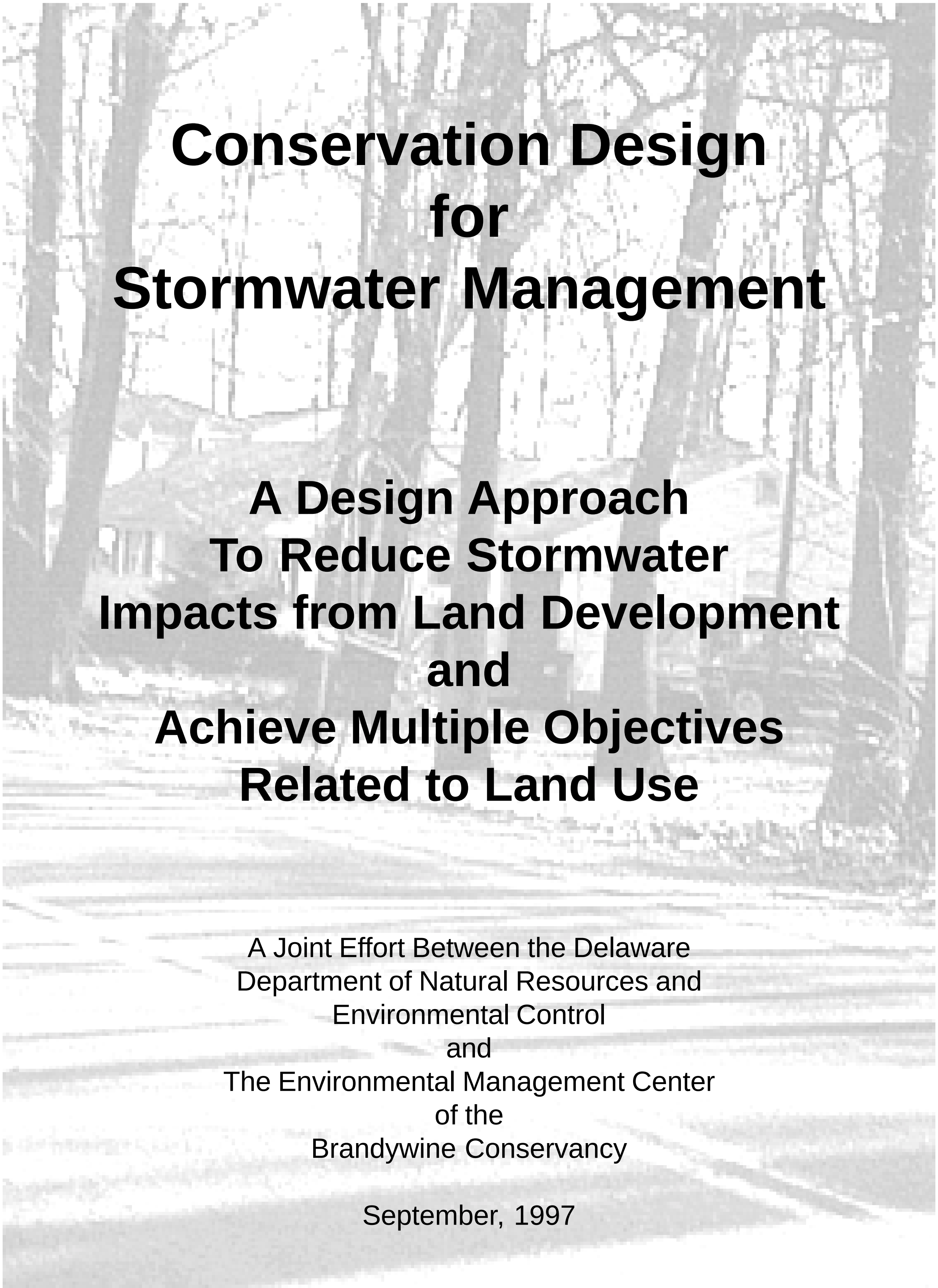

Conservation Design for Stormwater Management

A Design Approach To Reduce Stormwater Impacts from Land Development and Achieve Multiple Objectives Related to Land Use

A Joint Effort Between the Delaware
Department of Natural Resources and
Environmental Control
and
The Environmental Management Center
of the
Brandywine Conservancy

September, 1997

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By the Sediment and Stormwater Program
Delaware Department of Natural Resources and Environmental Control
and
The Environmental Management Center, Brandywine Conservancy

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September, 1997

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Introduction

> **"Conservation Design"** *is a design approach to site development that protects and incorporates natural site features into the stormwater management plan.*

Purpose

The primary purpose of this manual is to provide guidance for site design which incorporates conservation into land development.

The intent is to provide an incentive for land developers to retain and incorporate natural site features into the site development process and thereby reduce or eliminate the need for structural stormwater management controls.

The primary purpose of this manual is to provide guidance for site design which incorporates conservation into land development. The intent is to provide an incentive for land developers to retain and incorporate natural site features into the site development process and thereby reduce or eliminate the need for structural stormwater management controls. Other benefits are certainly realized through conservation design, such as more closely approximating the predevelopment water budget, protection of habitat, and reduced overall impact to the receiving system. Site features which will be discussed in the manual include:

- Wetlands
- Floodplains
- Forested areas
- Meadows
- Riparian buffers
- Soils
- Other natural features

Design procedures are provided which allow site designers to incorporate practices, inherently known to be good, but which have not had a sound rational basis to ensure plan approval. That rational basis will be provided in this manual for a variety of situations. The design approach will be flexible enough to allow for various conservation practices to be combined on one site and quantify the benefits of that combination.

It must be emphasized that structural controls will still be essential on many sites. A heavily-wooded site having a significant portion of the tree canopy removed will still have a significant increase in stormwater runoff, even with aggressive conservation planning. The practices detailed in this manual are provided as additional tools in the stormwater management toolbox. They may supplement structural control practices and may, in some situations, replace or reduce the need for structural practices while providing attractive site amenities.

Audience

The manual is primarily directed toward residential land developers and users. Commercial and industrial land uses generally have a much higher level of site imperviousness, which limits the degree that conservation design can be utilized. Conservation practices are still recommended on commercial and industrial sites, but the ability of conservation practices to eliminate or significantly reduce the need for structural practices on commercial or industrial sites may be limited.

July, 1989 flood in New Castle County
Christina Watershed

The Sediment and Stormwater Law was created in response to increasing land development pressures which caused increased levels and frequency of flooding, further degraded water quality, and impacts to aquatic organisms and habitat.

Background

Stormwater management has been implemented at a statewide level in Delaware since July 1, 1991. The Sediment and Stormwater Law was created in response to increasing land development pressures which caused increased levels and frequency of flooding, further degraded water quality, and impacted aquatic organisms and habitat. The major catalyst for approval of the law was a flood in July, 1989 which caused significant property damage. This flood heightened public awareness to the cumulative nature of flooding problems caused by continued land development.

In addition to flooding problems, there is increased recognition that other water-related problems were associated with land development. The most obvious, especially in Piedmont areas of the state is stream channel erosion with subsequent impacts to the stream biota. The development of land, especially within a watershed, increases the total volume of water running off the land during a rainfall event. This increased volume results during all storm runoff events and increases the potential for stream channels to erode. The channel capacity is increased (wider, deeper, or both) and results in the loss of private and public property and significant habitat degradation. There is documentation indicating that channel erosion in a watershed that is completely developed is the single largest source of sediment delivered downstream.

Channel erosion in a watershed undergoing development

All of us live in watersheds that have been impacted as a result of our activities on the land.

Other impacts associated with land development include the generation of pollutants carried off the landscape by stormwater runoff. Those pollutants include:

- sediments
- oxygen-demanding substances (decomposition of organic materials)
- nutrients (predominantly nitrogen and phosphorus)
- metals (many different ones but zinc, copper, lead are generally found)
- oil and grease
- microorganisms (human or animal waste)
- other pollutants (pesticides, herbicides, etc.)

Pollutant build up in a watershed, which are delivered to a receiving system, accumulate over time. Their impacts tend to be chronic rather than episodic, and increase over time. Examples of impacts associated with pollutant loadings include increased water supply treatment costs, fish kills resulting from dissolved oxygen reduction, destruction of aquatic plants and mussels, beach and shellfish area closures from bacterial contamination, and bioaccumulation of chemical pollutants. More subtle impacts include reduced harvesting or landings of fish and shellfish. All of us live in watersheds that have been impacted as a result of our activities on the land.

For all of these reasons, the Delaware State Legislature modified the existing State Sediment Control Law to improve the implementation of that program and to incorporate permanent stormwater management requirements for water quantity and water quality purposes.

Pollutants contained in urban runoff can clearly be seen on any street or parkingILot

As initially structured, the Sediment and Stormwater Regulations placed heavy emphasis on structural stormwater management practices to mitigate, to some extent, the adverse impacts of urban stormwater runoff.

The Sediment and Stormwater Regulations place heavy emphasis on structural stormwater management practices to mitigate, to some extent, the adverse impacts of urban stormwater runoff. Whenever site development is proposed, the land developer must consider both the quantity of water leaving the site, and the quality of that water. Criteria is specified in the Regulations that must be followed in terms of peak discharge exiting a property for various storms. Those peak control requirements include:

- projects located in New Castle County north of the Chesapeake and Delaware Canal shall not exceed the post-development peak discharge for the 2, 10, and 100 year frequency storm events at the predevelopment discharge rates for the 2, 10, and 100 year frequency storm events.
- projects in New Castle County that are located south of the Chesapeake and Delaware Canal, Kent County, and Sussex County shall not exceed the post-development

peak discharge for the 2- and 10-year frequency storm events at the predevelopment peak discharge rates for the 2- and 10-year frequency storm events.

For water quality treatment, a preferential list of practices has been defined in the regulations to be followed in all situations. The following design criteria are established for water quality protection:

For water quality treatment, a preferential list of practices has been defined in the regulations to be followed in all situations.

- In general, the preferred option for water quality protection shall be ponds. Ponds having a permanent pool of water must be considered before a pond having no permanent pool. Infiltration practices shall be considered only after ponds have been eliminated for engineering or hardship reasons as approved by the appropriate plan approval agency.
- Water quality ponds having a permanent pool shall be designed to release the first 1/2 inch of runoff from the site over a 24 hour period. The storage volume of the normal pool shall be designed to accommodate, at least, 1/2 inch of runoff from the entire site.
- Water quality ponds, not having a normal pool, shall be designed to release the first inch of runoff from the site over a 24 hour period.
- Infiltration practices, when used, shall be designed to accept, at least, the first inch of runoff from all streets, roadways, and parking lots.
- Other practices may be acceptable to the appropriate plan approval agency if they achieve an equivalent removal efficiency of 80% for suspended solids.

Typical stormwater management pond serving a residential community

A main goal of the 80% removal efficiency criterion is to allow for or encourage alternative design approaches. Innovative approaches may be considered at sites on a case-by-case basis if either documentation exists for achieving the 80% criterion or, in the opinion of the approving agency, innovative approaches will achieve the 80% goal. A major reason that innovative approaches have not been used more frequently is the lack of water quality performance documentation for a number of the more promising innovative approaches.

As can clearly be seen, stormwater management program implementation by the State historically has rested on the proper design and implementation of structural stormwater management. That reliance is based upon documentation of performance of these practices for water quality treatment. This is especially true for stormwater management ponds, resulting in their use being clearly specified in regulation. However, more information is now becoming available on various innovative practices, and this manual provides guidance on a desired alternative approach to site design for stormwater management.

Limitations of Structural Stormwater Management

Most stormwater management programs place a heavy reliance on implementation of structural stormwater management facilities. These facilities include ponds, both wet and dry; infiltration; filtration; and other variations of them all. The implementation of these facilities is necessary for their water quantity and water quality benefits and is expected to remain integral to program implementation, but there should not be an overreliance on them. These practices, in and of themselves, cannot eliminate adverse impacts of urban development. In addition, there are a number of limitations to structural facilities.

The implementation of structural facilities is necessary for their water quantity and water quality benefits and is expected to remain integral to program implementation, but there should not be an overreliance on them.

A stormwater management program relying solely on structural practices has a number of weaknesses.The existence of these weaknesses has been recognized for some time, but there has been little information available on alternative approaches that would justify their inclusion in a stormwater management program. In addition, clear guidance must be available on design approaches for practices which can be used by plan designers and approval agencies. The guidance must also lend itself to effective field implementation. The following items and their discussion present some of the weaknesses.

<u>Lack of Flexibility in Site Design</u>

A lack of flexibility in what a site developer can do for stormwater management will have an impact on how the site is developed. The requirement to construct a stormwater management pond will necessitate that site drainage be routed to that pond. This would mean that runoff which can travel through sheet flow across vegetated areas must be conveyed to the pond. This will normally entail conversion of the water from sheet flow into concentrated flow through a conveyance system.

Some flexibility is provided in the regulations by using an order of preference approach. This does not mandate one practice over another, but rather requires consideration of practices with known water quantity and quality performance over others. Some flexibility does exist in the regulations but that flexibility is only as broad as the interpretation of the individuals designing or approving the stormwater management plan. In reality, there is a perception, for the most part valid, that the preference for stormwater management ponds is too often a mandate. In addition, design consultants must deliver an approvable plan to the site developer. The expense associated with that plan is dependent on the consultant being reasonably comfortable that their cost estimate will provide for their time and expense in doing the site design. An innovative site design may receive a poor reception from the approval agency and necessitate a redesign with a more traditional approach to site control. Innovation is very difficult to budget for when monetary resources are limited.

