Chapter 7

BMP UPGRADES AND RETROFITS

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7.0. INTRODUCTION

Ideally, as land is developed structural controls are implemented to control stormwater runoff impacts. However, controlling stormwater from new development and redevelopment alone will not solve problems resulting from earlier development that did not incorporate stormwater management. Retrofitting is the process by which various kinds of controls are applied to reduce the water quantity and quality impacts from *existing* developed areas. The USEPA is requiring retrofitting as part of the MS4 permitting process, but non-MS4 communities also have runoff problems issuing from older developed areas.

Stormwater retrofits help restore watersheds by providing stormwater treatment in locations where practices previously did not exist or were ineffective. They are typically installed within the stream corridor or upland areas to capture and treat stormwater runoff before it is delivered to receiving waters. Retrofits are the primary practice used to restore small watersheds since they can remove pollutants, promote more natural hydrology and minimize stream channel erosion and minor flooding.

Due to the fact that they are intended to serve existing problem areas, retrofits are typically the responsibility of the local government, which must mitigate property flooding, reduce streambank erosion, or comply with TMDL or other water quality regulatory requirements. Localities can also negotiate some private sector retrofit projects through compliance offset options in the local SWM program (e.g., using fee-in-lieu funds for retrofit projects, allowing off-site compliance where total compliance can’t be achieved on the development site, etc.).

Retrofits must be integrated with existing and often diverse urban development, and they assume a wider range of forms than structural controls installed during new development. Space constraints, construction costs, acquisition of easements, safety precautions, economic vitality, and property rights all compete with the need to reduce nutrient loadings in the urban environment.

This chapter describes opportunities and techniques for retrofitting existing, developed sites to improve or enhance water quality mitigation functions. This chapter also identifies the conditions for which stormwater retrofits are appropriate, as well as the potential benefits and effectiveness of stormwater retrofits.

Why Retrofitting is Different

Most retrofit designers have some prior experience designing new stormwater practices. It is important, however, to note the many ways that retrofit design differs from the design of new stormwater treatment practices (**Table 7.1** below).

Retrofitting requires a different way of thinking; it requires sleuthing skills to determine what can work at highly constrained sites. Designers need to simultaneously envision restoration possibilities and anticipate potential problems. They must be extremely creative to find and design effective stormwater solutions within the built environment that produce desired watershed-scale results.

Table 7.1. Why Retrofitting is Different from New Stormwater Design

Urban Retrofit Practices	New Stormwater Practices
Construction costs typically 1.5 - 4 times greater	Designers seek the least costly options
Requires significant data collection	Much of the data may be borrowed from past designs
Assessment and design costs are higher	Focus is on low cost design and construction
Sized to meet small watershed restoration objectives (or the best one can do)	Sized to meet local stormwater design standards
Typically installed on public land	Installed at new development projects
Urban soils often cannot support infiltration	Soils may support infiltration
Fingerprinted around existing development and infrastructure	More flexibility on where to locate practices on the site
Must be acceptable to adjacent neighbors and landowners	Aesthetics are not always a major design factor
Most are publicly maintained and the public expects that they will be	Most require private maintenance, which is often not performed
Not all candidate sites are feasible	Nearly all sites are made to work
Often tied into the existing stormwater conveyance system	Usually creates the new stormwater conveyance system
Integrated with other restoration practices	Stand-alone practices
Public investment in watershed infrastructure	Private investment in stormwater infrastructure
A site visit is prerequisite for design	Design may occur without site visits

Source: CWP, 2007

The design, permitting and construction of retrofits are almost always more complex, expensive and time consuming than new stormwater practices. Also, since most projects are sponsored by the public sector, they must meet high standards for performance, community benefit and appearance. Designers should seek to maximize restoration objectives and not merely design toward a rule. The ethical bar for retrofit design is also higher – designers must ensure that their proposed retrofit adds to watershed function and does not impair existing wetlands, streams and forests. The goal is not just to get approval for a development project or secure a stormwater permit, but rather to create a project that will look good, perform well for many decades, and have a reasonable maintenance burden.

7.1. OBJECTIVES AND BENEFITS OF STORMWATER RETROFITS

The objective of stormwater retrofitting is to remedy problems associated with, and improve water quality mitigation functions of, older, poorly designed or poorly maintained stormwater management systems. In Virginia prior to the 1970s, site drainage design did not require stormwater detention for controlling post-development peak flows. As a result, drainage, flooding, and erosion problems are common in many older developed areas of the state. Furthermore, a majority of the stormwater detention facilities throughout the state have been designed to control peak flows, without regard for water quality mitigation. Therefore, many existing stormwater detention basins provide only minimal water quality benefits.

Incorporating stormwater retrofits into existing developed sites or into redevelopment projects can reduce the adverse impacts of uncontrolled stormwater runoff. This can be accomplished through reduction in unnecessary impervious cover, incorporation of small-scale runoff volume reduction practices, and construction of new or improved structural stormwater treatment practices. One of the primary benefits of stormwater retrofits is the opportunity to combine stormwater quantity and quality controls. Stormwater retrofits can also remedy local nuisance conditions and maintenance problems in older areas, and improve the appearance of existing facilities through landscape amenities and additional vegetation.

The retrofit process begins with a diagnosis of how small watershed development is currently degrading stream quality. The reader may consult **Appendix 5-**A of Chapter 5 this Handbook for an extended discussion of the Impervious Cover Model and how it can be used to diagnose the severity of problems in a subwatershed and determine restoration potential.

Setting restoration objectives early in the retrofitting process is extremely important. Restoration objectives define the purpose of retrofitting and target the specific small watershed problems to be solved. A good set of restoration objectives helps identify what pollutants need to be treated, how much storage is needed and where the most cost-effective locations are in the small watershed. Communities around the country have chosen many different restoration objectives to guide their retrofitting efforts. The most common of those objectives are described below.

Fix Past Mistakes & Maintenance Problems. Traditionally, communities have used retrofits to improve their existing stormwater infrastructure (e.g., to fix drainage problems, deal with under-sized culverts, protect water and sewer lines threatened by erosion, or address chronic maintenance problems within individual stormwater practices). These infrastructure retrofits are localized to address a specific problem and are seldom done on a watershed-wide basis. The type of storage usually is tailored to solve the specific problem at the site.

Solve Chronic Flooding Problems. Another common retrofit objective is to solve flooding problems at vulnerable locations within a small watershed. This retrofitting approach focuses on specific stream reaches or flood prone areas. Upstream storage retrofits may be investigated to reduce flood damage in small watersheds that were developed prior to local stormwater or floodplain management requirements. These large retrofits are typically sized to provide storage for extreme flood events (e.g., 25 to 100 year peak discharge control).

Stormwater Demonstration and Education. Many communities embark on retrofitting to demonstrate new stormwater practices on public lands or promote stormwater education and stewardship. As a result, demonstration retrofits are designed for individual site needs rather than to meet watershed goals. Most demonstration retrofits are sized to the treatment volume and intended to introduce new stormwater technologies. Well-designed and highly visible demonstration retrofits are a good tactic to build community support to finance more widespread retrofitting efforts in the future.

Trap Trash and Floatables. The objective of these retrofits is combine pollution prevention, storage retrofits and improved catch basins to trap trash and floatables before they enter receiving waters. Since trash is fairly easy to trap, most retrofits are sized based on a fraction of the treatment volume, although they typically require intensive maintenance after every major storm event. Retrofit programs to reduce trash have been conducted in diverse locations, including New York City, Los Angeles, Baltimore, Albuquerque, and the District of Columbia.

Reduced Runoff Volumes to Combined Sewers. In recent years, communities have recognized that on-site retrofits can greatly reduce stormwater inputs to combined sewers, thereby reducing the frequency and size of sewage overflows in urban subwatersheds. This retrofit strategy can greatly reduce the size and cost of traditional combined sewer overflow (CSO) abatement systems such as deep tunnels or storage pipes. In many cases, on-site retrofits only need to reduce a fraction of the treatment volume to become a cost-effective technique to reduce CSOs. Rooftop treatment or disconnection is the most common approach to reduce runoff volumes, and they have been applied in diverse settings, including Philadelphia, Pittsburgh, Portland, Milwaukee, and the District of Columbia.

Renovate the Stream Corridor. This objective focuses on installing retrofits to improve the habitat, diversity and overall quality of a stream corridor, whether it is a greenway, stream valley park, or a chain of wetlands or lakes. The retrofits are located in or near the stream corridor and are intended to improve water quality, create wetland and wildlife habitat, daylight urban streams, naturalize the stream corridor or demonstrate creative stormwater practices. Some progressive communities that have utilized retrofits to renovate stream corridors include Staten Island (the Staten Island Bluebelt), Minneapolis (Minnehaha Creek), and the Detroit Metro Area (Rouge River).

Reduce Pollutants of Concern. Pollutant reduction is often a primary objective of local retrofit programs. The reduction may be driven by a TMDL, a local watershed restoration plan or regional directive to reduce pollutant loads. The pollutant of concern may include sediment, nutrients, bacteria, metals and toxins. Retrofits are then systematically applied across a small watershed to achieve a pre-designated pollutant reduction goal. Retrofits are typically sized based on a target treatment volume, although individual retrofits may be under- or over-sized. Examples of communities that have retrofit small watersheds to maximize pollutant removal include Staten Island, various communities in Maryland and North Carolina; Austin, Texas; Santa Monica, California; and Burlington, Vermont.

Systematically Reduce Downstream Channel Erosion. A few communities have sought to reduce downstream channel erosion by installing retrofits in urbanizing watersheds. This approach requires systematic installation of channel protection storage retrofits throughout the stream corridor. The strategy works best in impacted watersheds where the greater storage volume needed for channel protection can be more easily found. In recent years, this restoration objective has been linked to reducing nutrient loads derived from eroding streambanks. Two notable small watersheds where channel protection has been a primary restoration objective are Watts Branch and Minebank Run in Maryland.

Support Stream Restoration. This objective uses upstream retrofits to provide hydrologic control to support downstream restoration projects. Individual retrofits are installed above specific stream reaches where stream restoration is planned. The retrofits may provide recharge, water quality, channel protection, or some combination, depending on the specific design needs of the downstream project. The retrofits regulate the volume, duration, frequency, or peak discharge of storm flow, thereby creating a more stable and predictable hydrologic regime for the new stream. The long-term success of many stream repair/restoration projects is often depends on effective upstream retrofits. Notable examples of paired retrofit/stream repair projects on individual streams include Accotink Creek in Virginia and Watts Branch, Longwell Branch and Wheaton Branch in Maryland.

Comprehensive Watershed Restoration. The ideal objective is a comprehensive approach to restore small watersheds that integrates retrofits in the context of other goals such as stream repair, riparian reforestation, discharge prevention, upland reforestation, pollution source control and improved municipal practices.

7.2. WHEN IS RETROFITTING APPROPRIATE?

Site constraints commonly encountered in existing, developed areas can limit the type of stormwater retrofits that are possible for a site as well as their overall effectiveness. Retrofit of an existing stormwater management facility, consistent with the design specifications contained in the Virginia Stormwater BMP Clearinghouse web site, may not be possible due to site-specific factors such as the location of existing utilities, buildings, wetlands, maintenance access, and adjacent land uses. **Table 7.2** below lists site-specific factors to consider in determining the appropriateness of stormwater retrofits for a particular site.

Table 7.2. Site Considerations for Determining the Appropriateness of Stormwater Retrofits

Factor	Consideration
Retrofit Purpose	What are the primary and secondary (if any) purposes of the retrofit project? Are the retrofits designed primarily for stormwater quantity control, quality control, or both?
Construction/Maintenance Access	Does the site have adequate construction and maintenance access and sufficient construction staging area? Are maintenance responsibilities for the retrofits clearly defined?
Subsurface Conditions	Are the subsurface conditions at the site (soil permeability, depth to groundwater/bedrock, presence of karst geology, etc.) consistent with the proposed retrofit regarding subsurface infiltration capacity and constructability?
Utilities	Do locations of existing utilities present conflicts with the proposed retrofits or require relocation or design modifications?
Conflicting Land Uses	Are the retrofits compatible with the land uses of adjacent properties?
Wetlands, Sensitive Water Bodies, Karst Topography, and Vegetation	How do the retrofits affect adjacent or down-gradient wetlands, sensitive receiving waters, karst features, and vegetation? Do the retrofits minimize or mitigate impacts where possible?
Complementary Restoration Projects	Are there opportunities to combine stormwater retrofits with complementary projects such as stream stabilization, habitat restoration, or wetland restoration/mitigation?
Permits and Approvals	Which local, state, and federal regulatory agencies have jurisdiction over the proposed retrofit project, and can regulatory approvals be obtained for the retrofits?
Public Safety	Does the retrofit increase or reduce the risk to public health and safety?
Cost	What are the capital and long-term maintenance costs associated with the stormwater retrofits? Are the retrofits cost-effective in terms of anticipated benefits?

Source: CT DEP, 2004

Newly designed and installed stormwater management facilities are typically more effective than retrofitted facilities in reducing pollutant loads. However, in most cases, some improvements in stormwater quantity and quality control are possible with retrofits, especially if a new use is planned for an existing development or an existing storm drainage system is upgraded or expanded. Incorporation of a number of runoff volume reduction practices or a treatment train approach may be necessary to achieve the desired level of effectiveness. It should also be recognized that increased stormwater quantity and peak flows often causes channel erosion, resulting in some of the most severe impacts to receiving waters and wetlands (Claytor, Center for Watershed Protection, 2000). Therefore, stormwater quantity control functions provided by existing stormwater management facilities should not be compromised significantly in exchange for pollutant removal effectiveness.

7.3. EXAMPLES OF SUCCESSFUL STORMWATER RETROFIT PROJECTS

Built-out spaces often require innovative ways to treat stormwater – sometimes because runoff and water quality problems have increased along with development, and sometimes because stormwater requirements were less stringent when the original development took place. When it comes to urban stormwater retrofitting, every little bit counts. But finding the space and means to incorporate stormwater measures is often a challenge. The following examples demonstrate how three sites across the nation have managed it.

7.3.1. Liberty Centre Parking Garage

In the case of the Liberty Centre Parking Garage in Portland, Oregon, two planters were squeezed between two exterior walls of the parking garage and the sidewalks (**Figure 7.1**). The planting areas make up just 5 percent of the drainage catchment area of the 36,000 square foot parking deck, but they can infiltrate almost all of the stormwater from a 2-year rainfall event. The project's reduction in stormwater volume and its use of native vegetation have qualified it for LEED (Leadership in Energy and Environmental Design) certification.

Figure 7.1. Planting Areas at the Liberty Centre Parking Garage
Source: Aird, 2009 (Ashworth Pacific, Inc.)

The project's goals were to (1) reduce the volume of stormwater flowing into the combined sewers in the area and (2) to improve the quality of water flowing into the nearby Willamette River. The planters absorb and infiltrate at least 2 inches of stormwater per hour. More details regarding the project's design and costs can be found in *Aird (2009)*.

7.3.2. Burnsville Rain Gardens

Stormwater used to flow down Rushmore Drive in Burnsville, Minnesota, right into Crystal Lake. The amount of phosphorus it carried was causing algae blooms in the lake, which affected recreation. Today, the suburban street is a site of a demonstration project where 17 of 25 homes have rain gardens (**Figure 7.2**) that capture and infiltrate runoff before it reaches the lake.

Figure 7.2. Front Yard Rain Garden, Burnsville, MN
Source: Aird, 2009 (Barr Engineering)

There was not enough space for traditional stormwater ponds in the neighborhood, which was built in the 1980s. However, Rushmore Drive has a gentle topography, sandy soils, and 15-foot rights-of-way (from the edges of the curb) that provide plenty of space for the rain gardens. The City initiated and funded the project, but there was a fairly significant educational component in order to obtain homeowner cooperation. Ultimately, more than 80 percent of the homeowners in the 5.3 acre drainage area wanted to participate, motivated by the opportunity to be part of improving local water resources.

According to city officials, the homeowners appear to be proud and happy with their rain gardens. They view them as amenities to their homes as well as water quality improvement measures, so they take good care of their own rain gardens. The project is different from most rain garden projects, which tend to be more spread out. However, city officials have concluded that the real positive impact is when rain gardens are clustered together.

Five years of monitoring the project indicates that the project has reduced runoff to the lake by 90 percent, when compared to similar neighborhoods nearby without rain gardens. In nearly all cases, the gardens have been able to infiltrate and treat at least 0.9 inch of stormwater runoff. Most gardens have dried within three or four hours, and there haven't been any adverse effects from ice buildup in winter. More details regarding the project's design and costs can be found in *Aird (2009)*.

7.3.3 Broadview Green Grid Project

Contrary to popular belief, Seattle, Washington, doesn't receive an excessive amount of annual rainfall. However, the 36 inches it does receive falls on slopes of dense glacial fill and impermeable urban surfaces. Stormwater there is causing the familiar problems: polluted runoff, eroded stream channels, and impaired wildlife habitat.

In 1999, Seattle Public Utilities (SPU) began its Natural Drainage System program. It focuses on increasing pervious areas along street edges by redesigning existing streets and installing landscaping that infiltrates stormwater efficiently. In 2004, SPU completed its Broadview Green Grid Project in partnership with the Seattle Department of Transportation. The project covers approximately 32 acres, almost an entire sub-basin of Piper's Creek, which leads to the Puget Sound.

The goals of the project were to move stormwater off of roads and properties, slow it down, and allow it to infiltrate into the soil before it reached Piper's Creek. This would recharge the groundwater and sustain the creek during the dry summer months, as well as reduce erosion in the creek and the amount of pollutants – oil, grease, heavy metals, pet waste, sediments, fertilizers, and pesticides – emptying into it.

The project encompasses 15 blocks of residential property, but the entire project is installed on public land: across the width of the streets and easements on both sides, for a total width of about 60 feet. As in Burnsville, city officials surveyed the residents to ensure they would support the project.

The roadway design affected only three north-south streets, which slope down to the west. They began as straight, 25-foot wide roadways with two-way traffic and continuous parking space on both sides. They've been narrowed to about 19-20 feet wide, and they now meander slightly, slowing the runoff and guiding it off the road. Every street still has two-way traffic, one parking lane, and room for emergency vehicles designed for urban areas. Some streets have a sidewalk. The narrow, winding streets provide a bonus for the residents – traffic moves very slowly, discouraging cut-through traffic and providing much more safety for pedestrians.

The easements on both the north-south and the east-west streets have some traditional drainage features, such as culverts and catch basins, as well as swales, bioretention cells or rain gardens, and cascades. The steeper the street, the more grade control was used.

The east-west streets have very steep downhill slopes. The swales, which are along only one side of the streets, are giant “swale cells.” They’re divided by concrete weirs, each with a notch to control the flow of water. The weirs act as a series of steps that slow stormwater as it flows down into the swales. Rock walls line one side of these swales (**Figures 7.3 and 7.4**).

Figure 7.3. Seattle’s 107th Street Cascade Before Planting. Source: Aird, 2009

Figure 7.4. Finished Swale Cells Along Seattle’s 107th Street, an East-West Street. Source: Aird, 2009

The north-south streets, which have cross slopes to a maximum of approximately 8 degrees, have 20-foot easements with swales along both sides of the streets. Rock walls line one side of the swales to maximize their area (**Figure 7.5** below). The bioretention cells are on flatter ground and aren’t designed to retain the high volumes of stormwater that swales do.

All of the features are landscaped with native plants, whose roots help stabilize the soil, absorb runoff, and remove pollutants. Smaller trees and shrubs were chosen that wouldn’t outgrow the easements, as well as grasses, sedges and rushes in dense groups and wetland plants in lower, moister areas. Most of the swales are designed to infiltrate ½-inch of stormwater per hour and all stormwater within three days. There is never more than 12 inches of standing water while it’s raining. Any water that doesn’t infiltrate flows into a pool where it’s treated and detained before continuing into the downstream stormwater network.

Figure 7.5. Swale and Curves Along Phinney, Avenue, a North-South Street in Seattle. Source: Aird, 2009

The homeowners maintain the landscape. Most of SPU's maintenance costs consist of keeping the landscape mulched. Sedimentation structures, which accumulate pollutants attached to dirt and particles, are cleaned out once a year. According to SPU projections, natural drainage systems such as this are costing at least 25 percent less than traditional stormwater systems because of decreased construction and maintenance costs. They also offer aesthetic improvements that traditional systems do not.

For examples of retrofits using some manufactured stormwater management devices, see Rafter (2008).

7.4. RAINFALL, RUNOFF AND RETROFITS

Once core retrofit objectives are selected, they need to be translated into subwatershed sizing criteria. For this reason, the retrofit team must understand the relationship between rainfall, runoff and retrofits in their community. Retrofitting is fundamentally driven by the distribution of rainfall events. This section introduces the concept of the rainfall frequency spectrum, and how it can be used to define the target runoff volumes for retrofitting.

In the course of a year, many precipitation events occur within a community. Most events are quite small but a few can be several inches deep. A rainfall frequency spectrum describes the average frequency of the depth of rainfall events that occur during a normal year (adjusted for snowfall). **Figure 10.1** (in **Chapter 10** of this Handbook) provides an example of a typical rainfall frequency spectrum that shows the percent of rainfall events that are equal to or less than the indicated rainfall depth. As can be seen, the majority of storms are relatively small but a sharp upward inflection point occurs at about one-inch of rainfall. A rainfall frequency spectrum can outline up to five different zones that define targets for different stormwater treatment objectives, as follows:

Recharge. This targets rainfall events that create little or no runoff but contribute much of the annual groundwater recharge at a site. (NOTE: The Virginia Stormwater Management Law and Regulations do not currently include any independent requirements for recharging groundwater, but local governments may establish their own criteria using the authority in the Law and Regulations to adopt more stringent criteria. See **Appendix 10-A** at the end of **Chapter 10.**)

Water Quality. This targets rainfall events that deliver the majority of the stormwater pollutants during the course of a year (denoted as Treatment Volume, or T_v**).**

Channel Protection. This targets storms that generate bankfull and sub-bankfull floods that cause stream channel erosion and enlargement.

Overbank Floods. This targets large and infrequent storm events that spill over to the floodplain and cause damage to infrastructure and streamside property.

Extreme Storms. This controls the largest, most infrequent and most catastrophic floods that threaten structures and public safety (e.g., commonly known as the 100-year storm). (NOTE: The Virginia Stormwater Management Law and Regulations do not currently include any independent requirements for extreme flood protection, but local governments may establish their own criteria using the authority in the Law and Regulations to adopt more stringent criteria.)

In general, retrofitting focuses on the lower end of the rainfall frequency spectrum (i.e., managing runoff for recharge, water quality and channel protection). Small watershed retrofitting to control overbank floods or extreme storms is rarely attempted, since it is hard to get enough retrofit storage to manage runoff at this end of the spectrum. As a result, flood mitigation projects are normally installed to prevent problems within a specific flood-prone reach and not on a watershed-wide basis.

Retrofit teams will achieve more precision in their results if they develop localized retrofit sizing criteria based on their own rainfall frequency spectrum analysis, using the following guidance (CWP, 2007):

1. Obtain a long-term rainfall record from the adjacent weather station (daily precipitation is fine, but try to obtain at least 30 years of daily records). NOAA has several websites with long-term rainfall records (see http://ols.nndc.noaa.gov).

2. Edit out small rainfall events that are 0.1 inch or less. Also edit out snowfall events that do not immediately melt.
3. Using a spreadsheet or simple statistical package, analyze the rainfall time series and develop a frequency analysis to determine the percentage of rainfall events greater than or equal to a given numerical value (e.g., 00.2, o.5, 1.0, 1.5 inches, etc.).
4. Construct a curve showing rainfall depth versus frequency, and create a table showing rainfall depth values for 50, 75, 90 and 95% frequencies.
5. Use the data to define the recharge event (20-50%), treatment event (90%), and one-year storm (99%).

If a community is large or has considerable variation in elevation or aspect, the RFSA should be conducted at multiple stations. Other regional and national rainfall analyses, such as TP-40 (NOAA) or USGS, should always be used for rainfall depths or intensity greater than one-year return frequency (e.g., 2, 5, 10, 25, 50 or 100 year design storm recurrence intervals). The rainfall frequency spectrum provides a strong basis to set targets for the desired water quality, runoff reduction or channel protection volume to seek in a subwatershed, as described below.

Setting Treatment Volume Targets for Retrofitting. The water quality treatment retrofit goal is to capture and treat the 90% storm (defined by the state regulations as the 1-inch rainfall event) or a local rainfall frequency spectrum (?). This criterion optimizes runoff capture resulting in high load reduction for many stormwater pollutants. Based on the treatment design storm, it is relatively easy to determine the retrofit storage volume needed at either the site or small watershed scale.

Several practical implications arise when establishing the treatment volume for a small watershed – particularly when it comes to finding enough retrofit sites to meet it. In general, when the T_V is large, fewer retrofit sites can be found that have adequate space to capture and treat it. An optimization point exists between the target volume and expected number of retrofit locations, as shown in **Figure 7.6**.

