	Sometimes	Sometimes	Sometimes
18. Stormwater Education	Often	Often	Often
19. Residential Stewardship	Always	Often	NA

Source: NRC (2008)

Forecasting the Scale of Current and Future Development. The choice of what BMPs to use depends on the area that needs to be serviced. It turns out that some BMPs work best over a few acres, whereas others require several dozen acres or more. Some are highly effective only for the smallest sites, while other work best at the stream corridor or subwatershed level. **Table 5.1 of Chapter 5** includes a column (entitled “Where”) that is related to the scale at which individual BMPs can be applied. The BMPs mainly applied at the site scale include runoff volume reduction (e.g., rainwater harvesting and vegetated), runoff treatment (e.g., settling, filtering, and biological uptake) and pollution prevention BMPs (especially at hotspots). As one goes up in scale, BMPs like runoff volume reduction (both vegetated and subsurface), earthwork minimization, and erosion and sediment control take on a more prominent role. At the largest scales, watershed and land-use planning, conservation of natural areas, reforestation and soil conservation, peak flow reduction, buffers and managed floodplains, stream rehabilitation, municipal housekeeping, illicit discharge detection and elimination (IDDE), stormwater education, and residential stewardship play a more important role. Some BMPs are useful at all scales, such as product substitution and impervious cover minimization.

5-B.2.4.5 Defining Stressors of Concern

The primary pollutants or stressors of concern (and the primary source areas or stormwater hotspots within the watershed likely to produce them) should be carefully identified for the watershed. Although the Virginia Stormwater Management Regulations dictate certain keystone pollutant removal criteria, it is important that the community ensure that BMPs are designed to prevent or reduce the maximum load of pollutants of greatest concern locally, as well, especially where TMDL waste load allocations are in place. The choice of pollutants of concern is very important, since individual BMPs have been shown to have highly variable capabilities to prevent or reduce specific pollutants.

5-B.2.4.6 Noting the Physical Constraints

The specific physical constraints of the watershed terrain and the development pattern will influence the selection and assemblage of BMPs. The application of BMPs must be customized in every watershed to reflect its unique terrain (such as karst, high water tables, shallow or steep slopes, freeze-thaw depth, soil types, and underlying geology). Each BMP has different restrictions or constraints associated with these terrain factors. Consequently, the BMP prescription changes as one moves from one physiographic region to another (e.g., the flat coastal plain, the rolling Piedmont, the ridge and valley, and mountainous headwaters).

5-B.2.4.7 Determining Goals for Receiving Waters

It is important to set biological and public health goals for the receiving water(s) that are achievable given the ultimate impervious cover intended for the local watershed. If the receiving water is too sensitive to meet these goals, one should consider adjustments to zoning and development codes to reduce the amount of impervious cover. The biological goals may involve a keystone species (e.g., trout, crabs, cave-adapted invertebrates, etc.); a desired state of biological integrity in a stream; or a maximum level of eutrophication in a lake. In other communities, stormwater goals may be driven primarily by the need to protect a sole-source drinking water supply, cave streams, or karst springs, or to maintain water contact recreation at a beach, lake or river. Once again, the watershed goals that are selected have a strong influence on the assembly of BMPs needed to meet them, since individual BMPs vary greatly in their ability to achieve different biological or public health outcomes.

5-B.2.4.8 Fine-Tune Goals for the Watershed and Its Subwatersheds

Use known information about impacts to the watershed, and the goals of larger drainage units (e.g., river basins), to refine and develop goals for the watershed. In addition, determine objectives for each subwatershed to achieve the broader watershed goals. The general goals identified in *Step 1* should be added to and modified to reflect the results and inferences of the data collected and analyses performed in *Steps 2-7*.

Goal setting is among the most important steps in watershed planning, and the management structure should ensure full involvement from stakeholders at this stage. Goal setting should proceed from the broad basin and sub-basin goals to the more specific goals needed for the watershed. These goals, in turn, need to be translated into even more specific objectives for each individual subwatershed. To set appropriate and achievable goals, the watershed planning team needs to perform the following tasks.

Task 1: Interpret Goals at the River Basin Level that May Impact the Watershed

Watershed plans should be developed within the context of regional water resource management goals for river basins. Although not every river basin goal or objective may impact the watershed plan, managers should be aware of the larger basin plans, and consider them when developing their own goals and objectives. Some examples of river basin goals that may directly influence the goal setting process at the watershed level include:

- Flood control
- Meeting state water quality standards / designated use
- Meeting Chesapeake Bay or other impaired stream TMDL requirements
- Wildlife habitat enhancement
- Greenway establishment

Task 2: Develop Specific Goals for the Watershed

The goals set at the watershed level are the "bottom line" of the watershed plan. While these goals may be similar to those developed at the river basin level, they are usually more specific and quantifiable. Examples of watershed goals include:

- Reduce flood damage from current levels
- Reduce pollutant loads from the current level (or to meet an established threshold)
- Maintain or enhance the overall aquatic diversity in the watershed
- Maintain or improve the current channel integrity in the watershed
- Prevent development in the floodplain
- Allow no net loss of wetlands
- Maintain a connected buffer system/green space throughout the watershed
- Accommodate economic development in the watershed
- Promote public awareness and involvement

These goals apply to the watershed as a whole, but may not always apply to every sub-watershed within it. In addition, a watershed plan may have more unique multi-objective goals, such as developing a trail system for walking, biking, and jogging, preserving historically significant areas, and establishing outdoor education programs to foster community awareness and involvement. With diverse goals such as these, the importance of broad-based stakeholder involvement becomes all the more apparent.

Task 3: Assess if Sub-Watershed Management Objectives Can Be Met with Existing Zoning

Controlling and managing land use is an important tool to meet watershed management objectives. If a target development or impervious cover goal has been established for a watershed, managers will need to review current zoning and/or projected future land use to determine if these goals can be met. One method is to conduct a build-out analysis of current zoning to determine the projected land use and/or impervious cover in each sub-watershed. This analysis can be used to identify which management objectives can be met with existing zoning.

Task 4: Determine if Land Use Patterns Can Be Shifted Among Watersheds

If the current zoning is not compatible with the management objectives, development may need to be shifted to other watersheds or subwatersheds. One way to accomplish this goal is by upgrading the zoning in watersheds that are designated to accommodate growth, while down-zoning those watersheds that exceed the management goals or to which other land management goals may apply (e.g., preserving prime agricultural land). The effect is to shift development away from the streams and other water resources that will be most impacted by development, and toward areas where there is not as great of an impact (e.g., redevelopment/revitalization areas where urban infrastructure already exists). Other possible options include preserving undisturbed conservation areas (e.g., through land trusts, conservation easements, etc.) in a watershed, or by implementing strategies to reduce impervious cover.

The process described above is not simple. While controlling land use may be the most effective way to protect watersheds and sub-watersheds, it can also be the most controversial and politically-charged recommendation in a watershed or sub-watershed plan. Any change in zoning will require input from citizens, the development community, and local government. Furthermore, actually changing zoning can take a long time. Communities will need to use the legal tools they have available (e.g., transfer of development rights, overlay zones, floating zones, etc.) to change zoning appropriately.

5-B.2.4.9 Choosing Among On-Site, Distributed, and Larger Consolidated BMPs

Using individual, on-site structural stormwater controls for each development is the typical approach in most communities for controlling stormwater quantity and quality, as is described in **Chapter 5**. The developer finances the design and construction of these controls and, initially, is responsible for all operation and maintenance. However, after construction is completed, the local government is likely to become responsible for maintenance activities if the owner fails to carry them out. A potential alternative approach is for a community to install a few strategically located regional stormwater controls in a sub-watershed rather than require on-site controls (see **Figures 5-B.3 and 5-B.4** below). Watershed management plans can identify conditions and locations in the watershed where regional stormwater management facilities may be more appropriate or effective than on-site controls for both stormwater quality and quantity controls.

For this Handbook, regional (watershed) stormwater controls are defined as facilities designed to manage stormwater runoff from multiple projects and/or properties through a local jurisdiction-sponsored program, where the individual properties may assist in the financing of the facility, and the requirement for on-site controls is either eliminated or reduced.

Historically the on-site approach to stormwater management has been more common in Virginia. In this approach, land developers have responsibility for deploying treatment practices and runoff controls at individual development sites. Developers are responsible for constructing on-site stormwater management facilities to control stormwater pollutant loadings and the volume and flow rate of runoff from the site. The local government is responsible for reviewing the design of stormwater management facilities relative to specified design criteria, inspecting the constructed facilities to ensure conformance with the design, and ensuring that operation and maintenance plans are provided and implemented for the facilities. The on-site approach addresses stormwater pollution close to its source, offers greater opportunities to preserve pre-development hydrologic conditions, and reduces the overall volume of stormwater runoff.

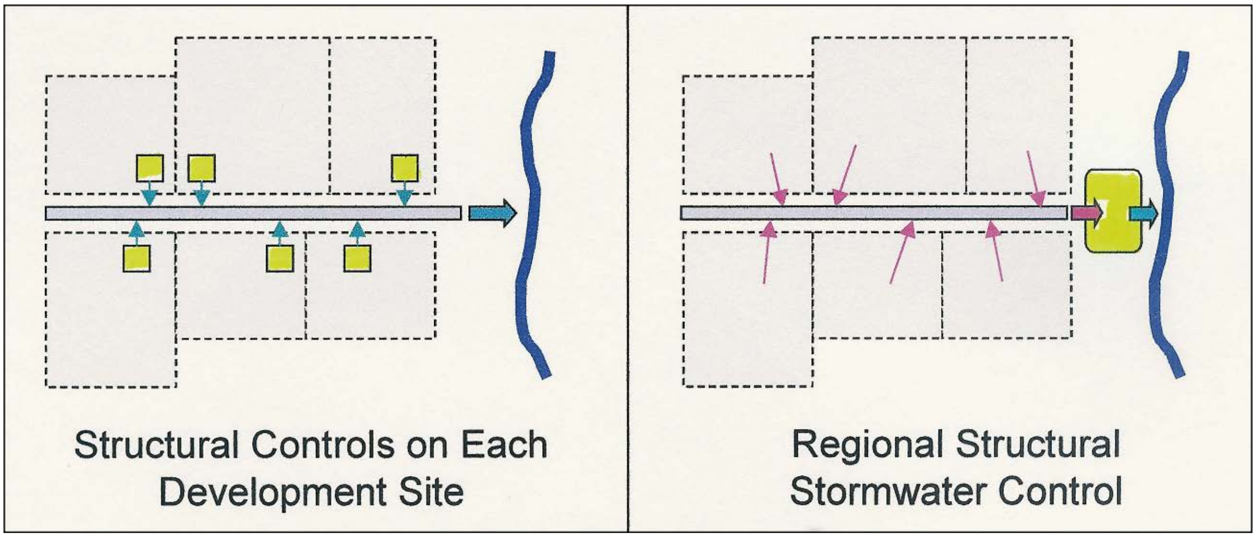

Figure 5-B.3. On-Site versus Regional Stormwater Management
Source: ARC (2001)

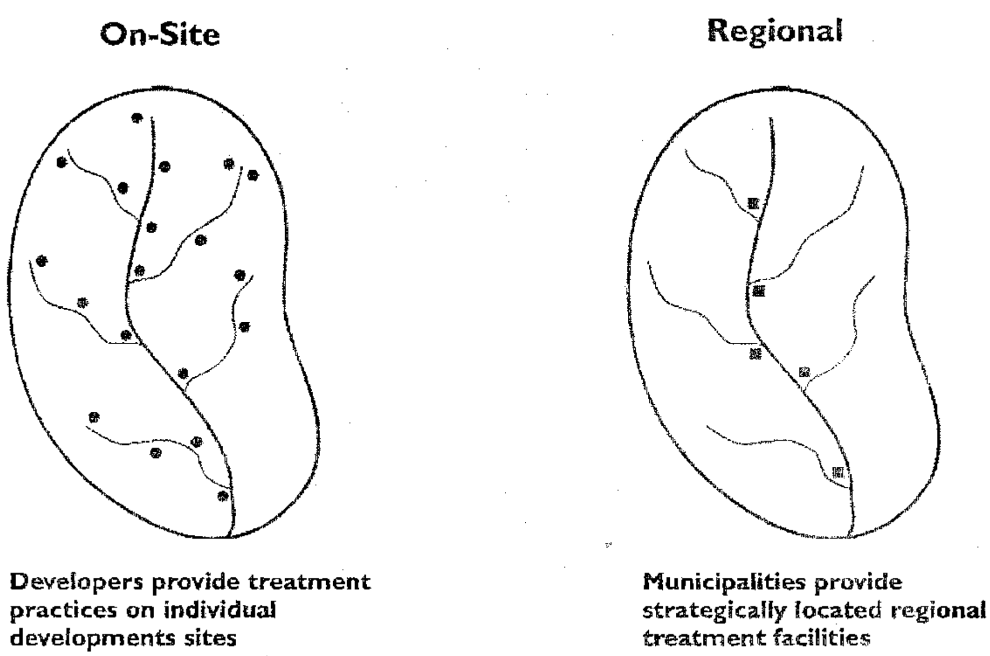

Figure 5-B.4. On-Site and Regional Stormwater Management Approaches
(Source: Adapted from Novotny, 1995, and Connecticut 2004 Stormwater Quality Manual)

The watershed approach involves strategically siting stormwater management facilities to control stormwater runoff from multiple development projects or large drainage areas. Most of the advantages of the watershed approach can be attributed to the need for fewer stormwater management facilities that are strategically located throughout the watershed (Novotny, 1995). Local or regional governments assume the capital costs for constructing the regional facilities. Design and construction of regional controls are estimated to cost from $1,250 to $2,000 per acre of residential development and $1,750 to $2,500 per acre of non-residential development. Capital costs are typically recovered from upstream developers as development occurs. Individual regional facilities are often sited and phased in as development occurs according to a comprehensive watershed management plan. Municipalities generally assume responsibility for operation and maintenance of regional stormwater facilities (Novotny, 1995).

There are also several disadvantages to regional stormwater controls that have limited the widespread use of the watershed approach, including significant required advanced planning, financing, and land acquisition.. In many cases, a community must provide capital construction funds for a regional facility, including the costs of land acquisition, before the majority of the watershed is developed, with reimbursement by developers over build-out periods of many years (WEF and ASCE, 1992).. However, if a downstream developer is the first to build, that person could be required to construct the facility and later be compensated by upstream developers for the capital construction costs and annual maintenance expenditures. Conversely, an upstream developer may have to establish temporary control structures if the regional facility is not in place before construction.

Maintenance responsibilities generally shift from the homeowner or developer to the local government when a regional approach is selected. Because consolidated facilities are typically larger than on-site BMPs, mechanized maintenance equipment can be used, allowing for greater efficiency and lower costs. However, the local government may need to establish a stormwater utility or some other program to fund and implement stormwater control.

Due to these limitations, the watershed approach generally is more appropriate for (Pennsylvania Association of Conservation Districts et al., 1998):

- Highly developed watersheds with severe water quality and flooding impacts, where stormwater controls for new development alone cannot adequately address the impacts in these areas; and
- Watersheds where the timing of peak runoff may increase downstream flooding if on-site peak runoff attenuation criteria are applied uniformly throughout the watershed.

If a community decides to implement a regional stormwater control, then it must ensure that the conveyances between the individual upstream developments and the regional facility can handle the design peak flows and volumes without causing adverse impact or property damage. Full build-out conditions in the regional facility drainage area should be used in the analysis. In addition, unless the system consists of completely man-made conveyances (i.e. storm drains, pipes, concrete channels, etc.), then on-site structural controls for water quality and downstream channel protection may still need to be required for all developments within the regional facility’s drainage area.

Federal water quality provisions do not allow the degradation of water bodies from untreated stormwater discharges, and it is USEPA policy to not allow regional stormwater controls that would degrade stream quality between the upstream development and the regional facility. Further, without adequate channel protection, wetlands, aquatic habitats and water quality in the channel network upstream of a regional facility may be degraded by streambank erosion, if they are not protected from bankfull flows and high velocities. Based on these concerns, both the EPA and the U.S. Army Corps of Engineers have expressed opposition to *in-stream* regional stormwater control facilities. In-stream facilities should be avoided if possible and will likely be permitted on a case-by-case basis only.

In most watersheds, a mix of regional and on-site controls is desirable and has the greatest potential for success when implemented as part of a comprehensive watershed management plan. (DEP, 1995). Both approaches have a number of advantages and disadvantages, which are summarized in **Table 5-B.3** below**.**

Based on the foregoing factors and using state-established BMP design specifications as a foundation, the community could consider adapting specific sizing, selection, and design requirements for BMPs, ensuring that the adaptations achieve equivalent water quality and quantity management results. The Virginia Stormwater Management Law allows localities to adopt criteria more *stringent* than the State's criteria within certain parameters. The regulations also allow localities to disallow the use of some BMPs within their jurisdictions, subject to certain conditions. However, if adaptations are made, these need to be coordinated with the DEQ and, ultimately, approved by the State Water Control Board.

Resulting BMP performance criteria may be established in a local or regional stormwater design manual or by reference in a local watershed management plan. In general, the watershed- or receiving water-based criteria are more specific and detailed than would be found in the State-established criteria. For example, the local stormwater guidance criteria may be more prescriptive with respect to runoff reduction and BMP sizing requirements, outline a preferred sequence for BMPs, and indicate where BMPs should (or should not) be located in the watershed. Like the identification of stressors or pollutants of concern, this step is rarely taken under current paradigms of stormwater management. The Minnesota Stormwater Steering Committee (MSSC, 2005) provides a good example of how BMP guidance can be customized to protect specific types of receiving waters (e.g., high quality lakes, trout streams, drinking water reservoirs, and impaired waters).

Table 5-B.3. Comparison of on-Site and Watershed Stormwater Management Approaches

Approach	Advantages	Disadvantages
On-site	• Requires much less (and less involved) advanced planning • Addresses stormwater pollution close to its source~~,~~ thereby reducing the volume of stormwater runoff and the need for treatment controls • Provides greater groundwater recharge benefits • Private ownership and maintenance responsibility is an advantage to the community (less responsibility and cost)	• Results in a large number of facilities that may not be adequately maintained by developers, homeowners or HOAs • Consumes more on-site land that could be used for other purposes • May increase downstream flooding and quantity control problems • Encourage lower-density development and, thus, urban-suburban sprawl • Less opportunity to treat off-site (e.g., streets and ROWs) runoff • Limited opportunities to treat previously developed land without BMPs
Watershed	• Generally more cost-effective than numerous individual on-site controls • Reduced capital costs through economies of scale in designing and constructing regional facilities • Reduced operation and maintenance costs because there are fewer facilities to maintain • Greater reliability because communities are more likely to ensure long-term maintenance of regional facilities • Nonpoint source pollutant loadings from existing developed areas can be affordably controlled at the same regional facilities that are sited to control future development • Maximize the use of developable land by minimizing the amount of land that must be set aside for stormwater control measures • Can be integrated with local greenway networks • Regional facilities provide greater opportunities for multi-purpose uses that also provide recreational and aesthetic benefits, flood control, and wildlife habitat and corridors • Can be used to treat runoff from public streets, which is often missed by on-site facilities • Provides opportunities for retrofit practices to reduce regional stormwater pollutant loadings and provides a schedule for implementing appropriate controls • Less safety risk than for on-site controls – more visible, easier to secure	• Significant advanced planning and, perhaps, permitting required • Regulatory hurdles regarding proposed *in-stream* BMPs • May be difficult to site due to larger facility size and limited land availability • Requires up-front financing (land acquisition, design and construction) • May promote “end-of-pipe” treatment mentality rather than the use of on-site controls to reduce stormwater runoff volume and the need for stormwater treatment • Without on-site BMPs, regional BMPs do not protect smaller streams (upstream from the regional facilities) from degradation and streambank erosion • Upstream inundation from regional BMPs can eliminate floodplains, wetlands and other habitat • Greater administrative responsibility for local governments • Lack of adequate training for local staff needed to administer such a program • Some treatment practices are not appropriate for large drainage areas (e.g., swales, filter strips, media filters, and oil/particle separators, etc.) • Potential for different standards applicable in neighboring jurisdictions within the same watershed • Some safety or liability concerns for larger, regional facilities

Source: Adapted from NRC (2008)

5-B.2.4.10 Developing BMP Guidance and Performance Criteria for the Local Watershed

Based on the foregoing factors and using state-established BMP specifications as a foundation, the community could consider adapting specific sizing, selection, and design requirements for BMPs, ensuring that the adaptations achieve equivalent water quality and quantity management results.

Within certain parameters, the Virginia Stormwater Management Act allows localities to adopt criteria *more stringent* than the State's criteria. The regulations also allow localities to disallow the use of some BMPs within their jurisdictions, subject to certain conditions. However, if adaptations are made, these need to be coordinated with the DEQ and, ultimately, approved by the State Water Control Board. Resulting BMP performance criteria may be established in a local or regional stormwater design manual or by reference in a local watershed management plan.

In general, the watershed- or receiving water-based criteria will be more specific and detailed than the State-established BMP design specifications. For example, the local stormwater guidance criteria may be more prescriptive with respect to local precipitation amounts for various design storms, runoff reduction and BMP sizing requirements, outline a preferred sequence for BMPs, and indicate where BMPs should (or should not) be located in the watershed. Like the identification of stressors or pollutants of concern, this step is rarely taken under current paradigms of stormwater management. The Minnesota Stormwater Steering Committee (MSSC, 2005) provides a good example of how BMP guidance can be customized to protect specific types of receiving waters (e.g., high quality lakes, trout streams, drinking water reservoirs, and impaired waters).

5-B.2.4.11 Develop Watershed and Subwatershed Plans

A watershed plan is a detailed blueprint to achieve objectives established in the last step. A typical plan may include: revised zoning, stormwater design criteria and requirements, potential regional structural stormwater control locations, description of new programs proposed, stream buffer widths, monitoring protocols, and estimates of budget and staff needed to implement the plan. Tasks needed to establish the watershed plan include the following four.

Task 1: Select Watershed Indicators

Indicator monitoring provides timely feedback on how well aquatic resources respond to management efforts. Simple indicators can be selected to track changes in stream geometry, biological diversity, habitat quality, and water quality. For example, macroinvertebrate sampling is a relatively quick and inexpensive method to assess biological diversity. It can also be used to qualitatively assess aquatic habitat and water quality. This type of monitoring can be done by citizen volunteer networks, to minimize the expense (e.g., the Save-Our-Streams program and Virginia Citizen Monitoring Network, affiliated with the Virginia Department of Environmental Quality). A wide range of indicators can be used to assess the performance of management plans. The most appropriate indicators will depend largely on the management categories of the individual watersheds.

Task 2: Conduct Watershed-Wide Analyses and Surveys, if Needed

In some situations, a watershed plan may need to incorporate special analyses at the watershed level to supplement basic monitoring and analyses. A manager may decide to include a flood management analysis, pollutant load reduction analysis, or recreational greenway analysis. Other analyses that may be desirable include the following:

- Fishery and habitat sampling
- Stream reconnaissance surveys
- Stormwater structural control performance monitoring
- Bacteria source surveys
- Stormwater outfall surveys
- Detailed wetland identification
- Pollution prevention surveys
- Nutrient budget calculations
- Surveys of potential contaminant source areas
- Hazardous materials surveys
- Stormwater retrofit surveys
- Shoreline littoral surveys
- In-lake monitoring
- Hydro-geologic studies to define surface/groundwater interactions

Task 3: Prepare Sub-Watershed and Aquatic Corridor Management Maps

Maps that present the plan in a clear, uncomplicated manner are a key product of the sub-watershed planning process. Maps range from highly sophisticated GIS maps to simple overlays of USGS quadrangle sheets. Mapping can generally be conducted at two scales, the subwatershed scale and the aquatic corridor scale.

Subwatershed maps represent an entire subwatershed on a single map and should be a component of all watershed plans. These maps represent the natural features and institutional information needed to produce a watershed plan. Aquatic corridor maps are produced at a much finer scale than sub-watershed maps, and represent only the area immediately adjacent to the stream corridor or shoreline. Aquatic corridor maps are highly recommended, particularly when stream buffers or floodplain development limits are an important consideration in the watershed plan.

Task 4: Adapt and Apply Watershed Protection Tools

Just as different goals need to be established depending on a watershed's management category, so do the various tools used to protect that resource. For example, while structural stormwater controls are recommended as a component of all management plans, the types of controls used will be different depending on the specific characteristics of a given watershed. An example of a watershed plan presenting different management control alternatives for its sub-basins is shown in **Table 5-B.4**.

Table 5-B.4. Example of Subwatershed Management Alternatives from a Watershed Plan

Subbasin/Scenario	Control Alternative													
	Stormwater Detention	Quantity (ac)	Streambank Restoration	Quantity (lf)	Riparian Zone Restoration	Quantity (lf)	Pool Development	Quantity (each)	Upland Water Quality Detention	Enhanced Erosion Control	Major Creek Clean-up	Enhanced Removal of Illicit Connections	Development Controls	Capital Cost ($M)
Upper North Fork Peachtree Creek Subbasin														
Scenario 1-Rehab Tribs and Main Stem	X	120	X	286,740	X	430,110	X	70				X		51.2
Henderson Mill Creek Subbasin														
Scenario 1-Rehab Tribs and Main Stem	X	58	X	66,685	X	80,020								18.7
Lower North Fork Peachtree Creek Subbasin														
Scenario 1-Rehab Tribs with Industrial Source Control	X	212	X	250,300	X	216,925	X	264	X		X	X		78.7
Scenario 2-Rehab Tribs and Main Stem	X	212	X	313,315	X	271,540	X	442			X	X		78.3
Burnt Fork Creek Subbasin														
Scenario 1-Rehab Tribs and Main Stem	X	50	X	73,070	X	77,130					X	X		18.5
Peavine Creek Subbasin														
Scenario 1-Rehab Tribs and Main Stem			X	58,815	X	67,860	X	75						2.2
South Fork Peachtree Creek Subbasin														
Scenario 1-Rehab Main Stem	X	189	X	24,885	X	62,215	X	104						54.9
Scenario 2-Rehab Tribs and Main Stem	X	189	X	61,890	X	92,515	X	124						56.6
Tanyard Creek Subbasin (Stormwater Area)														
Scenario 1-Rehab Tribs	X	17	X	10,880	X	24,175	X	0		X		X		5.2
Scenario 2-Rehab Tribs and Main Stem	X	17	X	17,580	X	39,060	X	48		X		X		5.5
Clear Creek Subbasin (Stormwater Area)														
Scenario 1-Rehab Tribs	X	32	X	27,230	X	17,020	X	0		X		X		10.7
Scenario 2-Rehab Tribs and Main Stem	X	32	X	48,485	X	30,300	X	22		X		X		12.0
Peachtree Creek Subbasin														
Scenario 1-Rehab Main Stem	X	120	X	67,540	X	75,045	X	167				X		37.1
Scenario 2-Rehab Tribs and Main Stem	X	120	X	97,305	X	223,875	X	228				X		38.9

Note: ac = acre; lf = linear foot; $M = million dollars
- Pool development involves the placement of boulders in the stream to allow the formation of pools downstream of the boulder cluster.
- "0" value indicates that alternative was found to be impractical due to intermittent flows.

Source: ARC (2001)

5-B.2.4.12 Establishing a Trading and Offset System

A stormwater trading or offset system is a critical option for situations when on-site BMPs are not feasible or desirable in the watershed. Communities may choose to establish some kind of stormwater trading or off-site mitigation system in the event that full compliance is not possible on-site due to physical constraints or because it is more cost-effective or equitable to achieve pollutant reductions elsewhere in the local watershed. The most common example is providing an offset/in-lieu fee based on the cost to remove an equivalent amount of the target pollutant(s) (such as phosphorus here in Virginia). This kind of trading can provide for greater cost equity between low-cost Greenfield sites and higher-cost ultra-urban sites.

5-B.2.4.13 Ensuring the Safe and Effective Performance of the Drainage Network, Streams, and Floodplains

The urban water system is not solely designed to manage the quality of runoff. It also must be capable of safely handling flooding from extreme storms to protect life and property. Consequently, communities need to ensure that their stormwater infrastructure can prevent increased flooding caused by development (and possibly exacerbated future climate change). In addition, many BMPs must be designed to safely pass extreme storms when they do occur. This usually requires a watershed approach to stormwater management to ensure that quality and quantity control are integrated together, with an emphasis on the connection and effective use of conveyance channels, streams, riparian buffers, wetlands and floodplains.

In fact, in more undeveloped watersheds, consideration should be given to protecting the riparian corridors (streams, wetlands, and floodplains) from development encroachment and, where feasible, restoring degraded streams and wetlands. As Ian McHarg taught and practiced decades ago, this allows the natural system to function as nature intended – as the primary stormwater management system for the watershed. These corridors can be integrated into the community's public green space (parks, trails, recreation areas, etc).

5-B.2.4.14 Establishing Community Objectives for the Publicly Owned Elements of Stormwater Infrastructure

The stormwater infrastructure in a community normally occupies a considerable surface area of the landscape, once all the SCMs, drainage easements, buffers, and floodplains are added together. Consequently, communities may require that individual BMP elements are designed to achieve multiple objectives, such as landscaping, parks, recreation, greenways, trails, habitat, sustainability, and other community amenities (as discussed extensively above). In other cases, communities may want to ensure that BMPs do not cause safety or vector problems and that they look attractive. The best way to maximize community benefits is to provide clear guidance in local BMP criteria at the site level and to ensure that local watershed plans provide an overall context for their implementation.

5-B.2.4.15 Establishing an Inspection and Maintenance Plan

The long-term performance of any BMP is fundamentally linked to the frequency of inspections and maintenance. As discussed in **Chapter 9** of this Handbook, lack of regular inspections and maintenance is truly the weak element of effective, on-going stormwater management. Without it, the considerable investment of time and money in BMPs is wasted after the fact. One can imagine the results if a person neglects to inspect and maintain the systems that sustain his or her home (water supply, sewage disposal, heating and air conditioning, landscaping, etc.) or automobile (tires, lubricants, coolant, brakes, engine parts, etc.). In short order, these very expensive investments would begin to break down and lose substantial value. The same is true of investments in our stormwater management systems, which serve individual homeowners, subdivisions and communities.

As a result of the historic lack of maintenance, Virginia's SWM regulations permit conditions for industrial, construction, and municipal permittees specify that all BMPs must be adequately maintained. MS4 communities are also required under NPDES stormwater permits to track, inspect, and ensure the maintenance of the collective system of BMPs and stormwater infrastructure within their jurisdictions. In larger communities, this can involve hundreds or even thousands of individual BMPMs located on either public or private property. In these situations, communities need to devise a workable model that will be used to operate, inspect, and maintain the stormwater infrastructure across their local watershed.

Communities have the lead responsibility in their MS4 permits to assure that BMPs are maintained properly to ensure their continued function and performance over time. They can elect to assign the responsibility to the public sector, the private sector (e.g., property owners, homeowners associations or contractors), or a hybrid of the two. But under their MS4 permits, they have ultimate responsibility to ensure that BMP maintenance actually occurs. This entails assigning legal and financial responsibilities to the owners of each BMP in the watershed, as well as maintaining a tracking and enforcement system to ensure compliance. Maintenance should be a primary consideration in the watershed plan, which provides an opportunity to achieve significant overall cost-efficiencies.

5-B.2.4.16 Adopt and Implement the Plan

The best ways to ensure that a watershed plan is effectively implemented are to involve the right stakeholders, realistically assess budgetary resources, develop a scientifically and economically sound plan, and mandate its use in the development process. A good plan in itself does not guarantee implementation. As the plan is being developed, and afterwards, watershed planners need to work to ensure that the local government has both the regulatory authority and the resources to implement the plan. It is important that the plan is not isolated from other government planning and construction activities.

Once a watershed management plan has been developed, a community requires the necessary means to implement the plan and accomplish its goals. Watershed plan implementation is an involved process that requires the simultaneous consideration of many issues. Implementation of the recommendations of a local watershed management plan can take place through a number of related mechanisms. The following mechanisms can be used to implement watershed plan goals. Each of these mechanisms will generally be used in some form in every watershed, but their application will most likely vary from one community or one watershed to the next.

- ***Stormwater Ordinance.*** In some communities the watershed or master plan is adopted (often by reference) in its stormwater ordinance and essentially becomes an overlay district wherein development decisions must follow plan recommendations for various parts of the watershed. In others it is not mandatory, but is referred to when rezoning and plan approval decisions are made by staff and zoning boards. Compliance is monitored through the plan review and approval process, construction inspections, and oversight of long-term BMP maintenance.

- ***Environmental Site Design Techniques.*** A community can promote a suite of environmental site design practices and techniques (see **Chapter 6** of this Handbook) to reduce the amount of stormwater runoff and pollutants generated in a watershed, as well as to provide for non-structural treatment and control of runoff. The watershed plan should specify which environmental site design techniques are most applicable in individual sub-watersheds to meet the plan's goals and objectives.
- ***Land Acquisition and Conservation.*** Land acquisition and land conservation are important elements of any watershed management program. They allow a community to protect critical environmental areas and stormwater management resources. There are several techniques that can be used to conserve land, which provide a continuum ranging from absolute protection to very limited protection. Representative land conservation techniques include land purchases, land donations, conservation easements, and public sector stewardship.
- ***Land Use Planning / Zoning.*** Zoning and land use planning are the most widely used tools for managing growth and development that communities have at their disposal. Comprehensive plans can be modified to incorporate the recommendations of the watershed or stormwater master plan into long-term land use planning, transportation plans, etc., and then referred to when rezoning and plan approval decisions are made by staff and zoning boards. Parks and open space plans can use the results of the plan to ensure the multi-objective nature of the plans are implemented, combining engineering functions with aesthetics and recreational opportunities. This can be used to preserve sensitive areas, maintain or reduce the impervious cover within a given sub-watershed, and redirect development toward sub-watersheds that can support a particular type of land use and/or density. A wide variety of land use planning and/or zoning techniques can be used to manage land use and impervious cover within a watershed. The more commonly used techniques are summarized in **Table 5-B.5** below.
- ***Riparian Buffers and Greenways.*** The creation of a riparian buffer system is key in mitigating flood impacts and protecting water quality and streambanks in urban areas. Technically speaking, a buffer is a type of land conservation area, but it has added importance in a stormwater management sense in its ability to provide water quality, flood prevention and channel protection benefits. Buffers create a natural "right of way" for streams that protect aquatic ecosystems and provide a safe conduit for potentially dangerous and damaging floodwaters. Buffers provide water quality benefits and protection for streams, rivers and lakes. Buffers also serve as valuable park and recreation systems that enhance the general quality of life for residents. Finally, buffers can provide valuable wildlife habitat and act as wildlife corridors for smaller mammals and bird species that are present in urban areas. Establishing a comprehensive and contiguous buffer system, or "greenway," should be a goal of virtually all watershed plans. To achieve this goal, effective and clear guidance and enforcement must occur at the site level, especially for smaller headwater streams.
- ***Computer Modeling.*** Some communities use the computer models of the drainage system developed in a watershed or master plan in a real-time format as tools to assist in decision making about the need for detention, downstream impact assessment, zoning approvals, etc. and also to track management and maintenance of the drainage infrastructure.

