Pennsylvania Stormwater Best Management Practices Manual

Chapter 5

Non-Structural BMPs

363-0300-002 / December 30, 2006

Chapter 5 Non-Structural BMPs

Chapter 5 Comprehensive Stormwater Management: Non-Structural BMPs

5.1 Introduction

The terms "Low Impact Development" and "Conservation Design" refer to an environmentally sensitive approach to site development and stormwater management that minimizes the effect of development on water, land and air. This chapter emphasizes the integration of site design and planning techniques that preserve natural systems and hydrologic functions on a site through the use of Non-Structural BMPs. Non-Structural BMP deployment is not a singular, prescriptive design standard but a combination of practices that can result in a variety of environmental and financial benefits. Reliance on Non-Structural BMPs encourages the treatment, infiltration, evaporation, and transpiration of precipitation close to where it falls while helping to maintain a more natural and functional landscape. The BMPs described in this chapter preserve open space and working lands, protect natural systems, and incorporate existing site features such as wetlands and stream corridors to manage stormwater at its source. Some BMPs also focus on clustering and concentrating development, minimizing disturbed areas, and reducing the size of impervious areas. Appropriate use of Non-Structural BMPs will reflect the ten "Principles" presented in the Foreword to this manual, and will be an outcome of applying the procedures described in Chapter 4.

From a developer's perspective, these practices can reduce land clearing and grading costs, reduce infrastructure costs, reduce stormwater management costs, and increase community marketability and property values. Blending these BMPs into development plans can contribute to desirability of a community, environmental health and quality of life for its residents. Longer term, they sustain their stormwater management capacity with reduced operation and maintenance demands.

Conventional land development frequently results in extensive site clearing, where existing vegetation is destroyed, and the existing soil is disturbed, manipulated, and compacted. All of this activity significantly affects stormwater quantity and quality. These conventional land development practices often fail to recognize that the natural vegetative cover, the soil mantle, and the topographic form of the land are integral parts of the water resources system that need to be conserved and kept in balance, even as land development continues to occur.

As described in Chapter 4, identifying a site's natural resources and evaluating their values and functional importance is the first step in addressing the impact of stormwater generated from land development. Where they already exist on a proposed development site, these natural resources should be conserved and utilized as a part of the stormwater management solution. The term "green infrastructure" is often used to characterize the role of these natural system elements in preventing stormwater generation, infiltrating stormwater once it's created, and then conveying and removing pollutants from stormwater flows. Many vegetation and soil-based structural BMPs are in fact "natural structures" that perform the functions of more "structural" systems (e.g., porous pavement with recharge beds). Because some of these "natural structures" can be designed and engineered, they are discussed in Chapter 6 as structural BMPs.

5.2 Non-Structural Best Management Practices

This Manual differentiates BMPs based on Non-Structural (Chapter 5) and Structural (Chapter 6) designations. Non-Structural BMPs take the form of broader planning and design approaches – even principles and policies – which are less "structural" in their form, although non-structural BMPs do have very important physical ramifications. An excellent example would be “reducing imperviousness” (see BMPs 5.9 and 5.10 below) by reducing road width and/or reducing parking ratios. In this way, a proposed building program can be accommodated but with reduced stormwater generation. These non-structural BMPs can be applied over an entire site and are not fixed and designed at one location. Virtually all of the Non-Structural BMPs set forth in this Chapter of the manual share this kind of site-wide policy characteristic. Structural BMPs, on the other hand, are decidedly more locationally specific and explicit in their physical form.

Sometimes called Low Impact Development or Conservation Design techniques, Non-Structural BMPs are not always markedly different from Structural BMPs. In fact, some of the BMPs described in Chapter 6, such as Vegetated Swales and Vegetated Filter Strips, are largely based in natural systems and are intended to function as they would have prior to disturbance. Nevertheless, such BMPs can be thought of as natural structures, which are designed to mitigate any number of stormwater impacts: peak rates, total runoff volumes, infiltration and recharge volumes, non-point source water quality loadings and temperature increases.

Perhaps the most defining distinction for the Non-Structural BMPs set forth in this chapter is their ability to prevent stormwater generation and not just mitigate stormwater-related impacts once these problems have been generated. Prevention can be achieved by developing land in ways other than through use of standard or conventional development practices. Prevention and Non-Structural BMPs go hand in hand and can be contrasted with Structural BMPs that provide mitigation of those stormwater impacts, which cannot be prevented and/or avoided.

Several major “areas” of preventive Non-Structural BMPs have been identified in this manual:

Protect Sensitive and Special Value Features
Cluster and Concentrate
Minimize Disturbance and Minimize Maintenance
Reduce Impervious Cover
Disconnect/Distribute/Decentralize
Source Control

More specific Non-Structural BMPs have been identified for each of these generalized areas to better define and improve implementation of each of these areas. This list of specific BMPs will be refined and expanded as these stormwater management practices become more common throughout Pennsylvania.

A uniform format has been developed for the BMPs presented in Chapters 5 and 6 of this manual. It provides as many engineering details as possible, facilitated through diagrams, graphics and pictures. There are constant tradeoffs that must be made between providing a more complete explanation for the countless variations which can be expected to emerge across the state versus the need to be concise and user friendly.
The uniform format has been applied to all of the Non-Structural BMPs included in Chapter 5, to encourage recognition that these Non-Structural techniques are every bit as essential as the techniques presented in Chapter 6 Structural BMPs.

One of the most challenging technical issues considered in this manual involves the selection of BMPs that have a high degree of NPS reduction or removal efficiency. In the ideal, a BMP should be selected that has a proven NPS pollutant removal efficiency for all pollutants of importance, especially those that are critical in a specific watershed (as defined by a TMDL or other process). Both Non-Structural BMPs in Chapter 5 and Structural BMPs in Chapter 6 are rated in terms of their anticipated pollutant removal performance or effectiveness. The initial BMP selection process analyzes the final site plan and estimates the potential NPS load, using Appendix A. The targeted reduction percentage for representative pollutants (such as 85% reduction in TSS and TP load and 50% reduction in the solute load) is achieved by a suitable combination of Non-Structural and Structural BMPs. This process is described in more detail in Chapter 8.

5.3 Non-Structural BMPs and Stormwater Methodological Issues

The methodological approach set forth in Chapter 8 provides a variety of straightforward and conservative ways to take credit for applying Non-Structural BMPs, provided that the "specifications" defined for each BMP in Chapter 5 are properly followed.

Because so many of the Non-Structural BMPs seem so removed from the conventional practice of stormwater engineering, putting these BMPs into play may be a challenge. Many of these Non-Structural BMPs ultimately require a more sophisticated approach to total site design. Some of the Non-Structural BMPs don't easily lend themselves to stormwater calculations as conventionally performed. How do we get stormwater credit for applying any of these techniques? Taking BMPs 5.6.1 and 5.6.2 again as examples, minimizing impervious cover by reducing road width or impervious parking area directly translates into reduced stormwater volumes and reduced stormwater rates of runoff. Site planners and designers will also recognize that many of the other Non-Structural BMPs, such as clustering of uses, conserving existing woodlands and other vegetative cover, and disconnecting impervious area runoff flows, all translate into reduced stormwater volume and rate calculations. As such, these BMPs are self-crediting.

5.4 Protect Sensitive and Special Value Resources

BMP 5.4.1: Protect Sensitive and Special Value Features

To minimize stormwater impacts, land development should avoid affecting and encroaching upon areas with important natural stormwater functional values (floodplains, wetlands, riparian areas, drainageways, others) and with stormwater impact sensitivities (steep slopes, adjoining properties, others) wherever practicable. This avoidance should occur site-by-site and on an area wide basis. Development should not occur in areas where sensitive/special value resources exist so that their valuable natural functions are not lost, thereby doubling or tripling stormwater impacts. Resources may be weighted according to their functional values specific to their municipality and watershed context.

Key Design Elements	Potential Applications
▪ Identify and map floodplains and riparian area ▪ Identify and map wetlands ▪ Identify and map woodlands ▪ Identify and map natural flow pathways/drainage ways ▪ Identify and map steep slopes ▪ Identify and map other sensitive resources ▪ Combine for Sensitive Resources Map (including all of the above) ▪ Distinguish between including Highest Priority Avoidance Areas and Avoidance Areas ▪ Identify and Map Potential Development Areas (all those areas not identified on the Sensitive Resources Map) ▪ Make the development program and overall site plan conform to the Development Areas Map to the maximum; minimize encroachment on Sensitive Resources.	Residential: Commercial: Ultra Yes Yes Urban: Industrial: Yes Yes Retrofit: Yes Yes Highway/Road: **Stormwater Functions** Volume Reduction: Very High Recharge: Very High Peak Rate Control: Very High Water Quality: Very High **Water Quality Functions** TSS: Preventive TP: Preventive NO3: Preventive

Description

A major objective for stormwater-sensitive site planning and design is to avoid encroachment upon, disturbance of, and alteration to those natural features which provide valuable stormwater functions (floodplains, wetlands, natural flow pathways/drainage ways) or with stormwater impact sensitivity (steep slopes, historic and natural resources, adjoining properties, etc.) Sensitive Resources also include those resources of special value (e.g., designated habitat of threatened and endangered species that are known to exist and have been identified through the Pennsylvania Natural Diversity Inventory or PNDI). The objective of this BMP is to avoid harming Sensitive/Special Value Resources by carefully identifying and mapping these resources from the initiation of the site planning process and striving to protect them while defining areas free of these sensitivities and special values (Potential Development Areas). BMP 5.4.2 Protect/Conserve/Enhance Riparian Areas and BMP 5.6.2 Minimize Soil Compaction in Disturbed Areas build on recommendations included in this BMP.

Variations

- BMP 5.4.1 calls for actions both on the parts of the municipality as well as the individual landowner and/or developer. Pennsylvania municipalities may adopt subdivision/land development ordinances which require that the above steps be integrated into their respective land development processes. A variety of models are available for municipalities to facilitate this adoption process, such as through the PADCNR *Growing Greener* program.

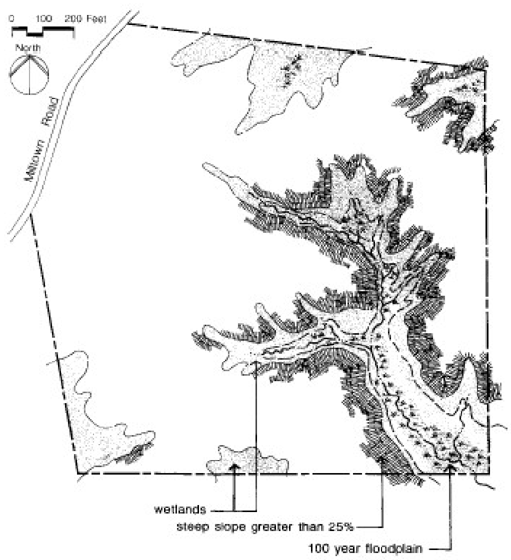


Figure 5.1-1. Growing Greener's Conservation Subdivision Design: Step One, Part One – Identify primary conservation areas.

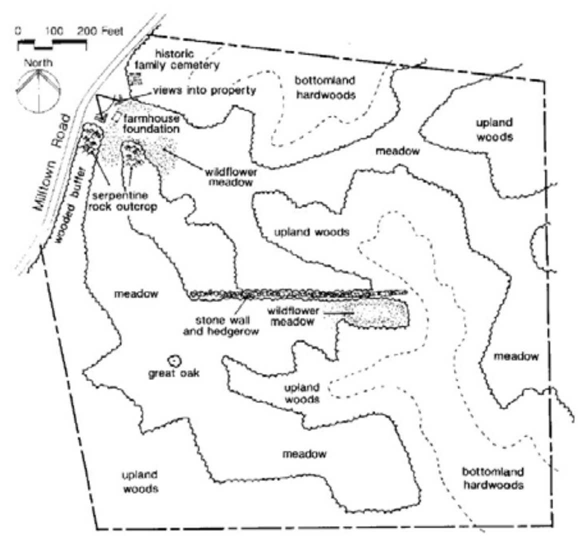


Figure 5.1-2. Growing Greener's Conservation Subdivision Design: Step One, Part Two – Identify secondary conservation areas.

Source: Growing Greener: Putting Conservation Into Local Codes; Natural Land Trusts, Inc. 1997

- The above steps use the *Growing Greener* Primary Conservation Areas and Secondary Conservation Areas designations and groupings. Identify and map the essential natural resources, including those having special functional value and sensitivity from a stormwater perspective, and then avoid developing (destroying, reducing, encroaching upon, and/or impacting) these areas during the land development process. Additionally, it is possible that Primary and Secondary can be defined in different ways so as to include different resources.

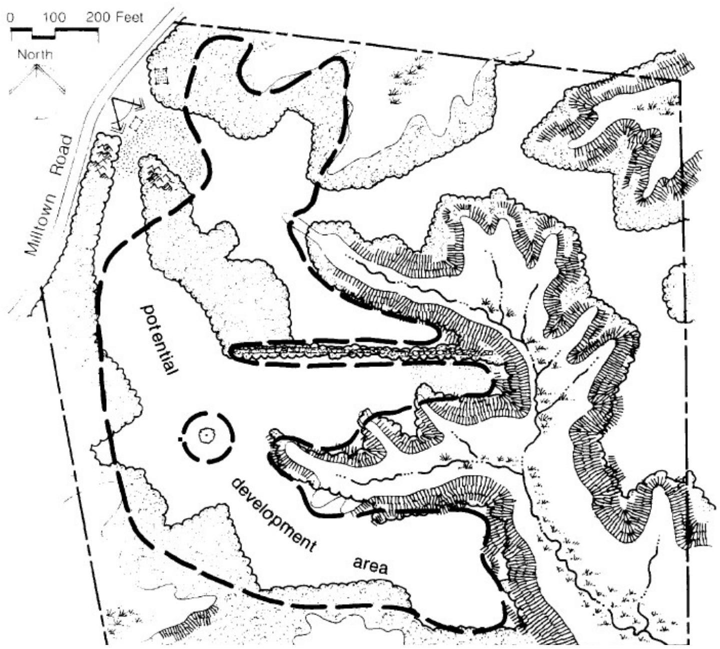


Figure 5.1-3. Growing Greener's Conservation Subdivision Design: Step One, Part Three – potential development areas.

Source: Growing Greener: Putting Conservation Into Local Codes; Natural Land Trusts, Inc. 1997

- Definition of the natural resources themselves can be varied. The definition of Riparian Buffer Area varies. Woodlands may be defined in several ways, possibly based on previous delineation/definition by the municipality or by another public agency. It is important to note here that Wooded Areas, which may not rank well in terms of conventional woodland definitions, maintain important stormwater management functions and should be included in the delineation/definition. Intermittent streams/swales/natural flow pathways are especially given to variability. Municipalities may not only integrate the above steps within their subdivision/land development ordinances, but also define these natural resource values as carefully as possible in order to minimize uncertainty.

- The level of rigor granted to Priority Avoidance and Avoidance Areas may be made to vary in a regulatory manner by the municipality and functionally by the owner and/or developer. A municipal ordinance may prohibit and/or otherwise restrict development in Priority Avoidance Areas and even Avoidance Areas. All else being equal, the larger the site, the more restrictive these requirements may be.

Applications

A number of communities across Pennsylvania have adopted ordinances that require natural resources to be identified, mapped, and taken into account in a multi-step process similar to the Growing Greener program. These include:

BUCKS COUNTY
Milford Township SLDO (Sep. 2002)

CHESTER COUNTY
London Britain Township (1999)
London Grove Township (2001)
Newlin Township (1999)
North Coventry Township (Dec. 2002)
Wallace Township (1994)
West Vincent Township (1998)

MONTGOMERY COUNTY
Upper Salford Township (1999)

MONROE COUNTY
Chestnuthill Township (2003)
Stroud Township SLDO (2003)

YORK COUNTY
Carroll Township (2003)

Figure 5.1-4. Steep slope development with woodland removal

BMP 5.4.1 applies to all types of development in all types of municipalities across Pennsylvania, although variations as discussed above allow for tailoring according to different development density/intensity contexts.

Design Considerations

Not applicable.

Detailed Stormwater Functions

Impervious cover and altered pervious covers translate into water quantity and water quality impacts as discussed in Chapter 2 of this manual. Additional impervious area may further eliminate or in some way reduce other natural resources that were having especially beneficial functions.

Water quality concerns include all stormwater pollutant loads from impervious areas, as well as all pollutant loads from the newly created maintained landscape (i.e., lawns and other). Much of this load is soluble in form (especially fertilizer-linked nitrogen forms). Clustering as defined here, and combined with other Chapter 5 Non-Structural BMPs, minimizes impervious areas and the pollutant loads related to these impervious areas. After Chapter 5 BMPs are optimized, “unavoidable” stormwater is then directed into BMPs as set forth in Chapter 5, to be properly treated. Similarly, for all stormwater pollutant load generated from the newly-created maintained landscape, clustering as defined here, and combined with other Chapter 5 Non-Structural BMPs, minimizes pervious areas and the pollutant loads related to these pervious areas, thereby reducing the opportunity for fertilization and other chemical application. Water quality prevention accomplished through Non-Structural BMPs in Chapter 5 is especially important because Chapter 6 Structural BMPs remain poor performers in terms of mitigating/removing soluble pollutants that are especially problematic in terms of this pervious maintained landscape. See Appendix A for additional documentation of the water quality benefits of clustering.

See Chapter 8 for additional volume reduction calculation work sheets, additional peak rate reduction calculation work sheets, and additional water quality mitigation work sheets.

Construction Issues

Clearly, application of this BMP is required from the start of the site planning and development process. In fact, not only must the site developer embrace BMP 5.4.1 from the start of the process, the BMP assumes that the respective municipal officials have worked to include clustering in municipal codes and ordinances, as is the case with so many of these Chapter 5 Non-Structural BMPs.

Figure 5.1-5. Example of steep slope development.

Maintenance Issues

As with all Chapter 5 Non-Structural BMPs, maintenance issues are of a different nature and extent, when contrasted with the more specific Chapter 6 Structural BMPs. Typically, the designated open space may be conveyed to the municipality, although most municipalities prefer not to receive these open space portions, including all of the maintenance and other legal responsibilities associated with open space ownership. In the ideal, open space reserves ultimately will merge to form a unified open space system, integrating important conservation areas throughout the municipality. These open space segments may exist dispersed and unconnected. For those Pennsylvania municipalities that allow for and enable creation of homeowners associations or HOA's, the HOA may assume ownership of the open space. The HOA is usually the simplest solution to the issue.

In contrast to some of the other long-term maintenance responsibilities of a new subdivision and/or land development (such as maintenance of streets, water and sewers, play and recreation areas, and so forth), the maintenance requirements of "undisturbed open space" by definition should be minimal. The objective is conservation of the natural systems, including the natural or native vegetation, with little intervention and disturbance. Nevertheless, some legal responsibilities must be assumed and need to be covered.

Cost Issues

Clustering is beneficial from a cost perspective in several ways. Development costs are decreased because of less land clearing and grading, less road construction (including curbing), less sidewalk construction, less lighting and street landscaping, potentially less sewer and water line construction, potentially less stormwater collection system construction, and other economies.

Clustering also reduces post construction costs. A variety of studies from the landmark *Costs of Sprawl* study and later updates have shown that delivery of a variety of municipal services such as street maintenance, sewer and water services, and trash collection are more economical on a per person or per house basis when development is clustered. Even services such as police protection are made more efficient when residential development is clustered.

Additionally, clustering has been shown to positively affect land values. Analyses of market prices of conventional development over time in contrast with comparable cluster developments (where size, type, and quality of the house itself is held constant) have indicated that clustered developments with their proximity to permanently protected open space increase in value at a more rapid rate than conventionally designed developments, even though clustered housing occurs on considerably smaller lots than the conventional residences.

Figure 5.1-6. Woodland removal for steep slope development with retaining walls

Specifications

Clustering is not a new concept and has been defined, discussed, and evaluated in many different texts, reports, references and sources detailed in the References for BMP 5.5.1

BMP 5.4.2: Protect /Conserve/Enhance Riparian Areas

The Executive Council of the Chesapeake Bay Program defines a Riparian Forest Buffer as "an area of trees, usually accompanied by shrubs and other vegetation, that is adjacent to a body of water and which is managed to maintain the integrity of stream channels and shorelines, to reduce the impact of upland sources of pollution by trapping, filtering and converting sediments, nutrients, and other chemicals, and to supply food, cover, and thermal protection to fish and other wildlife."

Key Design Elements

- Linear in Nature
- Provide a transition between aquatic and upland environments
- Forested under natural conditions in Pennsylvania
- Serve to create a "Buffer" between development and aquatic environment
- Help to maintain the hydrologic, hydraulic, and ecological integrity of the stream channel.
- Comprised of three "zones" of different dimensions:
  - **Zone 1**: Adjacent to the stream and heavily vegetated under ideal conditions (Undisturbed Forest) to shade stream and provide aquatic food sources.
  - **Zone 2**: Landward of Zone 1 and varying in width, provides extensive water quality improvement. Considered the Managed Forest.
  - **Zone 3**: Landward of Zone 2, and may include BMPs such as Filter Strips.