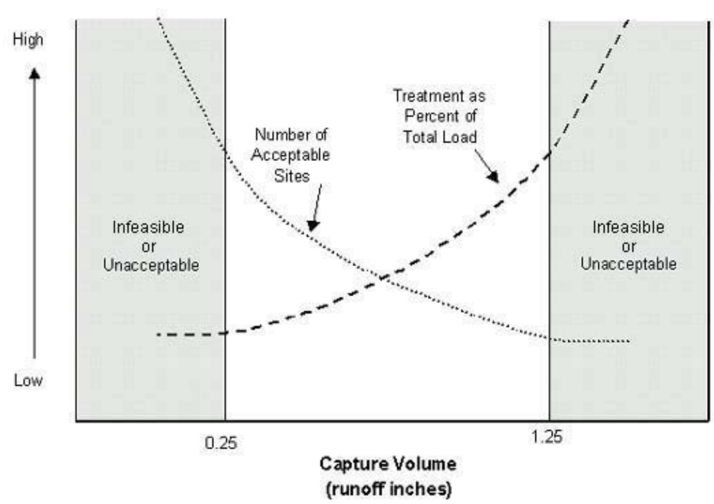


Figure 7.6. Optimization Point for Retrofit Treatment
Source: CWP, 2007

One curve shows how the fraction of subwatershed treatment increases when the capture volume becomes progressively greater. The second curve shows how the number of feasible retrofit sites declines as a function of a higher capture volume. An optimization point exists in most small watersheds where the two curves intersect. The retrofit optimization point also reflects the degree of watershed impervious cover – shifting towards 0.25 inches in highly developed watersheds and as much as 1.25 inches in lightly developed ones. This optimization point is an important factor to define early in the retrofit scoping process.

Setting Runoff Reduction Volume Targets. The target storage volume for runoff reduction typically ranges from 20-50 percent of the Tv and can be attained through canopy interception, rooftop disconnection, infiltration, rainwater harvesting, evaporation or long-term storage. The target runoff reduction volume is determined based on local watershed characteristics, and the desired degree of CSO relief, groundwater recharge or baseflow maintenance. Runoff reduction volumes are deceptively low in comparison to other target volumes. Designers should be aware that most storage retrofits do not reduce much runoff volume, so that dozens or even hundreds of small on-site retrofits may be needed to achieve runoff reduction objectives, depending on the size of the site or watershed. As noted above, the Virginia Stormwater Management Law and Regulations do not currently include any independent requirements for reducing runoff or recharging groundwater, but local governments may establish their own criteria using the authority in the Law and Regulations to adopt more stringent criteria.)

Setting Channel Protection Volume Targets. The recommended channel protection criterion is 24 hours of extended detention for the runoff generated by the 1-year 24-hour design storm. This is generally equivalent to the rainfall depth for the 99% storm. Past practice has resulted in runoff being stored (detention) and gradually released over a 24-hour period so that critical erosive velocities in downstream channels are not exceeded during the entire storm hydrograph. As a very rough rule, the storage capacity needed to provide channel protection is about 60% of the one-year storm runoff volume. However, it is possible that the need for detention facilities can be avoided if sufficient runoff volume reduction is achieved by other control measures. Designers will normally need to define actual channel protection volumes using hydrologic and hydraulic models that simulate specific channel conditions and subwatershed characteristics.

Channel protection storage generally exceeds the treatment volume by 20 to 40%. It may seem intuitive that the channel protection volume should always be higher than the T_v, since the rainfall depth associated with the 99% storm must always be greater than the 90% storm. The key difference is that the T_v is defined as 100% of the runoff volume produced by the 90% rain depth; whereas the channel protection volume is estimated as 60% of the runoff volume produced for the 99% rain depth.

Both the T_v and the channel protection storage volume may be needed to attain certain small watershed retrofit objectives, which effectively doubles the total storage volume needed. The best conditions for finding enough channel protection storage are in small sensitive or impacted watersheds that have a high existing pond density and/or abundant public land in stream corridors. In many cases, complete retrofit channel protection is not possible for the watershed as a whole, but it may be feasible for individual stream reaches where stream repairs are being proposed.

7.5 THE SEARCH FOR WATERSHED STORAGE

Watershed treatment is an important concept when assessing retrofit potential. Designers need to calculate the total water quality treatment volume needed to meet the restoration objectives. The feasibility of capturing and treating this volume will be different in every watershed. Conceptually, subwatershed treatment is represented by the following equation:

Total volume = Storage retrofits + on-site retrofit storage + future redevelopment treatment

The redevelopment term reflects future opportunities to provide stormwater treatment within the watershed as land is redeveloped. While redevelopment is not an explicit component of the retrofitting process, it is important to update existing stormwater criteria to take advantage of long-term opportunities to install new/additional treatment measures.

The challenge of retrofitting is to find enough storage to make a real difference in a watershed. The required storage volume can consume a significant percentage of watershed area, particularly when channel protection and flood control storms are being managed.

Retrofitting becomes more and more difficult and costly to pursue as subwatershed imperviousness increases. At lower levels of impervious cover, it is generally possible to find needed storage volumes for water quality treatment and, sometimes, channel protection. Available land to provide water quality and/or channel protection is harder to come by at higher levels of watershed impervious cover (45-60%).

7.6. THE RANGE OF RETROFIT PRACTICES

Retrofits can be classified by the amount of subwatershed area they treat. *Storage retrofits* treat drainage areas ranging from five to 500 acres. By contrast, *on-site* residential retrofits may individually treat as little as 500 square feet of contributing drainage area. On-site, non-residential retrofits normally treat less than five acres of contributing drainage area, and frequently less than one.

Storage and on-site retrofits represent two different approaches to attain treatment storage and involve different design and assessment methods (**Table 7.3**). As a general rule, storage retrofits are the most cost-effective approach to meet most subwatershed restoration objectives, although both retrofit approaches may be needed to get the desired level of subwatershed treatment.

Storage Retrofit Classification. Storage retrofits are classified using common locations in a subwatershed where large storage volumes can be found. The six major storage retrofit locations are described in detail in **Table 7.4**. Most storage retrofits are located on publicly owned or controlled land, and rely on some combination of extended detention, wet pond, constructed wetland or bioretention for stormwater treatment.

On-Site Retrofit Classification. On-site retrofits are classified based on the type or location of impervious area they treat, such as individual rooftops, small parking lots, streets, stormwater hotspots and other small impervious areas. Seven onsite retrofit locations are described in **Table 7.5**. On-site retrofits treat the quality and/or reduce the volume of runoff generated by small urban source areas and rely on bioretention, filtering, infiltration, swales or rooftop treatment. On-site retrofits are an effective strategy in ultra-urban subwatersheds that lack space for storage retrofits, and can also provide excellent opportunities to improve public awareness and involvement. Most on-site retrofits are normally installed on private land but involve some form of public delivery.

Table 7.3. Two Different Approaches to Retrofitting

Storage Retrofits	On-Site Retrofits
Serve 5 to 500 acres	Serve 0.1 to 5 acres
Generally constructed on public land	Generally constructed on private land
May need dozens in a subwatershed	May need hundreds in subwatershed
Assessed at subwatershed scale	Assessed at catchment/neighborhood scale
Moderate cost per impervious acre treated	High cost per impervious acre treated
Impractical in ultra urban areas	Practical in ultra-urban areas
Permitting can be extensive	Few permits are needed
Can address all stormwater control targets	Only provide recharge and water quality control
Public construction	Public delivery
Use extended detention, wet pond, and wetlands	Rely on bioretention, filtering, infiltration, swales and other treatment practices

Source: CWP, 2007

Table 7.4. The Six Most Common Storage Retrofit Locations in a Subwatershed

Where to Look	How to Get Storage
Add Storage to Existing Ponds	Add water quality treatment storage to an existing pond that lacks it by excavating new storage on the pond bottom, raising the height of the embankment, modifying riser elevations/dimensions, converting unneeded quantity control storage into water quality treatment storage and/or installing internal design features to improve performance.
Storage Above Roadway Culverts	Provide water quality storage immediately upstream of an existing road culvert that crosses a low gradient, non-perennial stream without wetlands. Free storage is created by adding wetland and/or extended detention treatment behind a new embankment just upstream of the existing roadway embankment.
New Storage Below Outfalls	Flows are split from an existing storm drain or ditch and are diverted to a stormwater treatment area on public land in the stream corridor. Works best for storm drain outfalls in the 12- to 36- inch diameter range that are located near large open spaces, such as parks, golf courses and floodplains.
Storage in Conveyance Systems	Investigate the upper portions of the existing stormwater conveyance system to look for opportunities to improve the performance of existing swales, ditches and non-perennial streams. This can be done either by creating in-line storage cells that filter runoff through swales and wetlands or by splitting flows to off-line treatment areas in the stream corridor.
Storage in Road Rights-of-Way	Direct runoff to a depression or excavated stormwater treatment area within the right of way of a road, highway, transport or power line corridor. Prominent examples include highway cloverleaf, median and wide right of way areas.
Storage Near Large Parking Lots	Provide stormwater treatment in open spaces near the down-gradient outfall of large parking lots (5 acres plus).

Source: Adapted from CWP, 2007

Table 7.5. The Seven Most Common On-Site Retrofit Locations in a Subwatershed

Where	How
Hotspot Operations	Install filtering or bioretention treatment to remove pollutants from confirmed or severe stormwater hotspots discovered during field investigation.
Small Parking Lots	Insert stormwater treatment within or on the margins of small parking lots (less than five acres). In many cases, the parking lot is delineated into a series of smaller on-site treatment units.
Individual Streets	Look for opportunities with the street, its right of way, cul-de-sacs and traffic calming devices to treat stormwater runoff before it gets into the street storm drain network.
Individual Rooftops	Disconnect, store and treat stormwater runoff generated from residential and commercial rooftops close to the source.
Little Retrofits	Convert or disconnect isolated areas of impervious cover and treat runoff in an adjacent pervious area using low tech approaches such as a filter strip.
Landscapes and Hardscapes	Reconfigure the plumbing of high visibility urban landscapes, plazas and public spaces to treat stormwater runoff with landscaping and other urban design features.
Underground	Provide stormwater treatment in an underground location when no surface land is available for surface treatment. Use this as a last resort at dense ultra-urban sites.

Source: Adapted from CWP, 2007

7.7. STORMWATER RETROFIT OPTIONS

Stormwater retrofit options include many of the same source control and stormwater treatment practices for new developments that are described in other chapters of this Manual. Common stormwater retrofit applications for existing development and redevelopment projects include:

- Source control retrofit
- Stormwater drainage system retrofits
- Stormwater management facility retrofits
- New stormwater controls at storm drain outfalls
- New stormwater controls at roadway culverts and above roadway crossings
- New stormwater controls for highway rights-of-way
- Individual streets
- Parking lot stormwater retrofits
- In-stream practices in existing drainage channels
- Wetland creation and restoration
- Hotspots
- Individual rooftops
- Little retrofits
- Landscapes/hardscapes
- Underground

7.7.1 Source Control Retrofit

Source control techniques, sometimes referred to as "good housekeeping practices," attenuate runoff and/or pollutant generation before it enters a storm drain system, (e.g., reducing impervious areas, using pollution prevention practices, covering road salt/sand storage piles, etc.) These are especially important in areas where build-out prevents the establishment of a significant number of new facilities, and where redevelopment will not have a significant impact on water quality.

7.7.2 Stormwater Drainage Systems

Existing drainage systems can be modified to improve water quality mitigation and sediment removal functions. These retrofits alone typically provide limited benefits, but are most successful when used in conjunction with other source controls and stormwater treatment practices. Due to their very nature as an integral part of the stormwater collection and conveyance system and inherent solids trapping function, these retrofits typically have high maintenance requirements. Common examples of stormwater drainage system retrofits include:

Deep Sump Catch Basins with Hoods. Older catch basins without sumps can be replaced with catch basins having four to six-foot deep sumps. Sumps provide storage volume for coarse sediments, provided that accumulated sediment is removed on a regular basis. Hooded outlets, which are covers over the catch basin outlets that extend below the standing water, can also be used to trap litter and other floatable materials. A study conducted in New York City demonstrated that catch basins equipped with hoods increase the capture of floatables by 70 to 80 percent over catch basins without hoods and greatly extend the cleaning interval without degraded capture performance (Pitt, 1999 in NRDC, 1999).

Catch Basin Inserts and Storm Drain Structures. A number of manufactured devices have been developed that can be inserted into storm drains or catch basins to capture sediment and other pollutants directly beneath the grate. These products typically utilize filter media or vortex action for removal of solids from incoming stormwater runoff. These devices are ideally suited for developed sites since they fit inside of or replace existing catch basins, or are installed beneath existing parking lots with minimal or no additional space requirements.

Treatment in the Conveyance System. This retrofit obtains storage within altered zero and first order stream channels that comprise about half of the channel network in most subwatersheds. These channels lack perennial flow, have minimal floodplains and typically have a contributing drainage area of 15 to 50 acres in humid regions. However, these channels rarely show up on local GIS maps (**Figure 7.7** below).

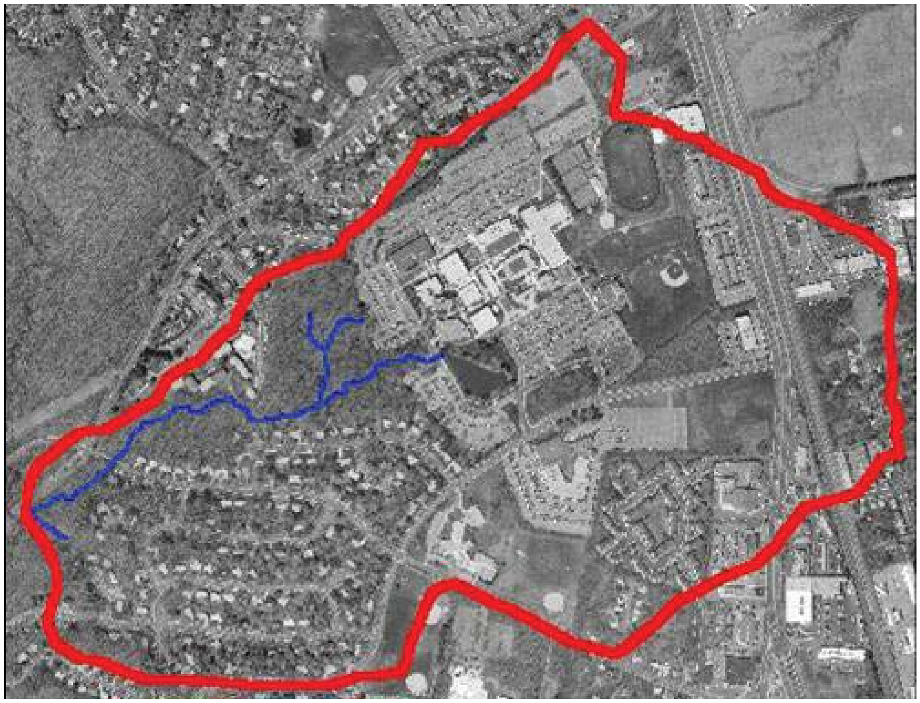


Figure 7.7. Most ditch lines and zero-order streams do not show up on local GIS maps (Source: CWP, 2007)

Conveyance retrofits create storage, bioretention or wetland cells in an existing ditch, swale or non-perennial stream channel (**Figure 7.8** below). Conveyance retrofits are particularly appropriate in small headwater channels that have been channelized and/or hardened in the past.

There are two basic design variants for the conveyance retrofit – *in-channel* designs where stormwater treatment storage is obtained within the channel and *off-channel* designs where the treatment storage is provided in cells adjacent to the channel. In-channel retrofits obtain storage by:

- Installing small weir walls or check dams in the channel to provide more storage
- Converting a channel or ditch into dry swale or wet swale
- Creating a linear series of wetland or bioretention treatment cells in the channel

Off-channel retrofits split storm flows from the channel to an adjacent depression or excavated treatment area (also **Figure 7.8**). Off-channel retrofits can be effective when floodplain reconnection or wetland creation is a subwatershed restoration objective. Constructed wetlands and bioretention are preferred for off-channel applications since they minimize the need for major excavation and embankments.

The stormwater conveyance system is a good location for storage retrofits since the land is usually located in a dedicated easement or right of way.

The ideal conditions for a conveyance retrofit are when the channel has:

- Gradient ranging between 0.5 and 2.0%
- Contributing drainage area of 15 to 30 acres of in humid regions with tight soils. Minimum drainage areas for conveyance retrofits are greater in arid and semi-arid regions with permeable soils
- Been altered to promote efficient drainage (e.g., ditch, swale or concrete-lined channels
- Less than three feet of elevation difference between the top of bank and the channel bottom
- Been used for roadway drainage in the right of way
- An unutilized parcel of public land located adjacent to the channel.

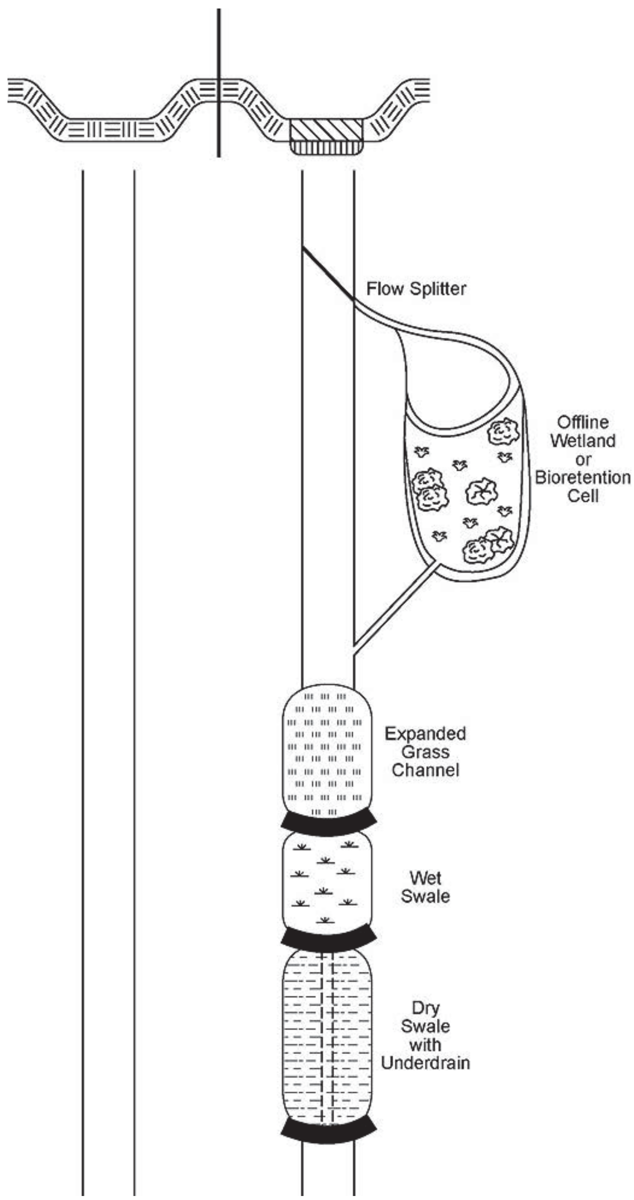


Figure 7.8. Both in-channel or off-channel treatment are possible in a conveyance.
Source: CWP, 2007

Figure 7.9 illustrates several examples of good candidate sites in the conveyance system for retrofit storage.

Figure 7.9. Four opportunities within the conveyance system for retrofitting
Source: CWP, 2007

Conveyance retrofits are generally *not* a good idea when the existing channel:

- Is in natural condition and has adjacent mature forests or wetlands
- Is rapidly degrading/incising or has a knick point advancing upstream
- Has a channel gradient of 5% or more and/or steep side slopes
- Has perennial flow
- Is located close to a residential neighborhood
- Is privately owned or lacks a drainage easement

7.7.3. Stormwater Management Facilities

Stormwater Treatment Options for Retrofitting. Eight different stormwater treatment options can be used for retrofitting. Each treatment option differs greatly in its pollutant removal capability, hydrologic benefit and retrofit suitability. More detailed information about each stormwater treatment option can be found in CWP 2007. Some of the basic differences are compared in **Table 7.6** below.

Table 7.6. Stormwater Treatment Options for Retrofitting

Stormwater Treatment Option	How It Works
Extended Detention (BMP #15)*	This option relies on 12-24 hour detention of stormwater runoff after each rain event within a pond, with portions of the pond drying out in between storm events. Extended detention (ED) allows pollutants to settle out, and if enough storage is available, can also provide downstream channel protection.
Wet Ponds (BMP #14)*	Wet ponds consist of a permanent pool of standing water. Runoff from each new storm enters the pond and partially displaces pool water from previous storms. The pool also acts as a barrier to re-suspension of sediments and other pollutants removed during prior storms.
Constructed Wetlands (BMP #13)*	Constructed wetlands are shallow depressions that receive stormwater for treatment. Runoff from each new storm displaces runoff from previous storms, and the residence time of several days to weeks allows multiple pollutant removal processes to operate.
Bioretention (BMP #9)*	Bioretention is an innovative urban stormwater practice that uses native forest ecosystems and landscape processes to enhance stormwater quality. Bioretention areas capture sheet flow from impervious areas and treat the stormwater using a combination of microbial soil processes, infiltration, evapotranspiration, and plants.
Filtering Practices (BMP #12)*	Filter practices function by filtering runoff through an engineered media and collecting treated runoff in an underdrain. The media may consist of sand, soil, compost, or a combination of these.
Infiltration Practices (BMP #8)	An infiltration trench is a rock-filled chamber with no outlet that receives stormwater runoff. Stormwater runoff passes through some combination of pretreatment measures, such as a swale or sediment basin, before entering the trench where it infiltrates into the soil.
Swales (BMP # ‘s 3, 10 and 11)*	Swales are a series of engineered, vegetated, open channel practices that are designed to treat and attenuate stormwater runoff for a specified water quality volume.
Other Retrofit Treatment (BMP #’s 1, 2, 4, 5, 6, 7 and 9)*	These on-site practices provide treatment of roof runoff using rain gardens, rain barrels, vegetated roofs, cisterns, stormwater planters, dry wells, or permeable pavers.
* Practice specifications can be found on the Virginia Stormwater BMP Clearinghouse web site at http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html . NOTES: See **Chapter 8** for more specific descriptions of these BMPs. More specific and thorough guidance about stormwater treatment retrofits can be found in CWP (2007a).	

Source: Adapted from CWP, 2007a

More specific and thorough guidance about conveyance system retrofits can be found in CWP (2007a).

Modifications to Existing Facilities. Existing stormwater management facilities originally designed for channel protection or flood control can be modified or reconfigured for water quality mitigation purposes or increased hydrologic benefit. Older detention facilities offer the greatest opportunity for this type of retrofit (**Figure 7.10** below). Traditional dry detention basins can be modified to become extended detention basins, wet ponds, or stormwater wetlands for enhanced pollutant removal. This is one of the most common and easily implemented retrofits since it typically requires little or no additional land area, utilizes an existing facility for which there is already some resident acceptance of stormwater management, and involves minimal impacts to environmental resources.

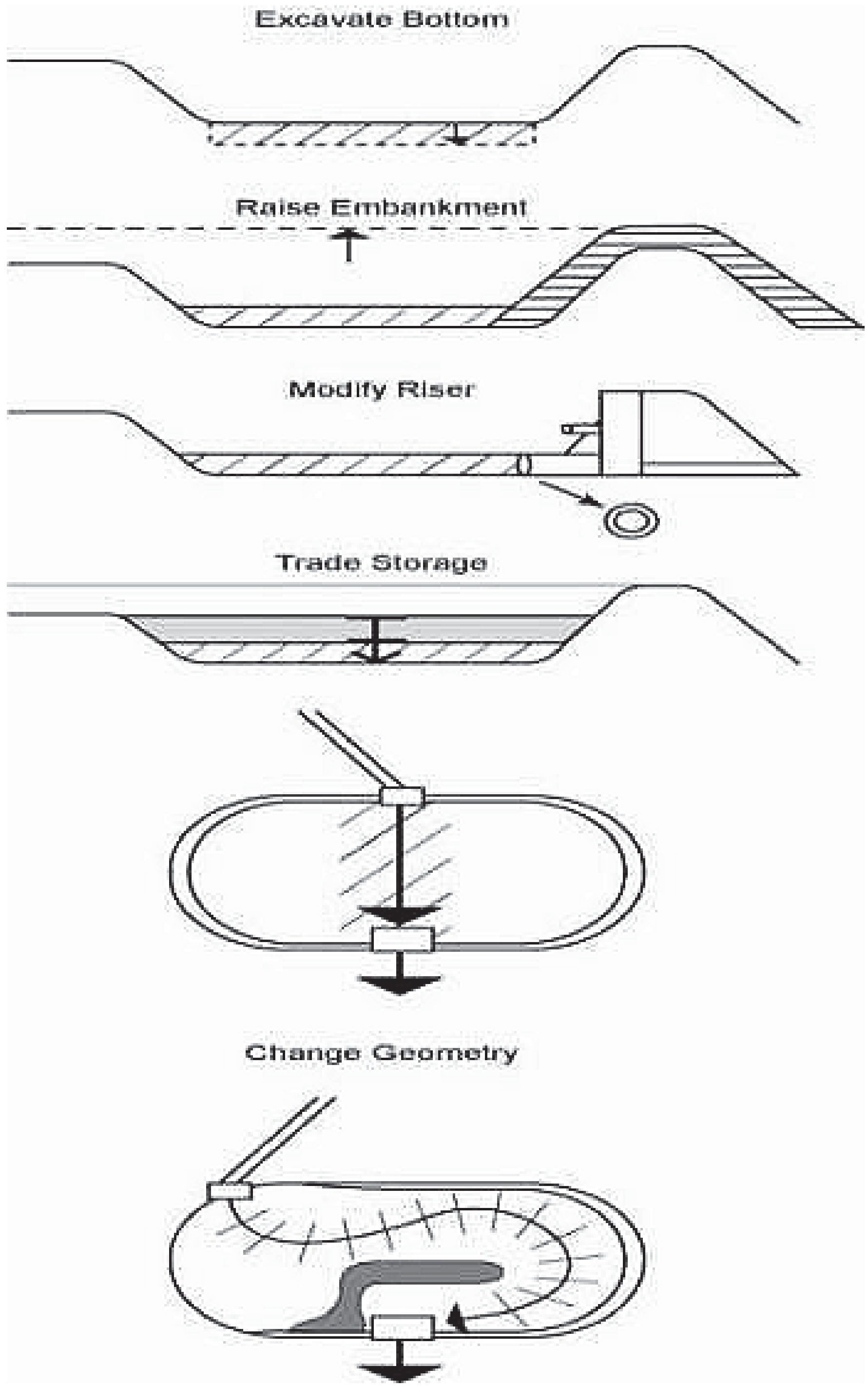


Figure 7.10. Some Modifications That Can Be Made to Existing Detention Ponds.
Source: CWP 2007

Specific modifications to existing detention basins for improved water quality mitigation are summarized as follows (Sources: CT DEP, 2004, adapted from Claytor, CWP, 2000; Pennsylvania Association of Conservation Districts et al., 1998; and NJDEP, 2000):

- Excavate the basin bottom to create more permanent pool storage
- Raise the basin embankment to obtain additional storage for extended detention
- Modify the outfall structure to create a two-stage release to better control small storms while not significantly compromising flood control detention for large storms
- Increase the flow path from inflow to outflow and eliminate short-circuiting by using baffles, earthen berms, or micro-pond topography to increase residence time of water in the pond and improve settling of solids
- Replace paved low-flow channels with meandering vegetated swales
- Provide a high flow bypass to avoid resuspension of captured sediment/pollutants during high flows
- Eliminate low-flow bypasses
- Incorporate stilling basins at inlets and outlets and sediment forebays at basin inlets
- Re-grade the basin bottom to create a wetland area near the basin outlet or re-vegetate parts of the basin bottom with wetland vegetation to enhance pollutant removal, reduce mowing, and improve aesthetics
- Create a wetland shelf along the perimeter of a wet basin to improve shoreline stabilization, enhance pollutant filtering, and enhance aesthetic and habitat functions
- Create a low maintenance “no-mow” wildflower ecosystem in the drier portions of the basin

Stormwater detention basin retrofits should include an evaluation of the hydraulic characteristics and storage capacity of the basin to determine whether available storage exists for additional water quality treatment. Dry pond locations are typically easy to identify on fine-resolution aerial photos (**Figure 7.11**). A typical retrofit of an existing detention basin is shown in **Figure 7.12** below.