Table 5-B.5. Land Use Planning Techniques

Land Use Planning Technique	Description	Use as a Watershed Protection Measure
Watershed-Based Zoning	Zoning restrictions specific to a particular watershed or subwatershed	Can be used to protect water resources in a particular watershed and/or relocate development
Overlay Zoning	Superimposes additional regulations or specific development criteria within specific mapped districts	Can require development restrictions or allow alternative site design techniques in specific areas
Impervious Overlay Zoning	Specific overlay zoning that limits total impervious cover within mapped districts	Can be used to limit potential stormwater runoff and pollutants from a given site or watershed
Performance Zoning	Specifies a performance requirement that accompanies a zoning district	Can be used to require additional levels of performance within a watershed or at the site level
Large-Lot Zoning	Zones land at very low densities	May be used to decrease impervious cover at the site or subwatershed level, but may have an adverse impact on regional or watershed imperviousness and may promote urban sprawl
Transfer of Development Rights (TDRs)	Transfers potential development from a designated "sending area" to a designated "receiving area"	May be used in conjunction with watershed-based zoning to restrict development in specified areas and encourage developing in areas capable of accommodating increased densities
Limiting Infrastructure Extensions	A conscious decision is made to limit or deny extending infrastructure (e.g., public sewer, water, roads) to designated areas to avoid increased development there; OR may allow extension of infrastructure into the designated areas if specific (e.g., sustainability) requirements are met.	May be used as a temporary method to limit or manage growth or incentivize desirable development techniques and features in a targeted watershed or subwatershed.

Source: ARC (2001)

- ***Elimination of Non-Stormwater Discharges.*** In some watersheds, non-stormwater discharges (e.g., combined sewer overflows, or CSOs, and grey water from commercial entities) and illicit connections to storm sewers can contribute significant pollutant loads to receiving waters. Key program elements in a watershed plan include inspections of private septic systems, repair or replacement of failing systems, using more advanced on-site septic controls, identifying and eliminating illicit connections from municipal stormwater systems, and preventing toxic chemical and fuel spills.
- ***Capital Improvement Plan.*** Elements of the local long-term capital improvement plan can be derived from the recommendations of the watershed management plan. Special assessment

districts, fee-in-lieu charges, system development charges, or other funding mechanisms can be established to help pay for specific improvements identified in the plan.

- ***Watershed Stewardship Programs.*** The goal of watershed stewardship is to increase public understanding and awareness about the watershed plan and goals. A watershed public information and education program strives to increase stakeholder awareness of their role in the protection of water resources, promote better stewardship of private lands, and develop reliable funding to sustain watershed management efforts. Basic programs that communities should consider to promote greater watershed stewardship include the following:
  - Watershed and stormwater/nonpoint source pollution education
  - Pollution prevention
  - Adopt-a-Stream programs
  - Watershed maintenance and cleanup activities
- ***Inter-Staff Management Team.*** An ad hoc inter-staff team is often effective in coordinating the provisions of the plan across local government departments.

***Budget and Funding*.**

As with the watershed planning process, a serious challenge confronting a community is how to implement watershed and sub-watershed plans within existing budget constraints. The implementation of a watershed plan typically costs about 10 times as much as the planning process. As part of the planning effort, the watershed planning team will need to identify the stable and reliable sources of funding that are available and develop budgets for both the subwatershed and watershed plan implementation efforts. One of the greatest costs of watershed implementation is the staff resources needed to continue monitoring in the watershed, design and build structural controls and retrofits, and enforce the ordinances and laws that might be called for in the plan. Many of the local program funding mechanisms discussed in **Section 3.1.15 of Chapter 3** of this Handbook are also applicable to watershed plan implementation efforts.

Stakeholder Involvement

Stakeholder involvement and interaction is essential to the implementation of watershed plans. A citizen advisory committee (CAC) is an important feature of an effective watershed management structure. A typical CAC is open to broad citizen participation and provides direct feedback to the management structure on public attitudes and awareness in the watershed. Meaningful involvement by a CAC is often critical to convince the community and elected leaders of the need for greater investment in watershed protection.

Some of the possible functions of a citizen's advisory committee are as follows:

- Organize media relations and increase watershed awareness:
  - Press releases
  - Informational flyers
  - Watershed awareness campaigns
  - Liaison between citizen groups and government agencies
- Provide input on workable stewardship programs
- Coordinate programs to engage watershed volunteers, such as:
  - Stream monitoring

  - Stream clean-ups
  - Adopt-a-Stream programs
  - Tree planting days
  - Storm drain stenciling
- Explore funding sources to support greater citizen involvement

Another common feature of an effective watershed management structure is the reliance on a technical advisory committee (TAC) to support the overall watershed planning effort. A TAC is routinely made up of a public agency staff and independent experts who have expertise in scientific matters. Some of the possible functions of a technical advisory committee are as follows:

- Evaluate current and historic monitoring data and identify data gaps
- Coordinate agency monitoring efforts within the watershed to fill these gaps
- Interpret scientific data for the whole watershed management organization
- Assess and coordinate currently approved implementation projects

Various recommendations in a watershed plan may be implemented through non-profit citizen groups who "adopt" the watershed. These groups can be instrumental in gaining public acceptance and involvement, carrying out the recommendations of the plan, obtaining funding, and providing surveillance and reporting of watershed activities.

5-B.2.4.17 Monitor and Assess Performance

There are several different monitoring techniques or indicators that can be used to assess the performance of a watershed plan. The range of monitoring extends from the more complex chemical or toxicity testing methods to more simplified physical or biological techniques. **Table 5-B.6** below provides a list of watershed monitoring techniques or indicators that can be used in watershed monitoring, as well as the initial planning process. The list covers a wide range of alternatives that can be used to assess positive and/or negative trends in water quality, aquatic integrity and watershed health.

Regardless of the specific indicators selected, it is important to use scientifically valid assessment techniques, quality controls, and valid sampling protocols to ensure that results are repeatable, consistent, and compatible with other data collection efforts.

To effectively monitor the performance of the watershed plan, it is recommended that water quality and biological monitoring be performed on an aggregate basis at key locations in the watershed and not on a site-by-site basis. Monitoring for the NPDES MS4 program and numerous other studies have confirmed the extreme variability of stormwater quality and physical stream/habitat conditions due to many influencing factors. These factors are most variable at a single individual site. At the larger watershed level, however, some of the variability is dampened, allowing for a better evaluation of plan implementation on stream and watershed health.

Table 5-B.6. Potential Watershed Indicators

Indicator Category	Potential Indicators
Water Quality Indicators	• Water quality pollutant monitoring • Toxicity testing of contaminants • Non-point source loadings • Frequency of water quality violations • Sediment contamination • Human health criteria
Biological Indicators	• Fish assemblage • Macro-invertebrate assemblages • Single species indicator • Composite indicators • Other biological indicators
Programmatic Indicators	• Number of illicit connections identified/ corrected • Number of structural controls installed, inspected • Permitting and compliance
Physical and Hydrological Indicators	• Stream widening/downcutting • Physical habitat changes affecting biodiversity • Impacted dry weather flows • Increased flooding frequencies • Stream temperature changes
Social Indicators	• Public attitude surveys • Industrial/commercial pollution prevention • Public involvement and monitoring • User perception
Site Indicators	• Structural control performance monitoring • Industrial site compliance monitoring

Source: ARC (2001)

5-B.2.4.18 Revisit and update the plan

Periodically update the plan based on new development in the watershed or results from monitoring data. A one-time watershed study only identifies what problems exist in a watershed. Many local governments, for one reason or another, take on watershed planning without realizing that it is an ongoing process rather than a report.

Each subwatershed or watershed plan should be prepared with a defined management cycle of 5-7 years. Individual plan elements should be prepared in an alternating sequence, so that a few are started each year with all plans within a given region or jurisdiction ideally being completed within a 5-7 year time span. This is similar to how many communities update their comprehensive land use plans. A management cycle helps balance workloads of watershed staff and managers, by distributing work evenly throughout the cycle's time period.

5-B.3.0 INTEGRATION OF SITE AND WATERSHED-LEVEL STORMWATER PLANNING

5-B.3.1 Introduction

Integrating site level development and watershed level planning can be a significant institutional challenge. It is likely that local governments will need to reevaluate their standard operating procedures for stormwater management and evolve towards a less compartmentalized mentality that strives for open communication between departments and agencies. In addition, interjurisdictional cooperative efforts are often needed, where communication and consensus building among stakeholders is critical.

Many local stormwater programs already have both development requirements and watershed level planning components. However, the challenge is to develop a set of incentives and/or requirements that site planners and engineers will adopt and follow in order to comply with watershed level planning efforts. In addition, watershed plans should be developed and implemented in a manner that considers the potential adverse impacts of site development. In other words, watershed protection measures should coincide with the development cycle (i.e., planning, design, construction, and post-construction).

5-B.3.2 Using the Local Review Process to Ensure Compliance with Watershed Plans

An important, yet frequently overlooked, task facing local regulators and plan reviewers is to ensure that local review requirements are tied to the watershed plan. There are several opportunities during the site development process where local regulators can check for agreement and consistency with existing watershed plans.

The final plan submittal and review, permit acquisition, and recordation of the final plat are mandatory steps. The requirement of an as-built plan submittal at the end of the project is strongly recommended, since this information demonstrates ultimate compliance and is important documentation for the long-term BMP maintenance process. However, both developers and local governments will find that participating in the other opportunities will generally result in better quality plans and minimize the risk of mistakes and potential compliance and enforcement issues. These checks serve as an enforcement mechanism for watershed plan implementation. The following are five key review occasions:

- Pre-consultation Meeting and Joint Site Visit
- Stormwater Management Concept Plan Submittal
- Preliminary / Final Stormwater Site Plan Submittal
- Permit Acquisition
- Final Record / As-Built Plat

These recommended checkpoints are directly applicable to the procedure for preparing and reviewing stormwater management site plans that is described in more detail in **Appendix 6-A** of **Chapter 6** of this Handbook. By utilizing this series of checkpoints throughout the local review process, communities can help to ensure that existing watershed plans are consistently referred to and that necessary measures can be taken to comply with the goals and objectives of the plans. Multiple checkpoints also provide some assurance that the sometimes diverse goals and objectives of a watershed plan are adequately reviewed by qualified and appropriate regulators.

Pre-consultation Meeting and Joint Site Visit. The primary purpose of this checkpoint is to ensure that the proposed land use of the development project is consistent with the goals and objectives of the watershed plan. This step allows the local review authority to outline any specific stormwater management requirements from the watershed plan, as well as any opportunities for site resource conservation and improved stormwater management on the development site and within the subwatershed.

Stormwater Management Concept Plan Submittal. It is recommended that a stormwater management concept plan be prepared, reviewed, and approved by the local review authority. At this review checkpoint, qualified staff should ensure that the preliminary designs being proposed not only meet all of the on-site stormwater management requirements of the local jurisdiction, but that the plan also considers broader issues associated with applicable watershed plans. For example, if fecal bacteria loads are a concern within the watershed, the plan reviewer should look to see that proposed stormwater control practices have a demonstrated ability to provide adequate bacteria removal. From a flood control standpoint, the reviewer would ensure that there are no conflicts with the proposed development and mapped floodplain boundaries from the watershed plan.

Preliminary/Final Stormwater Site Plan Submittal. At this checkpoint, the local review authority must confirm that the proposed stormwater management system from the concept plan has been adequately designed and analyzed to meet the watershed plan goals. For example, a watershed plan may have structural stormwater control maintenance goals. If maintenance agreements are not already a component of the local stormwater management criteria, this would be a case where the reviewer could require specific maintenance conditions for the development.

Permit Acquisition. There are a host of permits that may be required for a development project, such as clearing and grading, building, construction NPDES erosion and sediment control, wetlands, floodplain, etc. The permitting stage is another important checkpoint to ensure consistency with watershed plans, as permitting authorities are often part of a separate local department. In some cases, permitting will involve state and federal agencies (e.g., Corps of Engineers 404 wetlands permits). By definition, there are criteria that must be met for a permit to be issued; however, it should not be presumed that these criteria are consistent with, or as stringent as, the goals and objectives of a watershed plan.

In some cases, it may be desirable to have conditions attached to a permit so that the goals of the watershed plan can be met. For example, a watershed may have historically experienced significant sediment loading from uncontrolled construction sites, and consequently, a goal of the watershed plan is to promote construction site phasing by limiting the amount of contiguous cleared area to a specified number of acres. Under this scenario, the issuer of the clearing and grading permit might place a condition on the permit that restricts the amount of land cleared at a given time.

Final Record/As-Built Plat. A final method to ensure that the goals of a watershed plan are being implemented at the site level through the review process is to record any significant easements, buffers, or resource protection areas on the final record plat or as-built (i.e., legal document). This helps to maintain important protection areas through any land acquisition or transfer deals. Protection areas that might be recorded on a final plat include conservation easements, riparian buffer zones, and other open space conservation areas.

5-B.3.3 Integrating Watershed Plans Into Enforceable Permits

The planning, engineering, and regulatory responses to stormwater management issues are not as effective when applied independently. They are much more effective when they are applied integrally in the context of a local watershed plan. The mere existence of a plan does not result in effective stormwater management unless it is fully implemented. Relatively few watershed protection or restoration plans have progressed into actual implementation, primarily because there is no mechanism for accountability and enforcement. The clear implication is that local subwatershed plans should ideally be translated into a long term watershed-based permit to ensure implementation. The best permitting vehicle appears to be the municipal NPDES stormwater permit system. With some adaptation, these permits can be implemented on a subwatershed basis, using the process outlined below:

Step 1. Define interim water quality and stormwater goals (i.e., pollutants of concern, biodiversity targets) and the primary pollutant source areas and hotspots that cause them.

Step 2. Delineate subwatersheds within community boundaries.

Step 3. Measure current and future impervious cover within individual subwatersheds.

Step 4. Establish the initial subwatershed management classification using ICM.

Step 5. Undertake field monitoring to confirm or modify individual subwatershed classifications.

Step 6. Develop customized management strategies within each subwatershed classification that will guide or shape how land use decisions are made at the subwatershed level, and how watershed practices will generally be assembled at individual sites.

Step 7. Undertake restoration investigations to verify restoration potential in priority subwatersheds.

Step 8. Agree on the specific implementation measures that will be completed within the permit cycle. Evaluate the extent to which each of the six minimum management practices can be applied in each subwatershed to meet municipal objectives.

Step 9. Agree on the maintenance model that will be used to operate or maintain the stormwater infrastructure, assign legal and financial responsibilities to the owners of each element of the system, and develop a tracking and enforcement system to ensure compliance.

Step 10. Define the trading or offset system that will be used to achieve objectives elsewhere in the local watershed objectives in the event that full compliance cannot be achieved due to physical constraints.

Step 11. Establish sentinel monitoring stations in select subwatersheds to measure progress towards goals.

Step 12. Revise subwatershed management plans in the subsequent NPDES permitting cycle, based on monitoring data.

The core of the approach is to customize management strategies for each class of subwatershed so as to apply the most appropriate planning, engineering and regulatory tool (see **Table 5-B.7** below). The benefit of subwatershed-based permits is that it also provides accountability mechanism in the form of compliance monitoring on a subwatershed basis. In all subwatersheds, it makes sense to measure and track changes in both impervious cover (IC) created and impervious cover treated. Within individual subwatersheds, however, the focus of monitoring efforts may differ. For example, monitoring of biological metrics is recommended in sensitive and impacted streams to ensure they are meeting their objectives. Outfall monitoring continues to be important for non-supporting streams (i.e., no biological diversity), particularly if stormwater quality data are compared to action levels to identify the most polluted subwatersheds for greater treatment.

Managing urban watersheds can be challenging. The best chance of achieving stream quality objectives arises when the many tools of watershed protection and restoration are organized and aligned in the context of a stream classification system based on the Impervious Cover Model (**Appendix 5-A**) and an enforceable watershed-based permit system is established to implement them. The proposed approaches outlined in this chapter are intended to be an initial guide to help local managers to shift to a new subwatershed approach.

Table 5-B.7. Examples of Customized Subwatershed Management Strategies

Subwatershed Management Issue	Sensitive Streams (2 to 10% IC)	Impacted (IC 10 to 24%)	Non-Supporting (IC 25 to 59%)	Urban Drainage (60% + IC)
Land Use Planning and Zoning	Extensive land conservation and acquisition to preserve natural land cover. Site-based or watershed IC caps	Reduce IC created for each zoning category by changing local codes and ordinances	Encourage redevelopment, and intensification of development to decrease per-capita IC utilization in the landscape. Develop watershed restoration plans to maintain or enhance aquatic resources	
Site-Based Stormwater Reduction and Treatment Objectives	Treat runoff from two year design storm using practices to achieve 100% runoff reduction volume	Treat runoff from one year design storm using practices to achieve 75% runoff reduction volume	Treat runoff from the 90% annual storm and achieve at least 50% runoff reduction volume	Treat runoff from the first flush storm and achieve at least 25% runoff reduction volume
Site-Based IC Fees	Establish Excess IC Fee for projects that exceed IC zoning category		Allow IC Mitigation Fee	Allow IC Mitigation Fee
Subwatershed Trading	Receiving Area for Conservation Easements, Restoration Projects and Retrofit		Receiving or Sending Area for Retrofit	Sending Area, for Restoration Projects
Stormwater Monitoring Approach	Measure in-stream metrics of biotic integrity	Track subwatershed IC and measure practice performance	Check outfalls and measure practice performance	Check municipal action levels at outfalls
TMDL Approach	Protect using anti-degradation provisions	IC-based TMDLs that use flow or IC as a surrogate for traditional pollutants	Pollutant TMDLs to identify problem subwatersheds	Pollutant TMDLs to identify priority source areas
Dry Weather Water Quality	Check for failing septic system	Outfall and channel screening for illicit discharges	Dry weather sampling in streams and outfall screening	Dry weather sampling in receiving waters
Addressing Existing Development	Ensure farm, pasture and forest best practices are used	Stream repairs, riparian reforestation & residential stewardship	Storage retrofits and stream repairs	Pollution source controls and municipal housekeeping

5-B.4.0 INTER-JURISDICTIONAL WATERSHED PLANNING

Because watershed boundaries do not coincide with political jurisdictions, more than one city or county may need be involved in watershed planning efforts. Cross-jurisdictional cooperation is likely to become more important as the USEPA considers requiring local MS4 permit programs to be implemented on a watershed-by-watershed basis. Successful watershed management can only occur if all jurisdictions within a watershed boundary are involved at some level and committed to the same set of goals.

The challenge is to develop effective inter-jurisdictional watershed plans that are pro-active, well-defined, well-funded, and adequately staffed. The key ingredients to meet the challenge are as follows:

- Develop a broad-based consensus for the need to protect and manage the specified watershed. Establish a memorandum of understanding (MOU) or a memorandum of agreement between interested/concerned jurisdictions and agencies.
- Obtain some level of funding commitments from signatory parties.
- Establish a technical committee to develop and coordinate watershed management efforts.
- Consistently evaluate and update the watershed plan efforts.

An example of an inter-jurisdictional watershed planning effort is the Big Haynes Watershed Protection Program. The Big Haynes Creek Watershed is an 82 square mile watershed located about 20 miles east of Atlanta in Gwinnett, Newton, Rockdale and Walton Counties (see **Figure 5-B.5**). The watershed drains into the Big Haynes Reservoir, the water supply source for Rockdale County and the city of Conyers.

The reservoir watershed was urbanizing rapidly and faced pollution problems from stormwater runoff. Rockdale County provided protection measures for the creek, which was first identified as a possible water source in the 1970's, by establishing three-acre minimum zoning in the proposed reservoir watershed. However, a major obstacle to protection is that about 76 percent of the 82 square mile watershed is controlled by jurisdictions outside Rockdale County. The challenge facing these governments was, and is, to develop and implement a plan to maintain a high quality water supply source while also allowing continued economic and population growth in an area facing significant development pressure.

To develop more flexible standards than the State Environmental Protection Department's 25% impervious cover rule, while still providing water quality protection, the governments in the watershed and the Atlanta Regional Commission committed to conduct and finance a watershed study and the development of a watershed management plan in 1991. The study recommendations included a 2020 land use scenario as well as options for the local governments in developing their own watershed protection measures.

Following the study's completion, the participating governments signed an inter-governmental agreement in September 1995 creating the Big Haynes Watershed Council as well as a supporting Technical Advisory Committee to oversee enactment of study recommendations, review effectiveness of the watershed protection program, and to meet on mutual concerns. In 1999, the Watershed Council began a study of regional stormwater ponds through a federal grant that may eventually result in a demonstration project for regional ponds in the watershed. Big Haynes serves as a good model as to how local, regional, and state governments can cooperatively work to achieve specific water resource protection goals.

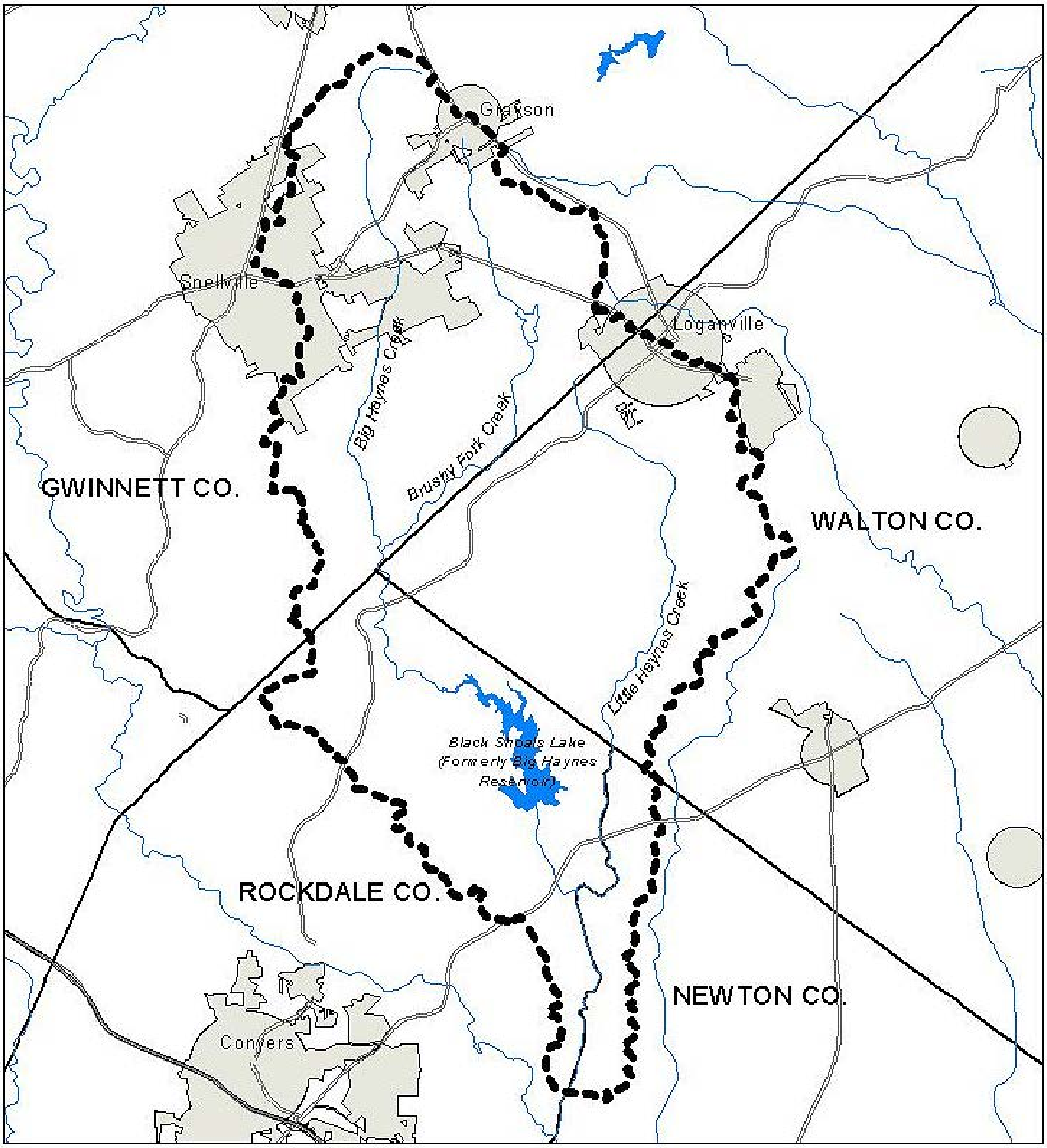

Figure 5-B.5 Big Haynes Creek Watershed
Source: ARC (2001)

5-B.5.0 OTHER WATERSHED PLANNING RESOURCES

The Center for Watershed Protection has numerous resources to assist with watershed planning and management. These resources can be accessed at the Center's website at:

http://www.cwp.org/Resource_Library/Watershed_Management/index.htm

5-B.6.0 CASE STUDIES

5-B.6.1 Henrico County Regional Stormwater Management Plan

Henrico County's regional/watershed plan for stormwater management is a very good example of how a community can develop alternative approaches to comply with state stormwater management requirements. Several particular features exemplify the kinds of flexibility that may be achieved in such plans:

- The County designated its urban/commercial corridors as Intensely Developed Areas. New development or redevelopment occurring within these areas is not required to have on-site stormwater management practices, due to the high level of imperviousness and high cost of land typical of these sites. Instead, the developers are allowed to pay a fee-in-lieu of an amount calculated to cover the cost of treatment elsewhere that will achieve an equivalent amount of pollutant (phosphorus) reduction.

- The County uses funds collected from these fees to do one of two things: (1) build regional-scale stormwater management facilities (typically ponds); or (2) restore degraded stream corridors, using natural channel design techniques (a la David Rosgen) and creating new or expanded riparian forest buffers – often with level spreaders installed to ensure sheet flow through the buffers – adjacent to the County's stream system. This latter strategy aims at establishing a natural stream system that will convey storm flows without damage to the stream's structure or streambank erosion, which improves the eco-health of the streams. By reducing sediment loads from these streams, the County expects to also reduce a sufficient amount of attached phosphorus to achieve the equivalent levels of TP-reduction needed to comply with the state regulations.

- Developments everywhere in the County still must comply with water quantity requirements, to assure that flows discharged from development sites do not erode natural receiving channels or create nuisance flooding.

- Developments outside of the commercial corridor zones must, of course, provide traditional on-site stormwater management practices to achieve the water quality and water quantity requirements in the state regulations.

Of course, an important key to making a plan like Henrico's work well is the timing of the installation of the regional-scale BMPs and stream restoration/buffer projects. Simply allowing developers to pay into a fund that continually grows – without expending the funds in a timely manner to construct the offset measures – does not solve the stormwater problems. In fact, it allows more problems to occur during the waiting period. Prior to approving watershed plans, the DEQ and the Board will expect localities to show how they will avoid this risk and assure timely implementation of offset measures.

Ideally, a community should identify sites for such regional facilities and prioritize stream restoration projects as part of the watershed plan. Then, through a bond mechanism or other up-front funding, the community should construct offset measures fairly early in a watershed's development, using the collected fees-in-lieu to repay the bond or other debt obligations.

It is also possible for communities to establish Stormwater Utilities (§ 15.2-2114, Code of Virginia), charging local citizens service fees as they do for sewage and water treatment services, trash collection and recycling. The Stormwater Utility could be associated with the watershed plan, and some of the collected funds might be used to construct and maintain the offset BMPs.

5-B.6.2 Chesterfield County's Swift Creek Watershed Stormwater Management Plan

Figure 5-B.6. Swift Creek Reservoir

The Swift Creek Reservoir was constructed in 1965 as a public water supply for Chesterfield County, Virginia. The 12 million gallon per day capacity Addison-Evans Water Treatment and Laboratory Facility provides on average 7.5 million gallons per day of drinking water to the County. The reservoir is a 1,700-acre impoundment containing approximately 5.2 billion gallons of water. The Swift Creek Reservoir Watershed is located in the northwest part of the county and encompasses 61.9 square miles. Its headwaters are located in Powhatan County. The watershed is divided into the following subwatersheds, based on its tributary streams:

- Little Tomahawk Creek
- Tomahawk Creek
- Turkey Creek/Swift Creek
- Otterdale Creek
- Horsepen Creek/Blackman Creek/Deep Creek
- West Branch
- Dry Creek
- Fuqua Creek

Initiatives for the Protection of the Swift Creek Reservoir Watershed

Chesterfield County conducted an assessment of the conditions of the Swift Creek Reservoir Watershed in 1989. Three years later, the Board of Supervisors adopted goals to protect the Swift Creek Reservoir and established a Watershed Management Committee that included citizen and staff representatives. This committee was charged with identifying strategies and alternatives to protect the reservoir. Based on recommendations from the committee in 1997, the Board established, through ordinance, a phosphorus loading limit of 0.22 pounds per acre per year (lbs/ac/yr) for new residential development and 0.45 lbs/ac/yr for nonresidential development. These loading limits were established by setting a 0.05 milligrams per liter (mg/L) in-lake phosphorus limit and calculating an allowable annual phosphorus input load. The Board also directed staff to prepare a regional master plan that included a funding strategy requiring the land development industry to fund the construction of regional stormwater management facilities. Additionally, development within the watershed was to fund the maintenance of the regional facilities.

In 2000, the Board unanimously approved the Watershed Management Master Plan and Maintenance Program (regional plan). The regional plan was developed to meet the goals and strategies set forth in Watershed Management Plan of 1996 through the construction of a system of regional storm water treatment facilities. One of these facilities, the regional in-stream pond component, was to provide the greatest reduction of pollutants.

In January 2006, the use of regional in-stream ponds met with resistance from federal regulatory agencies. During a meeting with the regulatory agencies, staff was advised that the in-stream regional pond component would not receive permitting and any future regional facilities would require off-line construction.

Modifications to the Watershed Master Plan

The regional in-stream pond component would have provided the greatest portion of storm water quantity and quality control for the protection of the reservoir. The inability to use this type of treatment, due to regulatory restrictions from federal agencies, greatly impacts the plan's performance. Staff has identified a framework of tasks and steps needed to modify the plan to meet the regulatory challenges and to provide opportunities to further protect the reservoir.

The modifications can be grouped into three main tasks:

- Requiring new construction to address storm water management on-site;
- Acquiring additional detailed information on current and future land-use phosphorus contributions; and
- Modifying the Watershed Master Plan.

Storm water pollution is directly related to the amount of impervious surface within a development. Conventional storm water controls collect runoff from these areas and convey the concentrated storm water, ultimately discharging it to a water body. Reducing impervious surface reduces the amount of runoff and limits the pollutant concentration resulting in the protection of county waters and the reservoir. The following will aid in reducing impervious surface starting with a review of existing county ordinances.

- **County Ordinances (Site Plan and Subdivision):** A preliminary review of county ordinances has identified several ordinances which could assist in the reduction of pollutant loads from new development. A more comprehensive review of the county's ordinances will be conducted to determine those areas where modifications may help to improve storm water runoff.
- **Preservation and Restoration of Natural Cover and Areas:** Retaining the existing natural conditions such as vegetation, soils and wetlands provides a natural and cost-effective way to manage storm water quantity and quality.
- **Low Impact Site Design Techniques:** LID is a site design strategy with the goal of maintaining or replicating the pre-development hydrologic regime through the use of design techniques to create a functionally equivalent hydrologic landscape.
- **Using Natural Features for Stormwater Management:** Traditional storm-water systems are designed to collect, concentrate and convey storm flows efficiently away from the development. Natural drainage patterns tend to be ignored and replaced with structural controls. A nontraditional approach would seek to incorporate the site's existing natural features. These could include natural drainage patterns, depressions, permeable soils, wetlands and vegetative areas. This would reduce the number of structural controls and provide for more natural storm water control through infiltration, pollutant filtration and maximizing on-site storm water storage.

The above measures will help to minimize the pollutant loads from future development by controlling the pollutants at the source. That portion of the future loads which can not be reduced as part of the on-site treatment and is in excess of the target load limit is referred to as the 'orphan load'. The reduction of load will need to be addressed through county run projects. The program will be executed through funds collected as part of the pro-rata fees. Many of these projects will be regional in nature and aimed at reducing identified pollutants loads.

Documents contain detailed information and presentations that have been provided to public and county officials regarding the watershed plan can be found on the County's website at:

http://www.chesterfield.gov/content.aspx?id=2854

5-B.6.3 Norman Oklahoma Comprehensive Watershed-Wide Stormwater Management Plan

Editor's Note: The Norman plan is included here as an excellent example of a very thorough, comprehensive watershed management plan incorporating numerous major stormwater management goals (Source: Stormwater Magazine, May 2010).

Like countless municipalities across the nation, the city of Norman, Oklahoma, has had to contend with increased flooding and erosion and diminished water quality resulting from urbanization. Home to the University of Oklahoma and a population of approximately 112,000, Norman seeks to address these problems, particularly a decline in water quality in Lake Thunderbird, the city's primary source of drinking water. A recently completed Storm Water Master Plan (SWMP) will greatly facilitate Norman's efforts to reduce dangers associated with flooding, protect water quality, comply with federal and state stormwater quality regulations, enhance the environment, improve recreational opportunities, and outline funding options for related program activities.

Examining the Streams and Watersheds

Located in central Oklahoma, Norman has an annual average rainfall of nearly 35 inches and is prone to flash flooding. The city comprises an area of nearly 190 square miles, of which almost 30 square miles have undergone significant development to date. Population growth and greater urbanization have caused increased flooding, erosion, and various water-quality problems in the city's watersheds, particularly among urban streams.

Norman hired PBS&J to develop the SWMP in 2007. Shortly thereafter, the city created a Storm Water Task Force to help guide the city and PBS&J, as well as to provide one of several forms of public input used during the project. Members of the task force met regularly with representatives of the city and PBS&J to review progress and offer suggestions. In addition, the city requested public input through its Web site and held six public meetings to solicit input directly from the public.

