Pennsylvania Stormwater Best Management Practices Manual

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Section 5
Comprehensive Stormwater Management: Non-Structural BMP's

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Section 5 Comprehensive Stormwater Management: Non-Structural BMP's

5.1 Introduction

Conventional land development too often results in extensive site clearing, where existing vegetation is destroyed, and the existing soil is disturbed, manipulated, and compacted in the process of accommodating a proposed building program – **all of which has significant impact in terms of stormwater quantity and quality.** These conventional land development practices too often fail to recognize that the natural vegetative cover, the soil mantle, and even the topologic form of the land are an integral part of the water resources system – the water cycle – that needs to be conserved and kept in balance – even as land development continues to occur.

Identifying a site's natural resources and evaluating their values and their functional importance is the first step in minimizing the impact of stormwater generated from land development. It is the first step in the comprehensive stormwater management process, as has been described in Section 4 with its Recommended Site Design Procedure for Comprehensive Stormwater Management. Where these natural resources already exist on a proposed development site, these natural resources should be conserved and in some cases carefully utilized as a part of the stormwater management solution, translating into an array of stormwater-preventive Non-Structural BMP's, which are featured in this Section 5. 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. In fact, many vegetation and soil-based structural BMP's are in fact "natural structures" that perform the functions of more "structural" systems (e.g., porous pavement with recharge beds); all of these structural BMP's are described in the following Section 6. Because some of these "natural structures" can be designed and engineered, they are discussed in Section 6 as structural BMP's.

5.2 Non-Structural Best Management Practices

This Manual differentiates BMP's based on Non-Structural (Section 5) and Structural (Section 6) designations. Non-Structural BMP's take the form of broader planning and design approaches – even principles and policies – which are less "structural" in their form, although non-structural BMP's do have very important physical ramifications. An excellent example would be "reducing imperviousness" (see BMP's 5.9 and 5.10 below) where reducing road width and/or reducing parking ratios becomes an excellent way to accommodate a proposed building program, but with reduced stormwater generation through using these "reduced imperviousness" policies. The physical ramifications of "reducing imperviousness" obviously are critical, but the BMP itself applies an entire site, possibly multiple roadways, and is not fixed and designed at one location. Virtually all of the Non-Structural BMP's set forth in this section of the manual share this kind of site-wide policy characteristic. Structural BMP's, on the other hand, are decidedly more locationally specific and explicit in their physical form.

Other stormwater management programs and their manuals have used different systems, oftentimes classifying the BMP's discussed in this Section 5 as Low Impact Development or Conservation Design techniques, both of which overlap, although even the Non-Structural and Structural differentiation is not perfect. In many cases, BMP's described in Section 6, such as Vegetated Swales and Vegetated Filter Strips, are not structures in the conventional "bricks and mortar" sense and are largely based in natural systems and function as they would prior to disturbance. Nevertheless, such BMP's 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, nonpoint source water quality loadings, temperature increases, and the like. Certainly some of these Section 6 “structures” become quite structural in a more conventional sense.

Perhaps the most defining distinction for the Non-Structural BMP’s set forth here in Section 5 is their ability to <u>prevent</u> stormwater generation and the creation of stormwater impacts – not just mitigate stormwater-related impacts once these impacts have been generated. Prevention can be achieved as the result of making the land development happen in ways other than through use of standard or conventional development practices. Prevention and Non-Structural BMP’s go hand in hand and can be contrasted with Structural BMP’s that provide mitigation of those stormwater impacts, which cannot be prevented and/or avoided. In the course of preparing this Pennsylvania manual, multiple different BMP manuals have been reviewed, each of which draw the lines between BMP’s somewhat differently. For the purposes of this manual, the concept of preventive versus mitigative – Non-Structural versus Structural - makes the best descriptive and functional sense in the process of sorting out different BMP’s for Pennsylvania municipalities.

Several major “areas” of preventive Non-Structural BMP’s 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 BMP’s have been identified for each of these generalized areas, to better define and improve implementation of each of these areas of Non-Structural stormwater prevention. Through use and re-use, this list of specific BMP’s hopefully can and will be refined and expanded as stormwater management practice continues throughout Pennsylvania municipalities.

A uniform format has been developed for all BMP’s presented in all sections of this manual, including Section 5 and Section 6. This uniform format is intended to be as condensed and user friendly as possible, providing as many engineering details as possible, facilitated through diagrams, various graphics, even pictures. The overall intent has been to minimize words. The uniform format has been more easily applied in the more explicit Section 6 Structural BMP’s, although even in structural BMP’s, there are constant tradeoffs required between providing a more complete explanation for the countless different variations which can be expected to emerge across the state, versus the need to be concise and seemingly user friendly. The challenge to condense and reduce words is especially great in Section 5’s Non-Structural BMP’s, because the very definition of these Non-Structural BMP’s, involving broader policies and principles, tends to require more words than comparable Structural BMP’s. This awkwardness in application notwithstanding, the uniform format has been applied to all of the Non-Structural BMP’s included in Section 5, so that all stakeholders will be encouraged to understand that these Non-Structural techniques are every bit as essential a the techniques presented in Section 6 Structural BMP’s. For many Pennsylvania stormwater stakeholders, Section 5 Non-Structural BMP’s will appear “unconventional” and harder to apply. Use of a uniform format, though sometimes an awkward fit, is intended to facilitate the use and application of the Non-Structural BMP’s.

One of the most challenging technical issues considered in this Manual involves the selection of BMP's 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 BMP's in Section 5 and Structural BMP's in Section 6 are rated in terms of their pollutant removal performance or effectiveness. The initial BMP selection process analyzes the final site plan and estimates the potential NPS load, using Table 2-2 and Appendix A. The required 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 BMP's. This process is described in more detail in Section 9.

5.3 Non-Structural BMP's and Stormwater Methodological Issues

Because so many of the Non-Structural BMP seem so removed from conventional practice of stormwater engineering, putting these Non-Structurals into play may be a challenge. So many of these Non-Structural BMP's ultimately require a more sophisticated approach to total site design and are therefore more difficult to simply "legislate" through simple imposing of a relatively simply regulatory standard. An especially awkward problem is that at least some of the Non-Structural BMP's don't easily lend themselves to stormwater calculations - as conventionally performed. The immediate question becomes: how do we get stormwater credit for applying any of these techniques? Granted, a few of these Non-Structurals have some obvious stormwater benefits. Taking BMP's 5.9 and 5.10 again as examples, clearly reduction of impervious cover – in whatever ways are reasonable, such as through reduction in road width or reduction in impervious area being created for parking – directly translates into reduced stormwater volumes and reduced stormwater rates of runoff. And the more thoughtful site planner and designer will also realize that many of the other Non-Structural BMPs, such as clustering of uses, conservation of existing woodlands and other vegetative cover and disconnection of impervious area runoff flows, as appropriate, all translate into reduced stormwater volume and rate calculations. As such these BMP's are self-crediting.

The methodological approach set forth in Section 9 strives to provide a variety of straightforward and conservatively cautious ways to take credit for applying these Non-Structural BMP's, provided that the "specifications" defined for each BMP in Section 5 are properly followed. In so doing, the hope is that these preventive Non-stuctural BMP's will be positively incentivized and put into use across the state, sooner rather than later.

5.4 Protect Sensitive and Special Value Resources

Protect Sensitive and Special Value Resources

BMP 5.1: Protect Sensitive and Special Value Features

In order to minimize stormwater impacts, land development should avoid reducing, impacting, encroaching upon areas with especially important natural stormwater functional values (floodplains, wetlands, riparian areas, others) and with especially great stormwater impact sensitivities (steep slopes, others). This avoidance should occur site-by-site and on an areawide basis. Development should occur in areas where sensitive/special value resources do not exist so that their valuable natural functi ons are not lost, thereby doubling or tripling stormwater impacts. Resources may be weighted (Primary and Secondary) according to their functional values specific to their municipality and watershed context.

Key Design Elements

- Identify and map floodplains and riparian area (Primary Areas)
- Identify and map wetlands (Primary Areas)
- Identify and map woodlands (Primary or Secondary Areas)
- Identify and map natural flow pathways/drainage ways (Primary or Secondary Areas)
- Identify and map steep slopes (over 25 percent as Primary Conservation; 15 through 25 percent as Secondary Conservation)
- Identify and map other sensitive resources (Secondary Conservation)
- Combine for Sensitive Resources Map (including all of the above; distinguish between Primary and Secondary Conservation Areas), including Highest Priority Avoidance Areas (Primary Conservation) and Avoidance Areas (Secondary Conservation)
- 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.
- Municipalities should require the above steps in their respective land development process (similar to PADCNR's *Growing Greener 4-Step Design Process*). Regardless of this municipal requirement, each development should follow these steps.

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:	Very High
Water Quality:	Very High

Pollutant Removal

TSS:	Preventive
TP:	Preventive
NO_3:	Preventive

Description

A major objective for stormwater-sensitive site planning and design is to avoid encroachment upon, disturbance of, and impact to those natural features which are both especially sensitive to land development impacts and which, if disturbed or eliminated, result in especially valuable functional losses: floodplains, wetlands, natural flow pathways/drainageways (including but not limited to intermittent and perennial streams), steep slopes, and other natural resources of local importance. Sensitive Resources also include those resources of special value (e.g., designated habitat of threatened and endangered species which are known to exist and have been identified, such as through the Pennsylvania Natural Diversity Inventory or PNDI). The objective of this BMP is to avoid impacting Sensitive/Special Value Resources by carefully identifying and mapping these resources from the initiation of the site planning process and striving to protect them, defining areas free of these sensitivities and special values (Potential Development Areas). BMP 5.2 Protect/Conserve/Enhance Riparian Areas and BMP 5.6 Minimize Total Disturbed Area-Grading build on recommendations included in this BMP.

Variations

- BMP 5.1 calls for both public and private actions – both on the parts of the municipality as well as the individual landowner and/or developer. Pennsylvania municipalities should 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.

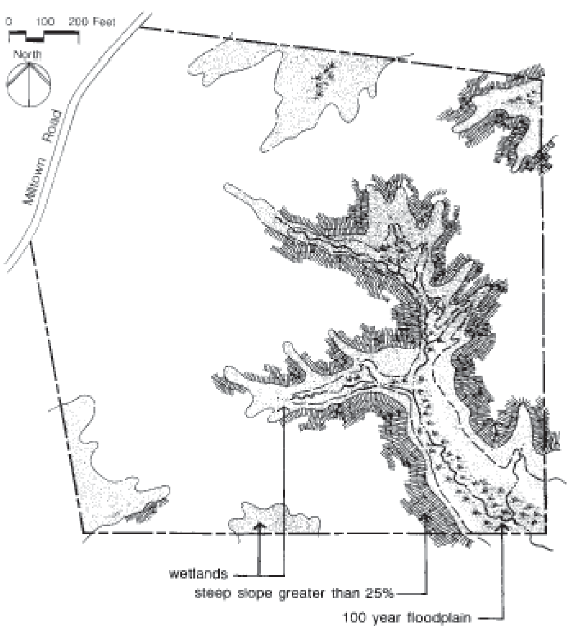


Figure 5.1-1. Growing Greener’s Conservation Subdivision Design: Step One, Part One - Identify Primary Conservation Areas

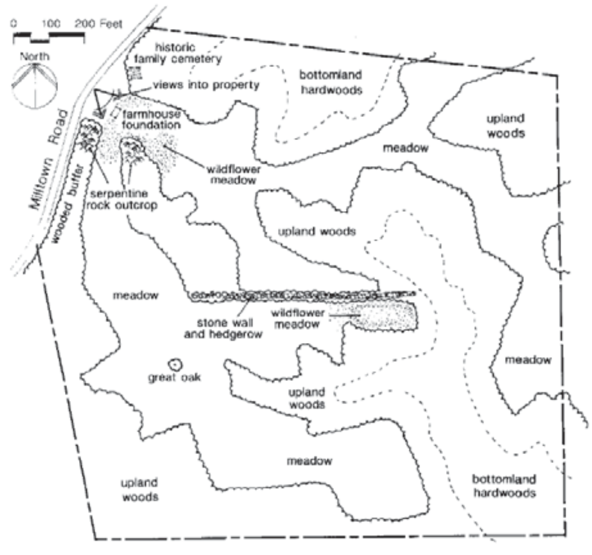


Figure 5.1-2. Growing Greener’s Conservation Subdivision Design: Step One, Part Two - Identify Secondary Conservation Areas

Source: Growing Greener: Putting Conservation Into Local Codes; Natural Lands Trust, Inc. 1997

- The above steps use the *Growing Greener* Primary Conservation Areas and Secondary Conservation Areas designations and groupings, for the sake of consistency with this important State program already in existence. This is not essential. In fact, regardless of the nomenclature used, the concept is to 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 values 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 (e.g., Woodlands may be considered as Primary/Priority Avoidance Areas, rather than Secondary/Avoidance Areas). It is possible to weight Priority Avoidance Areas (Primary) and Avoidance Areas (Secondary) differently; for example, Priority Avoidance may be given twice the weight of Avoidance.