Figure 7.11. Dry Ponds Are Easy to Identify on Fine-Resolution Aerial Photos
Source: CWP, 2007

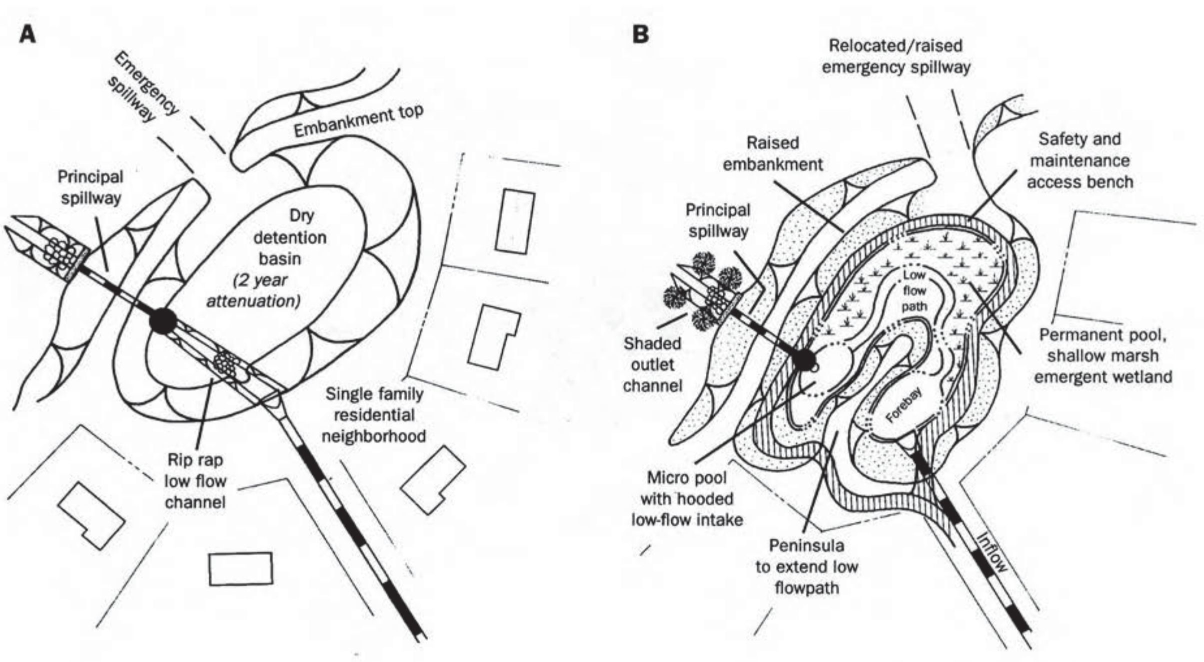


Figure 7.12. Stormwater Retrofit of an Existing Dry Detention Basin
Source: Claytor, CWP, 2000; CT DEP, 2004

Additional enhancements to existing BMPs include rehabilitating failed infiltration practices, adding bioretention or filtering to ponds, and increasing the treatment volume, flow path, retention time, or wetland elements of existing BMPs.

7.7.4. Storm Drain Outfalls

New stormwater treatment practices can be constructed at the outfalls of existing drainage systems. The new stormwater treatment practices are commonly designed as off-line devices to treat the water quality volume and bypass larger storms. Water quality swales, bioretention, sand filters, constructed wetlands, and wet ponds are commonly used for this type of retrofit, although most stormwater treatment practices can be used for this type of retrofit given enough space for construction and maintenance. Manufactured, underground treatment devices are also commonly installed as off-line retrofits at or upgradient of stormwater outfalls. Velocity dissipation devices such as plunge pools and level spreaders can also be incorporated into the retrofit design.

This retrofit creates new treatment adjacent to the stream corridor near the terminus of an existing storm drain outfall. Outfall retrofits are designed off-line by splitting flow from the existing storm drain pipe (or ditch) and diverting it to a stormwater treatment area formed by an existing depression, excavation or constructed berm (**Figure 7.13** below). A flow splitter allows larger storms to remain in the existing pipe (or ditch) and bypass the retrofit. Typical stormwater treatment options at outfall retrofits are a combination of extended detention, pond or constructed wetland storage (**Figure 7.14** below). Constructed wetlands are preferred in floodplains where groundwater elevations are high and space is available. Bioretention may also work if the outfall has no dry weather flow and a small contributing drainage area (**Figure 7.15** below).

Outfall retrofits are ideal because they are close to the stream and maximize the upland drainage area treated. In addition, their offline location usually means fewer stream permitting problems. Finally, outfall retrofits only need to be designed to provide the desired storage for water quality and/or channel protection; larger flood flows bypass the retrofit. More specific and thorough guidance about outfall retrofits can be found in CWP (2007a).

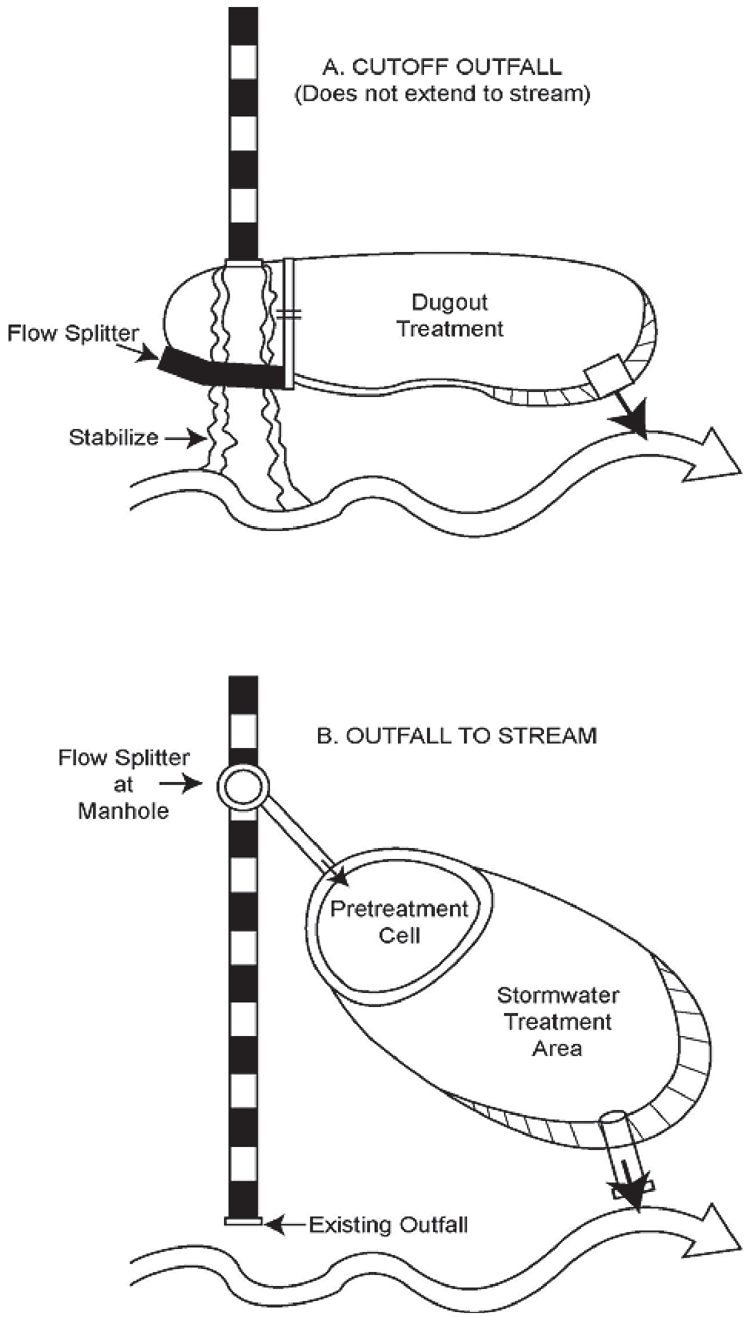


Figure 7.13. Two strategies for outfall retrofits in the stream corridor
Source: CWP, 2007a

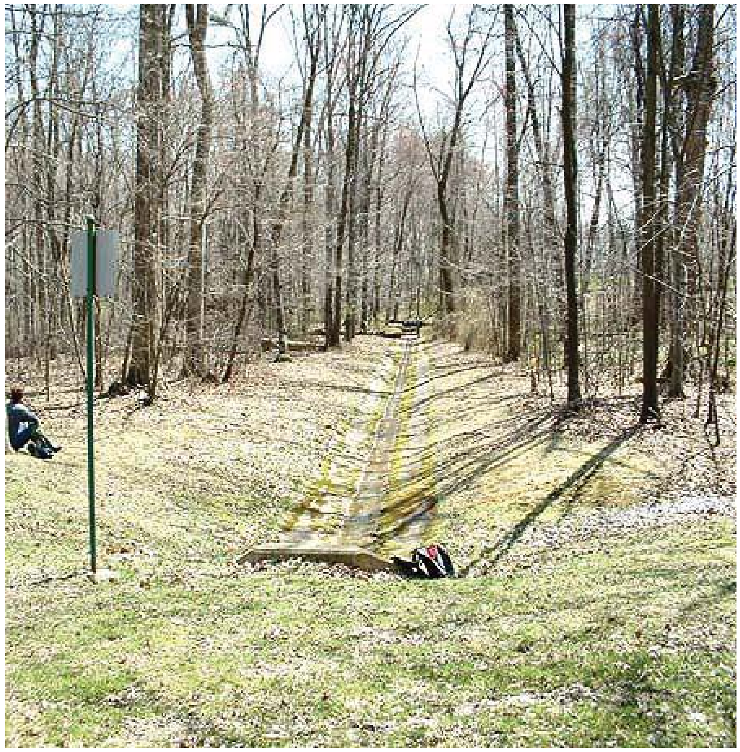


Figure 7.14. Example of a "cutoff" outfall discharging well away from the stream to a wetland area (out of picture)
Source: CWP, 2007

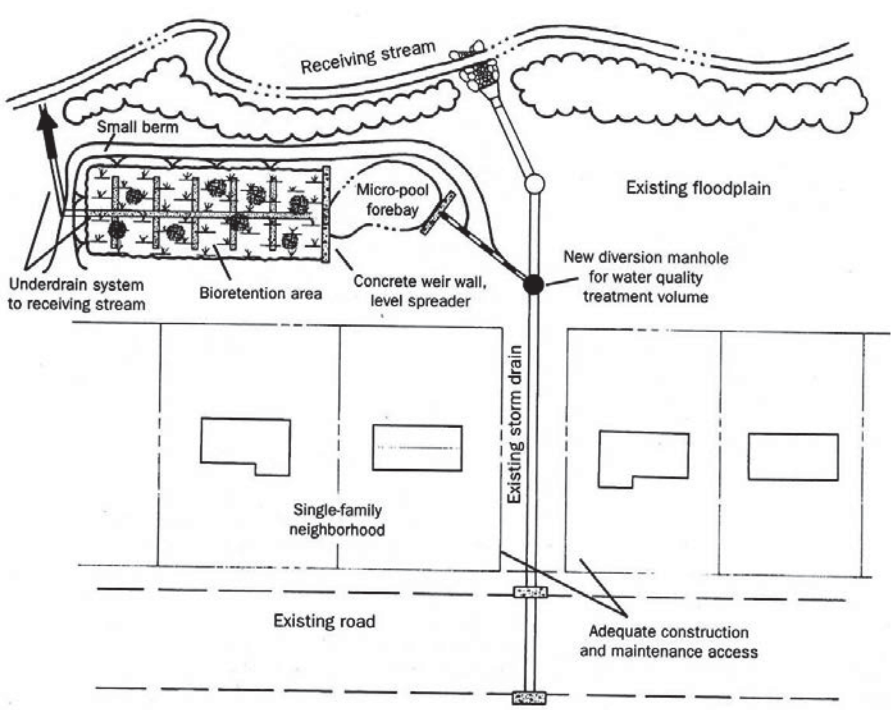


Figure 7.15. Typical Stormwater Retrofit at an Existing Storm Drain Outfall Directly to a Stream. Source: CWP, 2007

7.7.5. Storage Above Roadway Crossings

Road crossings can be modified to provide temporary water quality storage on the upstream side of an existing road culvert. Storage can be obtained by installing a new embankment above the crossing to get "free" storage (**Figure 7.16**). The new embankment would protect the roadway embankment from seepage effects. Available storage can also be increased by excavating areas adjacent to the upstream channel. In general, road crossing retrofits should be applied to non-perennial stream channels to avoid permitting problems (i.e., zero and first order streams). Otherwise, road crossing retrofits can be complicated because various environmental permits and landowner approvals may be needed to construct them.

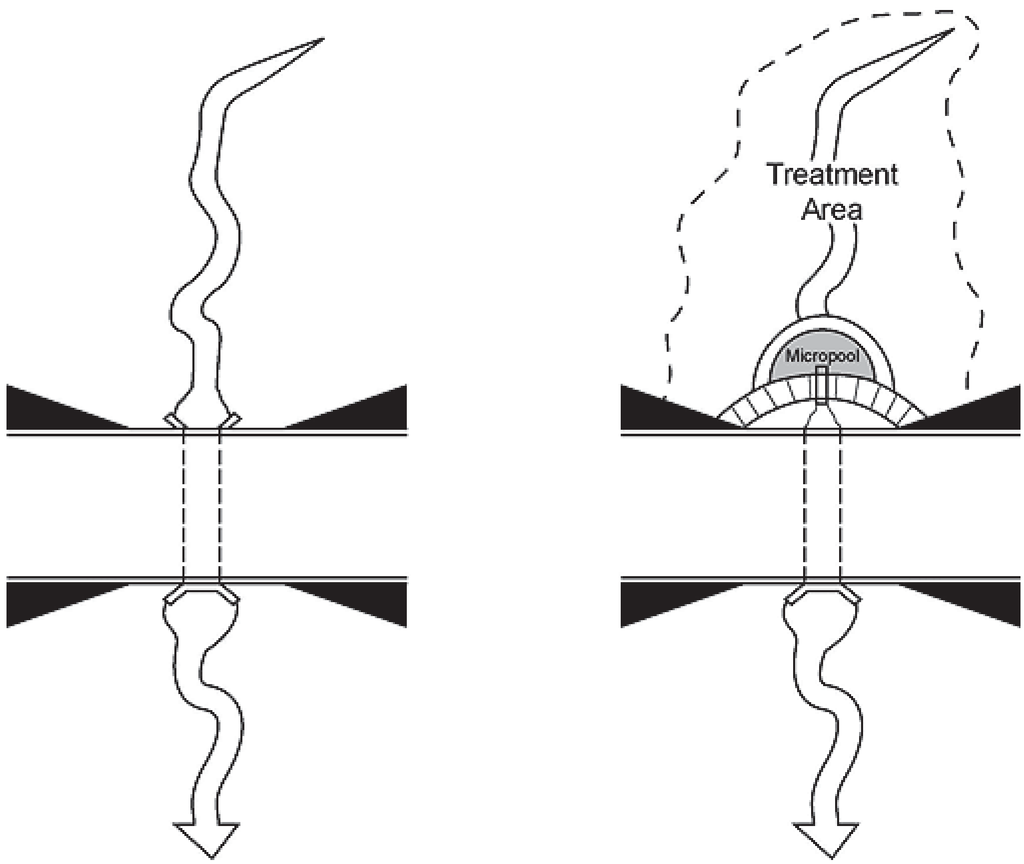


Figure 7.16. Strategy for getting free storage above a road crossing
Source: CWP, 2007

A control structure would normally be installed through the new embankment that creates an upstream micropool (**Figure 7.17** below). The control structure typically consists of a gabion or concrete weir or a riser/barrel. The micropool has a small permanent pool sized to be at least 10% of the total T_V. Extended detention, constructed wetlands and wooded stormwater wetlands are recommended treatment options for road crossing retrofits (see **Figure 7.18** below). Road crossings may also contain enough storage to provide channel protection storage. Crossing retrofits are ideal because they take advantage of free upstream storage, which reduces excavation costs. Opportunities for road crossing retrofits are easy to find in GIS systems when the road network and drainage layers are superimposed (**Figure 7.19** below).

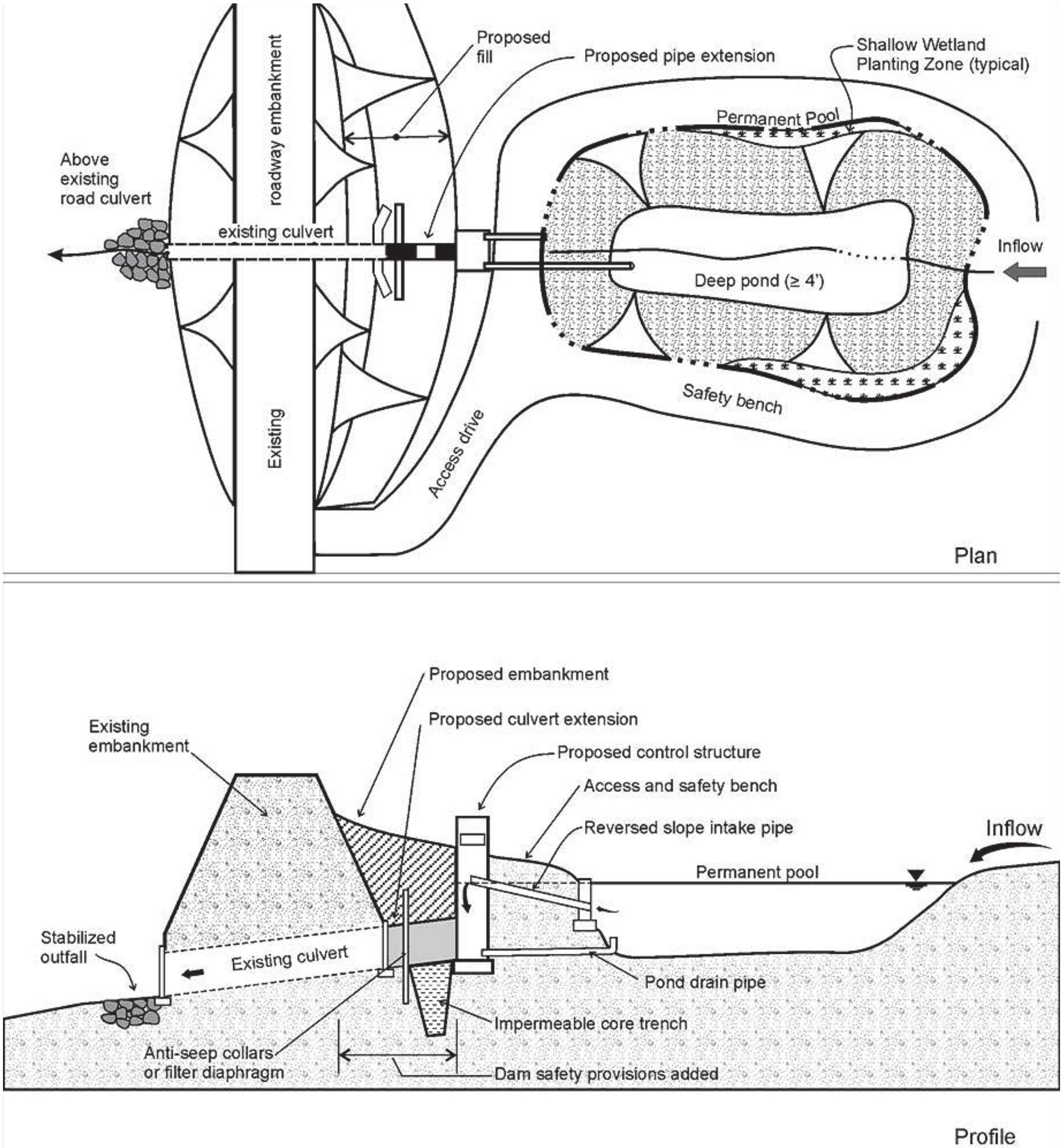


Figure 7.17. Typical plan and profile of crossing retrofit showing secondary embankment
Source: CWP, 2007

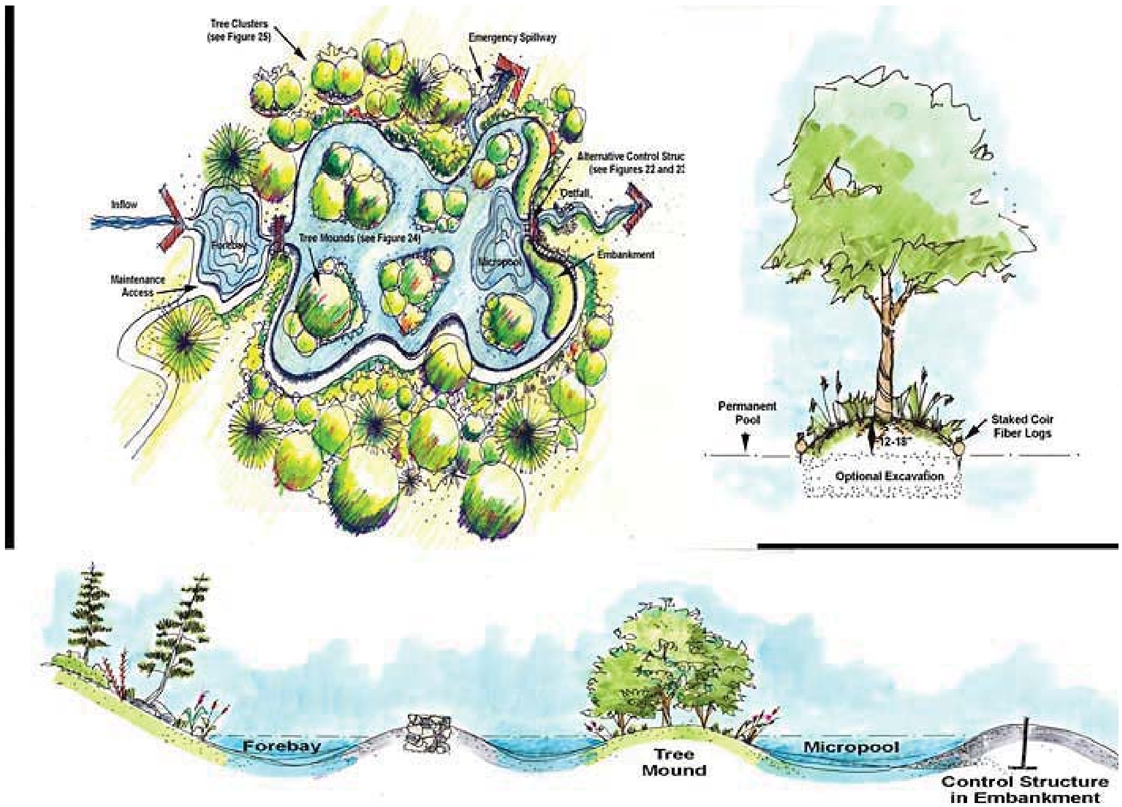


Figure 7.18. Wooded wetlands are a preferred stormwater treatment option for crossing retrofits
Source: CWP, 2007

Figure 7.19. Crossing retrofits are easy to find when road network and drainage layers are superimposed
Source: CWP, 2007

Ideal Conditions for Crossing Retrofits

The best situation for a road crossing retrofit is when:

- Ideally, the existing road culvert was already designed as a principal spillway pipe.
- The existing culvert has sufficient hydraulic capacity to pass desired storm flows.
- Upstream land is in public ownership.
- Channel has ephemeral (wet weather) flow only (e.g., zero or first order stream – less likely to require permits).
- Upstream channels are low gradient, are connected to the floodplain, and have short streambanks.
- The retrofit is timed to coincide with scheduled repair/replacement of the existing culvert. In such cases:
    - Avoid using anti-seep collars, which can actually promote failures.
    - Instead, a concrete cradle and pipe joints with gaskets are recommended.
- The retrofit is upstream of a proposed stream restoration or wetland mitigation project.

More specific and thorough guidance about crossing retrofits can be found in CWP (2007a).