Altered Site Hydrology

The only structural stormwater management practices that attempt to mimic predevelopment site hydrology are infiltration practices. Infiltration practices reduce the total volume of stormwater runoff, provide groundwater recharge, and augment base flow in streams. Unfortunately, infiltration practices cannot be placed everywhere. They cannot be used where clay soils exist, where there is a high groundwater table, on steep slopes, or where bedrock is close to the surface of the ground. In addition, the long-term performance of infiltration practices has been questionable due to clogging of soils.

The pond's purpose is to reduce, to the extent possible, the adverse impacts of the altered site hydrology.

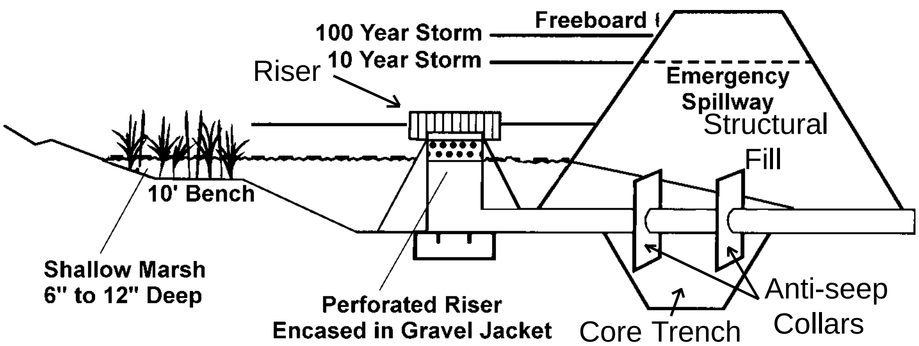
Other stormwater practices, such as ponds, only provide a degree of mitigation to land development. The volumes of stormwater runoff are increased, and consequently the duration of storm flows from these stormwater management practices is considerably longer than that which would have occurred prior to site development. From a water quantity standpoint, the intent is to hold the site's stormwater long enough to allow the watershed's storm flows to pass the site, and thus reduce downstream flooding. They provide water quality treatment primarily through settling processes that are designed into the practice.

Use of ponds is a recognition and acceptance that site hydrology has drastically been modified, and an increase in the volume of stormwater runoff is inevitable. The pond's purpose is to reduce, to the extent possible, the adverse impacts of the altered site hydrology. If the site hydrology were not altered to the degree that is normally accomplished, downstream impacts would be reduced.

Expense

In addition to design costs, there is the greater expense associated with the construction of structural stormwater management practices. These practices can be very expensive. Too often the sizing of stormwater management practices is based on the generic land use draining to the practice and does not consider that portions of the site, if left undisturbed, would not generate the amount of runoff that results from the developed portion of the site.

Stormwater management practices, as generally implemented, are structural practices. They must have properly designed structural components such as a core trench, anti-seep collars, a riser assembly with a trash rack, a barrel, and structural fill. These components are expensive and require care in their proper installation and performance.



Cross-section of a stormwater management wet pond

For the most part discussion in this manual will address ponds as the current primary means for stormwater management in site development. There are a number of other practices which are allowed in State regulation and all of these other practices are structural practices. Other primary practices include infiltration basins, trenches, dry wells, and modular or porous paving. They also include filtration practices that rely on the movement of water through a filter media, usually sand, to provide a water quality benefit. But ponds are the current choice, especially for residential development.

Conservation design practices will also utilize site area, but they can more easily be blended into the overall site development plan than can stormwater management ponds.

Loss of site area

Stormwater management ponds take up site area. When a land developer decides to develop a given piece of property, an initial consideration is how many housing units can be placed on that property, and their potential sale prices. A factor in this determination includes how much of the site must be devoted to the stormwater management pond, maintenance access to the pond, a set-aside area for sediments removed from the pond, and drainage components that convey water to the pond. All of these features limit what can be done by the land developer on the remainder of the property. Conservation design practices will also utilize site area, but they can more easily be blended into the overall site development and required open space plan than can stormwater management ponds.

Potential increased impacts to site and watershed natural resources

Generally, the lowest elevation of the site will be where the stormwater management pond is to be located. This will ensure gravity flow throughout the site to the pond. If this portion of the site is wooded or wetland, construction in this area or near this area could adversely impact on those resources. The preferential list is a significant impediment to a site design that has a major goal of maintaining natural features of a site.

Even if wetlands or other natural features are avoided by the stormwater management practice, getting a reasonable return on the project may necessitate disturbance in those areas for another aspect of site development.

Even if wetlands or other natural features are avoided by the stormwater management practice, getting a reasonable return on the project may necessitate disturbance in those areas for another aspect of site development. This could occur because housing lots may need to have a greater wetland area contained in their boundary or may necessitate cutting down more trees to get the minimum number of lots needed.

Increased disruption of natural site features can have impacts off-site. Downstream wetlands may have greater sedimentation as a result of increased site disturbance or increased disturbance of steep slopes, or erodible soils, etc. Delaware has lost approximately 50 percent of its nontidal wetlands. Those wetlands were not lost overnight or as the result of one activity. Adverse stormwater impacts are cumulative in nature and result from numerous activities having a marginal individual impact.

Configuration of Development

The traditional approach to stormwater management seems to also fit with the traditional approach to site development. The site design approach allocates a portion of the site to stormwater management in con-

Typical type of residential development where site hydrology has been dramatically altered

junction with a "cookie cutter" logic to site layout. Site development is configured in a traditional pattern that easily goes through the local government approval process. Traditional structural stormwater management is now well understood and is just incorporated in an overall site plan with little consideration of the need to protect existing site resources.

Example of a site being developed where some attention has been given to retaining trees. The stormwater management pond is on the right side of the site

Connection of Impervious Areas

Where a site has significant impervious area, those impervious areas are usually linked by conventional storm drains. Storm drains are efficient water conveyance systems which collect and quickly pass runoff into a structural stormwater management practice. Rapid travel through an enclosed storm drain system eliminates any potential for pollutants to be removed from the stormwater conveyance system prior to it's entry into the stormwater management practice. This results in the stormwater management practice being the only means of treating the runoff water quality, and providing for water quantity control.

Disregards Site Resource Conservation Benefits

There is little incentive, under the existing approach to stormwater management, to leave trees in a given location, to establish a meadow in open space, or to maintain low areas as wetlands. All of these practices reduce the total volume of runoff and provide water quality benefits. There is no incentive if structural stormwater management is still required for the land development, and the volume and areal extent of the practice cannot be reduced.

There is little incentive, under the existing approach to stormwater management, to leave trees in a given location, to establish a meadow in open space, or to maintain low areas as wetlands.

Curb cuts allowing water to pass across the vegetative filter strip prior to exiting the site thus disconnecting the impervious areas

Protecting and preserving site natural features requires a greater effort during the land development process. At present, there is little incentive for the land developer to take additional natural feature protection efforts, especially if public perception indicates that site buyers might prefer a more manicured site. The land developer must receive an economic benefit by leaving natural features if that individual is to "sell" eventual property owners on the rationale for leaving natural features.

Maintenance Obligations

Operation and maintenance of structural stormwater management practices is a significant responsibility if long term performance of the practices is to occur.

Operation and maintenance of structural stormwater management practices is a significant responsibility if long- term performance of the practices is to occur. Structural practices require routine and periodic inspections to ensure proper function and all system components need to be checked. Individuals conducting these inspections need to be trained to recognize when a problem exists and what steps need to be taken to rectify them. Inspection report forms need to be completed and given to those individuals responsible for maintenance of the practice.

Actual maintenance of the structural practice is generally divided into two categories: routine and nonroutine. Routine maintenance needs to be ongoing, such as mowing, debris removal, lubrication of any moving parts to the practice, etc. Nonroutine maintenance is done on an "as-needed" basis and can include sediment removal, replacement of worn parts, needed structural repairs, and other activities associated with a particular structural practice. Maintenance activities represent a significant commitment of time and resources to ensure long term function of the stormwater management practice.

Also, the issue of who is responsible for operation and maintenance can be a problem. This can exist where stormwater facilities such as ponds have been installed in new subdivisions. Landowner's associations or maintenance organizations may not have the expertise, awareness, or inclination to address operation and maintenance obligations or problems. There may also be a potential liability problem in the event of stormwater facility failure.

When maintenance is not accomplished, the results can range from increased downstream flooding and increased pollutant discharge, all the way to potential loss of life and property. Maintenance is a major expense associated with structural stormwater management practices.

Stormwater management pond lacking effective maintenance

Conservation design approaches reflect a totally different philosophy towards site design which integrates stormwater management into the very core of site design, as opposed to being considered an afterthought to site design.

Conservation Design Approaches

Conservation design approaches reflect a totally different philosophy towards site design which integrates stormwater management into the very core of site design, as opposed to being considered an afterthought to site design. These approaches can include an almost endless universe of practices, strategies, planning, and common sense. This manual cannot include all potential components but will provide guidance and information on many that are currently recognized where data exists or can be generated to substantiate their benefits from a water budget perspective.

It is important to develop a conservation ethic which treats stormwater runoff as a "resource" rather than a "by-product" of development. As such, there are a number of key site design components to consider:

- Reducing impervious surfaces
- Constructing biofiltration practices
- Creating natural areas
- Leaving areas undisturbed
- Clustering development

Conservation approaches will be discussed through the manual but some are briefly discussed here to provide an initial awareness of the range of options that will be discussed later in greater detail. Examples of conservation approaches include the following.

Reducing the total amount of imperviousness is the single most important conservation tool available.

Reducing Impervious Surfaces

Impervious surfaces (roads, roofs, sidewalks) prevent the passage of water through the surface into the ground. Water must then be transported across the surface to a point of discharge. Reducing the total amount of imperviousness is the single most important conservation tool available. Residential subdivisions can reduce the width of roadways, or design the roadways to limit the total length needed to service individual properties. In conjunction with imperviousness, roof downdrains may be directly connected to streets when providing splash blocks and discharging the water away from impervious surfaces (sidewalks, streets) will allow for a greater amount of water to infiltrate into the ground.

Residence having a stone sidewalk which reduces total site imperviousness

Important in limiting impervious surfaces and separating roof drains from direct connection to streets is the need for education of homeowners regarding their awareness and responsibility to ensure continued function of these practices. Homeowners often change the orientation of downspouts or otherwise redirect lot drainage to impervious surfaces which undoes a lot of conservation benefits. Community education and involvement is integral if program implementation is to be effective.

Construct Biofiltration practices

The use of vegetative swales and buffer strips can provide a significant water quality benefit in addition to reducing the total volume of stormwater runoff.

The use of vegetative swales and buffer strips can provide a significant water quality benefit in addition to reducing the total volume of stormwater runoff. The primary processes involved in their performance are filtering of pollutants contained in stormwater runoff, and infiltration of runoff into the ground.

Even with curbs being needed to prevent traffic movement off of paved surfaces, curb cuts or openings can be placed in the curb to allow water to pass off of the paved surface into a biofiltration facility. This would allow for both objectives (public works and stormwater) to be attained.

Biofiltration swale

Create Natural Areas

In many site development situations, the predevelopment condition may be farmfield or other disturbed condition. Creation of a meadow as open space would have significant stormwater management benefits for both water quantity and water quality. The area, if well designed and constructed, could become an attractive amenity to a community and enhance the value of the properties.

Leave Areas Undisturbed

Many sites have existing resources which, in addition to other values, have stormwater management benefits. These natural systems include forested areas, wetlands, and other areas of natural value such as meadows and are discussed in greater detail in Chapter 3.

Forested areas provide for rainfall interception by leaf canopy. In addition, an organic "duff area" develops on the woodland floor which acts very much as a sponge to capture the water and prevent overland flow. In addition, trees use and store nutrients for long periods of time. Trees also moderate temperatures during the summer and provide wildlife habitat, thus providing other environmental benefits.

Aerial view of a wooded area and a wetland

Wetlands are valuable resources and provide numerous benefits including flood control, low streamflow augmentation, erosion control, water quality, and habitat. They are very productive ecosystems whose maintenance would have significant water quantity and quality benefits. Where they exist on a land developing site, they could become an important element in site design.

Cluster Development

Conventional land development encourages sprawl while other approaches to land development can provide significant stormwater benefits.

How a site is developed and to what degree the entire site must be utilized will have a significant impact on stormwater runoff from the site. Conventional land development encourages sprawl, while other approaches to land development can provide significant stormwater benefits. Cluster development encourages smaller lots on a portion of a site, allowing the same site density, but leaving more site area in open space. Clustering entails designing residential neighborhoods more compactly, with smaller lots for narrower single-family homes, as are found in traditional villages and small towns. Cluster development can provide for protection of site natural areas, while at the same time reducing total site imperviousness by reducing the areal extent of roads.

Watershed Wide Approaches

Watershed wide considerations, from a broad perspective, are important and should be the context from which many resource based land development decisions are made.

While not a focus of this manual, watershed-wide considerations, from a broad perspective, are important and should be the context from which many resource-based land development decisions are made. This document strongly supports watershed based approaches to land use decisions. This context is important from a number of perspectives.