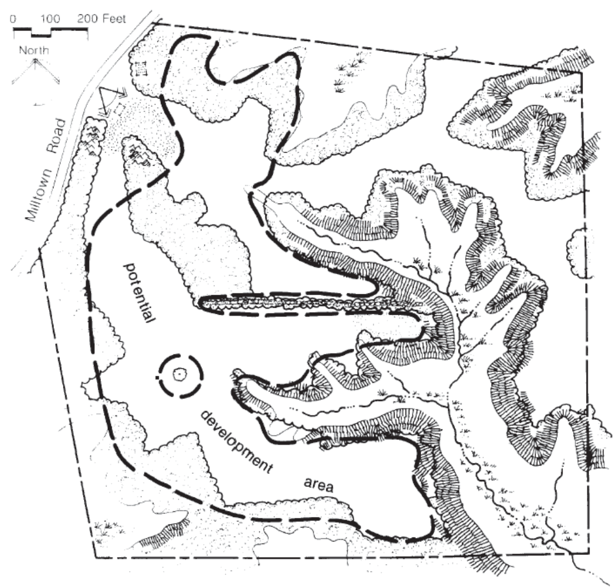


Figure 5.1-3. Growing Greener's Conservation Subdivision Design: Step One, Part Three - Potential Development Areas *(Source: Growing Greener: Putting Conservation Into Local Codes; Natural Lands Trust, Inc. 1997)*

- Definition of the natural resources themselves can be varied. Definition of Riparian Buffer Area varies, sometimes defined as a Zone 1 and 2 at 75 feet from the stream top-of-bank, sometimes defined as 100 feet, and so forth. Woodlands may be defined variably, possibly based on previous delineation/definition by the municipality or by another public agency, possibly based on a recommended tree diameter at a specific density from a reputable source. It is important to note here that Wooded Areas which may not rank well in terms of conventional woodland definitions in terms of mature specimen hardwoods species, nevertheless, maintain important stormwater management functions and should be included in the delineation/definition (i.e., Wooded Areas which are relatively "immature" and "scrubby" still have valuable stormwater management functions). Intermittent streams/swales/natural flow pathways are especially given to variability. Municipalities should 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 and confusion.

- 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, even Avoidance Areas, provided legal tests (such as a takings determinations) are passed acceptably. 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 which require that natural resources be identified, mapped, and taken into account in the multistep process similar to the Growing Greener program, including:

Figure 5.1-4. Steep Slope Development with Woodland Removal

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)

BMP 5.1 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 directly appropriate.

Detailed Stormwater Functions

Development – with its impervious cover and altered pervious covers – translates into water quantity and water quality impacts as discussed in Section 2 of this manual in any situation. If this development further eliminates or in some way reduces other natural resources which were having especially beneficial natural resource functions, such as floodplains and riparian areas, wetlands,

Water quality includes all that nonpoint source pollutant load from impervious areas, a well as all that 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). Clustering as defined here, and combined with other Section 5 Non-Structural BMP's, minimizes impervious areas and the pollutant loads related to these impervious areas. After Section 5 BMP's are optimized, "unavoidable" stormwater is then directed into BMP's as set forth in Section 5, to be properly treated. Similarly, for all that nonpoint source pollutant load generated from the newly-created maintained landscape, clustering as defined here, and combined with other Section 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. Water quality prevention accomplished through Non-Structural BMP's in Section 5 is especially important because Section 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 Section 9 for additional volume reduction calculation work sheets, additional peak rate reduction calculation work sheets, and additional water quality mitigation work sheets.

Construction Issues

Application of this BMP clearly is required from the start of the site planning and development process. In fact, not only must the site owner/builder/developer embrace **BMP 5.1** 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 Section 5 Non-Structural BMP's.

Figure 5.1-5. Example of Steep Slope Development

Maintenance Issues

As with all Section 5 Non-Structural BMP's, maintenance issues are of a different nature and extent, when contrasted with the more specific Section 6 Structural BMP's. Typically, the issue that immediately rises to the top of the list is "who takes care of the open space?" Legally, the designated open space may be conveyed to the municipality, although in most cases, 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, development site by development site, ultimately 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 such that municipalities may prefer not to own them, even if developers are willing to convey them free of charge. For those Pennsylvania municipalities which allow for and enable creation of homeowners associations or HOA's, the HOA, if created by the developer, 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, and so forth), the maintenance requirements of "undisturbed open space" by definition should be minimal. The objective here is conservation of the natural systems, including the natural or native vegetation, already present, with minimal, if any, 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 (this information is further detailed and supported in Appendix A). Costs to build 100 clustered single-family residential homes is less when clustered than when not clustered, holding the type of home constant plus all other relevant infrastructure constant (i.e., assumed sewering, watering, and so forth). 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. Cost benefits are further detailed in Appendix A.

Post-construction, clustering also reduces 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 – the land uses that are clustered. Analyses of market prices of conventional development over time in contrast with comparable residential units (where size, type, and quality of the house itself is held constant) 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.

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, sources, as set forth below; more specifications for clustering can be found in....

Protect Sensitive and Special Value Resources

BMP 5.2: 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:** Upstream of Zone 1 and varying in width, provides extensive water quality improvement. Considered the Managed Forest.
  - **Zone 3:** Upstream of Zone 2, and may include BMPs such as Filter Strips.

Potential Applications

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

Stormwater Functions

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

Pollutant Removal

TSS:	Preventive
TP:	Preventive
NO_3:	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 by past practices.

BMP 1.2 focuses on protection, maintenance, and enhancement of existing Riparian Forest Buffers. Restoration of Riparian Forest Buffers is treated in Section 5 as a Structural BMP.

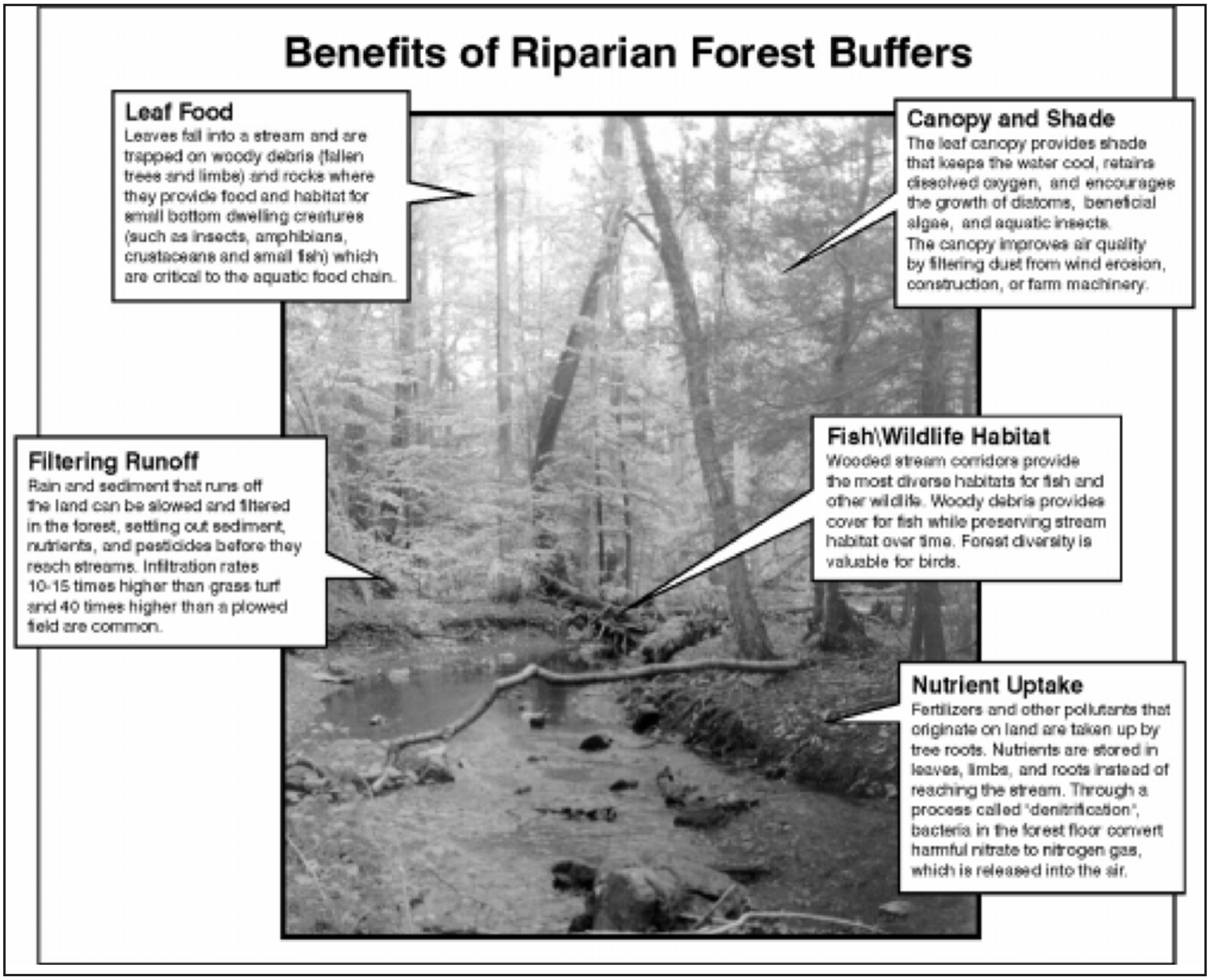


Figure 5.2-1. Riparian buffer zones support various ecological functions.

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, 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, creating pools and microenvironments 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 sustain 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 but become relatively even more critical as one moves "up" the stream toward headwaters and 1st order streams.

Zone 2: Removes, transforms, and stores nutrients, sediments, and other pollutants flowing as sheet flow on the surface as well as flowing in the shallow sub-surface root zone through the groundwater. A healthy Zone 2 has the potential of removing substantial quantities of excess nitrogen forms (i.e., nitrate) through shallow sub-surface root zone uptake of nitrate which customarily can be significantly elevated when adjacent land use are agricultural uses or urban/ suburban uses (i.e., developed). Runoff moving on the land surface will be physically slowed and filtered by a healthy Zone 2, including particulate sediment and bound phosphorus. Additionally, the increased infiltration which results also will promote uptake of additional nitrogen forms via root systems, rather than being discharged directly into the stream system. 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; additional microbial degradation processes.