Potential Applications

Residential:
Commercial: Ultra Yes Yes
Urban: Industrial: Yes Yes
Retrofit: Yes Yes
Highway/Road:

Stormwater Functions

Volume Reduction: Medium
Recharge: Medium
Peak Rate Control: Low/Med.
Water Quality: Very High

Water Quality Functions

TSS: Preventive
TP: Preventive
NO3: Preventive

There are two components to Riparian Buffers to be considered in the development process:

1. Protecting, maintaining, and enhancing existing Riparian Forest Buffers.
2. Restoring Riparian Forest Buffers that have been eliminated or degraded by past practices.

BMP 5.4.2 focuses on protection, maintenance, and enhancement of existing Riparian Forest Buffers. Restoration of Riparian Forest Buffers is treated in Chapter 6 as a Structural BMP.

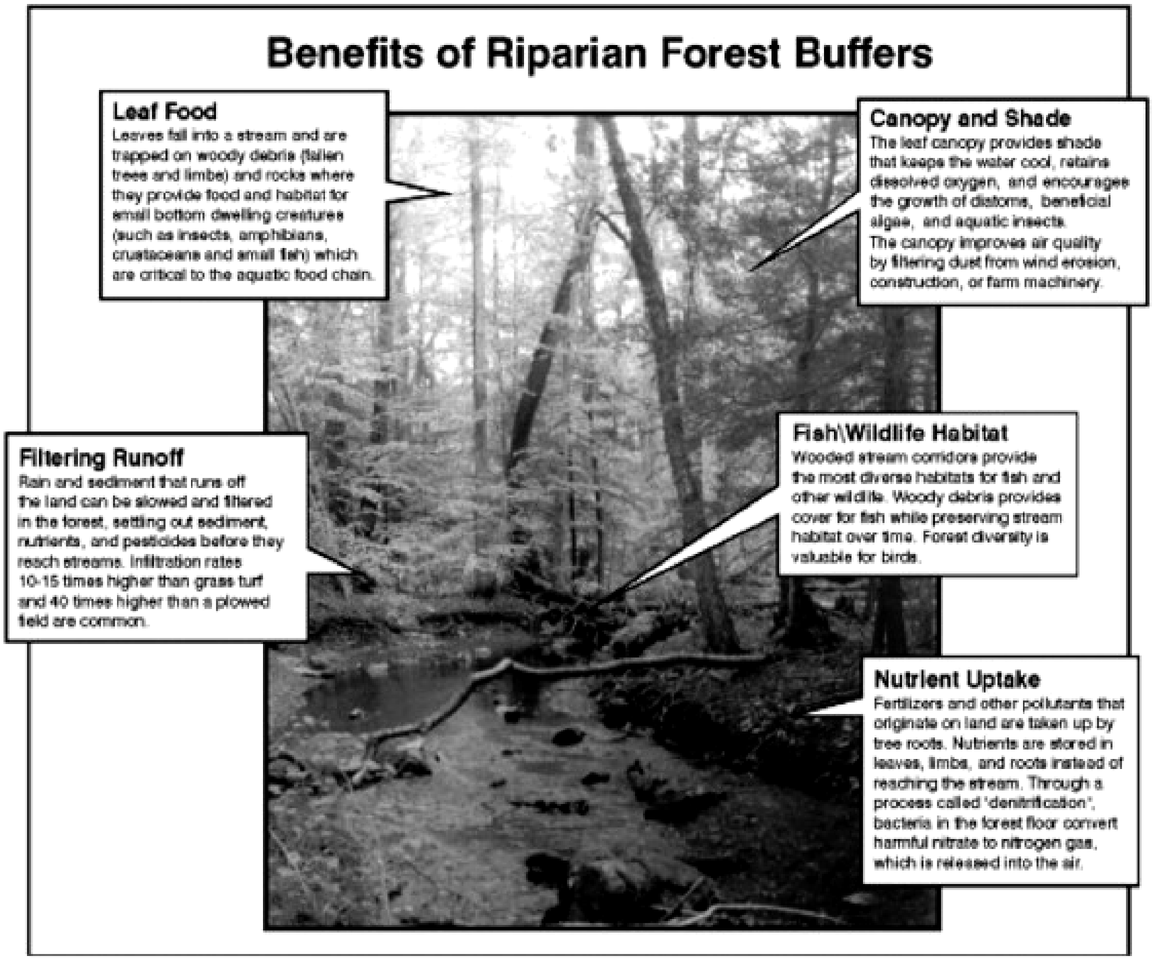


Figure 5.2-1. Riparian buffer zones support various ecological functions.

Detailed Stormwater Functions

Riparian Corridors are vegetated ecosystems along a waterbody that serve to buffer the waterbody from the effects of runoff by providing water quality filtering, bank stability, recharge, rate attenuation and volume reduction, and shading of the waterbody by vegetation. Riparian corridors also provide habitat and may include streambanks, wetlands, floodplains, and transitional areas. Functions can be identified and sorted more specifically by Zone designation:

Zone 1: Provides stream bank and channel stabilization; reduces soil loss and sedimentation/nutrient and other pollution from adjacent upslope sheet flow; roots, fallen logs, and other vegetative debris slow stream flow velocity, creating pools and habitat for macroinvertebrates, in turn enhancing biodiversity; decaying debris provides additional food source for stream-dwelling organisms; tree canopy shades and cools water temperature, critical to sustaining certain macroinvertebrates, as well as critical diatoms, which are essential to support high quality species/cold water species. Zone 1 functions are essential throughout the stream system, especially in 1st order streams.

Zone 2: Removes, transforms, and stores nutrients, sediments, and other pollutants flowing as sheet flow as well as shallow sub-surface flow. A healthy Zone 2 has the potential to remove substantial quantities of excess nitrates through root zone uptake. Nitrates customarily can be significantly elevated when adjacent land uses are agricultural or urban/suburban. Healthy vegetation in Zone 2 slows surface runoff while filtering sediment and particulate bound phosphorus. Total nutrient removal is facilitated through a variety of complex processes: long-term nutrient storage through microbe uptake, denitrification through bacterial conversion to nitrogen gases and additional microbial degradation processes.

Zone 3: Provides the first stage in managing upslope runoff so that runoff flows are slowed and evenly dispersed into Zone 2. Some physical filtering of pollutants may be accomplished in Zone 3 as well as some limited amount of infiltration.

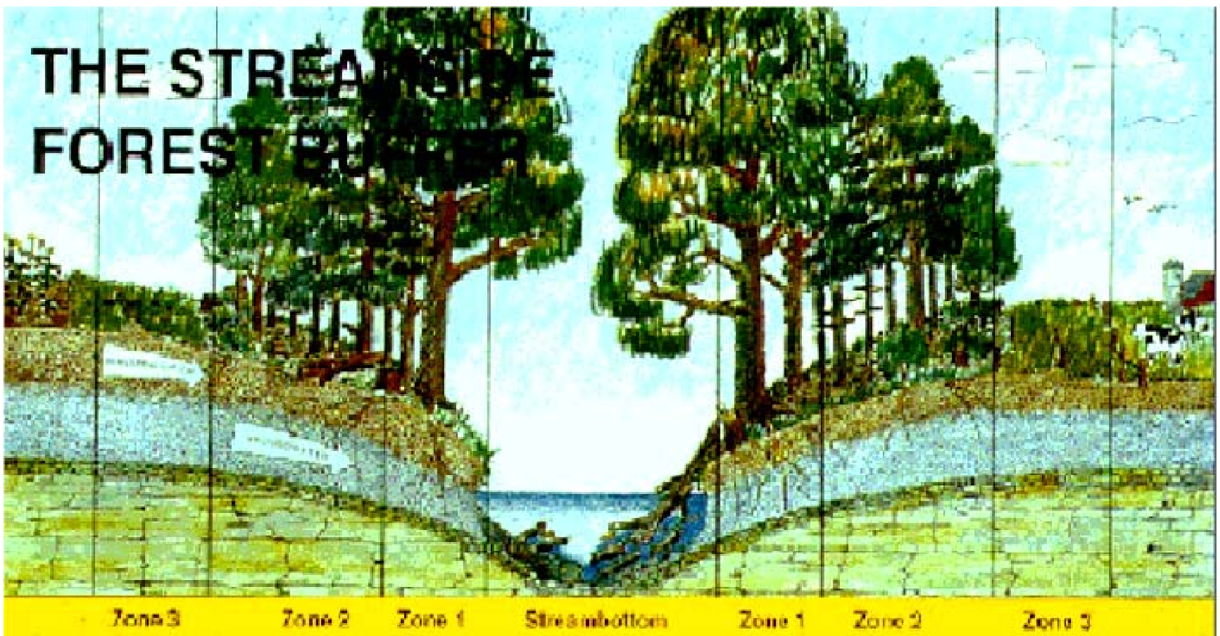


Figure 5.2-2. Riparian buffer zones (DJ Welsh, 1991).

Design Considerations/Variations

Although this manual refers frequently to the Chesapeake Bay Program's Riparian Handbook, many different sources of guidance have been developed in recent years. Not all of these are exactly comparable in terms of their recommendations and specifications. To some extent these variations relate to different land use development contexts.

Riparian Forest Buffer Zone widths should be adjusted according to site conditions and type of upslope development. Variation in standards (see Specifications below) should vary with the function to be performed by the forested buffer. In undisturbed forested areas where minimal runoff is expected to be occurring, standards can be made more flexible than in agricultural contexts where large quantities of natural vegetation have been removed and significant quantities of runoff are expected. In addition to factors related to technical need, practical and political factors also must be considered. In urbanized settings where hundreds, if not thousands of small lots may abut riparian areas and already intrude into potential forested buffer zones, buffer standards must be practicable.

Lastly, confusion has emerged between the concept of floodplain and riparian forest buffer. In many cases, mapped and delineated floodplain may overlap and even largely coincide with riparian forest buffer zones. On the other hand, mapped 100-year floodway/floodplain may not coincide with the forest buffer due to either very steep topography or very moderate slopes. A second important clarification is that floodplain ordinances typically manage use to prevent flood damage, which contrasts to riparian forest buffer regulation which manages clearing and grading actions in the zones, specifically for environmental reasons.

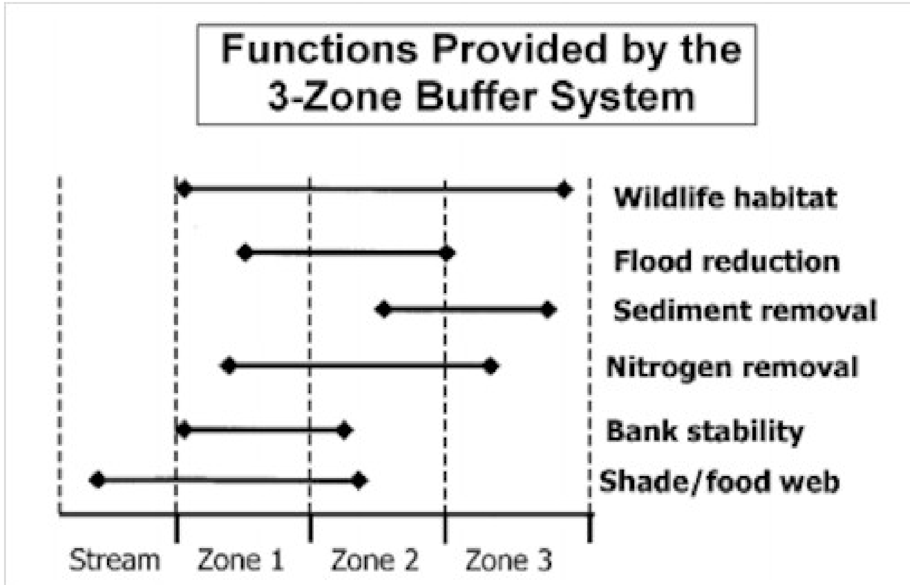


Figure 5.2-3. Riparian buffer zone functions.

Construction Issues

Riparian Forest Buffer Protection should be defined and included in municipal ordinances, including both the zoning ordinance and subdivision and land development ordinance (SALDO). The Riparian Forest Buffer should be defined and treated from the initial stages of the land development process, similar to floodplain, wetland or any other primary conservation value. It is the municipality's responsibility to determine a fair and effective riparian forest buffer program, balancing the full range of water resource and watershed objectives along with other land use objectives. A fair and effective program should evolve for all municipal landowners and stakeholders. State-supported River Conservation Plans, Act 167 Stormwater Management Plans, and other planning may contribute to this effort.

Whether a respective municipality has included riparian forest buffers in its ordinances or not, landowners/developers/applicants should include riparian forest buffers in their site plans from the initiation of the site planning process. If standards and guidelines have been set forth by the municipality or by other relevant planning group, these standards and guidelines should be followed. If none of these exist, standards recommended in this manual should be followed.

The ease of accommodating a riparian forest buffer can be expected to vary based on intensity of land use, zoning at the site and size of the parcel. Holding all other factors constant, as site size decreases, the challenges posed by riparian zone accommodation can be expected to increase. As sites become extremely small, reservation of site area for riparian forest buffer may become problematic, thereby requiring riparian forest buffer modification in order to accommodate a reasonable building program for the site. Zoned land use intensity is another factor to be considered. As this intensity increases and specifications for maximum building area and impervious area and total disturbed area are allowed to grow larger, reserving site area for the riparian forest buffer becomes more challenging. Riparian forest buffer programs need to be sensitive to these constraints.

All of these factors should be reviewed and integrated by the municipality as the riparian forest buffer program is being developed.

Cost Issues

Costs of riparian forest buffer establishment are not significant, defined in terms of direct development. In these cases, costs can be reasonably defined as the lost opportunity costs of not being able to use acreage reserved for the riparian forest buffer in the otherwise likely land use. A likely land use might be defined in terms of zoned land use. Depending upon the zoning category provisions and the degree to which a riparian forest buffer's Zone 1 or Zone 2 or Zone 3 might be able to be included as part of a land development plan or as part of yard provisions for lots in a residential subdivision acreage included within the riparian forest buffer may or may not be able to be included as part of the development. If riparian acreage must be totally subtracted, then it's fair value should be assessed as a cost. If riparian forest buffers can be credited as part of yards (though still protected), then that acreage should not be considered to be a cost. Any one-time capital cost can be viewed alternatively as an annualized cost.

To the extent that the riparian forest buffer coincides with the mapped and regulated floodplain, where homes and other structures and improvements should not be located, then attributing any lost opportunity costs exclusively to riparian forest buffers is not reasonable. The position can be argued that any riparian forest buffer area, which is included within floodplain limits, should not be double-counted as a riparian forest buffer cost. Alternatively, any riparian forest buffer area that extends beyond the floodplain could be assigned a cost.

Lost opportunity costs can be expected to vary depending upon land use. Alternative layouts, including reduced lot size configurations, may be able to provide the same or close to the same number of units and the same level of profitability.

Over the long-term, some modest costs are required for periodic inspection of the riparian forest buffer plus modest levels of maintenance. Generally, the buffers require very little in the way of operating and maintenance costs.

If objective cost-benefit analysis were to be undertaken on most riparian forest buffers, results would be quite positive, demonstrating that the full range of environmental and non-environmental benefits substantially exceeds costs involved. Protection of already existing vegetated areas located adjacent to streams, rivers, lakes, and other waterways is of tremendous importance, given their rich array of functional benefits.

Stormwater Management Calculations

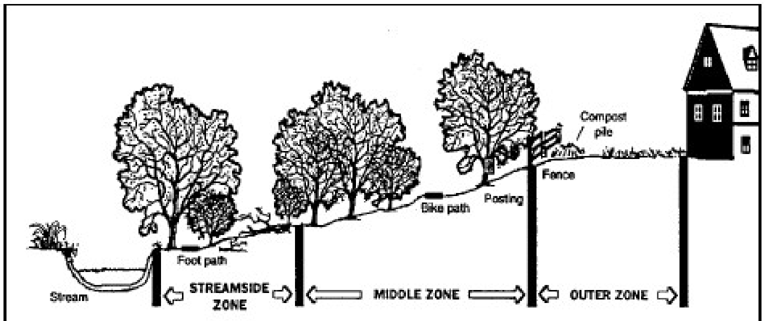
Stormwater calculations in most cases for Volume Control and Recharge and Peak Rate will not be affected dramatically. See Chapter 8 for more discussion relating to Water Quality.

Specifications

The Chesapeake Bay Program's Riparian Handbook provides an in-depth discussion of establishing the proper riparian forest buffer width, taking into consideration:

1. existing or potential value of the resource to be protected,
2. site, watershed, and buffer characteristics,
3. intensity of adjacent land use, and
4. specific water quality and/or habitat functions desired. (Handbook, p. 6-1)

At the core of the scientific basis for riparian forest buffer establishment are a variety of site-specific factors, including: watershed condition, slope, stream order, soil depth and erodibility, hydrology, floodplains, wetlands, streambanks, vegetation type, and stormwater system, all of which are discussed in the Handbook. Positively, this body of scientific literature has expanded tremendously in recent years and provides excellent support for effective buffer management. The downside is that this scientific literature now exceeds quick and easy summary. Fortunately, this Handbook and many additional related references are available online without cost (given the comprehensiveness of the Handbook itself, it is recommended that the reader start here).



CHARACTERISTICS	STREAMSIDE ZONE	MIDDLE ZONE	OUTER ZONE
FUNCTION	Protect the physical integrity of the stream ecosystem	Provide distance between upland development and streamside zone	Prevent encroachment and filter backyard runoff
WIDTH	Min. 25 feet, plus wetlands and critical habitats	50 to 100 feet, depending on stream order, slope, and 100 year floodplain	25 foot minimum setback to structures
VEGETATIVE TARGET	Undisturbed mature forest. Reforest if grass	Managed forest, some clearing allowable	Forest encouraged, but usually turfgrass
ALLOWABLE USES	*Very Restricted* e.g., flood control, utility right of ways, footpaths, etc.	*Restricted* e.g., some recreational uses, some stormwater BMPs, bike paths, tree removal by permit	*Unrestricted* e.g., residential uses including lawn, garden, compost, yard wastes, most stormwater BMPs

Figure 5.2-4. Three zone urban buffer system (Schueler, 1995 and Metropolitan COG, 1995).

Zone 1: Also termed the "streamside zone," this zone "…protects the physical and ecological integrity of the stream ecosystem. The vegetative target is mature riparian forest that can provide shade, leaf litter, woody debris, and erosion protection to the stream. The minimum width is 25 feet from each streambank (approximately the distance of one or two mature trees from the streambank), and land use is highly restricted…." (Handbook, p. 11-8)

Zone 2: Also termed the "middle zone," this zone"…extends from the outward boundary of the streamside zone and varies in width depending on stream order, the extent of the 100-year flood plain, adjacent steep slopes, and protected wetland areas. The middle zone protects key components of the stream and provides further distance between upland development and the stream. The minimum width of the middle core is approximately 50 feet, but it is often expanded based on stream order, slope of the presence of critical habitats, and the impact of recreational or utility uses. The vegetative target for this zone is also mature forest, but some clearing is permitted for stormwater management Best Management Practices (BMPs), site access, and passive recreational uses…." (Handbook, p. 11-8)

Zone 3: Also termed the "outer zone," this zone "…is the 'buffer's buffer.' It is an additional 25-foot setback from the outward edge of the middle zone to the nearest permanent structure. In many urban situations, this area is a residential backyard. The vegetative character of the outer zone is usually turf or lawn, although the property owner is encouraged to plant trees and shrubs to increase the total width of the buffer… The only significant restrictions include septic systems and new permanent structures." (Handbook, p. 11-9)

The Handbook also provides more detailed specifications for riparian forest buffers (Appendix 1), as developed by the USDA's Forest Service.

BMP 5.4.3: Protect/Utilize Natural Flow Pathways in Overall Stormwater Planning and Design

Identify, protect, and utilize the site's natural drainage features as part of the stormwater management system.

Key Design Elements

- Identify and map natural drainage features (swales, channels, ephemeral streams, depressions, etc.)
- Use natural drainage features to guide site design
- Minimize filling, clearing, or other disturbance of drainage features
- Utilize drainage features instead of engineered systems whenever possible
- Distribute non-erosive surface flow to natural drainage features
- Keep non-erosive channel flow within drainage pathways
- Plant native vegetative buffers around drainage features

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: No
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low
Peak Rate Control: Med./High
Water Quality: Medium

Water Quality Functions

TSS: 30%
TP: 20%
NO3: 0%

Description

Most natural sites have identifiable drainage features such as swales, depressions, watercourses, ephemeral streams, etc. which serve to effectively manage any stormwater that is generated on the site. By identifying, protecting, and utilizing these features a development can minimize its stormwater impacts. Instead of ignoring or replacing natural drainage features with engineered systems that rapidly convey runoff downstream, designers can use these features to reduce or eliminate the need for structural drainage systems. Naturally vegetated drainage features tend to slow runoff and thereby reduce peak discharges, improve water quality through filtration, and allow some infiltration and evapotranspiration to occur. Protecting natural drainage features can provide for significant open space and wildlife habitat, improve site aesthetics and property values, and reduce the generation of stormwater runoff. If protected and used properly, natural drainage features generally require very little maintenance and can function effectively for many years.

Figure 5.3-1 Protect natural drainage features

Variations

Natural drainage features can also be made more effective through the design process. Examples include constructing slight earthen berms around natural depressions or other features to create additional storage, installing check dams within drainage pathways to slow runoff, and planting additional native vegetation.

