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.

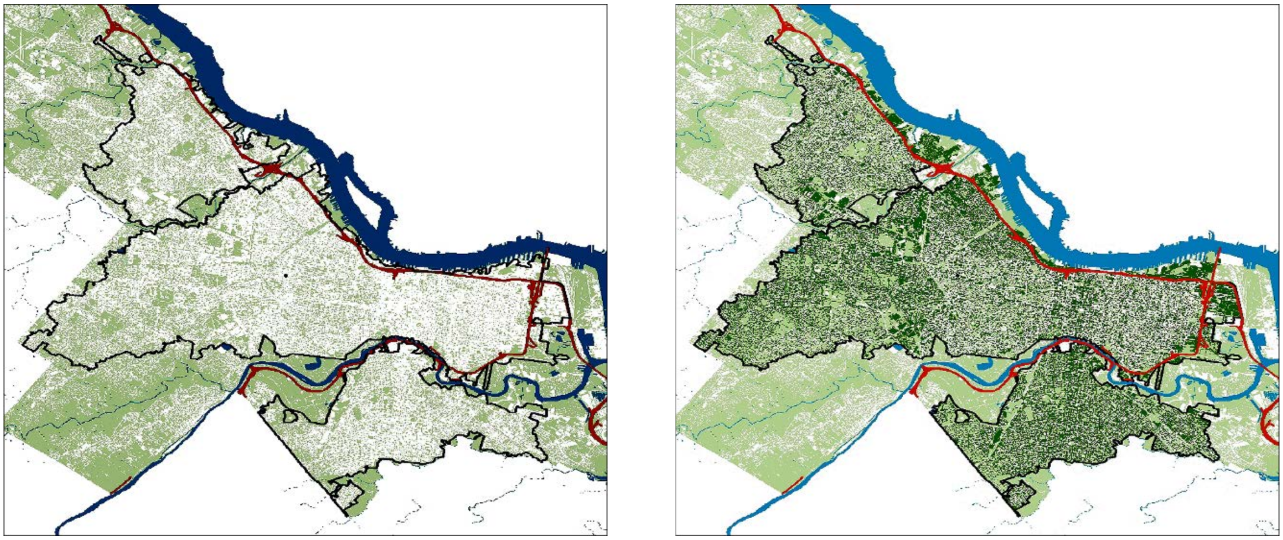

Figure 5-C.2. Starting (left) and Projected Coverage after 30 Years (right) of Redevelopment SWM Requirements, Green Streets and Other Retrofits in Philadelphia, PA
Source: Chesapeake Stormwater Network

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.

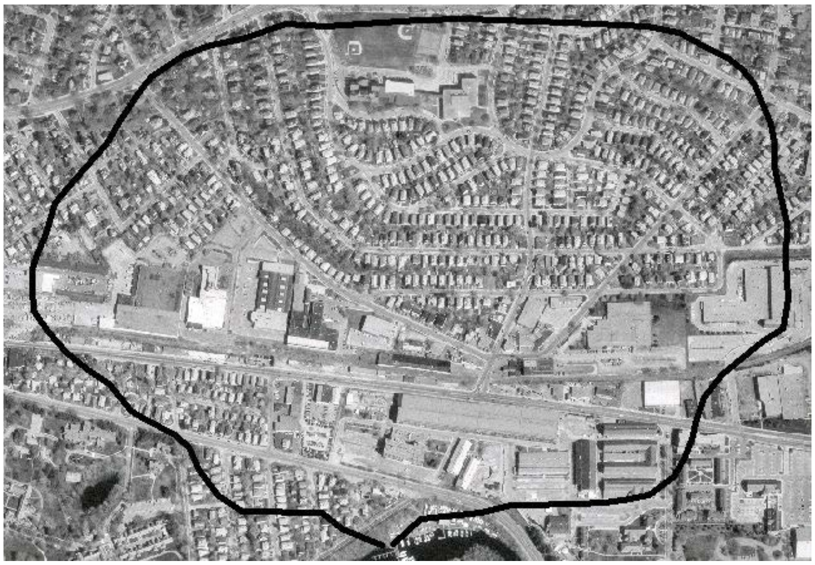

Figure 5-C.3. An Urban Drainage Shed
Source: Chesapeake Bay Stormwater Training Partnership

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.