Zone 3: Provide the first stage in managing upslope runoff, in the form of acting in a variety of ways as effective level spreading devices so that runoff flows are slowed and evenly dispersed into Zone 2 and then Zone 1, so that the function of these essential zones can be fully maintained. Some physical filtering of pollutants may be accomplished in zone 3 as well as some limited amount of infiltration, depending upon how much of what is provided in Zone 3.

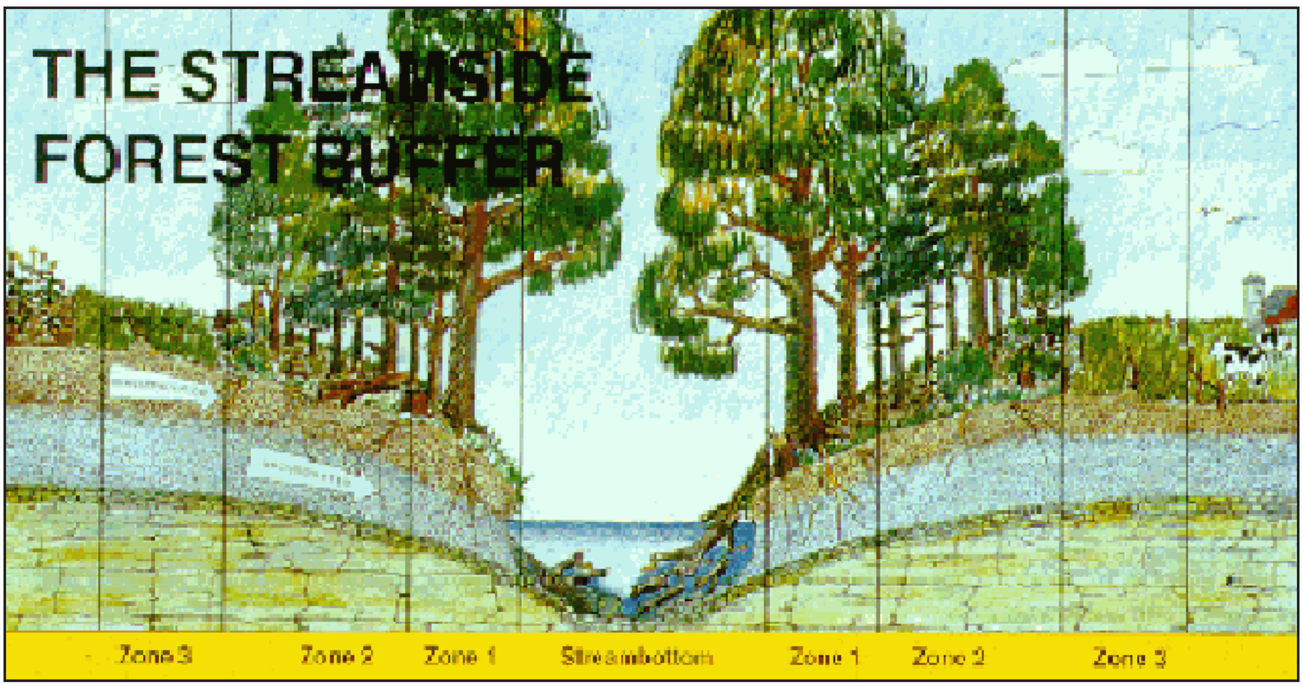


Figure 5.2-2. Riparian Buffer Zones (D.J. Welsch, 1991)

Design Considerations/Variations

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

- Forest
- Agriculture
- Suburban/Developing
- Urban

Zone standards for Riparian Forest Buffer Protection in these different land development contexts are likely to vary for a variety of reasons. Technically, variation in standards (see Specifications below) should vary with the “work” need to be performed by the forested buffer. In undisturbed forested areas where minimal runoff is expected to be occurring and flowing into stream systems, standards can be made to be more flexible than in agricultural contexts where large quantities of

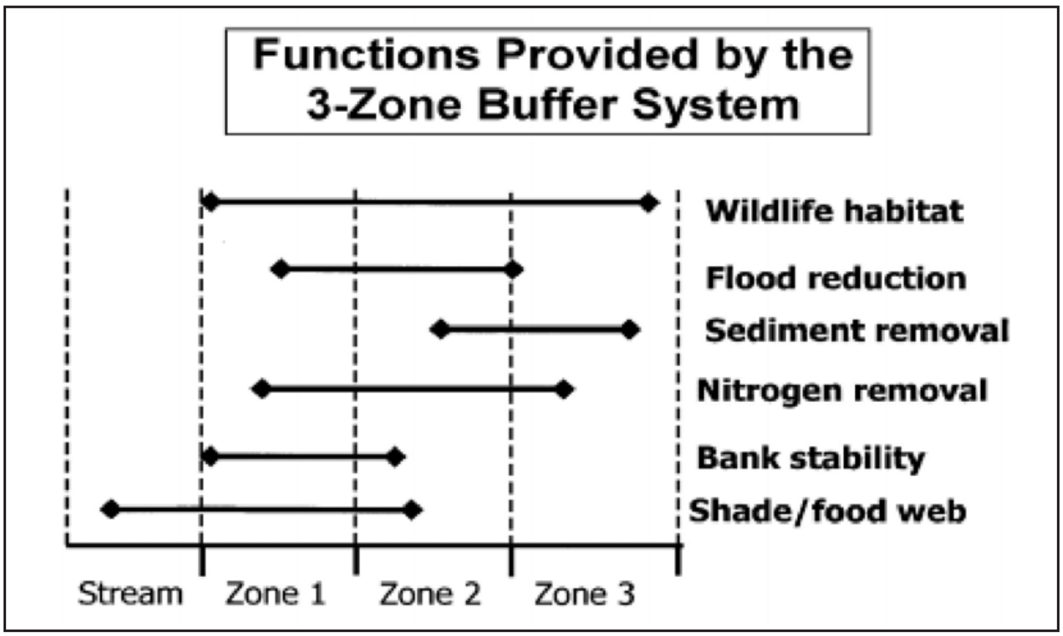


Figure 5.2-3. Riparian buffer zone functions.

natural vegetation have been removed and significant quantities of runoff which are not otherwise managed 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 made to 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, as recommended here. On the other hand, mapped 100-year floodway/floodplain may be topographically constricted and severe sloped at a site and therefore be more limited; alternatively, area adjacent to a river or stream may be very gradually sloped such that floodplain extends well beyond a much more limited riparian forest buffer. A second important clarification is that floodplain ordinances typically manage use for the purposes of managing flood damage, which is in contrast to riparian forest buffer regulation which manages disruptive clearing and grading actions in the zones, specifically for environmental reasons.

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). As such, the Riparian Forest Buffer should be defined and treated from the initial stages of the land development process, treated as floodplain or 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, given that municipality's position in the watershed, documented values, and so forth, with other land use objectives. In so doing, 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, again from the initiation of the site planning process. If standards and guidelines have been set forth by the municipality or by other relevant planning, these standards and guidelines should be followed. If not, standards recommended in this manual should be followed.

The ease of accommodating a riparian forest buffer can be expected to vary across several factors, including intensity of land use and zoning at the site, together with size of 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. At some point owners/developers/applicants may argue that a reasonable building no longer is viable and an economic taking has occurred. This factor is exacerbated, as sites grow smaller as well. Although such arguments are often exaggerated, 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 in order to develop a program that "fits" the municipal watershed context with maximum environmental performance, but still reflects existing land development and zoning realities so that necessary modifications are kept to a minimum.

Cost Issues

Costs of riparian forest buffer establishment are not significant, defined in terms of direct development; the assumption of this BMP is that the existing riparian forest buffer vegetation will be protected and conserved. In these cases, costs can be reasonably defined as the lost opportunity costs, as they might be called, of not being able to use acreage reserved for the riparian forest buffer in the otherwise likely land use, with some important qualifications. 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 (use restrictions notwithstanding), 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.

Also, 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 (floodproofing aside), 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 which extends beyond the floodplain assigned a cost.

Lost opportunity costs can be expected to vary depending upon land use. To the extent that the land could be cleared and cultivated in some manner, a net income per acre figure can be applied to whatever acreage is being removed from active cultivation and constitutes a lost opportunity. To the extent that protection of a riparian forest buffer reduces lot yield in a proposed residential subdivision or development, reduced development potential can translate into a larger effective cost number, although 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. For already existing vegetated areas, the act of simple protection of these areas located adjacent to stream, rivers, lakes, and other waterways is of tremendous importance, given their rich away of functional benefits.

Stormwater Management Calculations

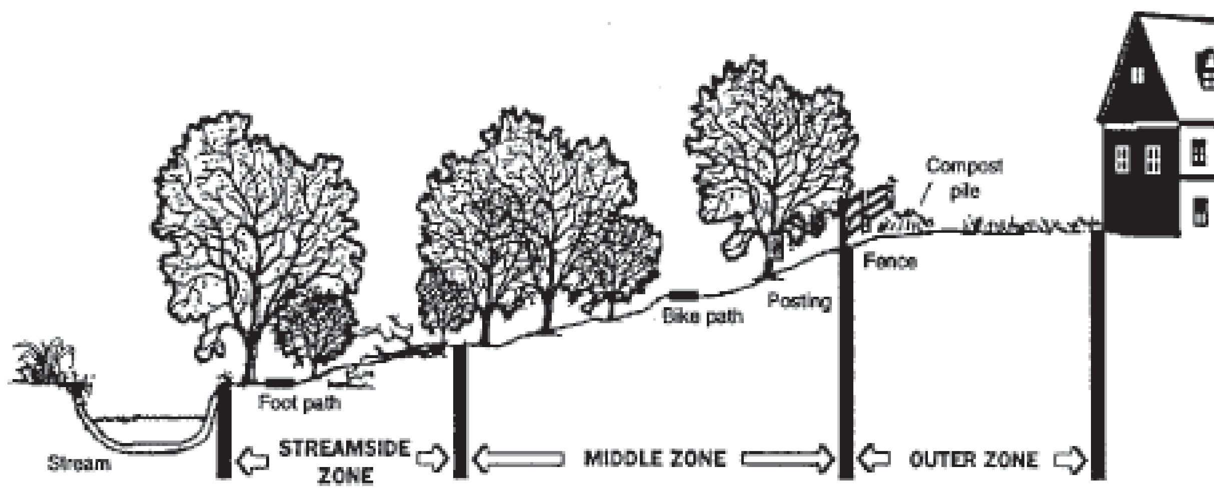
Stormwater calculations in most cases for Volume Control and Recharge and Peak Rate will not be affected dramatically. See Section 9 for more discussion relating to Water Quality.

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, start there).



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 mininum 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.

Protect Sensitive and Special Value Resources

BMP 5.3: 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
- Distributed, non-erosive surface flow to natural drainage features
- Non-erosive channel flow within drainage pathways
- Native vegetative buffers around drainage features

Potential Applications

Residential:	YES
Commercial:	YES
Ultra Urban:	NO
Industrial:	YES
Retrofit:	YES
Highway/Road:	NO

Stormwater Functions

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

Pollutant Removal

TSS:	30%
TP:	20%
NO_3:	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.