- Watershed approaches allow for a recognition and consideration of where growth distribution should occur.
- Impervious surfaces are important to consider if downstream areas are to be protected. Consideration of land use from a watershed perspective allows for a greater awareness of the cumulative impacts of watershed development.
- A comprehensive approach to resource protection can be developed and implemented based on consideration of watershed specific issues such as steep slopes, high water table, the need for aquifer recharge, etc.
- A watershed approach allows for developers and the general public to understand the basis by which land use decisions were made in a rational format which can be easily understood.
- Land use decisions based on watershed wide analyses provide the local government a basis for making land use decisions that can be defended.

Wooded riparian buffer adjacent to a lake

As desirable as watershed-wide approaches are, it must be recognized that significant resources and costs may be needed to accomplish those efforts. Depending on the goals of the effort, significant data needs may exist.

Manual Organization

The manual is composed of six chapters which discuss the following topics.

Chapter 1 - Importance of Water Budgets: General Issues

Various aspects and relative importance of considering pre- and post-development site water budgets will be discussed. These will include groundwater recharge, surface water runoff, wastewater applications, etc.

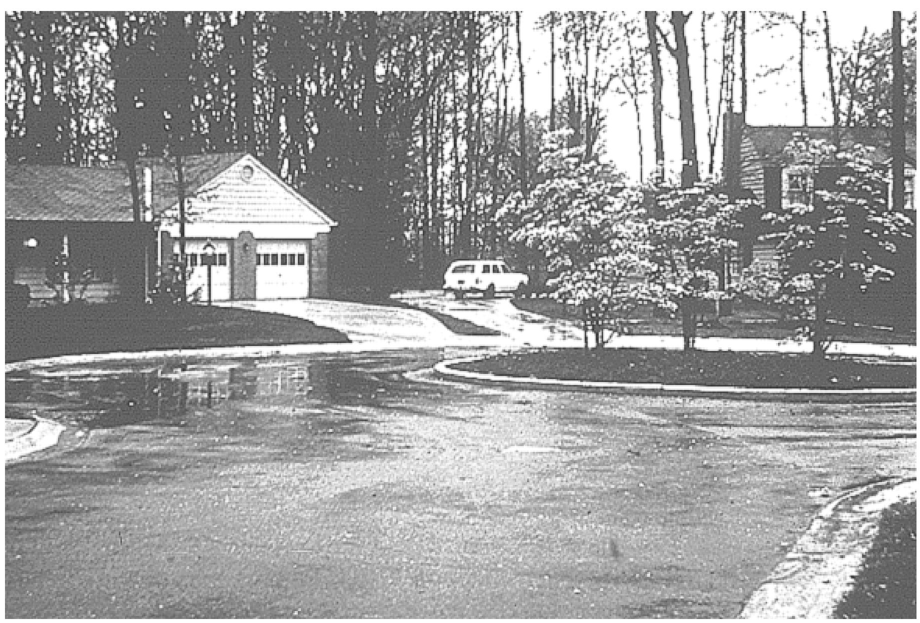
Chapter 2 - Site Resources and Limitations

Case studies of conventional residential site development will be presented, in each case highlighting adverse impacts associated with the development's structural stormwater management approach.

Site resources and limitations will be discussed in terms of their inclusion as components of overall site design. This will include a discussion of wetlands, floodplains, forested or meadow areas, riparian buffers, or other natural features whose inclusion may reduce adverse impacts.

Chapter 3 - The Conservation Approach: Nonstructural Conservation Techniques Defined

A conservation or natural approach to site design will be presented, utilizing an array of nonstructural conservation techniques. Such techniques will include: reduction in site imperviousness, use of swales versus traditional curb/gutters, clustering of development to reduce site disturbance, lengthening of stormwater flow paths, forest preservation for stormwater control, and others. Also, possible actions to reduce run-



Typical Cul-de-Sac where the center area is made pervious which reduces overall site Imperviousness

Narrow residential road, no curbs, retained trees, and vegetated swales all minimize adverseiImpacts related to stormwater runoff

A conservation or natural approach to site design will be presented utilizing an array of nonstructural conservation techniques.

off from predevelopment conditions and increase groundwater recharge through natural means will be investigated (e.g., planting of meadows on previously cultivated land, woodland creation, etc.). Benefits of each nonstructural conservation technique will be quantified in terms of quality and quantity performance and evaluated in terms of achieving Delaware stormwater management criteria.

Chapter components will include:

- Identification of conservation techniques
- Performance evaluation of conservation techniques
- Cost evaluation of conservation techniques
- Relate conservation techniques to different settings

<u>Chapter 4 - Conservation Design Procedure</u>

A stormwater management design procedure will be provided for generic use. It will include a checklist, approach to computational analysis, etc.

<u>Chapter 5 - Case Study Applications</u>

Case studies of conventional residential site development will be presented, in each case highlighting adverse impacts associated with the development's structural stormwater management approach. Hydrologic calculations will be presented to detail these impacts. These case studies will be designed to incorporate an array of different factors (soil hydrologic groups A,B,C,D), variation in slope (0-2,2-5,10,20 percent), density of development (very rural to townhouse), and predevelopment land use/cover (agriculture, meadow, forest, etc.). Costs will be developed as well.

Using the design procedure developed in Chapter 4, each case study will then be reevaluated for comprehensive application of nonstructural conservation techniques. Special questions to be addressed in these cases will consider:

- Can stormwater objectives be accomplished without reducing density?
- Can nonstructural conservation techniques eliminate the need for structural measures? If so, in what circumstances?
- Can conservation approaches be made to be compatible with zoning and subdivision regulations in the three Delaware counties?
- Can predevelopment water budgets be maintained?
- Can development and maintenance costs be reduced?
- Do different configurations of development, such as villages, offer potential benefit in terms of stormwater management objectives?

An important issue in nonstructural technique program success relates to long term effectiveness and how to make sure that institutional capability will be available to maintain the effectiveness of nonstructural techniques.

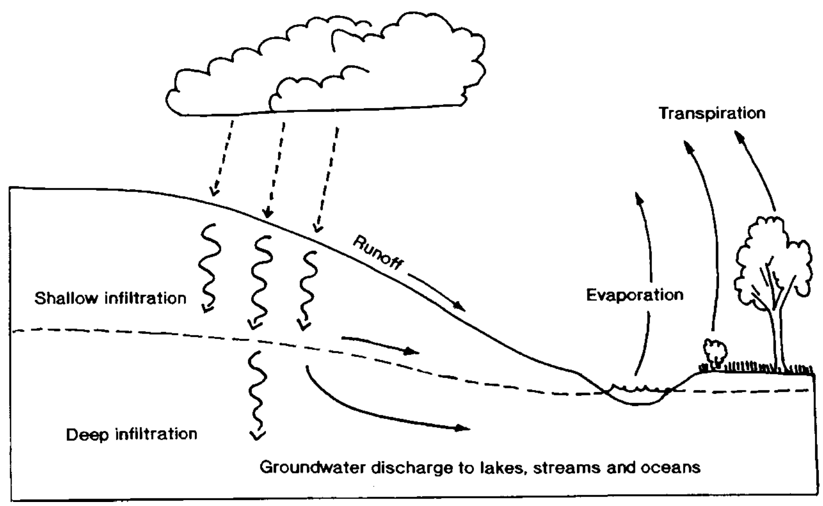
Chapter 1 Importance of the Water Cycle in Stormwater Management

The Water Cycle

To understand how we impact and are impacted by water in our world, the concept of the water cycle is key.

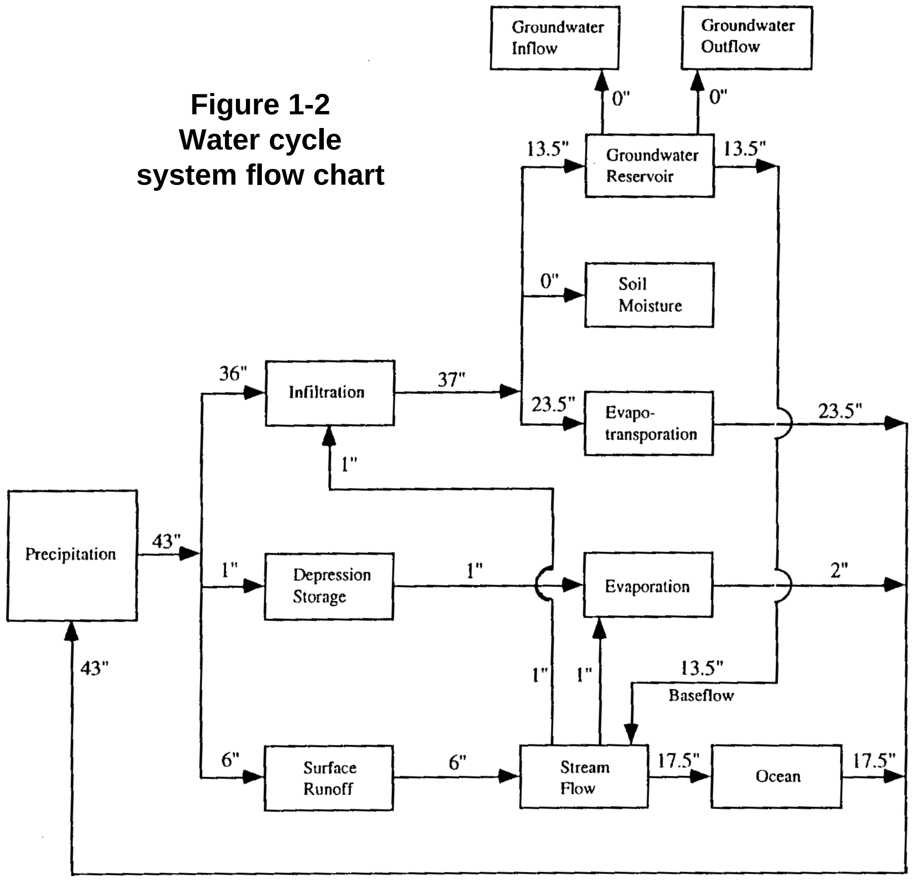
To understand how we impact and are impacted by water in our world, the concept of the water cycle is key. Appreciation of the water cycle is especially important in order to understand stormwater and achieve successful stormwater management. Figure 1-1 illustrates in simple form the essential dynamics of the water cycle (or hydrologic cycle, a term which can be used interchangeably). The water cycle arrows make the

Figure 1-1
Water cycle



point of continuous movement. Of all the aspects of the water cycle which must be emphasized, its <u>dynamic</u> quality--the never-ending cycling from atmosphere to the land and then to surface and groundwater pathways and back to the atmosphere--is most critical to appreciate. The often-heard observation that we drink the same water today that Native Americans drank hundreds of years ago is a function of this continuous cycling and recycling. The concept of continuous movement is essential in order to understand the Water Cycle system.

Figure 1-2
Water cycle
system flow chart



Impacts on one part of the water cycle by definition create comparable impacts elsewhere in the cycle.

The water cycle includes a variety of components which can be displayed in the form of a system flow chart (Figure 1-2) for an average year in our general climate zone. Figure 1-2 is generic in nature and provides only a basic accounting rather than a detailed one. The amounts are specific to a given area and will vary depending on location. Precipitation data is based on precipitation gages and includes data recorded over many years at many different stations. Total stream flow data, where available, similarly is based on stream gage data, typically recorded by the US Geological Survey, over as many years as possible, with special procedures applied to separate out stormwater runoff from ongoing stream baseflow occurring during nonstorm periods. Different watersheds with different land covers and different geologies and aquifer characteristics will demonstrate some variation in stormwater runoff and stream baseflow in average years, although the general relationships are remarkably consistent in this region.

Before delving into any one of the cycle elements in any depth, it is important here to stand back and appreciate that the system itself is a closed loop. What goes in must come out. Impacts on one part of the cycle by definition create comparable impacts elsewhere in the cycle. If inputs to infiltration are <u>decreased</u> by 10 inches, then inputs to surface runoff and/or depression storage must be comparably <u>increased</u> by this amount. Furthermore, infiltration outputs will have to be reduced by this 10 inches. Following along on the flow diagram, the groundwater reservoir, evapotranspiration and soil moisture elements together will be reduced by this 10 inches, which will further be reflected in stream baseflow reductions.

To repeat, the point here is that impacting one part of the system invariably results in impacts throughout the system. This action/reaction system sensitivity has important ramifications for any attempt to manipulate and manage elements within the water cycle. Management programs which focus on one aspect of stormwater--for example, controlling only for peak rates of runoff as we have done so often, without paying attention to the total water cycle volume impacts--produce all sorts of "surprises" and typically are doomed to failure.

Land development has come to mean a significant change in the natural landscape, including creation of impervious surfaces. When we pave over and make impervious, we increase surface runoff. Figure 1-3 dem-

Land development has come to mean a significant change in the natural landscape, including creation of impervious surfaces.