Primary goals developed during the creation of the SWMP included reducing flood dangers, improving water quality, enhancing the environment, and advancing recreational opportunities. During the development of the SWMP, existing sources of information and data were relied on as much as possible. However, additional information needed to be collected to provide a solid foundation for the plan. Although Norman's 15 major watersheds were subdivided into 36 tributary watersheds and further subdivided into 665 subareas for more detailed study, some were analyzed to a greater degree than others. Analyses pertaining to assessments of watersheds and streams, stream flooding, and stream erosion were conducted in accordance with one of four "levels" of study.

Figure 5-B.7. Streambank erosion along the Little River

Figure 5-B.8. Fallen trees and debris resulting from stream erosion block a section of Imhoff Creek

A level 1 study entailed conducting detailed examinations of hydrology, hydraulics, and floodplain mapping for certain streams and their respective watersheds. New hydrologic and hydraulic models were developed for these streams based on the most recent topography and aerial coverage available from the city, field surveys of road crossings and selected cross sections, field reconnaissance visits, and detailed delineations of drainage areas, land use coverages, impervious cover, soils, and updated US Geological Survey intensity-duration-frequency rainfall relationships. These models then were used to depict existing and future build-out flooding conditions, along with the improved flooding conditions expected to result from the proposed solutions. Watershed assessments, meanwhile, were developed using field reconnaissance as well as city GIS files to obtain data pertaining to such details as land use (or zoning), impervious cover, floodplain locations, soils, and other watershed data. Finally, stream assessments were developed using extensive field reconnaissance visits and the city's aerial and topographic data to document stream channel and overbank flow conditions and locate and characterize stream erosion sites.

A level 2 study was the next most detailed. Similar to a level 1 study in most respects, a level 2 study used hydrologic and hydraulic models from studies and study updates previously submitted to, and accepted by, FEMA. Generally, the FEMA models were reviewed and modified only if obvious errors were apparent. Like their level 1 counterparts, the models were used to depict existing and future build-out flooding conditions, along with the improved flooding conditions expected to result from the proposed solutions.

Level 3 and 4 studies generally were used for stream reaches that have more than 40 acres of drainage area and are not located in Norman's urban core, where small drainage systems primarily consist of storm sewers and manmade channels. Level 3 and 4 streams and their watersheds were subject to general studies regarding their hydrology, hydraulics, and floodplain mapping. Watershed assessments were developed using city GIS files for land use (or zoning), floodplains, soils, and other watershed data. Stream assessments were limited to describing general characteristics of the particular stream reaches considered, based on very limited field reconnaissance and city GIS data. Although level 3 and 4 reaches were studied in the same manner, level 3 streams have been identified by the city as the next in line for detailed studies when funds are available in the future.

In summary, hydrologic analyses and watershed assessments were performed for 307 square miles of watershed area, while hydraulic analyses and floodplain mapping were developed for almost 400 stream miles, which included 59 miles along detailed (levels 1 and 2) streams and 333 miles along general (levels 3 and 4) streams. Additionally, 69 field-documented stream reach assessments were performed in level 1 and level 2 watersheds, while more general assessments using available data were performed for 635 stream reaches city-wide.

Identifying Stormwater Solutions

Stormwater problems were grouped into four categories—stream flooding, stream erosion, water quality, and local drainage—to assist in understanding the overall magnitude of each problem type. Fifty-nine problem areas were identified, spread over a large swath of the city. Complicating matters, many of the problems occur on property lacking sufficient drainage easements or rights of way. As a result, the estimated costs for solutions in such locations include expenses related to purchasing such easements or rights of way. **Table 5-B.8** shows the number of problem areas in watersheds subjected to level 1 or 2 studies, as well as the estimated costs of the proposed solutions. Although solutions for stream flooding and erosion were proposed only for level 1 and 2 stream reaches, solutions related to water quality are more programmatic and, therefore, apply more broadly across the city as a whole.

As noted earlier, the combined 59 solutions recommended as part of the SWMP have an estimated cost of nearly $83 million. Of this amount, nearly 90% is related to solutions in five urban watersheds: Bishop Creek, Brookhaven Creek, Imhoff Creek, Merkle Creek, and Woodcrest Creek. Stream flooding occurs in several locations in these watersheds, and stream erosion frequently destabilizes the mid and lower stream reaches in these watersheds.

Table 5-B.8. Summary of Proposed Norman, Oklahoma Stormwater Projects

Watershed	Stream Flooding		Stream Stabilization		Local Drainage		Watershed Total Cost	Percent of City Totals
	No.	Costs	No.	Costs	No.	Costs		
Bishop Creek	6	$5,347,808	6	$1,817,248	5	$4,720,055	$11,885,111	14.4
Brookhaven Creek	4	$2,613,904	4	$2,106,735	3	$1,278,962	$5,999,601	7.3
Clear Creek	-	-	-	-	1	$1,794,023	$1,794,023	2.2
Canadian River	-	-	-	-	1	$400,645	$400,645	0.5
Dave Blue Creek	2	$1,786,733	-	-	-	$1,786,733	$1,786,733	2.2
Imhoff Creek	9	$24,439,559	2	$6,816,509	1	$43,717,155	$43,717,155	53.0
Little River	1	$305,233	1	$123,682	-	$428,915	$428,915	0.5
Tributary G to Little River	1	$992,182	-	-	-	$992,182	$992,182	1.2
Woodcrest Creek	3	$3,167.165	1	$110,965	-	$3,278,130	$3,278,130	4.0
Merkle Creek	4	$8,856,558	-	-	-	$8,856,558	$8,856,558	10.7
Rock Creek	3	$3,135,111	-	-	-	$3,136,111	$3,136,111	3.8
Ten Mile Flat Creek	-	-	-	-	1	$255,326	$255,326	0.3
Citywide Totals	**33**	**$50,645,253**	**14**	**$10,975,139**	**12**	**$20,910,098**	**$82,530,490**	**100.0**

To the extent feasible, integrated solutions were developed to address stormwater issues as comprehensively as possible. Generally, problems in a given location tended to take the form of one major type, such as stream flooding. However, even in locations in which only one problem predominated, the proposed solution was developed in such a way that it would also improve other stormwater aspects. For example, a conceptual solution for addressing stream flooding would be designed in such a manner so as to protect the stream from future erosion. Whenever possible, bioengineering and natural channel design concepts and techniques were incorporated to improve or protect a stream's environmental integrity. Meanwhile, the adopted solutions target future watershed development conditions projected in the city's 2025 Land Use Plan. In this way, solutions will better help the city address future stormwater needs and provide a more complete "blueprint" for managing stormwater.

Figure 5-B.9. This reach of Shoal Creek was restored Using bioengineered techniques and natural materials

Of the 59 projects proposed as part of the SWMP, 33 would mitigate stream flooding through the use of such approaches as bioengineered stream modifications, storm sewer improvements, and stormwater detention. Of those 33 projects, 26 are intended to address flooding of structures. All told, the 26 projects would remove 652 structures from the 100-year baseline floodplain. Of the 33 projects for mitigating stream flooding, 29 would include upgrades to road crossings that are routinely overtopped during flood events. In fact, 36 road crossings would be protected to design levels. Although an effort was made to minimize property buyouts, 12 of the 33 projects would rely on buyouts of flood-prone structures. The SWMP identifies 62 properties as possible candidates for a buyout.

The level of protection for most stream flooding solutions varied somewhat. However, improvements associated with channel capacity and roadway bridge openings used projected 100-year baseline (future) peak discharges, while roadway culvert openings used 50-year peak flows. Exceptions occurred in special cases where 10-year protection was judged to be preferred because of limited space and the costs associated with larger improvements.

Twelve projects called for in the SWMP would address local drainage problems, while another 14 projects would use stabilization measures to address stream erosion. Overall, the SWMP identifies 10,050 feet of eroding streams to be stabilized by a combination of techniques, including channel grade control, streambank armoring, slope flattening, and bank toe protection. Various combinations of materials were recommended for achieving these techniques, including rock riprap, erosion protection fabric, geogrids to hold certain specific structures together, and select vegetation.

General cost estimates for each recommended project solution were developed using unit costs and estimated quantities for the construction bid items required to construct the respective projects. The SWMP also includes cost estimates for new drainage easements and/or rights of way needed to ensure construction of project improvements on property owned by the city or made available through city easements. Costs were obtained from city staff based on historical costs, location of the problems, and adjacent local land use.

Another important element of the SWMP was the integration of the recommended stormwater solutions with proposed greenbelt routes. During development of the SWMP, Halff Associates, a member of the consultant team, prepared a plan for greenbelt trails in the city. Throughout the project, team members coordinated to ensure that stormwater projects could be integrated with greenbelts whenever possible. During the design effort for any particular project, its integration with greenbelts can be considered further and incorporated into the project if the city desires.

Prioritizing the Solutions

Two critical aspects of the SWMP involved prioritizing the solutions and developing optional financing methods to help the city decide which projects to conduct first and how to finance them. The system developed for prioritizing solutions evaluates, scores, and ranks each one, in terms of its ability to solve the problem under consideration, provide for public safety, provide sustainability, utilize funding advantages, positively affect neighborhoods and the environment, and benefit other functions such as transportation. This prioritization identifies the most critical projects for addressing the stormwater needs in Norman and provides an important tool for the city as it determines the order in which solutions might be implemented and how they might be financed.

Each prioritization factor was given a weight based on its importance. Factors were grouped and classified in four categories. The factors in the most important category were given a weighting of four, the factors in the second category were given a weighting of three, the factors in the third category were given a weighting of two, and the factors in the fourth category were given a weighting of one. The various factors are shown in **Table 5-B.9** below along with scoring examples for hypothetical projects.

To evaluate a project using this prioritization "matrix," each factor then was assigned a project-specific rating between zero and three, with three being the highest, two being moderate, one being low, and zero indicating the degree to which the factor had relevance, or a positive impact on, the project. Once each factor was rated for a project, the factor weighting was multiplied by the rating to give a factor score. The individual factor scores were then totaled to give a total prioritization score for the project. A higher the score means the subject project has greater importance. This process was followed for each identified project. Once project prioritization scores were obtained, the project rankings were then compared on the basis of watersheds, wards, and citywide.

Table 5-B.9. Norman, Oklahoma, Watershed Plan Project Prioritization Scoring Sheet

Prioritization Ranking Factors	Ranking Factor Weight	A Road Drainage Ditch		Wet Creek Buyouts		Maximum Possible Score	
		Project-Specific Score	Project-Specific Weighted Score	Project-Specific Score	Project-Specific Weighted Score	Project-Specific Score	Project-Specific Weighted Score
Public Safety	4	3	12	3	12	3	12
Flood, erosion, and water quality significance	4	1	4	2	8	3	12
Engineering economy (good benefit/cost relationship)	4	2	8	3	12	3	12
Potential for recreation/open space/connectivity for linear parks	4	2	8	3	12	3	12
Sustainability or low operations and maintenance cost	3	1	3	3	9	3	9
Environmental enhancement	3	1	3	3	9	3	9
Funding sources (leverage of participants' available funds)	2	2	4	2	4	3	6
Beneficial neighborhood impacts	2	1	2	1	2	3	6
Degree of economic impact on local businesses	2	2	4	3	6	3	6
Dependency on other projects	1	0	0	1	1	3	3
Improved economic development/redevelopment potential	1	3	3	2	2	3	3
Mobility or effects on transportation system	1	3	3	0	0	3	3
Time to implement or construct	1	2	2	1	1	3	3
Ease of permitting	1	1	1	3	3	3	3
Project Total Specific Score			57		81		99

Protecting Water Quality in Lake Thunderbird

Individual projects aside, the SWMP also evaluated how Norman should protect and improve water quality throughout the city and especially in its drinking water supply, Lake Thunderbird. The Oklahoma Department of Environmental Quality (DEQ) has designated Lake Thunderbird as a sensitive water supply lake. However, elevated levels of chlorophyll a – an accepted measure of algal content – have been found in the reservoir, prompting the Oklahoma DEQ to add Lake Thunderbird to its list of impaired water bodies, in accordance with Section 303(d) of the Clean Water Act.

Unless significant steps are taken to reduce the influx of pollutants to the lake, further degradation of the lake's water quality can be expected as land development progresses in the Lake Thunderbird watershed. Current high loadings of nutrients – the main factor contributing to algal growth in the lake – are only expected to increase with urbanization. The prospect of more algal growth includes an increased threat of toxins being produced in the lake from algal masses, exacerbating taste and odor problems with drinking water and decreasing recreational opportunities. Although other urbanized or urbanizing areas to the north contribute significant stormwater to the lake, Norman is the largest municipal area draining to Lake Thunderbird. In fact, roughly half of the area that drains to the reservoir is in the city limits. Therefore, the SWMP includes recommendations for management practices that can help protect water quality in Lake Thunderbird.

Because limiting nutrient loadings will require a combination of structural and nonstructural measures, the SWMP included recommendations for particular approaches expected to provide the greatest benefits. Although implementing controls in previously developed areas would be difficult, using such controls in future developments will greatly assist Norman in its efforts to improve water quality in Lake Thunderbird.

Measures recommended in the SWMP include stream planning corridors (SPCs), various structural and nonstructural controls, fertilizer use education, fertilizer use controls, a continuation of present development density controls, and low-impact development practices. If implemented properly, these management practices will significantly assist in preserving and protecting the Lake's water quality and the city's primary water source.

The SWMP proposes the dedication of SPCs within drainage areas greater than 40 acres in watersheds that contribute to Lake Thunderbird. SPCs are defined as the area of land along both sides of a stream or natural drainage corridor that encompasses the area projected to be inundated by the 1% probability flood (i.e., the 100-year floodplain) in any given year, assuming full build-out watershed conditions. As proposed, an SPC could possibly include an additional buffer width to aid in further filtering runoff and providing environmental protection of stream riparian areas. Such corridors are particularly useful in headwater areas, where the features have the best opportunity for filtering runoff and facilitating infiltration. Of course, the city will have to make certain legal and political changes before SPCs may be implemented.

Evaluating Structural and Nonstructural Controls

Norman already is implementing programmatic water-quality solutions in its urbanized areas as part of efforts to comply with the Oklahoma DEQ's permit requirements for municipal separate storm sewer systems (MS4s). As a supplement to these efforts, the city will need to require that new developments incorporate certain structural and/or nonstructural water-quality controls.

In general, the SWMP recommends that Norman require structural stormwater controls in the same manner and locations as required for stormwater detention throughout the city. Such controls include extended detention basins, wet ponds or retention basins, filtration basins, porous pavement, and grassed swales. These structural controls can be constructed in conjunction with stormwater detention facilities in most instances. Because of maintenance costs and concerns regarding public safety and nuisance considerations, the city plans to encourage the use of dry detention facilities rather than wet detention facilities in most, but not all, cases.

In terms of nonstructural controls, the SWMP recommends that the city continue to ensure that the minimum control measures conducted as part of the MS4 program be met. Such measures include fertilizer application controls, street sweeping, oversight of septic system installation and operation, and area-specific development density limitations.

The SWMP recommends new ordinance requirements pertaining to structural and nonstructural controls. For example, the SWMP suggests that Norman require that water-quality facilities be constructed to capture and treat runoff from all proposed developments exceeding 1 acre (or some smaller size selected by the city). The runoff "capture and treatment volume" should be set to 0.5-inch of runoff from the development area, unless otherwise specified for a special condition. Furthermore, the SWMP recommends that the city should allow and encourage developers to use low-impact development techniques such as rain gardens and biofilters to meet a portion or all of their water-quality control requirements, assuming that the developers provide sufficient technical justification for the techniques.

Presenting Financial Options

It is anticipated that many of the recommended solutions will be included in a capital improvement program (CIP) to be implemented by the city. Funding for this CIP program and other stormwater costs are anticipated to come from a stormwater utility that the city of Norman proposes to establish. If approved by city voters, stormwater utility fees will be based on the amount of impervious cover on each respective property within the city, regardless of land use type. In fact, the SWMP serves as a basis for the creation of the utility.

Financial analyses were performed to determine how best to meet the funding needs for the programs and activities associated with the SWMP. The revenue required for the stormwater management activities and improvements outlined in the SWMP can be divided into several categories of need. These include needs for debt service, creation of a reserve fund less any non-operating revenues such as interest earnings, continued general overall operation and maintenance, shared city services, minimum control measures for stormwater MS4 regulatory compliance, enhanced maintenance for streams and stormwater detention facilities, trail construction, easements and rights-of-way acquisition, and stormwater capital improvement projects paid for with cash.

In addition to reducing funding requirements from a stormwater utility, the city decided to propose funding a portion of the stormwater capital improvements with general obligation bonds to provide necessary projects more quickly in areas of critical stormwater needs.
Three rate options were developed to fund the stormwater capital improvements using the split between general obligation bonding and stormwater utility rates over a 20-year program, as defined by the city. As shown in **Table 5-B.10** below and consistent with the CIP costs for proposed solutions, the total 20-year CIP needs in 2008–2009 dollars were estimated to be approximately $83 million. To cover these costs, three options for financing this portion of the overall program were developed, with varying amounts of general obligation bonding and stormwater utility user fees.

Table 5-B.10. Three Rate Options: Fiscal Year 2008-2009 Dollars (Uninflated)

Item	Option 1	Option 2	Option 3
Capital Improvement program (20-year period)	$83,000,000	$83,000,000	$83,000,000
Funding source: general obligation bonds	$30,000,000	$38,500,000	$40,000,000
Funding source: Stormwater user rates (Pay-go) financing	$53,000,000	$44,500,000	$43,000,000
Total	$83,000,000	$83,000,000	$83,000,000
Program period, years	20	20	20
Capital Improvement projects funded by rates, per year	$2,650,000	$2,225,000	$2,150,000

Considering all revenue requirements identified, monthly stormwater rates for a median single-family home having approximately 3,100 square feet of impervious cover were determined to be $6.26, $5.85, and $5.78 for options 1, 2, and 3, respectively.

Conclusion

Although the SWMP is complete, the city of Norman still must decide how to implement and finance the plan's recommendations. This process will require the sustained involvement of stakeholders and approval of a stable funding source by Norman's citizens, along with efforts by the city to continue to refine its future needs and goals regarding stormwater and watershed protection. Using the SWMP as a solid foundation, Norman will be able to satisfy its regulatory requirements, enhance recreational opportunities, protect the environment, and meet local challenges relating to flooding, stream erosion, drainage problems, and water quality.

5-B.6.4 Big Darby Accord Watershed Master Plan, Columbus, Ohio

The Big Darby Accord consists of local governments within the Franklin County, Ohio area of the Big Darby Creek watershed (see **Figure 5-B.10** below). The mission of the Big Darby Accord is to cooperatively develop, implement and enforce a multi-jurisdictional plan and accompanying preservation and growth strategies designed to:

- Preserve, protect and improve, when possible, the Big Darby Creek watershed's unique ecosystem by using the best available science, engineering and land use planning practices;
- Promote responsible growth by taking measures to provide for adequate public services and facilities and promote a full spectrum of housing choice, as well as adequate educational, recreational and civic opportunities for citizens of each jurisdiction and for Central Ohio;
- Create a partnership that recognizes the identity, aspirations, rights, and duties of all jurisdictions and that develops methods of cooperation among the partners through means which include the cooperative use of public services and facilities; and
- In development of the plan, capitalize on the results of other efforts by considering local comprehensive plans and zoning efforts, as well as the work of other policy teams and advisory committees aimed at environmentally-sensitive development.

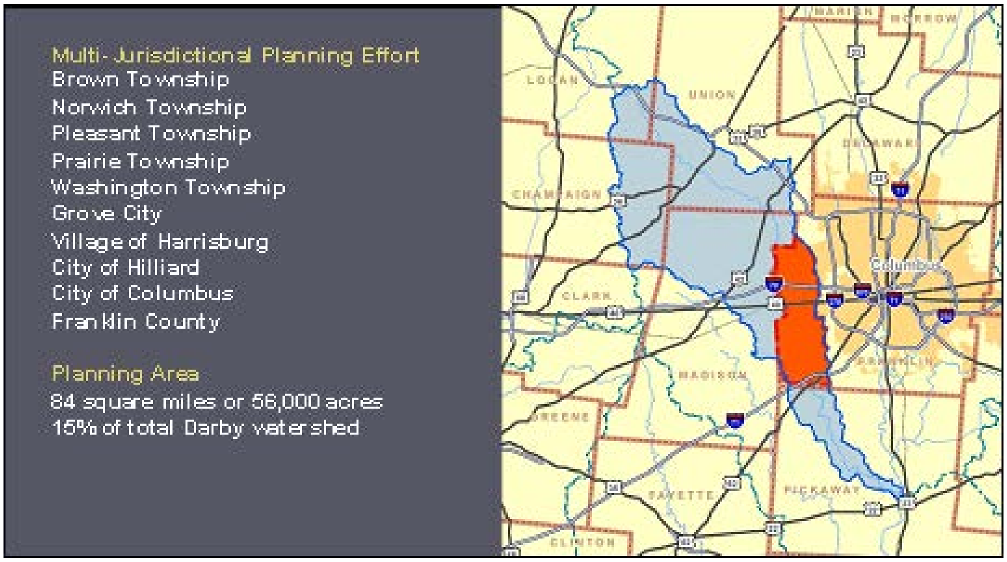

Figure 5-B.10. Big Darby Creek Watershed Planning Area
Source: AECOM

Leading up to establishment of the Big Darby Accord, the watershed environment had displayed long-trending evidence of decline – severe in some places – in biological diversity of the aquatic ecosystem. Stream monitoring had revealed impairments involving several key water quality parameters. Some watercourses had severe physical degradation and, in some cases, loss of functional components of the drainage system. The land development pattern within the study area had evolved over time as the City of Columbus grew and annexed land.. Along the eastern boundary of the study area and near Interstate 70, development was more dense and reflective of suburban patterns.

The remainder of the study area was mostly rural in nature, including agricultural lands and low-density residential development on large lots. Land use and zoning policies in place at the time were promoting an additional 20,000 households in the study area, more than doubling the existing number of households. The Accord Plan proposed a similar level of development, but in a pattern that would be more manageable, sustainable, and environmentally sensitive. The accord process itself established a new regional-scale approach to managing development within the watershed. A number of drivers provided the framework for the creation of a regional watershed plan:

- The Darby watershed was home to 38 state- and federally-listed threatened or endangered aquatic species when the Plan was initiated;
- The Ohio EPA (OEPA) had declared the Darby watershed impaired in 2004, which paved the way for development of a TMDL in 2006.
  - o The OEPA was developing a new water quality management plan that included water quality provisions for Big Darby Creek.
  - o Modeling conducted by OEPA as part of the TMDL process for the entire watershed set aggressive water quality targets to reduce TSS by 95% and Total Phosphorus by 82%.
- Previous state and local planning efforts and initiatives helped to drive the focus on water quality; and

- Public water and sewer services, provided predominantly by the City of Columbus throughout the region, were approaching capacity; and
- Development rights under the existing zoning were recognized as a baseline for future development.

The challenge was to create a plan that would achieve the new water quality standards and address other environmental concerns, while not eliminating all land development. The process (see **Figure 5-B.11**) took several years of studies, planning, and negotiation among participating jurisdictions and stakeholders. The final Big Darby Accord Watershed Master Plan, now adopted, was heavily focused on implementation, since none of this would work unless all the jurisdictions involved agree to work together and uphold the same standards. The necessary cooperation was largely achieved in response to a three-year building moratorium imposed in the study area by the Columbus water and sewer authority, to be ended only when a regional plan was in place. The process involved the following planning activities:

- Analysis of existing conditions to understand the existing environmental constraints. This step included GIS analysis and an environmental resources sensitivity analysis to inform the development industry of appropriate land use alternatives;
- Development of a conservation strategy based upon the environmental sensitivity analysis and existing natural resources. The conservation strategy laid the foundation for land use recommendations;
- Hydrological modeling of land use alternatives to determine the impact on water quality measured in terms of pollutant loading (sensitive to project land use changes);
- Evaluation of potential pollutant loadings, including groundwater pollution potential;
- Creating a solid foundation of information and data upon which to develop policies and implementation actions; and
- Conducting extensive public outreach, with frequent stakeholder group meetings and citizen focus groups.

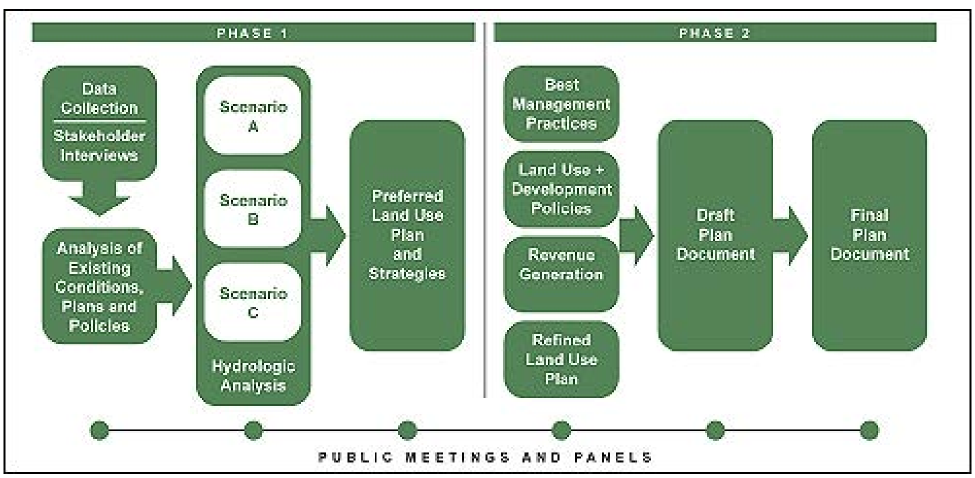

Figure 5-B.11. Big Darby Accord Watershed Planning Process Diagram
Source: AECOM

The initial planning activities culminated in an environmental sensitivity analysis of lands in the watershed. This analysis identified over 32,000 acres as having some level of environmental significance. The analysis reinforced the importance of stream corridors in the area, and ultimately it became the foundation for the conservation strategy that was a fundamental part of the plan.

This led to development of the conservation strategy for the watershed (**Figure 5-B.12**) aimed at protecting significant natural resource areas. The Plan sets forth an aggressive goal of protecting 25,000 acres of land within a comprehensive green infrastructure network. Approximately 7,000 acres of land were already subject to some type of protection. The areas were prioritized and divided into three tiers, with the understanding that new zoning policies would be needed to adequately protect these lands.

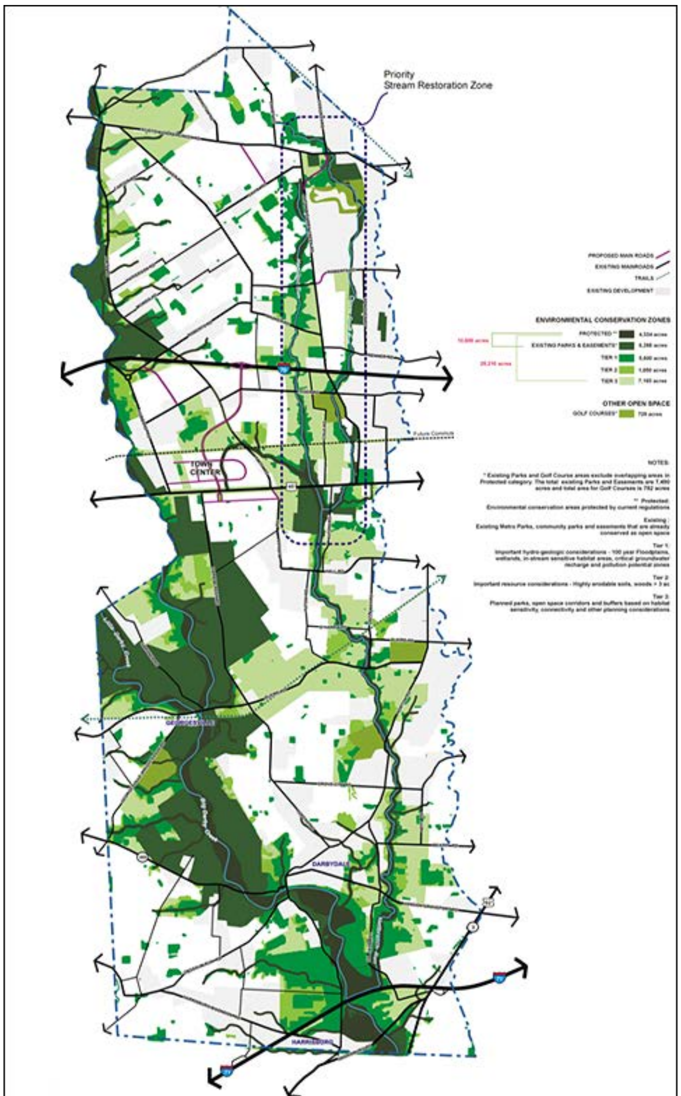

Figure 5-B.12. Big Darby Watershed Conservation Strategy
Source: AECOM

- Tier 1 (5,600 acres): First priority for acquisition or other land protection programs (e.g., floodplains, wetlands, groundwater recharge areas, pollution potential zones, etc.);

- Tier 2 (1,850 acres): Second priority for acquisition (e.g., highly erodible soils, large wooded areas, etc.); and
- Tier 3 (7,160 acres): Third priority, for land use easements and conservation development (e.g., connections, habitat corridors, linkages, trails, etc.),

The planning analysis showed that approximately 49,000 people lived in the study area, but at build-out (based on the existing land use policies) the population would surge to 100,000 in a very low-density development pattern. Three alternative development scenarios (see **Figure 5-B.13**) were developed, using the existing "by right" policies as a baseline target. Each alternative explored different land use patterns and densities to accommodate projected growth and had varying infrastructure considerations (e.g., water/sewer, etc.):

- Option A: Continue with existing policies (very low density development)
- Option B: Concentrate development along a new corridor
- Option C: Cluster development in village centers

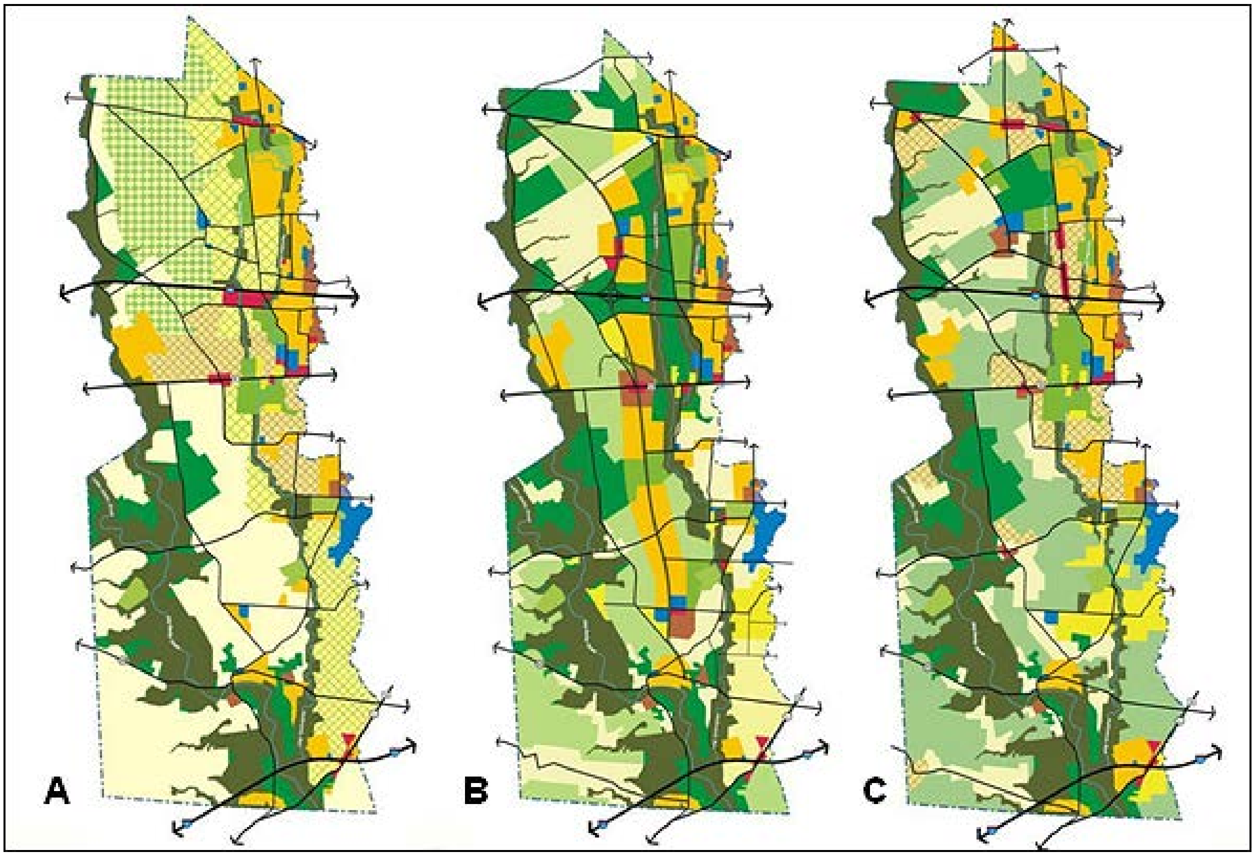

Figure 5-B.13. Three Alternative GIS Land Use Scenarios for Big Darby Watershed Plan
Source: AECOM

Using mutually agree-upon zoning classifications, land uses were determined for each option and fed into a hydrological model (Soil and Water Assessment Tool, or SWAT) to evaluate the impacts each scenario (and associated land uses) would have on water quality. Additional modeling revealed that a change in land use policies would help to accomplish the various goals of the plan while allowing the use of BMPs that could potentially achieve lower pollutant removals than the TMDL required. However, it became clear that BMPs and, in many cases, treatment trains of BMPs would be necessary to achieve the water quality targets.

The final preferred watershed land use plan included many positive elements growing out of the extensive planning and analysis as well as negotiations among stakeholders and local governments. Characteristics of the plan included the following:

- Conservation development:
  - Clustering of units allows environmentally responsible development
  - Requires maintaining 50% open space in the watershed within each development
- Property owners have options:
  - Plan continues to allow for the existing level of development/use
  - Owner can develop per the plan and existing zoning and meet applicable environmental standards, BMPs, and development regulations
  - Alternatively, the owner can sell the property's development rights and continue to live, farm, etc. on the land (conservation easement placed on the property)
  - Owner can sell the property
- Character of development:
  - Mix of uses
  - 5,000 additional dwelling units within a newly identified town center
  - Integrated parks and green spaces
  - Comprehensive stormwater drainage/treatment system, incorporating regional BMPs
  - Use of Low Impact Development (LID) techniques and practices
- Town Centers:
  - Focuses development in appropriate the location
  - Lowers environmental sensitivity and impacts
  - Capitalizes on existing infrastructure
  - Provides full spectrum of housing prices
  - Allow extension of sewer lines without annexation
  - Allows for the use of central sewer service, avoiding the need for septic systems
- Balanced conservation and growth
  - Protects environmentally sensitive areas by directing development away from those resources
  - Requires BMPs to achieve the TMDL limits
  - Encourages LID
  - Recommends a water quality monitoring program
  - Encourages regional stream restoration

To move the plan forward to implementation, an advisory panel composed of members from each participating local government jurisdiction was established. The purpose of the panel is to guide local decision-making and to help establish revenue mechanisms that can fund land protection and water quality improvement programs within the study area. Land development will play a part in the funding effort. An earlier review of potential funding methods had helped build support for the plan's final policies.