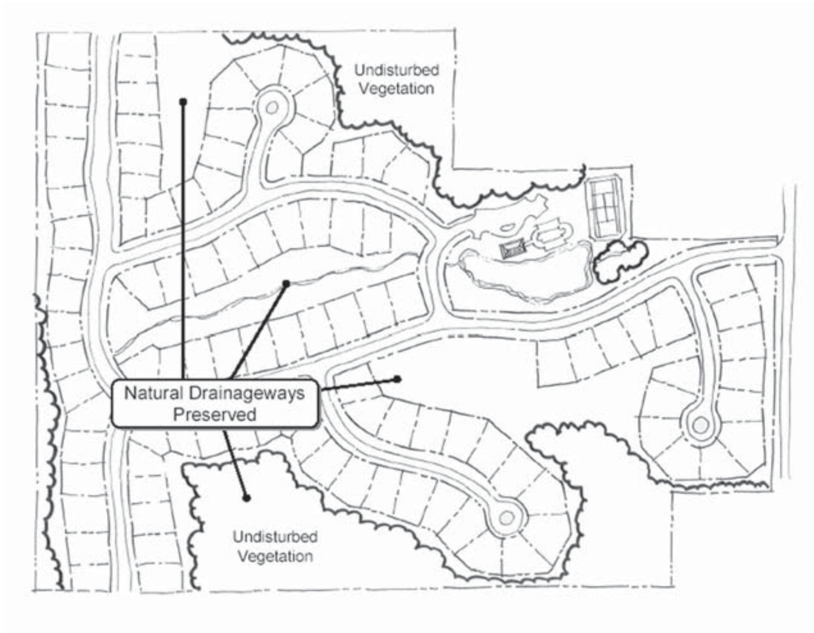


Figure 5.3-1. Protecting natural drainage features

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.**

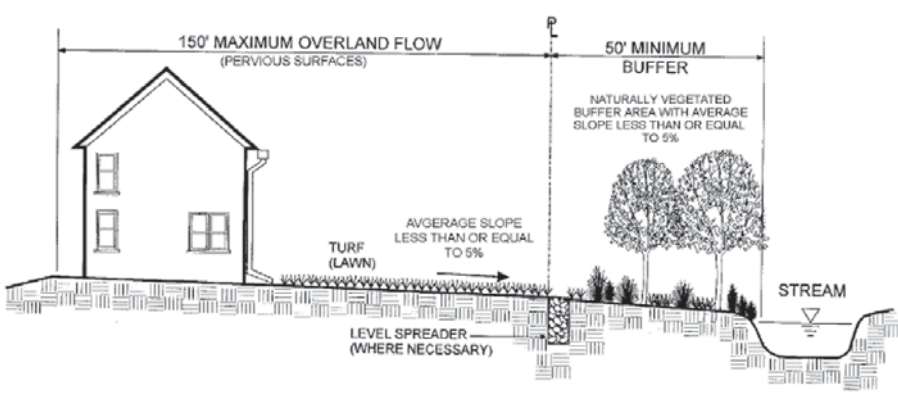


Figure 5.3-2. Section of buffer utilization

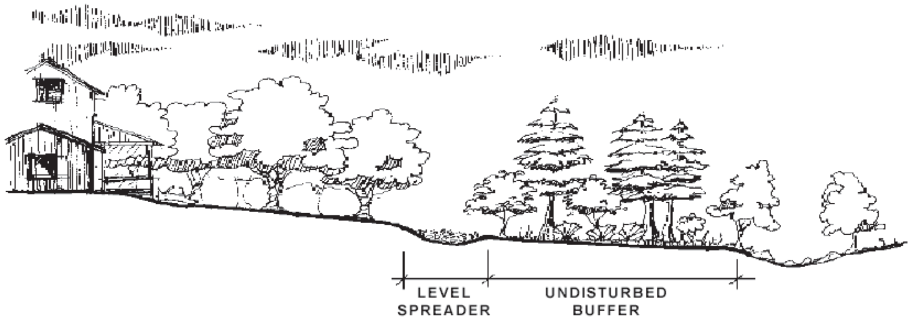


Figure 1.4.2-28 Use of a Level Spreader with a Riparian Buffer
(Adapted from NCDENR, 1998)

Figure 5.3- 3. Section of buffer utilization

- **Use natural drainage pathways instead of structural drainage systems**

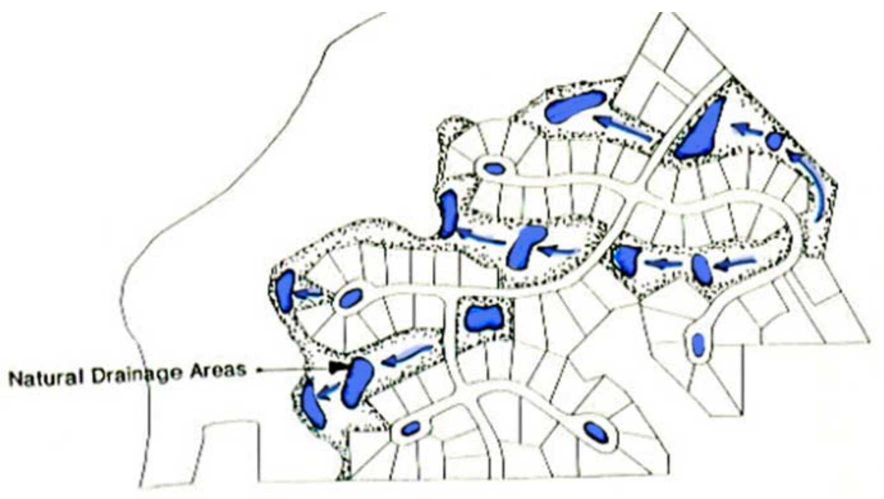


Figure 5.3-4. The natural surface can provide stormwater drainage pathways

- **Use natural drainage features to guide site design**

Figure 5.3-5. Natural drainage features can guide the site design.

- **Use natural depressions for temporary stormwater storage**

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

- **Others…**

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 Section.

Subtle site features such as swales, ephemeral streams, drainage pathways, and natural depressions should be delineated in addition to commonly mapped hydrologic elements such as wetlands, perennial and intermittent streams, and waterbodies.

2. NATURAL DRAINAGE FEATURES GUIDE SITE DESIGN. Instead of imposing a two-dimensional 'paper' design on a particular site, designers can use nature 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 whenever 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 must be protected from any increased runoff volumes and rates due to development. The design must 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, check dams, etc. can also be used to protect natural drainage features.

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 Section 9 for volume reduction calculation methodologies.

Peak Rate Mitigation Calculations
Protecting/utilizing natural drainage features 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. 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 Section 9 for Water Quality Improvement methodologies.

Construction Issues

1. At the start of construction, natural drainage features to be protected must be flagged/ fenced with signage as shown on the construction drawings.
2. Non-disturbance and minimal disturbance zones must 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 access 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.

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.

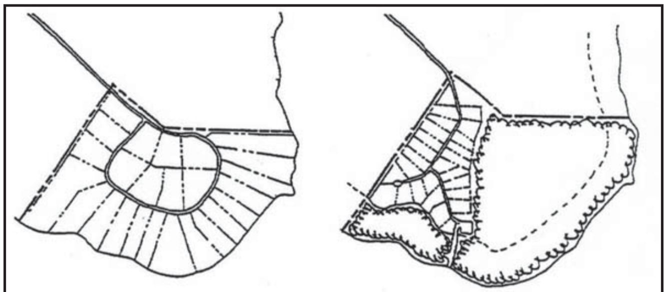
Specifications

Not applicable

5.5 Cluster and Concentrate

Cluster and Concentrate

BMP 5.4: 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.?).
- Cluster provisions are usually allowed as an option by the municipality; a municipality may have several clustering options.
- Pending answers to above questions, have lot sizes been reduced to the maximum, 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, regardless of municipal ordinance limits?

Potential Applications

Residential:	**YES**
Commercial:	**YES***
Ultra Urban:	**Limited**
Industrial:	**Limited**
Retrofit:	**YES**
Highway/Road:	**YES***

** Depending on site size, site constraints, other factors*

Stormwater Functions

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

Pollutant Removal

TSS:	**Preventive**
TP:	**Preventive**
NO_3:	**Preventive**

Description

See Key Design Elements.

Variations

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

- Density bonus/lot size reduced. 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 (see Appendix __), 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 5.5-1: The kind of subdivision most frequently created in Pennsylvania is the type which blankets the development parcel with house lots, and which pays little if any 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. However, 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 5.5-2: 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 5.5-3: 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 5.5-4: Hamlet or Village; 36 lots; Lot Size Range: 6,000 to 12,000 sq. ft.; 70% undivided open space

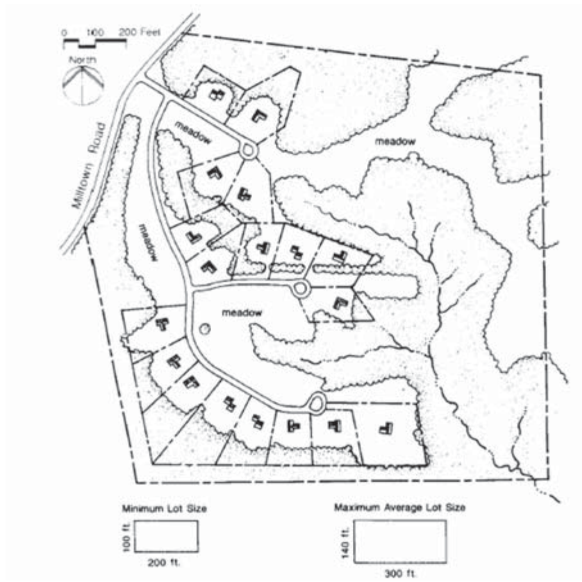


Figure 5.4-2 Clustered Development, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

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

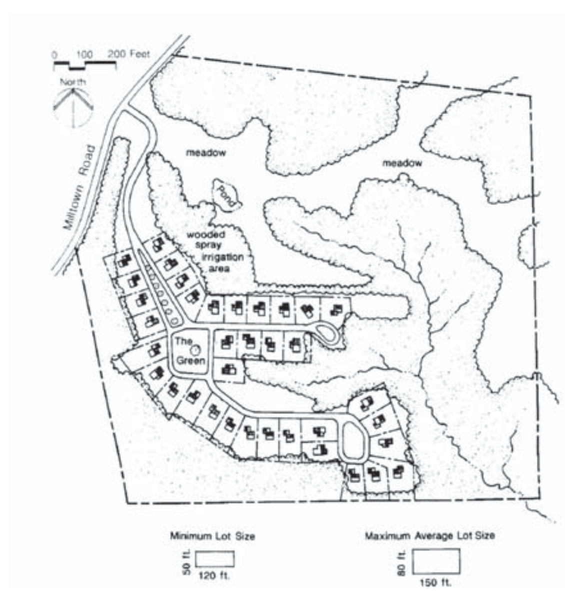


Figure 5.4-4 Hamlet or Village, (Source: Growing Greener: Putting Conservation Into Local Codes. Natural Lands Trust, Inc., 1997)

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

Design Considerations

Objectives:
- Maximize open space.
- Maximize open space that 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 land uses and the proper densities/intensities of these land uses, site by site. 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 BMP's, as defined in this Section, 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, 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 includes all that nonpoint source pollutant load from impervious areas, a well as all that 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). Clustering as defined here, and combined with other Section 5 Non-Structural BMP's, minimizes impervious areas and the pollutant loads related to these impervious areas. After Section 5 BMP's are optimized, "unavoidable" stormwater is then directed into BMP's as set forth in Section 6, to be properly treated. Similarly, for all that nonpoint source pollutant load generated from the newly-created maintained landscape, clustering as defined here, and combined with other Section 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. Water quality prevention accomplished through Non-Structural BMP's in Section 5 is especially important because Section 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 Section 9 for additional volume reduction calculation work sheets, additional peak rate reduction calculation work sheets, and additional water quality mitigation work sheets.