7.7.6. Highway Rights-of-Way

Open spaces associated with highway rights-of-way such as medians, shoulders, and cloverleaf areas also present opportunities to incorporate new stormwater treatment practices. Common treatment practices used in these types of retrofits include vegetated swales, bioretention, constructed wetlands, and extended detention ponds. Traffic, safety, and maintenance access are important considerations for determining appropriate locations for highway right-of-way retrofits.

Highways contain un-used land within their right-of-way where storage can be obtained by diverting highway runoff into a depression or excavated area. Highways frequently cross local drainage divides, which reduces contributing drainage area and makes the corresponding Tv storage more manageable. In most cases the contributing drainage area to a highway retrofit is less than 10 acres. The most common stormwater treatment options for highway retrofits are ponds and constructed wetlands, although linear bioretention and dry swales may also be feasible in wider medians and rights-of-way (**Figure 7.20** below). In general, infiltration is not recommended as a stormwater treatment option, unless there is enough pretreatment to fully capture and contain a 10,000 gallon spill.

Ideal Conditions for Highway Retrofits

The best conditions to shoehorn storage retrofits into the highway system occur at:

- Cloverleaf interchanges
- Depressions created by approach ramps
- Open section drainage within a right-of-way that is wider than 30 feet and located down-gradient from the road and free of utilities
- Drainage leading to bridges that cross streams with extensive floodplains

- Highway drainage that can be diverted to adjacent public land
- Targets of opportunity in highway widening/realignment construction projects

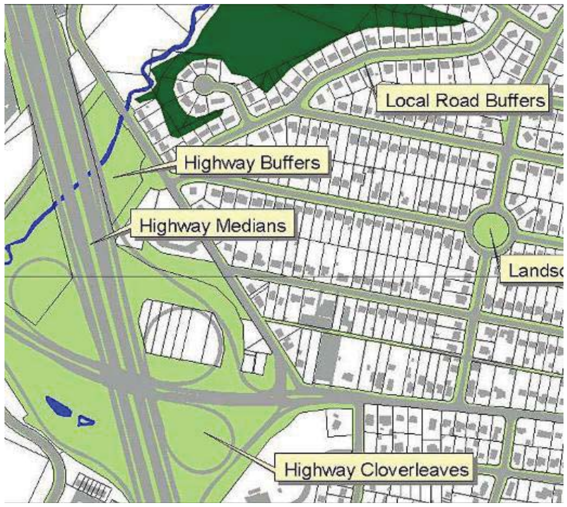


Figure 7.20. Highway Corridors Present Numerous Retrofit Opportunities. Source: CWP, 2007

Potential highway retrofit sites can be found using several methods. The quickest is to visually examine aerial photos, since major highway features tend to really standout (**Figure 7.21**). A more systematic method is search existing local, state or federal highway right-of-way GIS layers against open land and the stream network. The combined land area in open space and right of way should generally meet a minimum acreage threshold of one acre. Most highway agencies have good maps of their road drainage, so try to get copies to take into the field (**Figure 7.22**). These maps should be analyzed to find any existing highway stormwater treatment practices that might be suitable for retrofitting. More specific and thorough guidance about highway right-of-way retrofits can be found in CWP (2007a).

Figure 7.21. Highway retrofits really standout inaerial photos, although highway drainage does not. Source: CWP, 2007

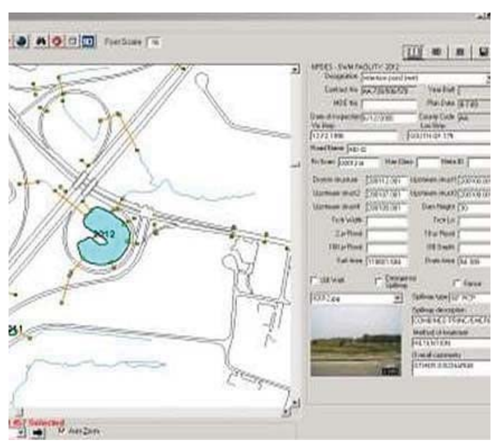


Figure 7.22. Many highway agencies have good GIS data for their stormwater infrastructure. Source: CWP, 2007

7.7.7. Individual Streets

This group of on-site retrofits provides stormwater treatment within the roadbed or right of way of individual streets. A wide range of retrofit strategies can be employed depending on whether the street has open or closed drainage:

- Install stormwater treatment within open section drainage
- Convert enclosed drainage into open section and install stormwater treatment practices
- Divert stormwater for surface treatment before it enters the storm drain
- Make storm drain pipes less efficient at delivering stormwater by promoting infiltration in the storm drain pipe.

Stormwater treatment options for open section street retrofits include dry swales, grass channels, bioretention cells and wet swales. Streets with closed drainage may utilize street bioretention, expanded tree pits, cul-de-sac bioretention, catch basin inserts or perforated storm drain pipes. **Figure 7.23** illustrates many different ways stormwater treatment can be applied to street retrofits.

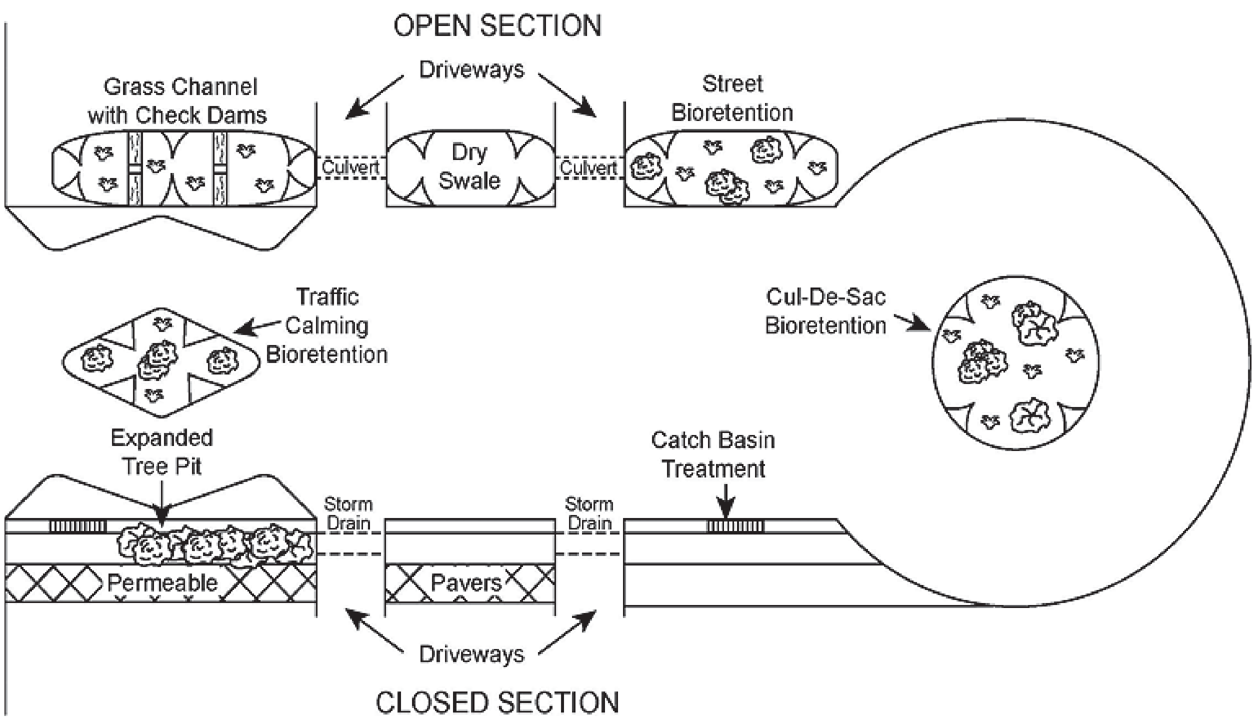


Figure 7.23. Retrofit strategies depend on whether the street has open of enclosed drainage
Source: CWP, 2007a

Streets are a significant urban pollutant source area and act as the primary conduit to move stormwater runoff from rooftops, lawn and driveways. Street retrofits treat stormwater near the source, improve neighborhood appearance, calm traffic and act as a focal point to educate adjacent residents about stormwater quality. Creative techniques to retrofit streets are shown in **Figures 7.24 through 7.27**.

Figure 7.24. Bioretention in Street Median
Source: CWP, 2007a

Figure 7.25. Curb Cut to Rain Garden
Source: CWP, 2007a

Figure 7.26. Bioretention in Traffic Calming Areas. Source: CWP, 2007a

Figure 7.27. Designers need to find creative ways to pass runoff across driveways and sidewalks. Source: CWP, 2007a

Ideal Conditions for Street Retrofits

Most communities maintain hundreds or even thousands of residential street miles (Law, 2006). Key suitability factors for street retrofits include:

- Streets classified as having a moderate to severe pollution severity, as measured by field surveys.
- Neighborhoods that request traffic calming devices to slow residential speeding
- Streetscaping projects or neighborhood revitalization efforts where street drainage can be modified
- Bundling retrofits as part of upcoming water and/or sewer rehabilitation projects
- Wider streets that serve large lots (1/2 acre lots and up)
- Wide street right of ways that provide room for stormwater treatment options
- Streets where utilities are located underneath the pavement or on only one side of the street

More specific and thorough guidance about individual street retrofits can be found in CWP (2007a).

7.7.8. Parking Lots

Parking lots can be ideal candidates for a wide range of stormwater retrofits. Potentially applicable retrofits include site planning techniques and small-scale management measures to reduce impervious coverage and increase infiltration, as well as a variety of larger, end-of-pipe treatment practices. Redevelopment of older commercial properties, which were often designed with oversized parking lots and almost 100 percent impervious coverage, is one of the most common and environmentally beneficial opportunities for parking lot stormwater retrofits.

Alternative site design and LID management practices are well suited to existing developed areas because most of these practices use a small amount of land and are easily integrated into existing parking areas. Examples of these parking lot stormwater retrofits include:

Incorporating Bioretention Into Parking Lot Islands and Landscaping. Parking lot islands, landscaped areas, and tree planter boxes can be converted into functional bioretention areas and rain gardens to reduce and treat stormwater runoff.

Removing Curbing and Adding Slotted Curb Stops. Curbs along the edges of parking lots can sometimes be removed or slotted to re-route runoff to vegetated areas, buffer strips, or bioretention facilities. The capacity of existing swales may need to be evaluated and expanded as part of this retrofit option.

Infiltrating Clean Roof Runoff From Buildings. In some instances, building roof drains connected to the stormwater drainage system can be disconnected and redirected to vegetated areas, buffer strips, bioretention facilities, or infiltration structures (dry wells or infiltration trenches).

Incorporating New Treatment Practices at the Edges of Parking Lots. New stormwater treatment practices such as bioretention, sand filters, and constructed wetlands can often be incorporated at the edges of large parking lots.

Use of Permeable Paving Materials. Existing impermeable pavement in overflow parking or other low-traffic areas can sometimes be replaced with alternative, permeable materials such as modular concrete paving blocks, modular concrete or plastic lattice, or cast-in-place concrete grids. Site-specific factors including traffic volumes, soil permeability, maintenance, sediment loads, and land use must be carefully considered for the successful application of permeable paving materials for new development or retrofit applications.

Figure 7.28 below depicts some of the parking lot stormwater retrofits described above.

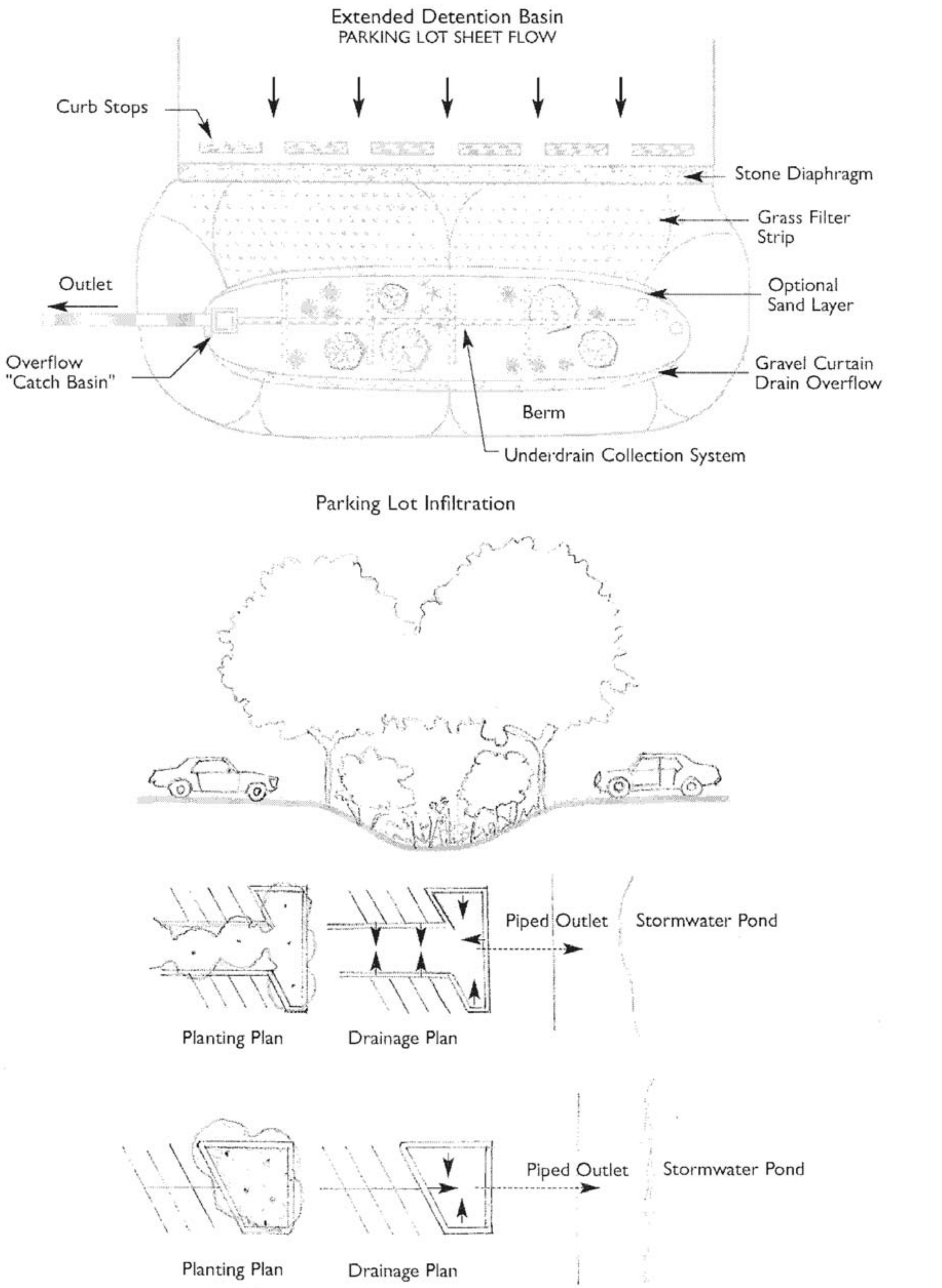


Figure 7.28. Parking Lot Stormwater Retrofit Schematics
Source: CT DEP, 2004; Metropolitan Council, 2001 (Adapted from VBWD, 2000); and NYDEC, 2001

7.7.8.1. Large Parking Lot Retrofits

Large parking lots are a good retrofit opportunity to treat runoff quality. *Large parking lots are defined as five acres or greater in size, including any connected rooftops (see* **Figure 7.29**). Common examples include lots serving municipal buildings, high schools, regional shopping malls, stadiums, auto dealerships, airports, commuter lots, hospitals and big box retail stores. Larger parking lots are normally served by extensive storm drain systems and contain numerous inlets, underground pipes and outfalls.

This retrofit strategy excavates centralized treatment storage in unutilized land located down-gradient of the lot (**Figure 7.30**). Common stormwater treatment options include wet ponds, extended detention, ponds, constructed wetlands or a large bioretention area. Centralized retrofits are not the only retrofit strategy for parking lots, but the centralized retrofit strategy is generally more cost-effective on a per acre treated basis than an on-site strategy. Large parking lots are an ideal retrofit because they generate more stormwater runoff and pollutants on a unit area basis than any other land use in a subwatershed.

Figure 7.29. Large Parking Lots are a Key Retrofit Target. Source: CWP, 2007a

Figure 7.30. Down-Gradient Open Land Reserved in Setbacks Is Ideal for Treatment. *Source:* CWP, 2007a

Ideal Conditions for Large Parking Lot Retrofits

Parking lots built in the last few decades are good retrofit opportunities since local codes often require more generous setbacks for screening, landscaping and noise reduction. Recently developed suburban commercial zones are only about 70% impervious, suggesting that a decent fraction of the site may be available for surface treatment (Cappiella and Brown, 2001). Other good retrofit situations are:

- Parking lots serving large institutions, corporate campuses and colleges that tend to have even lower percentage of impervious cover for the whole site.
- Municipally-owned parking lots such as commuter lots, park access, and schools adjacent to open areas
- Industrial parking lots designated as stormwater hotspots
- Any parking lot served by an existing stormwater detention pond (use SR-1)

Restoration Alternatives at Large Parking Lots

Even if a storage retrofit is not feasible, it may still be possible to install other restoration practices inside the parking lot or along its margins, such as:

- *Reforestation* in open spaces, parking lot islands and setbacks using the planting methods outlined in Cappiella *et al.* (2006a).
- *Pollution prevention practices,* particularly when the lot is used for vehicle storage or is frequently resealed
- *Regular vacuum sweeping and litter control* to keep gross solids and trash from entering the storm drain system.

7.7.8.2. Small Parking Lot Retrofits

This on-site retrofit strategy treats the quality of runoff from existing parking lots less than five acres in area. Surface retrofits can be installed within the parking lot, along its perimeter, or in adjacent pervious areas (**Figure 7.31**).

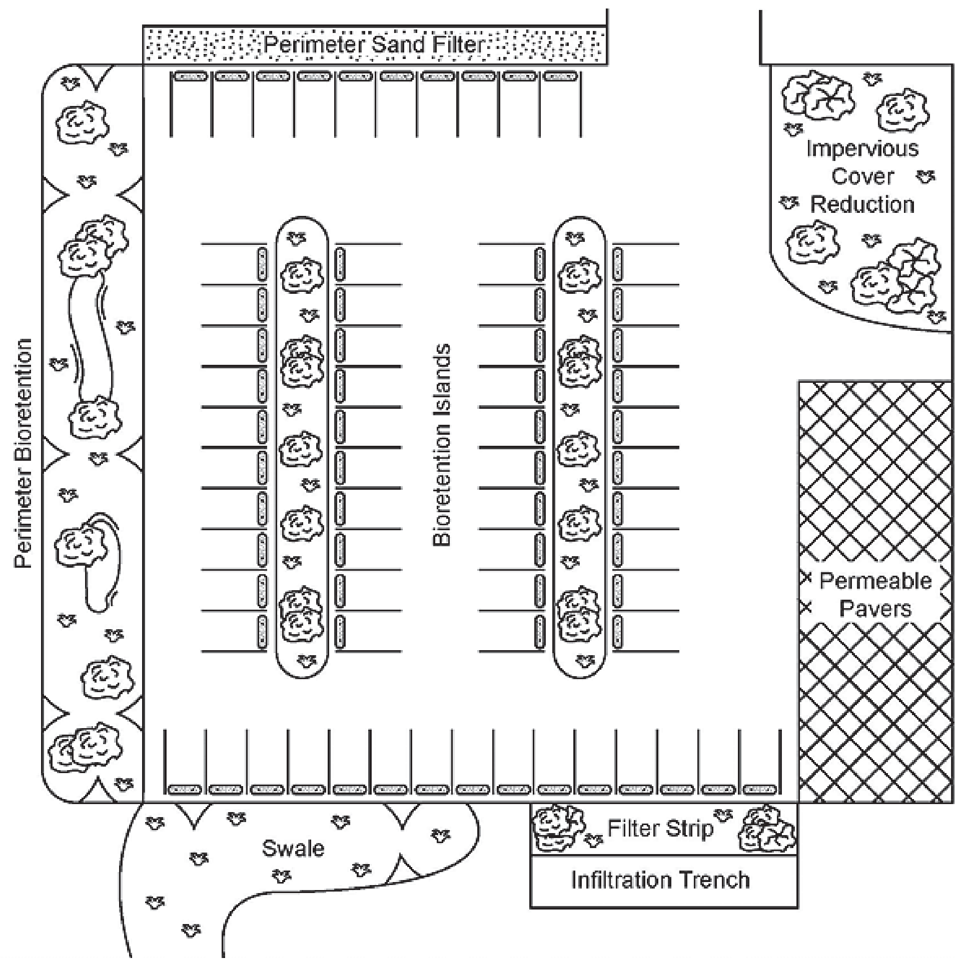


Figure 7.31. Many different retrofit strategies can be employed to retrofit parts of a smaller lot.
Source: CWP, 2007a

Small parking lots are generally quite easy to spot on aerial photographs or GIS data layers (**Figure 7.32**). A more systematic approach may restrict the search to parking lots in municipal or institutional ownership where permission to retrofit may be easier to get. Otherwise, the feasibility small parking lot retrofits is normally determined in the field.

Figure 7.32. Orthophotos can help find small parking lots and for concept sketches.
Source: CWP, 2007a

A wide range of stormwater treatment options can be adapted for this retrofit, including:

- Impervious Cover Reduction
- Permeable Pavers
- Bioretention Islands
- Perimeter Bioretention
- Perimeter Sand Filter
- Filter Strips
- Infiltration
- Dry Swales

Parking lots are an ideal location for on-site retrofits since they generate extremely high unit area runoff volumes, pollutant loads and temperature spikes. Parking lot retrofits also have great demonstration value due to their high visibility. **Figure 7.33** below presents numerous examples of small parking lot retrofit techniques.

Ideal Conditions for Small Parking Lot Retrofits

The best conditions to retrofit small parking lots are when:

- Communities retrofit a municipally owned parking lot as a demonstration project
- New parking lots are constructed as part of redevelopment or infill projects
- Existing parking lots are slated for resurfacing, reconfiguration or renovation (their normal design life is about 15 to 25 years)
- Local stormwater regulations trigger water quality control at time of lot renovation or rehabilitation
- Parking lots were built with generous landscaping, open space, screening or frontage setbacks
- Parking lots are not fully utilized because they were designed using excessive parking demand ratios

Alternative Restoration Practices for Small Parking Lots

Even if an on-site retrofit is not feasible, the following restoration practices may still be viable:

- *Tree planting* in parking islands, lot margins and setbacks.
- *Vacuum sweeping and litter control* in the parking lot.

- *Parking lot pollution prevention practices*, especially for vehicle storage and parking lot maintenance.

More specific and thorough guidance about parking lot retrofits can be found in CWP (2007a).

Figure 7.33. Examples of retrofits employed at small parking lots: (a) permeable pavers; (b) dry swale; (c) perimeter sand filter; (d) grass filter//infiltration trench; (e) filter strip; (f) internal bioretention; (g) underground infiltration; and (h) island bioretention. Source: CWP, 2007a

7.7.9. In-stream Practices in Drainage Channels

Existing (man-made) channelized streams and drainage conveyances such as grass channels can be modified to reduce flow velocities and enhance pollutant removal. Weir walls or riprap check dams placed across a channel create opportunities for ponding, infiltration, and establishment of wetland vegetation upstream of the retrofit (Claytor, Center for Watershed Protection, 2000). In-stream retrofit practices include stream bank stabilization of eroded areas and placement of habitat improvement structures (i.e., flow deflectors, boulders, pools/riffles, and low-flow channels) in impacted natural streams and along stream banks. In-stream retrofits may require evaluation of potential flooding and floodplain impacts resulting from altered channel conveyance, as well as local, state, or federal approval for work in wetlands and watercourses. More comprehensive urban stream and stream corridor restoration practices are beyond the scope of this Manual. Additional sources of information on stream restoration practices are included at the end of this chapter.

7.7.10. Wetland Creation and Restoration

Wetland creation or restoration can partially substitute for lost ecological functions of a destroyed or degraded wetland system in developed areas. Creation or restoration of freshwater or tidal wetlands can improve the pollutant removal, longevity, adaptability, and habitat functions of wetland systems (CT DEP, 1995). Techniques to improve pollutant removal in created or restored wetlands include (Schueler et al., 1992):

- Increasing wetland volume to increase residence time
- Increasing the surface area to volume ratio of the wetland
- Increasing the flow path through the wetland
- Providing energy dissipation and primary sedimentation either prior to the wetland or in a sediment forebay at the wetland inflow locations
- Integrating with other treatment practices such as extended detention

When wetlands are altered through clearing of vegetation, impoundment of water, or dredging, the microhabitats used by many wildlife species are changed or lost. This may result in unsuitable breeding habitat for many amphibians, including vernal pool species. Similarly, created wetlands usually lack the structural diversity, microhabitats, and hydrology to support vernal pool breeding amphibians (Calhoun and Klemens, 2002). Altered and created wetlands often support highly adaptable, widespread, “weedy” species (e.g., bullfrogs or green frogs) that prey upon, or successfully out-compete, vernal pool-breeding amphibians, which reduces or locally eliminates populations of these habitat specialists. Created wetlands that do not have the appropriate habitat often function as “decoy” pools and trap breeding amphibians. Therefore, these wetland creation and restoration techniques should only be implemented with careful consideration of the effects to wetland function and hydrology and in conjunction with applicable local, state, and federal wetland and watercourses regulatory agencies.

7.7.11. Hotspots

These retrofits provide on-site water quality treatment at confirmed stormwater hotspots, defined as any operation that generates higher concentrations of stormwater pollutants and/or has a higher risk of spills, leaks or illicit discharges. Pollution prevention practices such as covering, secondary containment, and employee training should always be considered first. However, when prevention practices are not sufficient to provide full treatment, on-site retrofits are needed to treat the quality of runoff from the stormwater hotspot (**Figure 7.34**).