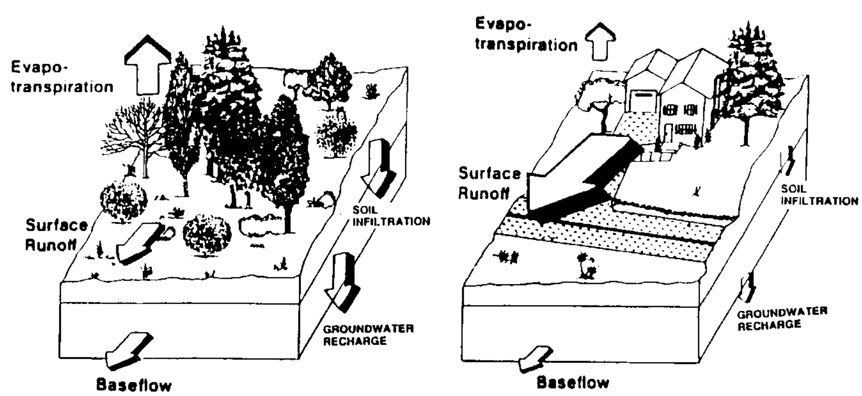
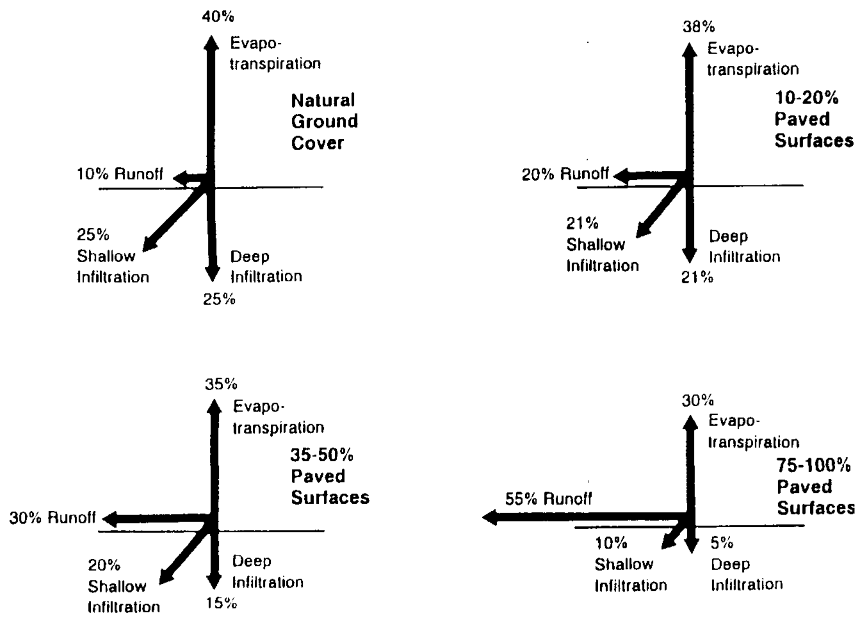


Figure 1-3
Example of change in the natural landscape

onstrates the impact. The arrows in the illustration are drawn to suggest size or extent of impact (in this case, total quantities of water involved year after year). Note that when we move from the predevelopment to post-development site, the 3 medium-sized arrows become one increased surface runoff arrow with both evapotranspiration and infiltration substantially decreased in size. Figure 1-4 carries the comparison several steps further, contrasting a Natural Ground Cover scenario with 10-20 % Impervious, 35-50% Impervious, and 75-100% Impervious scenarios. Again, the point to be made is that increasing surface runoff total volumes translates into significantly reduced total volumes of infiltration, with significant consequences later in the water cycle.

In the past, many stormwater management programs have focused exclusively on peak rate management. Detention basins are engineered to satisfy this single stormwater management need in order to prevent

Figure 1-4
Contrasting ground cover scenarios



Typical changes in runoff resulting from paved surfaces.

flooding on adjacent parcels downstream. Peak rates, pre- to post-development, are held constant, although large increases in total runoff volumes are generated. Because such efforts are so partial in concept and in effect as is explained in more detail below, because this approach to stormwater management fails to acknowledge and plan for critical systemwide water cycle impacts, stormwater management itself can become a problem, rather than a solution. **Only through understanding full water cycle dynamics can we hope to achieve some sort of near system balance and minimize water cycle impacts when managing stormwater. As the saying goes, "...nature to be commanded...must be obeyed."**

Precipitation

The logical first step in any discussion of the water cycle is precipitation in all forms. Obviously, precipitation is fundamental to the concept of stormwater. In Delaware, average annual precipitation does vary to some extent from location to location, but long-term rain gage data generally indicate average annual precipitation to be more than 40 inches--in other words, a relatively humid climate pattern. In sum, Delaware's water cycle is distinguished by a substantial precipitation input which tends to be distributed throughout the year in frequent events of modest size. The long-term charting of precipitation month-by-month confirms this even distribution . No one specific month or season tends to be excessively wet or dry, though certainly times of extremes have occurred.

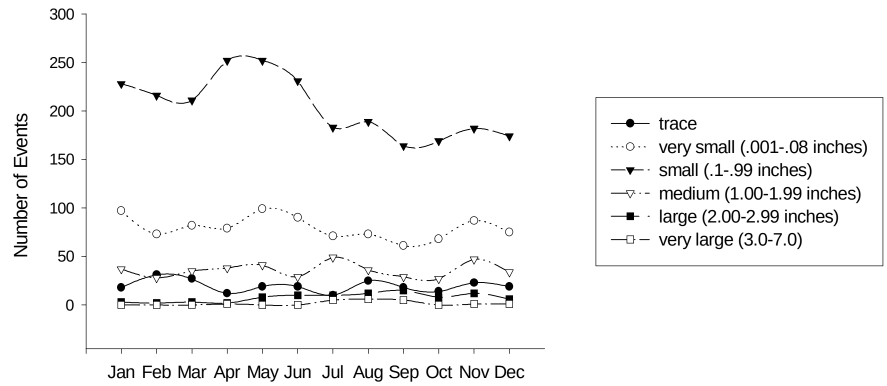
Only through understanding full water cycle dynamics can we hope to achieve some sort of near system balance and minimize water cycle impacts when managing stormwater.

Figure 1-5 graphically shows the rainfall information. The consistency in

Having rainfall throughout the year indicates that ground cover should be applied throughout the year as sediment laden runoff can occur at any time.

rainfall throughout the year indicates that the mid-Atlantic region does not have a defined wet or dry season as other areas of the country have. This rainfall potential throughout the year has significant implications for consideration of stormwater runoff, especially stormwater quality. Having rainfall throughout the year indicates that ground cover should be applied throughout the year as sediment laden runoff can occur at any time. In addition, the inter-event dry period, when pollutants are building up on the ground tends to be for a fairly short time period, which

Figure 1-5 - Comparison of the number of monthly rainfall events between six categories of intensity (event size) for the period 1948-1992; Chadds Ford, PA.



(from Hydrosphere 1992)

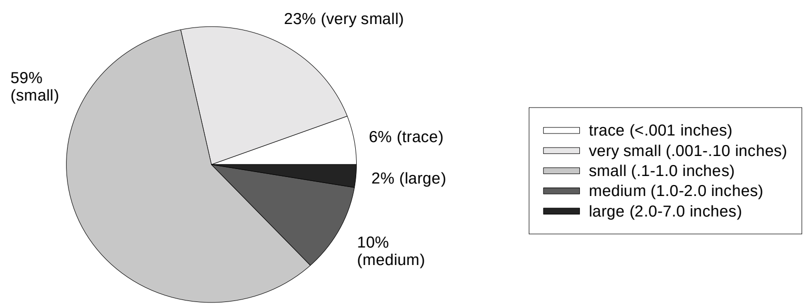
enters into sizing of stormwater facilities or considering the benefits that conservation design can provide.

Also important to stormwater is the distribution of rainfall by <u>size of event</u>. Figure 1-6, based on 35 years of data from the Wilmington rain gage, indicates that precipitation occurs mostly during smaller events. Ninety-eight percent of the total number of events during this extended period were classified in the “less than 2 inches” categories. Even more important from a water cycle perspective, 96 percent of the average annual rainfall volume occurred in storms or “events” of less than 3 inches (which is less than the 2-year, 24 hour storm); 85 percent of the average annual rainfall volume occurred in storms or “events” of less than 2 inches (defined as 2 inches of precipitation occurring during a 24-hour period, a standard precipitation definition; 2 inches happens to be less than the 1-year storm, as discussed below if using a 24 hour time period for the precipitation). Over half of the average annual precipitation occurs in “less than 1-inch” precipitation events. The vast bulk of precipitation occurs in the smaller and more frequent storm events.

The vast bulk of precipitation occurs in the smaller and more frequent storm events.

This understanding of storm size distribution is important for a variety of reasons in stormwater management. For example, if our concern is keeping the water cycle in balance, is it necessary to design to “capture” the

Figure 1-6 - Distribution of the number of rainfall events by intensity (event size) for the period 1948-1992.



(from Hydrosphere 1992)

larger and more rare storm events, say the 5-year, 10-year, 25-year, 50-year, 100-year storms, given that sizing groundwater recharge-oriented stormwater management BMPs for these larger volumes often is difficult and considerably more costly. The storm size distribution data presented here suggest that using the 1- or 2-year storm as the basis of design (rather than the 100-year storm) will capture the vast bulk of stormwater runoff and provide adequate water cycle balance. It is important to recognize that this issue of water cycle balance is different from concerns of downstream flooding increases where consideration of larger storms is necessary.

The storm size distribution data presented here suggest that using the 1- or 2-year storm as the basis of design will capture the vast bulk of stormwater runoff and provide adequate water cycle balance.

Precipitation events have been classified in storm events as below in Table 1-1:

Table 1-1
Rainfall depths for Delaware
Approximate Rainfall Depths in Inches
1, 2, 10, and 100 Year Storm Events
24 Hour Duration

Storm Frequency	Kent County	New Castle County	Sussex County
1 Year	2.8	2.7	2.9
2 Year	3.4	3.3	3.5
10 Year	5.4	5.2	5.6
100 Year	7.6	7.3	7.9

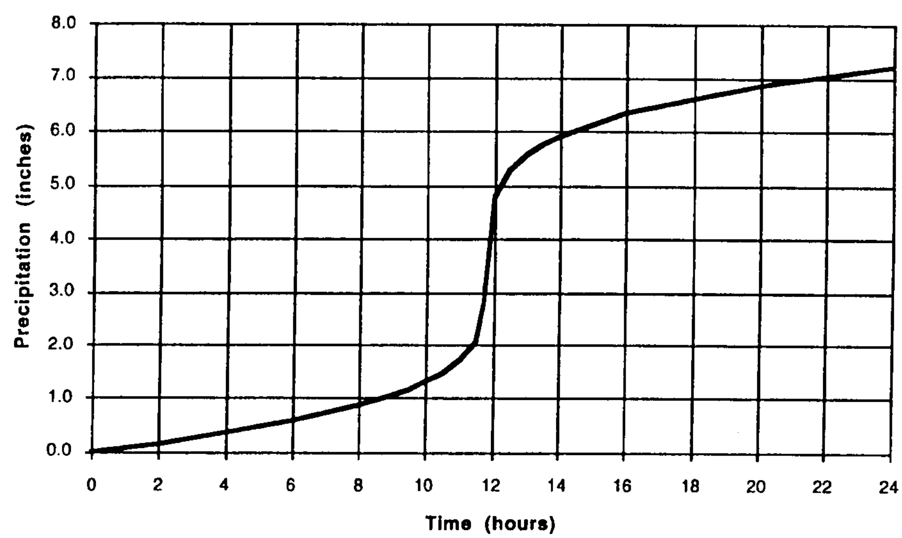
Each event is defined as precipitation occurring over a 24-hour duration. These events are to be understood as statistical probabilities. The 1-year storm has a 100 percent chance of occurring during any one year. A 2-year storm has a 50 percent chance of occurring in any one year, and so forth. The largest storms in Delaware, certainly the 100-year storm, tend to be hurricane-related events, although not all storms fit the pattern.

Variations in duration and rainfall intensity (rates) can be tremendous from one storm to another.

Another aspect of precipitation events deserving attention is the distribution of rainfall occurring during any one particular storm event. Clearly, storms occur in many different ways. Variation in duration and rainfall intensity (rates) can be tremendous. However, to rationalize the engineering and design process, agencies such as the USDA-NRCS (former Soil Conservation Service) have evaluated storm data and developed standard curves which plot rainfall during the course of the storm (Figure 1-7); the figure is a plot of total cumulative rainfall by hour into the storm, but its slope also depicts rate of rainfall as well). Typically recommended for use in stormwater management system design is the Type II Distribution Storm, shown here for the 100-year storm. Note that the rate of rainfall is estimated to increase dramatically during Hour 11, after a reasonably constant rate of rainfall occurs during the first 10 hours of the storm. In fact, rate skyrockets to about 8 inches per hour, a remarkably high rate, reflective of 1996 storm event rates, although this rate does not continue for any extended period of time in the Type II Storm. Rate falls off just as dramatically after Hour 13 or so. All of these assumptions have important ramifications for stormwater engineering design and stormwater storage volumes which must be accommodated, especially when peak rates of runoff most be controlled (i.e., if we assume that a 7.2-inch 100-year storm event dumps all of its precipitation quite suddenly, volume required to control peak rates is <u>much</u> larger than if we assume that the precipitation is more evenly distributed over

Figure 1-7
100 Year Type II Rainfall Distribution

Rainfall Mass Distribution Curve
(SCS, 1986)



the 24 hours where maximum infiltration is taking place during the course of the 24-hour storm).