The plan cost approximately $700,000 in consulting costs, as well as additional costs for the localities in staff time and public process expenses. The process took a year-and-a-half to complete, including time for stakeholder debate and local government negotiations. As a result of this process and its ongoing implementation, a new spirit of collaboration and cooperation is occurring in the region. Revised and coordinated zoning policies have been drafted, including conservation development and stream buffer setbacks. A draft Town Center Master Plan is under review (http://www.bigdarbyaccord.com/updates/towncenter.cfm). The revenue program is under development. New programs for open space and land conservation have been established. Finally, the county and the City of Columbus have entered into a utilities agreement. This plan demonstrated clearly that, while land use is inextricably linked to watershed health, plans need to go beyond land use to adequately protect watershed health.

For more information, visit the Big Darby Accord website at:

http://www.bigdarbyaccord.com/index.cfm

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Appendix 5-C

SPECIAL STORMWATER MANAGEMENT CONSIDERATIONS FOR REDEVELOPMENT

Adapted from Chesapeake Stormwater Network Technical Bulletin No. 5
Stormwater Design for Redevelopment Projects in
Highly Urban Areas Of the Chesapeake Bay Watershed
Version 3.0 (May, 2011)

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5-C.1.0. INTRODUCTION

Redevelopment occurs when an existing development is adaptively reused, rehabilitated, restored, renovated, and/or expanded, resulting in disturbance or clearing of a defined footprint at the site. In the context of this guidance, redevelopment normally occurs within urban watersheds that are served by existing water, sewer and public infrastructure. When redevelopment is done properly, it is a key element of smart growth and sustainable development (USEPA, 2005, 2006).

The potential for water quality improvements due to redevelopment stormwater requirements is considerable. To achieve these improvements, however, requires creative policy and engineering approaches at the local and state level. The purpose of this Appendix is to provide stormwater managers with the best available engineering and policy approaches that work in the challenging setting of redevelopment.

It should be noted that this Appendix *primarily* applies to high intensity redevelopment projects, where pre-development impervious cover (IC) exceeds 65%. Stormwater practices can be installed much more easily and cost-effectively at redevelopment projects with less than 65% IC. These less intensive sites have more extensive surface area, where LID and traditional stormwater treatment practices can be located.

5-C.2.0. VIRGINIA'S REDEVELOPMENT STORMWATER CRITERIA

Most Bay states have established or proposed a performance standard for runoff and/or pollutant reduction for redevelopment projects. The redevelopment criteria are typically less stringent that those for new development sites in greenfield settings. Virginia's redevelopment criteria are found in § 9 VAC 25-870-63 A 2 of the Virginia Stormwater Management Regulations, as follows:

- If the redevelopment project disturbs greater than or equal to 1 acre *and* there is *no increase* of total impervious cover from the pre-development condition, then the project must reduce the pre-development Total Phosphorus (TP) load by 20%.
- If the redevelopment project disturbs less than 1 acre *and* there is *no increase* of total impervious cover from the pre-development condition, then the project must reduce the pre-development TP load by 10%.
- If the redevelopment project results in a net increase in impervious cover over the pre-development condition, the design criteria for new development must be applied to the *increased* impervious area, while the appropriate redevelopment criteria above will apply to the existing impervious area, based on the size of the disturbed area.
- For linear redevelopment projects (e.g., VDOT roads), the TP load of the project occurring on prior developed land must be reduced 20% below the pre-development TP load.
- In any case, the TP load is *not* required to be reduced to below the standard for new development (0.41 lbs./acre/year of TP), *unless* a more stringent standard has been developed by the local stormwater management program.

As a point of comparison, **Table 5-C.1** shows the various redevelopment stormwater treatment standards among the Bay States, as well as for cities outside the Chesapeake Bay watershed. As can be seen, several cities such as Philadelphia and Los Angeles have established runoff reduction requirements for redevelopment sites that meet or exceed those of the states in the Chesapeake Bay region.

Table 5-C.1. Examples of Redevelopment Stormwater Requirements in the Chesapeake Bay Watershed and in Other Selected Cities [1]

Jurisdiction	Redevelopment Requirement	Min. Area (sf)	Offsets Available?	Status
Virginia	Reduce existing phosphorus load from existing impervious surfaces by 10 to 20% depending on redevelopment site area. Added impervious cover must meet the new development water quality (WQ) standard.	10,000 (2,500 in a Ches. Bay Preserv. Area)	Yes	2011
District of Columbia	Reduce or Treat Runoff Volume from 1.2 inch rainfall event	250	Yes	2011
Maryland	Reduce existing phosphorus load from existing impervious surfaces by 50%. Added impervious cover must meet the new development WQ standard as well as recharge and channel protection.	5,000	Yes	2010
Delaware	Reduce existing phosphorus load from existing impervious surfaces by 50% and meet water quantity control requirements as well.	5,000	Fee-in-lieu	2012
West Virginia	Treat runoff from 0.25 to 1.0 inch of rainfall, depending on number of qualifying project redevelopment credits	1 acre (some MS4s have lower thresholds)	Fee in lieu	2009
New York	New IC: Reduce or Treat Runoff Volume from 1 inch rainfall event Existing IC: Reduce by 25% through IC reduction, BMPs or alternative practices	10,000	Yes	2010
Pennsylvania	20% WQ treatment for the site	10,000	?	2009
Federal Gov't	Reduce Runoff Volume from the 95th percentile rainfall event (1.2 to 1.9 inches in watershed)	5,000	No?	2010
Philadelphia, PA	Reduce or Treat Runoff Volume from 1 inch rainfall event	5,000	Yes	2008
Los Angeles, CA	Treat runoff from 0.75 inch of rainfall	5,000	?	2007
Austin, TX	Treat runoff from 1.0 inch of rainfall	500	Yes	2006
Chicago, IL	Treat runoff from 0.5 inch of rainfall	Varies	?	2008

[1] Some states and localities may also impose further stormwater storage or runoff reduction volumes for channel protection or flood control purposes, depending on downstream conditions and how much new impervious cover is created at the redevelopment site.

The federal government is leading by example by requiring runoff volume reduction from the 95th percentile rainfall event for redevelopment projects at federal facilities and lands nationwide. This new nationwide stormwater requirement is described in US DOD (2009) and USEPA (2009b), and is derived from Section 438 of the 2008 Energy Independence and Security Act. In Virginia, this design storm requirement would amount to about 1.2 to 1.9 inches of rainfall, depending on where the project is located in the Commonwealth.

5-C.3.0. WHY REDEVELOPMENT STORMWATER REQUIREMENTS ARE IMPORTANT

It is important for communities to require more stringent stormwater requirements for redevelopment projects than has been done in the past. In short, redevelopment appears to be increasing as a share of total development in Virginia. The urban watersheds where redevelopment projects occur have poor water quality, and many of them are now subject to the Chesapeake Bay TMDL and other TMDLs. The TMDLs will require localities to achieve significant reductions in stormwater pollutants in the coming years.

The Chesapeake Stormwater Network estimates that about two million acres of untreated or marginally treated impervious cover currently exist in the urban areas of the Chesapeake Bay watershed In Virginia, we can visualize the majority of our metropolitan land areas, built prior to the 1980’s with no stormwater management of any kind. After that stormwater quantity control requirements were enacted, but between 1990 and 2005, only the coastal plain communities in Virginia were required to implement stormwater quality control requirements. Localities can significantly reduce their pollutant reduction liability if they are able to use the redevelopment process to get incremental pollutant reductions from untreated impervious cover over time.

5-C.3.1. Recent Growth in Redevelopment Activity

Historically, new development in the suburbs and rural areas of the Chesapeake Bay watershed has far exceeded the amount of infill and redevelopment, in terms of land consumed and new impervious cover created. In recent years, however, there is evidence that urban sprawl may be cresting as a result of high energy prices, road congestion, falling housing prices, reduced job mobility and other economic forces, including the recent recession. Recent land use statistics show a slowdown in the rate of land conversion for sprawl development during the last five years.

At the same time, there is some evidence that infill and redevelopment are increasing as a share of total development, at least in some regions. For example, according to one study, 42% of the land currently classified as “urban” in the United states will be redeveloped by 2030 (Brookings Institute, 2004). More recent statistics show a sharp increase in residential redevelopment projects in core cities and inner suburbs of major metropolitan areas, including cities in the Chesapeake Bay watershed (US EPA, 2010b).

The trend is being driven by increasing numbers of urbanites seeking the amenities of city life. This “back to the city” trend is reinforced by surveys of real estate investors that forecast increasing infill and redevelopment activity in coastal cities (ULI, 2010). In any event, the increasing age of existing residential and commercial development in metropolitan areas suggests that much of it will need to be rehabilitated or redeveloped in the future (Jantz and Goetz, 2008).

5-C.3.2. Poor Water Quality in Ultra-Urban Runoff

Some indication of the strength of urban stormwater can be found in **Table 5-C.2**, which compares the event mean concentrations of stormwater pollutants from highly urban watersheds in the City of Baltimore to the national median concentration from the National Stormwater Quality Database (data predominantly from more suburban monitoring stations). As can be seen, median pollutant concentrations from the highly urban watersheds are significantly higher than the national average. Given that highly urban watersheds generate higher stormwater runoff volumes, they discharge greater pollutant loadings than their suburban counterparts, even if their pollutant concentrations are identical (**Figure 5-C.1**).

Table 5-C.2. Comparison of Stormwater Quality Event Mean Concentrations from Runoff

Stormwater Pollutant	Baltimore City	Suburban National Median
Fecal Coliform Bacteria	36,025 MPN/100 ml	5,091 MPN/100 ml
Total Copper	28 ug/l	16 ug/l
Total Lead	64 ug/l	16 ug/l
Total Nitrogen	2.8 mg/l	2.0 mg/l
Total Phosphorus	0.32 mg/l	0.27 mg/l
Oxygen Demand	19.3 mg/l	8.6 mg/l

Source: Baltimore City (Diblasi, 2008) and National Suburban (Pitt et al, 2004)

Figure 5-C.1. Urban Street Dirt Contains Many Harmful Pollutants
Source: Chesapeake Stormwater Network

Highly urban watersheds also deliver very high loads of trash and litter to receiving waters (COB 2006), compared to more suburban or rural watersheds. Increasingly, many cities in the Bay watershed are recognizing that trash is a pollutant in its own right, which strongly influences the public's perception about water quality (or the lack of it) in urban areas. Consequently, several Total Maximum Daily Loads (TMDLs) have recently been issued to reduce or eliminate trash and debris in Baltimore, the District of Columbia, and Montgomery County, Maryland, which now have specific MS4 permit requirements to meet them.

5-C.3.3. Urban Watersheds, Impaired Receiving Waters, and TMDLs

Water quality tends to be poor in the receiving waters of highly urban watersheds within the Chesapeake Bay, as a result of polluted discharges of stormwater and, in some cases, combined sewer overflows. It should come as no surprise that the most polluted receiving waters in the Chesapeake Bay – the Anacostia River, the Elizabeth River, the Inner Harbor, and the Back River – are subject to stormwater discharges from their highly urban watersheds. Monitoring data consistently indicates chronic water quality impairments for multiple pollutants, including bacteria, nutrients, sediment, trash, metals and hydrocarbons. Consequently, most urban receiving waters are listed as being impaired for water quality.

In order to meet water quality standards, localities in these highly urban watersheds are subject to establishment of TMDLs for many of their local streams and rivers. In addition, beginning in 2011, localities will need to prepare local watershed implementation plans to show how they will comply with pollutant reductions specified under the Bay-wide TMDL. In both cases, localities are required to achieve major load reductions from existing development for nitrogen, phosphorus, sediment and other pollutants. The precise reductions needed differ in each community, and in some cases, are still be worked out. However, early estimates indicate that reductions of as much 40% to 90% will be needed for some pollutants.

Reducing pollutants from existing developed areas is difficult and costly, since it usually involves widespread implementation of retrofit practices to treat the stormwater from previously untreated impervious cover, among other restoration strategies. One key strategy that localities should not overlook is the use of more stringent redevelopment stormwater requirements to incrementally treat the quality of runoff from existing, untreated developed land within a community. *Over a period of several decades, such requirements can gradually reduce nutrient and pollutant discharges to urban receiving waters – at very little cost to the community*.

Some indication of the long term potential for treating stormwater from existing impervious cover through a combination of redevelopment stormwater requirements and green street retrofits is exemplified by the spatial projections developed by the Philadelphia Office of Watersheds (**Figure 5-C.1** below). Based on projected trends in redevelopment and green street implementation, the City forecasts that the amount of land treated by effective stormwater practices will increase from 2% to 59% of city land area within three decades.

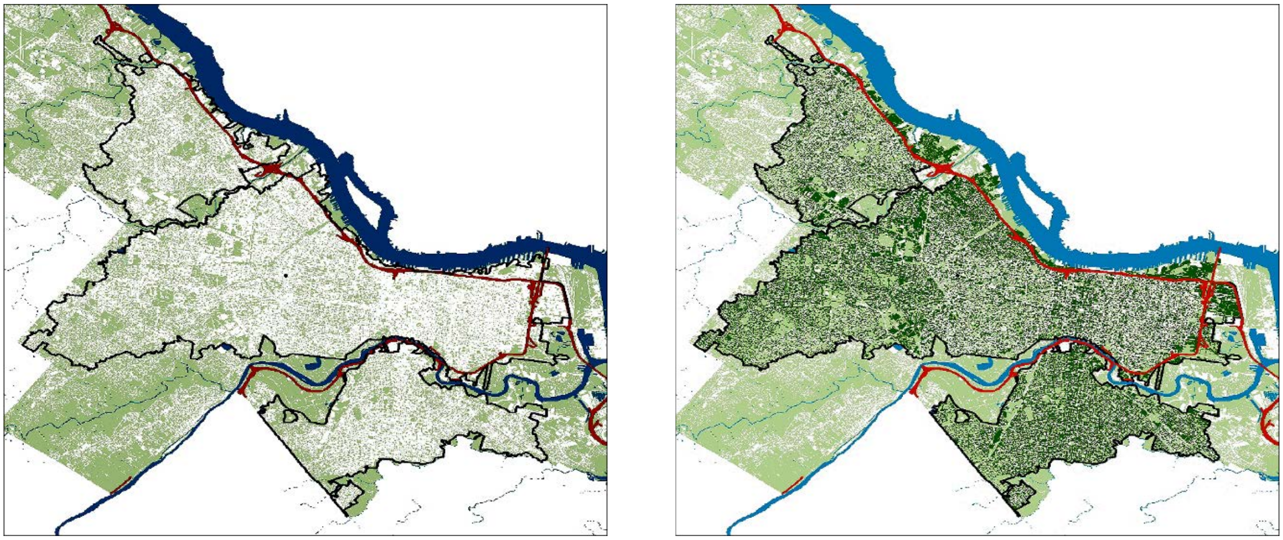

Figure 5-C.2. Starting (left) and Projected Coverage after 30 Years (right) of Redevelopment SWM Requirements, Green Streets and Other Retrofits in Philadelphia, PA
Source: Chesapeake Stormwater Network

While it is doubtful that stringent redevelopment stormwater management requirements alone can eliminate a city's pollutant load liability subject to its established TMDLs (at least with the implementation time frame of the Chesapeake Bay TMDL), they do have the potential to sharply reduce that liability, which could save millions of dollars in capital expenditures for retrofits. In addition, offset fees, recovered when compliance with redevelopment stormwater requirements is not feasible, represent a significant local revenue stream to help finance watershed retrofits.

5-C.3.4. An Alternative Strategy to Abate Combined Sewer Overflows

Many older cities in the Chesapeake Bay watershed have combined sewers that can discharge untreated sewage and polluted stormwater during rainfall events. Examples include the District of Columbia, Alexandria, Richmond, and Lynchburg, Virginia, and Harrisburg, Pennsylvania. Traditionally, combined sewer overflows (CSOs) require extremely expensive treatment devices, such as deep tunnels and swirl concentrators, to store and treat the overflows.

In recent years, however, several cities have realized that LID practices installed at redevelopment sites can sharply reduce stormwater inflows into CSOs, and thereby greatly reduce the frequency and magnitude of overflow events to rivers and estuaries (Limnotech, 2007). The practical benefit is that, by reducing runoff volumes to the combined sewer system, application of LID practices can help reduce the large capital costs associated with CSO abatement. Several examples of cities that are using LID practices as an integral element of their CSO abatement projects include the District of Columbia, Philadelphia, Pennsylvania, Chicago, Illinois, Milwaukee, Wisconsin, and Portland, Oregon.

5-C.3.5. Green Building and the Sustainability Movement

Another driver behind the installation of LID practices in urban watersheds has been the green building movement. Designers that seek LEED certification for their green buildings are awarded points for use of innovative stormwater practices. Other certification systems such as the Sustainable Sites Initiative (ASLA, 2009 – see **Appendix 6-E of Chapter 6** of this Handbook) provide even more incentives to install LID practices, since they reward effective stormwater design solutions applied throughout the site, and not just the building itself. Together, these certification systems provide powerful incentives to create innovative stormwater solutions at redevelopment projects.

The green building movement has been supported by a great deal of research, demonstration and experience with specialized LID practices that are specifically adapted for highly urban areas. These new stormwater practices promote broader sustainability objectives, such as increased energy efficiency, water conservation, greater building longevity, community greening, safer and more walkable communities and more creative architectural solutions.

5-C.4.0. WHY MANAGING STORMWATER IN ULTRA-URBAN AREAS IS CHALLENGING

It is important to clearly understand the challenges and constraints – physical, technological, economic and institutional – that the urban environment imposes on stormwater management at high intensity redevelopment projects. Although the challenges are daunting, they can be overcome if localities craft their stormwater management requirements to reflect the unique conditions and economic realities found at redevelopment sites. To do so, stormwater managers need to fundamentally rethink and reshape the traditional stormwater design paradigm that has been applied to suburban land development.

5-C.4.1. Physical Challenges and Constraints

Site Constraints. Most infill and redevelopment projects are quite small in area and are already highly impervious. As consequence, the use of traditional stormwater practices is often constrained by a lack of space. In addition, designers are often constrained by the invert positions of existing storm drain pipes and the location of existing underground utilities.

Land Costs. The cost of land is frequently at a premium in many urban areas, which makes it problematic to use surface land for the location of stormwater practices. As a result, many cities have traditionally waived stormwater requirements for redevelopment, or required costly underground vaults and filter systems.

Compacted and Polluted Soils. The soils of many urban watersheds have been graded, eroded and reworked by past development, often compacting them to such a degree that runoff cannot be effectively infiltrated. In the most severe cases, legacy problems from past industrial and municipal activity create “brownfields” with soils that are so polluted they must be capped to prevent infiltrating runoff from leaching pollutants and/or further contaminating the soils (US EPA, 2008).

Even sites that are not designated as brownfields can have urban soils that are enriched with trace metals (e.g., lead, zinc, cadmium and copper) as a result of historical air deposition. For example, research in Baltimore has revealed high soil metal levels, particularly in older neighborhoods and adjacent to highways (Yesilonis et al, 2008). Consequently, although infiltration practices are a key tool in runoff reduction, they need to be used with extreme caution in many urban watersheds.

Stormwater Hotspots. In many cases, current or future operations at a proposed redevelopment site can be classified as stormwater hotspots, which produce runoff with higher concentrations of trace metals, toxics and hydrocarbons and/or present a greater risk of spills, leaks or illicit discharges (CWP, 2004). Therefore, it is important to (1) determine whether a redevelopment site has the potential to become a stormwater hotspot, and (2) implement pollution prevention and filtering measures at the site.

Natural Stream Network Is Altered or Buried. Past urbanization often has severely altered, reduced or eliminated the natural stream network (NRC, 2008). This has several implications for redevelopment projects. The urban stream system that remains is often highly degraded and enlarged, and most projects discharge to existing storm drain pipes or conveyance channels rather than streams.

5-C.4.2. Technical Challenges Associated with Redevelopment Practices

Another key challenge is that many of the stormwater technologies used in the suburbs are not applicable to high intensity redevelopment projects. Thus, designers need to shift to alternative practices that are unfamiliar and not fully understood.

Limited List of Effective Redevelopment Practices. Many traditional stormwater practices are extremely space intensive and are of marginal value for many intensive redevelopment projects. Practices such as rooftop disconnections, wet swales, filter strips, grass channels, constructed wetlands, extended detention ponds and wet ponds are seldom feasible for redevelopment projects. Even the new micro-LID practices consume too much land to be effective at high intensity redevelopment projects. In general, the list of practices that are feasible for use at redevelopment sites diminishes sharply in response to increasing impervious cover, as shown in **Table 5-C.3** below, especially when imperviousness exceeds 85% of the site area.

Limited Design Guidance for Redevelopment. Most state stormwater manuals are inherently biased toward suburban and exurban development situations. Most devote only a few paragraphs or pages on how to manage stormwater in redevelopment situations. More importantly, they often lack detailed specifications and design examples for the specialized practices that do work in ultra- urban watersheds. This new Handbook and the new Virginia Stormwater Best Management Practice Design Specifications provide much more helpful information applicable to redevelopment situations. This Appendix is intended to bridge the information gap even more.

Table 5-C.3. Effect of Redevelopment Intensity on Stormwater Practice Selection

Post-Development Impervious Cover (IC) at the Site			
Less than 40%	**40 to 65%**	**66 to 85%**	**85 to 100%**
Alternate Surfaces	Alternate Surfaces	Alternate Surfaces	Alternate Surfaces
Landscaping-ESD	Landscaping-ESD	Landscaping-ESD	Landscaping-ESD
IC Reduction	IC Reduction	IC Reduction	
Micro-ESD	Micro-ESD		
Disconnections			
Ponds			Underground Sand Filters

Note: These are generalized recommendations, from which some redevelopment sites may depart
Key:
Alternate surfaces = vegetated roofs and permeable pavement
Landscaping ESD = foundation planters, expanded tree pits, urban bioretention and green streets
IC Reduction = conversion of pre-existing *impervious* cover to hydrologically functional *pervious* cover
Micro-ESD practices = space intensive practices such as micro-infiltration, bioretention, grass channels, wet swales, bioswales etc.)
Disconnections = disconnecting impervious surfaces and treating them in a grass filter path
Ponds and Wetlands = conventional detention and retention designs

Lack of Experience with Ultra-Urban Practices. Surveys indicate that many designers and plan reviewers in have little or no experience in designing the practices that are most appropriate for redevelopment projects. For example, CBSTP (2010) surveyed more than 200 stormwater professionals in the Chesapeake Bay watershed and found the following:

- 70% had never designed a vegetated roof
- 60% had never designed a rainwater harvesting system
- 65% had no experience with soil amendments or impervious cover conversion
- 45% had never designed permeable pavements or dry swales

Designers probably have even less experience with various forms of urban bioretention and green streets, although the survey did not address those practices. The limited use of effective redevelopment practices can be explained by several factors. First, they often require specialized design consultants, unique construction materials or experienced installation contractors. Second, many of the preferred practices also require greater and earlier coordination with architects and site designers. Finally, many designers express reluctance to use preferred practices due to perceived concerns about the cost, maintenance requirements, practice longevity, and the ability to get projects approved.

5-C.4.3. Redevelopment Economics

Another key challenge is the cost and feasibility of complying with stormwater requirements in redevelopment settings.

***Higher Cost of Compliance*.** The cost of constructing LID practices at redevelopment projects in highly urban settings (85% or more IC) can be four times more expensive ($191,000 per impervious acre) than installing them at low density new development projects (25% IC or less – $46,500 per impervious acre), where more land is available (CSN, 2011). It should be noted that there is not much difference between the construction costs for stormwater management at less intensive redevelopment projects (i.e., less than 65% IC) and the costs at greenfield projects, since a wider range of cost-effective LID practices can be employed in both scenarios (CSN, 2011).

The alternative approach is to provide underground stormwater treatment, using sand filters or vaults. The underground approach is also extremely expensive, compared to surface treatment at greenfield development sites. The cost of stormwater compliance for underground practices is roughly equivalent to the cost of installing LID practices at high-intensity redevelopment projects, according to a recent study in the District of Columbia (Leistra et al, 2010).

***Difficulty in Compliance*.** Full compliance with more stringent stormwater requirements cannot always be achieved at high-intensity redevelopment projects due to space and feasibility constraints. Developers have argued that this may stop desirable redevelopment projects or require unacceptable reductions in project density. Consequently, it is important to have a “safety valve” (e.g., offset fees or other options for off-site compliance) to allow the projects to proceed when full compliance is not physically feasible or are prohibitively expensive.

Smart Growth Considerations. When viewed from a watershed or regional perspective, high-density redevelopment is considered an essential element of smart growth, green infrastructure and sustainable cities. The common theme is that increased density and land use efficiency are desirable in urban watersheds (USEPA, 2005 and NRC, 2008). The use of scarce land for surface stormwater treatment, the high cost of LID practices, or the inability to fully comply with stormwater requirements all have the potential to act as barriers to smart growth. Localities need to craft creative and flexible stormwater policies to prevent this from happening.

5-C.4.4. Institutional Challenges

The last redevelopment challenge is an institutional one. Few communities have much experience with managing stormwater at high intensity redevelopment sites. Most have traditionally waived, exempted, relaxed or otherwise reduced stormwater requirements for redevelopment projects (e.g., Virginia’s redevelopment requirement to reduce the pre-development total phosphorus load by 10-20% is easier to comply with than the requirement applied to a new development site).

The key point is that many communities do not yet have a strong culture of stormwater implementation. Thus, they are somewhat reluctant to adopt innovative LID practices. The culture will hopefully change as more stringent redevelopment requirements evolve in the coming years, but this will require a major shift by stormwater review agencies. However, the fact that there are many challenges confronting stormwater managers is not meant to imply that stormwater treatment should be avoided at high-intensity redevelopment sites. Rather, these challenges demonstrate the need to craft effective stormwater solutions that are specifically tailored to the unique conditions and economic realities found at redevelopment sites. The traditional suburban stormwater design approach needs to be fundamentally reworked to address the challenges of redevelopment.

5-C.5.0. UNIQUE STORMWATER DESIGN APPROACH FOR REDEVELOPMENT PROJECTS

Since the conventional stormwater design approach employed at greenfield sites does not work in ultra-urban watersheds, the approach needs to be extensively modified to meet the challenges of redevelopment sites. This section presents some guiding principles for the design of stormwater practices at high intensity redevelopment projects.

5-C.5.1. Understand the Watershed Context

At greenfield sites, designers don't need to know much about the watershed in which the project resides (**Figure 5-C.3**). They may have to deal with special watershed performance standards, or address issues specific to the site, such as floodplain impacts. However, most of the stormwater management solutions are implemented within the confines of the development site.

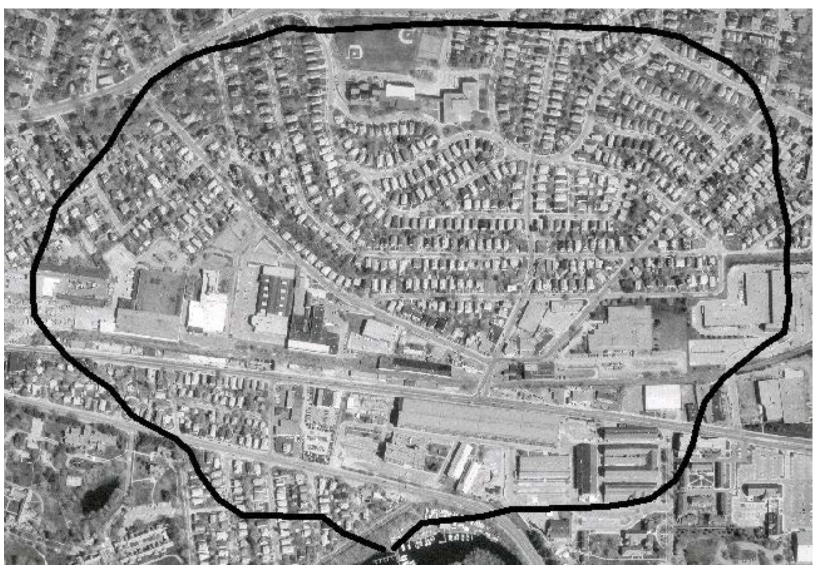

Figure 5-C.3. An Urban Drainage Shed
Source: Chesapeake Bay Stormwater Training Partnership

The situation is much different for redevelopment projects. Designers must fully understand the urban watershed context in which their redevelopment site is located. At a minimum, the designer should be able to address the following watershed questions, and incorporate the specific answers into their stormwater design for the redevelopment site.

- ***Does the redevelopment project discharge to a receiving water that is impaired?*** If so, what is the specific pollutant(s) of concern causing the impairment? The pollutant of concern often dictates which pollutant removal mechanisms should be optimized in the design of stormwater practices.

- ***Is the project located in a watershed served by combined or separate sewers?*** If the project is located in a CSO watershed, the designer will want to maximize runoff volume reduction to minimize the amount of stormwater runoff that might enter the combined sewer system. This is particularly relevant if the community is subject to a consent decree or long-term control plan to reduce CSP discharges.

- ***What is the average age of development in the watershed?*** Stream systems in older watersheds (e.g., 70+ years) often have progressed through the entire cycle of channel incision/enlargement and have achieved a new level of channel equilibrium or stability. However, if the average age of watershed development is just a few decades, it is likely that that the watershed may still be experiencing stream degradation. Such conditions would demand more runoff volume reduction, channel protection or downstream channel rehabilitation (Schueler, 2004).

- ***What is the habitat condition and aquatic diversity of the receiving stream? Or has aquatic habitat and life been eliminated altogether?*** As noted earlier, many streams in highly urban watersheds have been degraded, altered or buried by past development. Therefore, the current health and restoration capacity of the receiving stream is an important factor in stormwater design for redevelopment. If the stream has been eliminated or interrupted, which frequently occurs when watershed IC exceeds 60% (Schueler et al, 2009 and CWP, 2003), then designers may want to shift their focus from maximizing runoff volume reduction toward increasing water quality treatment. However, if the redevelopment site discharges to a stream segment that is still in fair or good condition, the designer should definitely select practices that maximize runoff volume reduction.

- ***Does the existing stormwater conveyance system or floodplain have enough hydraulic capacity to safely convey large flood events?*** Most urban watersheds are prone to flooding due to aging or undersized stormwater infrastructure. If a redevelopment site discharges to an area that experiences chronic or historical flooding problems, designers may want to manage larger storms to prevent increased peak flows and reduce flooding.

- ***Is there a watershed restoration plan that contains off-site options for stormwater retrofits and stream restoration?*** If so, such projects may offer a cost-effective watershed-scale solution, in the event that full compliance at the redevelopment site is either not feasible or prohibitively expensive.

5-C.5.2. Conduct a Site History Investigation

Green-field sites require very little in the way of site history investigations, apart from some limited geotechnical data. Redevelopment projects, on the other hand, frequently require special environmental site assessments to evaluate soil conditions and determine whether the site is subject to brownfield remediation requirements. The assessments typically involve a site history investigation, soil testing and groundwater analysis to determine whether a site cleanup or remediation is needed (US EPA, 2001). Stormwater designers can use site history investigations to determine the following:

- Whether or not stormwater infiltration should be encouraged or discouraged
- Whether soils are contaminated and need to be capped
- Whether existing utilities will constrain stormwater design
- Whether the existing conveyance system has adequate hydraulic capacity
- Whether the depth to groundwater will influence the design of stormwater BMPs
- Whether historical drainage paths can be used to treat runoff

The results of these investigations can also be extremely helpful in determining the best locations for LID practices and how they can be connected together as an effective system (i.e., treatment trains). Additional stormwater guidance for brownfield sites can be found in USEPA (2008).

5-C.5.3. Environmental Site Design in the Urban Context

Many of the original principles of Environmental Site Design were crafted in the context of low density suburban development (CWP, 1998). These principles need to be adapted to meet the unique constraints of the urban built environment, where the objective is often to maximize development intensity for the sake of land use efficiency (CWP, 2001). In particular, the goal of urban better site design may not be to reduce impervious cover, but rather to promote greater density and sustainability (i.e., smart growth). Some of the key principles of urban environmental site design include the following:

- Innovative urban parking management solutions (COE, 2005)
- Municipal green street specifications (SMC, 2009)
- Context-sensitive road design standards to provide stormwater treatment in right-of-way (MC, 2008)
- Modification of traditional streetscape standards to use street trees as a stormwater filtering device (COPO, 2008 and Cappiella et al 2006)
- Changes in plumbing codes to allow or incentivize the use of rainwater harvesting systems
- Reducing parking demand through mass transit or shared or structured parking (CWP, 2001)
- Integration of stormwater treatment into site landscaping (COPO, 2008)
- Green area zoning ordinances that set minimum thresholds for functional green cover for various building zones and incentives LID practices (Parker, 2010)

The key to implementing urban environmental site design is to conduct a comprehensive review local land development codes, ordinances and regulations to make specific code changes or interpretations that enable the use of stormwater control measures that are most effective for urban redevelopment projects. **Appendix 3-C of Chapter 3** of this Handbook provides example Code and Ordinance review checklists for this purpose. Some of the more notable areas of local codes to investigate include the following:

- Plumbing codes (to permit rainwater harvesting systems and set water quality standards for end use)
- Building codes (to allow vegetated roofs)
- Public space restrictions that may impeded green street opportunities
- Road codes (to allow and promote green streets)

- Landscaping codes (to promote foundation planters)
- Urban street tree requirements (to allow for expanded tree pits)

A good example of a comprehensive local code review to promote more effective use of stormwater practices can be found in the report and recommendations of such a review conducted for Montgomery County, Maryland (Biohabitats, 2010). As well, numerous Virginia localities have conducted local codes reviews. The DEQ can provide examples of useful local code language resulting from these reviews.

5-C.5.4. Identify Potential Hotspot Generating Areas

Designers should review future site operations and activities at the redevelopment site to identify potential stormwater hotspot generating areas (HGAs), such as is depicted in **Figure 5-C.4**. HGAs may entail loading/unloading areas, fueling and vehicle cleaning areas, outdoor storage areas, exposed dumpsters and compactors, and outdoor maintenance areas, and usually involve only a fraction of the total redevelopment site.