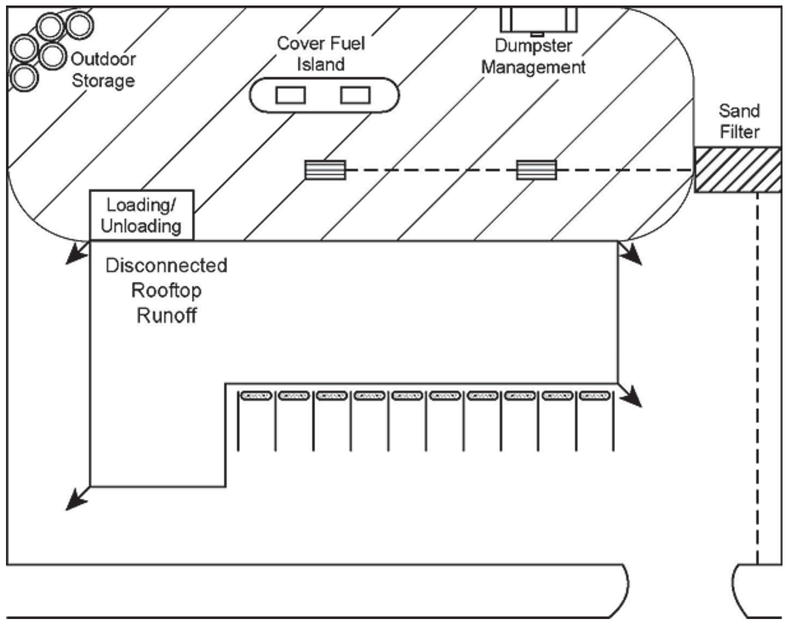


Figure 7.34. Schematic showing typical treatment at hotspot generating areas
Source: CWP, 2007a

The preferred stormwater treatment option at hotspot operations are filtering practices (**Figure 7.35**). Alternatively, bioretention without exfiltration may be used. The use of infiltration is strongly discouraged due to the risk of groundwater contamination.

Hotspots are good locations for on-site retrofits since they contribute higher stormwater pollutant loads than any other urban source area. Second, many communities have the regulatory authority to compel private landowners to install onsite retrofits to comply with municipal or industrial stormwater requirements.

Figure 7.35. Filtering Practices Are Preferred for Retrofits at Hotspot Sites. Source: CWP, 2007a

Ideal Conditions for Hotspot Retrofits

Retrofits should always be considered for any operation:

- Found to be a severe hotspot during a hotspot site investigation
- Covered by an existing industrial stormwater permit or specifically designated as a stormwater hotspot in the local water quality ordinance
- Where site investigation shows that pollution prevention practices alone are not sufficient to remove pollutants in stormwater runoff

Alternative Restoration Projects at Stormwater Hotspots

A nonstructural approach can effectively prevent pollution from many stormwater hotspot operations. CWP 2005a describe pollution prevention practices that can be applied to hotspots:

- Vehicle Maintenance and Repair
- Vehicle Fueling
- Vehicle Washing
- Vehicle Storage
- Loading and Unloading
- Outdoor Storage
- Spill Prevention and Response
- Dumpster Management
- Building Repair and Remodeling
- Building Maintenance
- Parking Lot Maintenance
- Turf Management
- Landscaping/Grounds Care
- Swimming Pool Discharges
- Unique Hotspot Operations

What to Look for When Investigating Hotspots

The team can isolate areas to search for hotspots in the field by reviewing maps depicting commercial, industrial or municipal land use (**Figure 7.36** below). Local knowledge can also be helpful. A more systematic approach for finding hotspot sites involves searching local business databases using standard industrial codes (SIC). Methods for conducting an SIC database search can be found in CWP 2005a. Another approach to find potential stormwater hotspots is to search databases of industrial operations that hold stormwater permits.

Procedures to inspect and rank stormwater hotspots are described in the Hotspot Site Investigation (HSI) component of CWP 2005b. The HIS involves a rapid visual assessment to inspect site operations that may cause a stormwater hotspot. If a site is ranked as a confirmed or severe hotspot, then the crew looks into the "plumbing" at the site to determine whether additional stormwater treatment is needed beyond standard pollution prevention practices.

Figure 7.36. Hotspots are too small to find on aerial photos but can be found by searching business databases. Source: CWP, 2007a

Five steps are used to assess the feasibility of on-site treatment at a stormwater hotspot:

- *Define hotspot generating area (HGA)* – which is the area actually generating higher levels of pollutants. The HGA is usually associated with:
  - Vehicle Operations
  - Outdoor Materials
  - Waste Management
  - Physical Plant Maintenance
  - Intensive Turf/Landscaping
- *Evaluate pollution prevention practices* – whether the HGA can be fully treated by non-structural practices such as covering, secondary containment, or employee training. Full treatment is operationally defined as no exposure of the polluting operation to rainfall or runoff. If full treatment cannot be obtained, the crew moves to the next step.
- *Evaluate the hotspot's connection to public storm drain system* – tracing the path of runoff from the HGA as it crosses the site and enters offsite drainage and whether the connections are legal or illicit.
- *Select the stormwater treatment option* – available hydraulic head is usually the key feasibility constraint and is defined as the vertical distance between the elevation of the stormwater inlet and the bottom elevation of the existing storm drain system to which it discharges.
- *Get retrofit design information* – record the details of the selected treatment device, such as the adjusted drainage area, surface and pipe slopes, and notes on soil and subsurface conditions.

More specific and thorough guidance about hotspot retrofits can be found in CWP (2007a).

7.7.12 Individual Rooftops

This group of onsite retrofits captures, stores, treats and then gradually releases runoff from individual rooftops. The goal is to systematically retrofit as many residential and non-residential rooftops as possible within a given subwatershed. The many different ways that rooftops can be retrofit are portrayed in **Figure 7.37**. A variety of stormwater treatment options can be employed for rooftop retrofits as shown below:

Residential rooftops
- Simple Disconnection
- Rain Barrels
- Rain Gardens
- French Drain/Dry Wells

Non-residential rooftops
- Simple Disconnection
- Rain Gardens
- Stormwater Planters
- Cisterns
- Green Rooftops

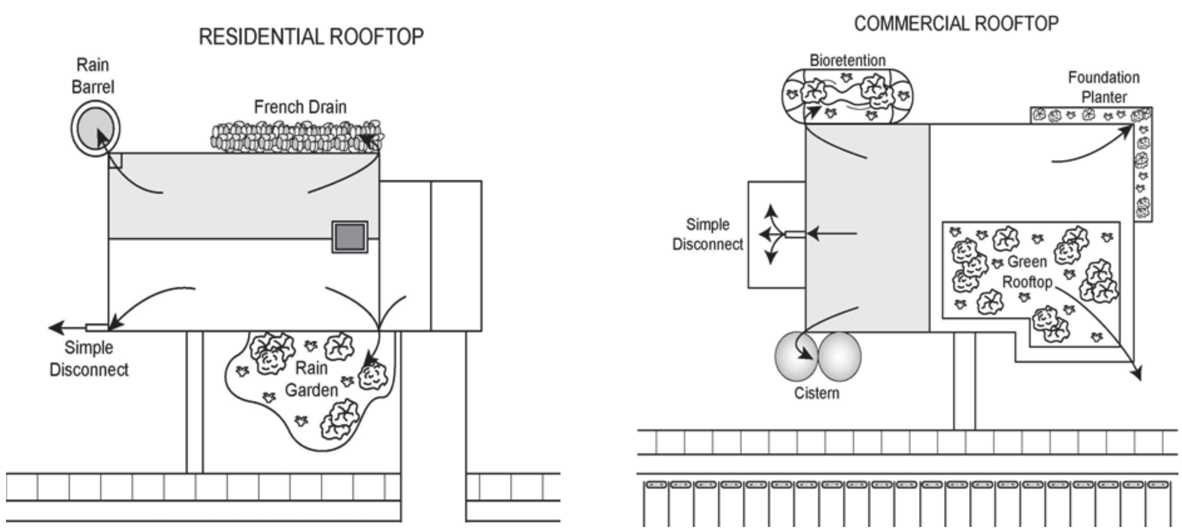


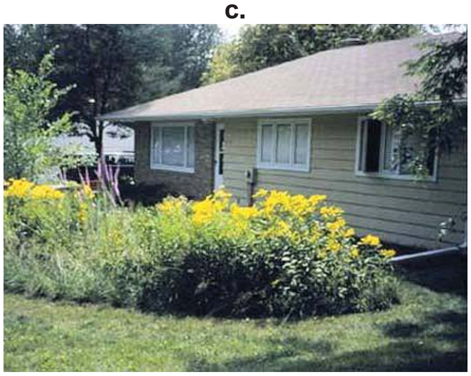
Figure 7.37. A variety of retrofit strategies can be applied to treat the quality of runoff
Source: CWP, 2007a

Examples of rooftop retrofit techniques are shown in **Figures 7.38 through 7.40** below. Rooftop retrofits are ideal when a comprehensive delivery system is developed to implement them on a widespread basis. From a cost-benefit standpoint, it makes more sense to target residential rooftops first since they comprise a greater fraction of subwatershed area and are less expensive on a unit-area treated basis.

a.

b.

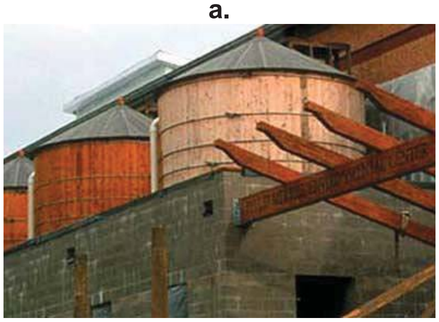
c.



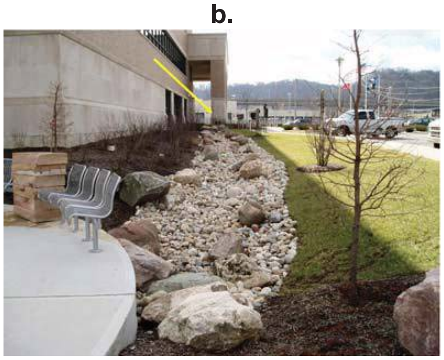
d.

Figure 7.38. Residential rooftops can be treated by (a) french drains, (b) rain barrels, or (c&d) rain gardens. Source: CWP, 2007a

a.



b.



c.

Figure 7.39. Runoff from larger rooftops can be treated in (a) cisterns, (b) infiltration areas, or (c) bioretention planting beds. Source: CWP, 2007a

Figure 7.40. Green rooftops can also treat the quality of runoff from flat rooftops. Source: CWP, 2007a

Rooftop retrofits are particularly well-suited in subwatersheds where runoff reduction is a major restoration goal (e.g., to reduce the volume of stormwater runoff entering a combined sewer system). Retrofitting rooftops for water quality purposes is less effective since rooftop runoff tends to be cleaner than other urban source areas (with the possible exception of metals). On the other hand, incremental rooftop retrofitting can be an effective long range strategy to control runoff in highly urban subwatersheds.

Ideal Conditions for Rooftop Retrofits

The ideal conditions to retrofit residential rooftops are when a neighborhood:

- Has no basements (if infiltration is used)
- Has homes where roof leaders are directly connected to storm drain system
- Is located in a subwatershed where stormwater reductions can reduce combined sewer overflows
- Has a strong neighborhood association, environmental concern or community activism
- Has medium-density residential lot sizes in the 0.25 to 1.0 acre range.

Rooftop retrofits work best in nonresidential settings when:

- The rooftop is being built as part of redevelopment or infill project
- The rooftop is owned or being built by a municipality or a cooperative institution
- The rooftop can discharge to landscaping or open space adjacent to the building
- The rooftop has reached the end of its design life and needs replacement.
- The rooftop is large, flat and directly connected to the storm drain system
- The owner is interested in green building certification

Desktop Searching for Rooftop Retrofits

A search is not very helpful in finding individual rooftop retrofit sites, although the average age and lot size in a neighborhood are worth assessing, since homes built to the same drainage standards tend to have similar retrofit potential. Another GIS search option is to look for specific neighborhoods that deliver stormwater into combined sewers or have historic flooding or drainage problems. Rooftop retrofits alone may not solve these problems, but can play a role in a larger package of retrofit solutions. A GIS search that defines older commercial, industrial or institutional zones that are near the end of their design life may help find good candidates for non-residential rooftop retrofits. A search of all municipal buildings in a subwatershed may also be warranted to assess their suitability for demonstration retrofits.

More specific and thorough guidance about individual rooftop retrofits can be found in CWP (2007a).

7.7.13. Little Retrofits

Little retrofits are simple on-site practices that treat runoff from directly connected impervious areas less than one acre in size (**Figure 7.41**). Examples include sidewalks, bike paths, driveways, basketball and tennis courts, vacant lots, compacted ball fields, paved play areas, and other surfaces that are impermeable to rainfall. Recommended stormwater treatment options for little retrofits include swales, infiltration, filter strips, impervious cover conversion, impervious cover disconnection and soil compost amendments.

Figure 7.41. Rain Garden Treating Runoff from a Trail
Source: CWP, 2007a

Collectively, small impervious areas comprise less than 5% of total impervious area in a subwatershed. So why bother with little retrofits? The reason is that small impervious areas are easy to retrofit because they are isolated within larger pervious areas. Many small impervious areas fall below minimum area thresholds that trigger stormwater management requirement and were therefore built without consideration for engineered drainage or stormwater practice.

Little retrofits are ideal because they are low cost, require less sophisticated design and can solve localized drainage and erosion problems. In many cases, they can be constructed by watershed groups, homeowners associations or property managers with minimal engineering background. Furthermore, if a little retrofit doesn't work at a site, reforestation is always a restoration option.

Ideal Conditions for Little Retrofits

The best conditions for little retrofits are when the retrofit:

- Is located on publicly-owned land such as a park or school
- Would serve an educational or demonstration function
- Is in close proximity to a large pervious area
- Would alleviate an existing drainage or erosion problem
- Can take advantage of soils with a high infiltration rate
- Can be linked with a planned reforestation project for the site

7.7.14. Landscapes/Hardscapes

This class of retrofits relies on landscaping to treat stormwater in highly urban settings. Examples include commercial landscaping areas, plazas, waterfronts, urban streetscapes, and pocket parks (**Figure 7.42**). While these urban landscapes occupy a trivial amount of total subwatershed area, they are included here because they represent a great opportunity to demonstrate retrofits in highly visible locations. The basic strategy is to treat stormwater as a landscaping resource and design amenity using innovative practices such as rain gardens, stormwater planters, expanded tree pits or permeable pavers (**Figure 7.43** below).

Figure 7.42. Bioretention Area in a Public Park.
Source: CWP, 2007a

Figure 7.43. Landscape architects can creatively use stormwater as a resource in (a) foundation planters; (b) permeable pavers; (c) bioretention; and (d) stormwater tree pits. Source: CWP, 2007a

Landscape/hardscape retrofits are ideal because they have strong demonstration and education value, are frequently maintained, and may lower landscaping maintenance costs through reduced mowing, greater tree survival, or less irrigation.

Ideal Conditions for Landscape/Hardscape Retrofits

- Commercial, municipal, institutional and urban park settings
- Redevelopment and infill projects
- Public spaces with high exposure
- Area where urban water features are being designed as an amenity
- Downtown central business districts
- Waterfront developments
- Development constructed through public/private partnerships
- Neighborhood beautification and revitalization projects (**Figure 7.44** below)

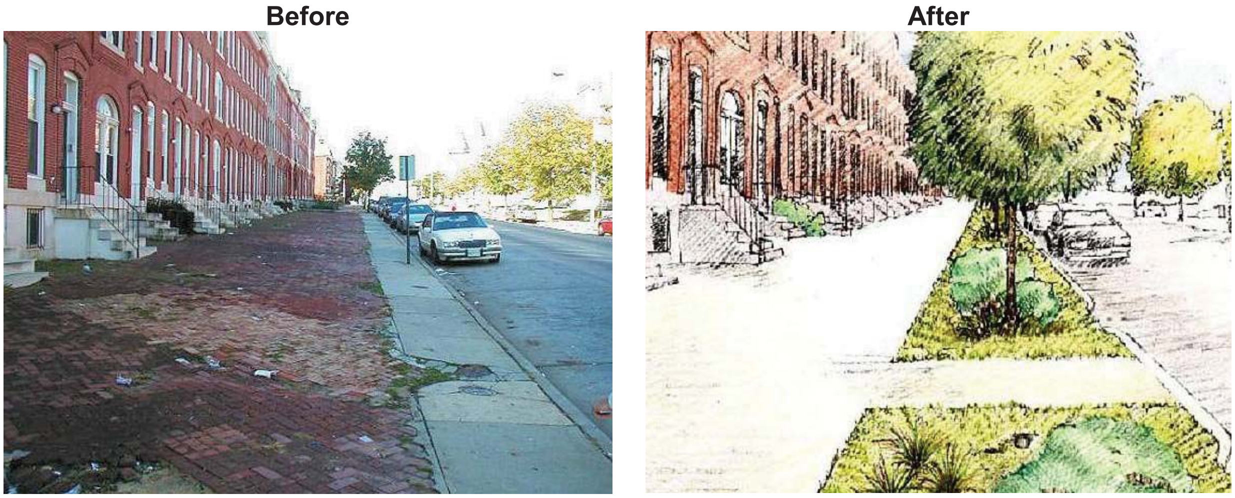


Figure 7.44. Urban foresters can treat stormwater using creative street tree planters.
Source: CWP, 2007a

7.7.15. Underground

Underground retrofits are the on-site retrofit of last resort due to their high cost. They make sense when other on-site retrofits cannot fit on the surface, or land acquisition costs are too high. Underground retrofits are normally restricted to small sites that generate high pollutant loadings discharging to sensitive waters. Common methods of underground treatment are shown in **Figure 7.45** and include:

- Infiltration galleries
- Underground sand filter
- Underground detention pipes
- Multi-chamber treatment train (MCTT)
- Proprietary stormwater treatment devices

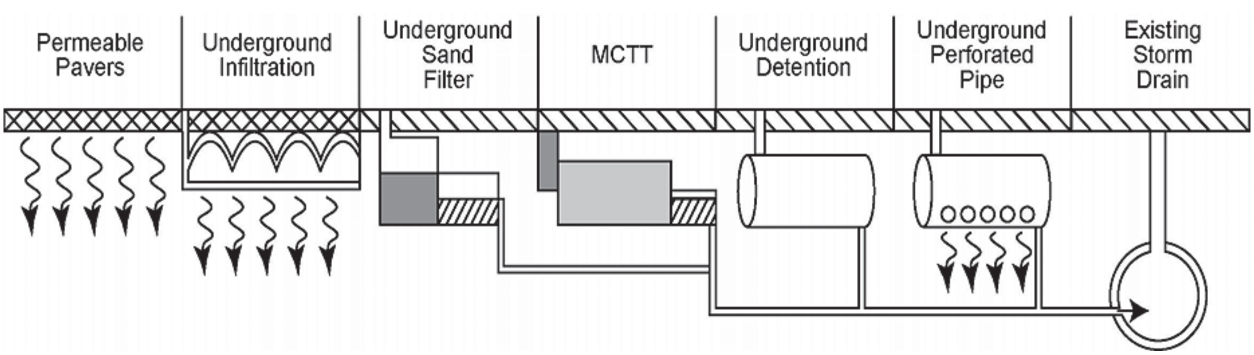


Figure 7.45. Numerous strategies can be used for underground retrofits.
Source: CWP, 2007a

This class of retrofits applies to ultra-urban subwatersheds that lack surface area for stormwater treatment. The most common form of treatment is the underground sand filter which provides effective pollutant removal. Underground sand filters make sense when water quality and public health issues are paramount.

Ideal Conditions for Underground Retrofits

The most ideal situations for underground retrofits are in:
- Ultra-urban areas that lack available space on the surface for treatment
- Redevelopment or infill projects where stormwater treatment requirements are triggered
- Severe stormwater hotspots or central business districts
- Sites where untreated direct stormwater discharges to extremely sensitive waters (e.g., intake for drinking water supply, swimming beaches, harbors, shellfish beds, waterfronts)
- Sites where pretreatment is needed prior to another retrofit
- Regions that have underlying soils with exceptionally good infiltration rates (e.g., glacial till, outwash plains, sandy plains)
- Parking lots that cannot be served by a surface retrofit
- Public works yards where crews can perform frequent maintenance
- The receiving storm drain system is only a few feet below ground level
- Owner/operator is unwilling or unable to frequently maintain it

Restoration Alternatives in Ultra Urban Areas

It can be extremely expensive to retrofit ultra-urban subwatersheds using underground retrofits. Alternatives for improving stormwater quality in these subwatersheds include non-structural practices, such as:
- Intensive street sweeping (see CWP, 2008)
- Regular cleanouts of storm drain inlets (see CWP, 2008)
- Pollution prevention practices (see CWP, 2005a)
- Detection and elimination of illicit discharges (see Brown *et al.*, 2004)
- Municipal housekeeping practices (see CWP, 2008)

7.8. BASIC STEPS IN STORMWATER RETROFITTING

An eight step process is recommended to systematically search for retrofit storage in a subwatershed (**Figure 7.46** below). The process begins with retrofit scoping and concludes with maintenance of the constructed retrofit. Chapter 4 of the Center for Watershed Protection's *Manual 3: Urban Stormwater Retrofit Practices* (CWP, 2007a) provides more specific information on each step of the retrofit process. One key step in the process is conducting a Retrofit Reconnaissance Investigation to accomplish the following purposes:
- Verify the feasibility of candidate retrofit sites
- Collect information to create initial concept designs for retrofit projects
- Develop an organized and objective estimate of candidate sites' project costs and benefits

Figure 7.46. One Model of the Basic Steps of Stormwater Retrofitting
Source: CWP, 2007

7.8.1 Watershed Retrofit Inventory

The first two steps in the process, Retrofit Scoping and Desktop Retrofit Analysis, lead to development of an inventory of many potential sites where retrofit projects would be appropriate and feasible within the watershed or community. The best retrofit sites fit easily into the existing landscape, are located at or near major drainage or stormwater control facilities, and are easily accessible. Usually the first step is completed in the office using available topographic mapping, low altitude aerial photographs (where available), storm drain master plans, and land use maps (zoning or tax maps are generally acceptable). Many of these tools may be incorporated into a local GIS (**Figure 7.47** below)

Before venturing into the field, there are two tasks that should be performed. First, the drainage areas should be delineated, and second, the potential surface area of the facility measured. The drainage area is used to compute a capture ratio. This is the percentage of the overall watershed that is being managed by the retrofit project(s). The surface area is used to compute a preliminary storage volume of the proposed facility. These two bits of information can be used as a quick screening tool. In general, an effective retrofitting strategy should aim to capture at least 50% of the watershed. Ideally, the minimum target storage volume for each retrofit is approximately 0.5 inch per impervious acre.

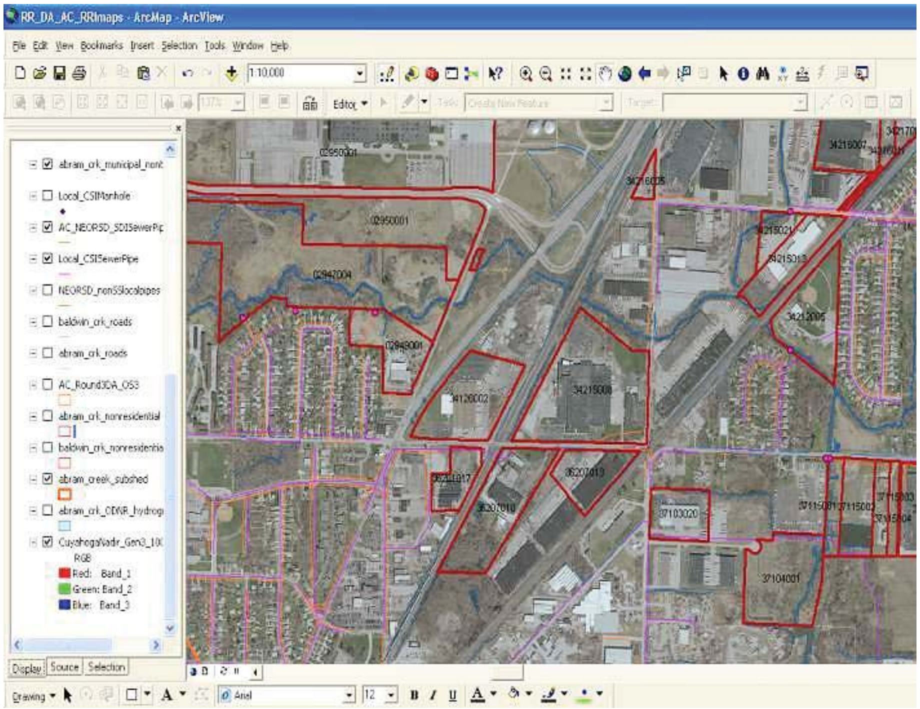


Figure 7.47. Desktop Analysis of Potential Retrofit Sites Using GIS System
(Source: CWP)

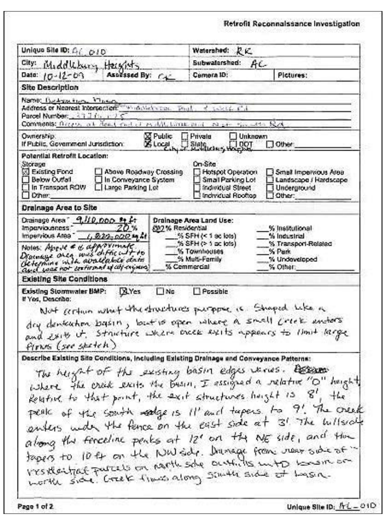
7.8.2 Field Verification of Candidate Sites

Figure 7.48. Retrofit Reconnaissance Investigation
(Source: CWP)

The next two steps involve a field reconnaissance and refinement of the site inventory. As shown in **Figure 7.48** above, the Retrofit Reconnaissance Investigation is one part of the process where local governments can involve volunteers from the community. **Appendix 7-B** provides a copy of the CWP's Retrofit Reconnaissance Investigation Checklist. Candidate retrofit sites identified during Scoping and Analysis should be investigated in the field to verify that they are indeed feasible sites. As well, the field exercise provides an opportunity to spot additional candidate sites that may not have been obvious from the resources analyzed earlier in the office. This field investigation involves a careful assessment of site specific information, such as:

- Presence of sensitive environmental features;
- Location of existing utilities;
- Type of adjacent land uses;
- Condition of receiving waters;
- Construction and maintenance access opportunities, and most importantly; and
- Evaluation of retrofit suitability.