Applications

- **Use buffers to treat stormwater runoff.**

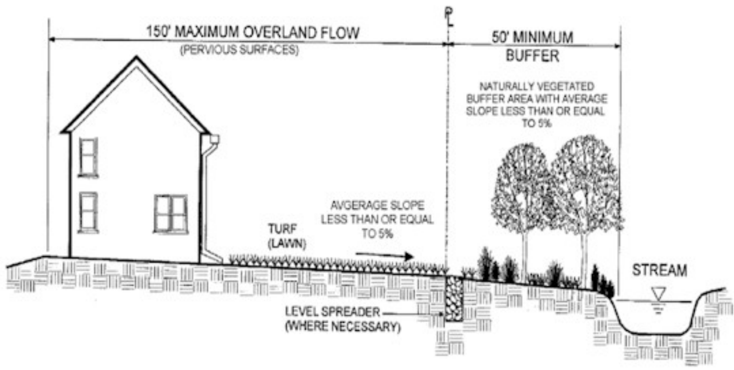


Figure 5.3-2 Section of buffer utilization

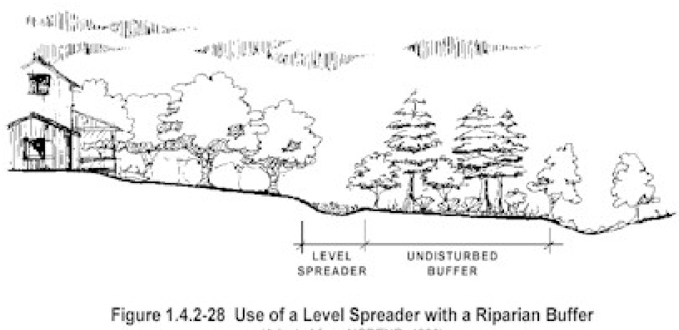


Figure 5.3-3 Section of buffer utilization

- Use natural drainage pathways instead of structural drainage systems

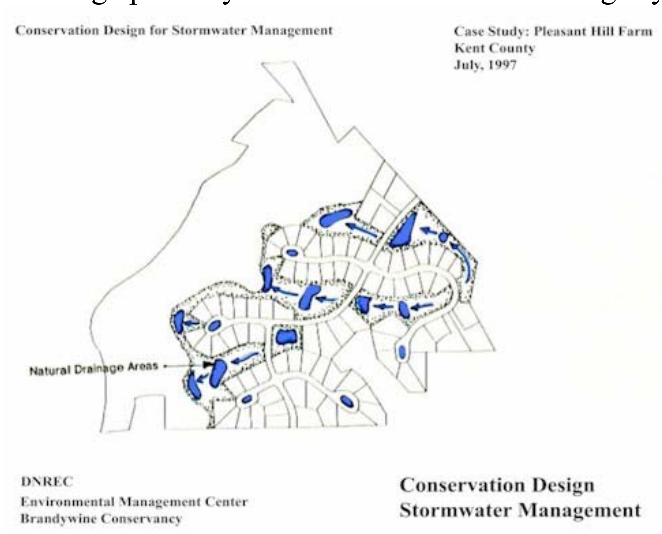


Figure 5.3-4 The natural surface can provide stormwater drainage pathways

- Use natural drainage features to guide site design

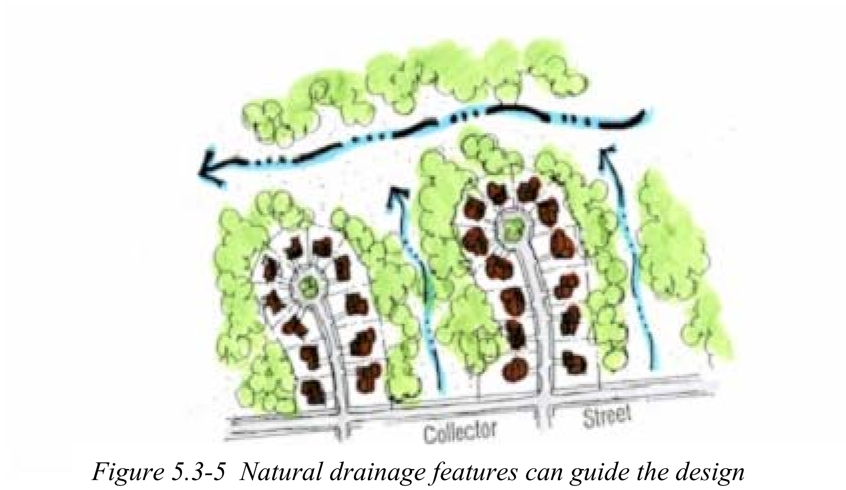


Figure 5.3-5 Natural drainage features can guide the design

- Others…


Figure 5.3-6 Natural surface depressions can temporarily store stormwater.

Design Considerations

1. IDENTIFICATION OF NATURAL DRAINAGE FEATURES. Identifying and mapping natural drainage features is generally done as part of a comprehensive site analysis. This process is an integral part of site design and is the first step for many of the non-structural BMPs described in this Chapter.

2. NATURAL DRAINAGE FEATURES GUIDE SITE DESIGN. Instead of imposing a two-dimensional 'paper' design on a particular site, designers can use natural drainage features to steer the site layout. Drainage features can be used to define contiguous open space/undisturbed areas as well as road alignment and building placement. The design should minimize disturbance to natural drainage features and crossings of them. Drainage features that are to be protected should be clearly shown on all construction plans. Methods for protection, such as signage and fencing, should also be noted on applicable plans.

3. UTILIZE NATURAL DRAINAGE FEATURES. Natural drainage features should be used in place of engineered stormwater conveyance systems wherever possible. Site designs should use and/or improve natural drainage pathways to reduce or eliminate the need for stormwater pipe networks. This can reduce costs, maintenance burdens, disturbance/earthwork related to pipe installation, and the size of other stormwater management facilities. Natural drainage features should be protected from any increased runoff volumes and rates due to development. The design should prevent the erosion and degradation of natural drainage features through the use of upstream volume and rate control BMPs. Level spreaders, erosion control matting, re-vegetation, outlet stabilization and check dams can also be used to protect natural drainage features, where appropriate.

4. NATIVE VEGETATION. Natural drainage pathways should be provided with native vegetative buffers and the features themselves should include native vegetation where applicable. If drainage features have been previously disturbed, they can be restored with native vegetation and buffers.

Detailed Stormwater Functions

Volume Reduction Calculations
Protecting/utilizing natural drainage features can reduce the volume of runoff in several ways. Reducing disturbance and maintaining a natural cover can significantly reduce the volume of runoff through infiltration and evapotranspiration. This will be self-crediting in site stormwater calculations through lower runoff coefficients and/or higher infiltration rates. Utilizing natural drainage features can reduce runoff volumes because natural drainage pathways allow infiltration to occur, especially during smaller storm events. Encouraging infiltration in natural depressions also reduces stormwater volumes. Employing strategies that direct non-erosive sheet flow onto naturally vegetated areas can allow considerable infiltration. See Chapter 8 for volume reduction calculation methodologies.

Peak Rate Mitigation Calculations
Protecting/utilizing natural drainage features can reduce the anticipated peak rate of runoff in several ways. Reducing disturbance and maintaining a natural cover can significantly reduce the runoff rate. This will be self-crediting in site stormwater calculations through lower runoff coefficients, higher infiltration rates, and longer times of travel. Using natural drainage features can lower discharge rates significantly by slowing runoff and increasing on-site storage.

Water Quality Improvement
Protecting/utilizing natural drainage features can improve water quality through filtration, infiltration, sedimentation, and thermal mitigation. See Chapter 8 for Water Quality Improvement methodologies.

Construction Issues

1. At the start of construction, natural drainage features to be protected should be flagged/fenced with signage as shown on the construction drawings.
2. Non-disturbance and minimal disturbance zones should be strictly enforced.
3. Natural drainage features must be protected from excessive sediment and stormwater loads while their drainage areas remain in a disturbed state.

Maintenance Issues

Natural drainage features that are properly protected/utilized as part of site development should require very little maintenance. However, periodic inspections and maintenance actions (if necessary) are important. Inspections should assess erosion, bank stability, sediment/debris accumulation, and vegetative conditions including the presence of invasive species. Problems should be corrected in a timely manner. If native vegetation is being established it may require some support – watering, weeding, mulching, replanting, etc. – during the first few years. Undesirable species should be removed and desirable replacements planted if necessary.

Protected drainage features on private property should have an easement, deed restriction, or other legal measure to prevent future disturbance or neglect. DEP has worked with the Pennsylvania Land Trust Association (PALTA) to develop an easement template with guiding commentary for permanently protecting forest riparian buffers. The model is tailored to protect a relatively narrow ribbon of land along a waterway or lake. Presumably, the riparian buffers will most often comprise lands of severely limited development potential and the landowner will not be seeking a charitable federal income tax deduction.

In preparing the model, it was also assumed that landowners would be receiving no more than a nominal sum for placing the restrictive covenants on their land. To promote landowner donation, the model was drafted to be as brief as possible while providing core protections to forest riparian buffers. The model with guiding commentary is available at http://conserveland.org/model_documents/#riparian PALTA is now offering landowners who use this model a grant of up to $6000 to cover associated costs such as attorney's fees.

Cost Issues

Protecting/utilizing natural drainage features generally results in a significant construction cost savings. Protecting these features results in less disturbance, clearing, earthwork, etc. and requires less re-vegetation. Utilizing natural drainage features can reduce the need and size of costly, engineered stormwater conveyance systems. Together, protecting and utilizing drainage features can reduce or eliminate the need for stormwater management facilities (structural BMPs), lowering costs even more.

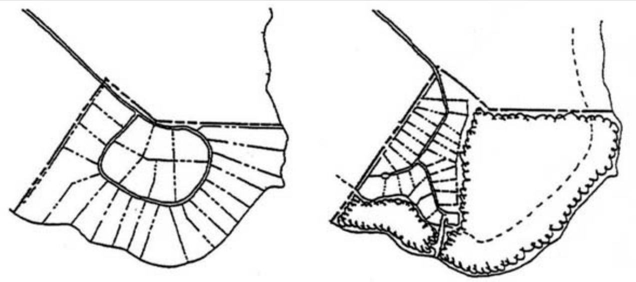
Design costs may increase slightly due to a more thoughtful, site-specific design.

Specifications

Not applicable

5.5 Cluster and Concentrate

BMP 5.5.1: Cluster Uses at Each Site; Build on the Smallest Area Possible



DNREC and Brandywine Conservancy, 1997)

As density is held constant, lot size is reduced, disturbed area is decreased, and undisturbed open space is increased.

Key Design Elements

- Reduce total site disturbance/total site maintenance and increase undisturbed open space by clustering proposed uses on a total site basis through moving uses closer together (i.e., reducing lot size) and/or through stacking uses (i.e., building vertically), even as amount of use (i.e., gross density) is held constant as per existing zoning (or any other gross density determination). As density is held constant (Example A), lot size is reduced, disturbed area decreases, and undisturbed open space increases (Example B).
- Per lot values/prices may decline marginally; however, development costs also decrease.
- Cluster provisions may/may not be allowed by municipal zoning; if no zoning exists, ability to cluster may not be clear (lacking zoning, has the municipality in any way set standards for site uses, gross densities of these uses, etc.?).
- Pending answers to above questions, have lot sizes been reduced to the minimum, given proposed uses? Given existing ordinance provisions? Given other development feasibility factors such as public water/sewer vs. on-site water and sewer and others?
- Is the applicant maximizing clustering as much as possible legally?
- Is the applicant maximizing clustering functionally within municipal ordinance limits?

Potential Applications

Residential: Yes
Commercial: Yes*
Ultra Urban: Limited
Industrial: Limited
Retrofit: Yes
Highway/Road: No

*Depending on site size, constraints and other factors.

Stormwater Functions

Volume Reduction: Very High
Recharge: Very High
Peak Rate Control: Very High
Water Quality: Very High

Water Quality Functions

TSS: Preventive
TP: Preventive
NO3: Preventive

Description

See Key Design Elements.

Variations

- Clustering can be mandated by a municipality as the so-called by-right provision of the zoning district, rather than allowed as a zoning option.

- Density bonus with reduced lot size. In some cases, when lot size is reduced, gross density allowed at the site may be increased, in order to balance what might be lesser values/profitability from smaller lots (Example C). Extent of bonus density is variable, becoming larger as lot size reduction increases (net effect is to always reduce net disturbed area); density bonuses may be made to increase as total undisturbed open space provisions are increased (e.g., for every 10 percent increase in undisturbed open space being provided, density is allowed to increase by 5 percent, and so forth; Example D).

- Extreme Clustering in the form of the Growing Greener 4-Step Design Process which includes: Step 1: Map of Primary and Secondary Conservation Areas; Step 2: Map of Potential Development Area with Yield Plan, calculated as per allowed gross density; Step 3: Map of Street and Trail Connection; Step 4: Map of Lot Lines

Applications

- Residential Clustering:
    - Example A, shown in Figure 5.4-1: The kind of subdivision most frequently created in Pennsylvania is the type which blankets the development parcel with house lots and pays little attention to designing around the special features of the property. In this example, the house placement avoids the primary conservation areas, but disregards the secondary conservation features. Such a sketch can provide a useful estimate of a site's capacity to accommodate new houses at the base density allowed under zoning- and is therefore known as a "Yield Plan."

Figure 5.4-1 Conventional Development, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

- Example B, shown in Figure 5.4-2: Density-neutral with Pre-existing Zoning; 18 lots; Lot Size Range: 20,000 to 40,000 sq. ft.; 50% undivided open space

- Example C, shown in Figure 5.4-3: Enhanced Conservation and Density; 24 lots; Lot Size Range: 12,000 to 24,000 sq. ft.; 60% undivided open space

- Example D, shown in Figure 5.4-4: Hamlet or Village; 36 lots; Lot Size Range: 6,000 to 12,000 sq. ft.; 70% undivided open space

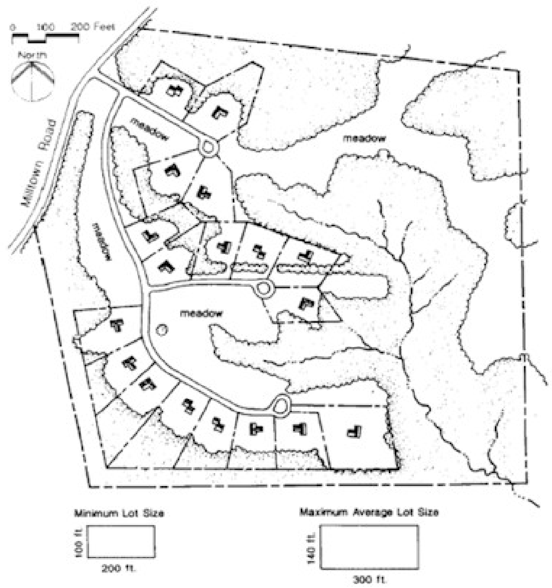


Figure 5.4-2 Clustered Development, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

Figure 5.4-3 Modest Density Bonus, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

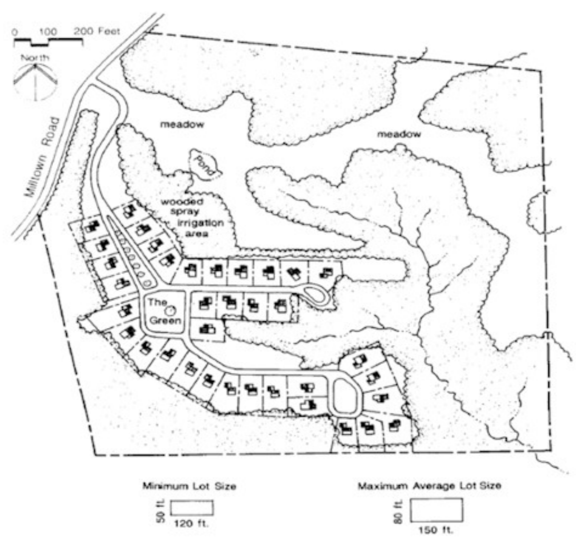


Figure 5.4-4 Hamlet or Village, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

- Non-Residential Clustering:
  - Conventional Development
  - Preferred Vertical Neo-Traditional Development

Design Considerations

Objectives:

- Maximize open space, especially when it includes sensitive areas (primary and secondary).
- Maximize access to open space.
- Maximize sense of place design qualities.
- Balance infrastructure needs (sewer, water, roads, etc.)

Clustering should respond to a variety of site considerations. This BMP discussion assumes that proper and effective work has been undertaken by the municipality to determine the proper site by site land uses and the proper densities/intensities of these land uses. The question is then: *how can X amount of Y uses be best clustered at a particular site*?

Detailed Stormwater Functions

Clustering, as defined here, is self-reinforcing. Clustering reduces total impervious areas, including street lengths and total paved area and is likely to link with other BMPs, as defined in this Chapter, including reduced imperviousness, reduced setbacks, reduced areas for drives and walkways, and so forth. All of this directly translates into reduced volumes of stormwater being generated and reduced peak rates of stormwater being generated, thereby benefiting stormwater planning. Additionally, clustering translates into reduced disturbance and increased preservation of the natural landscape and natural vegetative land cover, which further translates into reduced stormwater runoff, volume and peak. To the extent that this clustering BMP also involves increased vertical development, net site roof area and impervious area is reduced, holding number of units and amount of square footage of a use constant. In all cases, density bonuses, if utilized, should be scrutinized to make sure that additional density allowed is more than balanced by additional open space being provided, including further reductions in street lengths, other impervious surfaces, other disturbed areas, and so forth.

Water quality is affected by non-point source pollutant load from impervious areas, as well as the pollutant load from the newly created maintained landscape, much of which is soluble in form (especially fertilizer-linked nitrogen forms). Clustering, alone and when combined with other Chapter 5 Non-Structural BMPs, minimizes impervious areas and the pollutant loads related to these impervious areas. Similarly, clustering minimizes pollutant loads from lawns and other mowed areas. After Chapter 5 BMPs are optimized, “unavoidable” stormwater is then directed into BMPs as set forth in Chapter 6, to be properly treated. Chemical pollution prevention accomplished through Non-Structural BMPs is especially important because Structural BMPs remain poor performers in terms of mitigating/removing soluble pollutants that are especially problematic in terms of this pervious maintained landscape. See Appendix A for additional documentation of the water quality benefits of clustering.

See Chapter 8 for volume reduction calculation work sheets, peak rate reduction calculation work sheets, and water quality mitigation work sheets.

Construction Issues

Application of this BMP clearly is required from the start of the site planning and development process. Not only must the site owner/builder/developer embrace BMP 5.5.1 Cluster Uses at Each Site from the start of the process, the respective municipal officials must have included clustering in municipal codes and ordinances, as is the case with so many of these Chapter 5 Non-Structural BMPs. Any areas to be protected from development must be clearly marked in the field prior to the beginning of construction.

Maintenance Issues

As with all Chapter 5 BMPs, maintenance issues are of a different nature and extent then the more specific Chapter 6 Structural BMPs. Typically, the primary issue is "who takes care of the open space?" Legally, the designated open space may be conveyed to the municipality, although most municipalities prefer not to receive these open space portions, including all of the maintenance and other legal responsibilities associated with open space ownership. Ideally, open space reserves will merge to form a unified open space system, integrating important conservation areas throughout the municipality and beyond. In reality, these open space segments may exist dispersed and unconnected for a considerable number of years. For those Pennsylvania municipalities that allow for and enable creation of homeowners associations or HOA's, the HOA, may assume ownership of the open space. The HOA is usually the simplest solution to the "who takes care of the open space" question.

In contrast to some of the other long-term maintenance responsibilities of a new subdivision and/or land development (such as maintenance of streets, water and sewers, play and recreation areas, etc.), the maintenance requirements of "undisturbed open space" should be minimal. The objective here is conservation of the natural systems already present, with minimal intervention and disturbance. Nevertheless, invariably some legal responsibilities must be assumed and need to be covered.

Cost Issues

Clustering is beneficial from a cost perspective in several ways. Costs to build a single-family residential development is less when clustered than when not clustered, holding the home type and all other relevant infrastructure constant. Costs are decreased because of less land clearing and grading, less road construction (including curbing), less sidewalk construction, less lighting and street landscaping, potentially less sewer and water line construction, potentially less stormwater collection system construction, and similar savings.

Clustering also reduces post construction costs. A variety of studies from the landmark *Costs of Sprawl* study and later updates have shown that delivery of a variety of municipal services such as street maintenance, sewer and water services, and trash collection are more economical on a per person or per house basis when development is clustered. Even services such as police protection are made more efficient when residential development is clustered.

Additionally, clustering has been shown to positively affect land values. Analyses of market prices over time of conventional development in contrast with comparable residential units in clustered developments have indicated that clustered developments with their proximity to permanently protected open space increase in value at a more rapid rate than conventionally designed developments, even though clustered housing occurs on considerably smaller lots than the conventional residences.

Specifications

Clustering is not a new concept and has been defined, discussed, and evaluated in many different texts, reports, references, sources, as set forth below.