Figure 5-C.4. Potential Hotspot Generating Area
Source: Chesapeake Bay Stormwater Training Partnership

If HGAs are present at the redevelopment site, their contributing drainage areas should be isolated from the remainder of the site (usually by grading and drainage control) so that their runoff can be fully treated by a stormwater filtering practice to prevent toxic discharges to surface waters or groundwater. In other cases, hotspots should be covered by a roof to prevent exposure to rainfall or runoff. In all cases, employees should be trained on routine pollution prevention measures that must be employed at the site (see CWP, 2004).

Designers should also evaluate future activities at the proposed redevelopment site to determine if there is a risk of it becoming a *"trash" hotspot*. Trash is a significant problem in some communities that there have been TMDLs established with trash as the principle impairment. It is important to keep in mind that trash loads are not distributed equally across urban watersheds. Indeed, research has shown that higher trash loads are generated by unique land uses, commercial areas, areas of high development intensity, areas of heavy pedestrian or vehicular traffic, and areas with certain population demographics (Marias et al, 2004 and EOA, 2007). The practical implication of high trash loads is that they can interfere with the performance of stormwater practices and create a need for more pre-treatment and more frequent cleanouts.

5-C.5.5. Real Impervious Cover Reduction

Designers have a strong incentive to reduce existing impervious cover at redevelopment sites. It is possible that full stormwater compliance may be achieved by reducing the existing IC at the redevelopment site by 20% to 50%. Even a smaller reduction can sharply reduce the size and cost of stormwater control measures for the redevelopment project (**Figure 5-C.5** below).

It is important, however, to ensure that the conversion of impervious cover is *real*. Designers should ensure that impervious cover is not only reduced on the site plan, but is actually restored to a truly pervious condition on the ground. The new pervious cover should perform hydrologically as if it were uncompacted grass and, ideally, the area should be used to filter some runoff from remaining hard surfaces.

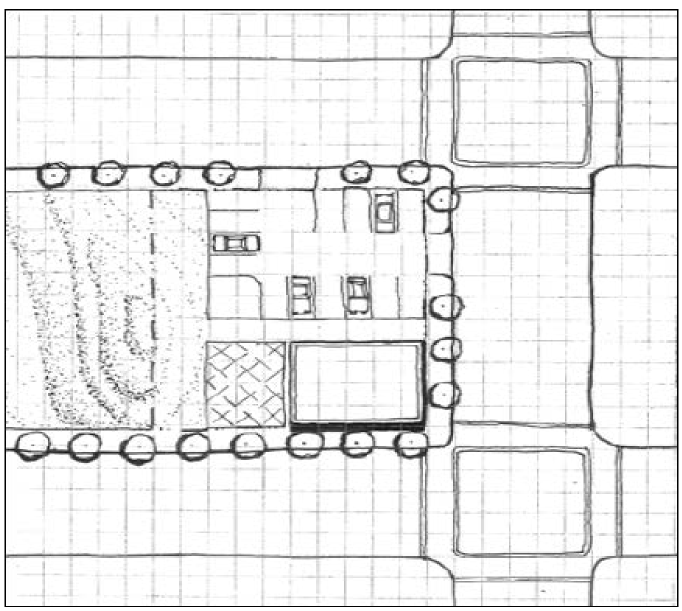

Figure 5-C.5. Sketching In Conversion of Impervious Cover to Pervious Cover and Adding Tree Canopy
Source: Chesapeake Bay Stormwater Training Partnership

The new pervious areas at redevelopment sites are likely to be extremely compacted and could still generate high volumes of stormwater runoff and attached nutrients. Consequently, designers may need specify that the area must be graded, deep-tilled and the soils amended with compost or other materials to increase the porosity and water holding capacity of the pervious area. In many cases, runoff from adjacent rooftops can be effectively disconnected and directed over these “improved” pervious areas. More specific design guidance on impervious cover reduction techniques can be found in **Section 5-C.6** of this Appendix.

5-C.5.6. Delineate the Site into Smaller Treatment Units

Even with the recent shift to LID practices, most greenfield development projects still plan around larger drainage areas, typically ranging from 20,000 to 100,000 square feet per practice. By contrast, the drainage area of many preferred redevelopment practices is much smaller. In general, designers need to delineate or break up redevelopment sites into smaller areas of about 5,000 to 20,000 square feet that serve individual units of surface cover (e.g., roofs, pedestrian areas, streets, open space and parking lots).

A unique LID solution should then be designed for each small unit. In this manner, stormwater practices are directly integrated into the design of buildings, parking lots and streetscapes. This avoids the need for underground structures or consumption of costly surface real estate. **Figure 5-C.6** graphically illustrates creative integration of multiple LID practices at dense urban redevelopment sites.

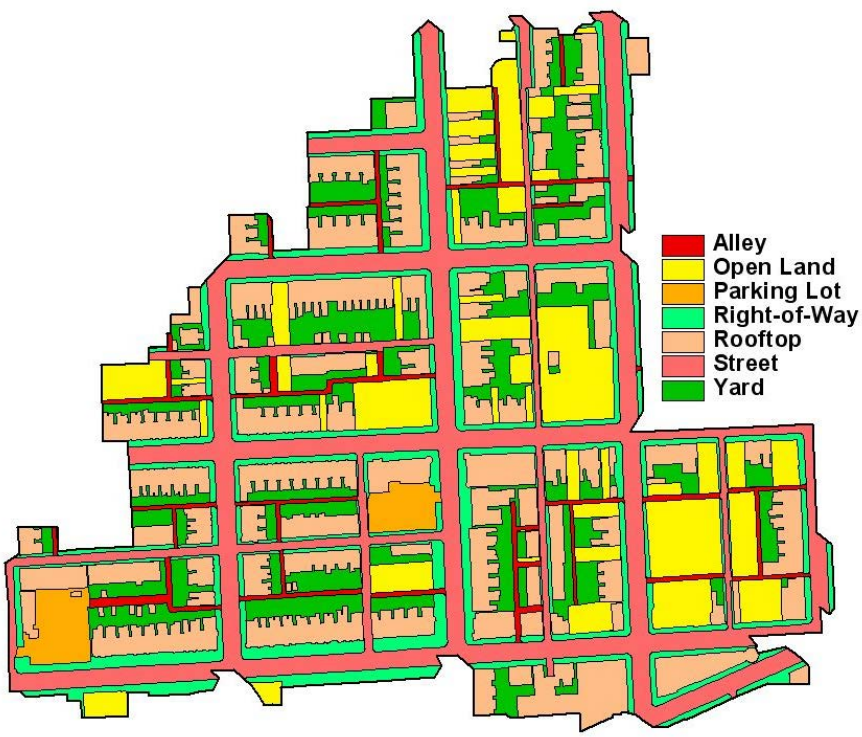

Figure 5-C.6. Decompose the Site into Smaller Drainage Units
Source: Chesapeake Bay Stormwater Training Partnership

The Virginia Runoff Reduction Method spreadsheet tool helps designers optimize the most appropriate LID practices for redevelopment sites (VA DCR, 2009). The City of Philadelphia and others have also developed a series of checklists and worksheets that achieve the same purposes (COPH, 2008 and COE, 2005). Urban communities in the Bay watershed can easily modify these spreadsheet tools to meet their unique redevelopment conditions.

5-C.5.7. Using "Roof to *Street*" Designs

The preferred stormwater approach in a greenfield development is to sequence LID practices (i.e., treatment trains) in pervious areas on the drainage pathway from the roof to the *stream*. Due to the typical space constraints, this design approach is less practical for redevelopment sites. Consequently, designers need to integrate a sequence of LID practices *within* the built environment, exploiting opportunities from the roof, the building walls, the streetscape and the street itself. The basic "roof to street" design approach uses the following principles to manage runoff:

- Manage rooftop runoff through vegetated roofs, rainwater harvesting, disconnection or storage-and-release from foundation planters. Where possible, use captured water for landscape irrigation, water features and fountains.
- Minimize surface parking and design it to reduce, store and treat stormwater using permeable pavements, bioretention or sand filters (SMC, 2009).
- Design urban hardscapes such as plazas, courtyards and pedestrian areas to store, filter and treat runoff using permeable pavements, stormwater planters and amenity bioretention areas.
- Ensure that all pervious and landscaping areas in the redevelopment project are designed for effective stormwater treatment using practices such as soil restoration, reforestation, and bioretention.
- Design the streetscape to minimize, capture and re-use stormwater runoff by using expanded tree pits, streetscape bioretention, curb cut extensions and other "green street" practices (COPO, 2008, COPH, 2008 and SMC, 2009).

5-C.5.8. Maximize Forest Canopy and Restore Natural Area Remnants

Conserving forests and natural areas is a key site design strategy for greenfield developments. However, much of the existing natural areas at redevelopment sites has been lost or degraded by past development. Therefore, a more restoration-oriented strategy is needed in urban watersheds to increase forest canopy and improve the hydrological function of natural areas.

The extent of forest cover that remains in urban watersheds is surprising – recent GIS studies have shown than urban cities in the Chesapeake Bay region have forest canopy ranging from 20% to 45% of their total area (CWP and USFS, 2009). Urban forests, forest fragments and even individual street trees provide ecosystem services, particularly when the forest canopy is located above or adjacent to hard surfaces. The amount of stormwater retained by tree canopy interception is impressive for the smaller storm events that most influence stormwater quality (American Forests, 1999 and 2002).

Stormwater managers now understand that significant stormwater benefits can be realized when they maintain and expand the extent of urban forest canopy to take advantage of the natural stormwater volume reduction and pollutant filtering that trees afford (see **Figure 5-C.7** below). In the past five years, dozens of cities and counties across the Chesapeake Bay watershed have established numeric goals to increase the extent of urban tree canopy within their jurisdictions (CWP and USFS, 2009).

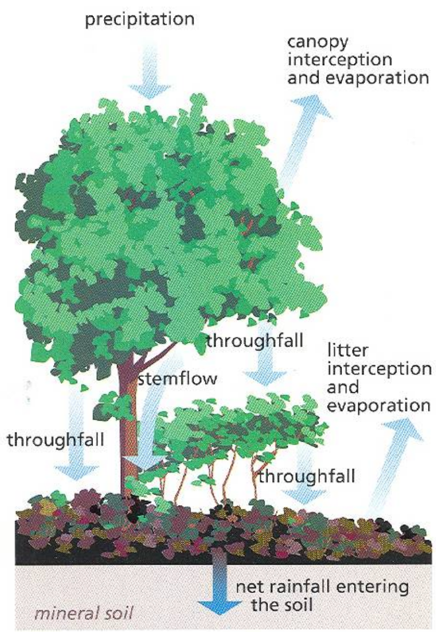

Figure 5-C.7. Hydrologic and Water Quality Benefits of Tree Canopy
Source: Chesapeake. Bay SW Training Partnership

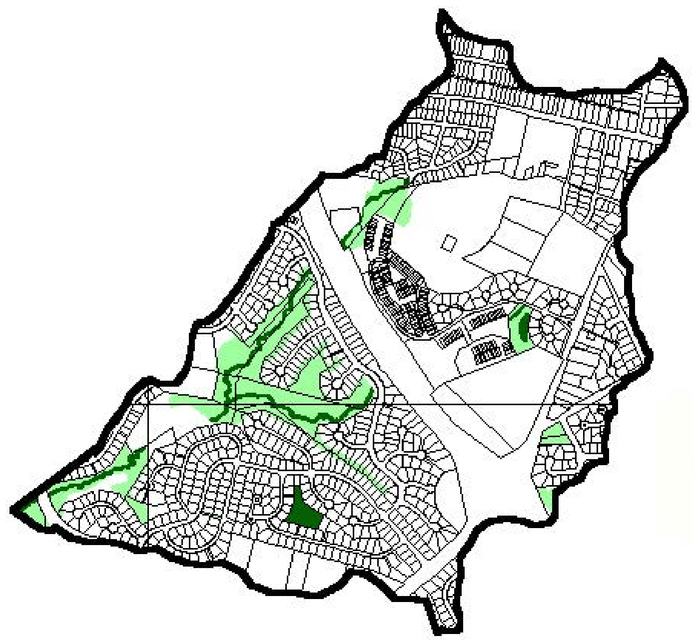

Figure 5-C.8. Identify Wetland and Natural Area Remnants for Restoration
Source: Chesapeake Bay SW Training Partnership

Increasing the extent of the existing forest canopy at redevelopment projects can provide incremental stormwater treatment. This may involve installation of expanded tree pits in the sidewalk zone, urban reforestation, and perhaps even stormwater credits for street trees (e.g., runoff volume reduction per tree planted). Useful guidance on techniques for integrating trees into urban stormwater practices is provided by the Center for Watershed Protection (Cappiella et al, 2005 and 2006). In addition, funds recovered from stormwater offset fees can be systematically used to increase forest canopy across a community or urban watershed.

Natural area fragments and wetlands typically constitute a small fraction of urban watershed area, due to historical losses from past development, filling and draining. Remnant natural areas tend to be highly degraded due to impacts from stormwater, invasive species and other urban stressors. Even so, natural area remnants are a critical component of the urban ecosystem. If urban wetlands or natural area remnants are present at a redevelopment site, it is important to restore their quality, diversity and hydrologic function as green infrastructure (**Figure 5-C.8** above). If wetland restoration is feasible at a redevelopment site but stormwater treatment is not, restoration could be considered an acceptable substitute.

5-C.5.9. Careful Urban Infiltration and Recharge

It is possible to get a good sense about soil properties at greenfield projects by simply analyzing soil surveys and a taking a few borings. The basic idea is to find the most permeable soils that allow for runoff infiltration. By contrast, very little is known in advance about the soils located in high intensity redevelopment sites. These sites require much greater investigation to determine whether they are suitable for infiltration or pose a contamination risk.

The primary reason is that most redevelopment projects are located over urban fill soils. Past development has destroyed their original soil structure, and compaction has greatly reduced their infiltration capacity. Most soil surveys simply refer to these as “urban soils”, which are defined as soils that have been mass-graded and/or significantly cut or filled in past cycles of land development.

Soil scientists have only recently begun to study and classify urban soils (Effland and Pouyat, 1997). They caution that it is hard to generalize about urban soils, since they are quite variable in their properties and hydrological response. At one extreme might be a site that has undergone several cycles of grading to a depth of a few dozen feet, with large additions of unknown or rubble fill, a high risk of past soil contamination and extreme surface compaction. The other extreme might be a residential site that experienced only minor grading and whose soils still retain some of their original permeability.

Despite this variability, urban soils are clearly different from their suburban and rural counterparts. Urban soils are more compacted, have a higher bulk density (often close to that of concrete – see **Figure 5-C.9**), and are enriched with trace metals which may exceed the EPA sediment soil screening guideline (Yesilonsis et al, 2008 and Pouyat et al, 2007).

Figure 5-C.9. Compacted Urban Soil
Source: Chesapeake Bay Stormwater Training Partnership

The hydrologic properties of urban fill soils are also markedly different from undisturbed areas. As a general rule, urban soils produce greater runoff volumes and discharge rates and lower infiltration rates than the same soil types in an undisturbed condition. While the USDA-NRCS cautions that urban soils cannot be assigned to any hydrological soil group (HSG), most practitioners assign them to HSG "D", which has the greatest runoff and least infiltration response. The New Jersey Department of Environmental Protection (NJDEP, 2009) recommends that urban soils be assigned a default HSG of D as well, unless specific on-site soil testing indicates a higher infiltration rate.

The key management question is whether it is advisable to infiltrate runoff into urban fill soils. As a general rule, infiltration of stormwater runoff should be done with extreme caution at redevelopment projects, given the degree of past soil compaction and pollution in urban watersheds. Some practitioners advise against infiltration, since groundwater pathways are poorly understood and could cause unintended damage to adjacent building foundations and underground infrastructure. Other practitioners recommend prohibiting infiltration at sites that are designated as stormwater hotspots and brownfields in order to minimize the risk of groundwater contamination. Yet other practitioners advocate for some degree of infiltration at certain redevelopment sites in order to recharge the depleted aquifers found in urban watersheds.
To reduce confusion, the Department proposes a four tiered set of infiltration restrictions, based on the redevelopment site history and on-site soil testing, as shown in **Table 5-C.4**, and described in the bulleted points below:

Table 5-C.4. Redevelopment Conditions and Infiltration Restrictions

Infiltration Restriction Tier	Site History or Condition	Risk	Infiltration Restriction
Tier 1	Undisturbed soils	Small risk of damage to underground infrastructure and foundations.	Infiltration encouraged, but confirm infiltration rates and respect setbacks.
Tier 2	Site was previously mass-graded and classified as Urban Fill Soils	Geotechnical concerns exist. Prior compaction suggests poor infiltration rates. Unsure of underlying soil quality and leaching risk.	**Unless on-site testing proves otherwise [1],** avoid intentional infiltration and use "closed" practices that do not interact w/ groundwater (e.g., sand filters, green roof, and rain tanks).
Tier 3a	Site is designated as a Potential Hotspot	Polluted stormwater can contaminate groundwater.	Treat at least half of the treatment volume in a closed practice prior to infiltration.
Tier 3b	Site is expected to be a Severe Hotspot	Polluted stormwater, spills, leaks and illicit discharges are likely to contaminate the groundwater.	Avoid intentional or unintentional infiltration, and used closed practices.
Tier 4	Site is designated as a brownfield	Infiltration increases the risk of pollutants leaching from contaminated soils	Install a cap or liner, and ensure that no intentional or unintentional infiltration occurs across the affected area.

[1] The recommended guidance for evaluating and testing urban soils can be found in Appendix E of the New Jersey Stormwater Manual (NJDEP, 2009)

- The *first tier* involves cases where existing soils appear relatively undisturbed and have been subject to only minor grading and surface compaction in the past. Examples might include older residential neighborhoods or institutional developments, or areas where recent USDA-NRCS soil surveys indicate the presence of permeable soils. In these cases, basic infiltration tests should be conducted to see if intentional infiltration is feasible. Stormwater control measures that result in unintentional infiltration are also permissible. Designers should still be mindful of standard setbacks to building foundations and underground infrastructure when locating infiltration practices.

- The *second tier* involves cases where soils are classified as urban fill or equivalent (e.g., urban land, cut and fill, or made land). In this situation, the decision to infiltrate or not is based on detailed on-site soil testing. The Department recommends using the protocols and soil test methods employed by Fairfax County, Virginia or the New Jersey Department of Environmental Protection (NJDEP, 2009). If the testing indicates the soils have acceptable infiltration rates throughout the entire soil profile and there are no signs of suspicious materials, then the site can be considered suitable for infiltration. If the soil tests are negative, then infiltration should be avoided, and closed LID practices or sand filters should be used as an alternative. Some unintentional infiltration through under drains may be permissible if soil quality is reasonably good.

- The *third tier* involves cases where a proposed redevelopment site is expected to become a potential or severe stormwater hotspot. A *potential hotspot* is considered a redevelopment site where there is minor risk of future spills, leaks or illicit discharges (e.g., a convenience store, fast food restaurant, dry cleaning establishment, car dealership, etc.). The stormwater strategy at these potential hotspots is to treat one half of the water quality volume with a filtering practice prior to any on-site infiltration. *Severe hotspots* include redevelopment projects where future activities or operations will have a significant risk of harmful spills or leaks and/or generate more polluted runoff. Infiltration of any kind (intentional or unintentional) should be avoided at these sites.

- The *fourth tier* involves cases where the site history investigation indicates that the redevelopment site is a brownfield, in which infiltration is prohibited (US EPA, 2008). Contaminated soils should be capped and stormwater BMPs should treat surface runoff in a "closed" system which does not allow any interaction with groundwater. This typically involves the use of stormwater filtering practices (e.g., sand filters and bioretention) that have impermeable bottom liners. Designers should also avoid practices that cause *unintentional infiltration* through the soil (e.g., bioretention or permeable pavement with an underdrain that allows for modest soil infiltration).

Infiltration can be an important strategy to meet runoff reduction requirements in urban areas. Each community should provide clear guidance and test procedures to evaluate risks and protect against the mobilization of legacy contaminants.

5-C.5.10. Establish an Appropriate Offset Fee

It is almost always possible to comply with stormwater requirements at greenfield development projects, because there is enough surface land to locate cost-effective stormwater BMPs. By contrast, full compliance at some high intensity redevelopment projects may never be physically or economically feasible, at least without sacrificing land use efficiency. Therefore, it is important to develop an offset program to handle these special cases.

The Virginia SWM Regulations allow communities to establish and administer a stormwater offset fee in cases where it is not feasible or cost effective to achieve full compliance at the development or redevelopment project site. Criteria for local offset programs and fees are set forth in § 9 VAC 25-870-60 of the regulations. Localities need to examine their development intensity, retrofit possibilities, land prices and redevelopment incentives and factor these into the offset program parameters.

The floor for the offset fee should be priced no lower than the equivalent cost to retrofit suburban greenfield development (the Chesapeake Stormwater Network estimates about $ 32,500 per untreated impervious acre). Offset fees in this range can ensure that the costs of on-site compliance do not become an impediment to redevelopment and smart growth. The funds collected from the offsets can then be used to finance effective stormwater retrofit and restoration projects elsewhere in the same watershed.

5-C.6.0. SELECTING STORMWATER PRACTICES FOR HIGH-DENSITY REDEVELOPMENT PROJECTS

This section compares the range of possible stormwater practices in the context of their applicability to high-intensity redevelopment projects and classifies them as preferred, acceptable, restricted or marginal (**Table 5-C.5** below). The technical basis for the classification of stormwater practices is detailed in the notes in this Table. Since every redevelopment site is unique, the classification should be considered a starting point, not an ending point.

The remainder of this section outlines some core design guidance to consider regarding stormwater redevelopment practices. This is not exhaustive guidance, but instead is intended to show how these critical strategies can be applied. In addition, several strategies are recommended to improve the acceptance and adoption rates of preferred stormwater practices. The Virginia Stormwater BMP Design Specifications referred to in the following discussions can be found at the following website:

http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

5-C.6.1. Preferred Redevelopment Stormwater Management Practices

5-C.6.1.1. Impervious Cover Conversion

This involves the removal of existing impervious cover at a redevelopment site, followed by soil restoration such that the new pervious area performs hydrologically as if it were uncompacted grass and filters runoff from adjacent hard surfaces. Impervious cover conversion is preferred since it is a relatively low-cost way to change the hydrologic response of a redevelopment site without having to install a structural practice.

Table 5-C.5. BMP Selection for High-Density Redevelopment Projects

Preferred [1]	Acceptable [2]	Restricted [3]	Marginal [4]
Impervious Cover Conversion	Sand Filters	Infiltration	Ponds & Wetlands
Green Roof and Rain Tanks	Bioretention	Proprietary Practices	Wet Swales
Rain Tanks and Water Reuse	Urban Tree Planting	Dry Wells	Grass Channels & Filter Strips
Permeable Pavers [5]	Dry Swales		
Foundation Planters	Restore Natural Area Remnants		
Extended Tree Pits [6]			
Green Street Retrofits [6]			
Soil Restoration & Reforestation			

[1] Provide significant on-site runoff reduction and are ideally suited for most redevelopment projects.
[2] An acceptable design solution for many redevelopment sites if some surface area is available or if infiltration restrictions require use of filtering practices (i.e., sand filters).
[3] Use of these practices may be limited due to urban infiltration restrictions or inadequate runoff reduction capability (i.e., proprietary practices).
[4] These practices can seldom be applied at high-intensity redevelopment projects because they are too space- intensive and/or consume too much land. There may some rare situations where they can be used to comply.
[5] Permeable pavement can be designed with under drains if located in an urban infiltration restricted area.
[6] These practices often require special permission of approvals from municipal agencies.

Barriers to Overcome. The main barrier is that designers and site planners currently have little or no experience with this concept and with the practice of amending soils.

Design Criteria. Impervious cover conversion is credited by improving the composite runoff coefficient in the Virginia Runoff Reduction Method calculations, as the land cover is changed from IC to managed turf or forest cover over a permeable hydrologic soil group. The following design criteria are proposed for impervious cover conversion:

- The minimum surface area to consider for impervious cover conversion credit should be 250 square feet.
- Site plans should show the specific areas where concrete or asphalt will be removed. Ideally, the concrete or asphalt should be recycled.
- Underlying compacted soils should be deep-tilled (**Figure 5-C.10**) and amended with compost to restore porosity, using the methods outlined in the Virginia Stormwater Design Specification No. 4, *Soil Compost Amendment*.

Figure 5-C.10. Deep Tilling Urban Soil
Source: Chesapeake Bay Stormwater Training Partnership

- The new pervious area should be graded to accept runoff from adjacent hard surfaces.
- The designer can receive additional treatment credit for the new pervious area if it is designed to accept runoff from adjacent impervious areas.
- The pervious area should be planted with an acceptable vegetative cover, which reflects landscaping objectives and anticipated future uses at the redevelopment site.
- The conversion should be permanent, and accompanied by a recorded deed restriction or covenant that specifies that the area cannot be built on or otherwise compacted in the future.
- The BMP maintenance agreement must specify that the vegetative condition of the pervious area shall be regularly inspected and must be regularly maintained to ensure that no soil erosion is occurring.

5-C.6.1.2. Vegetated Roofs

Vegetated Roofs (also known as *green roofs*, *living roofs* or *eco-roofs*) are alternative roof surfaces that typically consist of waterproofing, drainage materials and an engineered growing media that is designed to support plant growth (**Figure 5-C.11** below). Vegetated roofs capture and temporarily store stormwater runoff in the growing media before it is conveyed into the storm drain system. A portion of the captured stormwater evaporates or is absorbed by the plant roots, which helps reduce the runoff volume, peak runoff rate, and pollutant load from a development site.

Figure 5-C.11. Vegetated Roofs in an Urban Area
Source: Chesapeake Bay Stormwater Training Partnership

The most common design is the *extensive* vegetated roof system, which has a shallow growing media (4 to 8 inches deep) planted with carefully selected drought-tolerant vegetation (e.g., sedum, etc.). By contrast, *intensive* systems have a deeper media layer and can support a wider range of plants, including shrubs and small trees.

Why Is It Preferred? Vegetated roofs are preferred because they incorporate stormwater treatment directly into the architecture of the building, which eliminates the need to consume other land surface on the site. They provide modest levels of runoff reduction, and can be a major compliance element at many high intensity redevelopment sites. Their initial high installation cost is compensated for by long-term savings in energy consumption and roof longevity (i.e., lower life-cycle costs). Recent research indicates that buildings with vegetated roofs command a significant rental premium compared to traditional buildings (Ichihara and Cohen, 2011).

Barriers to Overcome. Several real and perceived barriers need to be surmounted to achieve wider implementation of vegetated roofs in Virginia. The single greatest barrier, by far, revolves around perceptions about high construction cost, which makes designers reluctant to consider them. Also, not all buildings are good candidates for vegetated roofs, since they require an informed and engaged building owner to provide the necessary maintenance.

Design Criteria are provided in Virginia Stormwater Design Specification No. 5, *Vegetated Roof*. The main difficulty is that there is no such thing as a generic vegetated roof. Each vegetated roof contractor has his/her own unique recipe of vegetated roof components, which need to be adjusted depending on the nature of the planned roof. Also, the average stormwater designer cannot size, design, specify or install a vegetated roof completely on his/her own, but must consult with architects, structural engineers and specialized vegetated roof experts.

Fostering Greater Implementation. Communities can apply the following strategies to expand the use of vegetated roofs:

- Develop a reference list of specialized and experienced vegetated roof contractors.
- Provide greater financial subsidies for vegetated roofs, in terms of lower stormwater utility rates, property tax discounts or demonstration grants.
- Consider providing stormwater credits for vegetated roofs, whereby a certain portion of non-rooftop area on the redevelopment site may be exempted from stormwater quality requirements.
- Share updated data on the installation costs and overall economics of vegetated roofs.
- Conduct training workshops for designers and enhance their interaction with vegetated roof specialists and local plan reviewers.
- Provide more specific design equations to size vegetated roofs and determine their runoff reduction capability.

5-C.6.1.3. Rainwater Harvesting

Rainwater harvesting systems (**Figure 5-C.12** below) intercept, divert, store and release rainfall for future use. Rainwater is harvested in cisterns, rain tanks or rain barrels, and the practice is often named after those storage mechanisms. Rainwater that falls on a rooftop is collected and conveyed into an above- or below-ground storage tank where it can be used for non-potable water uses and on-site stormwater disposal/infiltration. Non-potable uses may include flushing of toilets and urinals inside buildings, landscape irrigation, exterior building and vehicle washing, fire suppression systems, water cooling towers, landscape water fountains, and laundry, if approved by the local authority.

Why Is It Preferred? High redevelopment intensity often generates higher demand for both indoor non-potable water and outdoor landscape irrigation water, which means that substantial runoff volumes can be reused throughout the year. Installation costs are moderate in comparison to other preferred redevelopment practices at about $15 per cubic foot of runoff treated. In addition, a significant annual cost-saving can be achieved, reducing the amount of water purchased from the local water authority for those purposes.

Barriers to Overcome. The primary barrier to widespread installation of rainwater harvesting systems is conflicting or restrictive local plumbing or sanitation codes. Some communities require unnecessarily expensive treatment or disinfection requirements for harvested rainfall before it can be used, even for non-potable purposes. Other communities currently have no guidance on whether rainwater harvesting systems are permissible. Discussions are currently being conducted among relevant regulatory agencies (responsible for domestic water treatment standards and building codes) at both the state and national to create relevant regulatory guidance that will remove impediments to the construction of such systems. Another barrier is unfamiliarity with these systems, as noted above.

Figure 5-C.12. Rainwater Harvesting Cisterns
Source: Biohabitats, Inc.

Design Criteria are provided in Virginia Stormwater Design Specification No. 6, *Rainwater Harvesting*. As with vegetated roofs, novice stormwater designers typically can't size and write specifications for a rainwater harvesting system on their own. Approximately 60% of designers and local plan reviewers in the watershed have never designed or approved a rainwater harvesting system (CBSTP, 2010). They need to get technical assistance from rain tank vendors and designers with this kind of experience, and support from local plan reviewers, in order to get their systems approved.

Fostering Greater Implementation. The following strategies could increase the use of rainwater harvesting systems in Virginia:

- As noted above, DEQ is encouraging the process to develop unified standards for state and local plumbing and sanitation codes that enable use of non-potable water by rainwater harvesting systems.
- Develop a reference list of specialized rainwater harvesting system vendors, designers and contractors.
- Provide greater financial subsidies for rainwater harvesting systems, in terms of lower stormwater utility rates, property tax discounts or demonstration grants.
- Consider providing stormwater credits for rainwater harvesting systems, whereby a certain portion of non-rooftop area on the redevelopment site may be exempted from stormwater quality requirements.

- Share updated data on the overall economics of rainwater harvesting systems.
- Conduct training workshops for designers and enhance their interaction with rainwater harvesting system specialists and local plan reviewers.

5-C.6.1.4. Foundation Planters

Foundation Planters (also known as vegetative box filters or stormwater planters) take advantage of limited space available for stormwater treatment by placing soil filters in containers located in the landscaping areas between buildings and roadways (**Figure 5-C.13**). The small footprint of a foundation planter is typically contained within a precast or cast-in-place concrete vault.

Figure 5-C.13. Foundation Planter
Source: City of Portland, Oregon

Why Is It Preferred? The small footprint of foundation planters allows designer to combine stormwater treatment with attractive landscaping at many high intensity redevelopment projects.

Barriers to Overcome. To date, only a small number of foundation planters (providing stormwater treatment) have been installed in the Chesapeake Bay region, which suggests that most designers and plan reviewers are not familiar with them. In addition, DC has found that the best locations for planters are often outside the parcel footprint and in the public right-of-way. When this is the case, multiple approvals may have be obtained from different city agencies.

Design Criteria are provided in Virginia Stormwater Design Specification No. 9, *Bioretention*. The actual guidance regarding foundation planters is provided in the *Urban Bioretention* specification provided in Appendix A of that design specification. Although the specification includes useful sizing and design criteria, it could be augmented with the more detailed information from the recently updated Portland Stormwater Manual (COPO, 2009). Several other design issues need to be resolved to adapt the practice for climate and growing conditions of Virginia.

The following are suggestions for refining the existing design specification for foundation planters:

- Virginia-specific sizing equations need to be developed.
- Foundation planters work on a rapid-flow-through design. This means they operate more as a filtering practice than a runoff reduction practice, although some evapotranspiration does occur during the growing season. To this end, it is recommended that the planter's soil media should consist of two lifts with different media recipes. The bottom 12 inches should be 100% sand, whereas the top lift should be consist of 80% sand with the remainder as an organic soil compost mix that can meet plant nutrient requirements. The high sand recipe is needed to prevent water-logging and to reduce the potential for nutrient leaching from the organic media.
- Greater input is needed from landscape architects on the plant species or cultivars that flourish best in the sand media and moisture conditions of foundation planters, and yet still provide the desired landscape amenities. Although native species are preferred, non-native species should be allowed, given the ultra-urban environment.
- Simple maintenance and replanting guidelines also need to be developed, so landscape contractors can maintain the hydrologic function of planters as they conduct their routine seasonal landscaping tasks.
- Each individual planter should be stenciled or otherwise permanently marked to designate it as a stormwater practice. The stencil or plaque should indicate (1) its water quality purpose, (2) that it may pond briefly after a storm, and (3) that it is not to be disturbed except for required maintenance.

Fostering Greater Implementation. More widespread use of foundation planters at redevelopment sites could be achieved if the existing design specification is refined and the practice is included in training workshops for designers and local plan reviewers.

5-C.6.1.5. Permeable Pavement

Standard pavement surfaces are impervious, generating high volumes of stormwater runoff in the ultra-urban environment. Permeable Pavements are alternative paving surfaces that allow stormwater runoff to filter through voids in the pavement surface into an underlying stone reservoir, where it is temporarily stored and/or infiltrated (**Figure 5-C.14** below). A variety of permeable pavement surfaces are available, including pervious concrete, porous asphalt and permeable interlocking concrete pavers. While the specific designs may vary, all permeable pavements have a similar structure, consisting of a surface pavement layer, an underlying stone reservoir layer and a filter layer installed on the bottom.

Why Is It Preferred? Permeable pavers can be applied at pedestrian and parking areas, plazas and other hardscapes found at many redevelopment sites. As a shallow underground practice, permeable pavement reduces land consumption for stormwater treatment, and, when designed and installed properly, is an effective option for portions of high intensity redevelopment sites.