Usually information is recorded on a Retrofit Reconnaissance Form (**Figure 7.49**), notes may be made on maps (**Figure 7.50**),conceptual sketches are prepared and photographs are taken. During field reconnaissance, utilities should be located and an assessment made as to potential conflicts that can raise costs. It is advisable to contact the appropriate utility to verify field observations and discuss the potential facility. This may alleviate potential conflicts later.



Retrofit Reconnaissance Investigation

Unique Site ID: AC 010 | Watershed: RK
City: Middleburg Heights | Subwatershed: AC
Date: 10-12-09 | Assessed By: | Camera ID: | Pictures:

Site Description

Name:
Address or Nearest Intersection:
Parcel Number:
Comments:

Ownership: ☒ Public ☐ Private ☐ Unknown
If Public, Government Jurisdiction: ☒ Local ☐ State ☐ DOT ☐ Other:
City of Middleburg Heights

Potential Retrofit Location:

Storage: ☒ Existing Pond ☐ Below Outfall ☐ In Transport ROW ☐ Other: ☐ Above Roadway Crossing ☐ In Conveyance System ☐ Large Parking Lot

On-Site: ☐ Hotspot Operation ☐ Small Parking Lot ☐ Individual Street ☐ Individual Rooftop ☐ Small Impervious Area ☐ Landscape / Hardscape ☐ Underground ☐ Other:

Drainage Area to Site

Drainage Area: 9,110,000 sq ft
Imperviousness: 20 %
Impervious Area: 1,822,000 sq ft
Notes: Above # is approximate. Drainage area was difficult to determine with available data and was not confirmed by city engineers

Drainage Area Land Use: 80? % Residential; ___% SFH (< 1 ac lots); ___% SFH (> 1 ac lots); ___% Townhouses; ___% Multi-Family; ___% Commercial; ___% Institutional; ___% Industrial; ___% Transport-Related; ___% Park; ___% Undeveloped; ___% Other:

Existing Site Conditions

Existing Stormwater BMP: ☒ Yes ☐ No ☐ Possible
If Yes, Describe:
Not certain what the structures purpose is. Shaped like a dry detention basin, but is open where a small creek enters and exits it. Structure where creek exits appears to limit large flows (see sketch)

Describe Existing Site Conditions, Including Existing Drainage and Conveyance Patterns:
The height of the existing basin edges varies. ~~Because~~ where the creek exits the basin, I assigned a relative "0" height. Relative to that point, the exit structures height is 8', the peak of the south edge is 11' and tapers to 9'. The creek enters under the fence on the east side at 3'. The hillside along the fenceline peaks at 12' on the NE side, and then tapers to 10 ft on the NW side. Drainage from rear side of residential parcels on north side outfalls into basin on north side. Creek flows along south side of basin.

Page 1 of 2 Unique Site ID: AC-010

Figure 7.49. Retrofit Recon Form
Source: CWP

Figure 7.50. Field Notes on an Aerial Photo
Source: CWP

The sensitivity of existing natural resources, such as wetlands, streams, and forests, should be evaluated. Impacts to these resources should be avoided or minimized, if possible. Finally, adjacent land uses should be identified and evaluated for opportunities to install stormwater control measures that are compatible with nearby properties.

7.8.3. Prioritize Sites for Implementation (Figure 7.51)

Once sites have been identified and determined to be feasible and practical, the next step is to set up a plan for future implementation. It is prudent to have an implementation strategy based on a predetermined set of objectives. For example, in some watersheds, implementation may be based on a strategy of reducing pollutant loads to receiving waters where the priority of retrofitting might target the land uses or sites with the highest pollutant loadings first. Whereas if the strategy is oriented more towards restoring stream channel morphology, priority retrofits might be targeted to capture the largest drainage areas and provide the most storage.

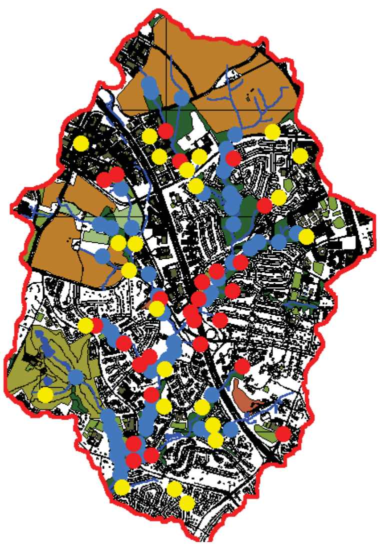


Figure 7.51. Retrofit Priorities Map
Source: CWP

Category	Ranking Factor	Potential Score	
Potential for Treatment			**40**
	Total drainage area treated	15	
	Impervious area treated	15	
	Land use treated	10	
Potential for Greater Ecological and Community Benefits			**25**
	Potential education / demonstration project AND/OR public accessibility	15	
	Treatment of area(s) of concern	5	
	Potential to support other planned or on-going watershed restoration projects and activities	5	
Site Constraints			**35**
	Access for construction and maintenance	15	
	Potential for conflict with existing utilities	5	
	Potential ecological conflicts	10	
	Project for further consideration (yes/maybe)	5	
Total Potential Score			**100**

Figure 7.52. Retrofit Priority Scoring Sheet
Source: CWP

Whatever the restoration focus, it is useful to provide a scoring system that can be used to rank each retrofit site based on a uniform criteria (**Figure 7.52**). A typical scoring system might include a score for the following items:

- Pollutant removal capability
- Stream channel protection capability
- Flood protection control capability
- Cost of facility (design, construction and maintenance costs)
- Ability to implement the project (land ownership, construction access, permits)
- Potential for public benefit (e.g., education, location within a priority watershed, visible amenity, supports other public involvement initiatives, etc.)

7.8.4 Public Involvement Process

This step in the process is not noted in the Center for Watershed Protection's model of the process, as shown in **Figure 7.46** above. However, this aspect of the process is critical in order to gain support for retrofit installations. A successful project must involve the immediate neighbors who will be affected by the changed conditions. Nearly all retrofits require modifications to the existing environment. A dry detention pond may be a very desirable area for some residents in the community. It is a community space and only rarely is there any water in the pond. A stormwater pond or wetland retrofit, on the other hand, may have large expanses of water and may have highly variable water fluctuations. Adjacent owners may resist these changes. In order to gain citizen acceptance of retrofits they must be involved in the process from the start and throughout the planning, design and implementation process. Citizens who are informed about the need for, and benefits of, retrofitting are more likely to accept projects.

Still, some citizens and citizen organizations will never support a particular project. This is why it is mandatory that there be an overall planning process which identifies potential projects early in the selection process and allows citizen input before costly field surveys and engineering designs are performed. Project sites and retrofit techniques that simply cannot satisfy citizen concerns may need to be dropped from further consideration.

A good retrofit program must also incorporate a good public relations plan. Slide shows or field trips to existing projects can be powerful persuasions to skeptical citizens. Every site that goes forward to final design and permitting should be presented at least once to the public through a public hearing or "town hall" type meeting.

7.8.5. Retrofit Design

This step involves the subwatershed or drainage treatment analysis (**Figure 7.53**) and detailed engineering designs and construction plans of the retrofit practices (**Figures 7.54 and 7.55**, below).

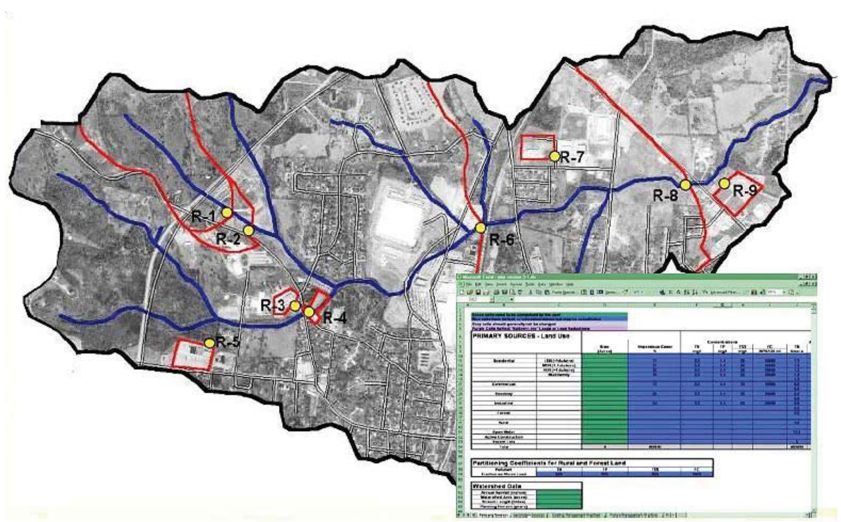


Figure 7.53. Subwatershed Analysis
Source: CWP

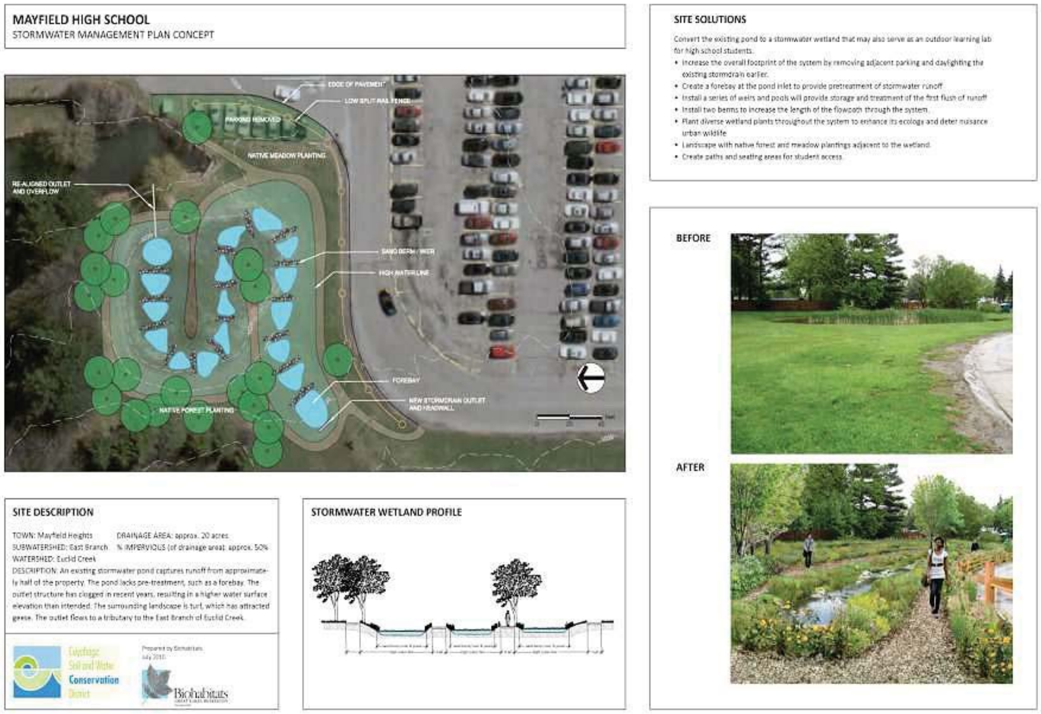


Figure 7.54. Conceptual Retrofit Design Layout for a School Site
Source: CWP

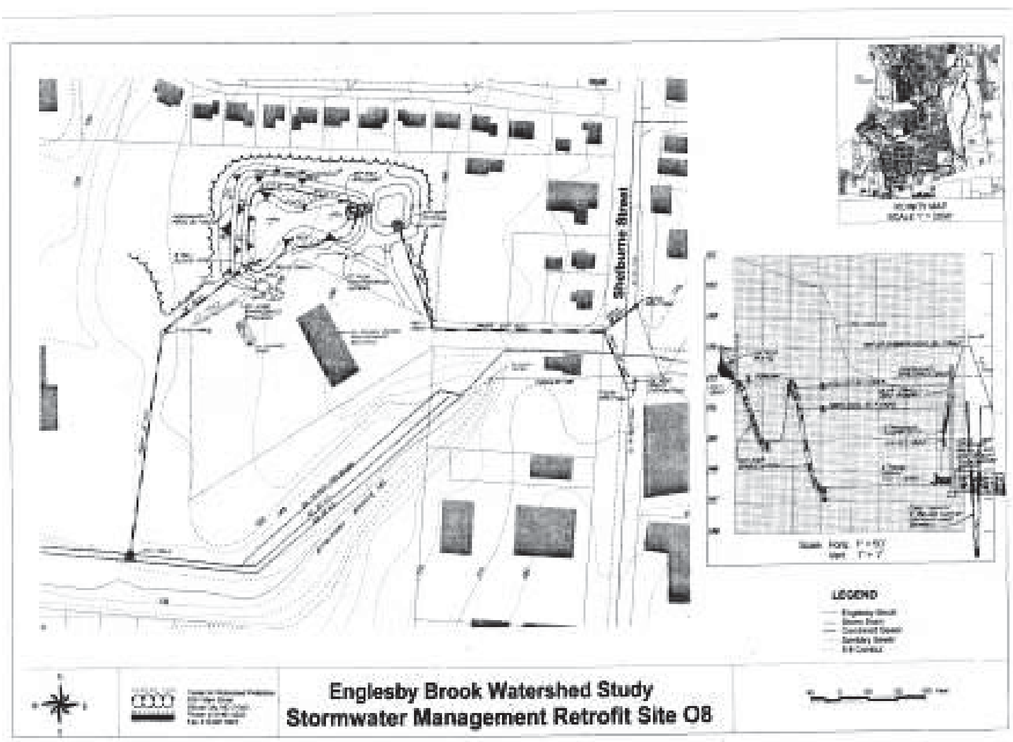


Figure 7.55. Engineering Drawing of a Retrofit Project
Source: CWP

Design of retrofit projects should incorporate the same elements as any other structural control design including, but not limited to the following:

- Adequate hydrologic and hydraulic modeling
- Detailed topographic mapping
- Property line establishment
- Site grading
- Structural design
- Geotechnical investigations
- Erosion and sediment control design
- Construction phasing and staging

Normal structural control design usually follows prescribed design criteria (e.g., control of the 1-year and 10-year storms, sizing for a specified treatment volume, etc.). Retrofit designers must work backwards from a set of existing site constraints to arrive at an acceptable level of stormwater control obtainable. Also, a preliminary cost estimate should be a part of the design phase. Retrofits can vary widely as to cost from a few thousand dollars to several hundred thousand dollars. This process may yield facilities that are too small or ineffective, or too costly for the benefit achieved, and therefore not practical for further consideration.

Designers should look for opportunities to combine projects, such as stream stabilization or habitat restoration with the retrofit in a complementary manner. For example, Green Street retrofits might be held until a target street must resurfaced or dug up for utility repair or replacement. The key to successful retrofit design is in balancing the ability to achieve the maximum pollutant removal, channel erosion protection and flood control while limiting the impacts to adjacent infrastructure, residents or other properties. Designers must consider issues like avoiding relocations of existing utilities, minimizing existing wetland and forest impacts, maintaining existing floodplain elevations, complying with dam safety and dam hazard classification criteria, avoiding maintenance nuisance situations, and providing adequate construction and maintenance access to the site.

7.8.6. Permitting, Construction, Inspections and Maintenance

Perhaps the most difficult permitting issues for retrofit projects involve impacts to wetlands, forests and floodplain alterations. Many of these impacts are either unavoidable or necessary to achieve reasonable storage targets. The primary issues that permitting agencies are looking for is to ensure that the impacts have been minimized to the maximum extent practicable and that the benefits of the proposed project are clearly recognizable and justifiable. In some instances, mitigation may also be required in order to satisfy permitting. If so, additional costs may be involved.

Like any design project, proper construction, inspection, and administration is integral to a successful facility. Retrofitting often involves construction of unique or unusual elements, such as flow splitters, underground sand filters, or stream diversions. Many of these practices may be unfamiliar to many contractors. Most publicly funded projects are awarded to the low bidder who may be qualified to do the work, but may never have constructed projects of this nature.

/Therefore, it is almost a necessity to retain the retrofit designer of record or other qualified professional to answer contractor's questions, approve shop drawings, conduct regular inspections, hold regular progress meetings, conduct construction testing, and maintain construction records. Preparation of As-Built drawings should also be a part of the construction process. These drawings are used for long-term maintenance purposes.

Always the last element and often the least practiced component of a stormwater management program, maintenance is doubly important in retrofit situations. The reasons are simple: most retrofits are undersized when compared to their new development counterparts, and space is at a premium in urban areas where provisions such as access roads and stockpiling or staging areas are either absent or woefully undersized.

7.9 CALCULATING NUTRIENT REDUCTIONS FOR INDIVIDUAL RETROFIT PROJECTS

Stormwater retrofits are a diverse group of BMP projects that provide nutrient and sediment reduction from existing development that is currently untreated by any BMP or is inadequately treated by an existing BMP. The amount of nutrient reduction that results from any particular stormwater retrofit BMP depends on several factors:

- The class of retrofit (e.g., new and full-sized, an existing BMP being enhanced, etc.);
- The specific type of retrofit BMP selected (e.g., disconnection, bioretention, etc.);
- The baseline nutrient load to the BMP
- The volume of rainfall captured
- The amount of runoff volume reduction achieved

Retrofits can be problematic when it comes to defining a nutrient removal rate. For example:

- Every retrofit project is unique to some degree, depending on the drainage area it treats, the treatment mechanism(s) of the selected BMP, the runoff volume it captures, and the degree of prior stormwater treatment at the site, if any. Due to site constraints, many retrofit BMPs are under-sized in comparison to new BMPs designed to new development standards, This typically results in reduced pollutant removal capacity. Some adjustment in pollutant removal capability is needed to account for situations where the retrofit BMP cannot capture and treat the specified treatment volume.
- There is virtually no research available specifically for stormwater retrofits, so removal rates must be inferred from other known BMP and runoff reduction performance data.
- Many retrofits employ innovative combinations of runoff treatment mechanisms and may not be easily classified according to the existing CBP- or state-approved BMP removal rates.
- Localities often evaluate dozens or even hundreds of candidate projects during retrofit investigations to find the best ones. Therefore, localities will need fairly simple protocols to estimate pollutant reduction achieved by individual retrofits projects as part of their watershed assessment and retrofit investigation.

7.9.1. Method for Calculating Retrofit BMP Nutrient Removal

Assigning a single universal pollution removal rate for stormwater retrofit BMP projects is not practical or scientifically defensible. Instead, DEQ proposes the use of a method developed by the USEPA Chesapeake Bay Program's Urban Stormwater Work Group (Schueler and Land, 2012), which has been endorsed by state SWM program managers throughout the Chesapeake Bay region. Using this method, the removal rate for each individual retrofit project is determined based on the amount of runoff it treats and the degree of runoff volume reduction it provides. For ease of use, a set of three curves was developed, as portrayed in **Figures 7.56 - 7.58**. The technical derivation of the curves is provided in **Appendix 7-C** of this chapter. There are four steps in this method:

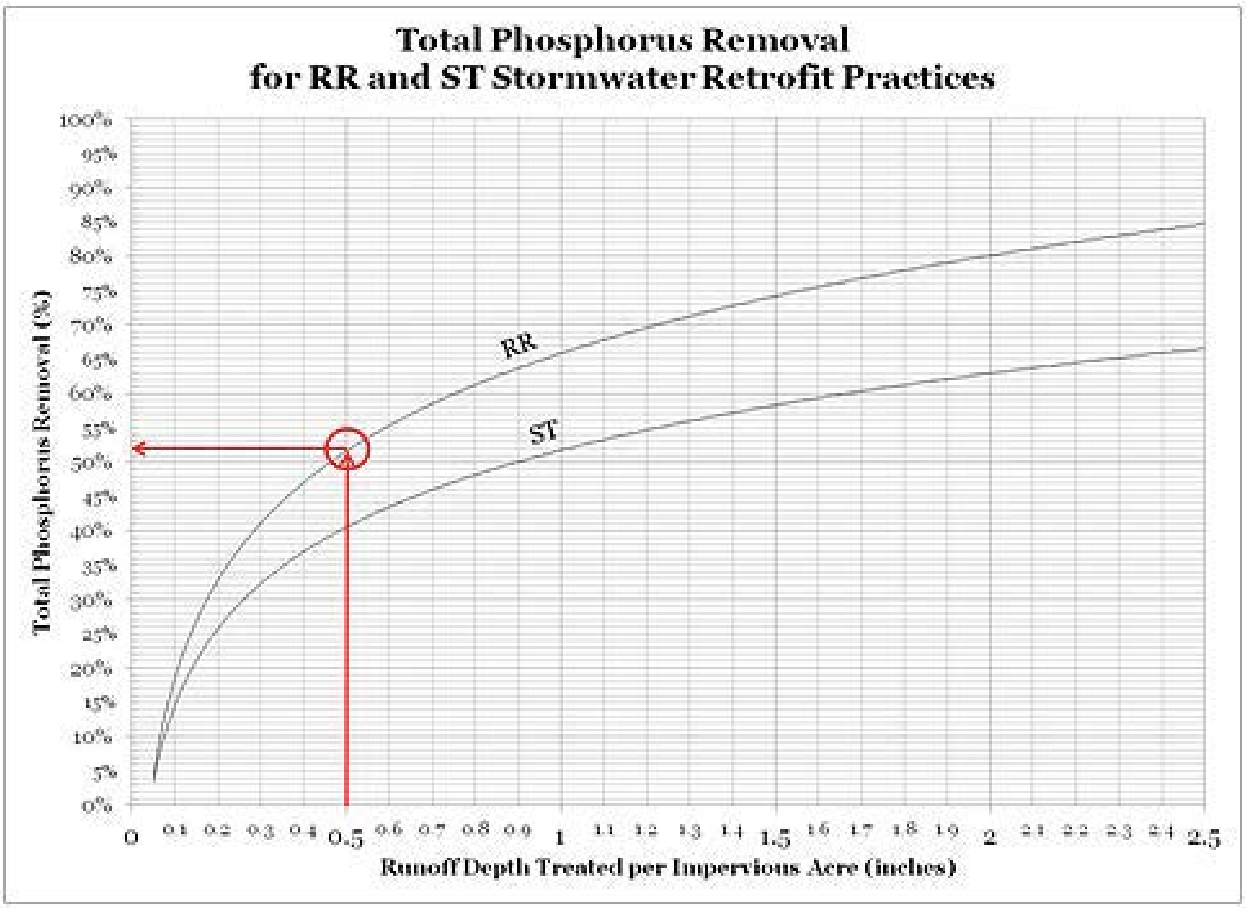


Figure 7.56. Retrofit Pollutant Removal Adjustor Curve for Total Phosphorus (TP)

- ***Step 1:*** Compute the baseline nutrient load (use TP as the indicator) for the site area draining to the proposed retrofit BMP using the Virginia Runoff Reduction Method spreadsheet. This calculation method closely tracks the EPA Chesapeake Bay Model projections for baseline nutrient loads for urban and suburban lands.

- ***Step 2:*** Select the appropriate method to define a project-specific retrofit removal rate, based on its appropriate retrofit classification:
  - o New retrofit facility;
  - o BMP conversion;
  - o Existing BMP enhancement;
  - o Greet Street retrofit; or
  - o On-site LID retrofit

- ***Step 3:*** Adjust the removal rate using the runoff adjustment method.

- ***Step 4:*** Multiply the adjusted retrofit removal rate by the pre-retrofit baseline nutrient load to determine the total pounds of nutrients reduced by the retrofit project.