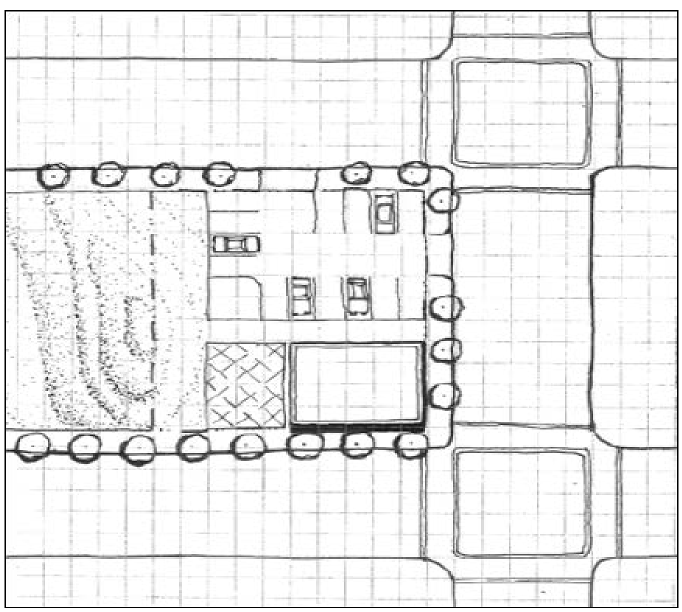

Figure 5-C.5. Sketching In Conversion of Impervious Cover to Pervious Cover and Adding Tree Canopy
Source: Chesapeake Bay Stormwater Training Partnership

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.

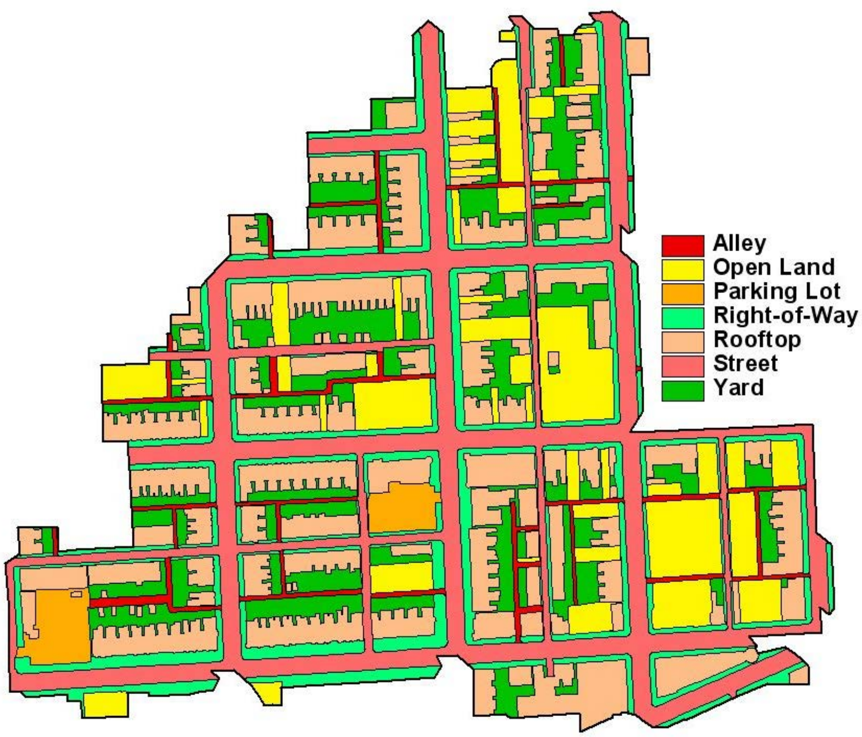

Figure 5-C.6. Decompose the Site into Smaller Drainage Units
Source: Chesapeake Bay Stormwater Training Partnership

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).

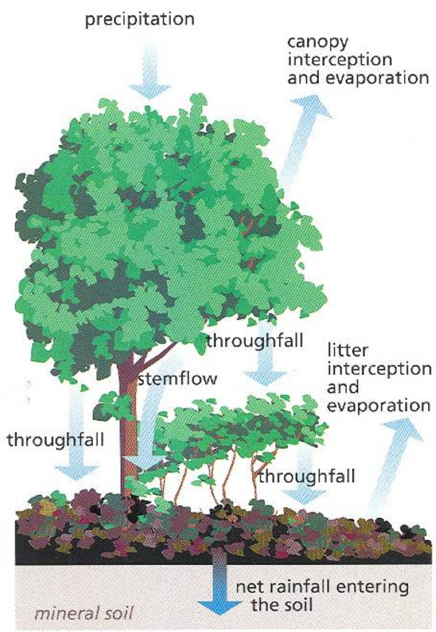

Figure 5-C.7. Hydrologic and Water Quality Benefits of Tree Canopy
Source: Chesapeake. Bay SW Training Partnership