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BMP 5.5.2: Concentrate Uses Area wide through Smart Growth Practices

On a municipal, multi-municipal or areawide basis, use of "smart growth" planning techniques, including neo-Traditional/New Urban planning principles, to plan and zone for concentrated development patterns can accommodate reasonable growth and development. These practices direct growth to areas or groups of parcels in the municipality that are most desirable and away from areas or groups of parcels that are undesirable. BMP 5.5.2 can be thought of as Super Clustering that transcends the reality of the many different large and small parcels that exist in most Pennsylvania municipalities. Clustering parcel by parcel simply cannot accomplish the growth management that is so essential to conserve special environmental and cultural values and protect special sensitivities. These smart growth techniques include but are not limited to, transfer of development rights (TDR), urban growth boundaries, effective agricultural zoning, purchase of development rights (PDR) by municipalities, donation of conservation easements by owners, limited development and bargain sales by owners, and other private sector landowner options. "Desirability" is defined in terms of environmental, historical and archaeological, scenic and aesthetic, "sense of place," and quality of life sensitivities and values.

Key Design Elements

- Establish baseline growth and development context for the municipality or multi-municipal area (how much of what by when and where, using decade increments, plus ultimate build out).
- On macro level (defined as municipality-wide, multi-municipality-wide, areawide), define criteria for growth "desirability" (opportunities) and "undesirability" (constraints) on a multi-site and/or municipality-wide and/or areawide basis.
- Apply these "desirability" and "undesirability" criteria.
- Contrast baseline growth and development (first step) with third step; highlight problems.
- Apply smart growth techniques as needed to re-form "business as usual" future to max out "desirability" and "undesirability" performance. Techniques include: transfer of development rights (TDR), urban growth boundaries, effective agricultural zoning, purchase of development rights (PDR), donation of conservation easements by owners, limited development and bargain sales by owners, and other private sector landowner options.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Very High
Recharge: Very High
Peak Rate Control: Very High
Water Quality: Very High

Water Quality Functions

TSS: Preventive
TP: Preventive
NO3: Preventive

Variations

Because of the broadness of this BMP and its macro scale, variations in this BMP can be substantial. Variations include: 1) how areas deemed to be desirable for growth are defined, whether clusters, hamlets, villages, towns and/or cities; 2) how areas deemed undesirable for growth are defined (conserving natural resources, agricultural lands and other vital resources); and 3) how any of this is made to happen and what blend of smart growth techniques can be applied (where and when) to implement 1 and 2.

1. Defining Desirable Growth – Opportunities for Growth: Clusters, Hamlets, Villages, Towns and Cities

The vision for growth and development can take many different forms and can vary substantially depending upon the respective municipality, group of municipalities, or area. Rural areas (Figure 5.5-1) striving to preserve their rural character can concentrate development through adherence to building onto or even creating Hamlets and Villages. If adjacent communities exist, development can be directed into the town or at the town edge (Figure 5.5-2). Clustering (see BMP 5.5.1) on a site-by-site basis is superior from a site perspective but yields a pattern that is less than optimal from a multi-site or area wide perspective (Figure 5.5-3). However, this overall pattern is vastly preferable to the business as usual approach across many different sites comprising the entire area (Figure 5.5-4).

Figure 5.5-1 Rural landscape of Pennsylvania

Areas already developed and urbanized are likely to define appropriate in-fill development and re-development at higher densities. Multiple community planning sources with specific community building standards and specifications are available for reference. The importance of careful definition of growth zones and the performance standards that define these growth zones cannot be overemphasized. Often this BMP has been driven by environmental conservation objectives such as saving the undesirable growth areas (Sending Zones in TDR parlance) as discussed below but every bit as much care must be taken in defining and planning the desirable growth areas (Receiving Zones).

Figure 5.5-2 Use of TDR to protect rural landscapes and direct development into the Town or Town Edge

Figure 5.5-3 Site clustering provides a partial open space network, though less than that provided by TDR

Figure 5.5-4 Large lot zoning ignores natural and cultural resource values.

2. Defining Undesirable Growth Areas – Constraints: High Value Watershed Areas, Agricultural Areas, Eco-Sensitive Habitat Areas, Headwaters, and Stream Designations

Criteria used by a municipality or area for managing development may be expected to vary to some extent. Municipalities may include special watershed areas, which have Pennsylvania Code Chapter 93 Special Protection Waters designation (Exceptional Value and High Quality), as well as critical headwater (first order streams) portions of watersheds. Source Water Protection zones may exist, including areas of especially important groundwater recharge, or habitat areas where the Pennsylvania Natural Diversity Inventory (PNDI) indicates especially important species presence. Also, important wetlands, floodplains and other natural features may exist. Prime Agricultural Lands and Agricultural Security Districts may be deserving of conservation. Areas may be especially sensitive due to rugged topography or steep slopes. Areas may be sensitive due to richness of historical and archaeological and even scenic values. All of these important values are likely to extend well beyond individual parcel boundaries and require smart growth area wide growth management techniques.

3. Mixing and Matching Smart Growth Techniques: Public and Private

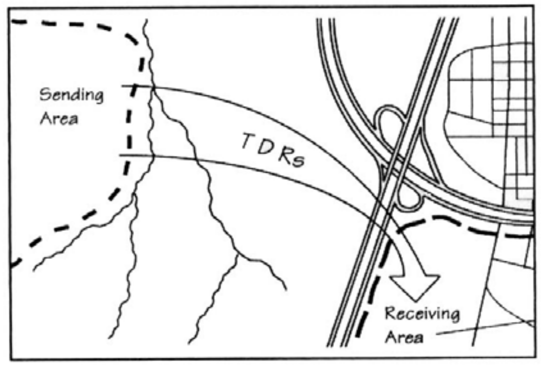
If a municipality consists of only a handful of enormous parcels where BMP 5.5.1 Clustering can work together to achieve the areawide "desirable growth" and "undesirable growth" patterns for the entire municipality as described above, BMP 5.5.2 would be made unnecessary. Such is usually not the case. A municipality may decide to use all or most of the smart growth techniques discussed here. A municipality may decide that "less is more" and try to achieve its objectives with the most simple growth management program possible, using the fewest techniques. The blend of public techniques versus private techniques is also important. Most of what is involved here entails public sector management action, such as zoning ordinance provisions. A few municipalities in Pennsylvania (West Marlborough, Chester County) have achieved municipality-wide success through private landowner actions, such as voluntary donation of conservation easements to conservancies and land trusts.

The optimal blend of smart growth techniques is not easily determined. Each technique has pros and cons, in terms of technical effectiveness, ease of implementation, political and socioeconomic implications, and integration with the local culture. Municipalities may decide to hire a local planning consultant (contact the Pennsylvania Planning Association for additional references), or may decide to consult with a free or low cost information resource such as the Pennsylvania Environmental Council or 10,000 Friends of Pennsylvania. The direct state government agency contact is the Pennsylvania Department of Community and Economic Development. These organizations and agencies offer a variety of planning resources by providing information on smart growth techniques and their potential usefulness in any one particular municipal setting. The organizations' respective websites should be consulted for more detailed information.

Applications

Transfer of Development Rights (TDR)

Transfer of Development Rights (TDR, see Figure 5.5-5) is allowed as an option in Pennsylvania under the Municipalities Planning Code. TDR creates an overlay (Sending Zone) in the zoning ordinance where property owners are allowed to sell development rights for properties where growth is deemed to be less than desirable for any number of reasons. In a second created overlay zone (Receiving Zone), these development rights that have been purchased may be used to increase development density, above the maximum baseline or conventional zoned density. TDR has been in existence for some years and has been used by a relatively small number of Pennsylvania municipalities, although it has been used more widely in New Jersey and several other states. Although TDR is created in the municipal zoning ordinance, all TDR transactions or transfers of development rights may occur within the private sector, between Sending Zone owners and Receiving Zone purchasers or developers. TDR has been used in Buckingham Township (Bucks County), West Bradford and West Vincent Townships (Chester County), Manheim and Warwick Townships (Lancaster County).



Source: Maryland Office of Planning

Figure 5.5-5 Example of Transfer of Development Rights

Growth Boundaries:

Growth Boundaries (Urban Growth Boundaries, see Figure 5.5-6) are based on the concept that infrastructure such as public road systems and public water and wastewater treatment systems have a powerful growth inducing and growth shaping influence on an area wide basis. By controlling the location and timing of this infrastructure through municipal or public sector action, municipalities can encourage development in certain areas and discourage development in others. Growth Boundaries define where municipalities will directly and indirectly encourage, and even provide infrastructure services, significantly increasing zoned densities. Areas lacking such infrastructure services are zoned at significantly decreased densities. The State of Oregon has been a leading advocate of Growth Boundaries. Lancaster County for some years has been applying Growth Boundary principles in its comprehensive planning (go to their website to the annual Growth Tracking reports which document how their planning is achieving Growth Boundary objectives).

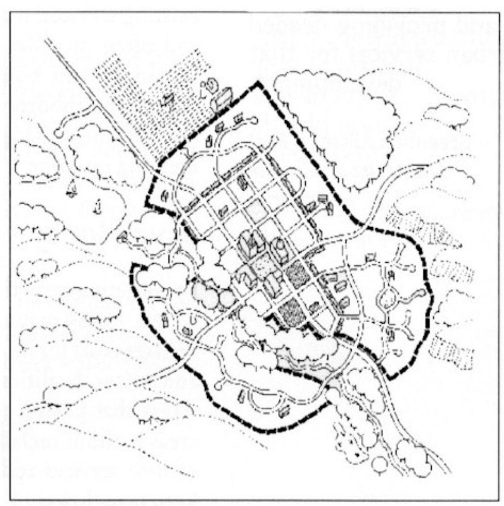

Source: Greenbelt Alliance

Figure 5.5-6 Example of Urban Growth Boundary

Effective Agricultural Zoning:

Large lot zoning (usually defined as zoning that requires average lot size to be greater than 2 acres per lot) has been rejected by Pennsylvania courts as exclusionary and unacceptable. However, very large minimum lot size to maintain existing agricultural uses has been deemed to be acceptable by Pennsylvania courts and is being practiced throughout Pennsylvania, especially in intensive agricultural communities in southcentral Pennsylvania (e.g., multiple municipalities in Adams, Berks, Chester, Lancaster, York, etc.). Effective agricultural zoning may take the form of a specified mapped zoning category with a minimum lot size of 10,15, 20, or 25 acres (this varies). Sliding scale agricultural zoning is a popular variation, where additional lots to be created and subdivided are a function of the size of the total agricultural tract (though gross density remains very low). The intent is to allow a small number of lots to be created over time, possibly for family members or for agricultural workers, but to keep the functioning farms as intact as possible without residential subdivision or any other development intrusion. The concept here is that the so-called "highest and best use of the land" is agricultural use, which will be best maintained through protection of the farming community and through this very low-density zoning. Application of Agricultural Zoning has been restricted to areas where agriculture can be defined explicitly, typically in the presence of prime farmland soils, intensive agricultural activity, formation of Agricultural Security Districts, or other indicators of important agricultural activity. Obviously, this smart growth technique has limited application in terms of a growth management technique.

Purchase of Development Rights:
Similar to TDR, the concept of Conservation Easements hinges on the notion that development rights for any particular property can be defined and separated from a property. These development rights can then be purchased and in a sense retired from the open market. The Pennsylvania Farmland Preservation Program, which purchases development rights from existing agricultural owners and allows farmers to continue their ownership and their agricultural activities, has become one of the most successful agricultural preservation programs in the country. This program is highly competitive and obviously limited to agricultural properties and contexts. The Farmland Preservation Program is a priority of the current administration, will continue to be funded, and has been reinforced in several counties with county-funded farmland preservation programs in order to stretch the state dollars.

Some counties (Bucks, Chester, Montgomery Counties) and municipalities (North Coventry, East Bradford, Pennsbury, Solebury, West Vincent and others) have enacted special open space and recreation acquisition programs. They are funded in various ways (bond issues, real estate taxes, small payroll taxes) to purchase additional county-owned and municipality-owned lands, for use as active and passive recreation as well as open space conservation. These efforts can be used in conjunction with TDR programs, whereby a municipality funds a revolving fund-supported land development bank which purchases development rights from vulnerable and high priority properties in Sending Zones. It later sells these development rights (Warwick Township in Lancaster County has done this) to Receiving Zone developers.

Conservation Easements (Donation and Purchase): Brandywine Conservancy, Natural Lands Trust, Western Pennsylvania Conservancy, Others
Similar to TDR, the concept of Conservation Easements hinges on the notion that development rights for any particular property can be defined and separated from a property. These development rights can then be donated to an acceptable organization to support the public's health, safety and welfare, in the form of a conservation easement which restricts the owner's ability to develop the property in perpetuity, regardless of municipal zoning. Historically, a major incentive for these conservation easement donations has been the major tax benefits afforded such donations. Organizations such as the Brandywine Conservancy, Natural Lands Trust, the Western Pennsylvania conservancy and many others have protected thousands of acres of otherwise developable property in Pennsylvania through privately donated conservation easements, with absolutely no public expenditure of funds. Brandywine's 30,000 acres of conservation easements in the Brandywine Creek Watershed is an excellent case in point. Municipalities such as West Marlborough Township in Chester County have large portions of their jurisdictions permanently conserved as the result of this Conservation Easement program. Conservation Easements also can be purchased by a conservation organization or government agency. National organizations such as the Nature Conservancy, the Trust for Public Land, the Land Trust Alliance, and others are active in Pennsylvania and are excellent sources of technical information relating to this smart growth technique. In parts of Pennsylvania, these larger

organizations are helping fledgling local land trusts form and begin their important work of land conservation.

Bargain Sale/Limited Development Options:
A variation on the donation of development rights through conservation easements is a "bargain sale," where a portion of the development rights value is donated (in the manner described above) but the property owner still enjoys a return on his/her property. In any number of development-pressured municipalities in Pennsylvania, fair market value for a large 100-acre farm to be developed as single-family residences or some other use may reach 2 or 3 million dollars. The owner, beyond tax benefits, may need a monetary settlement, though not in the order of 2 to 3 million dollars. In such cases, a defined "bargain sale" might be arranged if a source of funds can be located to provide a partial financial settlement for the owner. The owner benefits from an approved donation of the remainder of the value that can reduce the owner's tax bill. The property is conserved.

A further variation would be a limited development option wherein a substantially reduced development program is developed which conserves much if not most of the property in question. An existing farmstead or homestead is retained and the property owner may even retain this farmstead/homestead. A much smaller number of lots surrounded by open space is carefully created; these lots typically command a considerably higher value than would be the case for a conventional subdivision. A large amount of open space is created and protected through a conservation easement, which may be donated as well, providing further tax benefit. The outcome is that the property owner, after taxes, may be almost as well off after a Limited Development approach to the property than would be the case with a complete conventional "as of right" approach to development. If the Limited Development concept has been prepared carefully, total property disturbance can be substantially reduced.

Sustainable Watershed Management and Water-Based Zoning: Green Valleys Association and the Brandywine Conservancy

Design Considerations:

Objectives for BMP 5.5.2 resemble BMP 5.5.1, although they must be understood as municipality-wide, rather than just site-wide:

- Maximize open space, especially sensitive areas (primary and secondary) and areas of special value.
- Maximize "sense of place" design qualities where growth is desirable.
- Balance infrastructure needs (sewer, water, roads, etc.) and use infrastructure to shape desirable growth

BMP 5.5.2 relies on application of smart growth techniques. The specific optimal blend of these smart growth techniques should respond to a variety of municipality characteristics and considerations. This BMP discussion assumes that proper and effective work has been undertaken by the municipality to determine the proper land uses and the proper densities/intensities of these land uses, municipality-wide. The question is then: how can these uses – this future development - be best planned within the municipality, achieving the best and most livable communities for the future, even as disruption to the natural landscape is minimized?

Detailed Stormwater Functions

Concentrating growth, as defined here, is self-reinforcing from a stormwater management perspective – in terms of peak rate reduction, runoff volume reduction, and nonpoint source load reduction. Concentrating growth reduces total impervious areas and is likely to link with other BMP's in this Section, including reduced imperviousness, reduced setbacks, reduced areas for drives and walkways, etc. All of this directly translates into reduced volumes of stormwater being generated and reduced peak rates of stormwater being generated, thereby benefiting stormwater planning. Additionally, concentrating growth translates into reduced disturbance and increased preservation of the natural landscape and natural vegetative land cover, which further translates into reduced stormwater runoff. To the extent that this BMP also involves increased vertical development, net site roof area and impervious area is reduced, holding number of units and amount of square footage of a use constant. In all cases, density bonuses, if utilized in Receiving Zones, should be scrutinized to make sure that additional density allowed is more than balanced by additional open space being provided, including further reductions in street lengths, other impervious surfaces, other disturbed areas, and so forth. If properly implemented, these smart growth techniques such as TDR and Growth Boundaries will almost always translate into reduced total disturbed area and reduced total impervious area, even more dramatically than non-structural techniques such as clustering.

Documentation of the positive water quality effects of area wide growth concentration, holding total growth and development constant, is provided by the City of Olympia's (Washington) *Impervious Surface Reduction Study: Final Report 1995*. Holding population projected to 2015 constant, two dramatically different scenarios of land development (a baseline pattern of low density unconcentrated development reflecting recent development trends versus a concentrated pattern of increased density development in and near existing developed areas) were defined. These were mapped (Figure 5.5-7) and tested for a variety of stormwater-related impacts (total impervious area, total disturbed area, stormwater generation, non-point source pollutant generation). The analysis results indicated that the concentrated development scenario significantly reduced total impervious area. This was due to significant reductions in impervious surfaces being created in outlying rural and low density areas and more efficient utilization of impervious surfaces already created in areas of existing development. Other studies focusing on concentrated growth patterns have similarly confirmed these relationships and further documented a reduction in total disturbed areas created, stormwater being generated, and total non-point source pollutant loads being generated.

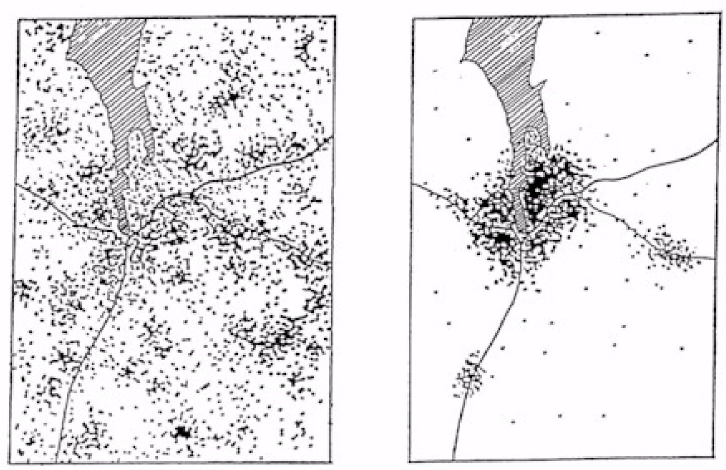


Figure 5.5-7 Dispersed versus Concentrated Development at the Regional Scale, (Source: "Impervious Surface Reduction Study", City of Olympia, 1995)

As stated above in BMP 5.5.1, water quality issues include all the non-point source pollutant load from impervious areas, a well as all the pollutant load from the newly created maintained landscape (i.e., lawns and other), much of which is soluble in form (especially fertilizer-linked nitrogen forms). Concentrating growth as defined in BMP 5.5.2, and combined with other Chapter 5 Non-Structural BMP's, minimizes impervious areas and the pollutant loads related to these impervious areas. After Chapter 5 BMP's are optimized, "unavoidable" stormwater is then directed into BMP's as set forth in Chapter 6, to be properly treated. Similarly, for all that non-point source pollutant load generated from the newly-created maintained landscape and combined with other Chapter 5 Non-Structural BMP's, minimizes pervious areas and the pollutant loads related to these pervious areas, thereby reducing the opportunity for fertilization and other chemical application. Prevention of water quality degradation accomplished through Non-Structural BMP's in Chapter 5 is especially important because Chapter 6 Structural BMP's remain poor performers in terms of mitigating/removing soluble pollutants that are especially problematic in terms of this pervious maintained landscape. See Appendix A for additional documentation of the water quality benefits of clustering.

See Chapter 8 for additional volume reduction calculation work sheets, additional peak rate reduction calculation work sheets, and additional water quality mitigation work sheets.

Construction Sequence

Application of this BMP must be undertaken by the municipality and must precede the start of any individual site planning and development process. In most cases, the municipality must take action in its comprehensive plan and then in its zoning and SLDO to incorporate the optimal blend of these smart growth techniques in their respective municipal planning and growth management program (the proactive municipality may act further to program for use of conservation easements, creation of a local land trust, and the like). At the same time, the site owner/builder/developer may elect to embrace options set forth in BMP 5.5.2 Concentrate Uses Area wide from the start of the process. Use of conservation easement donation, bargain sale or limited development all require careful consideration by the site owner/builder/developer from the beginning of the site development process.

Maintenance Issues

Very few maintenance problems or issues are generated by BMP 5.5.2. Because most of these smart growth techniques are preventive in nature and in fact translate into maximum retention of undisturbed open space and the natural features contained within this open space, typically in private ownership, specific maintenance requirements as defined in a conventional manner are extremely limited, if not nonexistent.

Cost Issues

According to Delaware's recent *Conservation Design for Stormwater Management: A Design Approach to Reduce Stormwater Impacts from Land Development*, application of the municipality-wide or areawide smart growth techniques will require some additional costs. Application of an optional TDR program or Growth Boundary program could cost a municipality in technical planning fees, including incorporation into the comprehensive plan and zoning ordinance (other costs may be required as well). Although it is hard to specifically document, a program of structural BMP's which mitigate adverse impacts of land development and achieve the same level of water resource (quantity and quality) performance throughout the municipality and its respective watershed areas becomes much more difficult to achieve, and much more expensive when all development and all lots are tallied. Prevention is simply much more cost effective.