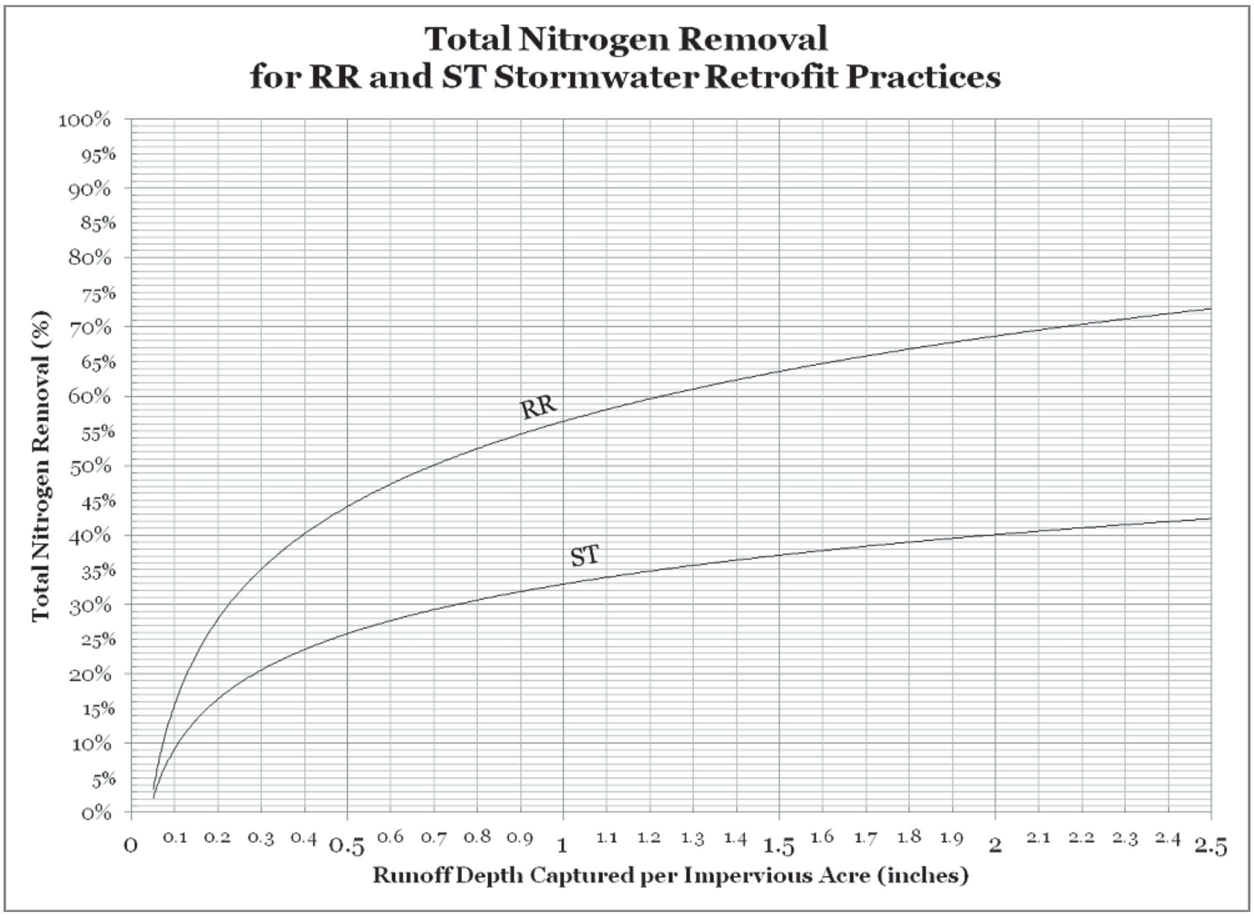


Figure 7.57. Retrofit Pollutant Removal Adjustor Curve for Total Nitrogen (TN)

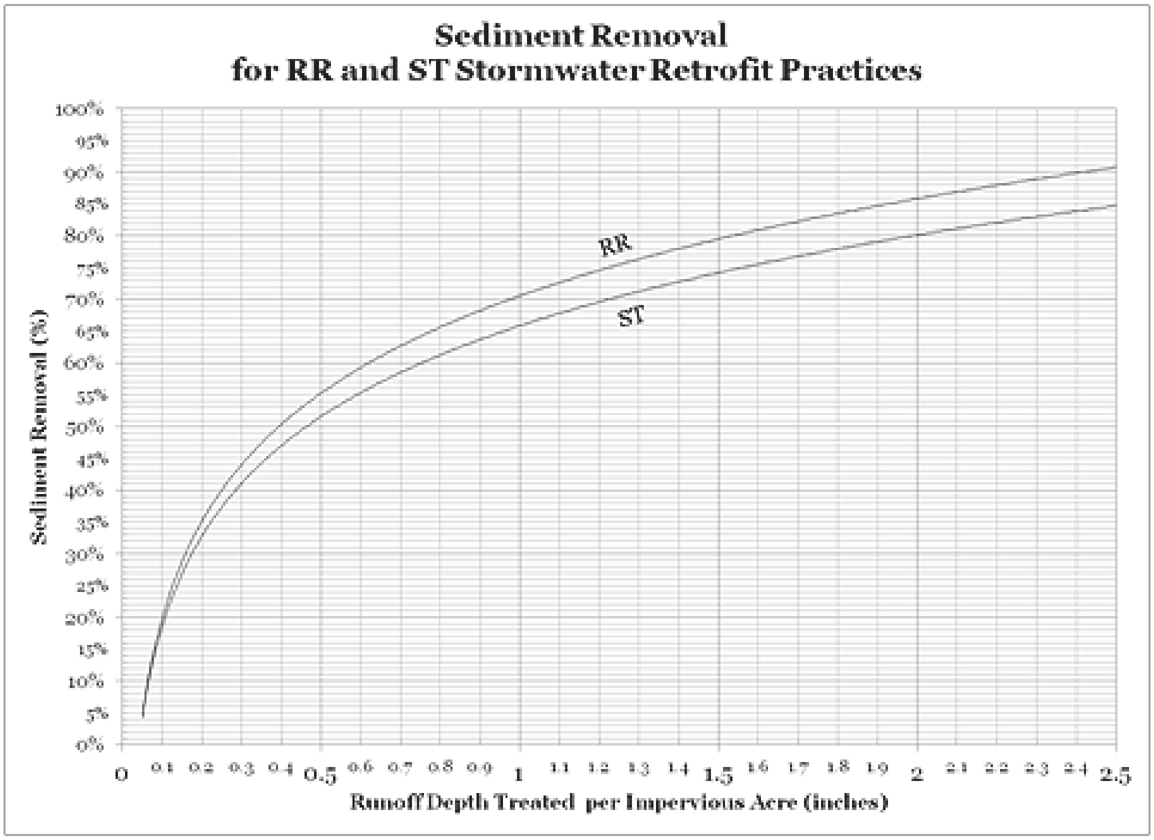


Figure 7.58. Retrofit Pollutant Removal Adjustor Curve for Total Suspended Solids (TSS)

In order to determine the runoff volume treated by a retrofit practice, the designer must first estimate the Runoff Storage volume (RS) in acre-feet. This, along with the Impervious Area (IA) in acres, is used in the standard retrofit equation to determine the amount of runoff volume in inches treated at the site:

$$= \frac{(RS)(12)}{IA}$$

Where:

RS = Runoff Storage Volume (acre-feet)
IA = Impervious Area (acres)

Once the amount of runoff captured by the practice is determined, the retrofit removal adjustor curves make it easy to determine pollutant removal rates for individual stormwater retrofits. The designer first defines the runoff depth treated by the project (on the x-axis), and then determines whether the project is classified as having runoff reduction (RR) or stormwater treatment (ST) capability (from **Table 7.7** below). The designer then goes upward to intersect with the appropriate curve, and moves to the left to find the corresponding removal rate on the y-axis. An example is provided in **Figure 7.56** above, using the TP removal adjustor curve (since TP is the basis for water quality compliance in the Virginia SWM Regulations). Removals for TN and TSS can be determined in like manner by using the adjustor curves in **Figure 7.57** and **Figure 7.58** above, respectively.

Table 7.7. Classification of BMPs based on Runoff Reduction Capability

Runoff Reduction Practices (RR)	Stormwater Treatment Practices (ST)
Site Design/Non-Structural Practices	**Constructed Practices**
Landscape Restoration/Reforestation	Constructed Wetlands
Riparian Buffer Restoration	Dry Extended Detention Ponds
Rooftop Disconnection (aka Simple Disconnection to Amended Soils, to a Conservation Area, to a Pervious Area, Non-Rooftop Disconnection)	Filtering Practices (aka Constructed Filters, Sand Filters, Stormwater Filtering Systems)
Sheetflow to Filter/Open Space* (aka Sheetflow to Conservation Area, Vegetated Filter Strip)	Proprietary Practices (aka Manufactured BMPs)
All Environmental Site Design BMPS – Chapter 6 of the this Handbook	Wet Ponds (aka Retention Basin)
Constructed Practices	Wet Swale
Bioretention or Rain Garden (Standard or Enhanced)	
Dry Swale	
Expanded Tree Pits	
Grass Channels (w/ Soil Amendments, aka Bio-swale, Vegetated Swale)	
Green Roof (aka Vegetated Roof)	
Green Streets	
Infiltration (aka Infiltration Basin, Infiltration Bed, Infiltration Trench, Dry Well/Seepage Pit, Landscape Infiltration)	
Permeable Pavement (aka Porous Pavement)	
Rainwater Harvesting (aka Capture and Re-use)	
*May include a berm or a level spreader	

Runoff reduction is defined as the total post development runoff volume that is reduced through canopy interception, soil amendments, evaporation, rainfall harvesting, engineered infiltration, extended filtration or evapotranspiration. Retrofit projects that achieve at least a 25% reduction of the annual runoff volume are classified as providing Runoff Reduction (RR), and therefore earn a higher net removal rate. Retrofit projects that employ a permanent pool, constructed wetlands or sand filters have less runoff reduction capability, and their removal rate is determined using the Stormwater Treatment (ST) curve.

Table 7.7 above assigns BMPs referenced in Bay State stormwater management manuals into either the ST or RR category, so that designers can quickly determine which curve they should use based on the primary treatment practice employed by the retrofit. In situations where a mix of ST and RR practices are used within the same retrofit project, the designer should use the curve based on either the largest single practice used in the project or the ones that provide the majority of the retrofit treatment volume.

The removal rates determined from the retrofit removal rate adjustor curves are applied to the *entire* drainage area to the retrofit, and not just its impervious acres. Also, the retrofit reporting unit is the *entire* treated area, regardless of whether it is pervious or impervious.

7.9.1.1. New Retrofit Facilities

This category includes new retrofit projects that create storage to reduce nutrients from existing developed land that is not currently receiving any stormwater treatment. Common examples of new retrofits include creating new storage upstream of roadway crossings, near existing stormwater outfalls, within the existing stormwater conveyance system or adjacent to large parking lots. Desktop and field methods for discovering opportunities for new retrofits are described in Schueler (2007). There are two options to define removal rates for this class of retrofit projects:

- ***Chesapeake Bay Program (CBP) Rate Option*:** If the new retrofit project can be classified into one of the existing CBP urban BMP categories and has enough treatment volume to treat the runoff from at least one inch of rainfall, then the appropriate CBP approved rates should be used (**Table 7.8** below).

Table 7.8. Current BMP Efficiencies Approved by the Chesapeake Bay Program (2/9/2011) [1, 2, 3]

URBAN BMP		MASS LOAD REDUCTIONS		
		Total Nitrogen	Total Phosphorus	TSS
Wet Ponds & Constructed Wetlands		20	45	60
Dry Detention Ponds		5	10	10
Dry Extended Detention Ponds		20	20	60
Infiltration		80 (85) [4]	85	95
Filtering Practices (sand filters)		40	60	80
Bioretention	C&D w/ UD	25	45	55
	A&B w/ UD	70	75	80
	A&B w/o UD	80	85	90
Permeable Pavement	C&D w/ UD	10 (20)	20	55
	A&B w/ UD	45 (50)	50	70
	A&B w/o UD	75 (80)	80	85
Grass Channels	C&D w/o UD	10	10	50
	A&B w/o UD	45	45	70
Bioswale	aka Dry Swale	70	75	80
Nutrient Management		17	22	NA
Street Sweeping	Bi-monthly	3	3	9
Forest Buffers		25	50	50

[1] In many cases, removal rates have been discounted from published rates to account for poor design, maintenance and age, and apply to generally practices built prior to 2008

[2] Current Practices are designed to more stringent design and volumetric criteria, and may achieve higher rates – see **Table 7.8** below

[3] Some practices, such as forest conservation, impervious cover reduction, tree planting are modeled as a land use change. Urban stream restoration is modeled based on a reduction per linear foot of qualifying stream restoration project

[4] Numbers in parentheses reflect design variation with a stone sump to improve long term infiltration rates

Table 7.9. Comparative Runoff Reduction and Nutrient Removal for Practices

Practice	BMP Design Level	Runoff Reduction	TN EMC Removal[3]	TN Mass Load Removal	TP EMC Removal	TP Mass Load Removal [6]
Rooftop Disconnect	*1 [2]*	*25 to 50 [1]*	*0*	*25 to 50 [1]*	*0*	*25 to 50 [1]*
	No Level 2 Design					
Sheet Flow to Veg. Filter or Conserv. Open Space	*1*	*50*	*0*	*50*	*0*	*50*
	2 [5]	*50 to 75 [1]*	*0*	*50 to 75 [1]*	*0*	*50 to 75 [1]*
Grass Channels	*1*	*10 to 20 [1]*	*20*	*28 to 44 [1]*	*15*	*24 to 41 [1]*
	No Level 2 Design					
Soil Compost Amendment	Can be used to Decrease Runoff Coefficient for Turf Cover at Site. See the design specs for Rooftop Disconnection, Sheet Flow to Vegetated Filter or Conserved Open Space, and Grass Channel					
Vegetated Roof	*1*	*45*	*0*	*45*	*0*	*45*
	2	*60*	*0*	*60*	*0*	*60*
Rainwater Harvesting	*1*	*Up to 90 [3, 5]*	*0*	*Up to 90 [3, 5]*	*0*	*Up to 90 [3, 5]*
	No Level 2 Design					
Permeable Pavement	*1*	*45*	*25*	*59*	*25*	*59*
	2	*75*	*25*	*81*	*25*	*81*
Infiltration Practices	*1*	*50*	*15*	*57*	*25*	*63*
	2	*90*	*15*	*92*	*25*	*93*
Bioretention Practices	*1*	*40*	*40*	*64*	*25*	*55*
	2	*80*	*60*	*90*	*50*	*90*
Urban Bioretention	*1*	*40*	*40*	*64*	*25*	*55*
	No Level 2 Design					
Dry Swales	*1*	*40*	*25*	*55*	*20*	*52*
	2	*60*	*35*	*74*	*40*	*76*
Wet Swales	*1*	*0*	*25*	*25*	*20*	*20*
	2	*0*	*35*	*35*	*40*	*40*
Filtering Practices	*1*	*0*	*30*	*30*	*60*	*60*
	2	*0*	*45*	*45*	*65*	*65*
Constructed Wetlands	*1*	*0*	*25*	*25*	*50*	*50*
	2	*0*	*55*	*55*	*75*	*75*
Wet Ponds	*1*	*0*	*30 (20) [4]*	*30 (20) [4]*	*50 (45) [4]*	*50 (45) [4]*
	2	*0*	*40 (30) [4]*	*40 (30) [4]*	*75 (65) [4]*	*75 (65) [4]*
Ext. Det. Ponds	*1*	*0*	*10*	*10*	*15*	*15*
	2	*15*	*10*	*24*	*15*	*31*

Notes [1] Lower rate is for HSG soils C and D, Higher rate is for HSG soils A and B.

[2] The removal can be increased to 50% for C and D soils by adding soil compost amendments, and may be higher yet if combined with secondary runoff reduction practices.

[3] Credit up to 90% is possible if all water from storms of 1-inch or less is used through demand, and the tank is sized such that no overflow occurs. The total credit may not exceed 90%.

[4] Lower nutrient removal in parentheses apply to wet ponds in coastal plain terrain.

[5] See BMP design specification for an explanation of how additional pollutant removal can be achieved.

[6] Total mass load removed is the product of annual runoff reduction rate and change in nutrient EMC.

- ***Stormwater Retrofit Removal Rate Adjustor:*** To determine the nutrient and sediment removal rates for an individual new retrofit project, the designer should use the appropriate adjustor curve (**Figures 7.56 - 7.58** above) to find the unique rate for the combination of runoff depth captured and runoff reduction/stormwater treatment that is achieved. The designer should also estimate the total contributing drainage area to the retrofit.

7.9.1.2. BMP Conversions

The specific method for defining the removal rate depends on the type and age of the BMP being converted:

- ***If the BMP being converted is a dry detention pond or flood control structure that currently is providing <u>no</u> effective water quality treatment***, then the existing BMP will have a zero removal rate. A higher CBP-approved BMP rate that reflects the improved stormwater treatment mechanism associated with the conversion can be taken directly from Table A-5 of Appendix A (i.e., dry ED, wet pond, constructed wetland or bioretention)

- ***If the BMP being converted involves a significant increase in runoff capture volume and/or an increase in runoff reduction, than an incremental rate is used***. The removal rate for the existing BMP should be determined from the adjustor curve. A higher removal for the converted BMP will reflect the higher degree of runoff treatment and/or runoff reduction associated with the retrofit, as determined from the retrofit removal adjustor curves (**Figures 7.56 - 7.58** above). This method will generally be the most applicable to the majority of conversion retrofits.

In all cases, the designer should also estimate the total contributing drainage area to the retrofit. Examples are provided in the next section, that illustrate how both of these methods are applied to conversion retrofits.

7.9.1.3. Existing BMP Enhancements

This retrofit category applies to projects whereby the basic treatment mechanism of the existing BMP is not changed, but its nutrient reduction capability is enhanced by increasing its treatment volume and/or increasing the hydraulic retention time within the practice. BMP enhancements are a good strategy for older and larger ponds and wetlands built under less stringent sizing and design standards. BMP enhancement may also be a good strategy for the first generation of bioretention and filtering practices, which had design criteria that lacked the features now known to enhance nutrient removal.

An example of a retrofit enhancement for an older wet pond might be to increase its treatment volume, realign inlets to prevent short circuiting, add internal cells and forebays to increase flow path, and add aquatic benches, wetland elements and possibly even floating islands to enhance overall nutrient reduction.

At first glance, it would seem to be difficult to assign removal rates for such BMP enhancements, although Virginia now uses a two-level design system shared by many Bay states, whereby nutrient removal rates are increased when certain treatment volume and design features are met or exceeded (http://www.vwrrc.vt.edu/swc/NonProprietaryBMPs.html). Therefore, the recommended option to estimate the nutrient reduction achieved by BMP enhancement retrofits is as follows:

- ***Step 1:*** The base nutrient removal rate for the existing BMP (prior to enhancement) should be rate originally assigned to the BMP design under the Virginia Chesapeake Bay Preservation Act Program or the 1999 Virginia Stormwater Management Handbook. If the BMP is older than either of these programs (i.e., pre-1990), use the conservative CBP-approved rates found in **Table 7.8** above.

- ***Step 2:*** The designer should then evaluate the range of BMP enhancements to see if they qualify for the higher Level 1 or Level 2 rates shown in **Table 7.9** above.

- ***Step 3:*** The nutrient removal rate for the retrofit is then computed as the difference from the Level 1 or 2 rates and the existing Virginia or CBP-approved rate.

As an alternative, the nutrient and sediment removal rates for individual BMP enhancement retrofits are also expressed as an incremental removal rate (enhanced BMP - existing BMP).

- The rate for the existing BMP is defined based on its combination of runoff treatment and runoff reduction using the retrofit removal adjustor curves (**Figures 7.56 - 7.58** above). Designers may reduce the actual amount of runoff treatment in the existing BMP that is not effective (e.g., treatment volume that is ineffective because of short-circuiting or other design problems that reduce the hydraulic retention time).

- The enhanced BMP will have either a greater runoff treatment volume and/or achieve a better runoff reduction rate. Designers can determine the higher rate for the enhanced BMP using the retrofit removal adjustor curves.

- The removal rate for the BMP enhancement is then defined as the difference between the enhanced rate and the existing rate. An example of how to apply this protocol for BMP enhancements is provided in the next section.

7.9.1.4. BMP Restoration

The removal rate for BMP restoration depends on whether the existing BMP has been previously reported and included in the state's CBWM input deck.

- If the BMP was installed prior to July 1, 2009 and has *not* been previously reported, then the BMP is considered to be a new retrofit facility with the applicable removal rate from (1) the 1999 edition of the *Virginia Stormwater Management Handbook*, if applicable, (2) **Table 7.8** above, if a CBP-approved BMP, or (3) the as determined by using the retrofit removal adjustor curves for the drainage area contributing to the BMP.

- If the BMP was installed prior to July 1, 2009 and *is* included in the state's CBWM input deck, then the removal rate for a restored BMP is expressed as an incremental removal rate (restored BMP - existing BMP). The existing BMP removal rate is determined from (1) the 1999 edition of the *Virginia Stormwater Management Handbook*, if applicable, (2) **Table 7.8** above, if a CBP-approved BMP, or (3) using the curves for all others, based on the original BMP sizing and design criteria. The restored BMP rate is defined using the retrofit removal rate adjustor curve for the runoff treatment volume "restored" (i.e., by sediment cleanouts, vegetative harvesting or practice rehabilitation) and/or shifting to RR runoff reduction (i.e., media replacement).

To prevent double counting in reports to the USEPA Chesapeake Bay Program (for TMDL accounting purposes), the removal rate of a restored BMP should be reported to EPA in a two-step process. First, it should be reported at the degraded condition (lower/original removal rate) for at least one annual model progress run. Second, the incremental improvement associated with the BMP's restoration should then be reported for the next year's model progress run.

7.9.1.5. Green Street Retrofits

Green Streets use a combination of LID practices within public street rights-of-way, and they are gaining popularity as an attractive option to treat stormwater runoff in highly urban watersheds (CSN, 2011c). Green Streets provide many urban design benefits and create a more attractive and functional urban streetscape. Green Streets typically involve a combination of practices such as permeable pavers, street bioretention, expanded tree pits, individual street trees, impervious cover removal, curb extensions and filtering practices. The linear nature of Green Streets makes them a very efficient composite LID practice that can treat several acres of impervious cover in a single system.

Numerous Green Street or Green Alley demonstration projects have been installed in cities within the Bay watershed. At the current time, there is no standard design for Green Streets, since each project must deal with unique constraints present in each individual Green Street section (e.g. street width, right-of-way width, underground utilities, development intensity, parking needs, street lighting, and pedestrian/automotive safety, etc.).

Consequently, it is not feasible to assign a generic nutrient and sediment removal rate for Green Streets at this time. As an alternative, the nutrient removal credit for Green Streets can be estimated in a simple two-step process:

- ***Step 1: Impervious Cover Reduction Credit.*** The Simple Method (Schueler, 1987) can be used to compute the change in nutrient load that can be attributed the reduction in impervious cover associated with a narrower street. This is easily done by adjusting the site runoff coefficients to reflect the lower impervious cover associated with the Green Street.

- ***Step 2.*** The Green Street project can then be analyzed as a whole to determine the actual rainfall depth it controls and degree of runoff reduction it achieves. Based on these factors, designers can select the appropriate mass removal rates from the retrofit removal adjustor curves (**Figures 7.56 - 7.58** above).

7.9.1.6. On-Site LID Retrofits

This category includes the installation of a large number of small on-site retrofits, such as rain gardens, compost amendments, rain barrels, rooftop disconnections and tree planting, at the scale of a residential neighborhood. These retrofits are typically delivered by local governments, watershed groups, or neighborhood associations, who provide incentives and subsidies to individual property owners to implement them. In many cases, dozens or even hundreds of these small retrofits might be installed in any given subwatershed.

To simplify analysis, it is recommended that localities record the cumulative area of impervious cover treated by on-site retrofits, based on the average rainfall depth that is controlled, designers can select the appropriate mass removal rates from the retrofit removal adjustor curves (**Figures 7.56 - 7.58** above).

7.9.1.7. Local Tracking, Reporting and Verification

Localities should maintain a project file for each retrofit project installed. The file should be maintained for the entire period of time during which the retrofit nutrient removal credit will be claimed. The typical duration for the credit will be approximately 25 years, although the locality may be required to conduct a performance inspection at least once every five years to verify that the practice is being adequately maintained and operating as designed.

Localities should also submit some basic documentation to the state about each retrofit, including the following:

- GPS coordinates for the project location
- The year the retrofit project was installed
- Identify the type of BMP (BMP name)
- Identify the class of BMP (e.g., new retrofit facility or existing BMP retrofit as converted, enhanced, restored, etc.)
- The 12-digit watershed (Virginia 6th Order Watershed) in which it is located
- The total drainage area and impervious cover area treated
- The runoff volume treated or reduced (optional)
- The nutrient (and sediment) reduction credits claimed (and the method used to compute them)
- A signed certification that the retrofit has been inspected after construction and meets its performance criteria.

Localities are also responsible for long-term inspection and maintenance of permanent SWM BMPs and will be held accountable for the level of their continued performance, if they are located within the Virginia portion of the Chesapeake Bay watershed and subject to Chesapeake Bay TMDL pollution reduction targets. Localities are encouraged to develop a GIS-based BMP tracking system in order to schedule routine inspections and maintenance activities over time.

7.9.1.8. The Baseline Load Issue

This method for calculating pollutant removal loads for retrofit BMP projects does not require localities to define a pre-retrofit baseline load. However, DEQ acknowledges that many localities may want to estimate pre-retrofit baseline loads when it comes to finding the most cost-effective combination of retrofit projects to pursue in their local subwatershed retrofit investigations. Consequently, the Department recommends several options to use in planning level analyses of comparative retrofit load removal capability. These include the:

1. Generic state-wide CBWM urban unit loading rates
2. Simple Method (Schueler, 1987)
3. Watershed Treatment Model

Baseline loads are not needed to justify retrofit load reductions over time in the context of the Chesapeake Bay TMDL, since the CBWM calculates these directly based on the model segment in which the retrofit is located.

7.9.1.9 Analyzing Retrofit Options in the Context of CAST/VAST

A retrofit assessment protocol may not fit easily within the context of assessment and scenario builder tools, such as Chesapeake Assessment Scenario Tool (CAST) and Virginia Assessment Scenario Tool (VAST), that have been recently developed to assist states and localities to evaluate BMP options to develop watershed implementation plans (i.e., each retrofit has a unique rate and consequent load reduction, while the CAST and VAST apply a universal rate for all retrofits).

The USEPA Chesapeake Bay Program’s modeling team has expressed a willingness to incorporate the adjustor curves presented above into the CAST modeling framework in the next year or so. Until such refinements are made, it is reasonable, for planning purposes, to assign a single removal rate to characterize the performance of a generic type of retrofit in order to evaluate alternative BMP scenarios. For example, DEQ could assume a generic stormwater retrofit that is a 50/50 blend of runoff reduction (RR) and stormwater treatment (ST) and treat 1-inch of runoff from the impervious area. This generic retrofit rate could be used in the context of CAST/VAST to compare load reductions for different levels of local drainage area treated by retrofits.