Construction Issues

Application of this BMP clearly is required from the start of the site planning and development process. In fact, not only must the site owner/builder/developer embrace BMP 5.4 Cluster Uses at Each Site 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 Section 5 Non-Structural BMP's.

Maintenance Issues

As with all Section 5 Non-Structural BMP's, maintenance issues are of a different nature and extent, when contrasted with the more specific Section 6 Structural BMP's. Typically, the issue which immediately rises to the top of the list is "who takes care of the open space?" Legally, the designated open space may be conveyed to the municipality, although in most cases, 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, development site by development site, ultimately 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 such that municipalities may prefer not to own them, even if developers are willing to convey them free of charge. For those Pennsylvania municipalities which allow for and enable creation of homeowners associations or HOA's, the HOA, if created by the developer, 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, and so forth), the maintenance requirements of "undisturbed open space" by definition should be minimal. The objective here is conservation of the natural systems, including the natural or native vegetation, already present, with minimal, if any, 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 (this information is further detailed and supported in Appendix ___). Costs to build 100 clustered single-family residential homes is less when clustered than when not clustered, holding the type of home constant plus all other relevant infrastructure constant (i.e., assumed sewering, watering, and so forth). 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. Cost benefits are further detailed in Appendix ___.

Post-construction, clustering also reduces 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 police protection are made more efficient when residential development is clustered.

Additionally, clustering has been shown to positively affect land values – the land uses that are clustered. Analyses of market prices of conventional development over time in contrast with comparable residential units (where size, type, and quality of the house itself is held constant) 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; more specifications for clustering can be found in:….

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Cluster and Concentrate

BMP 5.5: Concentrate Uses Areawide through Smart Growth Practices

On a municipal or multi-municipal or areawide basis, use "smart growth" planning techniques, including neo-Traditional/New Urbanist planning principles, to plan and zone for concentrated development patterns which accommodate reasonable growth and development by directing growth to areas - to groups of parcels - in a the municipality which are most desirable and away from areas - groups of parcels - which are undesirable/least desirable. BMP 2.2 can be thought of as Super Clustering where the push and pull of development forces needs to transcend the reality of the many different large and small parcels which happen to exist in most Pennsylvania municipalities and where clustering parcel by parcel simply cannot accomplish the growth management which 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 "business as usual" 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:	YES

Stormwater Functions

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

Pollutant Removal

TSS:	Preventive
TP:	Preventive
NO_3:	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 – building communities that make sense for the future – clusters and/or hamlets and/or villages and/or towns and/or cities; 2) how areas deemed undesirable for growth are defined – conserving our essential natural resources and agricultural lands and other vital resources; and 3) how any of this is made to happen – 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 – 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 Towns exist, development can be directed into the Town or at the Town edge (Figure 5.5-2). Clustering (see BMP 5.4) on a site-by-site basis, however superior from a site perspective, yields a pattern which is less than optimal from a multi-site or areawide perspective (Figure 5.5-3), although this overall pattern is vastly preferable to the business as usual approach across the 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 – the new communities for the future – cannot be overemphasized. So often this BMP has been driven/motivated solely by environmental conservation objectives – saving the Sending Zone (in TDR parlance) as discussed below (i.e., Undesirable Growth Areas), but every bit as much care must be taken in defining and planning the desirable growth areas – the so-called 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 discouraging 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 (i.e., Exceptional Value and High Quality), as well as critical headwaters (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, as well as constellations of important wetlands and floodplain and other natural features. Prime Agricultural Lands and Agricultural Security Districts may be deserving of conservation. Areas may be especially sensitive due to particularly rugged topography and steep slopes. Areas may be especially 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 areawide growth management techniques.

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

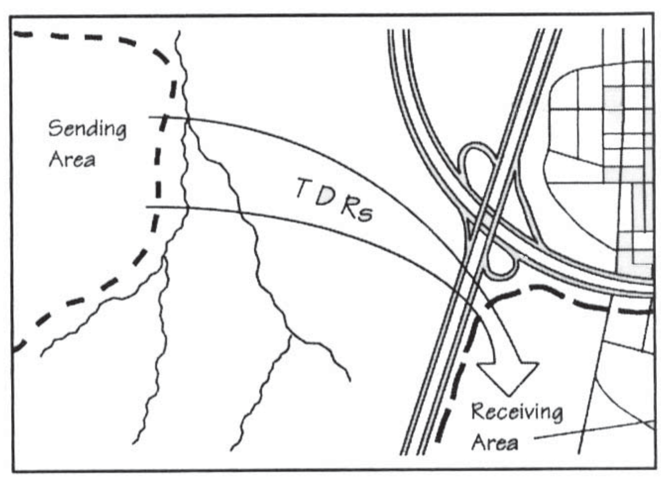
If a municipality consists of only a handful of enormous parcels where BMP 5.4 Clustering can work together to achieve the areawide “desirable growth” and “undesirable growth” patterns for the entire municipality as described above, BMP 5.5 would be made unnecessary. Such is never the case. In fact, municipalities typically are characterized by a bright and energetic municipality may decide to use all or most of the smart growth techniques discussed here (possibly even more). Or 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. Although most of what is involved here entails [public sector management action, such as zoning ordinance provisions, a few municipalities in Pennsylvania such as West Marlborough in 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, in terms of ease of implementation, in terms of political and socioeconomic implications and "fit" with the local culture. Municipalities can decide to hire a local planning consultant, of which there are many (go to the Pennsylvania Planning Association for additional references). Municipalities 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, which provides a variety of planning resources providing information on these different smart growth techniques and their potential usefulness in any one particular municipal setting. Consult their respective websites.

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, the Receiving Zone, these development rights that have been purchased may be used to increase development density, above and beyond 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 (i.e., 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). Numerous articles and manuals have been prepared which outline various websites provide additional information on TDR as follows:….



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 areawide basis; therefore by manipulating location and timing of this infrastructure through municipal or public sector action, municipalities can encourage development in certain areas (increased density), and discourage development (decreased density) in others. Growth Boundaries define where municipalities will directly and indirectly encourage/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 their annual Growth Tracking reports which document how their planning is achieving Growth Boundary objectives). Various websites provide additional information on Growth Boundaries as follows: …

Figure 5.5-6 Example of Urban Growth Boundary

Effective Agricultural Zoning:
Although large lot zoning (usually defined as zoning requiring that average lot size be greater than 2 acres per lot) has been rejected by Pennsylvania courts as exclusionary and unacceptable, very large minimum lot size to maintain existing agricultural uses has been deemed to be acceptable by Pennsylvania courts and being practiced throughout Pennsylvania, especially in intensive agricultural communities in central Pennsylvania (e.g., multiple municipalities in Adams, Berks, Chester, Lancaster, York, and other counties). 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 terms presence of prime farmland soils, intensive agricultural activity, formation of Agricultural Security Districts, and 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.

Additionally, some counties (e.g., Bucks, Chester, Montgomery Counties) and municipalities (North

Coventry, East Bradford, Pennsbury, Solebury, West Vincent, others) have enacted special open space and recreation acquisition programs, funded in various ways (bond issues, real estate taxes, small payroll taxes, and so forth), to acquire through 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, as available, and then later sells these development rights (Warwick Township in Lancaster County has done this and made a profit!) 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" literally 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 which are 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, though not all, 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, for example, a source of funds ($750,000?) can be located to provide a partial financial settlement for the owner, even as the owner benefits from an approved donation of the remainder of the value, thereby reducing the owner's tax bill. The property is conserved.

A further variation would be a limited development option wherein a substantially reduced (vis a vis existing zoning) development program is developed which conserves much if not most of the property in question. An existing farmstead or homestead is retained; 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 resemble BMP 5.4, though must be understood as municipality-wide, rather than just site-wide:

- Maximize open space.
- Maximize open space that includes 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.); use infrastructure to shape desirable growth

BMP 5.5 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, including street lengths and total paved area, and is likely to link with other BMP's, as defined in this Section, 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, concentrating growth translates into reduced disturbance and increased preservation of the natural landscape, natural vegetative land cover, which further translates into reduced stormwater runoff, volume and peak. 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 effects of areawide growth concentration – holding total growth and development constant - on the water quantity side 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, mapped (Figure 5.5-7) and tested for a variety of stormwater-related impacts (total impervious area, total disturbed area, stormwater generation, nonpoint source pollutant generation). The analysis results indicated that the concentrated development scenario significantly reduced total impervious area, 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 nonpoint source pollutant loads being generated, when contrasted with the conventional baseline development scenario.

As stated above in BMP 5.4, water quality issues include all that nonpoint source pollutant load from impervious areas, a well as all that 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, and combined with other Section 5 Non-Structural BMP's, minimizes impervious areas and the pollutant loads related to these impervious areas. After Section 5 BMP's are optimized, "unavoidable" stormwater is then directed into BMP's as set forth in Section 6, to be properly treated. Similarly, for all that nonpoint source pollutant load generated from the newly-created maintained landscape, clustering as defined here, and combined with other Section 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. Water quality prevention accomplished through Non-Structural BMP's in Section 5 is especially important because Section 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 Section 9 for additional volume reduction calculation work sheets, additional peak rate reduction calculation work sheets, and additional water quality mitigation work sheets.

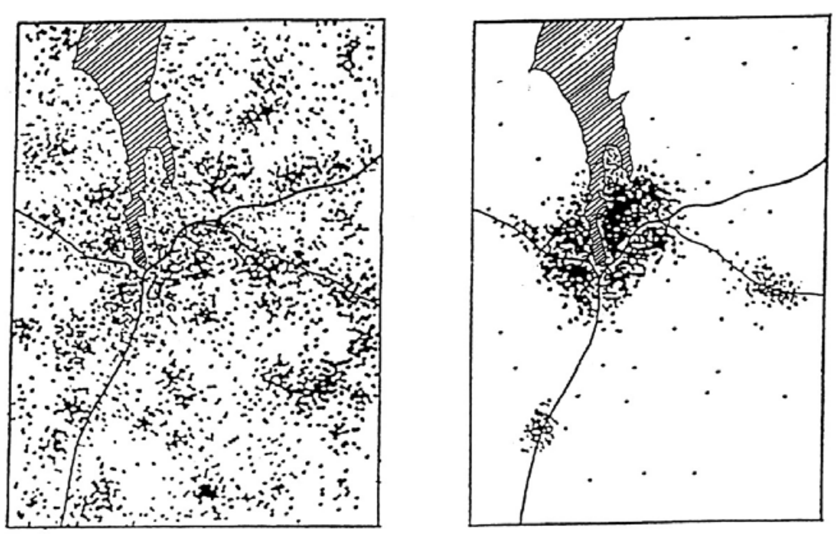


Figure 5.5-7 Dispersed versus Concentrated Development at the Regional Scale, (Source: "Impervious SUrface Reduction Study", City of Olympia, 1995)

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 Concentrate Uses Areawide from the start of the process. Use of conservation easement donation, bargain sale, 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 per se are generated by BMP 5.5. 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

To paraphrase 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 defined here for BMP 5.5 will require some additional costs. Hypothetically, application of an optional TDR program or Growth Boundary program could cost a municipality $50,000 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 (we note that even in municipalities where non-structural BMP's are optimized across a thousand or more different development sites, structural BMP's are necessary and their costs must be borne; however, successfully applied non-structural BMP's applied municipality-wide can significantly reduce the total costs of the large number of mitigative structural BMP's which would otherwise be required for each of these thousand or more development sites).