Furthermore, BMP 5.5.2's preventive smart growth techniques, when fully applied, achieve a level of performance that exceed even the best structural BMP's. This clearly demonstrates why non-structural BMP's are important for all Pennsylvania watersheds, but especially important for Special Protection Waters where High Quality and Exceptional Value designations call for extremely high levels of water resource protection. In these cases, significant amounts of development watershed-wide, even assuming use of Chapter 6 structural BMP's, may fail to provide the water resource protection which is needed to sustain special Protection Waters' values over the long-term.

Specifications

BMP 5.5.2 is not a new concept and has been defined, discussed, and evaluated in many different texts, reports, references, sources, as set forth below. More specifications for clustering can be found in references that are included in above discussions.

5.6 Minimize Disturbance and Minimize Maintenance

BMP 5.6.1: Minimize Total Disturbed Area - Grading

Without changing the building program, you can reduce site grading, removal of existing vegetation (clearing and grubbing) and total soil disturbance. This eliminates the need for re-establishment of a new maintained landscape for the site and lot-by-lot, by modifying the proposed road system and other relevant infrastructure as well as the building location and elevations to better fit the existing topography.

Key Design Elements

- Identify and avoid special value and environmentally sensitive areas
- Minimize overall disturbance at the site
- Minimize disturbance at the individual lot level
- Maximize soil restoration to restore permabilities
- Minimize construction-traffic locations
- Minimize stockpiling and storage areas

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Limited
Highway/Road: Limited

Stormwater Functions

Volume Reduction: High
Recharge: High
Peak Rate Control: High
Water Quality: High

Water Quality Functions

TSS: 40%
TP: 0%
NO3: 0%

Description

This Non-Structural BMP assumes that the special value and sensitive resource areas have been identified on a given development parcel and have been protected, and that clustering and area wide concentration of uses also have been considered and included in the site design. All of these BMPs serve to reduce site grading and to minimize disturbance/minimize maintenance. This BMP specifically focuses on how to minimize the grading and overall site disturbance required to build the desired program while maximizing conservation of existing site vegetation.

Reduction of site disturbance by grading can be accomplished in several ways. The requirements of grading for roadway alignment (curvature) and roadway slope (grade) frequently increase site disturbance throughout a land development site and on individual lots. Most land development plans are formulated in 2-dimensional plan, based on the potential zoned density, and seldom consider the constraints presented by topographic variation (slope) on the site. The layout and design of internal roadways on a land development site with significant topographic variation (slope) can result in extensive earthwork and vegetation removal (i.e., grading). Far less grading and a far less disruptive site design can be accomplished if the site design is made to better conform with the existing topography and land surface, where road alignments strive to follow existing contours as much as possible, varying the grade and alignment criteria as necessary to comply with safety limits.

Site design criteria have evolved in municipalities to make sure that developments meet safety standards (sight distance, winter icing, and so forth) as well as certain quality or appearance standards. A common perception among municipal officials is that little deviation should be allowed in order to maintain the integrity of the community. In fact, roadway design criteria should be made flexible in order to better fit a given parcel and achieve a more “fluid” roadway alignment. The avoidance of sensitive site features, such as important woodlands, may be facilitated through flexible roadway layout. Additionally, rigorous parcel criteria (front footage, property setbacks, etc.) often add to this “plane geometry” burden. Although the rectilinear grid layout is the most efficient in terms of maximizing the number of potential lots created at a development site, the end result is a “cookie cutter” pattern normally found in residential sites and the “strip” development found in most highway commercial districts, all of which are apt to translate into significant resource loss.

Figure 5.6-1 Residential Area with Disturbance Minimized

From the perspective of a single lot, the municipally-required conventional lot layout geometry can also impose added earthwork and grading that could be avoided. Lot frontage criteria, yard criteria, and driveway criteria force the placement of a structure in the center of every lot, often pushed well back from the roadway. Substantial terracing of the lot with added grading and vegetation removal is required in many cases. Although the intent of these municipal requirements is to provide privacy and spacing between units, the end result is often totally cleared, totally graded lots, which can be visually monotonous. Configuring lots in a rectilinear shape may optimize the number of units but municipalities should require that the site design in total should be made to fit the land as much as possible.

Municipal criteria that impose road geometry are usually contained within the subdivision and land development ordinance (SALDO), while densities, lot and yard setbacks, and minimum frontages are usually contained in the zoning ordinance. Variations in these land development standards should be accepted by the local government where appropriate, which should modify their respective ordinances. Municipalities should consider being more flexible without compromising public safety in terms of:

- Road vertical alignment criteria (maximum grade or slope).
- Road horizontal alignment criteria (maximum curvature)
- Road frontage criteria (lot dimensions)
- Building setback criteria (yards dimensions)

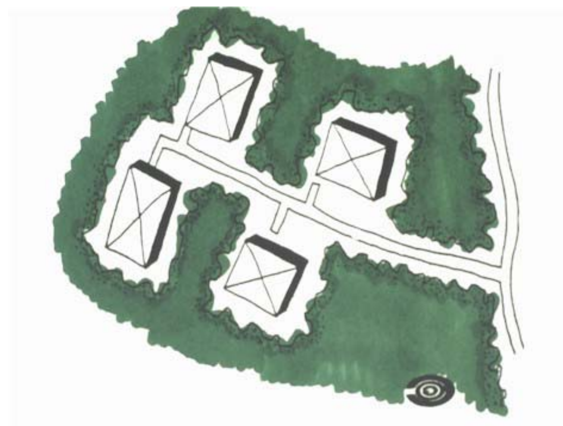


Figure 5.6-2 Minimally Disturbed Development

Related Non-Structural BMPs, such as road width dimensions, parking ratios, impervious surface reduction, chemical maintenance of newly created landscapes, and others are discussed as separate BMPs in this Chapter, though are all substantially interrelated.

Detailed Stormwater Functions

Volume Reduction Calculations: Minimizing Total Disturbed Area can reduce the volume of runoff in several ways. Reducing disturbance and maintaining a natural cover can significantly reduce the anticipated volume of runoff through increased infiltration and increased evapotranspiration. This practice will be self-crediting in site stormwater calculations through lower runoff coefficients and/or higher infiltration rates. Minimizing Total Disturbed Area can reduce anticipated runoff volumes because undisturbed areas of existing vegetation allow more infiltration to occur, especially during smaller storm events. Furthermore, employing strategies that direct non-erosive sheet flow onto naturally vegetated areas can allow considerable infiltration to occur and can be coupled with level spreading devices (see Chapter 6) and possibly other BMPs to more actively manage stormwater that cannot be avoided. In other words, Minimizing Total Disturbed Area/Maintained Area through Reduced Site Grading (Designing with the Land) not only prevents increased stormwater generation (a volume and peak issue), but also offers an opportunity for managing stormwater generation that cannot be avoided. See Chapter 8 for volume reduction calculation methodologies.

Peak Rate Mitigation Calculations: Minimizing Total Disturbed Area/Maintained Area through Reduced Site Grading (Designing with the Land) can reduce the peak rate of runoff in several ways. Reducing disturbance and maintaining a natural cover can significantly reduce the runoff rate. This will be self-crediting in site stormwater calculations through lower runoff coefficients, higher infiltration rates, and longer times of travel. Minimizing Total Disturbed Area/Maintained Area through Reduced Site Grading (Designing with the Land) can lower discharge rates significantly by slowing runoff and increasing on-site storage.

Water Quality Improvement: Minimizing Total Disturbed Area can improve water quality preventively by reducing construction phase sediment-laden runoff. Water quality benefits also by maximizing preservation of existing vegetation at a site (e.g., meadow, woodlands) where post-construction maintenance including application of fertilizers and pesticides/herbicides is avoided. Given the high rates of chemical application which have been documented at newly created maintained areas for both residential and non-residential land uses, eliminating the opportunity for chemical application is important for water quality – perhaps the most effective management technique. In terms of water quality mitigative functions, Minimizing Total Disturbed Area provides filtration and infiltration opportunities, assuming that undisturbed areas are being used to manage stormwater generated elsewhere on the development site, as well as thermal mitigation. See Chapter 8 for Water Quality Improvement methodologies.

Design Considerations

During the initial conceptual design phase of a land development project, the applicant's design engineer should provide the following information, ideally through development of a Minimum Disturbance/Minimum Maintenance Plan:

1. **Identify and Avoid Special Value/Sensitive Areas (see BMP 5.4.1)**

Figure 5.6-3 Woodlands Protected through Minimum Disturbance Practices

Delineate and avoid environmentally sensitive areas (e.g., Primary and Secondary Conservation areas, as defined in BMP 5.4.1); delineation of Woodlands, broadly defined to include areas of immature and mixed tree growth, is especially important; configure the development program on the balance of the parcel (i.e., Development Areas as discussed in BMP 5.4.1).

2. Minimize Disturbance at Site

Modify road alignments (grades, curvatures, etc.), lots, and building locations to minimize grading, earthwork, overall site disturbance, as necessary to maintain safety standards. Minimal disturbance design shall allow the layout to best fit the land form without significant earthwork. The limit of grading and disturbance should be designated on the plan documentation submitted to the municipality for review/approval, and should be physically designated at the site during construction by flagging, fencing, or other methods.

3. Minimize Disturbance at Lot

Limit lot grading to roadways and building footprints. Municipalities should establish Minimum Disturbance/Minimum Maintenance Buffers, designed to be rigorous but reasonable in terms of current feasible site construction practices. These standards may need to vary with the type of development being proposed and the context of that development (the required disturbance zone around a low density single-family home can be expected to be less than disturbance necessary for a large commercial structure), given the necessity for use of different types of construction equipment and the realities of different site conditions. For example, the U.S. Green Building Council's Leadership in Energy & Environmental Design Reference Guide (Version 2.0 June 2001) specifies the following:

"…limit site disturbance including earthwork and clearing of vegetation to **40 feet** beyond the building perimeter, **5 feet** beyond the primary roadway curbs, walkways, and main utility branch trenches, and **25 feet** beyond pervious paving areas that require additional staging areas in order to limit compaction in the paved area…"

Municipalities in New Jersey's Pinelands Preservation Zone for years have supported ordinances where limits are more restrictive than the LEED footages (e.g., clearing around single-family homes is reduced to 25 feet). Again, such requirements can be made to be flexible with special site factors and conditions. The limit of grading and disturbance should be designated on the plan documentation submitted to the municipality for review/approval, and should be physically designated at the lot during construction by flagging, fencing or other marking techniques.

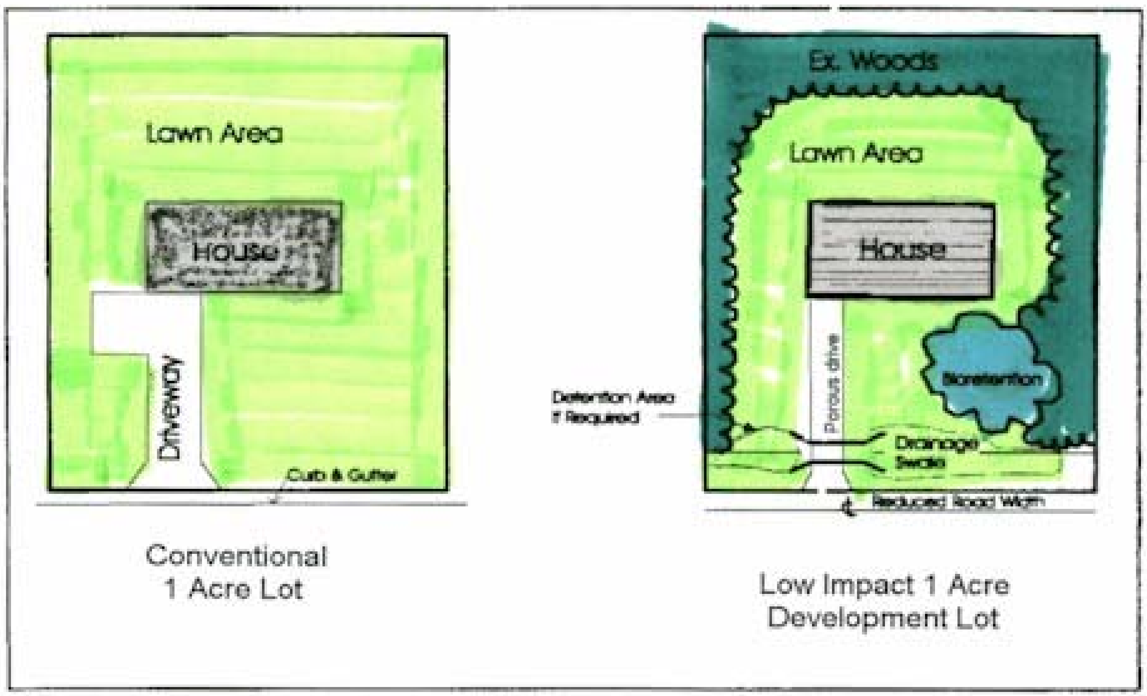


Figure 5.6-4 Convential Development Versus Low Impact Development

4. Maximize Soil Restoration

Where construction activity does require grading and filling and where compaction of soil can be expected, this disturbance should be limited. Soil treatments/amendments should be considered for such disturbed areas to restore permeability. If the bulk density is not reduced following fill, these areas will be considered semi-impervious after development and runoff volumes calculated accordingly.

5. Minimize Construction Traffic Areas

Areas where temporary construction traffic is allowed should be clearly delineated and limited. These areas should be restored as pervious areas following development through a required soil restoration program.

6. Minimize Stockpiling and Storage Areas

All areas used for materials storage during construction should be clearly delineated with the surface maintained, and subject to a soil restoration program following development. For low-density developments, the common practice of topsoil stripping might be unnecessary and should be minimized, if not avoided.

Construction Issues

Most of the measures discussed above are part of the initial concept site plan and site design process. Only those measures that restore disturbed site soils are related to the construction and post-construction phase, and may be considered as avoidance of impacts.

Cost Issues

Cost avoidance as a result of reduced grading and earthwork should benefit the developer. This BMP is considered to be self-crediting, given the benefits resulting from reduced costs. Cost issues include reduced grading and related earthwork (see Site Clearing and Strip Topsoil and Stockpile below), as well as reduced costs involved with site preparation, fine grading, and stabilization.

Calculation of reduced costs is difficult due to the extreme variation in site factors that will affect costs (amount of grading, cutting/filling, haul distances for required trucking, and so forth). Some relevant costs factors are as follows (as based on R.S. Means, *Site Work & Landscape Cost Data*, 2002):

Site Clearing

Cut & chip light trees to 6" diameter	$2,900/acre
Grub stumps and remove	$1,400/acre
Cut & chip light trees to 24" diameter	$9,700/acre
Grub stumps and remove	$5,600/acre

Strip Topsoil and Stockpile

Ranges from $0.52 to $1.78 / cy because of Dozer horse power, and ranges from ideal to adverse conditions
Assuming 8" of topsoil, the price per sq. yd. is $0.12 – $0.40
Assuming 8" of topsoil, the price per acre is $560 – $1,936

Site Preparation, Fine Grading, Seeding

Fine grading w/ seeding $2.33 /sq. yd.
Fine grading w/ seeding $11,277 /acre

In sum, total costs appear to approximate $20,000 per acre and could certainly exceed that figure in more challenging sites. Reducing graded and disturbed acreage clearly translates into substantial cost reductions.

Stormwater Management Calculations

No calculations are applicable for this BMP.

Specifications

The modification of road geometry is a site-specific issue, but in general any criteria that will result in significant earthwork should be reconsidered and evaluated.

BMP 5.6.2: Minimize Soil Compaction in Disturbed Areas

Minimizing Soil Compaction and Ensuring Topsoil Quality is the practice of enhancing, protecting, and minimizing damage to soil quality caused by land development.

Image Source: "Developing an Effective Soil Management Strategy: Healthy Soil Is At the Root Of Everything", Ocean County Soil Conservation District

Key Design Elements

- Protecting disturbed soils areas from excessive compaction during construction
- Minimizing large cleared areas and stockpiling of topsoil
- Using quality topsoil
- Maintaining soil quality after construction
- Reducing the Site Disturbance Area through design and construction practices
- Soil Restoration for areas that are not adequately protected or have been degraded by previous activities (Section 6)

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Very High
Recharge: Very High
Peak Rate Control: High
Water Quality: Very High

Water Quality Functions

TSS: 30%
TP: 0%
NO3: 0%

Description:

Soil is a physical matrix of weathered rock particles and organic matter that supports a complex biological community. This matrix has developed over a long time period and varies greatly within the state. Healthy soils, which have not been compacted, perform numerous valuable stormwater functions, including:

- Effectively cycling nutrients
- Minimizing runoff and erosion
- Maximizing water-holding capacity
- Reducing storm runoff surges
- Adsorbing and filtering excess nutrients, sediments, pollutants to protect surface and groundwater
- Providing a healthy root environment and creating habitat for microbes, plants, and animals
- Reducing the resources needed to care for turf and landscape plantings

Once natural soils are overly compacted and permeability is drastically reduced, these functions are lost and can never be completely restored (Hanks and Lewandowski, 2003). In fact, the runoff response of vegetated areas with highly compacted soils closely resembles that of impervious areas, especially during large storm events (Schueler, undated). Therefore this BMP is intended to prevent compaction or minimize the degree and extent of compaction in areas that are to be "pervious" following development.

Although erosion and sediment control practices are equally important to protect soil, this BMP differs from them in that it is intended to reduce the area of soil that experiences excessive compaction during construction activities.

Applications

This BMP can be applied to any land development that has existing areas of relatively healthy soil and proposed "pervious" areas. If existing soils have already been excessively compacted, Soil Restoration is applicable (Chapter 6).

Figure 5.7-1 Example of development with site compaction of soils

Design Considerations

Early in the design phase of a project, the designer should develop a soil management plan based on soil types and existing level of disturbance (if any), how runoff will flow off existing and proposed impervious areas, areas of trees and natural vegetation that can be preserved, and tests indicating soil depth and quality. The plan should clearly show the following:

1. **Protected Areas.** Soil and vegetation disturbance is not allowed. Protection of healthy, natural soils is the most effective strategy for preserving soil functions. Not only can the functions be maintained but protected soil organisms are also available to colonize neighboring disturbed areas after construction.

2. **Minimal Disturbance Areas.** Limited construction disturbance occurs - soil amendments may be necessary for such areas to be considered fully pervious after development. Areas to be vegetated after development should be designated Minimal Disturbance Areas.

3. **Construction Traffic Areas.** Areas where construction traffic is allowed - if these areas are to be considered fully pervious following development, a program of Soil Restoration will be required.

4. **Topsoil Stockpiling and Storage Areas.** These areas should be protected and maintained and are subject to Soil Restoration (including compost and other amendments) following development.

5. **Topsoil Quality and Placement.** Soil tests are recommended. Topsoil applied to disturbed areas should meet certain parameters as shown in Appendix C. Adequate depth (4" minimum for turf, more for other vegetation), organic content (5% minimum), and reduced compaction (1400 kPa maximum) are especially important (Hanks and Lewandowski, 2001). To allow water to pass from one layer to the other, topsoil must be "bonded" to the subsoil when it is reapplied to disturbed areas.

Figure 5.7-2 Example of site development with extreme soil compaction on steep slope

The first two areas (Protected and Minimal Disturbance) should be made as large as possible, identified by signage, and fenced off from construction traffic. Construction Traffic Areas should be as small as practicable.

Detailed Stormwater Functions

Volume Reduction Calculations

Minimizing Soil Compaction and Ensuring Topsoil Quality can reduce the volume of runoff by maintaining soil functions related to stormwater and thereby increasing infiltration and evapotranspiration. This can be credited in site stormwater calculations through lower runoff coefficients and/or higher infiltration rates. See Chapter 8 for volume reduction calculation methodologies.

Peak Rate Mitigation Calculations

Minimizing Soil Compaction and Ensuring Topsoil Quality can reduce the rate of runoff by maintaining soil functions related to stormwater. This can be credited in site stormwater calculations through lower runoff coefficients, higher infiltration rates, and/or longer times of travel. See Chapter 8 for peak rate calculation methodologies.

Water Quality Improvement

Minimizing Soil Compaction and Ensuring Topsoil Quality can improve water quality through infiltration, filtration, chemical and biological processes in the soil, and a reduced need for fertilizers and pesticides after development. See Chapter 8 for Water Quality Improvement methodologies.

Construction Issues

1. At the start of construction, Protected and Minimal Disturbance Areas must be identified with signage and fenced as shown on the construction drawings.
2. Protected and Minimal Disturbance Areas should be strictly enforced.
3. Protected and Minimal Disturbance Areas should be protected from excessive sediment and stormwater loads while upgradient areas remain in a disturbed state.
4. Topsoil storage areas should be maintained and protected at all times. When topsoil is reapplied to disturbed areas it must be "bonded" with the subsoil. This can be done by spreading a thin layer of topsoil (2 to 3 inches), tilling it into the subsoil, and then applying the remaining topsoil. Topsoil must meet certain requirements as detailed in Appendix C.

Maintenance Issues

Sites that have minimized soil compaction properly during the development process should require considerably less maintenance than sites that have not. Landscape vegetation will likely be healthier, have a higher survival rate, require less irrigation and fertilizer, and even look better.