The NRCS rainfall distributions are based on National Weather Service rainfall data. However, it should be understood that the distributions are synthetic and designed to handle events from a 0-24 hour duration. Therefore, short duration as well as long duration intensities can be accommodated. When we speak of 24 hour storms, it can be misleading because some people will think that the NRCS method can only handle storms of a 24 hour duration. In fact, the method is equally suitable for the 1 hour thunderstorm occurring over a 25 acre subdivision with a 20 minute time of concentration.

Groundwater Recharge and Stream Baseflow

As demonstrated in the Water Cycle figure, precipitation can take several routes after reaching the land surface. One possibility, depression storage, consists of small quantities of precipitation which are intercepted and temporarily ponded or pooled on the land surface, later to be evaporated. Depression storage tends to be relatively insignificant and not subject to significant change, pre-to post-development.

It should be noted that this discussion of the water cycle and the groundwater phase of this cycle has been highly simplified for this discussion. In fact, Delaware's hydrogeological context can be quite complex. In northern portions of New Castle County (the Piedmont Province physiographically), the consolidated aquifers do vary. Rock types may vary from high capacity carbonate formations to tighter and less water-yielding rock. Below the Fall Line in the Atlantic Coastal Province, aquifers are generally unconfined, although sub-zones of confined aquifers may exist. In the Coastal Plain, the aquifers are generally unconsolidated and unconfined, although layering of formations may translate into considerable variation where high water-yielding sands give way to clay layers and other aquifer impediments.

The discussion of water cycle must also be considered in terms of a "natural" water cycle versus a "predevelopment" water cycle.

A "predevelopment" water cycle may be very different from a "natural" water cycle.

The discussion of water cycle must also be considered in terms of a "natural" water cycle versus a "predevelopment" water cycle. A natural water cycle considers groundwater recharge from forested or natural lands as discussed in Chapter 3. A predevelopment water cycle may have land use in a watershed as predominantly agriculture. The existence of vast areas of agriculture indicates that there is a high level of stormwater runoff, soils are somewhat compacted, and infiltration rates are low. The conversion of this land from agriculture to urban development would possibly improve the groundwater component of the water cycle. These variations and complexities notwithstanding, the basic dynamics of the simplified hydrogeological model used here remain valid.

Really the focus of interest for stormwater management is both infiltration and surface runoff. As discussed above, surface runoff increase, means infiltration decrease. Land development creates both impervious surfaces and pervious surfaces such as lawns, both of which result in reduced quantities of infiltration when compared with the predevelopment condition. Important here is the predevelopment vegetative cover condition of the site; existing stands of forest or meadow or even scrub vegetation allow for considerably more infiltration than will occur with a post-development lawn on a disturbed and at least partially compacted soil base.

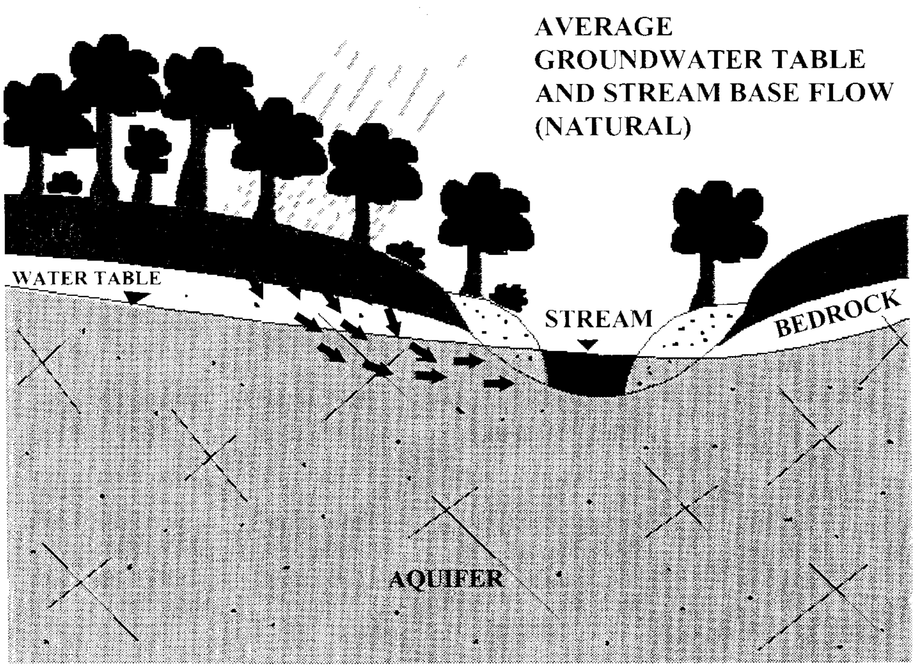
Reduction in infiltration from new land development translates into reduction in evapotranspiration. Soil moisture may decrease as well, although the assumption is made here that there are no net changes in total soil moisture content from the beginning of the year to the end of the year (never actually the case, but a reasonable assumption in this analysis). The primary water cycle impact here focuses on the groundwater reservoir component, also commonly referred to as groundwater or aquifer recharge. Decreases in infiltration mean decreases in the groundwater reservoir (note here that the assumption is made that there is no significant quantity of net groundwater inflow or groundwater outflow occurring in the system during the average year in question, meaning that in this hydrogeological context there is no significant underground water flowing in the form of underground "rivers" as might exist in other parts of the country; in other words, in most Delaware cases, whether in the Piedmont or Coastal Plain Provinces, there is a approximate coincidence between above-the-surface and below-the-surface drainage boundaries). Variations to this occur where groundwater is used for water supply or irrigation. In the case of groundwater water supply, groundwater is pumped, used in homes, businesses, or industry, and possibly sent to a sewage treatment plant, which would result in a net outflow from the system. In a similar fashion, irrigation water is pumped from the groundwater reservoir and released as evapotranspiration by the plants using the water. While not necessarily a stormwater issue, it is a part of the water cycle that is unimpacted by development

Subtract from infiltration and you subtract from the groundwater reservoir.

Subtract from infiltration and you subtract from the groundwater reservoir. As these subtractions continue acre-by-acre, development-by-development, their cumulative effect grows larger. As the effects accumulate, groundwater reservoir depletion grows more serious, and the water table, the uppermost surface of this groundwater reservoir, declines as well. Figure 1-8 illustrates a simplified predevelopment situation in cross-section, where normal precipitation patterns combine with natural vegetation to produce a particular groundwater reservoir or aquifer condition. In the post-development Figure 1-9, well development and impervious surfaces have been developed, resulting in reduced inputs to the groundwater reservoir, especially where public sewer is part of the development infrastructure. The water table declines. If we add in the effect of drought further reducing groundwater reservoir inputs and further lowering the water table, the cumulative effects of development and drought may become quite significant. Springs and streams--especially first order headwater streams--are jeopardized and may even dry up. Wells, especially older shallow wells, may fail, and wetlands, fed by groundwater discharge, will be adversely impacted. Depending upon location, salinity levels in both ground and surface water systems may increase.

Most wells can be re-drilled at greater depths, though at considerable

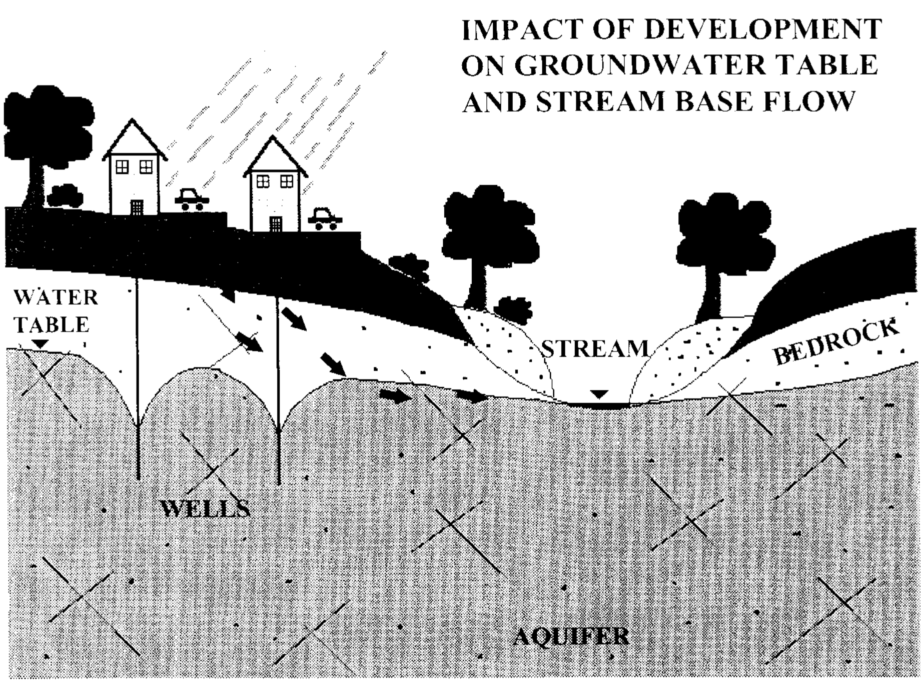
Figure 1-8
Pre-development situation



expense. Not so for headwater streams and springs--the lifeblood of the stream system. The illustrations in Figures 1-6 and 1-7, though simplified, clearly establish the dynamic and critical relationship between the groundwater reservoir and stream baseflow. If the water table declines, stream baseflow declines by definition. The groundwater reservoir might be thought of as a saturated sponge where precipitation inputs are added

If the water table declines, stream baseflow declines by definition.

Figure 1-9
Post-development situation



from time to time on the surface. In the consolidated aquifers of the Piedmont portion of Delaware, groundwater then moves gradually through a myriad of pathways down and through the nooks and crannies of the sponge, ultimately flowing gradually out at the bottom in the form of stream baseflow. However slow the movement and indirect the pathways might be for this continuous flow, however distant the point of stream discharge might be, the point here is that when subtractions are made from this groundwater reservoir flow, at some point the impact will be seen in the form of a lowered water table and reduced stream baseflow discharge. The model holds for unconsolidated aquifers in the coastal province as well.

When subtractions are made from the groundwater reservoir flow, at some point the impact will be seen in the form of a lowered water table and reduced stream baseflow discharge.

In the Delaware coastal and Piedmont physiographic contexts, stormwater runoff comprises stream flow a small fraction of the time, perhaps less than 20 percent of the time in first order headwaters streams. The vast bulk of the time, stream flow consists of stream baseflow discharged from the groundwater. This stream baseflow discharge occurs continuously, a reflection of the continuous movement occurring within the groundwater which is such a distinguishing characteristic of the water cycle.

Of course during dry periods, both the water table and stream baseflow decline as well. When the effects of drought and development are combined, the groundwater reservoir and water table may be so reduced that flows ultimately are virtually eliminated from the stream, and the stream dries up with significant ecological consequences. Even if stream baseflow is not entirely eliminated, reductions in flow occur which also adversely stress the aquatic community in a variety of ways, well before total dry up results. Dry periods are a part of the natural cycle, but the severity and duration of their impact will be increased if groundwater recharge resulting from urban development is reduced.

Adding to the seriousness of the problem is the fact that these stormwater-related impacts are magnified in the smallest streams--the headwaters zones--of the total stream system. Headwaters are defined here as 1st-order perennial streams, where the stream system with its aquatic community literally begins. In headwaters, stream baseflow by definition is modest even in predevelopment and non-drought conditions. Therefore, any subtraction from flows in these small streams proportionally has greatest adverse impact. The potential for actual dry up is greatest in this most vulnerable, most sensitive headwaters zone. Furthermore, headwaters zones comprise the largest percentage of the total stream system on a lineal percentage basis. Headwaters are the locations of critical ecological functioning where exchange of energy from land to water occurs most directly and is most ecologically vital. Headwaters zones therefore are both most sensitive and of special value.

In some cases the groundwater reservoir does not discharge to a stream, but rather to a wetland. Frequently, wetlands are zones of groundwater discharge and are in fact “fed” and kept alive by the groundwater reservoir. In these instances, reduced infiltration and a lowered water table ultimately translates into loss of wetlands themselves, reduced wetland extent, reduced wetland vibrancy and richness, and other wetland functional losses.

Another critical concern in Delaware involves the issue of saltwater intrusion into both surface and groundwaters--a classic example of water quantity effects creating problems in the quality arena. Without getting immersed in hydrogeologic system details, including the complexities of surface tidal dynamics in both surface and groundwater hydrology, the point here is that salt lines and salinity levels in both ground and surface water are important in Delaware for a variety of reasons. Preventing salt water intrusion into either surface or ground water sources is critical for public water supplies, for private wells, and for certain industries utilizing water in their production processes. Overall economic growth in many areas of the State would be impacted if saltwater encroachment either in surface or groundwaters were to occur. Stated very simply, the problem here is that reduced infiltration means reduced inputs to the groundwater reservoir and to the freshwater flow hydrostatic pressure occurring where fresh water meets waters of elevated salinity. Whether the concern is groundwater or surface water, salinity levels will move farther inland as infiltration and groundwater reservoir inputs are reduced, all else being equal. Maintaining the natural salinity gradient in any location is best accomplished through holding constant predevelopment infiltration, groundwater reservoir, and predevelopment stream baseflow inputs.

In sum, the impacts resulting from stormwater-related reduced inputs to the groundwater reservoir and stream baseflow have serious and far-reaching consequences. Comprehensive stormwater management must strive to recognize the full range of functional impacts occurring when new land development generates increased stormwater runoff. Comprehensive stormwater management strategies must strive to maintain as many of these critical water cycle-linked functions as possible.