Furthermore, BMP 5.5's preventive smart growth technique, when fully applied, achieve a level of performance that exceeds even the best structural BMP's, which is 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 performance. In these cases, significant amounts of development watershed-wide – even assuming use of Section 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 Concentrate Use Areawide 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 which are included in above discussions as well as at the end of this section.

5.6 Minimize Disturbance and Minimize Maintenance

Minimize Disturbance and Minimize Maintenance

BMP 5.6: Minimize Total Disturbed Area – Grading

Without changing the building program, reduce site grading, removal of existing vegetation (clearing and grubbing), total soil disturbance, as well as 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 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

Pollutant Removal

TSS: 40%
TP: 0%
NO_3: 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 (BMP 5.1, BMP 5.2, and BMP 5.3) and that clustering and areawide concentration of uses (BMP 5.4 and BMP 5.5) also have been considered and included in the site design. All of these BMP's serve to reduce site grading and to minimize disturbance/minimize maintenance. This BMP 5.6 specifically focuses on how to minimize the grading and overall site disturbance required in order to build the desired program, 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. Often 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 allowed to be made flexible in order to better fit a given parcel and achieve a more "fluid" roadway alignment, depending upon the specific site context. 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 and earthwork and grading which 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. And although configuring lots in a rectilinear shape may optimize the number of units, 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 must be found to be acceptable by the local government, which should modify their respective ordinances as necessary. Municipalities should consider reducing and/or being more flexible 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)

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

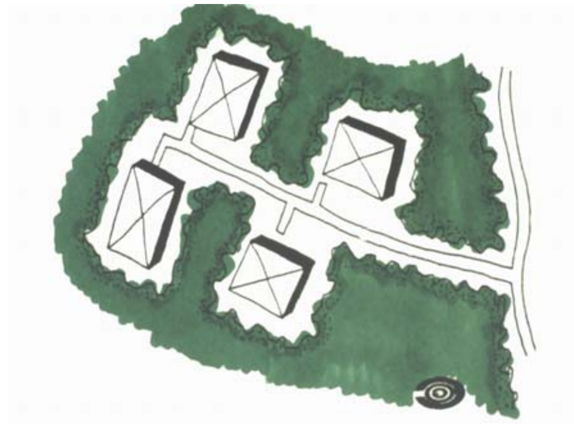


Figure 5.6-2 Minimally Disturbed Development

Detailed Stormwater Functions

Volume Reduction Calculations: Minimizing Total Disturbed Area/Maintained Area through Reduced Site Grading (Designing with the Land) can reduce the volume of runoff in several ways. Reducing disturbance and maintaining a natural cover can significantly reduce the volume of runoff through increased infiltration and increased evapotranspiration. This will be self-crediting in site stormwater calculations through lower runoff coefficients (such as Curve Numbers used in the TR-55 methodology where the Curve Number for undisturbed Meadow or Woodlands is lower and less runoff producing than Curve Numbers for a post-development lawn or other newly created maintained landscape) and/or higher infiltration rates. Minimizing Total Disturbed Area/Maintained Area through Reduced Site Grading (Designing with the Land) can reduce 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 Section 6) and possibly other BMP's 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 which cannot be avoided. See Section 9 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/Maintained Area through Reduced Site Grading (Designing with the Land) can improve water quality preventively by reducing construction phase sediment-laden runoff which is documented to occur, regardless of use of the most effective erosion and sediment control devices. 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/Maintained Area through Reduced Site Grading (Designing with the Land) 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 Section 9 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 5.1)

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 5.1); 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 5.1).

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. Limit of grading and disturbance should be designated on plan documentation submitted to the municipality for review/approval and should be physically designated at the site during construction via flagging, fencing, etc.

3. Minimize Disturbance at Lot

Limit lot grading to roadways and building footprints. Municipalities should establish Minimum Disturbance/Minimum Maintenance Buffer, 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 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:

> "…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. Limit of grading and disturbance should be designated on plan documentation submitted to the municipality for review/approval and should be physically designated at the lot during construction via flagging, fencing, etc.

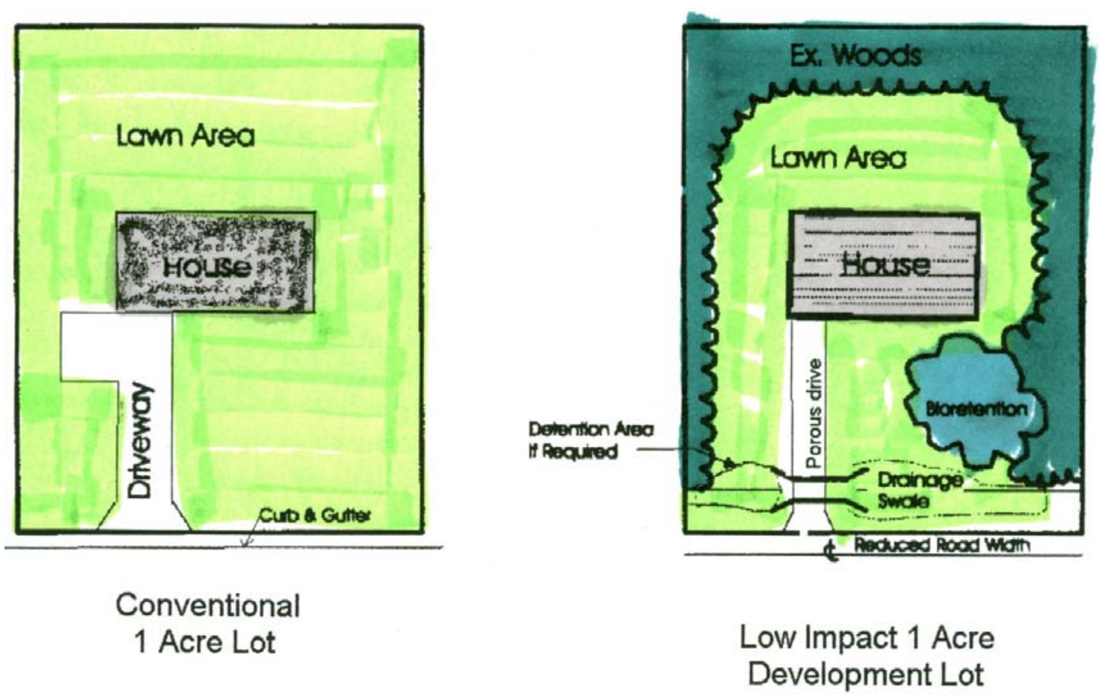


Figure 5.6-4 Convential Development Versus Low Impact Development

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 required 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 are to be restored as pervious areas following development, with a soil restoration program required.

6. Minimize Stockpiling and Storage Areas

All areas used for materials storage during construction will 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 might be considered as avoidance of impacts.

Cost Issues

The cost reduction of reduced grading and earthwork should benefit the developer, and so the BMP is considered to be self-crediting, given the benefits resulting from reduced costs. Cost issues include both 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, Seeding.

Calculation of reduced costs is difficult due to the extreme variation is site factors which 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 for acre would appear to approximate $20,000 per acre and could certainly exceed that figure in more challenging sites. Reducing acreage graded and disturbed 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 the rule should be that any criteria that will result in significant earthwork should be reconsidered and evaluated.

Minimize Disturbance and Minimize Maintenance

BMP 5.7: Minimize Soil Compaction in Disturbed Areas

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

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

Key Design Elements

- Protecting disturbed soils areas from excessive compaction during construction
- Avoidance of 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 (BMP 3.1)
- Soil Restoration for areas that are not adequately protected or have been degraded by previous activities (Section 6)

Potential Applications

Residential Subdivision:	**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**

Pollutant Removal

TSS:	**30%**
TP:	**0%**
NO_3:	**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 (Section 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.** If these areas are to exist they 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 required and minimum parameters that topsoil must meet. Topsoil applied to disturbed areas must 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 possible.

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 will credited in site stormwater calculations through lower runoff coefficients and/or higher infiltration rates. See Section 9 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 will be credited in site stormwater calculations through lower runoff coefficients, higher infiltration rates, and/or longer times of travel. See Section 9 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 Section 9 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 must be strictly enforced.
3. Protected and Minimal Disturbance Areas must be protected from excessive sediment and stormwater loads while upgradient areas remain in a disturbed state.
4. Topsoil storage areas must 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 (see BMP 5.8).

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

Topsoil should comply with topsoil specification in Appendix C. Soil Restoration specifications can be found in Section 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.

Minimize Disturbance and Minimize Maintenance

BMP 5.8: Re-Vegetate and Re-Forest Disturbed Areas, Using Native Species

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

In addition to minimizing areas of development sites which require landscaping and re-vegetation, landscaping and re-vegetation which is required should be driven by the selection and use of vegetation (i.e., native species) that does not require significant chemical maintenance by fertilizers, herbicides, and pesticides.

Key Design Elements

- Preserve all existing high quality plant materials and soil mantle (from BMP 3.1)
- Protect these areas during construction (from BMP 3.1)
- Develop Landscape Plan using native materials
- Reduce landscape maintenance, especially grass mowing
- Eliminate chemical applications to the site
- Eliminate fertilizer and chemical-based pest control programs

Potential Applications

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

Stormwater Functions

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

Pollutant Removal

TSS:	**85%**
TP:	**85%**
NO_3:	**50%**

Description of BMP

Minimum Disturbance/Minimum Maintenance is comprised of two distinct steps, neither of which involves structural BMP's. The first step is to preserve existing vegetation on the development site as defined in BMP 5.6, 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 vegetative species found locally (i.e., considered to be native species) have 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.

Minimum maintenance also relates to the production of biomass, such as grass clippings, as a significant pollutant source for water quality (if this biomass is not removed, overtime 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 as well as 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 is 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 Section 9 for Water Quality Improvement methodologies.

Design Considerations

Native species is a broad term. Different types of native species MD/MM landscapes may be created, from meadow to woodland areas, obviously requiring different approaches to planting. In terms of woodland areas, DNREC'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, woodlands.

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, BMP 5.8 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 initial 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 usual). 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 shall 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 plan documentation to the maximum extent and receive municipal review and approval. As stated in BMP 5.6, Existing Vegetation Being Preserved needs to be flagged/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/fencing similar to Existing Vegetation Being Preserved should be considered.

Cost Issues

BMP 5.8 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

In current dollars, these values would 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 Section 9 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

Reduce Impervious Cover

BMP 5.9: Reduce Street Imperviousness

Reduce street imperviousness by minimizing street widths and lengths.

Key Design Elements

- 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: Yes

Stormwater Functions

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

Pollutant Removal

TSS: Preventive
TP: Preventive
NO_3: Preventive

Description

Reducing street 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

- **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).