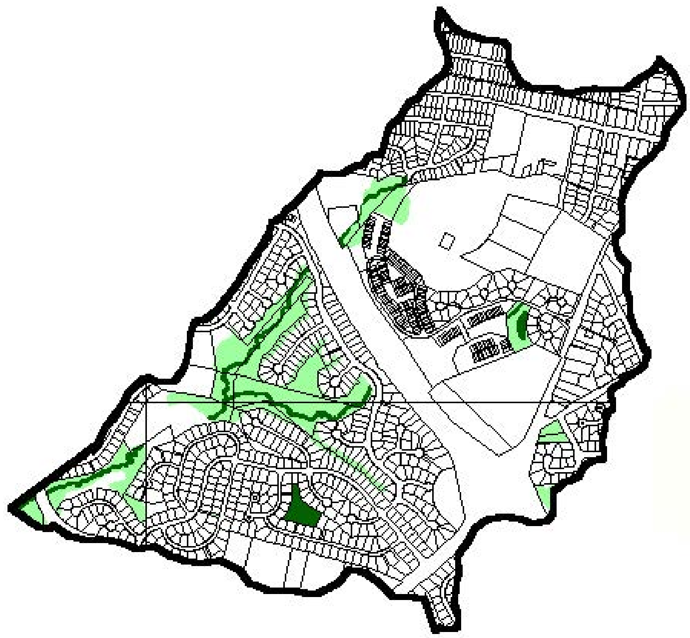

Figure 5-C.8. Identify Wetland and Natural Area Remnants for Restoration
Source: Chesapeake Bay SW Training Partnership

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.

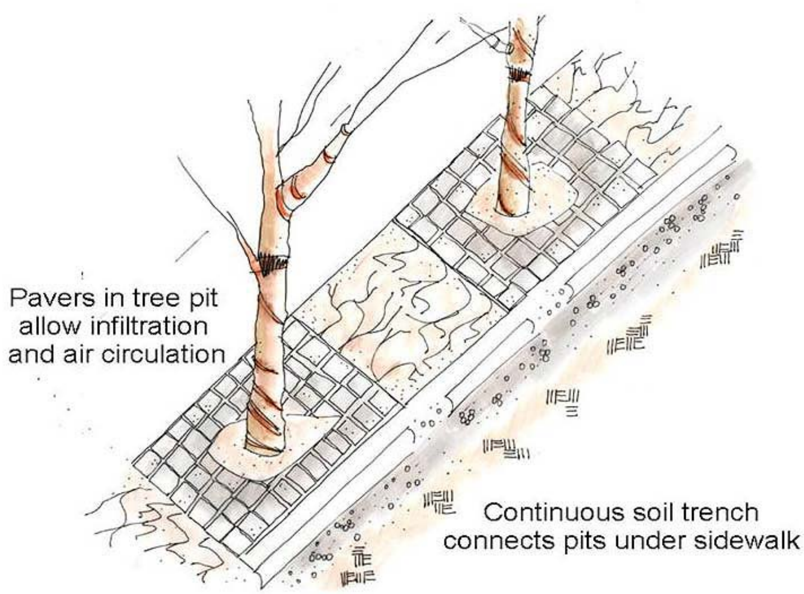

Figure 5-C.15. Extended Tree Pit
Source: Chesapeake Stormwater Training Partnership

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.