Impacts resulting from stormwater-related reduced inputs to the groundwater reservoir and stream baseflow have serious and far-reaching consequences.

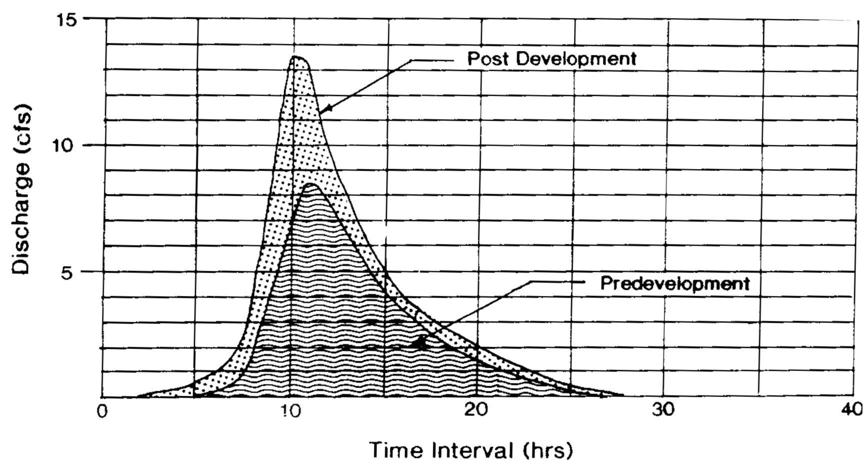
Comprehensive stormwater management must strive to recognize the full range of functional impacts occurring when new land development generates increased stormwater runoff.

Stormwater (Surface) Runoff

Because land development alters the water cycle by increasing stormwater runoff, the management concern historically has focused on how to handle excess water, how to prevent flooding. In fact, flood prevention continues to be the focus of most conventional stormwater management programs, although Delaware's program also incorporates management of nonpoint source pollutants as well.

Understanding stormwater runoff means understanding the concept of a hydrograph, a graphical comparison of runoff being discharged from any particular site (measured in cubic feet per second) on the vertical axis, versus time (measured as time into the storm event such as Hour 1, 2, 3, and so forth) on the horizontal axis. Hydrographs can be developed for sites of any size--one acre or 100 acres or 1,000 acres--and for all different size storm events. Hydrographs can actually be measured in the field (no simple matter) or can be estimated through a variety of mathematical modeling methodologies (the most typical approach). Figure 1-10 presents a hydrograph for a typical site before development has occurred (note that the actual discharge values, site sizes, etc. are largely irrelevant for sake of the comparison developed here). A storm--hypothetically, the 100-year storm--commences (see discussion above regarding assumptions for the Type II Distribution Storm and the manner in which precipitation rates occur during the storm event). As can be seen from the predevelopment hydrograph, runoff from the site does not begin for a while, until Hour 5 or so, at which point the site soils become saturated (when rate of precipitation exceeds the rate of permeability of the soils). At this time, the rate of precipitation increases dramatically, as assumed by the Type II Distribution Storm, such that the rate of runoff increases rapidly. As precipitation rates decline, runoff rates decline as well.

Figure 1-10
Typical site hydrograph pre- and post-development for uncontrolled conditions



The pattern of runoff, even in the predevelopment or natural site condition, is very much dictated by tthe assumed precipitation rates defining the storm event.

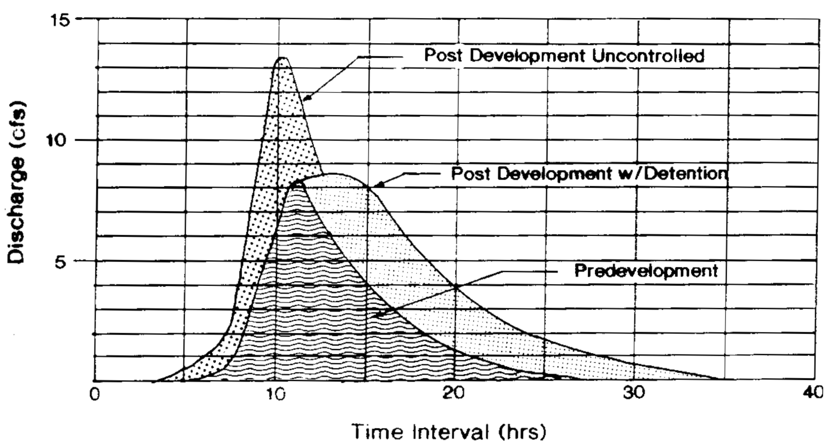
Note that the hydrograph is a graph of the rate of runoff. Rate must be carefully distinguished from volume of runoff. As mathematicians can attest, the area beneath the hydrograph curve in Figure 1-10 constitutes the total volume of runoff discharged from the site. A second point to be stressed is that the pattern of runoff even in the predevelopment or natural site condition is very much dictated by the assumed precipitation rates defining the storm event. If these assumed rates of precipitation were to be modified--if the Type II Distribution Storm were to take on a different distribution (were to be more evenly distributed, for example), then runoff rates would be modified as well. Lastly, note that there is runoff occurring even in predevelopment conditions for large storm events. Because the assumed rate of precipitation increases so dramatically in the Type II Distribution 100-year storm event, maximum infiltration rates are exceeded even without development. Even in forests, a considerable amount of runoff results during larger storms, given the assumed Type II storm distribution.

Figure 1-10 also includes a hypothetical development at the hypothetical site and presents a post-development hydrograph without any stormwater management controls in place (Post-Development Uncontrolled). Several observations relating to the two hydrographs can be made. First, the Post-Development Uncontrolled hydrograph rises or increases earlier in time when compared with Pre-Development. Runoff starts occurring earlier after development because portions of the site have been made impervious and immediately start to discharge as rain begins to occur. More importantly, Post-Development Uncontrolled runoff rapidly increases and peaks out at a runoff rate level which is considerably higher than the peak rate of runoff for Pre-Development. The extent of this peak rate increase is very much linked to the amount of impervious surface and other land cover changes involved in the development process. If only 10 percent or so of the site were to be made impervious, then increase in peak rate would not be so great. If 50 percent of the site is made impervious, extent of increase in peak rate would be dramatic.

Lastly, the Post-Development Uncontrolled hydrograph obviously encompasses the entire Pre-Development hydrograph. The area under the Post-Development Uncontrolled curve is considerably larger than the area under the Pre-Development curve, meaning that the Post-Development Uncontrolled volume discharge is larger as well.

Now let's introduce stormwater management to the picture. Figure 1-11 adds a Post-Development Controlled hydrograph to the comparison, where control is here defined as a detention basin which functions to maintain predevelopment rate of runoff constant by engineering design (via a notched weir or perforated riser or some other technique to regulate discharge rate). However, because the detention basin simply collects and detains the added runoff, discharging this increased volume at the maximum predevelopment rate over an extended period of time, the end result here is that the total area under the Post-Development Controlled hydrograph is considerably larger than the Pre-Development hydrograph. Total volume of stormwater being discharged, even with post-

Figure 1-11
Post-development controlled hydrograph



Postdevelopment uncontrolled runoff rapidly increases and peaks out at a runoff rate level which is considerably higher than the peak rate of runoff for predevelopment.

The extent of this peak rate increase is very much linked to the amount of impervious surface and other land cover changes involved in the development process.

development stormwater controls, still is significantly increased and may approximate post-development runoff not having stormwater management controls. By design, most stormwater facilities control runoff rates, but do not reduce increased post-development runoff volumes.

Peak rate control is a stormwater management strategy in large part designed to protect the adjacent downstream property. That objective usually is achieved. If the perspective is extended to the broader sub-watershed or watershed zone, what is the effect of this increased volume of runoff being discharged? What happens when many different sites throughout the watershed are developed with many different detention facilities discharging these increased volumes site-by-site? What is the cumulative watershed impact? These questions are reinforced by real world experiences where whole watersheds or sub-watersheds have been developed with reliance on a "no increase in peak rate/detention basin" philosophy and where flooding has worsened nonetheless. We need to educate people on regional watershed based hydrologic analyses.

We need to educate people on regional watershed based hydrologic analyses.

Figure 1-12 illustrates the possible flooding impacts (depending upon the location within the watershed) which can result when a peak rate control philosophy is used watershed-wide. Assumed here is a hypothetical Watershed A comprised of five hypothetical sub-basin development sites or Sub-Areas 1 through 5, each of which undergoes development and relies on a peak rate control/detention basin stormwater management approach. Pre-Development, the hypothetical storm occurs, five different hydrographs result for each Sub-Area 1 through 5 and combine to create a resultant Pre-Development hydrograph for Watershed A (note that the vertical y axis value for the total Watershed A hydrograph is simply the addition of the 5 y values for the 5 individual development sub-basins at any one point in time).

Figure 1-12
Possible flooding impacts depending on site location within a watershed

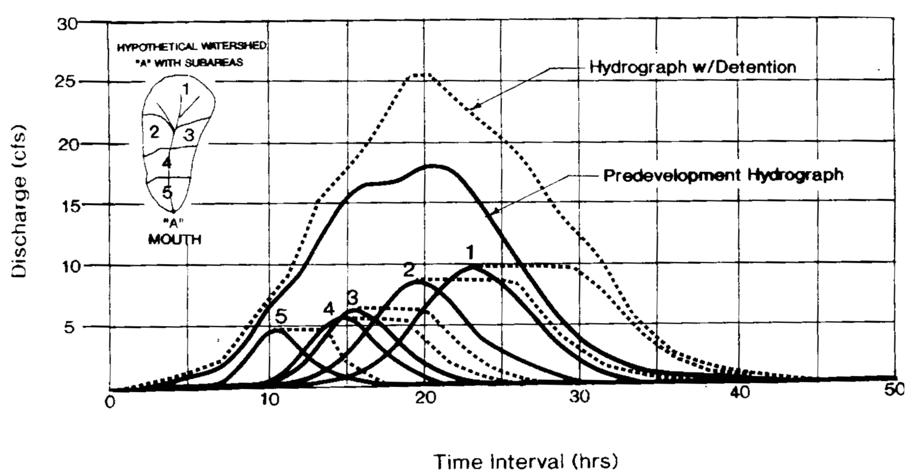


Figure 1-12 assumes that all five developments occur and utilize detention basins. The five hydrographs are modified as shown, with Pre-Development peak rates not being exceeded, but being extended. What is the impact at the base of the Watershed A? As these extended peak rates are added up, the resultant Watershed A Hydrograph grows taller. Not surprisingly, the resultant post-development with detention hydrograph for Watershed A not only exceeds the predevelopment hydrograph in terms of total area under the respective predevelopment and post-development curves (i.e., more volume clearly is discharged post-development, which would be anticipated), but peak rate of runoff for Watershed A increases considerably, because of the way in which these increased volumes are routed down the Watershed system and come together. In short, flooding may worsen considerably downstream, again even though elaborate and costly detention facilities have been installed at each individual development. The floodplain limit by definition will be expanded. Property loss, possible loss of life and limb--all the costs associated with flooding--can be expected to worsen.

Flooding may worsen considerably downstream, even though elaborate and costly detention facilities have been installed at each individual development.

Additionally, note that based on Figure 1-12, duration of flood flows--though not necessarily the absolute peak flooding rates--also increases and is extended tremendously. Looking at the Pre-Development hydrograph, the peak runoff rate may occur for an hour or so. Moving to Post-Development with Detention, that peak rate or near peak rate may extend for 11 or 12 hours. Although the hypothetical nature of all of these hydrographs must be kept in mind, the point here is that duration of serious, though not necessarily absolute, peak flooding can be expected to increase tremendously. This increased flooding results in serious impacts to the stream system, impacting its very nature and the nature and extent of the aquatic community within that system.

Ecological Response of Urbanization and Stormwater

The dynamic nature of wet-weather flow regimes and water quality make it difficult to assess the impact of urbanization and stormwater on aquatic resources. Physical habitat and biological measures reflect aquatic resource conditions over months and years and thus integrate these variable conditions into a more easily understood set of measures. In addition, these measures complement hydrologic and water quality measurements to provide a more complete picture of ecological quality. Physical habitat is a principle element of ecological assessments. Without the proper channel and riparian characteristics (e.g., floodplain, shade, stable banks, riffles, pools, etc.), improving hydrology and water quality will lead to little or no improvement in ecosystem function. Most importantly, the aquatic community (e.g., aquatic plants, invertebrates, fish, amphibians) provides a direct measure of ecosystem quality, and is a principal goal of the Clean Water Act.

Physical Habitat

Section 101(a) of the Clean Water Act:

"... protect and maintain the physical, chemical and biological integity of the Nation's waters"

"... provide for the protection and propagation of fish, shellfish, and wildlife..."

The increased frequency and magnitude of peak flows destabilizes stream banks and increases siltation. Sediment smothers stable and productive aquatic habitats such as rocks, logs, and aquatic plants. The roots of large trees are undercut and fall into the stream while new growth has less opportunity to become established. Bare soil stream banks are a common feature of urban streams.

The loss of stable riparian vegetation is further accelerated by the direct removal of trees and shrubs as part of urban development (e.g., houses, bridges, back yards, and parks). The resulting stream ecosystem is in a constant state of instability with little opportunity to become stable and more complex.