Recommendations by 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) be as narrow as 22 feet. Some municipalities have reduced their lowest trafficable residential roads to 18 feet or less. Higher volume roads are recommended to be wider. Table 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 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 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, lessening 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 5.9-1: Narrow Residential Street Widths

Jurisdiction	Residential Street Pavement Width	Maximum Daily Traffic (trips/day)
State of New Jersey	20 ft. (no parking) 28 ft. (parking on one side)	0-3,500 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. 20 ft. (no parking) 22 ft. (parking on one side) 26 ft. (parking on both sides) 26 ft. (parking on one side)	150 350-1,000 350 350 500-1,000
Bucks County, Pennsylvania	12 ft (alley) 16-18 ft. (no parking) 20-22 ft. (no parking) 26 ft. (parking on one side) 28 ft. (parking on one side)	--- 200 200-1,000 200 200-1,000

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

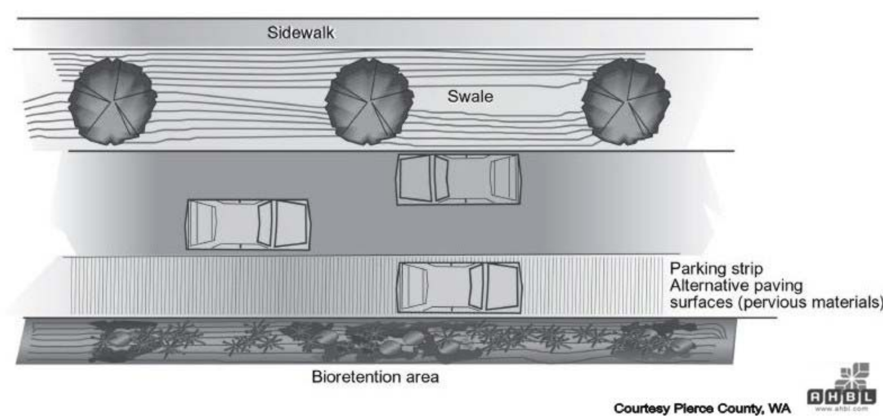


Figure 5.9-1. Reduced road width using adjacent pervious strips.

Table 5.9-2: 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 2 shows traditional and queuing lane designs.

- **Street Length**

Numerous factors influence street length including clustering techniques (discussed in a separate section). 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,

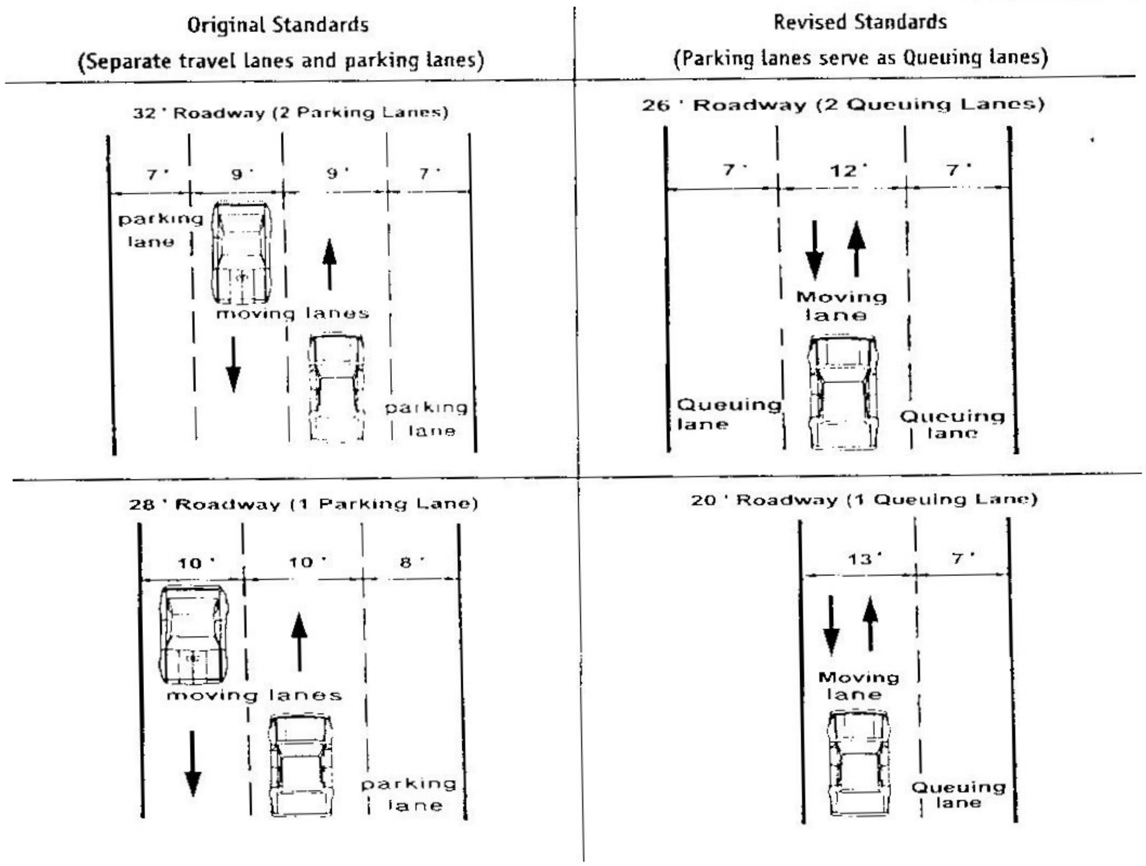


Figure 5.9-2. Traditional Streets vs. Traffic Queuing (Portland, Oregon Office of Transportation, 1994)

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.

The first alternative is to reduce the required radius of the cul-de-sac. Many jurisdictions have identified required turnaround radii (shown in Table 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 Section 5) 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 are estimated to be approximately $15/yd^2 (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 5.9-3: Example Cul-de-Sac Turnaround Radii

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

(Adapted from Center for Watershed Protection, 1998)

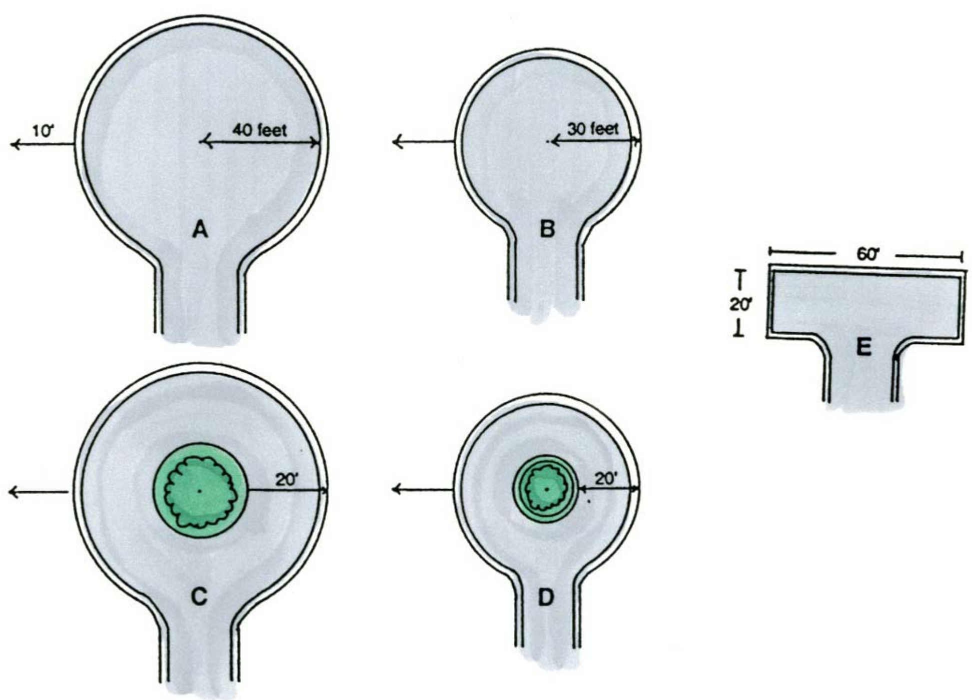


Figure 5.9-3. Five Turnaround Options for the end of a Residential Street, ("Better Site Design: A Handbook for Changing Development Rules in Your Community", Center for Watershed Protection, August, 1998)

Reduce Impervious Cover

BMP 5.10: Reduce Parking Imperviousness

Reduce imperviousness by minimizing imperviousness associated with parking areas.

Key Design Elements

- Evaluate parking requirements considering average demand as will 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.
- If 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:	No

Stormwater Functions

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

Pollutant Removal

TSS:	Preventive
TP:	Preventive
NO_3:	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 1, 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.

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

Table 5.10-1: 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)

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 the Reduce Street Imperviousness section) 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.

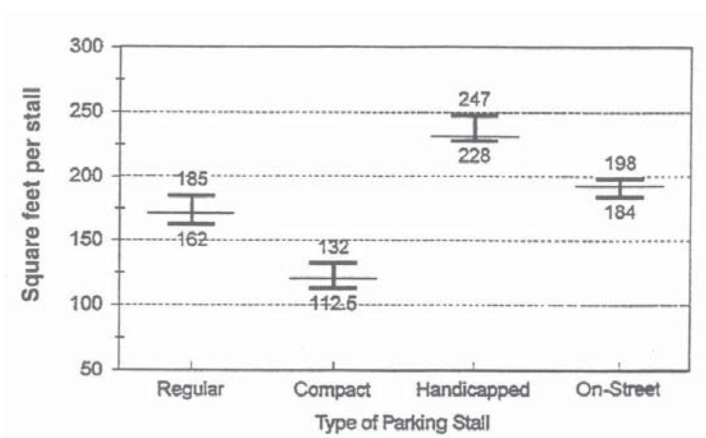


Figure 5.10-1. ("Conservation Design for Stormwater Management", DNREC, 1997)

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.

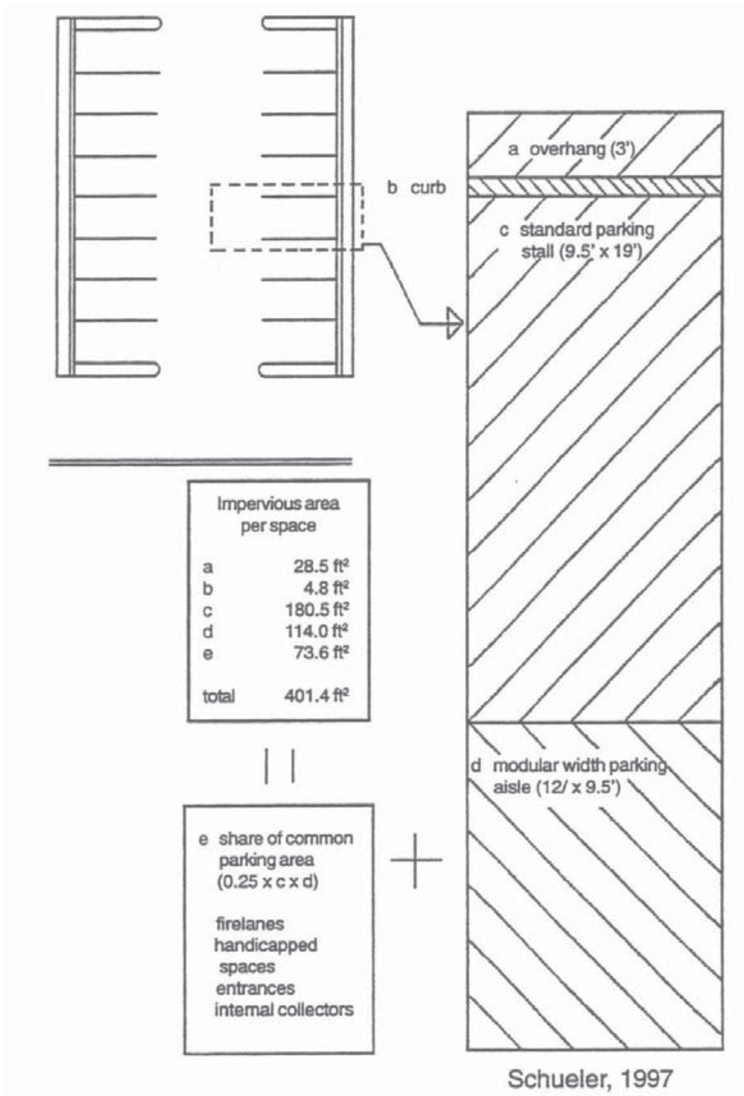


Figure 5.10-3. Parking Stall Dimensions (Schueler, 1997)

References

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

5.8 Disconnect / Distribute / Decentralize

Disconnect - Distribute - Decentralize

BMP 5.11: 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**

Pollutant Removal

TSS:	**30%**
TP:	**0%**
NO_3:	**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 Section 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.