Some maintenance activities such as frequent lawn mowing can cause considerable soil compaction after construction and should be avoided whenever possible. Planting low-maintenance native vegetation is the best way to avoid damage due to maintenance.

Protected Areas on private property could have an easement, deed restriction, or other legal measure to prevent future disturbance or neglect.

Cost Issues

Minimizing Soil Compaction and Ensuring Topsoil Quality generally results in a significant construction cost savings. Minimizing soil compaction can reduce disturbance, clearing, earthwork, the need for Soil Restoration, and the size and extent of costly, engineered stormwater management systems. Ensuring topsoil quality can significantly reduce the cost of landscaping vegetation (higher survival rate, less replanting) and landscaping maintenance.

Design costs may increase slightly due to a more thoughtful, site-specific design.

Specifications

Soil Restoration specifications can be found in Chapter 6.

References

Hanks, D. and Lewandowski, A. *Protecting Urban Soil Quality: Examples for Landscape Codes and Specifications*. USDA-NRCS, 2003.

Ocean County Soil Conservation District. *Impact of Soil Disturbance during Construction on Bulk Density and Infiltration in Ocean County, New Jersey*. 2001. Available at http://www.ocscd.org/publications.shtml as of May 2004.

Schueler, T. "The Compaction of Urban Soils," Technical Note #107 from *Watershed Protection Techniques*. 3(2): 661-665, undated.

BMP 5.6.3: Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species

Sites that require landscaping and re-vegetation should select and use vegetation (i.e., native species) that does not require significant chemical maintenance by fertilizers, herbicides, and pesticides.

Image: Rose Mallow, Bowman's Hill Wildflower Preserve, www.bhwp.org

Key Design Elements

- Preserve all existing high quality plant materials and soil mantle wherever possible
- Protect these areas during construction
- Develop Landscape Plan using native species
- Reduce landscape maintenance, especially grass mowing
- Reduce or eliminate chemical applications to the site, wherever possible
- Reduce or eliminate fertilizer and chemical-based pest control programs, wherever possible

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Low/Med.
Recharge: Low/Med
Peak Rate Control: Low/Med.
Water Quality: Very High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 50%

Description of BMP

Minimum Disturbance/Minimum Maintenance is comprised of two distinct steps, neither of which involves structural BMPs. The first step is to preserve existing vegetation on the development site as defined in BMP 5.6.1, so as to minimize the need for landscaping and re-vegetation. This BMP emphasizes the second step - the selection and use of vegetation that does not require significant chemical maintenance by fertilizers, herbicides and pesticides. Implicit in this BMP is the assumption that native species have the greatest tolerance and resistance to pests and require less fertilization and chemical application than non-native species. Landscape architects specializing in the local plant community usually are able to identify a variety of species that meet these criteria.

The production of biomass, such as grass clippings, is a significant pollutant source for water quality (if this biomass is not removed, over time this biomass decays and is converted to additional nutrient sources which add to the water quality problem). Native grasses and other herbaceous materials that do not require mowing are preferred. Because the selection of such materials begins at the concept design stage, where lawns are avoided or eliminated and landscaping species selected, this Non-Structural BMP can generally result in a site with reduced runoff volume and rate, as well as significant nonpoint source load reduction/prevention.

A native landscape may take several forms in Pennsylvania, ranging from re-establishment of woodlands to re-establishment of meadow. It should be noted that as this native landscape grows and matures, the positive stormwater benefits relating to volume control and peak rate control increase and these landscapes become much more effective in reducing runoff volumes than maintained landscapes such as lawns.

The elimination of traditional lawnscapes as a site design element can be an extremely difficult BMP to implement, given the extent to which the traditional lawn as an essential landscape design feature is embedded in current national culture.

Additional information relating to native species and their use in landscaping is available through PADCNR and its website: http://www.dcnr.state.pa.us/forestry/wildplant/native.aspx

Detailed Stormwater Functions

Volume Reduction Calculations and **Peak Rate Calculations** are not affected substantially by this BMP - at least in the short term. In the longer term, as species grow and mature, the runoff volume production of more mature native species can reasonably be expected to be lower than a conventionally maintained landscape (especially the conventionally mowed lawn). Native species are customarily strong growers with stronger and denser root and stem systems, thereby generating less runoff. If the objective is re-vegetation with woodland species, the longer-term effect is a significant reduction in runoff volumes, with increases in infiltration, evapotranspiration, and recharge, when contrasted with a conventional lawn planting. Peak rate reduction also is achieved. Similarly, meadow re-establishment is also more beneficial than a conventional lawn planting, although not so much as the woodland landscape. Again, these benefits are long term in nature and will not be forthcoming until the species have had an opportunity to grow and mature (one advantage of the meadow is that this maturation process requires considerably less time than a woodland area).

Water Quality Improvement
Minimizing Disturbance/Minimizing Maintenance through Use Native Species for Landscaping and Re-Vegetation can improve water quality preventively by minimizing application of fertilizers and pesticides/herbicides. Given the high rates of chemical application which have been documented at

newly created maintained areas for both residential and non-residential land uses, eliminating the opportunity for chemical application is important for water quality – perhaps the most effective management technique. Of special importance here is the reduction in fertilization and nitrate loadings. For example, Delaware's *Conservation Design for Stormwater Management* lists multiple studies, which document high fertilizer application rates, including both nitrogen and phosphorus, in newly created landscapes in residential and non-residential land developments. Expansive lawn areas in low density single-family residential subdivisions as well as large office parks – development which has and continues to proliferate in Pennsylvania municipalities - typically receives intensive chemical application, both fertilization and pest control, which can exceed application rates being applied to agricultural fields. Avoidance of this nonpoint pollutant source is an important water quality objective. See Chapter 8 for Water Quality Improvement methodologies.

Design Considerations

Native species is a broad term. Different types of native species landscapes may be created, from meadow to woodland areas, obviously requiring different approaches to planting. In terms of woodland areas, Delaware's *Conservation Design for Stormwater Management* states, "…a mixture of young trees and shrubs is recommended…. Tree seedlings from 12 to 18 inches in height can be used, with shrubs at 18 to 24 inches. Once a ground cover crop is established (to offset the need for mowing), trees and shrubs should be planted on 8-foot centers, with a total of approximately 430 trees per acre. Trees should be planted with tree shelters to avoid browse damage in areas with high deer populations, and to encourage more rapid growth." (p.3-50). As tree species grow larger, both shrubs and ground covers recede and yield to the more dominant tree species. The native tree species mix of small inexpensive saplings should be picked for variety and should reflect the local forest communities. Annual mowing to control invasives may be necessary, although the quick establishment of a strong-growing ground cover can be effective in providing invasive control. Native meadow planting mixes also are available. A variety of site design factors may influence the type of vegetative community, which is to be planned and implemented. In so many cases, the "natural" vegetation of Pennsylvania's communities is, of course, woodland.

Native species plantings can achieve variation in landscape across a variety of characteristics, such as texture, color, and habitat potential. Properly selected mixes of flowering meadow species can provide seasonal color; native grasses offer seasonal variation in texture. Seed production provides a food source and reinforces habitat. In all cases, selection of native species should strive to achieve species variety and balance, avoiding creation of single-species or limited species "monocultures" which pose multiple problems. In sum, many different aspects of native species planting reinforce the value of native landscaping, typically increasing in their functional value as species grow and mature over time.

Maintenance Issues

Although many conventional landscape management requirements are made unnecessary with this BMP, Using Native Species for Landscaping and Re-Vegetation can be expected to require some level of management – especially in the short term immediately following installation. Woodland areas planted with a proper cover crop can be expected to require annual mowing in order to control invasives. Application of a carefully selected herbicide around the protective tree shelters/tubes may be necessary, reinforced by selective cutting/manual removal, if necessary. This initial maintenance routine is necessary for the first 2 to 3 years of growth and may be necessary for up to 5 years until tree growth and tree canopy begins to form, naturally inhibiting weed growth. Once shading is adequate, growth of invasives and other weeds will be naturally prevented, and the woodland becomes self-maintaining. Review of the new woodland should be undertaken intermittently to determine if replacement trees should be provided (some modest rate of planting failure is typical). Meadow management is somewhat more straightforward; a seasonal mowing may be required, although care must be taken to make sure that any management is coordinated with essential reseeding and other important aspects of meadow re-establishment.

Construction Issues

During the initial conceptual design phase of a project, the design engineer should develop a Minimum Disturbance/Minimum Maintenance concept plan that includes the following:

- Areas of Existing Vegetation Being Preserved
- Areas to Be Re-Vegetated/Landscaped by Type (i.e., Native Species Woodland, Meadow, etc. plus Non-Native Conventional Areas)
- A landscape maintenance plan that avoids/minimizes mowing and other maintenance, except for limited areas of high visibility, special needs, etc.; specific landscape areas not to receive fertilization and other chemical applications should be identified in plan documentation

This information needs to appear on the plan drawings and receive municipal review and approval. Existing Vegetation Being Preserved must be flagged or fenced in the field. In terms of specific construction sequencing, all plantings including native species should be installed during the final construction phase of the project. Because native species plantings are likely to have a less "finished" appearance than conventionally landscaped areas, additional field identification for these areas through flagging or fencing similar to Existing Vegetation Being Preserved should be considered.

Cost Issues

BMP 5.6.3 cost implications are minimal during construction. Seeding for installation of a conventional lawn is likely to be less expensive than planting of a "cover" of native species, although when contrasted with a non-lawn landscape, "natives" often are not more costly than other non-native landscape species. In terms of woodland creation, somewhat dated (1997) costs have been provided by the *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers*:

$860/acre trees with installation
$1,600/acre tree shelters/tubes and stakes
$300/acre for four waterings on average

Current values may be considerably higher, well over $3,000/acre for installation costs. Costs for meadow re-establishment are lower than those for woodland, in part due to the elimination of the need for shelters/tubes. Again, such costs can be expected to be greater than installation of conventional lawn (seeding and mulching), although the installation cost differences diminish when conventional lawn seeding is redefined in terms of conventional planting beds.

Cost differentials grow greater when longer term operating and maintenance costs are taken into consideration. If lawn mowing can be eliminated, or even reduced significantly to a once per year requirement, substantial maintenance cost savings result, often in excess of $1,500 per acre per year. If chemical application (fertilization, pesticides, etc.) can be eliminated, substantial additional savings result with use of native species. These reductions in annual maintenance costs resulting from a native landscape re-establishment very quickly outweigh any increased installation costs that are required at project initiation. Unfortunately, because developers pay for the installation costs and longer term reduced maintenance costs are enjoyed by future owners, there is reluctance to embrace native landscaping concepts.

Stormwater Management Calculations

See Chapter 8 for calculations.

References

Bowman's Hill Wildflower Preserve, Washington Crossing Historic Park, PO Box 685, New Hope, PA 18938-0685, Tel (215) 862-2924, Fax (215) 862-1846, Native plant reserve, plant sales, native seed, educational programs, www.bhwp.org

Morris Arboretum of the University of Pennsylvania; 9414 Meadowbrook Avenue, Philadelphia, PA 19118, Tel (215) 247-5777, www.upenn.edu/morris, PA Flora Project Website: Arboretum and gardens (some natives), educational programs, PA Flora Project, www.upenn.edu/paflora

Pennsylvania Department of Conservation and Natural Resources; Bureau of Forestry; PO Box 8552, Harrisburg, PA 17105-8552, Tel (717)787-3444, Fax (717)783-5109, Invasive plant brochure; list of native plant and seed suppliers in PA; list of rare, endangered, threatened species.

Pennsylvania Native Plant Society, 1001 East College Avenue, State College, PA 16801 www.pawildflower.org

Western Pennsylvania Conservancy; 209 Fourth Avenue, Pittsburgh, PA 15222, Tel (412) 288-2777, Fax (412) 281-1792, www.paconserve.org

5.7 Reduce Impervious Cover

BMP 5.7.1: Reduce Street Imperviousness

Reduce impervious street areas by minimizing street widths and lengths.

Key Design Elements	Potential Applications / Stormwater Functions / Water Quality Functions
▪ Evaluate traffic volume and on-street parking requirements. ▪ Consult with local fire code standards for access requirements. ▪ Minimize pavement by using alternative roadway layouts, restricting on-street parking, minimizing cul-de-sac radii, and using permeable pavers.	**Potential Applications** Residential: Yes Commercial: Yes Ultra Urban: Limited Industrial: Yes Retrofit: Limited Highway/Road: Limited **Stormwater Functions** Volume Reduction: Very High Recharge: Very High Peak Rate Control: Very High Water Quality: Medium **Water Quality Functions** TSS: Preventive TP: Preventive NO3: Preventive

Description

Reducing impervious street areas performs valuable stormwater functions, in contrast to conventional or baseline development. Some of these functions are increasing infiltration, decreasing stormwater runoff volume, increasing stormwater time of concentration, improving water quality by decreasing the pollutant loading of streams, improving natural habitats by decreasing the deleterious effects of stormwater runoff and decreasing the concentration and energy of stormwater. Imperviousness greatly influences stormwater runoff volume and quality by facilitating the rapid transport of stormwater and collecting pollutants from atmospheric deposition, automobile leaks, and additional sources. Increased imperviousness alters an area's hydrology, habitat structure, and water quality. Stream degradation has been witnessed at impervious levels as low as 10-20% (Center for Watershed Protection, 1995).

Applications

Street Width

Streets comprise the largest single component of imperviousness in residential design. Universal application of high-volume, high-speed traffic design criteria results in many communities requiring excessively wide streets. Coupled with the perceived need to provide both on-street parking and emergency vehicle access, the end result of these requirements is residential streets that may be 36 feet or greater in width (Center for Watershed Protection, 1998).

The American Society of Civil Engineers (ASCE) and the American Association of State Highway and Transportation Officials (AASHTO) recommend that low traffic volume roads (less than 50 homes or 500 daily trips) can be as narrow as 22 feet. PennDot Pub. 70 gives a range of 18-22 foot width for low volume local roads. Some municipalities have reduced their lowest trafficable residential roads to 18 feet or less. Higher volume roads are recommended to be wider. Table 5.7-1 provides sample road widths from different jurisdictions.

The desire for adequate emergency vehicle access, notably fire trucks, also leads to wider streets. While it is perceived that very wide streets are required for fire trucks, some local fire codes permit roadway widths as narrow as 18 feet (as shown in Table 5.7-2). Concerns also exist about other vehicles and maintenance activities on narrow streets. School buses are typically nine feet wide from mirror to mirror; Prince George's and Montgomery Counties in Maryland require only a 12-foot driving lane for buses (Center for Watershed Protection, 1998). Similarly, trash trucks require only a 10-½ foot driving lane, as they are a standard width of nine feet (Waste Management, 1997; BFI, 1997). In some cases, road width for emergency vehicles may be added through use of permeable pavers for roadway shoulders (see Figure 5.7-1).

Snow removal on narrower streets is readily accomplished with narrow, 8-foot snowplows. Restricting parking to one side of the street allows accumulated snow to be piled on the other side. Safety concerns are also cited as a justification for wider streets, but increased vehicle-pedestrian accidents on narrower streets are not supported by research. The Federal Highway Administration states that narrower streets reduce vehicle travel speeds, decreasing the incidence and severity of accidents.

Higher density developments require wider streets, but alternative layouts can minimize street widths. For example, in instances where on-street parking is desired, impervious pavement is used for the travel lanes and permeable pavers are placed on the road apron for the parking lanes. The width of permeable pavers is often the width of a standard parking lane (six to eight feet). This design approach minimizes impervious area while also providing an infiltration and recharge area for the impervious roadway stormwater (Prince George's County, Maryland, 2002).

Table 5.7-1: Narrow Residential Street Widths

Jurisdiction	Residential Street Pavement Width	Maximum Daily Traffic (trips/day)
State of New Jersey	20 ft. (no parking)	0-3,500
	28 ft. (parking on one side)	0-3,500
State of Delaware	12 ft. (alley)	---
	21 ft. (parking on one side)	---
Howard County, Maryland	24 ft. (parking not regulated)	1,000
Charles County, Maryland	24 ft. (parking not regulated)	---
Morgantown, West Virginia	22 ft. (parking on one side)	---
Boulder, Colorado	20 ft.	150
	20 ft. (no parking)	350-1,000
	22 ft. (parking on one side)	350
	26 ft. (parking on both sides)	350
	26 ft. (parking on one side)	500-1,000
Bucks County, Pennsylvania	12 ft (alley)	---
	16-18 ft. (no parking)	200
	20-22 ft. (no parking)	200-1,000
	26 ft. (parking on one side)	200
	28 ft. (parking on one side)	200-1,000

(Cohen, 1997; Bucks County Planning Commission, 1980; Center for Watershed Protection, 1998)

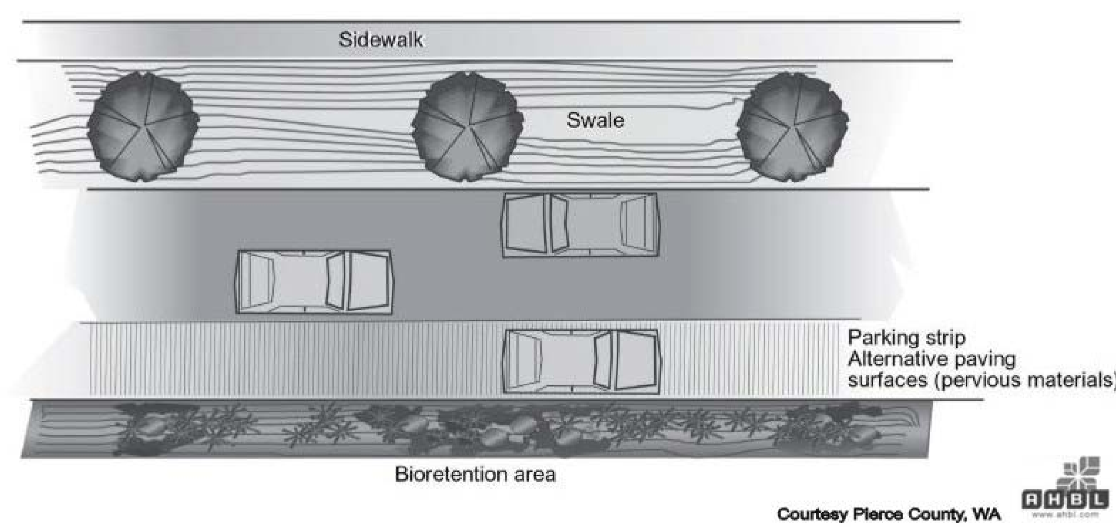


Figure 5.7-1 Reduced road width using adjacent pervious strips.

Table 5.7-2 Fire Vehicle Street Requirements

Source	Residential Street Width
U.S. Fire Administration	18-20 ft.
Baltimore County, Maryland Fire Department	16 ft. (no on-street parking) 24 ft. (on-street parking)
Virginia State Fire Marshall	18 ft. minimum
Prince George's County, Maryland Department of Environmental Resources	24 ft. (no parking) 30 ft. (parking on one side) 36 ft. (parking on both sides) 20 ft. (fire truck access)
Portland, Oregon Office of Transportation	18 ft. (parking on one side) 26 ft. (parking on both sides)

(Adapted from Center for Watershed Protection, 1998)

In residential neighborhoods, the perception of the need for large quantities of parking may lead developers to provide on-street parking; residential land use will greatly influence the quantity needed. Each on-street lane increases street impervious cover by 25%. Many communities require 2-2.5 parking spaces per residence. In single-lot neighborhoods, with both standard and reduced setbacks, parking requirements can likely be met using private driveways and garages. In townhouse communities, if on-street parking is required, providing one on-street space per residence is likely sufficient. Urban settings will require the greatest use of on-street parking. However, continuous parking lanes on both sides of the street, while common for all residential land uses, is often unnecessary.

When on-street parking is necessary, queuing lanes provide a parking system alternative that minimizes imperviousness. Communities are using queuing lanes to narrow roads while also providing two-way traffic access. In a queuing lane design, one traffic lane is used by moving traffic and the parking lanes allow oncoming traffic to pull over and let opposite traffic pass (Center for Watershed Protection, 1998). Figure 5.7-2 shows traditional and queuing lane designs.

Street Length

Numerous factors influence street length including clustering techniques (discussed in a separate Chapter). As with street width, street length greatly impacts the overall imperviousness of a developed site. While no one prescriptive technique exists for reducing street length, alternative street layouts should be investigated for options to minimize impervious cover.

Cul-de-sacs

The use of cul-de-sacs introduces large areas of imperviousness into residential developments, with some communities requiring the cul-de-sac radius to be as large as 50 to 60 feet. In most instances, and in large radius cul-de-sac designs especially, the full area of the circle is neither necessary nor utilized. When cul-de-sacs are necessary, two primary alternatives can reduce their imperviousness.