Ecosystem function and quality increases with increased complexity, and the more complex the habitat, the more complex the ecosystem function. Forests are more complex ecosystems than farm fields primarily because they are more stable and have developed a high degree of vertical stratification. Time is the engine that drives this increased complexity. The succession of a farm field to a climax hardwood forest takes 100-500 years. Controlling stormwater through structural and non-structural means allows aquatic resources to achieve a higher level of ecosystem quality by providing more stable habitat conditions.

<u>Biological Integrity</u>

<u>Impacts of Stormwater on Stream Habitat</u>

accelerated bank erosion
accelerated bank undercutting
increased siltation (burial of stable habitats)
elimination of meanders (channelization)
channel widening
reduced depth
reduced base flow
loss of shade
increased temperature

<u>Stable Habitats</u>

rocks
woody debris
aquatic plants
vegetated banks

Over time, changes in hydrology, water quality, and physical habitat transform high quality, if not pristine, streams with excellent species richness (i.e., diversity) and abundance to functional storm sewers. While not completely devoid of aquatic life, the biological community in urban streams is fundamentally changed to a lower ecological quality than was there before development occurred. In a study in Delaware, approximately 70% of the macroinvertebrate community found in streams of undeveloped forested watersheds were comprised of pollution sensitive mayflies, stoneflies, and caddisflies compared to 20% for urbanized watersheds (Maxted and Shaver 1996). The four most common species found in nonurban streams were almost totally absent from highly urbanized streams (Table 1-2). These pollution sensitive organisms were replaced by opportunistic and more pollution tolerant organisms such as midges, worms, and snails (Table 1-2).

The biological community in urban streams is fundamentally changed to a lower ecological quality than was there before development occurred.

Urbanization also impacts the fish community. In addition to a shift in

Table 1-2 - Relative abundance (%) and pollution tolerance (PT) of macroinvertebrate species commonly found in Piedmont streams of Delaware for three levels of urbanization; none (0-2% impervious cover), low (6-13%), and high (15-50%); PT range from 0 (low tolerance) to 10 (high tolerance).

				Relative Abundance (%) by degree of urbanization		
Class/Order	Genus species	Common Name	PT	none	low	high
Insecta/Trichoptera	*Diplectrona modesta*	caddisfly	0	14	2	1
Insecta/Ephemeroptera	*Ephemerella spp.*	mayfly	1	12	1	0
Insecta/Plecoptera	*Allocapnia spp.*	stonefly	3	10	18	3
Insecta/Ephemeroptera	*Eurylophella spp.*	mayfly	1	8	1	2
Insecta/Coleoptera	*Anchytarsus bicolor*	beetle	4	6	3	0
Insecta/Ephemeroptera	*Stenonema spp.*	mayfly	4	5	3	1
Insecta/Coleoptera	*Optiservus spp.*	beetle	4	4	2	8
Insecta/Coleoptera	*Oulimnius latiusculus*	beetle	2	4	3	5
Insecta/Trichoptera	*Cheumatopsyche spp.*	caddisfly	5	1	10	8
Insecta/Trichoptera	*Hydropsyche betteni*	caddisfly	6	1	4	5
Insecta/Diptera	*Simulium vittatum*	blackfly	7	0	8	1
Insecta/Diptera	*Parametriocnemus spp.*	midge	5	0	0	4
Oligochaeta	unidentified (Tubificidae)	worm	10	0	0	4

Note: rare organisms (fewer than 4 per 100 organisms) not included.

(from Maxted 1997)

the macroinvertebrate food source and the loss of productive habitats, urbanization increases the water temperature which impacts on coldwater fish (24^oC or 75^oF, DNREC 1993). This often results in complete elimination of salmonid species (trout and salmon) in urbanized watersheds. In localized areas near untreated stormwater discharges, the temperature may even exceed the level protective of warmwater fish (30^oC or 86^oF, DNREC 1993). The temperature of water discharged from a parking lot on a hot summer day can exceed 60^oC (140^oF). In a recent study of the warmwater fish, urbanization of a small watershed in the Piedmont Region of Virginia resulted in a significant reduction in species diversity, a five-fold reduction in fish abundance, and a shift in dominance to pollution tolerant species such as bluegill and shiners (Table 1-3).

Urbanization of a small watershed in the Piedmont Region in Virginia resulted in a significant reduction in species diversity, a five-fold reduction in fish abundance, and a shift in dominance to pollution tolerant species.

Need for Nonstructural Controls

Table 1-3 - Effects of urbanization of the fish community of Tuckahoe Creek, VA; composite of 6 sites.

	1958	1990
% urban (by land area)	7	28
total abundance	2,056	412
# species - total	31	23
# species - common*	21	6
% bluegill/shiner	28	67

* more than 10 individuals

(from Weaver and Garman 1994)

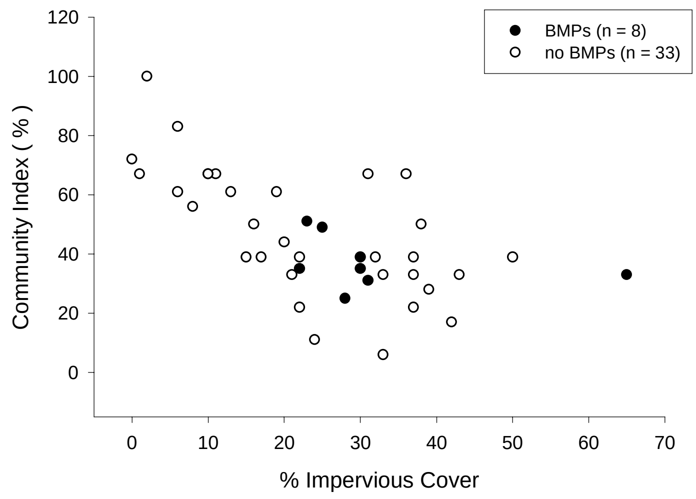
Today, retention basins designed to control stormwater are a common feature of residential and commercial developments. More recently, these facilities have evolved from simple wet or dry ponds designed to control peak runoff to ones that include constructed wetlands designed to maximize pollutant removal. As these structural facilities continue to be built and their designs continue to evolve, the question remains whether this approach to stormwater treatment is sufficient to protect the ecological integrity of wetlands, streams, and other aquatic resources.

Few studies have specifically addressed the effectiveness of stormwater controls in protecting downstream waters. Preliminary results from 8 sites in Delaware indicate that retention basins designed to reduce peak flows were inadequate, by themselves, to protect the biological community downstream. In fact, ponds themselves may have adverse thermal, D. O., or other impacts on downstream waters which must be mitigated for or allowed prior to achieving targeted environmental protection or enhancement goals. While these facilities were found to be successful in stabilizing stream channels and reducing erosion and sedimentation, there was no significant difference in the biological community between sites with and without stormwater control (Figure 1-12). These results highlight the need to include both structural and nonstructural controls within the context of overall watershed management. Conservation design elements applied before development takes place is the most effective way to achieve the goal of full protection of ecological integrity.

Watersheds in the early stages of urbanization would benefit the most from a combination of structural and conservation design alternatives.

Several studies, including those in Delaware (Figure 1-12), have shown that biological quality is reduced when watershed impervious cover increases. This decay in stream quality is very rapid in the early stages of watershed urbanization. Based upon this research, watersheds with less than 10% impervious cover are the most susceptible to the adverse effects of urbanization. Therefore, watersheds in the early stages of urbanization would benefit the most from a combination of structural and conservation design alteratives. Application of conservation designs in already developed watersheds would prevent further deterioration of

Figure 1-12 - Biological quality of streams in relation to the degree of urbanization, and the effectiveness of structural controls (BMPs); Community Index based upon macroinvertebrates, as % of reference.



(from Maxted and Shaver 1996)

ecological quality.

There are relatively few sites in the Piedmont region of Northern Delaware that have a high level of biological and physical habitat quality. In a recent survey, only 10% of the 271 miles of nontidal streams in the Northern Piedmont region of Delaware were found to have physical habitat and biological conditions comparable to streams in undeveloped forested watersheds (Figure 1-13). Streams in the “good” category would benefit the most from implementation of structural and nonstructural controls. The high proportion of streams in the “fair” category would benefit from efforts to prevent further degradation, and possibly improved to “good” conditions through targeted restoration efforts.

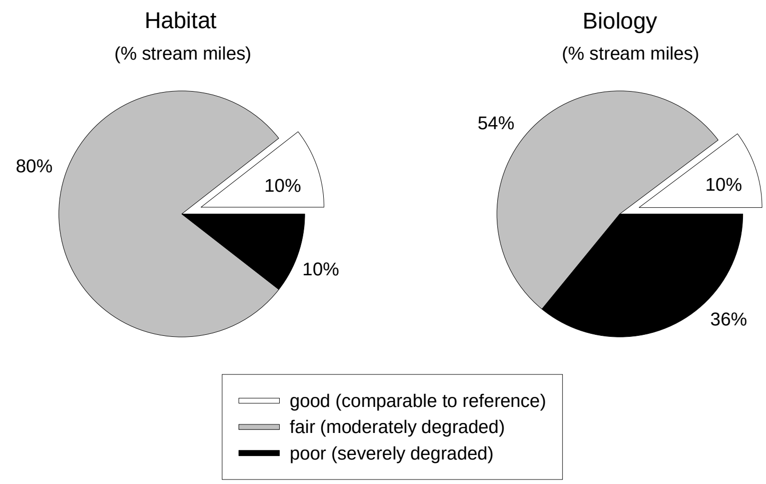
There are relatively few sites in the Piedmont region of Northern Delaware that have a high level of biological and physical habitat quality.

Other Impacts to the Water Cycle: Water Supply and Wastewater Management

Although this manual specifically focuses on more effective management of stormwater, nevertheless, discussion of land development impacts on the water cycle cannot ignore the important role of both water supply and wastewater management. The goal of Conservation Design, in a total sense, is the integration of all aspects of water--stormwater, wastewater, water supply--into a comprehensive program of management which sustains water resources, both groundwater and surface water, quantity and quality. Water supply and wastewater management both figure into the equation in important ways.

In the ideal, Conservation Design is intended to result in land development which is self-sustaining, balanced over the long-term. Conserva-

Figure 1-13 - Proportion of nontidal streams miles in Northern Delaware with three levels of physical habitat and biological quality.



(from DNREC 1994)

The goal of conservation design, in a total sense, is the integration of all aspects of water -- stormwater, wastewater, water supply -- into a comprehensive program of management which sustains water resources.

tion Design therefore translates into reliance on local (i.e., within the watershed) water supplies, in contrast to systems where significant transfer of water from one watershed to another occurs. Inter-basin transfers out of one watershed into another generally are to be avoided. There's no such thing as "free" water, although major water supply actions such as reservoir construction has occurred, will continue to occur, and provides a solution in certain circumstances, though never without impacts. It should also be noted that in those areas where sewer and water supply infrastructure already exists, where treatment capacity and distribution and collection systems already have been put in place, the concept of water cycle balance maintained watershed-by-watershed may need to be kept flexible in order to efficiently and effectively utilize this existing infrastructure. Where such infrastructure does not exist, however, the philosophy should be to maintain watershed balance as much as possible.

The wastewater management corollary principle for Conservation Design is simply to rely on land-based treatment systems which recycle treated wastewater effluent water back to its source, as close to the point of "origin" as possible. Of course, these objectives are not always achievable. If an area's soils are poor and impermeable (shallow depth to bedrock, high water table, other constraints), for example, such zones are not going to be acceptable for various alternative approaches to land application of wastewater effluent. Nevertheless, in so many rapidly developing portions of Delaware, there is opportunity to integrate and achieve Conservation Design objectives, where land-based wastewater treatment, as well as stormwater treatment, is incorporated into development design from the outset.

The approach to wastewater management has significant impact on any specific development proposal's water balance. If water supply is onsite or locally supplied, redirection of wastewater to a conventional treatment plant with possible disposal via stream discharge can be expected to cause significant water budget losses. Some loss during use is always experienced for residential uses and can be conservatively estimated at 10 percent on average, with this loss increasing significantly depending upon type of residential development being proposed. For nonresidential uses this loss may range from a negligible to a very large factor, if the use is especially water-consuming.

A much larger loss potentially occurs during the course of wastewater treatment. Export of wastewater with stream discharge is totally depletive in most cases. Onsite septic systems and community onsite septic systems are quite efficient in terms of quantity recycling. Spray irrigation systems are very efficient as well; although some sources maintain that evapotranspiration loss is significant at least in certain seasons, water budget modeling demonstrates that the annual water cycle benefit from spray systems is quite substantial. In addition, spray irrigation is better than stream discharge for groundwater recharge. Wastewater treatment options compatible with Conservation Design are discussed in various publications and reports. Contact DNREC's Groundwater Discharges Section for additional information on land-based systems at (302) 739-4761.