7.10. RETROFIT ECONOMICS

The first generation of retrofits primarily focused on demonstrating that retrofits could achieve restoration objectives, with little attention devoted to finding the least costly restoration solution. The next generation of retrofits, however, will need to demonstrate that they represent the most cost effective solution to the restoration problem they are designed to address. Some key findings on retrofit economics from the 2006 cost survey are shared below.

Retrofitting can be a costly enterprise. The cost to construct retrofits ranges from 1.5 to 4 times greater than the cost to construct stormwater practices at new development sites. The extra costs for retrofits are related to site constraints, higher excavation costs, greater design complexity, more construction contingencies, additional engineering studies, enhanced landscaping and the experimental nature of many designs. Given that many retrofits are prototypes, it is expected that unit costs may decline in the future as contractors gain more familiarity with them.

There may be rare instances when retrofit costs can be based on new practice cost equations, but only when: land is abundant to provide maximum flexibility in site layout, site topography is such that a neutral earth balance can be attained and no major investments are contemplated for special plumbing, environmental permits, utility relocation or major landscaping.

Figure 7.59 below compares the median and quartile range in base construction cost for 18 different retrofit techniques. As can be seen, pond retrofits, rain gardens and new storage retrofits are the least expensive to construct, whereas ultra-urban techniques such as underground filters, tree pits, permeable pavers and green rooftops are the most expensive. The design team should carefully review these unit costs during initial scoping to ensure they are targeting the most cost-effective retrofits in a subwatershed.

Storage retrofits are generally more cost-effective than on-site retrofits, primarily due to economies of scale related to the large drainage areas they treat. In general, retrofits serving the smallest drainage areas tend to have the greatest unit cost. This finding suggests that designers should try to exhaust all possibilities for storage retrofits in a subwatershed before they embark on an onsite retrofit approach.

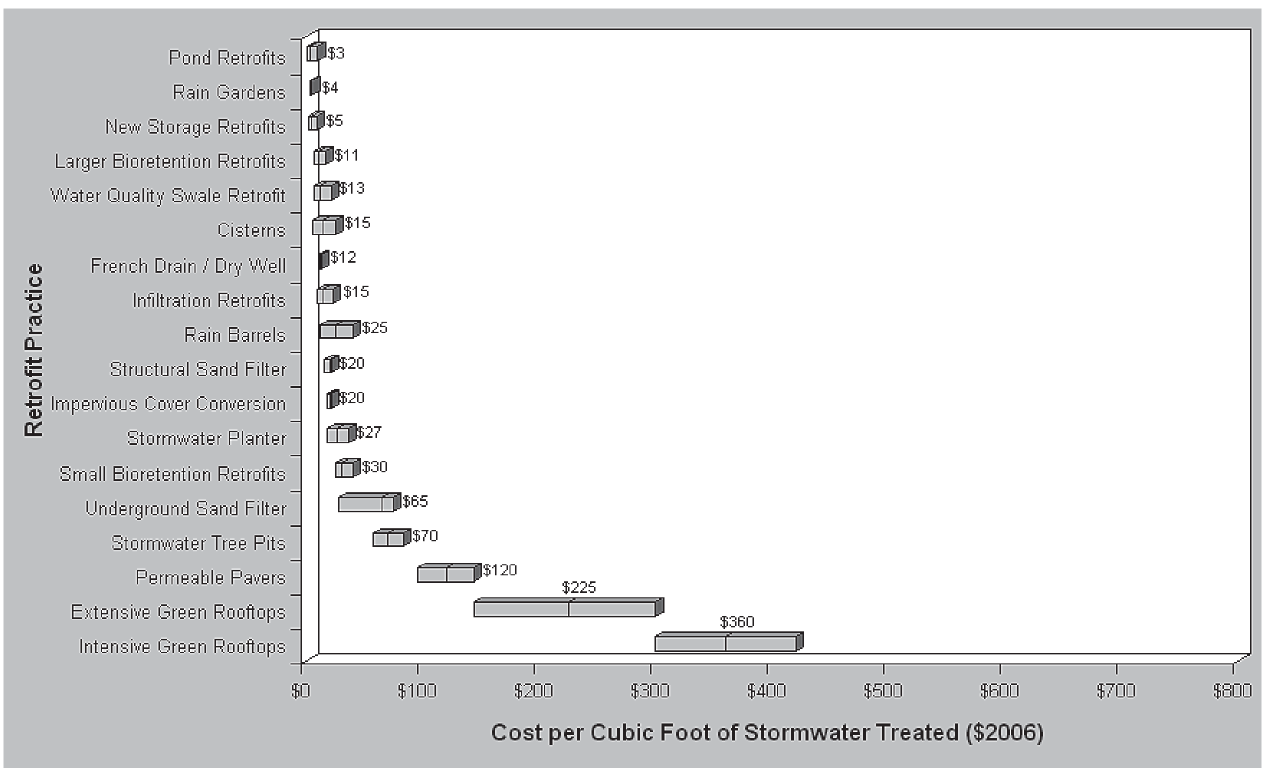


Figure 7.59. Range of base construction costs for various retrofit options.
(Note: Boxes show 25% and 75% quartiles; the line represents the median)
Source: CWP 2007

Construction costs for the same retrofit technique can vary by two orders of magnitude. For example, the unit construction cost for the least and most expensive pond retrofits ranged from $1,350 to $107,000 per impervious acre treated. An even wider range was reported for bioretention retrofits ($2,000 to $327,000 per impervious acre). Designers should always look for key factors that can drive up the cost of retrofitting when they evaluate individual retrofit sites.

The design and engineering (D&E) costs for both on-site and storage retrofits ranges from 32 to 40% of base construction cost (higher end when environmental permits must be secured). Total D&E costs for retrofits are higher than new stormwater practices, given their higher base construction costs. Land acquisition costs for all storage retrofits are assumed to be zero since they are generally constructed on public land. However, land acquisition costs must be added if land rights or easement need to be secured to build a project. On-site retrofits also have a hidden cost to persuade owners to install them on private land. The program cost to promote and deliver on-site retrofits may rival actual construction costs. Lastly, the retrofit costs shown here do not include the cost to find, assess and rank retrofits at the subwatershed level.

The most important number is the aggregate cost to construct retrofits across an entire subwatershed. Returning to the 5,000 acre subwatershed example, assume that 70% retrofit coverage is desired. If it is further assumed that storage retrofits are used to obtain 80% of the subwatershed treatment and on-sites for the remainder, it is possible to get a sense of the number and cost of retrofits needed for the subwatershed (**Table 7.10** below). At 10% subwatershed impervious cover, the retrofit bill is nearly $7 million and climbs to $20 to 40 million at higher levels of subwatershed impervious cover. While most communities spread out this investment over 5 or 10 years, it clearly underscores the need to devise creative retrofit delivery strategies to get the job done.

Table 7.10. Long Term Costs to Retrofit a 5,000 Acre Subwatershed

Subwatershed Impervious Cover	Impervious Acres Treated	Number of Retrofits Required	Base Construction Costs	Total Restoration Cost
10%	353	OS = 141 SR = 6	$1,582,000 $3,579,000	$6,700,000
30%	1,088	OS = 435 SR = 17	$4,892,500 $10,965,000	$20,600,000
45%	1,650	OS = 660 SR = 26	$7,425,000 $16,740,000	$31,400,500
60%	2,194	OS = 878 SR = 35	$9,900,000 $22,000,000	$41,500,000

Assumptions:
- 50 acres treated per storage retrofits (SR) and 0.5 acre treated per on-site (OS) retrofit
- 70% of the entire subwatershed area to be retrofit
- 80% of the watershed is treated by storage retrofits; 20% is treat with on-site retrofits
- Storage retrofits are equally split between pond retrofits and new facilities
- 25% of on-site retrofits are on residential land and 75% are on non-residential sites
- Costs per impervious acre treated are: $9,500 for pond retrofits; $15,500 for new storage facilities; $15,000 for residential on-site retrofits; and $25,000 for non-residential on-site retrofits
- Total cost includes D&E at 32% of base construction cost

Source: CWP, 2007

Also keep in mind that costs are likely to be higher at the demonstration stage, but they will come down when all involved, from public officials to designers and contractors, have more experience and confidence with the process. For example, the first green street retrofit projects in a community can be very costly and time-consuming, especially if multiple municipal agencies (streets, utilities, zoning, etc.) must independently permit the project. However, permitting can be streamlined with experience.

7.10.1. Tips for Cost-Effective Retrofit Implementation

Localities can take the following steps to maximize the cost-effectiveness of BMP retrofits implemented within their jurisdictions.

- ***Maximize the Use of Other Nutrient Reduction Practices.*** Implementing source control and "good housekeeping" practices, such as those in the following list, throughout the community can boost pollution reduction efforts and reduce the number of retrofits needed to reach local pollution reduction targets.
    - Reforestation
    - Stream restoration
    - Fertilizer restrictions
    - Septic system upgrades
    - BMP maintenance upgrades
    - Stream buffer upgrades
    - Providing appropriate incentives and credits for redevelopment
    - Street sweeping
    - Elimination of illicit discharge

- ***Develop Multiple Revenue Streams and Retrofit Delivery Mechanisms (*****Figure 7.60** below)***,*** such as the following:
    - Stormwater Utility credits or discounts (as incentives)
    - Capital Improvement Budget (funding source)
    - Stormwater maintenance budgets (funding source)
    - Stormwater offset fees (funding source)
    - Nutrient trading (funding source and/or delivery mechanism)
    - Public-private partnerships (funding source and/or delivery mechanism)
    - BMP Maintenance enforcement (delivery mechanism)
    - Piggyback on street/utility reconstruction (delivery mechanism)
    - Piggyback on municipal construction projects (delivery mechanism)

- ***Maximize the Drainage Area Treated by Individual Retrofits.*** Large storage-type retrofits are usually the most cost-effective solutions, although they do require more permitting, easements and neighborhood consultation. Experience has shown that storage retrofits can treat up to 20% – 30% of the subwatershed area in suburban areas (much less in dense urban areas). After storage retrofits, Green Street and LID-type retrofits are the most cost-effective methods to maximize the drainage area treated.

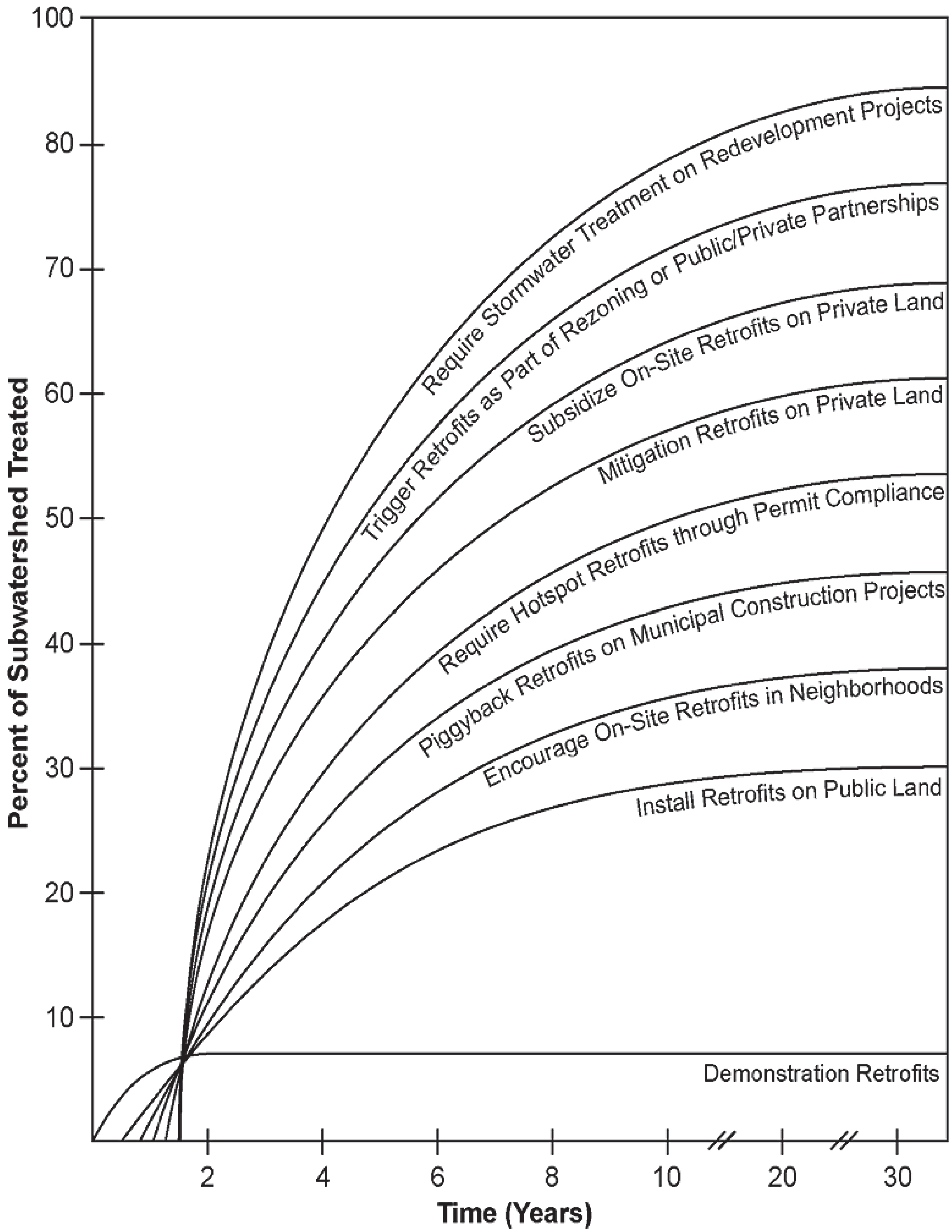


Figure 7.60. Ways to maximize retrofit delivery throughout the watershed
Source: CWP 2007

- ***Transform the Stormwater Maintenance Program.*** Use the local stormwater management maintenance inspection, tracking and enforcement authority to identify potential retrofits and/or significant opportunities to upgrade existing BMPs. This approach can result in identification of opportunities at both public and private stormwater management facilities.

- ***Streamline the Local Government Permitting and Contracting Process.*** Design, engineering, permitting and contracting costs can be 30% - 50% of the total cost of BMP retrofit installations. Project bundling, design/build contracts, call contracts, bid incentives and other project management tools can significantly reduce these costs and improve the quality of the resulting retrofits.

7.11. STRATEGIES TO DELIVER RETROFIT PROJECTS AT THE SUBWATERSHED LEVEL

Subwatershed retrofitting is a major long-term commitment where dozens or even hundreds of individual retrofit projects are built over a multi-year timeframe. As previously noted, retrofitting can be quite costly and is normally the single largest expense involved in watershed restoration. Given the large number of retrofit projects, their high cost and the long timeframe over which they are built, it is important to discuss the strategies on how retrofits can be delivered in a widespread manner.

This section describes a multi-pronged strategy to sustain public investment in retrofitting over many years. The strategy involves multiple ways to deliver retrofits on both public and private land. Many stormwater managers mistakenly believe that retrofitting primarily involves capital construction projects built on public land. Much greater subwatershed coverage, however, can be achieved by a creative combination of financing, education, subsidies, permit coordination and stormwater regulations. To some extent, the retrofit delivery methods are sequential in nature – the first methods are easier to implement early; whereas, latter methods provide expanded treatment in the future.

7.11.1. Demonstration Retrofits

Demonstration Retrofits are the usually the first retrofit delivery method. The best sites are located on public land that is highly visible or receives heavy foot traffic, such as community parks, greenway trails, local schools or the city hall. Severe municipal hotspots, such as public works yards, may also be good candidate sites. Demonstration retrofits are normally financed by state or federal water quality grants. Demonstration retrofits can be installed at any stage of the retrofit process, particularly when they can test a new or innovative retrofit technique.

Although demonstration retrofits serve only a small fraction of subwatershed area, they are an excellent early action project for several reasons. First, retrofits can educate residents about urban stream impacts and restoration potential through interpretive signs, tree planting and other stewardship measures. Second, demonstration retrofits show restoration partners and stakeholders what the retrofit "product" looks like, which helps to increase community acceptance for future projects. Third, demonstration projects enable local agency staff to gain valuable retrofit design and construction experience that can be used to deliver other retrofits later.

7.11.2. Retrofits on Public Land

The next retrofit delivery method involves construction of storage retrofit projects on public land in the subwatershed. These retrofits are typically located in stream valleys, parks, public right of way and publicly-owned stormwater infrastructure. Public land retrofits are easier to deliver because they do not require land acquisition and can provide community benefits. Storage retrofits are preferred because they can cost-effectively treat the greatest fraction of subwatershed area. Experience has shown that it is possible to treat as much as 30 to 50% of a subwatershed through public land retrofits, particularly if the community owns land in the stream corridor. **Appendix 7-A** provides a case study about the City of Charlottesville's program of retrofitting stormwater management practices on public lands.

Most public retrofits are financed by long-term capital construction budgets dedicated to retrofits or waterway improvements. Consequently, it may take a decade to construct all of the feasible public land retrofits. This phase of retrofit delivery also requires an agency commitment to efficiently manage construction of multiple retrofit projects over time. Another good retrofit strategy is to integrate retrofits into ongoing municipal stormwater maintenance programs, particularly if the facilities are located on public land. The capital budget for stormwater maintenance can be modified to allocate funds to retrofit older ponds to improve their performance at the same time major maintenance problems are being corrected.

7.11.3. Encourage On-site Retrofits in Neighborhoods

This phase of retrofit delivery educates homeowners to persuade them to install low cost on-site retrofits on their property, such as rooftop disconnections, rain barrels or rain gardens. The most effective campaigns educate the public about need to restore watersheds, provide some simple construction tips, and direct interested residents where they can get more specific information and technical assistance. Local governments may wish to hire local watershed groups to "retail" technical assistance directly to neighborhoods and community associations. While it is doubtful that more than 5% of subwatershed residents will install on-site retrofits though education alone (see CWP, 2005a), the relatively low cost of the education program and its outreach and awareness benefits make it a good delivery investment at the outset of the retrofitting process.

7.11.4. Bundle Retrofits into Municipal Construction Projects

The next method incorporates retrofit delivery into other municipal construction capital projects. Communities are constantly investing in streetscaping, transportation projects, school construction, park improvements, water and sewer line rehabilitation, drainage improvements and neighborhood revitalization. The strategy is to bundle retrofits into routine capital projects. In some cases, the match is relatively easy, e.g., including a storage retrofit as part of a culvert upgrade or installing water quality features into drainage improvements. Other bundled retrofits require much greater interagency education and coordination efforts since many agencies do not consider watershed restoration as part of their primary mission. The bundling strategy is definitely worth the effort since capital budgets for other municipal construction categories exceed water resource spending by a factor of 100 to 500 (U.S. Census, 2006). The largest municipal construction categories include schools, roads, water supply and wastewater treatment, parks and recreation and municipal building.

While some agencies may initially resist efforts to incorporate retrofits into their capital budgets, several recent trends may make it more appealing. First, many units of local government are now subject to municipal stormwater permits and are no longer exempt from treating the quality of the stormwater produced by their construction projects. Bundling retrofits into existing construction projects makes stormwater compliance easier. Second, municipal project managers are often subject to the same environmental permitting requirements as the private sector, and may find that constructing retrofits conveniently meets their off-site mitigation needs. Third, many communities have formally adopted policies to promote sustainable development and/or low impact design practices in their own municipal construction projects. Several progressive communities, such as Santa Monica, CA and Austin TX, have specified a minimum set-aside for construction of on-site stormwater retrofits in their municipal contracting process (CWP, 2006).

7.11.5. Require Hotspot Retrofits Through Permit Compliance

Stormwater hotspots deserve special attention when it comes to retrofit delivery, given their severe water quality impacts and unique regulatory status. The goal is to construct on-site retrofits to treat the quality of runoff from all severe stormwater hotspots in a subwatershed, using existing authority under industrial and/or municipal stormwater permits (see Retrofit Profile Sheet OS-7 in CWP, 2007a). The basic argument is that hotspot runoff violates water quality standards and warrants immediate treatment. Hotspot retrofits are identified based on two systematic levels of subwatershed field inspection – a Hotspot Site Investigation (HIS) to identify severe hotspots (CWP, 2005a) and a more intensive Hotspot Compliance Inspection (HCI) to determine whether a structural retrofit is needed to treat hotspot runoff at the site (CWP, 2005b). In this case, the cost of retrofitting is borne by the hotspot owner, although the locality may also incur costs to find them and enforce compliance.

Stormwater managers should carefully review their existing water quality or illicit discharge ordinances to determine if they actually possess the authority to inspect and enforce compliance over the full range of hotspot sites expected in a subwatershed. If not, local ordinances should be revised to provide for this manner of retrofit delivery. Since many hotspots are small businesses, communities should also consider non-regulatory tools to improve compliance, including employee training, technical assistance and even cost-sharing (CWP, 2005a).

7.11.6. Mitigation Retrofits on Public or Private Land

This method of retrofit delivery matches the mitigation needs of private and quasi-public entities to specific storage retrofits in the subwatershed. As might be imagined, this retrofit delivery method requires exceptional interagency communication and coordination. Developers, highway agencies, utilities and others often seek opportunities to meet offsite environmental mitigation needs (wetlands, water quality trading, stormwater fees or permit conditions). Existing projects in the subwatershed retrofit inventory can be extremely attractive to permit applicants since the feasibility of the projects is already established and they are located on public land.

Over time, stormwater managers should strive to integrate their retrofit program with any stormwater mitigation, water quality trading or wetland banking efforts that may exist in the community. Most water quality experts predict that water quality trading systems will be common in the future as a cost-effective way to meet TMDLs, wastewater permits or regional nutrient limits. Care should be exercised with mitigation retrofits since they have the potential to be a zero-sum gain, particularly when both the impact and the mitigation occur in the same subwatershed (i.e., the benefit of the mitigation is cancelled out by the impact from the mitigated project). Also, the retrofitting agency may be hesitant about inheriting costly monitoring or maintenance conditions specified in a mitigation permit.

7.11.7. Subsidize On-site Retrofits on Private Land

This retrofit delivery method involves targeted programs to subsidize landowners to install on-site retrofit practices on private land. Such programs go beyond mere education and normally include targeted direct technical assistance and economic incentives to make them happen. The cost of this retrofit delivery method may equal the cost of constructing several large storage retrofits, and may be financed either through grants, operating funds, or a line item in the capital budget.

About a dozen communities have subsidized on-site retrofit delivery at the neighborhood level, primarily to disconnect rooftop runoff from the combined sewer system. Neighborhood adoption rates as high as 15 to 50% have been reported, depending on the extent of the subsidy and the convenience of the retrofit (Profile Sheet OS-10 in Schueler, 2007). Economic incentives include direct cash subsidies, tax credits, discounts on water bills or stormwater utility fees, municipal installation, and provision of free rain barrels.

7.11.8. Trigger Retrofits as Part Public/Private Partnership

Local governments are often a major financial partner in redevelopment and rezoning projects designed to promote neighborhood or commercial revitalization. The community may subsidize development by granting payment in lieu of taxes, tax credits, low interest financing or parcel acquisition. Given the taxpayer investment in these development partnerships, the public should expect that these projects will incorporate sustainable stormwater practices and landscaping features to enhance their community benefit. Consequently, stormwater managers should maximize the use of on-site retrofits during urban design to make sure the final projects are compatible with the water quality goals of the subwatershed plan. These retrofit opportunities seldom appear in the retrofit inventory, so stormwater managers will need to frequently coordinate with local urban planners and economic development agencies to find the best targets of opportunity.

7.11.9. Require Stormwater Treatment for Redevelopment Projects

If a subwatershed still has considerable development potential, stormwater managers should make sure they are imposing the most stringent stormwater criteria possible so that increased pollutant loads generated by new development do not offset loads reduced through retrofitting. If existing stormwater quality criteria are outdated, stormwater managers should update local stormwater criteria to maximize pollutant removal performance.

The infill and redevelopment process provides an excellent opportunity to achieve stormwater treatment where it previously did not exist. The amount of subwatershed treatment that can be achieved by imposing redevelopment stormwater criteria is impressive over the long run. The urban landscape is in constant flux, with sites being continually vacated, demolished and redeveloped all the time. The same is true with public infrastructure. The design or service life of most structures and infrastructure is measured in decades, e.g., buildings (50 to 60 years), parking lots (20 to 30 yrs), bridge decks (40 to 50 yrs) and drainage infrastructure (30 to 50 yrs).

Thus, over several decades, it is quite likely that a sizeable fraction of every subwatershed will undergo redevelopment, infill, or infrastructure rehabilitation. Each of these represents an opportunity to retrofit stormwater treatment into the urban landscape. Therefore, an effective retrofit delivery strategy requires redevelopment and infill projects to address stormwater treatment in some manner. Guidance on developing effective and flexible stormwater treatment criteria for redevelopment projects can be found in CWP (2007b).

Most communities are reluctant to impose more stringent stormwater criteria because of the small size, sharply higher compliance costs, and physical constraints facing redevelopment projects. While on-site compliance is difficult, it does not imply that stormwater treatment criteria should be waived. Rather, it means that special stormwater criteria need to be developed for redevelopment projects that provide incentives to reduce impervious cover, increase forest cover, or promote the use of smart site practices during redevelopment (CWP, 2004a). Local stormwater managers may want to consider a fee-in-lieu approach at redevelopment and infill sites. The basic concept is to waive on-site stormwater requirements in exchange for a fee that is used by the local stormwater authority to build retrofit storage elsewhere in the subwatershed. The fee is usually derived based on the cost to retrofit an equivalent acre of impervious cover using a more economical storage retrofit. In other cases, the fee-in-lieu is based on the average cost to remove a pound of nutrients. Several communities have adopted a fee-in-lieu as an equitable and cost-effective way to treat runoff from small urban sites. Guidance on setting an appropriate fee schedule can be found in Winer (2003).

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