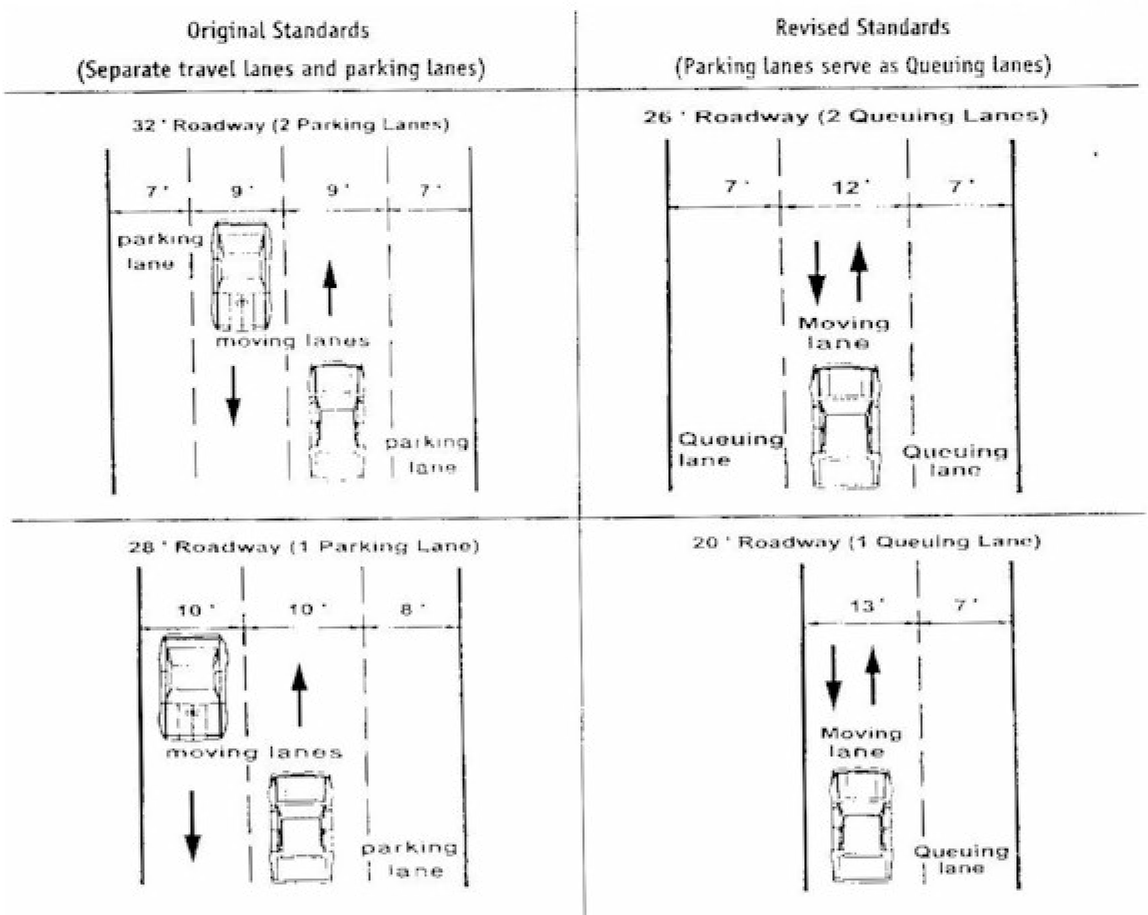


Figure 5.9-2 Traditional Streets vs. Traffic Queuing (Portland, Oregon Office of Transportation, 1994)

The first alternative is to reduce the required radius of the cul-de-sac. Many jurisdictions have identified required turnaround radii (shown in Table 5.7-3).

A second alternative is to incorporate a landscaped island into the center of the cul-de-sac. This design approach provides the necessary turning radius, minimizes impervious cover, and provides an aesthetic amenity to the community. In some instance, developments are placing bioretention cells (discussed in Chapter 6) in the center of cul-de-sacs to not only reduce imperviousness, but also provide a distributed method of treating stormwater runoff. Other cul-de-sac configurations have been developed which reduce impervious area.

Cost Issues

Street Width

Costs for paving have been estimated to be approximately $15/yd² (Center for Watershed Protection, 1998). At this cost, for each one-foot reduction in street width, estimated savings are $1.67 per linear foot of paved street. For example reducing the width of a 500-foot road by 5 feet would result in a savings of over $4,100. This cost is exclusive of other construction costs including grading and infrastructure.

Street Length

In addition to pavement, costs for street lengths, including traditional curb and gutter and stormwater management controls, are approximately $150 per linear foot of road (Center for Watershed Protection, 1998). Decreasing road length by 100 feet can produce a savings of $15,000. Simply factoring in pavement costs at $15/yd^2, a 100-foot length reduction in a 25-foot wide road would produce a savings in excess of $4,000.

Table 5.7-3: Example Cul-de-sac Turnaround Radii

Source	Residential Street Width
Portland, Oregon Office of Transportation	35 ft. (with Fire Deaprtment Approval)
Buck County, Pennsylvania Planning Commission	38 ft. (outside turning radius)
Fairfax County, Virginia Fire and Rescue	45 ft.
Baltimore County, Maryland Fire Department	35 ft. (with Fire Deaprtment Approval)
Montgomery County, Maryland Fire Department	45 ft.
Prince George's County, Maryland Fire Department	43 ft.

(Adapted from Center for Watershed Protection, 1998)

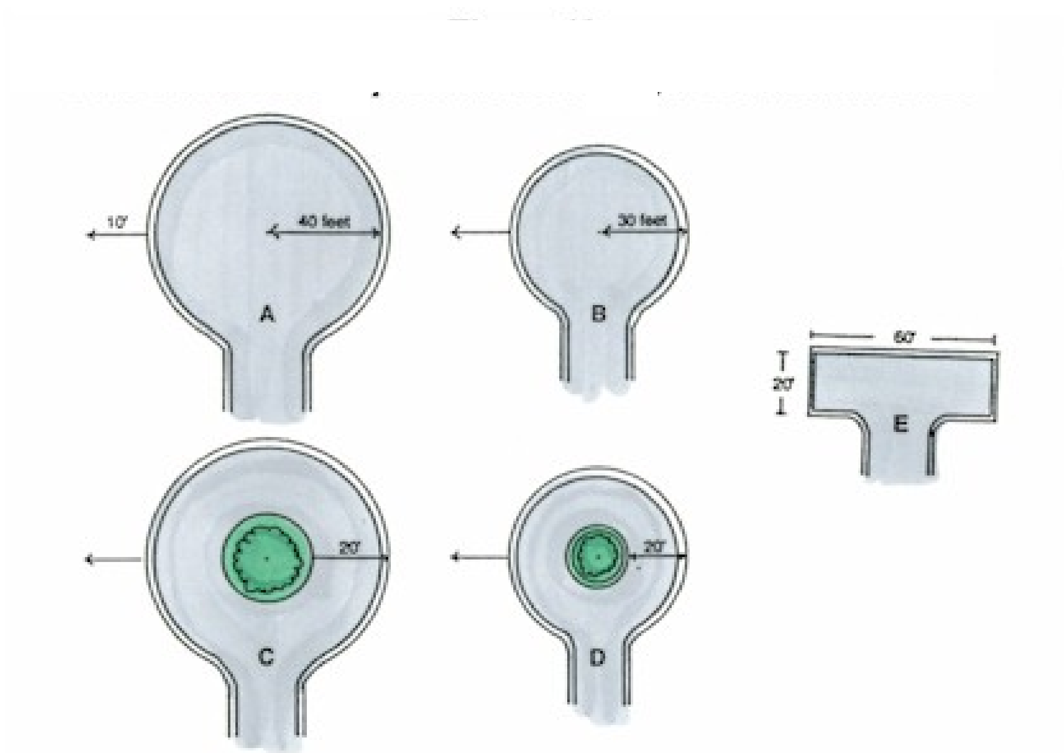


Figure 5.7-3 Five Turnaround Options for the end of a Residential Street, ("Better Site Design: A Handbook for Changing Development Rules in Your Community", Center for Watershed Protection, *August, 1998)*

BMP 5.7.2: Reduce Parking Imperviousness

Reduce imperviousness by minimizing imperviousness associated with parking areas.

Key Design Elements	Potential Applications / Functions
▪ Evaluate parking requirements considering average demand as well as peak demand. ▪ Consider the application of smaller parking stalls and/or compact parking spaces. ▪ Analyze parking lot layout to evaluate the applicability of narrowed traffic lanes and slanted parking stalls. ▪ Where appropriate, minimize impervious parking area by utilizing overflow parking areas constructed of pervious paving materials.	**Potential Applications** Residential: Yes Commercial: Yes Ultra Urban: Limited Industrial: Yes Retrofit: Limited Highway/Road: Limited **Stormwater Functions** Volume Reduction: Very High Recharge: Very High Peak Rate Control: Very High Water Quality: High **Water Quality Functions** TSS: Preventive TP: Preventive NO3: Preventive

Description

Reducing parking imperviousness performs valuable stormwater functions in contrast to conventional or baseline development: Increasing infiltration; Decreasing stormwater runoff volume; Increasing stormwater time of concentration; Improving water quality by decreasing the pollutant loading of streams; Improving natural habitats by decreasing the deleterious effects of stormwater runoff; Decreasing the concentration and energy of stormwater. Imperviousness greatly influences stormwater runoff volume and quality by facilitating the rapid transport of stormwater and collecting pollutants from atmospheric deposition, automobile leaks, and additional sources. Increased imperviousness alters an area's hydrology, habitat structure, and water quality. Stream degradation has been witnessed at impervious levels as low as 10-20% (Center for Watershed Protection, 1995).

Applications

In commercial and industrial areas, parking lots comprise the largest percentage of impervious area. Parking lot size is dictated by lot layout, stall geometry, and parking ratios. Modifying all or any of these three aspects can serve to minimize the total impervious areas associated with parking lots.

Parking Ratios

Parking ratios express the specified parking requirements provided for a given land use. These specified ratios are often set as minimum requirements. Many developers seeking to ensure adequate parking provide parking in excess of the minimum parking ratios. Additionally, commercial parking is often provided to meet the highest hourly demand of a given site, which may only occur a few times per year. Excess parking is often rationalized by the desire to avoid potential complaints from patrons that have difficulty finding parking. However, as shown in Table 5.7-4, average parking demand is generally less than typical required parking ratios and therefore much less than parking provided in excess of these ratios. The result of using typically specified parking ratios is parking capacity that is underutilized.

Table 5.7-4 Example Minimum Parking Ratios

Land Use	Parking Ratio	Average Parking Demand
Single Family Home	2 spaces per dwelling unit	1.1 spaces per dwelling unit
Shopping Center	5 spaces per 1,000 ft^2 of GFA	3.97 spaces per 1,000 ft^2 of GFA
Convenience Store	3.3 spaces per 1,000 ft^2 of GFA	Not available
Industrial	1 space per 1,000 ft^2 of GFA	1.48 spaces per 1,000 ft^2 of GFA
Medical/Dental Office	5.7 spaces per 1,000 ft^2 of GFA	4.11 spaces per 1,000 ft^2 of GFA

GFA – gross floor area, excluding storage and utility space

(Institute of Transportation Engineers, 1987; Smith, 1984; Wells, 1994)

In residential neighborhoods, the perception of the need for large quantities of parking may lead developers to provide on-street parking; residential land use will greatly influence the quantity needed. Each on-street lane increases street impervious cover by 25%. Many communities require 2-2.5 parking spaces per residence. In single-lot neighborhoods, with both standard and reduced setbacks, parking requirements can likely be met using private driveways and garages. In townhouse communities, if on-street parking is required, providing one on-street space per residence is likely sufficient. Urban settings will require the greatest use of on-street parking. However, continuous parking lanes on both sides of the street, while common for all residential land uses, is often unnecessary. When on-street parking is necessary, queuing lanes (discussed in BMP 5.7.1) provide a parking system alternative that minimizes imperviousness.

Parking Spaces and Lot Layout

Parking spaces are comprised of five impervious components (Center for Watershed Protection, 1998):

1. The parking stall;
2. The overhang at the stall's edge;
3. A narrow curb or wheel stop;
4. The parking aisle that provides stall access; and
5. A share of the common impervious areas (e.g., fire lanes, traffic lanes).

Of these, the parking space itself accounts for approximately 50% of the impervious area, with stall sizes ranging from 160 to 190 ft^2. Several measures can be taken to limit parking space size. First, jurisdictions can review standard parking stall sizes to determine their appropriateness. A typical stall dimension may be 10 ft by 18 ft, much larger than needed for many vehicles; while the largest SUVs are wider, the great majority of SUVs and vehicles are less than 7 ft providing opportunity for making stalls slightly narrower and shorter. In addition, typical parking lot layout includes parking aisles that accommodate two-way traffic and perpendicularly oriented stalls. The use of one-way isles and angled parking stalls can reduce impervious area.

Jurisdictions can also stipulate that parking lots designate a percentage of stalls as compact parking spaces. Smaller cars comprise 40% or more of all vehicles and compact parking stalls create 30% less impervious cover than average-sized stalls (Center for Watershed Protection, 1998). This is currently an underutilized practice that has potential to reduce the total area of parking lots.

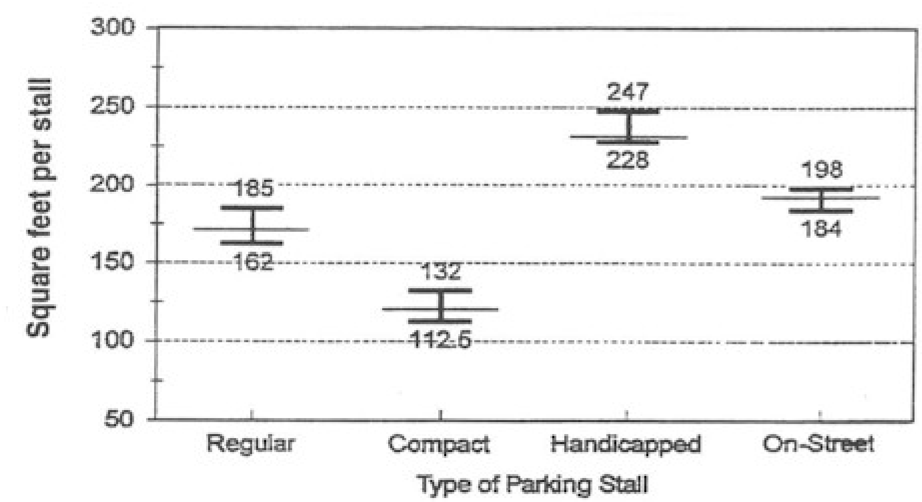


Figure 5.7-4 ("Conservation Design for Stormwater Management", DNREC, 1997)

Parking Lot Design

Because of parking ratio requirements and the desire to accommodate peak parking demand, even when it occurs only occasionally throughout the year, parking lots often provide parking capacity substantially in excess of average parking needs. This results in vast quantities of unused impervious surface.

A design alternative to this scenario is to provide designated overflow parking areas. The primary parking area, sized to meet average demand, would still be constructed on impervious pavement to meet local construction codes and American with Disabilities Act requirements. However, the overflow parking area, designed to accommodate increased parking requirements associated with peak demand, would be constructed on pervious materials (e.g., permeable pavers, grass pavers, gravel). This design approach focused on average parking demand will still meet peak parking demand requirements while reducing impervious pavement.

Figure 5.10-2 Overflow parking using permeable pavers

Cost Issues

Estimates for parking construction range from $1,200 to $1,500 dollars per space (Center for Watershed Protection, 1998). For example, assuming a cost of $1,200 per parking space, reducing the required parking ratio for a 20,000 ft^2 shopping center from 5 spaces per 1,000 ft^2 to 4 spaces per 1,000 ft^2 would represent a savings of $24,000.

Parking lots incorporating pervious overflow areas may not present cost savings, as permeable paving products are generally more expensive than traditional asphalt. However, the additional costs may be offset by reduced curb and gutter and stormwater management costs.

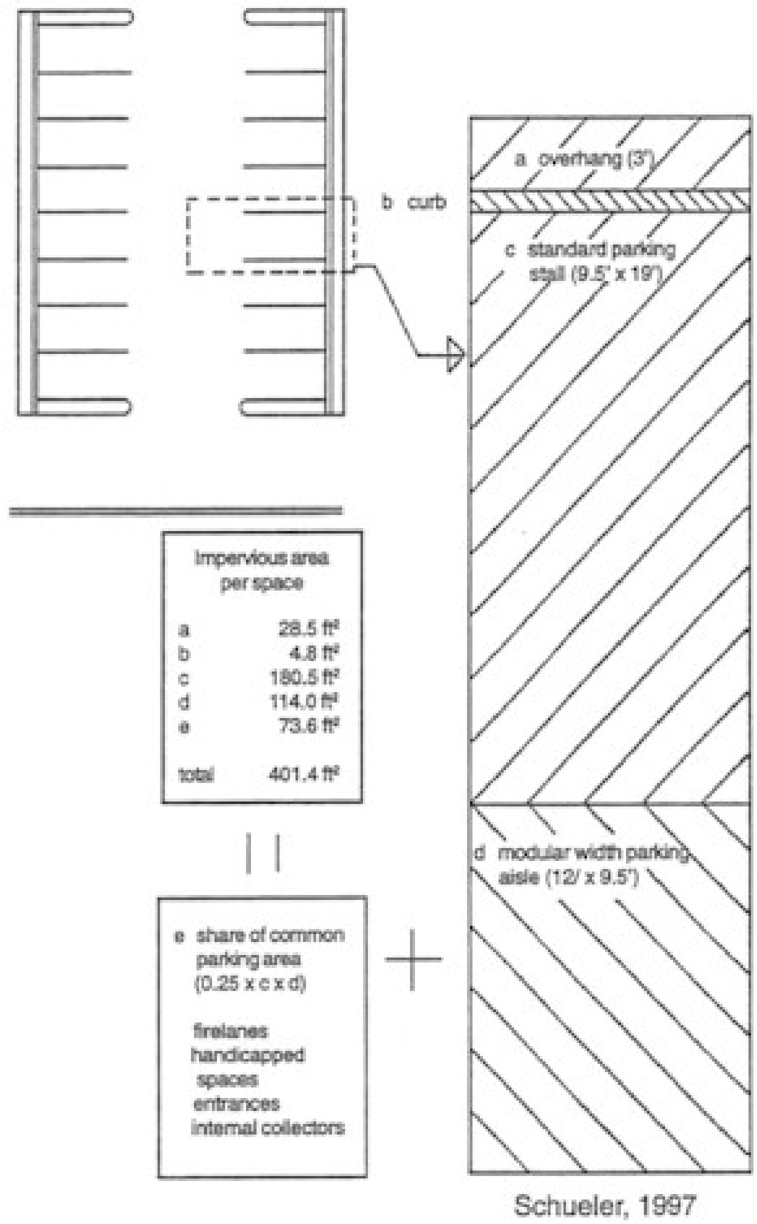


Figure 5.7-5 Parking Stall Dimensions (Schueler, 1997)

References

Center for Watershed Protection, 1998
Center for Watershed Protection, 1995

5.8 Disconnect/Distribute/Decentralize

BMP 5.8.1: Rooftop Disconnection

Minimize stormwater volume by disconnecting roof leaders and directing rooftop runoff to vegetated areas to infiltrate.

Key Design Elements

- Stormwater collection systems.
- Redirect rooftop overland flow to minimize rapid transport to conveyance structures and impervious areas, such as ditches and roadways.
- Direct runoff to vegetated areas designed to receive stormwater.

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Limited
Industrial: Limited
Retrofit: Limited
Highway/Road: Limited

Stormwater Functions

Volume Reduction: High
Recharge: High
Peak Rate Control: High
Water Quality: Low

Water Quality Functions

TSS: 30%
TP: 0%
NO3: 0%

Description

Traditionally, building codes have encouraged the rapid conveyance of rooftop runoff away from building structures. It is not uncommon for municipal codes to specify minimum slopes which serve to accelerate overland flow onto and across yards and lawns, directed ever more rapidly toward streets and gutters. Concerns pertaining to surface ponding of rooftop stormwater and potential ice formation on sidewalks and driveways are the main drivers of these lot requirements (Center for Watershed Protection, 1998). These requirements, stemming from a convention of rapid transmission of stormwater, serve to discourage on-site treatment of rooftop stormwater. This trend is further exacerbated in northern latitudes where icing concerns are paramount and, consequently, where downspouts may be connected directly to the stormwater collection system.

Disconnecting roof leaders from conventional stormwater conveyance systems allows rooftop runoff to be collected and managed on site. Rooftop runoff can be directed to designed vegetated areas (discussed in Chapter 6) for on-site storage, treatment, and volume control. This BMP offers a distributed, low-cost method for reducing runoff volume and improving stormwater quality through:

- Increasing infiltration and evapotranspiration.
- Increasing filtration.
- Decreasing stormwater runoff volume.
- Increasing stormwater time of concentration.

Variations

In addition to directing rooftop runoff to vegetated areas, runoff may also be discharged to non-vegetated BMPs, such as dry wells, rain barrels, and cisterns for stormwater retention and volume reduction. With proper design, this rooftop water can be used for lawn watering, gardening, toilet flushing and fire protection.

Applications

Routing rooftop runoff to naturally vegetated areas will reduce runoff volume and peak discharge, as well as improve water quality by slowing runoff, allowing for filtration, and providing opportunity for infiltration and evapotranspiration. The use of pervious areas for rooftop discharge has the ability to reduce the quantity of site stormwater runoff and improve the quality of the stormwater that does discharge from the site. Alternatives for disconnecting roof leaders and the use of vegetated areas should consider the following issues (Prince George's County Department of Environmental Protection, 1997; Maryland Department of the Environment, 1997).