Barriers to Overcome. Many designers and plan reviewers are hesitant to use permeable pavement due to general concerns about past failures, and more specific concerns about the wisdom of infiltrating at redevelopment sites, particularly those with urban fill or hydrologic Soil Group "D" soils. While there are some infiltration restrictions associated with urban soils (see **Section 5-C.5.9** of this Appendix), they can be designed for extended filtration rather than infiltration (i.e., installing an underdrain when the soil infiltration rate is low or infiltration is not desirable).

Figure 5-C.14. Permeable Pavers in Ocean City, Maryland
Source: Chesapeake Bay Stormwater Training Partnership

Design Criteria are provided in Virginia Stormwater Design Specification No. 7, *Permeable Pavement*. Designers can use the basic specification from scratch, but may want to contact paver manufacturers to get additional product guidance and obtain a list of certified pavement installers.

Fostering Greater Implementation. The following are several strategies to increase the acceptance and use of permeable pavement:

- Develop a reference list of specialized permeable pavement vendors, suppliers and certified installers.
- Provide more specific design equations to size permeable pavements and determine their runoff reduction capability.
- Eliminate any prohibition of pavers on HSG-D soils if they are installed with underdrains for extended filtration.
- Conduct more permeable pavement demonstration installations as part of municipal construction projects.

- Conduct training workshops for designers and enhance their interaction with permeable pavement vendors, specialists and local plan reviewers.

5-C.6.1.6. Extended Tree Pits

Extended Tree Pits are installed in the sidewalk zone near the street, where urban street trees are normally planted (**Figure 5-C.15**). What distinguishes this practice from a standard street tree planting is that the soil volume for the tree pit is increased and used for stormwater treatment.

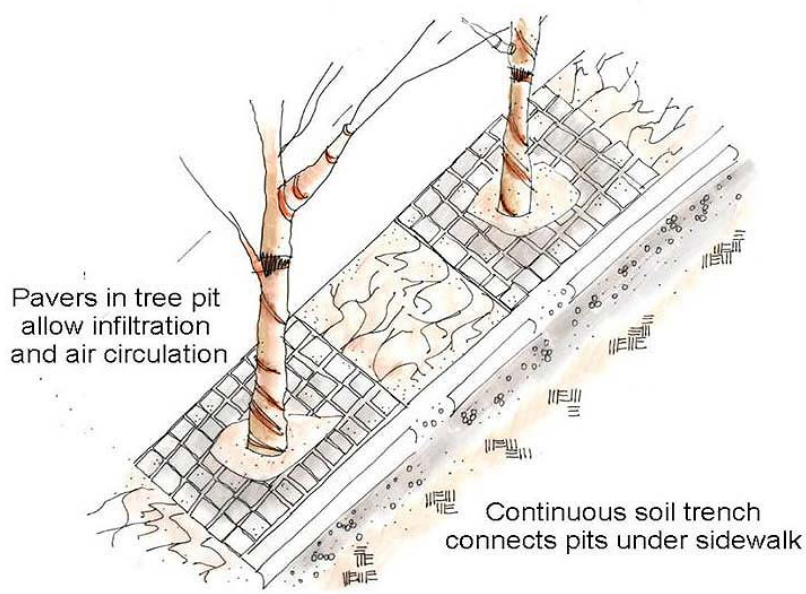

Figure 5-C.15. Extended Tree Pit
Source: Chesapeake Stormwater Training Partnership

The treatment volume can be increased by using a series of connected tree planting areas together in a row. The surface of the enlarged planting area may be mulch, grates, permeable pavers, or conventional pavement. The large and shared rooting space and a reliable water supply increase tree growth and survival rates in this otherwise harsh planting environment.

***Why Is It Preferred*?** Extended tree pits promote effective stormwater treatment and urban street tree survival in the urban streetscape without sacrificing space or urban function.

Barriers to Overcome. To date, very few Extended Tree Pits have been installed in the Chesapeake Bay region, although some demonstration projects have recently been implemented in city of Baltimore. The primary barrier to greater use of Extended Tree Pits are concerns among designers about whether tree pits would be approved by the many different municipal agencies, utilities and urban foresters that collectively regulate the design of the urban street right-of-way. Until standard tree pit specifications are accepted by the local agencies, it is difficult to substitute Extended Tree Pits for traditional urban street tree plantings requirements.

Design Criteria are provided in Virginia Stormwater Design Specification No. 9, *Bioretention*. The actual guidance regarding Extended Tree Pits is provided in the *Urban Bioretention* specification provided in Appendix A of that design specification. Some general concepts on tree pits are also provided by the Center for Watershed Protection (Cappiella et al, 2006). More detailed design schematics and sizing criteria for tree pits can be adapted from the Portland Stormwater Manual (COPO, 2009).

Fostering Greater Implementation. The use of Extended Tree Pits could be expanded if a state or regional work group of stormwater and urban forestry experts was convened and charged with creating a unified local model standard with accompanying details.

5-C.6.1.7. Green Street Retrofits

A private redevelopment project cannot install "green" streets without major assistance from the municipality. They are an attractive option, but they require considerable interagency coordination and leadership by the municipality. Given that installation of green streets is still in its infancy across the Bay watershed, they are considered a special category of preferred redevelopment practices, and are described in greater detail in **Section 5-C.7** of this Appendix.

5-C.6.1.8. Urban Soil Restoration and Reforestation

Urban Soil Restoration and Reforestation involves restoring compacted soils and planting trees at a redevelopment site with the explicit goal of establishing a mature forest canopy that will intercept rainfall, increase evapotranspiration rates, and enhance soil infiltration rates. Reforestation areas can be located on existing turf, barren ground or vacant land, or they can be established within impervious cover conversion areas.

Why Is It Preferred? Even small units of soil restoration and reforestation in urban watersheds can help meet local forest canopy goals and provide effective stormwater treatment at the same time.

Best Available Guidance. While there is excellent guidance on urban reforestation (Cappiella et al, 2006b) and a design specification for soil restoration (Virginia Stormwater Design Specification No. 4, *Soil Compost Amendment*), there is no explicit stormwater treatment credit to combine them together at a redevelopment site or as an offset. Designers do get some credit in the Virginia Runoff Reduction Method calculations for converting turf into forest.

Barriers to Overcome. The primary impediment to wider implementation of this practice is the lack of an approved specification that designers can use to get credit for stormwater treatment. Another barrier involves city ordinance that require routine mowing. Engineers and urban foresters are encouraged to work with DEQ to refine the recommended design criteria suggested above, and incorporate them into the Virginia Stormwater Design Specifications through the Virginia Stormwater BMP Clearinghouse (http://www.vwrrc.vt.edu/swc/).

Recommended Design Criteria. There is very limited data to evaluate the degree of runoff volume reduction associated with urban soil restoration and reforestation. An initial analysis of the runoff differential between turf and forest cover suggests that 10 acres of soil restoration and urban reforestation is equivalent to one inch of runoff reduction from one acre of impervious cover (Biohabitats, 2009). Put another way, each 5,000 square foot unit of restored forest would treat the equivalent of 360 cubic feet of runoff.

Designers can further increase the volume of stormwater treatment if the reforested area is used to disconnect adjacent impervious cover. This additional volume of treatment achieved by disconnection can be computed using the filter strip sizing rules and design criteria outlined in Virginia Stormwater Design Specification No. 2, *Sheet Flow to a Vegetated Filter or Conserved Open Space.*

Excellent guidance on urban reforestation is available from the Center for Watershed Protection (Capiella et al, 2006b) and soil restoration (see Virginia Stormwater Design Specification No. 4, *Soil Compost Amendments*). Designers in Virginia do get some credit in the Virginia Runoff Reduction Method spreadsheet for converting turf into forest.

Stormwater credits for soil restoration and reforestation should be subject to the following qualifying conditions:

- The minimum contiguous area of reforestation should be greater than 5,000 square feet.
- If soils are compacted, they will need to be deep tilled, graded and amended with compost to increase the porosity and water holding capacity of the pervious area, using the methods outlined in Virginia Stormwater Design Specification No. 4, *Soil Compost Amendment*.
- The proposed reforestation should be for the purpose of reducing and treating stormwater runoff, not for other more traditional forestry purposes, such as forest conservation or compensatory reforestation where commercial timber is harvested.
- A long-term vegetation management plan should be prepared and filed with the local review authority in order to maintain the reforestation area in forest condition.
- Planting plans for redevelopment sites should emphasize balled and burlapped tree stock from 1 to 4 inches in diameter. The primary reason is to quickly achieve the desired tree canopy and ensure that the individual trees are visible enough so they are not disturbed, mowed or otherwise damaged as they grow in the ultra-urban environment.
- The planting plan does not need to replicate a forest ecosystem or exclusively rely on native plant species, but it should be capable of achieving 75% forest canopy within 10 years
- The planting plan should be approved by the appropriate local authority, including any special site preparation needs.
- The construction contract should contain a care and replacement warranty extending at least 3 growing seasons, to ensure adequate growth and survival of the plant community. Control of invasive tree species should be a major part of the initial maintenance plan.
- The reforestation area should be shown on all construction drawings and erosion and sediment control plans during construction.
- The reforestation area should be protected by a perpetual stormwater easement or deed restriction which stipulates that no future development or disturbance may occur within the area, unless it is fully mitigated.

5-C.6.2. Acceptable Redevelopment Stormwater Management Practices

Four practices – sand filters, bioretention, urban tree planting and natural area restoration – are considered to be acceptable design solution at most redevelopment sites.

5-C.6.2.1. Sand Filters

Sand Filters (**Figure 5-C.16** below) make sense at redevelopment sites**,** particularly when hotspots are present or infiltration restrictions require the use of filtering practices. Several design variants (e.g., the perimeter or underground sand filter) can reduce space consumption at high-intensity redevelopment sites. The Virginia Stormwater Design Specification No. 12, *Filtering Practices*, provides design guidance. The basic design has not changed much since it was first published in the Maryland Stormwater Manual (MDE, 2000). Sand filters have reasonable nutrient removal rates, but do not appear to have much runoff volume reduction capability.

Figure 5-C.16. Delaware Sand Filter Under Grates
Source: Center for Watershed Protection

5-C.6.2.2. Bioretention

Bioretention (**Figure 5-C.17** below) is feasible for all but the most high-intensity redevelopment sites, since it requires a surface area of about 5% to 7% of the contributing drainage area at a highly impervious site. Bioretention is a versatile practice and most designers have a fair amount of experience with it. As noted above, Virginia Stormwater Design Specification No. 9, *Bioretention*, provides guidance for both the traditional and urban-oriented forms of bioretention.

Designers should keep in mind that there are some important differences in bioretention design when it is applied at high-intensity redevelopment projects rather than to lower density areas.

When bioretention is installed in highly urban settings, individual units are likely to be subject to higher public visibility, greater trash loads, and damage from pedestrian traffic, vandalism, and even errant vehicles. In addition, the presence of adjacent multi-story buildings subjects individual bioretention areas to a wider range of micro-climates and shading conditions. Designers should anticipate these urban stressors to create a design that prevents or at least minimizes future problems. The following should be considered:

Figure 5-C.17. Bioretention Along a Green Street
Source: Chesapeake Bay Stormwater Training Partnership

- When urban bioretention is used within sidewalks or areas of high foot traffic, the bioretention area should not impede pedestrian movement nor create a safety hazard.
- Designers may also install low fences, grates or other measures to prevent damage from pedestrians short-cutting across the bioretention area.
- The bioretention planting plan should reflect its urban landscape context, which might feature naturalized landscaping, a more formal landscape design, or a specialty garden. Landscape architects should be consulted to ensure that high-visibility urban bioretention areas are adapted for their micro-climate and are functional and attractive landscape amenities through all seasons of the year.
- Urban bioretention also requires more frequent landscape maintenance than more suburban applications, in order to remove trash, check for clogging, and maintain vigorous vegetation.

5-C.6.2.3. Urban Tree Planting

Urban Tree Planting (**Figure 5-C.18**)is essentially treated as a vertical runoff disconnection. The only available guidance on the stormwater benefits of urban trees is that each mature street tree is assumed to remove the equivalent of 100 square feet of impervious cover or about 15 cubic feet of runoff from a redevelopment site (COPH, 2009; also see COS, 2010). Recommended criteria for effective urban tree planting are described in considerable detail by the Center for Watershed protection (Cappiella et al, 2006b). While the technical basis for the street tree credit is rather limited, it can help provide a small fraction of treatment at high intensity redevelopment projects.

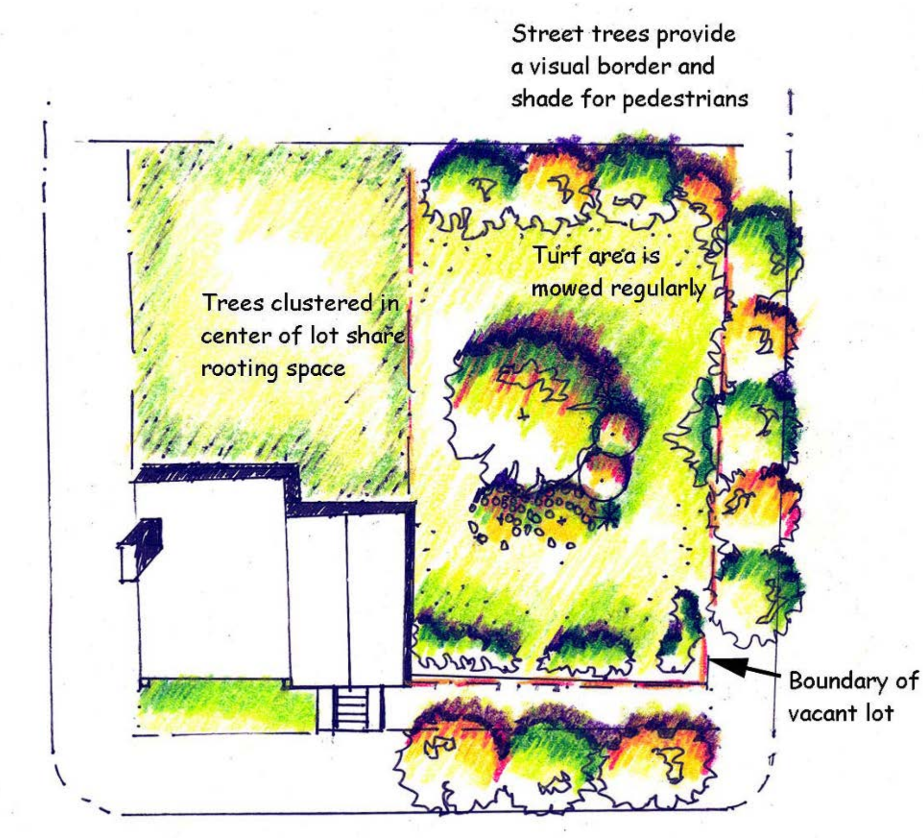

Figure 5-C.18. Tree Planting at a Vacant Lot
Source: Chesapeake Bay Stormwater Training Partnership

5-C.6.2.4. Restore Natural Area Remnants

As noted in **Section 5-C.5.8** of this Appendix, restoration of urban wetlands and natural area remnants at a redevelopment site should be considered an acceptable stormwater compliance alternative, particularly if the remnant current receives runoff generated from the site. Specific techniques for assessing urban wetland conditions and restoration potential are provided by the Center for Watershed Protection (CWP, 2005 and 2006).

Urban wetlands are an important element of green infrastructure, and their restoration can enhance hydrological function in small watersheds. The key problem is that designers cannot compute the precise runoff quantity or quality benefit achieved by an individual urban wetland restoration project. Given the importance of the remaining natural areas in the urban watershed, however, it is recommended that communities grant a generous credit for wetland restoration projects that integrate with stormwater treatment (either as a preferred offset or a 1-to-1 area credit).

5-C.6.3. Restricted Redevelopment Stormwater Management Practices

5-C.6.3.1. Proprietary Practices

Proprietary Practices include manufactured devices that use various hydrodynamic and/or filtration technologies to treat the stormwater flows from small areas. In general, they are designed to treat a rate of flow rather than a defined runoff treatment volume. Consequently, most have very low runoff volume reduction rates. In addition, reliable data on the pollutant removal performance are lacking for most proprietary practices, and relatively few are accepted for more than pretreatment purposes by stormwater agencies in the Chesapeake Bay region. Until better performance data becomes available, designers should restrict use of proprietary practices at redevelopment sites to those that have received state approval and have been assigned specific runoff and pollutant reduction rates. Several state and federal product testing programs have been established in recent years to provide an objective assessment of the capability of proprietary practices to remove nutrients and other pollutants.

5-C.6.3.2. Infiltration Practices

Infiltration practices are restricted in some redevelopment situations because of brownfield, hotspot or urban soil considerations, as described in **Section 5-C.5.9** of this Appendix. Otherwise, infiltration practices are an acceptable option, although it is advisable to provide extra pretreatment at high-intensity redevelopment sites. Design guidance is provided in Virginia Stormwater Design Specification No. 8, *Infiltration.*

Dry wells are the most common infiltration application used at residential redevelopment sites. Experience has shown that they appear to work effectively when properly located on permeable soils. The basic design of dry wells has not changed much since they were introduced (Schueler, 1987). A significant improvement in basic dry well design, however, was recently issued by Carroll County, Maryland (CC BRM, 2010, p. 45). The improved design includes a simple but more effective pretreatment system, and standardized "plumbing" components that are readily available from most hardware stores and can be assembled together easily.

5-C.6.4. Marginal Redevelopment Stormwater Management Practices

Several space-intensive stormwater practices are seldom feasible at high-intensity redevelopment projects, and are therefore classified as being of marginal value. They practices include the following:

- Most rooftop and non-rooftop disconnections
- Various micro-practices, such as landscape infiltration, submerged gravel wetlands, rain gardens and micro-bioretention
- Wet swales
- Filter strips
- Grass channels
- Constructed wetlands

- Extended detention ponds
- Wet (retention) ponds

The fact that a practice is classified as marginal is not meant to categorically exclude its use at redevelopment sites, but simply indicates that it will rarely be feasible except in a limited number of special cases. There are unique design variants of some marginal practices that might work at redevelopment sites. For example, while space is seldom available for conventional constructed wetlands, regenerative conveyance system (RCS) wetlands may be a useful option if runoff discharges to an eroded zero-order ravine. In addition, some marginal practices, such as ponds and constructed wetlands, are ideally suited for storage retrofits in highly urban watersheds (Schueler, 2007).

5-C.7.0. THE MUNICIPAL ROLE IN GREEN STREET RETROFITS

Green Streets are not exactly a stormwater management practice that can be applied on a redevelopment site in the same way that a vegetated roof can or bioretention practice can. Streets usually compose the periphery of redevelopment projects and are located on public land, rather than the private redevelopment site (**Figure 5-C.19**).

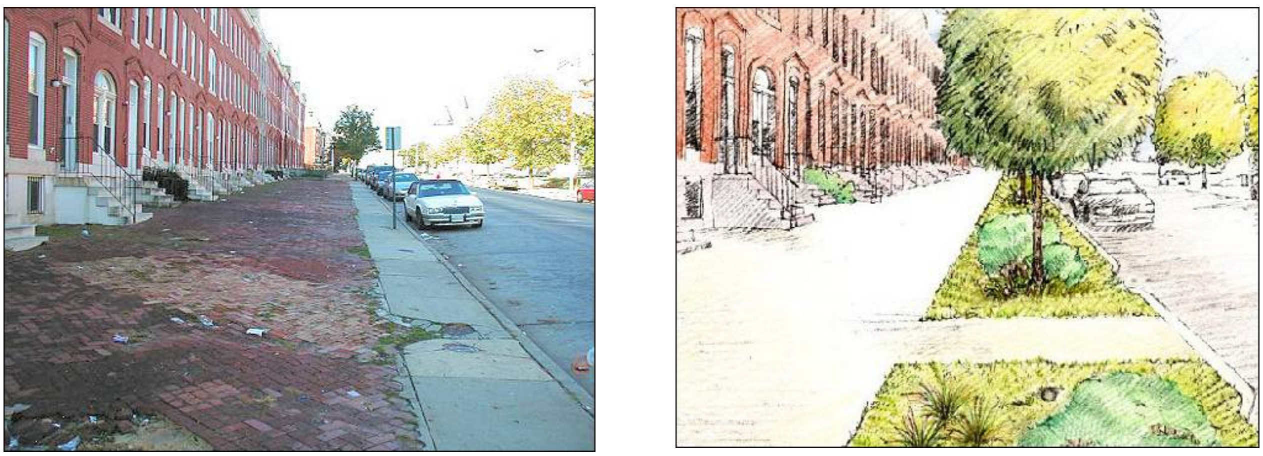

Figure 5-C.19. Street in Redevelopment Area of Baltimore (left), with Green Street Proposal (right)
Source: Chesapeake Bay Stormwater Training Partnership

However, greening of the streetscape, which is more akin to an urban retrofit practice, could be proposed as and off-site element of the total stormwater management solution for a redevelopment site, especially if the site is likely to be highly impervious with limited opportunities for compliance on the site itself. Unlike other off-site solutions, at least the streetscape is immediately adjacent to the site.

Green streets are gaining popularity in other parts of the country as an attractive option to treat stormwater runoff in highly urban watersheds. Green streets provide many urban design benefits and create a more attractive and functional urban streetscape (COE, 2005, COPH, 2008, COPO, 2008, SMC, 2009). The linear nature of a green street also makes it a very efficient stormwater control measure in that they can treat several acres of impervious cover in a high density area (compared to the much smaller drainage areas treated by other preferred redevelopment stormwater management practices).

To date, however, green streets have not been widely used within the Chesapeake Bay watershed. Less than a dozen green street retrofit projects have been installed, although several more are currently in the design phase. This section summarizes the experience gained so far in initial demonstration projects in the City of Baltimore and in the suburbs of Washington, DC.

5-C.7.1. Interagency Coordination and Leadership

A key lesson from the first generation of green streets is that they require an enormous amount of interagency coordination to get final approval. This should not a significant impediment once a community has figured out how to provide the necessary coordination.

The designs of urban streets and their rights-of-way are fundamentally shaped by dozens of competing demands and interests. Examples include water, wastewater and telecommunication utilities, street lights, traffic engineering, pedestrian movement and safety, street trees, urban design, merchant visibility, on-street parking (and meters), signage, and many others. Only recently has stormwater treatment arrived on the scene to compete on this crowded stage.

Significant municipal leadership is needed to motivate agencies and utilities to work together to support green street designs. The next critical step involves some initial demonstration projects on a few street segments to test green street concepts and convince the skeptics. The third step involves changing local street codes to allow a standard green street option. The last step is to create a delivery program so that green streets are the preferred option in municipal capital budgets for neighborhood revitalization, street improvements and urban streetscapes (**Figure 5-C.20** below). Many communities in the Pacific Northwest have evolved their green street programs through all four stages, but only a few Chesapeake Bay communities are now progressing through the first two stages.

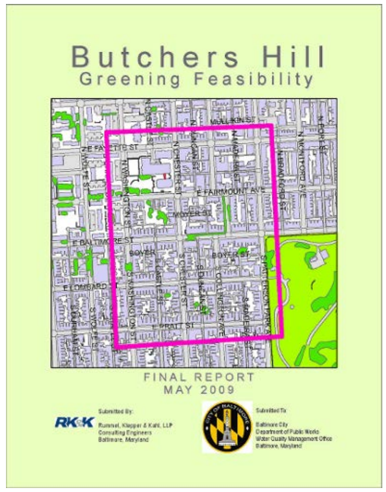

Figure 5-C.20. A Baltimore Green Street Feasibility Study
Source: Chesapeake Bay Stormwater Training Partnership

5-C.7.2. Public Support for the Green Street Product

Experience elsewhere indicates that once the public sees the green street product, they really like it, and they express *s*trong grass roots support to build more of them in their cities and neighborhoods (**Figure 5-C.21** below). While the public may not fully understand the role of green streets in managing stormwater, they clearly perceive strong benefits in the form of expanded tree canopy, attractive streetscapes, cleaner air, revitalization of neighborhoods and communities, safer and more pedestrian-friendly streets and, most important, increased property values. Public acceptance of green streets is so great in urban areas of Pacific Northwest that individual neighborhood associations compete for privilege of getting a green street retrofit.

The problem in the Bay watershed is that there are not yet a lot of green streets for the public to see and experience. Philadelphia has found success in developing before and after photos of the amenities that green streets afford (COPH, 2009).

Figure 5-C.21. A Neighborhood Green Street Retrofit Project
Source: Chesapeake Bay Stormwater Training Partnership

5-C.7.3. Initial Demonstration Projects Are Costly

The cost to install the first generation of green streets in the Chesapeake Bay region is about $167,000 per impervious acre treated. While this is roughly 3.5 times the cost of implementing LID practices at greenfield developments, it is slightly less than the private sector cost of installing LID practices at high-intensity redevelopment projects (**Table 5-C.6**).

Table 5-C.6. Cost to Treat One Acre of Impervious Cover [1] (2010 Dollars)

Stormwater Management Scenario	Sector	Cost
New development without using Environmental Site Design	Private	$ 31,700
New Development, using Environmental Site Design to MEP	Private	$ 46,500
Redevelopment using LID (ultra-urban)	Private	$ 191,000
Storage retrofits in rrban watershed	Public	$ 32,500
Green street retrofits in highly urban areas	Public	$ 167,100
Stream restoration achieving a nutrient equivalent	Public	$ 35,600
[1] Also equivalent to reducing one pound of total phosphorus (TP)		

Source: CSN (2011)

A major reason for the high cost is the "prototype effect" that is encountered when a new technology is constructed for the first time. For example, more than half of the total cost of the initial demonstration projects was devoted to project design, engineering, permitting, interagency approvals, neighborhood consultation and traffic management planning.

For example, the City of Baltimore (Stack, 2010) reports that nearly a dozen municipal permits or sign offs were needed to get final approval for demonstration green street projects there. Many city agencies were reviewing items they had never seen before, which greatly delayed the final approval process. Some of the key approvals included sign-offs on the use of city rights-of-way, highway designs, parking, street lighting, traffic engineering, erosion and sediment control, wastewater engineering and stormwater compliance. In addition, contractors bidding on the project were building green streets for the first time, and probably bid higher to cover unexpected contingencies.

Green street costs will begin to decline on a unit basis as more standardized design templates are developed and contractors gain more experience in building them. In addition, more analysis is needed to determine if there is any incremental cost difference between green streets and traditional street-scaping projects.

5-C.7.4. Specialized Construction Issues Associated with Green Streets

Constructing green streets in highly urban settings creates some unique issues that can drive up costs:

- ***Neighborhood Disruption* (Figure 5-C.22** below**).** The time frame to construct green street retrofits in Baltimore averaged 10 to 30 days, which means that public access to the streets, parking driveways, and sidewalks was severely curtailed. Consequently, it was important to notify and consult adjacent residents about these impacts prior to construction to minimize complaints and problems.

Figure 5-C.22. Construction of a Green Street in Baltimore, MD
Source: Chesapeake Bay Stormwater Training Partnership

- ***Maintenance of Traffic Flow*.** Early experience suggests that green street construction requires temporary closure of at least two travel lanes. These changes to traffic patterns and on-street parking availability require the contractor to budget for traffic control throughout the construction process to keep workers safe. This can be a significant project expense.
- ***Ongoing Coordination with Utilities and Other City Agencies*.** Most of the advance permits secured to construct green street projects include specific provisions to inspect existing city infrastructure during and after construction to ensure it is not damaged or degraded (e.g., street lights, parking meters, utility pipes, street surfaces, curb and gutters, storm drain inlets, etc). The project manager and contractor can expect multiple inspections during the course of construction.
- ***A Tough Construction Environment.*** Green streets pose several challenges that drive up the cost of construction. For example, there is not a lot of extra space at green street projects to store equipment and construction materials and stage the full sequence of construction. In addition, security at many sites is poor. Taken together, this means equipment may need to de-mobilized each day to prevent vandalism. Finally, most projects involve a lot of cut and virtually no fill, so that contractors face the added expense of hauling excavated soils and other materials away from the job site.

5-C.7.5. Local Green Street Design Templates and Unit Specifications

The ultimate goal of demonstration projects is to learn lessons about real world implementation that can be used to craft enhanced green design standards, as has been done elsewhere (COPO, 2008, COPH, 2008 and SMC, 2009). Cities and counties in Virginia are generally subject to road and street design standards established by the Virginia Department of Transportation (VDOT), which ultimately maintains the roads and streets once they are dedicated into the state road system. A few communities in the Commonwealth maintain their own roads and streets, providing them with more flexibility regarding road and street design standards.

VDOT has made some changes to its design standards in the past few years, in order to enable more environmentally sensitive designs (narrower streets with less imperviousness, allowing the use of grass drainage swales instead of curb and gutter, etc.). However, some communities still prefer to implement the more traditional designs.

Given the variability of existing urban street conditions, it is not prudent to establish a single road and right-of-way specification that applies to all green street retrofits. Instead, it makes more sense to develop a series of general green street design templates for a range of typical traffic, parking and sidewalk conditions (SMC, 2009). Each template would then show the recommended combination of LID "unit" practices that can be applied in the retrofit (e.g., foundation planters, expanded tree pits, permeable pavers, etc.). Ideally, there would be a locally adapted and approved design specification for each of these unit practices.

While each locality may ultimately need to draft its own green street standards, it makes sense to form a Bay-wide workgroup composed of highway engineers, stormwater designers and other urban street stakeholders to develop these design templates. Such an effort could greatly reduce the cost to individual localities of developing their own design templates and specifications from scratch. The workgroup could advance green streets by trading ideas about what has worked (or not), and sharing model language, design schematics and construction specifications. The workgroup could also assemble a visual library of green street demonstration projects across the Bay watershed to show both the public and skeptical city planners that the concept can be successfully imported to the Chesapeake Bay region.

5-C.8.0. DOCUMENTING REDEVELOPMENT NUTRIENT CREDITS

Localities in the Bay watershed have a keen interest in determining how much nutrient reduction can be attributed to their various stormwater treatment and watershed restoration actions. This has become even more critical as localities confront the need to document their nutrient reductions in a local Watershed Implementation Plan (or WIP) associated with the new Chesapeake Bay TMDL pollutant reduction targets. Localities will need to craft their own WIP plans in 2011-2012 to show how they intend to meet their load allocation in the Bay-wide nutrient TMDL.

The Chesapeake Stormwater Network (CSN) is currently writing guidance on stormwater nutrient accounting for bay communities, which is scheduled for release in late 2011. The guidance will be in the form of Technical Bulletin No. 9, which will present a comprehensive approach to accurately track stormwater loads from new, existing and redevelopment sectors within each Bay community.

To date, there has been no specific guidance on how to credit nutrient reductions associated with the adoption of more stringent redevelopment stormwater requirements. This section proposes a simple tracking approach that should be reasonably accurate and yet easy to administer.

The first step would be for the locality to track the cumulative number of impervious acres that are redeveloped each year and meet or exceed the local and/or state stormwater redevelopment requirements. This includes projects that treat stormwater on site and/or reduce pre-existing impervious cover through acceptable conversion techniques (**Section 5-C.6.1** above).

The treated area of each individual redevelopment project should only be added to the local database if it has received a post-construction certification that it is actually working as designed. In addition, a municipality should only receive the credit if it meets the minimum state or permit standards for on-site maintenance inspections and enforcement.

The second and final step is to multiply the qualifying impervious acres by the nutrient reduction credits shown in **Table 5-C.7**. These nutrient credits reflect the different levels of stormwater treatment required at redevelopment sites in the Bay states, as well as the extent to which on-site runoff reduction is implemented across a locality.

Table 5-C.7. Nutrient Reduction Credits for Redevelopment Stormwater Practices [1, 4]

Annual Load Reduced Per IC Acre Treated (in Lbs/acre/yea)r	**Rainfall depth for which stormwater treatment is computed (inches)**											
	0.25		**0.50**		**0.75**		**1.0**		**1.25**		**1.5**	
	Low[2]	**High**[3]	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
TP	0.4	0.6	0.6	0.9	0.75	1.1	**1.0**	**1.5**	1.25	1.65	1.4	1.8
TN	3.3	4.5	5.1	6.8	6.3	8.4	**8.4**	**11.3**	9.9	12.3	11.1	13.5

[1] See **Section 5-C.8.1** below for methodology used to derive the credits
[2] Practices employed employ stormwater treatment but have low or no runoff reduction capability
[3] Practices employed maximize runoff reduction and designed to Level 2 of BMP Design Specs
[4] Expressed in annual load reduced per IC acre treated (lbs/acre/year)

Source: CSN (2011)

Larger communities with high redevelopment rates and stringent stormwater requirements could expect to see substantial nutrient reduction, which they can deduct from their Bay TMDL nutrient liability.

The technical assumptions and computational methods to derive the nutrient credits are described in detail in **Section 5-C.8.1** below. An alternate method to compute credits in Virginia would be to track nutrient reductions from individual redevelopment sites, using the Virginia Runoff

Reduction Method compliance spreadsheet, and then aggregating the projects and reductions into a tracking database.

5-C.8.1. Methodology Used to Derive Redevelopment Nutrient Credits

The following methods and technical assumptions were made to derive the nutrient credits for variable levels of stormwater treatment at redevelopment sites, reflected in **Table 5-C.8** above.

Step 1: Compute Baseline Nutrient Load for Unit Acre of Impervious Cover. The Simple Method (Schueler, 1987) was used to compute annual nutrient loads, using standard assumptions for annual rainfall in the region, and regional event mean concentration for nutrients. The resulting annual stormwater load was computed to be 2 and 15 lbs/acre/year for TP and TN, respectively.

Step 2: Define the "Anchor" Reduction Rate for Composite Redevelopment Practice. An annual mass removal rate was computed using a composite of eight different preferred or acceptable redevelopment stormwater practices (see **Section 5-C.6** above), using the runoff reduction data provided in CWP and CSN (2008). The practices included rain tanks, green roofs, permeable pavers, urban bioretention, bioretention, dry swales, sand filters, and impervious cover removal with soil amendments. The mass removal rates are specific to the treatment of one inch of rainfall in Virginia, and the Level 1 and 2 approach was used to reflect the amount of runoff reduction an individual design achieved (Lo or Hi, as defined in CWP and CSN, 2008).

Step 3. The anchor rate was then adjusted for the inches of rainfall depths (0.25, 0.50 and 0.75, etc.), by estimating the untreated bypass volume from regional rainfall frequency curves, relative to the anchor rate (see **Table 5-C.8** below). For example, if the runoff from 0.25 inches of rainfall is treated, only 40% of the annual runoff volume would be treated (compared to 90% for the one inch event). The annual treatment volume was then used to define a lower nutrient reduction rate, based on the lower capture volume. The same basic approach was used to define maximum mass nutrient reduction rates for the 1.25 and 1.5 inch storm events.