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.

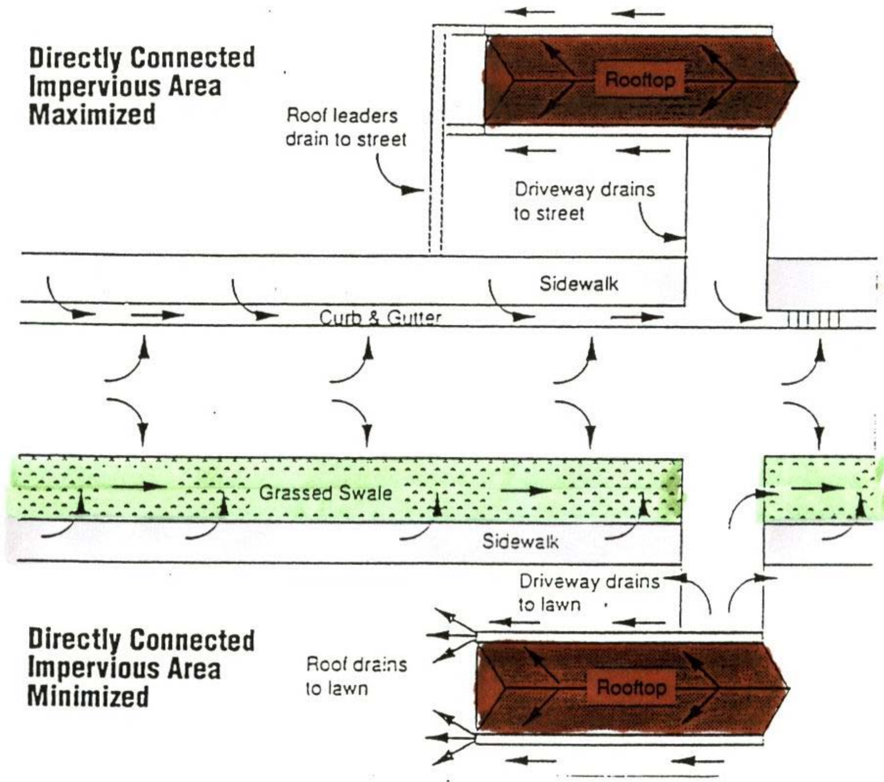


Figure 5.1-1. Examples of Directly Connected Impervious Areas (Roesner, ASCE, 1991)

- Limit the contributing rooftop area to a maximum of 500 ft^2 per downspout.
- Flow from roof leaders should not contribute to basement seepage.

Careful consideration should be giving 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 vegetated 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

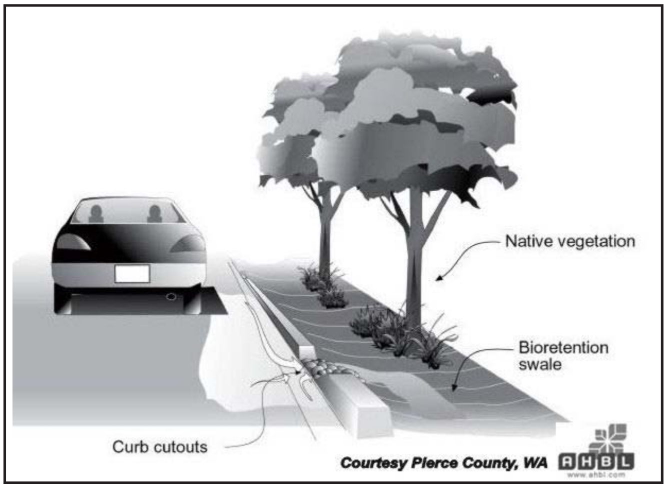
Construction cost estimates for vegetated areas should be similar or in line with that of conventional landscaping. If bioretention areas are incorporated into the site, their costs are slightly more than costs required for conventional landscaping. Commercial, industrial, and institutional site costs 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

Disconnect - Distribute - Decentralize

BMP 5.12: Disconnection from Storm Sewers



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

Key Design Elements

- Disconnect road and driveways from stormwater collection systems.
- Redirect road and driveway runoff into grassed swales, 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

Pollutant Removal

TSS:	30%
TP:	0%
NO_3:	0%

This BMP must not be viewed as lack of management. The test of this BMP is to be able to demonstrate that stormwater management is not relegated to a centralized system accomplished by centralized collection and conveyance.

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 (discussed in Section 6.8) 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 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 1. The choice of distributed BMP will depend upon site-specific characteristics including soil type, slope, and stormwater volume.

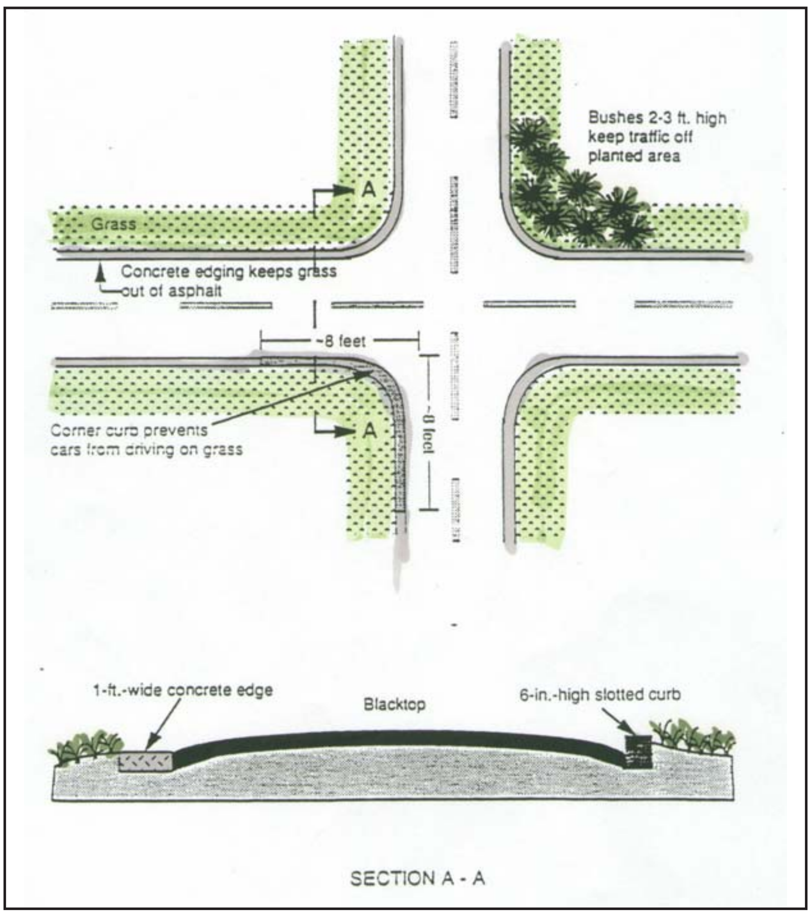


Figure 5.12-1. Example of Concrete Road Edging and Corner Curb (Roesner, ASCE, 1991)

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 keeping up the hydraulic and removal efficiency 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 Section 6. vegetated swale construction costs are estimated at approximately \$0.25 per ft2. 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

Source Control

BMP 5.13: 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

- 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 is 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**

Pollutant Removal

TSS:	**85%**
TP:	**85%**
NO_3:	**50%**

Description

National Urban Runoff Program (NURP) studies from the 1980's reported generally very poor results from streetsweeping a generation ago (1980's). In fact, in some cases, results suggested that water quality effects of conventional mechanical streetsweeping programs were actually negative, 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 which then are washed into receiving water bodies. However, new streetsweeping technology (see discussion below) has dramatically improved streetsweeping performance. And although on the one hand, these new street sweeping technologies are considerably more costly than previous streetsweeping technologies, on the other hand their pollutant reduction performance compares quite favorably to other pollutant reduction BMP's. In sum, streetsweeping can be quite cost effective in terms of water quality performance.

Figure 5.13-1 Vacuum Filter Streetsweeper

Variations

Variations in streetsweeping relate primarily to differences in equipment but also relate to important aspects of the streetsweeping programs, such as frequency of street0sweeping, 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 which 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 (60,000 in 2002, according to Stormwater).
Regenerative air: compressed air is directed onto the road surface, loosening fine particles which are then vacuumed. Includes Elgin's Crosswind J, Mobile's RA730 series, Schwarze's A-seires, Tymco sweepers. About twice as expensive as mechanical sweepers (120,000 in 2002,

according to Stormwater).

Vacuum filter: vacuum assisted small-micron particle sweepers, either wet or dry. Dry vacuum includes mechanical broomsweeping 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, then vacuumed. Four to 5 times as expensive as mechnical sweepers, according to Stormwater 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

Streetsweeping programs vary by sweeping frequency which I turn varies with several 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. But other factors such as frequency and intensity of rainfall also affect streetsweeping desired 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 (Table 1).

*Table 5.13-1 Average Expected Sediment Load Reduction (Percentage) as a Function of Sweeping Frequency for Two-High-Efficiency Sweeper Technologies (from Sutherland and Jelen, 1997)**

		Sweeping Frequency			
Sweeper Technology		Monthly	Bi-Weekly	Weekly	More Than Weekly
Residential Street					
	Regenerative air	42	53	64	71
	Vacuum dry	50	63	78	88
Major Arterial					
	Regenerative air	15	18	21	22
	Vacuum dry	50	60	77	79

**Expected load reduction based on computer model simulation using calibrated accumulation and washoff rates from Portland, Oregon. Sutherland, R.C. and S.L. Jelen, 1997. "Contrary to Conventional Wisdom, Street Sweeping Can Be an Effective BMP." Advances in Modeling the Management of Stormwater Impacts, Vol. 5 Ed. W. James. Computational Hydraulics International. Guelph, Ontario.*

Another factor to consider in streetsweeping programs is "washon" 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, streetsweeping 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 washon decreases and potential effectiveness of streetsweeping 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 streetsweeping 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 streetsweeping. Winter road applications affect streetsweeping programs

Cost Issues

Costs of streetsweeping include capital costs of purchasing the equipment, annual costs of maintenance, annual costs of operation, plus costs of disposal of the material which 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), streetsweeper costs are quite variable, with mechanical sweepers with a 5-year life cycle at $75,000, calculating to $30 per curb mile (all numbers would increase when adjusted to current value; Finley, 1996 and SWRPC, 1991), compared to vacuum streetsweepers with an 8-year life cycle at $150,000 for $15 per curb mile (Satterfield, 1996 and SWRPC, 1991). These costs are then further compared, including the variable of sweeping frequency (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 streetsweeping will vary with the frequency of the streetsweeping program, evaluations are demonstrating remarkably high pollutant removal, especially if the program includes weekly streetsweeping. The Center for Watershed Protection reports one recent study with 45-65 percent removal of total suspended solids, 30-55 percent total phophorus, 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 which is frequently better than all other BMP's.

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

Kurahashi & Associates, Inc. 1997. *Port of Seattle, Stormwater Treatment BMP Evaluation.*

Montgomery County Department of Environmental Protection, *2002. Street Sweeping for Pollutant Removal,* Montgomery County, MD.

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Sutherland and Jelen, 1997.

USEPA, 1999. *Preliminary Data Summary of Urban Storm Water Best Management Practices*

Urban Runoff in the Washington Metropolitan Area, 1983. Final Report: Washington DC Area Urban Runoff Project. USEPA Nationwide Urban Runoff Program, MWCOG Washington DC