- Encourage shallow sheet flow through vegetated areas, using flow spreading and leveling devices if necessary.
- Direct roof leader flow into BMPs designed specifically to receive and convey rooftop runoff.
- Direct flows into stabilized vegetated areas, including on-lot swales and bioretention areas.
- Rooftop runoff may also be directed to on-site depression storage areas.
- Runoff from industrial roofs and similar uses should not be directed to vegetated areas, if there is reason to believe that pollutant loadings will be elevated.
- Limit the contributing rooftop area to a maximum of 500 ft^2 per downspout.
- Flow from roof leaders should not contribute to basement seepage.

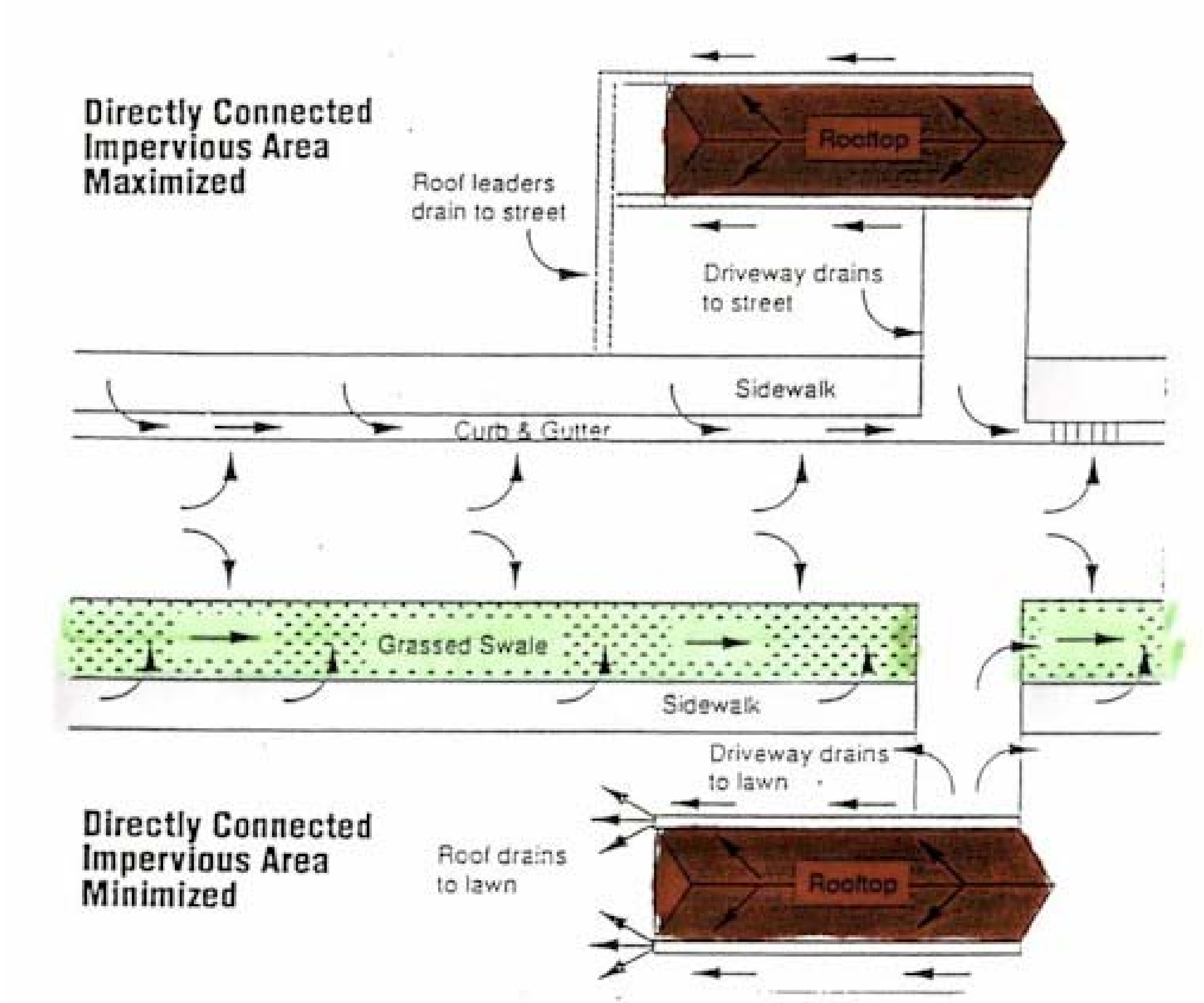


Figure 5.8-1 Examples of Directly Connected Impervious Areas (Roesner, ASCE, 1991)

Careful consideration should be given to the design of vegetated collection areas. Concerns pertaining to basement seepage and water-soaked yards are not unwarranted, with the potential arising for saturated depressed areas and eroded water channels. The proper design and use of bioretention areas, infiltration trenches, and/or dry wells will reduce or eliminate the potential of surface ponding and facilitate functioning during cold weather months.

Maintenance of the planted areas would be required, but would be limited. Routine maintenance would include a biannual health evaluation of the vegetation and subsequent removal of any dead or diseased vegetation plus mulch replenishment, if included in the design. This maintenance can be incorporated into regular maintenance of the site landscaping. If the vegetated area is located in a residential neighborhood, the maintenance responsibility could be delegated to the residents. The use of native plant species in the vegetated area will reduce fertilizer, pesticide, water, and overall maintenance requirements.

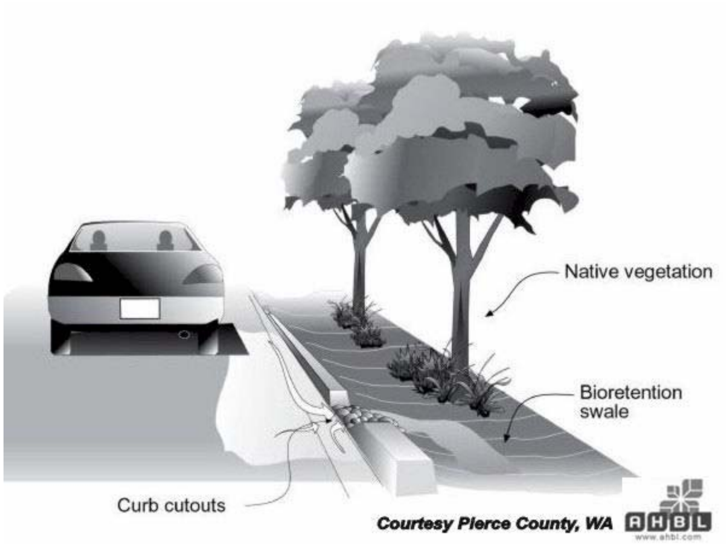
Cost Issues

Construction cost estimates for vegetated areas should be similar or in line with that of conventional landscaping. If bioretention areas are incorporated into the site, their costs are slightly more than costs required for conventional landscaping. Commercial, industrial, and institutional site costs range between $10 and $40 per square foot, based on the design of the bioretention area and the control structures included. These costs, however, can potentially be offset by the reduced costs of conventional stormwater management systems that otherwise would be required, if it were not for the reduction achieved through the application of this BMP.

References

Prince George's County Department of Environmental Protection, 1997
Maryland Department of the Environment, 1997
Center for Watershed Protection, 1998

BMP 5.8.2: Disconnection from Storm Sewers



Minimize stormwater volume by disconnecting impervious roads and driveways and directing runoff to grassed swales and/or bioretention areas to infiltrate.

Key Design Elements

- Disconnect road and driveways from stormwater collection systems.
- Redirect road and driveway runoff into grassed swales or other vegetated systems designed to receive stormwater.
- Eliminate curbs/gutters/conventional collection and conveyance.

Potential Applications

Residential:	Yes
Commercial:	Yes
Ultra Urban:	Limited
Industrial:	Limited
Retrofit:	Limited
Highway/Road:	Limited

Stormwater Functions

Volume Reduction:	High
Recharge:	High
Peak Rate Control:	High
Water Quality:	Low

Water Quality Functions

TSS:	30%
TP:	0%
NO3:	0%

Description

Impervious roads and driveways account for a large percentage of post-development imperviousness. These surfaces influence stormwater runoff volume and quality by facilitating the rapid transport of stormwater and collecting pollutants from atmospheric deposition, automobile leaks, and additional sources. Considered a source of more potentially damaging pollution than rooftops, roads and driveways contribute toxic chemicals, oil, and metals to stormwater runoff.

Conventional stormwater management has involved the rapid removal and conveyance of stormwater from these surfaces. The result of this management system has been increased runoff volume, decreased time of concentration, and greater pollutant mobility. Distributed stormwater management through the use of vegetated swales and bioretention areas (discussed in Section 6.4.8 and 6.4.5) can reduce the volume of stormwater runoff while providing on-site treatment and pollutant removal, providing:

- Increased infiltration and evapotranspiration.
- Increased filtration.
- Decreased stormwater runoff volume.
- Increased stormwater time of concentration.

Variations

A variety of alternatives exist for redirecting road and driveway runoff away from stormwater collection systems. In addition to vegetated swales, infiltration trenches or bioretention areas may be utilized. Curbing may be eliminated entirely or selectively eliminated, as shown in Figure 5.8-2. The choice of BMP will depend upon site-specific characteristics including soil type, slope, and stormwater volume.

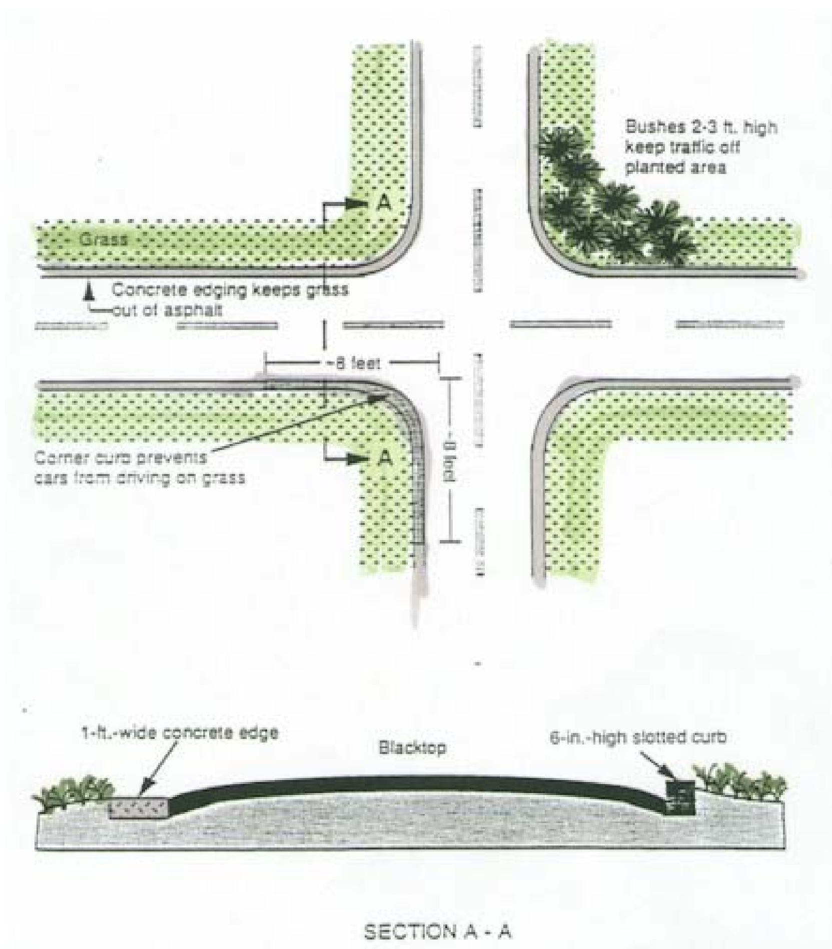


Figure 5.8-2 Example of Concrete Road Edging and Corner Curb (Roesner, ASCE, 1991)

Applications

Routing road and driveway runoff to vegetated swales will reduce runoff volume and peak discharge, as well as improve water quality by slowing runoff, allowing for filtration, and providing opportunity for infiltration and evapotranspiration. Most importantly, in contrast to conventional systems where roads and driveways are connected directly to the stormwater collection and conveyance system, vegetated swales offer the potential for pollutant reductions (see additional discussion in Section 6.8). When stormwater enters the stormwater system directly from road and driveways surfaces, a large variety of pollutants are introduced into the stormwater and eventually the receiving stream. These pollutants include toxic chemicals, oil, metals, and large particulate matter.

The use of vegetated swales, while slowing runoff discharge and permitting infiltration, also allows for pollutant reduction facilitated by the soil media complex and plant uptake. Thus, vegetated swales used in this manner serve a range of functions, intercepting runoff, reducing stormwater volume, and retaining and reducing pollutants. Proper design and implementation still allows stormwater to be quickly removed from road and driveway surfaces alleviating concerns over standing water.

The suitability of vegetated swales depends on land use, soil type, imperviousness of the contributing watershed, and dimensions and slope of the vegetated swale system. Use of natural low-lying areas is encouraged and natural drainage courses should be preserved and utilized.

Maintenance of the vegetated swale should include providing sufficient capacity of the channel and maintaining a dense, healthy vegetated cover. Maintenance activities should include periodic mowing (with plantings never cut shorter than the design flow depth), weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages.

Cost Issues

See discussion in Chapter 6.4.8. Vegetated swale construction costs are estimated at approximately $0.25 per ft2. By including design costs, this estimated cost increases to $0.50 per ft^2, allowing vegetated swales to compare favorably with other stormwater management practices.

5.9 Source Control

BMP 5.9.1: Streetsweeping

Use of one of several modes of sweeping equipment (e.g., mechanical, regenerative air, or vacuum filter sweepers) on a programmed basis to remove larger debris material and smaller particulate pollutants, preventing this material from clogging the stormwater management system and washing into receiving waterways/waterbodies.

Key Design Elements	Potential Applications / Functions
▪ Use proper equipment; dry vacuum filters demonstrate optimal results, significantly better than mechanical and regenerative air sweeping, though move slowly and are most costly ▪ Develop a proper program; vary sweeping frequency by street pollutant load (a function of road type, traffic, adjacent land uses, other factors); sweep roads with curbs/gutters ▪ Develop a proper program; restrict parking when sweeping to improve removal. ▪ Develop a proper program; seasonal variation for winter applications as necessary.	**Potential Applications** Residential: Yes Commercial: Yes Ultra Urban: Yes Industrial: Yes Retrofit: Yes Highway/Road: Yes **Stormwater Functions** Volume Reduction: Low/None Recharge: Low/None Peak Rate Control: Low/None Water Quality: High **Water Quality Functions** TSS: 85% TP: 85% NO3: 50%

Description

National Urban Runoff Program (NURP) studies from the 1980's reported generally very poor results from street sweeping. In some cases, results suggested that water quality effects of conventional mechanical street sweeping programs were actually negative. This is possibly explained by the fact that the superficial sweeping accomplished by mechanical sweepers removes a "crust" of large, coarser debris on many surfaces and exposes the finer particles to upcoming storm events. These particles are then washed into receiving water bodies. However, new street sweeping technology (see discussion below) has dramatically improved street sweeping performance. While these new street sweeping technologies are considerably more costly than previous street sweeping technologies, their pollutant reduction performance compares quite favorably to other pollutant reduction BMPs. Streetsweeping can actually be quite cost effective in terms of water quality performance.

Figure 5.13-1 Vacuum Filter Street sweeper

Variations

Variations in street sweeping relate primarily to differences in equipment but also relate to important aspects of the street sweeping programs, such as frequency of street sweeping, use of regulations such as parking prohibitions, and other program factors.

Equipment -

Mechanical broom: use of mechanical brooms/brushes with conveyor belts. Designed to remove standard road debris, using various types of circulating brushes that sweep material onto conveyors and then into bins. Some machines apply water to reduce dust. Includes the Elgin Pelican (3-wheel) and Eagle (4-wheel), Athey;s Mobile (3- and 4-wheel) and Schwarze M-series. Stormwater reports that the vast bulk of sweepers in use in the US are of this type. These sweepers are least expensive and vary in cost from (approximately $60,000 in 2002, according to Stormwater magazine).

Regenerative air: compressed air is directed onto the road surface, loosening fine particles that are then vacuumed. Includes Elgin's Crosswind J, Mobile's RA730 series, Schwarze's A-series, Tymco sweepers. About twice as expensive as mechanical sweepers ($120,000 in 2002, according to Stormwater magazine).

Vacuum filter: vacuum assisted small-micron particle sweepers, either wet or dry. Dry vacuum includes mechanical broom sweeping with a vacuum (Elgion's GeoVac and Whirlwind models and Schwarze's EV-series particulate management); this technology works well even in cold weather conditions. Wet vacuum uses water dust suppression with scrubbers that apply water to pavement; particles are suspended, and then vacuumed. Four to 5 times as expensive as mechanical sweepers, according to Stormwater magazine in 2002. Equipment has been constrained by slow driving speeds (max of 25 mph).

Tandem sweeping: using two machines, surfaces are mechanically swept and then vacuumed.

Applications

Streets weeping programs vary by sweeping frequency that in turn depends on several other factors. Certainly the most obvious factor is the intensity of the roadway and its expected pollutant load – the greater the traffic intensity, the greater the pollutant load. Other factors such as frequency and intensity of rainfall also affect desired street sweeping frequency. Sutherland and Jelen (1997), measuring sediment load reduction, found very high pollutant load reduction with weekly or greater sweeping frequencies in the Portland area with relatively frequent rainfall events.

Another factor to consider in street sweeping programs is "wash-on" or material that washes onto impervious areas from upgradient/upstream pervious surfaces. Obviously if large amounts of sediment and related-pollutants wash onto the paved surfaces during storm events themselves, street sweeping is going to be relatively ineffective. The Center for Watershed Protection maintains that as site imperviousness itself increases and as the imperviousness of upgradient watershed areas increases, potential for wash-on decreases and potential effectiveness of street sweeping increases (Article 121, Center for Watershed Protection *Technical Note 103 from Watershed Protection Techniques 3(1)*, pp. 601-604).

Lastly, pollutant loads being contributed by the rainfall itself, or wetfall (such as total solids, total nitrogen, chemical oxygen demand, extractable copper) will not be reduced or removed through street sweeping by definition. For example, research performed by the Metropolitan Washington Council of Governments found that 34 percent of total nitrogen, 24 percent of total solids, and 18 percent of COD occurred as wetfall (Urban Runoff in the Washington Metropolitan Area, 1983. Final Report: Washington DC Area Urban Runoff Project. USEPA Nationwide Urban Runoff Program, MWCOG Washington DC).

In general, the greater the traffic on a roadway and the greater the number of vehicles using a parking area, the greater the pollutant loads. The greater the pollutant loads, the greater the potential effectiveness of street sweeping. Winter road applications affect street sweeping programs

Cost Issues

Costs of street sweeping include capital costs of purchasing the equipment, annual costs of maintenance, annual costs of operation, plus costs of disposal of the material that is collected. According to the US Environmental Protection Agency's *Preliminary Data Summary of Urban Storm Water Best Management Practices* (August 1999, EPA-821-R-99-012), street sweeper costs are quite variable. A mechanical sweeper with $75,000 purchase price and a 5-year life cycle was found to cost $30 per curb mile (Finley, 1996 and SWRPC, 1991), while a vacuum street sweeper purchased at $150,000 and having an 8-year life cycle cost $15 per curb mile (Satterfield, 1996 and SWRPC, 1991). Further comparisons were made by the EPA, including the effects of varying frequency of sweeping (USEPA, 1999).

The point is that although mechanical sweepers are less expensive than vacuum sweepers, their economic life is shorter than vacuum sweepers. If pollutant removal effectiveness is included in the comparison, vacuum sweepers yield substantially better cost effectiveness in most cases.

Pollutant Removal Performance

Although pollutant removal performance for street sweeping will vary with the frequency of the street sweeping program, evaluations are demonstrating remarkably high pollutant removal, especially if the program includes weekly street sweeping. The Center for Watershed Protection reports one recent study with 45-65 percent removal of total suspended solids, 30-55 percent total phosphorus, 35-60 percent total lead, 25-50 percent total zinc, and 30-55 percent total copper (Kurahashi & Associates, Inc. 1997. *Port of Seattle, Stormwater Treatment BMP Evaluation*). In *Street Sweeping for Pollutant Removal* (Montgomery County Department of Environmental Protection, Montgomery County, Maryland, February 2002), additional pollutant removal effectiveness data is reported from studies performed by the Center for Watershed Protection (*Watershed Treatment Model,* 2001). Total suspended solids reduction ranged from 5 percent (major road) and 30 percent (residential street) for mechanical sweepers to 22 and 64 percent respectively for regenerative air and 79 to 78 percent respectively for vacuum sweepers. For nitrogen, mechanical sweeper pollutant removal was 4 and 24 percent removal for major roads and residential streets, regenerative air was 18 and 51 percent, and vacuum 53 and 62 percent. In summary, although pollutant removal performance for new mechanical sweepers has improved considerably over those of the past generation, the new vacuum technology is significantly better than either mechanical or even regenerative air sweepers and achieves a level of pollutant removal that is frequently better than all other BMPs.

References

Center for Watershed Protection, 2001. *Watershed Treatment Model.*

Center for Watershed Protection, *Article 121: Technical Note 103 from Watershed Protection Techniques 3(1)*, pp. 601-604

Finley, 1996 and SWRPC, 1991

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