Step 4. The baseline nutrient loads computed in *Step 1* were than multiplied by the corresponding removal rate for each combination of runoff treatment and runoff reduction, as shown in **Table 5-C.8**, to arrive at the recommended credits, as shown in **Table 5-C.7** above.

Table 5-C.8. Nutrient Removal Estimates For Volume and Type of Treatment

Nutrient Mass Removal Rate (%)	Rainfall depth for which stormwater treatment is computed (inches)											
	0.25		0.50		0.75		1.0		1.25		1.5	
	Low[1]	High[2]	Low	High	Low	High	Low	High	Low	High	Low	High
TP	20	30	30	45	38	56	**51**	**74**	63	82	70	90
TN	22	30	34	45	42	56	**56**	**75**	66	82	74	90

[1] Practices used employ stormwater treatment but have low or no runoff reduction capability
[2] Practices used maximize runoff reduction and designed to Level 2 of BMP Design Specs

Source: CSN (2011)

5-C.9.0. REDEVELOPMENT WEB LINKS

The specific redevelopment stormwater requirements for each Bay state can be accessed through the CSN website www.chesapeakestormwater.net .

Link to Virginia BMP Design Specifications that Pertain to Redevelopment

- Permeable Pavement (No. 7)
- Vegetated Roofs (No. 5)
- Urban Bioretention (No. 9, Appendix 9-A)
- Rainwater Harvesting (No. 6)
- Soil Compost Amendments (No. 4)
- Dry Swales (No. 10)
- Sand Filters (No. 12)

Online at http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html

Link to Rainwater Harvesting Design Spreadsheet

http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html *and then scroll down several pages to find the Excel spreadsheet (associated with the **Rainwater Harvesting** design specification).*

The following additional resources are recommended for managing stormwater at redevelopment projects.

Link to Urban Tree Canopy Guidance

http://www.forestsforwatersheds.org/urban-tree-canopy/

Philadelphia, PA: Stormwater Management Guidance Manual. Version 2.0 *(2008) – One of the best on the east coast for redevelopment practices.*
http://www.phillyriverinfo.org/Programs/SubprogramMain.aspx?Id=StormwaterManual

Portland Stormwater Management Manual *(2008) – This manual provides excellent design schematics and maintenance information for ultra-urban practices.*
http://www.portlandonline.com/bes/index.cfm?c=43428

San Mateo County: Design Manual for Green Streets and Parking Lots. *(2009)* **–** *From California,* ***t****his is one of the better design manuals for green street design.*
http://www.flowstobay.org/ms_sustainable_streets.php

Emeryville, CA: Stormwater Guidelines for Green Dense Redevelopment – Stormwater Quality Solutions *(2010) – This document outlines a useful approach for effectively managing stormwater in ultra-urban watersheds****.***
http://www.epa.gov/dced/emeryville.htm

Guidance on Smart Growth and Stormwater *(2009) – This EPA policy report presents strategies to integrate stormwater and smart growth.*
http://www.epa.gov/dced/stormwater.htm

Stormwater and Brownfield Sites *(2009) – This EPA report provides guidance on managing stormwater from brownfield sites.*
http://epa.gov/brownfields/tools/swcs0408.pdf

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Appendix 5-D

Stormwater Pollution Benchmarking Tool for Existing Industrial, Federal and Municipal Facilities in Virginia

Adapted from Chesapeake Stormwater Network Technical Bulletin No. 7:

Stormwater Pollution Benchmarking Tool for Existing Industrial, Federal and Municipal Facilities in the Chesapeake Bay Watershed Version 3.0, June 2011

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5-D.1.0. INTRODUCTION

This Appendix presents a visual method to assess the need for stormwater pollution practices, retrofits and stewardship at existing industrial, institutional, federal, state and municipal facilities. Thousands of these facilities exist across Virginia, each of which has the potential to be severe stormwater hotspots, which are defined as a site that generates higher loads of pollutants and toxics, and/or has a higher risk of leaks, spills or illicit discharges. Despite the impact of stormwater hotspots on the local receiving waters and the Chesapeake Bay, they have not been effectively regulated or managed for several reasons.

While as many as 30,000 facilities across the Bay watershed are technically regulated under EPA's industrial or municipal stormwater permit programs, most individual permits do not contain specific monitoring requirements or numeric limits on effluent quality. Thus, at many sites, all that is needed to comply with the permit is to make sure you have a paper document known as a stormwater pollution prevention plan present on your site. The chances that a local or state regulator will inspect your site are increasingly small (National Research Council, 2008). Even if sites are inspected, the permits do not require any site-specific or quantitative measurements to determine whether runoff is dirty or reasonably clean, which makes it difficult to trigger enforcement actions.

A second key issue is that many property managers and environmental compliance officers simply don't understand much about stormwater, in contrast to their knowledge about the more traditional environmental health and workplace safety issues they must deal with every day (e.g., hazardous waste storage and disposal and spill response). Few good training materials have been developed regarding site-based stormwater pollution prevention techniques, and even fewer tools exist to diagnose the actual stormwater pollution problems present at a site. Consequently, there is a strong need for a quantitative diagnostic tool to assess stormwater pollution problems and identify site-specific and cost-effective solutions.

There has been growing recognition about the need to expand pollution prevention activities, particularly at federal facilities (DOD, 2009 and EPA, 2009). These new stormwater initiatives seek to respond to the President's 2009 Executive Order 13805 on Enhancing Restoration of the Chesapeake Bay. For example, DOD (2009) conservatively estimated that existing federal facilities comprised nearly 85,000 acres of developed land in the Bay watershed, and there was a need for a comprehensive tool to evaluate pollution prevention, retrofitting and stewardship opportunities at individual facilities. In addition, the first guidance and assessment tools for managing runoff from municipal stormwater hotspots has just been released (CWP, 2009).

5-D.2.0. THE EVOLUTION OF THE STORMWATER BENCHMARKING TOOL

The current version of the stormwater benchmarking tool presented here has rapidly evolved in the last six years. It began with the release of the Hotspot Site Investigation or H.S.I. (CWP, 2005) which was a simple checklist to confirm whether a site could be classified as potential, moderate or severe stormwater hotspot, based on visual analysis of site conditions. The H.S.I. has been extensively tested over the last six years at hundreds of different sites around the country, and has been found to be a robust tool. Its main weakness, however, is that while it could discriminate between dirty and clean sites, it could not measure how green a facility is (i.e.,, has it gone beyond the minimum to build on-site stormwater retrofits, enhanced land management or foster greater watershed stewardship.

To bridge this gap, the Chesapeake Stormwater Network (CSN) developed a more comprehensive stormwater benchmarking tool, in cooperation with Coca-Cola North America and the World Wildlife Fund. The H.S.I was extensively modified to provide a benchmarking score for individual Coca Cola bottling facilities. The new tool was tested from 2007 to 2009 and refined based on comments from plant managers and environmental compliance officers at five different bottling facilities in the Southeastern U.S. Simultaneously, the CSN developed a similar benchmarking tool for three large port facilities in the Port of Houston, though a cooperative agreement between the Conservation Law Foundation and the Port Authority.

Based on this experience, the CSN concluded that it was possible to produce a generic stormwater benchmarking tool that could be applied to existing individual industrial, municipal, federal, corporate or institutional facilities of less than 50 acres in size within the Chesapeake Bay watershed. The new tool (CSN Technical Bulletin No. 7, 2010) provides a quantitative score to measure whether a facility is dirty, clean or green. It also helps users develop an action list of pollution prevention, stormwater retrofit, land management and watershed stewardship practices to implement at the site.

5-D.3.0. OBJECTIVES AND OUTCOMES FOR STROWMATER BENCHMARKING

Stormwater benchmarking involves a rapid office and field survey to identify correctable stormwater pollution problems at individual industrial or municipal facilities. The benchmarking tool is a comprehensive assessment that rates each facility against 22 performance benchmarks and identifies simple low cost pollution prevention actions that can be undertaken at each facility to improve its stormwater runoff quality. Each benchmark is associated with the completion of one to five individual tasks or practices that can improve stormwater quality.

The recommended goal for stormwater benchmarking is to attain a minimum total facility score of 95 or greater (out of a total of 100 points). Once the on-site team has completed its work, they tabulate the total score, and interpret it using the guidance provided in **Table 5-D.1** below. The assessment team should document their work with digital photos to show both good practices and existing stormwater problems, and incorporate these directly into employee training programs.

Based on the benchmarking exercise, the user can rank each facility among its peers, and provide detailed information to update stormwater pollution prevention plans that are legally required at many facilities. In addition, benchmarking can improve employee understanding about stormwater runoff, watersheds and community stewardship. In most cases, the initial scores will be rather low, but the tool helps identify a series of immediate, short-term and mid-term action items to complete at the facility in ensuing years.

The benchmarking tool has been designed to apply to a wide range of facility types. If it turns out that you do not engage in the indicated activity or practice for a specific benchmark, you can award yourself full points (e.g., no refueling occurs at your facility so this benchmark does not apply to you). If it turns out that more than a third of the benchmarks do not apply to your facility, you probably have a unique facility category, and may want to customize the tool by adding/subtracting benchmarks or changing the weight of points awarded among the benchmarks. The basic idea is to go beyond the minimum at every facility so that it is not only clean but green, such that a wide range of low cost practices are used or installed to ensure it has the least possible impact to local waters and the larger river basin.

Table 5-D.1. Interpreting the Initial Benchmark Score

Score	Rating	Comments
95 - 100	**Excellent**	**Congratulations:** Your activities and practices make you an industry leader in stormwater compliance. You go way beyond the minimum and deserve recognition in your community.
85 - 94	**Good**	**Great Start:** You run a clean, effective operation and only have a handful of areas for improvement to meet the goal.
75 - 84	**Fair**	**Needs Work:** Although you are doing a lot of things right, there are many areas where you can do more.
65 - 74	**Poor**	**Not so Good:** Your site is probably a hotspot for stormwater pollution, and your team needs to become more effective toward meeting the standard.
35 – 64	**Very Poor**	**Lots of Work to Do:** Your site is probably a severe hotspot, and your facility is probably noncompliant with your stormwater permit. The team and facility manager need an aggressive, effective action plan.
Less than 35	**Unacceptable**	**Shred the Evidence (just kidding):** Your site is almost certainly noncompliant with your stormwater permit, and you are exposing your company to regulatory risks, fines and citizen lawsuits! Improving your score should be an immediate facility-wide priority.

5-D.4.0. GETTING STARTED

The stormwater benchmarking exercise is designed to be completed in four hours or less, although some implementation activities may take longer. To get started, the environmental compliance officer should familiarize themselves with the benchmarking tool and read the pollution prevention resources provided in **Section 5-D.6.0**. Benchmarking should be done by a team of at least two individuals, and it may be helpful to involve other facility employees (especially maintenance staff) to enhance its training value. The assessment team doesn't need a lot to get started, as shown below:

- Standard Safety gear (blaze orange vests if there is a lot of truck traffic)
- Clipboard with notes
- Access to internet
- Digital Camera
- Site Map to Scale

5-D.5.0. DESCRIPTION OF THE STORMWATER BENCHMARKS

The team assesses benchmarks inside the building, outside of the building and along the stream or receiving water that the facility discharges to. The ensuing section outlines how to assess and score each benchmark through 22 profile sheets. Each profile sheet shows:

- The specific conditions to look for at the site
- Photographs that show how the indicated activity or operation can enhance or degrade stormwater runoff quality. These help show the survey team what is good or bad practice at their facility
- A specific description of the one to four different tasks that must be completed to earn points under each benchmark
- Guidance on how to score each benchmark
- Tips for evaluating each benchmark at your facility, including the recommended resources to learn more about best practices for your facility

The team should review the profile sheets carefully so they can better "see" the correctible stormwater problems present at the site, and then identify the most cost-effective solutions to address them.

5-D.5.1. Benchmark 1: Define Your Watershed Address

What to look for: The team uses a GIS or the internet (Google Earth or other mapping) to determine the stream to which the facility ultimately drains, as well as the larger watershed in which it resides.

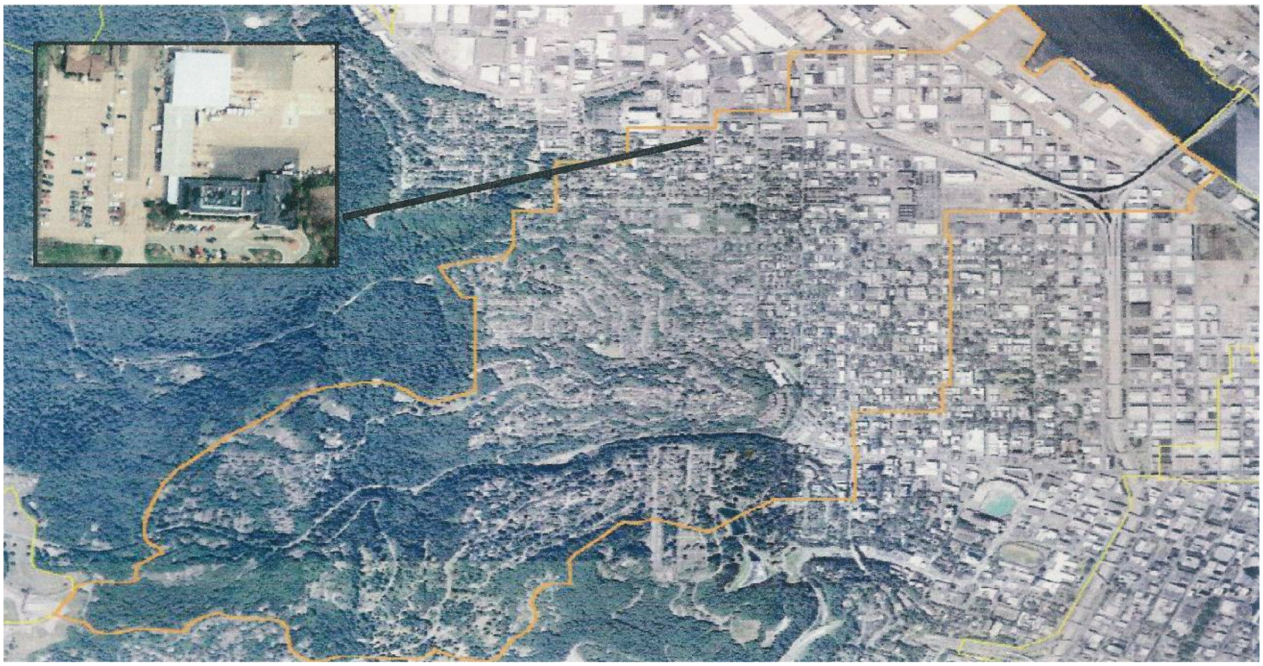

Figure 5-D.1. A Watershed Map Image Showing a Specific Facility Location

Tasks. Four specific tasks must be completed to meet this benchmark:

1. Use Google Earth to find the location of the facility in relation to the nearest named stream.
2. Determine the larger watershed in which it resides.
3. Do a web search to identify local or regional groups working to protect or restore the watershed and get basic contact information for those organizations.
4. Contact the groups to learn more about the key water quality and habitat issues that are a problem in your watershed.

Scoring: A **total of 4 points**. One point is awarded for each of the above tasks that is completed.

Tip: Several handy websites in **Section 5-D.6** below can quickly help to find your watershed address by simply entering the zip code of your facility. Other websites can help you find your local watershed group and learn about the key pollutants of concern.

5-D.5.2. Benchmark 2: Develop a Stormwater Profile for Your Facility

What to look for: Analyze the land cover present on the site plan to estimate the total site area and area/percentage of impervious cover so that you can quickly compute the annual stormwater runoff volume and pollutant load generated by your facility. Try to express the annual stormwater runoff volume in analogous terms your employees can relate to, such as cases of product shipped or the number of standard forty-foot shipping containers filled with product each year. Once employees understand the magnitude of their stormwater pollution "footprint," they are more likely to take action.

Figure 5-D.2. A Municipal Equipment Martialing Yard (nearly two 55-gallon drums of Oil Washed Off the Site Every Year).

For this site:

- Site Area = 24.1 acres
- % Impervious Cover = 92%
- Average Annual Runoff = 50 inches
- Total Phosphorus in Runoff = 56 lbs/yr
- Total Sediment in Runoff = 8.7 tons/yr
- Total Nitrogen in Runoff = 452 lbs/yr
- Oil and Grease in Runoff = 865 lbs/yr = 104 gal/yr
- Zinc in Runoff = 43 lbs/yr

Tasks. Four specific tasks must be completed to meet this benchmark:

5. Analyze the site plan to estimate the total site area, the area/percentage of impervious cover, and the runoff coefficient.
6. Determine the average annual rainfall at the site (you can find this at http://maps.howstuffworks.com/united-states-annual-rainfall-map.htm .
7. Compute the annual stormwater runoff volume produced at your site, and compare it to the volume of your annual production.
8. Compute the annual sediment, nutrient (phosphorus and nitrogen), zinc, and oil/grease loads generated from your facility.

Scoring: A **total of 4 points**. One point is awarded for each of the above tasks that is completed.

Tip: **Sections 5-D.7 and 5-D.8** show how to compute the annual runoff volume and pollutant load that washes off your site using the Simple Method (Schueler, 1987).

5-D.5.3. Benchmark 3: Improve Your On-Site Employee Training Efforts

What to look for: Use the stormwater benchmarking tool to train employees to spot stormwater runoff problems and opportunities across the site, and then create a team to work together to improve benchmark scores for the facility. The best training involves hands-on assessment out in and around the facility. Initially, many employees are not aware of how stormwater travels through their site and the potential for pollutants to wash off site surfaces into local streams. Experience has shown that "outside the building" training, using the benchmarking method, is an extremely effective learning tool.

Figure 5-D.3. Employee Training

Tasks. Four specific tasks must be completed to meet this benchmark:

9. Involve key employees in the stormwater benchmarking exercise and discuss the results with them and the plant or facility manager. Current stormwater benchmark scores should be posted in a prominent location in the facility.
10. Customize a basic stormwater pollution prevention training program for your site's employees, using data specific to your site.
11. Provide the new training program for all employees at least once a year.
12. Include tips on watershed stewardship that all employees can practice at home or in their community.

Scoring: A **total of 5 points**. Two points are awarded for Task 9, and one point is awarded for each of Tasks 10 through 12 that are completed.

Tips: Some guidance on employee training can be found in Profile Sheet MO-10 ("Employee Training") from the Center for Watershed Protection's *Manual 9* of their *Small Watershed Restoration Manual Series*. Another great resource for finding posters and brochures related to stormwater pollution and watershed stewardship is the U.S. EPA's *Nonpoint Source Outreach Tool Box* (online at www.epa.gov/nps/toolbox), which has more than 800 posters, brochures, and other watershed educational tools. These can be posted in employee lunch or meeting rooms to heighten employee awareness.

5-D.5.4. Benchmark 4: Update Your Stormwater Pollution Prevention Plan

What to look for: Check your files to see if you have an existing Stormwater Pollution Prevention Plan (SWPPP) for your site, if required by EPA's industrial or municipal stormwater NPDES/VPDES permit regulations. If you can't fine one, do some internet research to determine the regulatory status of your site. The objective of the benchmarking exercise is to develop an action plan that reflects your site-specific problems and opportunities.

Figure 5-D.4. Example Site Photo

At this facility, the action plan included one immediate corrective action, five actions to implement in the next 90 days, and 12 more by the end of the year. Five more actions that require capital funds or more detailed engineering were scheduled over the following three years.

Tasks. Three specific tasks must be completed to meet this benchmark:

13. Find and review your existing stormwater pollution prevention plan (if your facility is regulated under the NPDES/VPDES stormwater permit program). If not, find a good quality site plan or aerial photograph of your facility.
14. Designate a lead staff member or a small group to conduct annual stormwater benchmarking and to implement the SWPPP.
15. Create an annual work plan or punch list outlining new practices and retrofits to improve future benchmark scores.

Scoring: A **total of 5 points**. One point for each of the first two tasks, and three points for the annual work plan..

Tips: If you are not sure if your facility is covered by industrial stormwater regulations, then check online at http://cfpub.epa.gov/NPDES/stormwater/indust.cfm to learn more. Many municipal and federal facilities do not meet the strict definition of "industrial" but still contain operations or activities that can make them a stormwater hotspot. Refer to the Center for Watershed Protection's *Manual 8 ("Source Control Practices")* of their *Small Watershed Restoration Manual Series* and the web links in **Section 5-D.6** to learn more about stormwater pollution prevention.

5-D.5.5. Benchmark 5: Understand the Stormwater Plumbing at Your Site

What to look for: After carefully analyzing the facility plan, walk around to discover the pathways by which stormwater runoff flows across and, sometimes, underneath the site. The basic idea is to proceed from the roof (the highest point) to the lowest point where stormwater is discharged from the site. The team should trace how runoff flows from roof leaders, across pavement, into stormwater inlets, and then into channels or storm drain pipes. The pathway of stormwater flows can be complex at many facilities, particularly given the presence of sanitary sewer and drinking water pipes that are also present at the site. The survey is best done when it is raining. It should also pinpoint the location of storm drain outlets, which may be located off the site. Once you're done with the survey, make sure to mark all storm drain inlets on the site with the following label/tag: *Keep pollutants out – drains to XXX (stream or river or reservoir or bay).* Then employees will realize they are stormwater inlets and not connected to the wastewater treatment plant.

Figure 5-D.5. Surveying a Site's Stormwater "Plumbing"

Tasks. Four specific tasks must be completed to meet this benchmark:

16. Walk the site with the plan to determine the actual stormwater flow paths.
17. Confirm the locations of sanitary, stormwater and water pipes.
18. Mark the actual locations of these on the site plan or aerial photographs.
19. Provide permanent markers at each storm drain inlet (see first photo above)

Scoring: A **total of 5 points**. One point for each of the first three tasks, and two points for the Task 19.

Tips: Your survey should locate where underground stormwater, wastewater and drinking water pipes are currently going. Often, the pipes can be quickly identified by looking at the markings on surface manhole covers. If you are in doubt, simple dye testing may be needed to confirm which pipes are used to carry sewage, drinking water or stormwater. Guidance on storm drain marking can be found in Profile Sheet N-16 of the Center for Watershed Protection's *Manual 8 ("Source Control Practices")* of their *Small Watershed Restoration Manual Series* or from an EPA fact sheet that can be accessed online at http://cfpub.epa.gov/NPDES/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=15 .

5-D.5.6. Benchmark 6: Look for Opportunities to Reduce Rooftop Runoff

What to look for: Survey the perimeter of the building to find the points where rooftop runoff discharges to the ground (known as downspouts or roof leaders). Check to see which ones can be diverted to adjacent pervious or turf areas, where the runoff can be filtered or infiltrated into the ground. Roof downspouts that discharge to a paved surface and subsequently to a storm drain do not allow for any treatment of stormwater before it is discharged to the stream. There are a wide range of options for disconnecting and treating roof runoff, from simple disconnection over a pervious area to collecting the water in rain tanks or cisterns for reuse of the stormwater onsite, increasing the facility's water use efficiency.

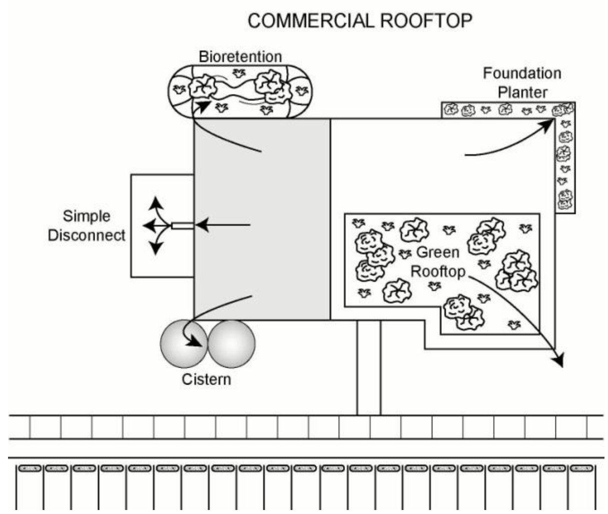

Figure 5-D.6. Reducing Rooftop Runoff

Tasks. Three specific tasks must be completed to meet this benchmark:

20. Evaluate every downspout to determine if it can be safely disconnected to filter runoff over an adjacent pervious area.
21. Evaluate the feasibility of rain tanks or re-use of stormwater in the site's landscaping.
22. Retain an engineering consultant to design a roof retrofit (e.g., a vegetated roof).

Scoring: A **total of 5 points**. One point for Task 20, and two points each for the Tasks 21 and 22.

Tips: Guidance on retrofitting rooftops can be found in Profile Sheet OS-10 of the Center for Watershed Protection's *Manual 3* of their *Small Watershed Restoration Manual Series*. Simple disconnections may involve using flexible pipes from the roof leader to divert runoff several feet to a more appropriate discharge point. If this is not possible, an engineering consultant can recommend the most cost-effective roof retrofit option for your facility, such as a vegetated roof, foundation planter, bioretention area, rain tank, etc.

5-D.5.7. Benchmark 7: Investigate Loading and Unloading Areas

What to look for: Nearly every facility has a distinct area where bulk inputs are delivered and products are shipped out. Spills and leaks are common at these loading and unloading areas, which are compounded by the fact that they are often located near an outdoor storm drain inlet. Consequently, spilled pollutants can enter the storm drain during a storm or be carried in wash-water when loading and unloading areas are cleaned. Covered loading areas at least prevent spilled materials from being washed away by rainwater.

Figure 5-D.7. Investigate Loading and Unloading Areas

Tasks. Two specific tasks must be completed to meet this benchmark:

23. Keep loading areas clean by regular sweeping (never by hosing to a storm drain).
24. Make sure loading areas are covered or redesigned to send any runoff to the sanitary sewer..

Scoring: A **total of 4 points**. Two points for successful completion of each task.

Tips: Some best practices for loading and unloading areas are described in Profile Sheet H-5 in the Center for Watershed Protection's *Manual 8* of their *Small Watershed Restoration Manual Series*. The facility team should look for outdoor water spigots in close proximity to the loading areas, which indicate that employees may often hose down the area to keep it clean. This practice should be avoided unless it is clear that the wash-water goes into the sanitary sewer system. The alternative practice is to manually sweep or vacuum the loading area and ensure disposal of solids is done properly.

5-D.5.8. Benchmark 8: Investigate Loading and Unloading Areas

What to look for: Walk all the employee and fleet parking lots to assess their condition. Look for the presence of obvious pollutants such as trash, oil stains and sediment deposits. Based on how dirty the lots are, the team can change current parking lot maintenance practices to improve the quality of parking lot runoff. Often the dirtiest parking lots occur when vehicles or heavy equipment are parked or stored for a long time. Monthly seeping of parking lots helps reduce wash-off of pollutants in storm water. Routine trash and litter pickup can sharply reduce trash loading delivered to nearby streams. Oil and hydraulic fluid leaks can be a problem in long-term parking lots, but they can remedied easily with spot applications of adsorbents. Unpaved parking lots can be a major source of sediment. These should either be stabilized or protected with erosion and sediment controls.

Figure 5-D.8. Parking Lot Pollution

Tasks. Two specific tasks must be completed to meet this benchmark:

25. Walk each lot monthly to find and fix fluid leaks.
26. Pick up trash and litter weekly and sweep at least once a month with a vacuum sweeper. Stabilize unpaved lots to prevent erosion, and exercise special care with routine pavement maintenance activities, such as power-washing and seal-coating.

Scoring: A **total of 5 points**. Two points for Task 25, and three points for Task 26.

Tips: Best practices for parking lot maintenance can be found in Profile Sheet H-11 of the Center for Watershed Protection's *Manual 8* of their *Small Watershed Restoration Manual Series*.

5-D.5.9. Benchmark 9: Prevent Spills and Runoff from Fueling Areas

What to look for: Check to see if there are any vehicle fueling areas at the site. If they are present, carefully inspect them to see if there is any risk that petroleum products can spill or wash into the storm drain system. Covered fueling areas are designed and constructed to keep rainwater away from any spilled gasoline or diesel fuel.

Figure 5-D.9. Covered vs. Uncovered Fueling Areas

Tasks. Three specific tasks must be completed to meet this benchmark:

27. Cover fueling islands to prevent rainwater contact with spilled fuel.
28. Ensure that dry spill response kits are readily available.
29. Redesign flow paths to prevent “run-on” or runoff from the fueling area into the storm drainage system.

Scoring: A **total of 4 points**. One point each for Tasks 27 and 28, and two points for Task 29.

Tips: Best practices for vehicle fueling areas are described in Profile Sheet H-2 in the Center for Watershed Protection’s *Manual 8* of their *Small Watershed Restoration Manual Series*. Just because a fueling area is covered does not automatically mean that it will be clean. Stormwater from adjacent paved areas can “run-on” to the fueling area and wash off petroleum products into the storm drainage system. So it is important for the facility team to find these adjacent storm drains and make sure they are protected by storm drain inserts that can capture hydrocarbons.

5-D.5.10. Benchmark 10: Deal with Outdoor Wash-Water and Winter Deicing Operations

What to look for: Locate all outdoor water spigots and identify what, if any, seasonal outdoor washing operations occur at the site. Find out where outdoor wash-water is directed, to make sure it is disposed of in the sanitary sewer system and ***not*** in the storm drainage system. Assess winter de-icing operations at the facility to ensure that salt is safely stored and excess chlorides are cleaned up in the Spring. Uncovered piles of road salt can send toxic pulses of high-salinity water to the drainage system and into nearby streams with each rainfall.

Figure 5-D.10. Outdoor Garden Center Wash Water Directed to the Storm Drain

Figure 5-D.11. Uncovered Pile of Road Salt

Tasks. Two specific tasks must be completed to meet this benchmark:

30. Ensure that water from seasonal outdoor washing operations do not enter storm drain inlets. This can be done by shifting them to pervious areas, or temporarily closing off storm drain inlets to prevent the entry of wash-water.
31. Assess winter de-icing operations to reduce entry of sediment and chlorides into the storm drainage system. This typically involves a spring cleanup of excess salt, spot revegetation, and environmentally safe storage of salts and deicers.

Scoring: A **total of 4 points**. Two points each for successful completion of Tasks 30 and 31.

Tips: Best practices for vehicle washing are described in Profile Sheet H-3 in the Center for Watershed Protection's *Manual 8* of their *Small Watershed Restoration Manual Series*. Operations at a site vary from season to season, so it may be a good idea to interview long-term workers to get a better idea of the range of operations during the course of a year. Then design effective pollution prevention practices. Best practices for managing road salt piles can be found online at http://cfpub1.epa.gov/NPDES/stormwater/menuofbmps/index.cfm?action=factsheet_results&view=specific&bmp=106 .

5-D.5.11. Benchmark 11: Keep Rain and Runoff Away from Vehicle Repairs

What to look for: Investigate all indoor and outdoor areas where vehicles and equipment are maintained or repaired to ensure that fluids and wash-water cannot enter the storm drainage system. Check to make sure that used batteries, vehicle fluids, solvents and tires are recycled properly and stored in a manner that prevents their exposure to rainfall. Ideally, shop drains should be connected to the sanitary sewer system, not the storm drainage system.

Figure 5-D.12. Indoor Truck Maintenance Area (with Proper Storage for Used Fluids, Rags, Solvents and Other Materials)

Tasks. Three specific tasks must be completed to meet this benchmark:

32. Do not allow or provide for outdoor vehicle maintenance or repairs.
33. Ensure that indoor shop drains are connected to the sanitary sewer system, ***not*** the storm drain system.
34. Properly store and recycle all used materials (e.g., oil, solvents, batteries, hydraulic fluids, etc.) so they are not exposed to rainfall or runoff.

Scoring: A **total of 4 points**. Two points for Task 32 and one each for Tasks 33 and 34.

Tips: Best practices for vehicle maintenance are described in Profile Sheet H-1 in the Center for Watershed Protection's *Manual 8* of their *Small Watershed Restoration Manual Series*. Interview a few long-term workers to find out it, when and where any outdoor repairs are made at the site. Also, look for where used fluids, batteries, tires and other waste products are stored. Both activities should be inside, or be designed in such a manner that they are fully covered and disconnected from the storm drainage system.

5-D.5.12. Benchmark 12: Evaluate Spill Control and Response Procedures

What to look for: Walk around the facility to identify the specific areas with the greatest risk of spills or leaks. Then create an unannounced "training drill" (using water and green dye) to critically analyze how quickly and effectively employees respond to finding and fixing the spill. Even small spills of oil, diesel fuel, paint, solvents or other fluids can have a dramatic impact on local streams. Although most facilities have some type of spill response plan, many employees may not be aware of it or know who to contact to make sure a spill is rapidly cleaned up and reported to the appropriate authority.

Figure 5-D.13. A Spill that Got Away

Tasks. Three specific tasks must be completed to meet this benchmark:

35. Make sure dry spill kits are readily available at all high risk areas; train key employees how to use these kits and assign them responsibility for spill cleanups.
36. Update emergency contact numbers and procedures and distribute these to employees.
37. Achieve a rapid and effective response to routinely scheduled training drills.

Scoring: A **total of 5 points**. Two points for each of Tasks 35 and 37, and one point for Task 36.

Tips: Best practices for spill prevention and response are described in Profile Sheet H-7 in the Center for Watershed Protection's *Manual 8* of their *Small Watershed Restoration Manual Series*. One facility created a simple business card for employees to carry in their wallets so they would know the correct internal and external people to notify and quickly understand the company's spill response procedures.

5-D.5.13. Benchmark 13: Prevent Runoff from Materials Stored Outside

What to look for: Walk the outside of the facility to look for any materials that are temporarily or permanently stored outside that could come into contact with rainfall or runoff. Keep in mind that items stored outdoors may change seasonally or even day-to-day, so it is useful to do this scan periodically. Simple best practices can prevent materials stored outside from becoming a stormwater runoff problem.

Figure 5-D.14. Exposed Pile of Mulch (Subject to Rainfall-Runoff)

Figure 5-D.15. Leaking Drums of Restaurant Cooking Grease

Tasks. Three specific tasks must be completed to meet this benchmark:

38. Make sure outdoor materials are placed on pallets to stay above runoff.
39. Make sure outdoor storage areas are covered or have secondary containment measures in place.
40. Make sure outdoor storage areas are located in a manner to prevent or minimize the opportunity for waste to enter a storm drain (as confirmed by a lack of stain or streak lines).

Scoring: A **total of 4 points**. One point for each of Tasks 38 and 39, and two points for Task 40.