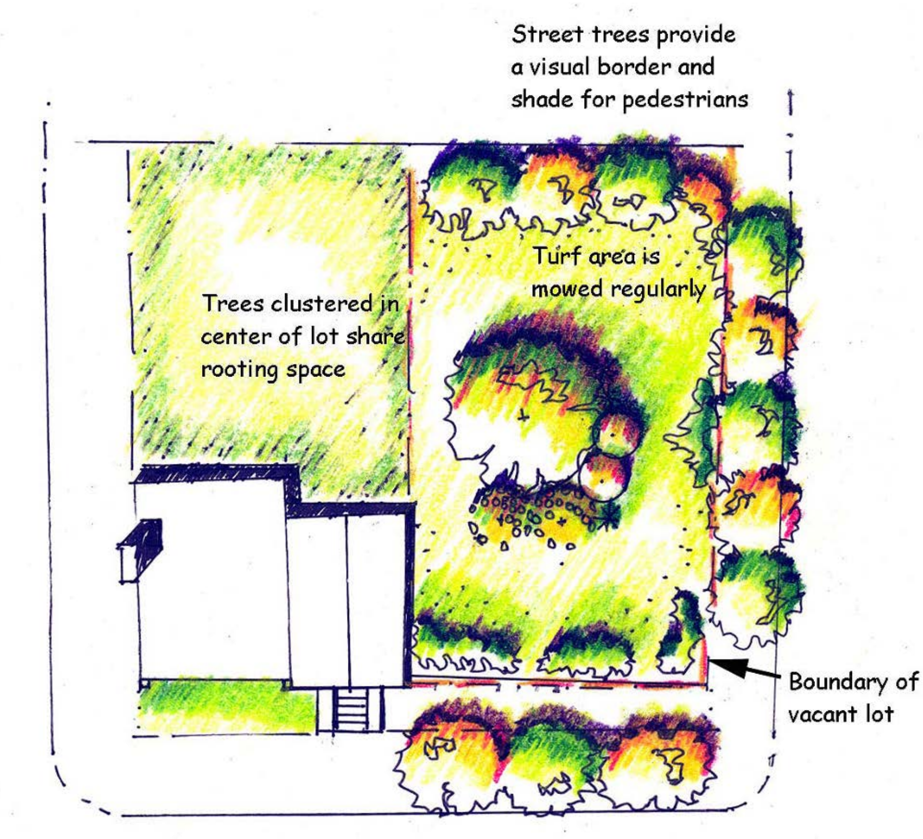

Figure 5-C.18. Tree Planting at a Vacant Lot
Source: Chesapeake Bay Stormwater Training Partnership

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**).

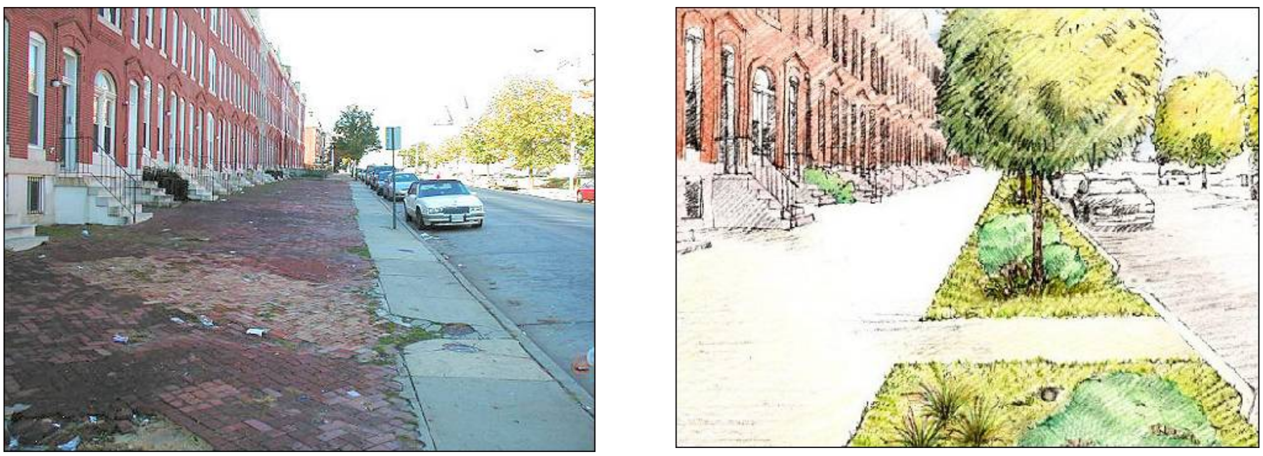

Figure 5-C.19. Street in Redevelopment Area of Baltimore (left), with Green Street Proposal (right)
Source: Chesapeake Bay Stormwater Training Partnership

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.

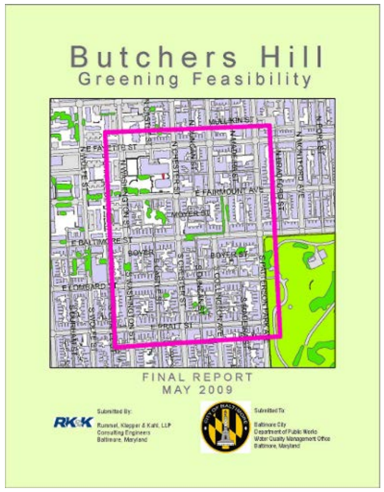

Figure 5-C.20. A Baltimore Green Street Feasibility Study
Source: Chesapeake Bay Stormwater Training Partnership

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, this 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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