Tips: Best practices for outdoor materials storage are described in Profile Sheet H-6 in the Center for Watershed Protection's *Manual 8* of their *Small Watershed Restoration Manual Series*. Key practices include: (a) temporary or permanent covers; (b) storing material on pallets or raised surfaces; (c) providing secondary containment to capture any fluids or particulate matter before they reach a storm drain; and (d) changing the location of material storage areas to maximize the distance to a storm drain.

5-D.5.14. Benchmark 14: Prevent Dumpster and Compacter "Juice"

What to look for: Walk the site to locate any outdoor dumpsters, compactors or solid waste receptacles to ensure that overflowing wastes or leaking "dumpster juice" cannot reach the storm drainage system. Dumpsters can be problematic if they handle fluids or are exposed to rainfall. Compactors that compress materials with fluids can cause chronic water quality problems when located close to storm drain inlets.

Figure 5-D.16. Dumpster Waste and Trash Compactor "Juice"

Tasks. Two specific tasks must be completed to meet this benchmark:

41. Make sure dumpsters and compactors are covered, have lids, are in good condition, and are water-tight.
42. Make sure dumpsters are located in areas that are disconnected from the storm drainage system.

Scoring: A **total of 4 points**. Two points each for successful completion of Tasks 41 and 42.

Tips: Best practices for dumpster management are described in Profile Sheet H-8 in the Center for Watershed Protection's *Manual 8* of their *Small Watershed Restoration Manual Series*. Work with your solid waste contractor to make sure dumpsters are water-tight, frequently emptied, and located well away from storm drain inlets.

5-D.5.15. Benchmark 15: Improved Turf Management and Turf Conversion

What to look for: Evaluate every area of turf and landscaping within the boundary of the facility to identify opportunities to convert existing turf cover into native forest or meadow, or modify turf so that it more effectively filters and treats stormwater runoff from adjacent impervious areas.

Figure 5-D.17. Turf Can Generate High Runoff Rates of Nutrients and Pesticides to Streams

Figure 5-D.18. Turf Areas Can Be Converted to Native Forest, Meadow, or Filter Infiltration Type Stormwater BMPs

Tasks. Two specific tasks must be completed to meet this benchmark:

43. Evaluate all turf areas present at the site to identify alternatives to turf cover or to enhance its ability to filter and infiltrate runoff.
44. Implement reduced mowing, soil restoration, reforestation, filter strips, or rain gardens on existing turf cover.

Scoring: A **total of 10 points**. Three points are awarded for the initial turf cover evaluation (Task 43), and then one point is awarded for each 5% increment of existing turf cover converted at the site (Task 44, up to a maximum of seven total points for conversion).

Tips: The *Urban Watershed Forestry Manual Series*, produced by the Center for Watershed Protection, can be accessed online at http://www.cwp.org . BMP Design Specifications for soil restoration, filter strips, bioretention and rain gardens can found at the Virginia Stormwater BMP Clearinghouse website at http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html .

5-D.5.16. Benchmark 16: Investigate the Feasibility of Parking Lot BMP Retrofits

What to look for: Walk around your parking lot to determine where stormwater flows to identify possible locations to treat runoff from all or part of the lot. Open areas in close proximity to the lot and comprise 3% to 5% of the parking lot area are excellent locations for BMP retrofits. If such areas exist, retain an engineering consultant to assess the feasibility and cost of designing and building them. Please note that the examples of BMPs shown in Figure 5-D.19 below are all public domain BMPs. However, there are proprietary BMPs that could be used to retrofit parking lots as well.

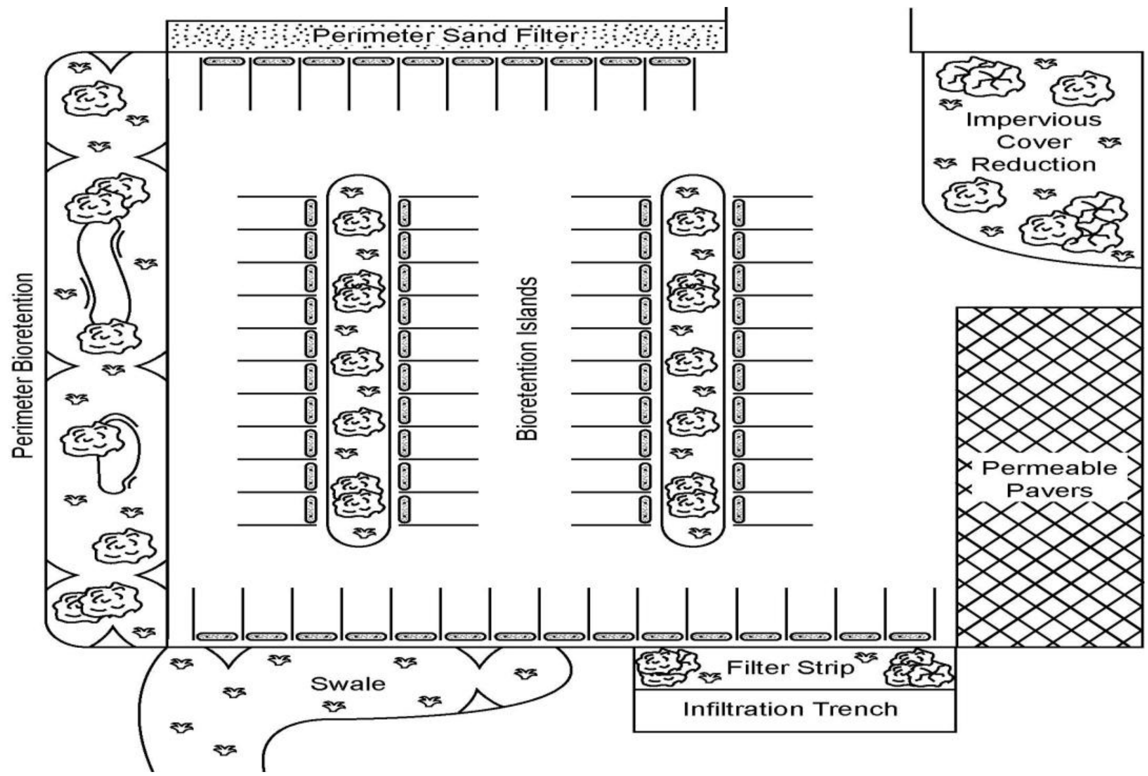

Figure 5-D.19. Different BMP Retrofit Options Available to Treat Parking Lot Runoff

Tasks. Two specific tasks must be completed to meet this benchmark:

45. Identify potential candidate BMP retrofits to treat parking lot runoff.
46. Retain an engineering consultant to assess their feasibility and cost.

Scoring: A **total of 5 points**. Two points Tasks 45 and three points for Task 46.

Tips: The tips and tricks for retrofitting large and small parking lots are described in Profile Sheets SR-6 and OS-7 in the Center for Watershed Protection's *Manual 3* of their *Small Watershed Restoration Manual Series*. There may be several small drainage areas within each parking lot that discharge to different points. It is often quite easy to integrate retrofits into landscaping setbacks or unoccupied turf areas found at these discharge locations.

5-D.5.17. Benchmark 17: Adopt "Green" Landscaping Practices

What to look for: Inspect all remaining turf and landscaping areas present at the site and work with landscaping contractors to reduce fertilization, pesticide application and irrigation and apply best practices to keep clippings and leaves out of the storm drain system.

Figure 5-D.20. The Clean Fence Line and Dead Vegetation Are Signs that Herbicides Have Been Applied

Figure 5-D.21. Lawn Clippings Left Along the Curb Can Be Washed Into the Storm Drain

Tasks. Three specific tasks must be completed to meet this benchmark:

47. Review and modify all landscaping contracts to minimize fertilizer and chemical use (or train employees if they perform this function), consistent with guidelines in the *Virginia Urban Nutrient Management Handbook* (DCR et al., 2011) or hire a lawn management contractor who is certified by the Virginia DCR as a Nutrient Management Planner in the Turf and Landscape category.
48. Use native species in all landscaping areas present at the site.
49. Avoid using herbicides along fence lines; use mechanical trimmers instead.

Scoring: A **total of 5 points**. Two points for successful completion of Tasks 47 and 48, and one point for completing Task 49.

Tips: Several useful best practices for better turf management and landscaping can be found in Profile Sheets H-12 and H-13 in the Center for Watershed Protection's *Manual 8* of their *Small Watershed Restoration Manual Series*. These profile sheets can be attached to landscaping contracts or provided to landscaping and grounds maintenance crews. *The Virginia Urban Nutrient Management Handbook* can be accessed online at http://www.ext.vt.edu and entering Publication number 430-350. Access information about the Virginia DCR's nutrient management certification program and water-friendly lawn management practices at http://www.dcr.virginia.gov/stormwater_management/nutmgt.shtml .The landscaping at your facility should reflect the native plant species found in your region of Virginia. Several excellent guides can be found online at http://www.acb-online.org/project.cfm?vid=85 ,or http://www.nps.gov/plants/pubs/Chesapeake/toc.htm .

5-D.5.18. Benchmark 18: Check for Illicit Dry Weather Flows at Storm Drain Outlets

What to look for: Follow your storm drain pipe(s) until they discharge into a ditch or stream channel, and check for the presence of dry weather polluted flows (or past evidence that they have occurred). Then do the necessary detective work to stop them. Even small-diameter storm drain pipes can be a source of episodic or transitory illicit discharges of pollutants. Keep in mind that sloped vegetated areas may discharge groundwater to the surface for a while (sometimes days) due to saturated soils following a rainstorm, so ideally these investigations should be conducted during the periods of the year in order to increase the chance of identifying illicit discharges.

Figure 5-D.22. Suspicious Flow from Storm Drain Pipe Outlet

Figure 5-D.23. Sample of Illicit Discharge From a Storm Drainage Pipe Outlet

Tasks. Two specific tasks must be completed to meet this benchmark:

50. Check for dry weather flows at storm drain outfalls at least four times a year.
51. If flows exist, perform an Outfall Reconnaissance Investigation (ORI) at all stormwater outfalls to find and fix the problem.

Scoring: A **total of 3 points**. One point for successful completion of Tasks 50, and two points for completing Task 51. If no dry weather flows are detected over the course of a year, award yourself the two points for Task 51.

Tips: Some simple detective methods to evaluate dry weather flows can be found in the *Outfall Reconnaissance Investigation and Field Sheet*, Chapter 11, of the Center for Watershed Protection's *Illicit Discharge Detection and Elimination Manual*, available online at: http://www.cwp.org .In many cases, the flows from large diameter storm drain pipes are derived from high ground water, so the flows are relatively clean. More detailed investigations should be triggered if the team notices suds, stains, odors, or turbid or discolored waters.

5-D.5.19. Benchmark 19: Regularly Maintain Your Stormwater Infrastructure

What to look for: Inspect all storm drain inlets, sumps and stormwater BMPs present at your facility for excessive sediment accumulation, and clean them out on a regular basis to keep sediment and other pollutants from reaching local streams, rivers, and the Bay. If manufactured BMPs are used on a site, the manufacturer's maintenance guidance should be followed.

Figure 5-D.24. Catch Basin Cleanout

Figure 5-D.25. Storm Drain Inlet Inspection

Tasks. Two specific tasks must be completed to meet this benchmark:

52. Perform an annual maintenance inspection of your stormwater infrastructure.
53. Clean out storm drain inlets (and any stormwater management practices) at least once a year.

Scoring: A **total of 5 points**. Two points for successful completion of Tasks 52, and three points for completing Task 53.

Tips: If your facility was built within the last two decades, there is a strong probability that there is some kind of stormwater BMP present at your site, usually a detention (dry) or retention (wet) pond. If one of these is present, you may want to consult the *Pond and Wetland Maintenance Guidebook* available at the Center for Watershed Protection's website (http://www.cwp.org) to assess the pond's maintenance condition and determine which specific maintenance tasks are needed. Sediments that accumulate in storm drain inlets and catch basins can be removed manually or by using a vactor truck. Make sure to properly dispose of these polluted sediments in a landfill or other approved facility.

5-D.5.20. Benchmark 20: Natural Area Conservation and Restoration

What to look for: Many facilities contain small fragments of forest, wetlands, floodplains, steep slopes or buffer areas that have been reserved for environmental protection. Over time, the habitat quality of these natural areas may become degraded by illegal dumping, invasive plant species, encroachment and clearing, disease, or poor soils. The facility team should walk through natural areas to assess their condition and diversity, and identify conservation and restoration practices that can improve their function and diversity.

Figure 5-D.26. A Typical Small Natural Area Remnant at An Industrial Site

Tasks. Two specific tasks must be completed to meet this benchmark:

54. Inventory the condition of any natural areas present at the site (e.g., forests, wetlands, meadows, buffer areas, etc.).
55. Implement conservation and restoration practices to improve the function and diversity of the natural areas.

Scoring: A **total of 5 points**. Two points for successful completion of the inventory (Task 54), and three points for implementation of the conservation practices (Task 55). If no natural areas are present at the site, then award yourself all five points.

Tips: Several resources can be consulted for the habitat assessment, including articles in the *Wetlands and Watershed Series* and the *Urban Watershed Forestry Manuals*, both of which can be accessed at the Center for Watershed Protection's website (http://www.cwp.org). For guides about how to identify and manage invasive plant species, consult the following websites:
http://www.fws.gov/chesapeakebay/bayscapes/bsresources/bs-invasives.htm or
http://www.plant-materials.nrcs.usda.gov/technical/invasive.html .

5-D.5.21. Benchmark 21: Become a Local Watershed Partner

What to look for: Meet with a local or regional watershed group (identified in Benchmark 1) to find ways to strengthen their efforts through volunteer work, product donations, board service or other cooperative measures. Hundreds of watershed groups exist in the Chesapeake Bay watershed, and it is very likely that at least one is located near your facility. These groups are your local connection to the local stream, river basin, or the Bay. They are an important source of watershed education, information and stewardship. Many of them exist on a shoestring budget, but are deserving of your support. After you have identified your local watershed organizations, you can gradually develop a strong mutually supportive relationship. Keep in mind that environmental stewardship also provides strong marketing opportunities in modern American culture.

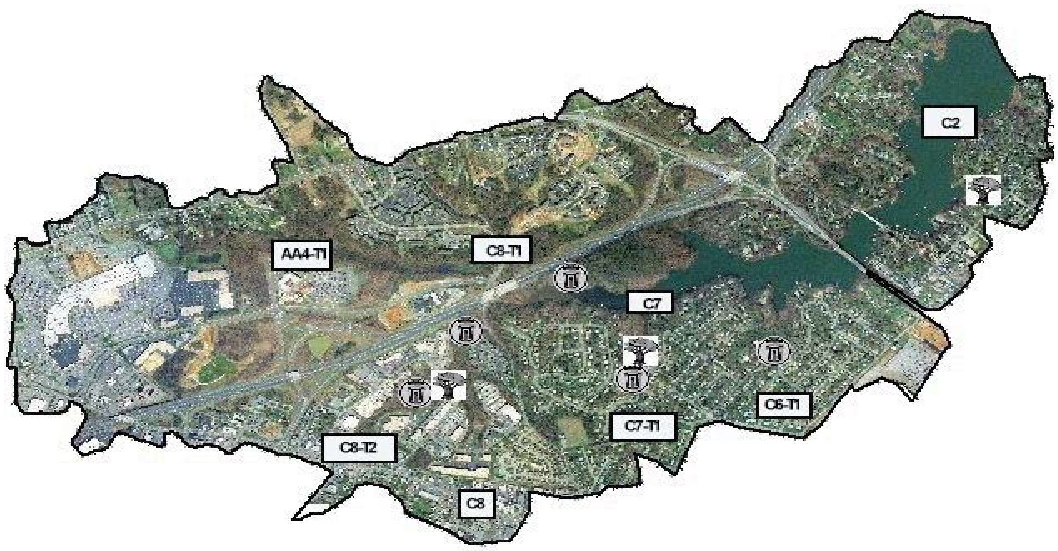

Figure 5-D.27. Partnering Watershed Organizations with Facilities Needing Help

Tasks. Two specific tasks must be completed to meet this benchmark:

56. Meet at least once with an appropriate local or regional watershed group.
57. Provide tangible evidence of your support to the group in the first year of association with them.

Scoring: A **total of 4 points**. Two points each for successful completion of Tasks 56 and 57.

Tips: What is tangible support? It can be as simple as attending a few board meetings, serving on a board of directors, becoming a corporate sponsor, encouraging your employees to make tax deductible donations, or donating surplus office equipment. One Coca-Cola bottler in Baltimore stored plastic syrup barrels in an old truck and made them available for free to local watershed groups to help make rain barrels. To find out which watershed organizations are active in your area, you can click on this directory of Bay region watershed groups:
http://www.chesapeakebay.net/findabaygroup.aspx?menuitem=14797 or find it using a map:
http://archive.chesapeakebay.net/georss/WatershedOrgsMap.kmz

5-D.5.22. Benchmark 22: Support a Local Stream Cleanup

What to look for: Take a walk down the closest thousand feet of stream to your facility (that has safe access from public property) to see if it needs a stream cleanup or adoption, in partnership with the local watershed group. Most watershed organizations offer a wide range of volunteer opportunities for your employees to have fun, make a difference, and demonstrate your commitment to community involvement and environmental stewardship.

Figure 5-D.28. A Stream Cleanup Martialing Area

Tasks. Two specific tasks must be completed to meet this benchmark:

58. Take a stream walk at the nearest accessible and safe stream segment downstream of your facility to better understand the waters to which your facility discharges stormwater runoff.
59. Participate in a stream cleanup or other watershed restoration activity conducted by a local or regional watershed organization.

Scoring: A **total of 4 points**. One point for successful completion of Task 58, and three points for completing Task 59.

Tips: The *Unified Stream Assessment (USA)* is an excellent tool to document urban stream problems and identify restoration opportunities. It is available online (http://www.cwp.org) as *Manual 10 of* the Center for Watershed Protection's *Small Watershed Restoration Manual Series*. Some helpful guidance on how to conduct a stream cleanup or adopt a stream can be found in Profile Sheets C-1 and C-2 of *Manual 4* in the *Small Watershed Restoration Manual Series*. Most watershed groups offer many different opportunities throughout the year for you and your employees to engage in a watershed restoration activity.

5-D.6.0. THE STORMWATER BENCHMARKING TOOL SCORE SHEET

This section provides a simple score sheet to keep track of your facility benchmarking activity.

STORMWATER BENCHMARKING TOOL SCORING SHEET FOR SURVEY			
Benchmark No.	**Description of Benchmark**	**Maximum Points**	**Points Awarded**
1. DEFINE YOUR WATERSHED ADDRESS			
1	Google Earth to find stream closest to facility	**1**	
2	Determine which major watershed stream drains to	**1**	
3	Identify the stream's major watershed group(s)	**1**	
4	Learn stream's key water quality and habitat issues	**1**	
	Subtotal	**4**	
2. DERIVE A STORMWATER PROFILE FOR THE SITE			
5	Analyze land cover on site plan	**1**	
6	Determine your annual rainfall	**1**	
7	Compute annual runoff from site	**1**	
8	Compute annual pollutant loads from site	**1**	
	Subtotal	**4**	
3. REVIEW PAST EMPLOYEE TRAINING			
9	Involve key employees to discuss benchmarks	**1**	
10	Customize stormwater training for the site	**1**	
11	Post Benchmark scores & train employees each year	**2**	
12	Give employees personal stewardship tips	**1**	
	Subtotal	**5**	
4. YOUR FACILITY'S STORMWATER POLLUTION PREVENTION PLAN			
13	Find and review existing SWPPP	**1**	
14	Designate lead staff responsible for it	**1**	
15	Full update of SWPPP and annual work plan	**3**	
	Subtotal	**5**	
5. UNDERSTAND THE STORMWATER PLUMBING AT YOUR SITE			
16	Walk the site to trace stormwater flows	**1**	
17	Identify water, wastewater, and stormwater lines	**1**	
18	Produce final site plan showing each	**1**	
19	Stencil or mark all storm drain inlets	**2**	
	Subtotal	**5**	

STORMWATER BENCHMARKING TOOL SCORING SHEET FOR SURVEY			
Benchmark No.	**Description of Benchmark**	**Maximum Points**	**Points Awarded**
6. REDUCE RUNOFF FROM THE ROOF			
20	Check for downspout disconnection potential	**1**	
21	Evaluate feasibility of rain tank or rainwater reuse	**2**	
22	Retain consultant to design system	**2**	
	Subtotal	**5**	
7. INVESTIGATE LOADING AND UNLOADING AREAS			
23	Keep loading areas clean by sweeping	**2**	
24	Cover loading docks or redesign drainage	**2**	
	Subtotal	**4**	
8. PREVENT POLLUTION FROM PARKING LOTS			
25	Walk areas monthly to find and mitigate fluid leaks	**2**	
26	Weekly trash/litter pickup, monthly vac/sweeping	**3**	
	Subtotal	**5**	
9. PREVENT SPILLS FROM FUELING AREAS			
27	Cover fueling islands	**1**	
28	Install dry spill response kits conveniently	**1**	
29	Redesign flows to prevent storm drain entry	**2**	
	Subtotal	**4**	
10. DEAL WITH SEASONAL OPERATIONS AND OUTDOOR WASH-WATER			
30	Assess seasonal operations (e.g., salting, etc.)	**2**	
31	Keep outdoor wash-water out of storm drains	**2**	
	Subtotal	**4**	
11. KEEP RAIN AND RUNOFF AWAY FROM VEHICLE REPAIRS			
32	No outdoor vehicle repairs	**2**	
33	Make sure indoor shop drains go to sanitary sewer	**1**	
34	Indoor storage of used fluids/batteries, etc.	**1**	
	Subtotal	**4**	
12. EVALUATE SPILL CONTROL AND RESPONSE			
35	Provide spill kits at high risk areas of site	**2**	
36	Update emergency contact numbers	**1**	
37	Adequate response during spill training drill	**2**	
	Subtotal	**5**	

STORMWATER BENCHMARKING TOOL SCORING SHEET FOR SURVEY			
Benchmark No.	**Description of Benchmark**	**Maximum Points**	**Points Awarded**
13. PREVENT RUNOFF FROM MATERIALS STORED OUTSIDE			
38	Place materials on pallets or raised surfaces	**1**	
39	Temporary covers or secondary containment	**1**	
40	No streak or stain lines on path to storm drain	**2**	
	Subtotal	**4**	
14. EXTERIOR DUMPSTER MANAGEMENT			
41	Dumpsters covered, have lids or are water-tight	**2**	
42	Dumpsters disconnected from storm drains	**2**	
	Subtotal	**4**	
15. TURF MANAGEMENT			
43	Evaluate all turf areas at site for alternative mgmt.	**3**	
44	Implement reduced mowing, soil restoration, reforestation, filter strips or rain gardens on existing turf areas (1 point per 5% of turf area)	**7**	
	Subtotal	**10**	
16. PARKING LOT BMP RETROFITS			
45	Identify candidate retrofit projects at parking lot(s)	**2**	
46	Retain engineer to investigate feasibility	**3**	
	Subtotal	**5**	
17. ADOPT "GREEN" LANDSCAPING PRACTICES			
47	Modify contracts to reduce chemical inputs	**2**	
48	Use native species in landscaping areas	**2**	
49	Avoid use of herbicides along fence lines	**1**	
	Subtotal	**5**	
18. CHECK FOR DRY WEATHER FLOWS AT STORM DRAIN OUTFALLS			
50	Check for illicit dry weather flow in storm drains	**1**	
51	If flows exist, perform outfall investigation to correct	**2**	
	Subtotal	**3**	
19. REGULARLY MAINTAIN YOUR STORMWATER INFRASTRUCTURE			
52	Perform semi-annual maintenance inspections	**2**	
53	Clean out storm drain inlets & catch basins annually	**3**	
	Subtotal	**5**	

STORMWATER BENCHMARKING TOOL SCORING SHEET FOR SURVEY			
Benchmark No.	**Description of Benchmark**	**Maximum Points**	**Points Awarded**
20. NATURAL AREA CONSERVATION			
54	Assess condition of existing forests/wetlands on site	**2**	
55	Implement conservation/restoration practices	**3**	
	Subtotal	**5**	
21. BECOME A LOCAL WATERSHED PARTNER			
56	Join a local watershed group	**2**	
57	Provide tangible evidence of support for the group	**2**	
	Subtotal	**4**	
22. ORGANIZE OR PARTICIPATE IN A LOCAL STREAM CLEANUP			
58		**1**	
59		**3**	
	Subtotal	**4**	
	GRAND TOTAL	**100**	

SCORING NOTES:

5-D.7.0. HANDY INTERNET LINKS TO FIND YOUR WATERSHED ADDRESS AND LEARN MORE ABOUT WATERSHEDS AND STORMWATER POLLUTION PREVENTION

5-D.7.1. Find Your Watershed Address

The U.S. EPA has two handy websites to help you find your watershed address by simply entering the zip code of your facility:

http://cfpub.epa.gov/surf/locate/index.cfm

http://www.ctic.purdue.edu/KYW/glossary/whatiswsaddress.html

5-D.7.2. Learn More About Watersheds

To find out which watershed organizations are active in your area, you can click on this directory of Chesapeake Bay region watershed groups:

http://www.chesapeakebay.net/findabaygroup.aspx?menuitem=14797

or find organizations by zooming into a Chesapeake Bay Map as found at:

http://archive.chesapeakebay.net/georss/WatershedOrgsMap.kmz

Several websites provide excellent information about watersheds including:

BAY PROGRAM:	http://www.chesapeakebay.net/index.aspx?menuitem=13853
USEPA:	http://www.epa.gov/owow/watershed/
CWP:	http://www.cwp.org
RN:	http://www.rivernetwork.org

5-D.7.3. Pollution Prevention Resources

- Urban Subwatershed Restoration Manual 11: *Unified Subwatershed and Site Reconnaissance: A User's Manual* (Center for Watershed Protection, 2005) http://www.cwp.org/Store/usrm.htm

- Urban Subwatershed Restoration Manual 10: *Unified Stream Assessment: A User's Manual* (Center for Watershed Protection, 2005) http://www.cwp.org/Store/usrm.htm

- Urban Subwatershed Restoration Manual 9: *Municipal Pollution Prevention/Good Housekeeping Practices* (Center for Watershed Protection, 2008) http://www.cwp.org/Store/usrm.htm

- Stormwater Phase II Final Rule Fact Sheet 2.8: *Pollution Prevention/Good Housekeeping* (US EPA, 2005)
  http://www.epa.gov/npdes/pubs/fact2-8.pdf

- Stormwater Fact Sheet No. 5: *Municipal Pollution Prevention Planning* (Land of Sky Regional Council (NC), 1994)
  http://h2o.enr.state.nc.us/su/PDF_Files/Land_of_Sky_factsheets/FactSheet_5.pdf

- Model Urban Runoff Program: *A How-To Guide for Developing Urban Runoff Programs for Small Municipalities* (California Coastal Commission, 2002)
  http://www.coastal.ca.gov/la/murp.html

Source Control Practices General Resources

- National Menu of Stormwater Best Management Practices: *Pollution Prevention/Good Housekeeping* (US EPA, 2007)
  http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

- Urban Subwatershed Restoration Manual 8: *Pollution Source Control Practices* (Center for Watershed Protection, 2005)
  http://www.cwp.org/Store/usrm.htm#8

- *California Stormwater Best Management Practice Handbook: Municipal* (California Stormwater Quality Association, 2003)
  http://www.cabmphandbooks.org/municipal.asp

- *Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices* (US EPA, 1992)
  http://cfpub1.epa.gov/npdes/docs.cfm?document_type_id=1&view=Policy%20and%20Guidance%20Documents&program_id=6&sort=name

- King County (WA) Stormwater Pollution Prevention Manual (King County (WA) Department of Natural Resources and Parks, 2005)
  http://www.kingcounty.gov/environment/waterandland/stormwater/documents/pollution-prevention-manual.aspx

Vehicle Operations

- Auto Repair and Fleet Maintenance Pollution Prevention Website (US EPA Region 9, 2007)
  http://www.epa.gov/region09/waste/p2/autofleet/

- *Vehicle and Equipment Wash Water Discharges Best Management Practices Manual* (Washington State Department of Ecology, 2007)
  http://www.ecy.wa.gov/pubs/95056.pdf

Outdoor Materials

- Stormwater Management Fact Sheet: *Spill Prevention Planning* (US EPA, 1999) www.epa.gov/owm/mtb/spillprv.pdf

- Community Partners for Clean Streams Fact Sheet 1: *Housekeeping Practices* (Washtenaw County (MI), 1996) http://www.ewashtenaw.org/content/dc_drnbmp1.pdf

Turf/Landscaping Areas

- Integrated Pest Management Manual (US Department of the Interior National Park Service, 2003) http://www.nature.nps.gov/biology/ipm/manual/ipmmanual.cfm

- Best Management Practice Fact Sheet: Landscape and Grounds Maintenance (Alameda County (CA) Clean Water Program, 1998) http://www.cleanwaterprogram.org/land_ground_main.pdf

5-D.8.0. ESTIMATING THE ANNUAL POLLUTANT LOAD FOR A FACILITY USING THE SIMPLE METHOD

The Simple Method estimates the annual pollutant load exported in stormwater runoff from small urban catchments (Schueler, 1987). The Simple Method sacrifices some precision for the sake of simplicity and ease of use, but is a reasonably accurate way to predict annual pollutant loads. The annual pollutant load exported in pounds per year from the contributing drainage area of a plant can be determined by solving the Pollutant Export Equation (each of the terms in the equation can be extracted from data contained in a facility plan).

$$L = [(P)(Pj)(Rv) \div 12] \times [(C)(A)(2.72)]$$

Where:

L = Average annual pollutant load (pounds)
P = Average annual rainfall depth (inches)
Pj = Fraction of minor rainfall events that produces runoff
Rv = Runoff coefficient, which expresses the fraction of rainfall converted to runoff
C = Event mean concentration of the pollutant in urban runoff (mg/l)

Depth of Rainfall (*P*)

P represents the depth of precipitation that falls on the contributing drainage area of the retrofit site during the course of a normal year. Annual rainfall data for select U.S. cities can be obtained from "official" local rainfall gages (usually located at an airport or a NOAA-National Weather Service office) with reliable, long-term (> 20 years) records. Another reliable source of rainfall data is the NOAA Atlas 14 website (http://hdsc.nws.noaa.gov/hdsc/pfds/orb/va_pfds.html), although this data is not as locally-specific and precise as a local rain gage. For most of Virginia, an annual value of 45 inches can be used.

Adjustment for Minor Storms (*Pj*)

Some of the storms that occur during a given year are so minor that they generate no stormwater runoff. The rainfall from these small storms is stored in surface depressions and either evaporates into the air or infiltrates into the ground. To account for these storms, the correction factor (***Pj***) is used. The design team can analyze local rainfall-runoff patterns to determine the value of *Pj* or simply use prior analyses from the Washington DC area, which indicate *Pj* is approximately 10% of the annual rainfall depth (Schueler, 1987). The default value for *Pj* should be 0.9 unless local rainfall-runoff analyses result in a different number.

The Runoff Coefficient (*Rv*)

The runoff coefficient (***Rv***) is a useful measure of a development site's response to rainfall events. In theory, it is calculated using the following equation:

$$Rv = 0.05 + 0.009(I)$$

Where:

I = The amount of impervious cover on the site, expressed as a percentage of the total site area. ***I*** should be expressed as a whole number within the equation (i.e., a site that is 75% impervious would use ***I*** = 75 when calculating the ***Rv***)

The designer is trying to solve the equation for *R* and does not know the value of *Rv*. A study of rainfall/runoff relationships for many small watersheds across the U.S. showed that *Rv* has a distinctly linear relationship with impervious cover (Schueler, 1987). The runoff coefficient increases in direct proportion to the percent impervious cover (*I*) present in a catchment. The resulting equation (above) can be used to estimate *Rv* for the contributing drainage area (CDA) of the facility.

Contributing Drainage Area (*A*)

The contributing drainage area (*A*, in acres) can be directly obtained from the drainage area provided in the facility site plan.

Event Mean Pollutant Concentration (*C*)

The last input datum needed is the event mean concentration (EMC) for five different pollutants. Designers can consult national stormwater quality monitoring databases that define event mean concentration statistics derived from a large population of runoff monitoring samples. The National Stormwater Quality Database (NSQD) is an extremely helpful tool to define expected EMCs for a wide range of different stormwater pollutants (Pitt *et al.*, 2004). **Table 5-D.2** below summarizes EMCs for five common pollutants as measured for industrial land uses in the NSQD.

Table 5-D.2. National Averages of Pollutant Event Mean Concentrations for Industrial Land Uses

POLLUTANT	CONCENTRATION (mg/l)
Total Suspended Solids (TSS)	81.0
Total Phosphorus (TP)	0.26
Total Nitrogen (TN)	2.09
Oil and Grease	4.0
Zinc (Zn)	0.20

5-D.9.0. ESTIMATING THE ANNUAL RUNOFF VOLUME FOR A FACILITY USING THE SIMPLE METHOD

Many of the same parameters can be used to determine the annual runoff volume generated by your facility. The annual volume of stormwater runoff per acre of impervious cover at your facility is calculated by the following equation:

$$ARI = [(P)(Pj)(Rv) \div (12)]$$

Where:

ARI = annual runoff volume in acre-feet produced from one acre of impervious cover (i.e., one foot of water depth over an acre)

P, ***Pj*** and ***Rv*** = as previously defined.

The total annual stormwater runoff volume produced by your facility can be quickly computed as:

$$TAR = (ARI)\ (IA)$$

Where:

TAR = total annual runoff volume (in acre feet) produced by the entire facility

ARI = annual runoff volume per impervious acre (from equation above)

IA = number of impervious acres at your facility

The final *TAR* number you calculate will be a big number, but it is hard for most people to comprehend. So the next step is to convert it to gallons of runoff.

$$Gallons = (TAR)(3.259 \times 10^{5})$$

It will be useful to translate this into terms a facility's employees can relate to. For example, at a bottling facility, the standard unit of production is a case of soda, which comprises about 2.25 gallons per case. Over a course of a year a bottling facility might ship 12 million cases of soda, and also generate 12 million "cases" of stormwater runoff. As another example, a Bay port facility measures its production in the number of standard forty-foot shipping containers it moves each year. Assuming about 18,500 gallons per container, a single impervious acre of port facility in the Chesapeake Bay watershed produces the equivalent of more than 50 shipping containers of runoff each year. By converting annual runoff into gallons and then comparing it to a common measure of site capacity, it is possible to educate employees about the scope of their runoff problems.

5-D.9.0. REFERENCES

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