Stormwater and Water Quality

The discussion thus far in the manual has been largely quantity--not quality--focused. The importance of quantity issues notwithstanding, several important points need to be made regarding water quality and stormwater. We sometimes make this distinction between water quality and water quantity, as though the two issues were separable and unrelated. But the truth is that although the distinction between quality versus quantity may make sense in certain cases, the reality is that both aspects of stormwater are inextricably linked. As will become more apparent as we move through the discussion of Conservation Design techniques, strategies which effectively address <u>quantity</u> will in many cases address <u>quality</u> as well. As the much referenced quote advises, "...everything is connected to everything else." Runoff from newly paved surfaces--both the increased volume and rate of runoff--means that pollutants are scoured, suspended, and swept away. Strategies which reduce this impervious surface and/or immediately redirect runoff into natural swales directly reduce the source of stormwater and indirectly reduce the agent which transports stormwater-linked pollutants. If we eliminate runoff quantitatively, erosion by definition will be eliminated.

Strategies which effectively address quantity will in many cases address quality as well.

"Everything is connected to everything else".

Once in the stream, increased volumes and rates of runoff mean streambank erosion, undercutting, flattening and straightening of the channel, resuspension of sediment, all of which become serious quality problems. Even if flooding is not worst case, full or near full bank flooding has serious water quality ramifications. Therefore, although the focus of this chapter has been on water quantity and the water cycle, both quantity and quality are very much at issue.

Even so, not all quality pollutant loads can be eliminated through quantity reduction techniques. Some roads and highways are necessary which will generate vehicle use and pollutant generation by definition (i.e., there is some proportion of these pollutant loads which are not variable and will be generated even if maximum reduction in quantity can be made to happen). At the other end of the quantity spectrum--reductions in stream baseflow--water quality and water quantity issues emerge as well. To the extent that any fixed or constant source of pollution--for example, point source discharges or malfunctioning onsite septic systems--continue to generate pollution loads as infiltration and stream baseflow decline, this reduced stream baseflow translates into increased concentrations of instream pollutants with pollution-related problems growing more severe.

Water quality aspects of stormwater management have become a major concern nationwide. In fact, stormwater-linked nonpoint source pollution--the mix of pollutants which is washed off the earth's surface with each precipitation event--is often cited as the primary water quality problem in the nation today. As a result, numerous manuals have been produced on the federal, state, and county levels setting forth management programs designed to minimize stormwater-linked water quality problems.

Pollutant loads are generated both from impervious areas which are created as well as from pervious zones.

Stormwater-linked pollutants vary with type of land use and intensity of use and have been shown to include bacteria, suspended solids, nutrients, hydrocarbons, metals, herbicides and pesticides, other toxics, organic matter, and others. Pollutant loads are generated both from impervious areas which are created (hot spots such as gas stations, fast food parking lots, and heavily traveled roadways are primary culprits) as well as from pervious zones, such as the chemically-maintained lawns and landscaped areas where chemical maintenance can be considerable. Some nonpoint pollutants are even airborne, deposited onto the land surface and then are washed into receiving waterbodies. Sources of this pollution include:

- vehicles
- vegetative decay (leaves, grass, etc.)_
- direct atmospheric deposition
- petroleum based
- general litter, including pet litter
- soil erosion
- road surface applications (salt, sand, etc.)
- fertilizer
- pesticides/herbicides

It should be noted that water quality already is addressed by the Delaware stormwater program. BMPs with emphasis on permanent pool ponds have already been defined by DNREC; criteria and standards have been established. The state's approach is intended to capture 80 percent of the total suspended solids generated. To the extent that new land developments utilize the ponds and other BMP's specified by the State, other water quality mitigation will be provided as well. For example, not only will substantial portions of particulate-form pollutants settle out through use of these systems, but soluble-form pollutants such as nitrates can be reduced as well.

Physical Types of Pollutants: Soluble vs. Particulate

The physical form of the pollutant has major bearing on all aspects of stormwater management. One very important way of differentiating pollutants is the extent to which pollutants are particulate vs. soluble in nature. Good examples of this comparison are the nutrients phosphorus and nitrogen. Phosphorus typically occurs in particulate form, often bound to soil particles. Because of this physical form, stormwater management practices which rely on physical filtering and/or settling out can be largely successful for phosphorus removal. In stark contrast is nitrogen, which tends to exist in highly soluble forms where any sort of attempt at physical filtering has little if any effect. As a consequence, stormwater management approaches for nitrogen must be quite different in approach (wetlands/wet ponds and other approaches where anaerobic conditions are promoted and where denitrification can occur are preferable). Unfortunately, strategies to remove nitrogen through anaerobic activity may cause deposited phosphorus to become resuspended in the water column. One stormwater facility cannot of itself remove all types of pollutants. That is why the treatment train is so important to stormwater management, and why a conservation approach to site development will necessitate consideration of a number of site resources to work in conjunction with one another to improve efforts at pollution reduction.

The physical form of the pollutant has major bearing on all aspects of stormwater management.

One very important way of differentiating pollutants is the extent to which pollutants are particulate versus soluble.

Natural Mechanisms for Stormwater Pollutant Reduction/Mitigation

Although stormwater-related pollution often can be reduced if not eliminated through preventive Conservation Design approaches driven by quantity reduction objectives (addressed in more detail in Chapter 4), not all stormwater pollution can be avoided. In such cases, an array of natural pollutant removal processes are available for use and should be exploited to the maximum. Because these processes tend to be associated with, even reliant upon both the vegetation and soil realms, they can be readily incorporated into other Conservation Design approaches. Such natural pollutant removal processes include:

Settling/Deposition: as discussed above, the kinetic energy of stormwater washes all types of matter, particulate form and other, from land cover surfaces. Particles remain suspended in stormwater flows as long as the energy level is maintained. Larger particles require more kinetic energy in order to remain in suspension. As the energy level declines--as the storm flow slows, these suspended particles begin to settle out by gravity, with larger, heavier particles settling out most quickly and the smallest colloidal particles requiring considerably more time for settling. To the extent that time can be maximized, more settling can be expected to occur, holding all other factors constant. Therefore, approaches which delay stormwater movement or approaches which reduce kinetic energy in some manner (e.g., energy dissipaters) serve to maximize settling and deposition.

Filtering: another natural process is physical filtration. As pollutants pass through the surface vegetative layer and then down through the soil, larger particles are literally physically filtered from stormwater. Vegetation on the surface ranging from grass blades to underbrush removes larger pollutant particles. Stormwater sheet flow through a relatively narrow natural riparian buffer of trees and understory herbaceous growth has been demonstrated to physically filter surprisingly large proportions of larger particulate-form stormwater pollutants from stormwater flows. Both filter strip and grassed swale BMPs rely very much on this filtration process. Filtration may also occur in stormwater which is infiltrated and then gradually moves downward through the various soil layers, although once this infiltration process begins, a variety of other pollutant removal processes (see below) are set into motion as well.

A vast and complex community of microorganisms exists within the soil mantle, and though microscopic in scale, the myriad of natural processes occurring within this realm is just remarkable.

Biological Transformation and Uptake/Utilization: though grouped as one type, this category includes a complex array of different processes that reflect the remarkable complexity of different vegetative types, their varying root systems, and their different needs and rates of uptake of different “pollutants” (in this case, clearly “resources out of place”). An equally vast and complex community of microorganisms exists within the soil mantle, and though more micro in scale, the myriad of natural processes occurring within this realm is just as remarkable. Certainly both nutrients phosphorus and nitrogen are essential to plant growth and therefore are taken up typically through the root systems of the various vegetative types, from grass to trees. Nitrogen processing is quite complex, a function of nitrate/nitrite and ammonia/ammonium forms. The important process of denitrification occurs through the action of widely present facultative heterotrophs, which function to facilitate the exchange of ions in the absence of oxygen and ultimately convert nitrates for release in gaseous form. These processes ultimately become chemical in nature (as discussed in the next section). As wetland species are introduced, all of this processing becomes more chemically complex.

Chemical Processes: For that stormwater which has infiltrated into the soil mantle and then moves vertically toward groundwater aquifers, various chemical processes also occur within the soil. Important processes occurring include adsorption through ion exchange and chemical precipitation. Cation Exchange Capacity (CEC) is a rating given to soil which relates to a particular soils ability to remove pollutants as stormwater infiltrates through the soil mantle (i.e., through the process of adsorption). Adsorption will increase as the total surface area of soil particles increases; this surface area increases as soil particles become smaller, as soil becomes tighter and denser (in other words, large particle sandy soils end up having considerably lower total surface areas per unit volume measure than a heavy clayey soil. CEC values typically range from 2 to 60 milliequivalents (meq) per 100 grams of soil. Coarse sandy soils have low CEC values and therefore are not especially good stormwater pollutant removers (a value of 10 meq is often considered to be the minimum necessary to accomplish a reasonable degree of adsorption-related pollutant removal). Conversely, "tighter" soils such as clayey types have much higher CEC values.

Conservation design techniques offer an array of natural processes and techniques which substantially increase pollutant removal potential above and beyond mitigation being provided by many of the structural BMP's currently utilized.

Conservation Design techniques offer an array of natural processes and techniques which substantially increase pollutant removal potential above and beyond mitigation being provided by many of the structural BMPs currently utilized as part of Delaware's stormwater management program. Through a combination of vegetative-linked removal combined with a host of processes occurring within the soil mantle, pollutants entrained in stormwater runoff are removed and in some cases even eliminated. In this way, pollution is prevented from making its way into either the groundwater or surface water systems. The various Conservation Design techniques and the pollutant removal performance of these various techniques is presented in more detail in Chapter 4.

Chapter 2
Site Resources and Limitations

Site resources are those natural features or site characteristics which, to a large extent, provide a benefit to receiving systems through their existence.

Introduction

Site resources are those natural features or site characteristics which, to a large extent, provide a benefit to receiving systems through their existence. They also provide a benefit to the general public by their continued function to reduce peak rates and volumes of stormwater runoff, provide for water quality treatment, and prevent damage to improved or natural lands either on the site where the site resources exist, or downstream of those resources. Site resources can include a wide variety of items, but those discussed here are considered primary resources which should be recognized and considered in site development and use. In terms of this Chapter, the following site resources are important to discuss due to their stormwater management benefits:

- Wetlands
- Floodplains
- Forested areas
- Meadows
- Riparian buffers
- Soils
- Other natural features

It must be recognized that site resources may overlap in that a riparian buffer may lie within a floodplain or a forested area may be within a riparian buffer. For the sake of this chapter, they are discussed individually although their benefits may be, and generally are, cumulative.

Ecology and Landscape Position

It is often said that there are three principal factors that determine the economic value of real estate: location, location, and location. The same is true of natural resources. Where natural features are located on a site is just as important as the characteristics of the natural features themselves. The importance of landscape position has spawned an entire field of ecological study called landscape ecology.

There are several basic principles of ecology, and more specifically landscape ecology, that determine ecosystem function and value (Smith 1996). These principles apply to all of the site resources presented in this Chapter, and serve as an introduction to the information presented for each site resource.

Principles of Ecology and Landscape Position
as applied to Urban Design

- Old is more valuable than new
(wetlands and forests are key resources)
- Complex habitats are more valuable than simple ones
- Large tracts are more valuable than small tracts
(floodplains are key resources)
- Fragmentation reduces ecosystem function
- The value of small tracts is increased if connected to larger tracts
(headwaters are key resources)
- Rare species are important and easily overlooked
- Our knowledge is limited
(need for safety factors)

Ecosystem Age and Complexity

Wetlands, floodplains, and mature forests are key resources in conservation design because they are generally the oldest and least disturbed natural resources. While wetlands and floodplains have been substantially altered by agricultural and urban development, those that remain are the wettest and the least disturbed. Mature upland forests take 100-200 years to develop so their existence indicates a lack of recent disturbance.

Wetlands, floodplains, and mature forests are key resources in conservation design because they are generally the oldest and least disturbed natural resources.

Ecosystem function increases with time. The development of ecosystem complexity and function over time can be seen in the following example of succession from a farm field to a mature forest.

When an uninhabited environment is first colonized by plants and animals, the community is quite simple, changes rapidly (i.e., unstable), and shows little organization (photo #1). Plants that are suited to soil that is low in organic content, are rapid colonizers, are able to withstand long dry periods, and require direct sunlight will thrive here. This level of ecosystem development takes 1-5 years.

With the passage of time, distinct clumps or patterns appear. Groups or assemblages of species appear that partition the environment into layers or strata that begin to increase the complexity of the system (photo #2). The increased complexity is most easily seen by the displacement of grasses and herbaceous plants by woody shrubs and small trees. The organic content of the soil increases as the vegetation decays and the shade reduces evaporation. The increased complexity of the physical environment in turn supports a greater variety of animals. This change

1. Fallow farm field with weeds

2. Late successional field

takes 5-10 years.

With of passage of more time, trees to dominate. The ability of trees to grow above the shrub layer allows them to intercept the energy from the sun. The vertical complexity of the system increases as the vegetation pushes higher. In the early stages of forest maturity, the understory or shrub layer is still heavily developed and the trees are close together. These forests are often difficult to walk in due to this dense vegetation (photo #3). Getting to this point takes 10-50 years since the initial disturbance. An undisturbed forest with little or no understory that is easy to walk in is usually at least 100-200 years old (photo #4).

3. Early successional forest

4. Late successional forest

Complex ecosystems often look messy to our civilized eyes. Natural resources can take on a wild appearance as they become more complex, as shown by the previous example of forest succession. In the past, when we used these lands, we modified and simplified them by cutting trees, clearing fields, and draining wetlands. Our cultural bias for control over natural resources must be understood and set aside in order to allow these altered ecosystems to be restored to their full complexity and function.

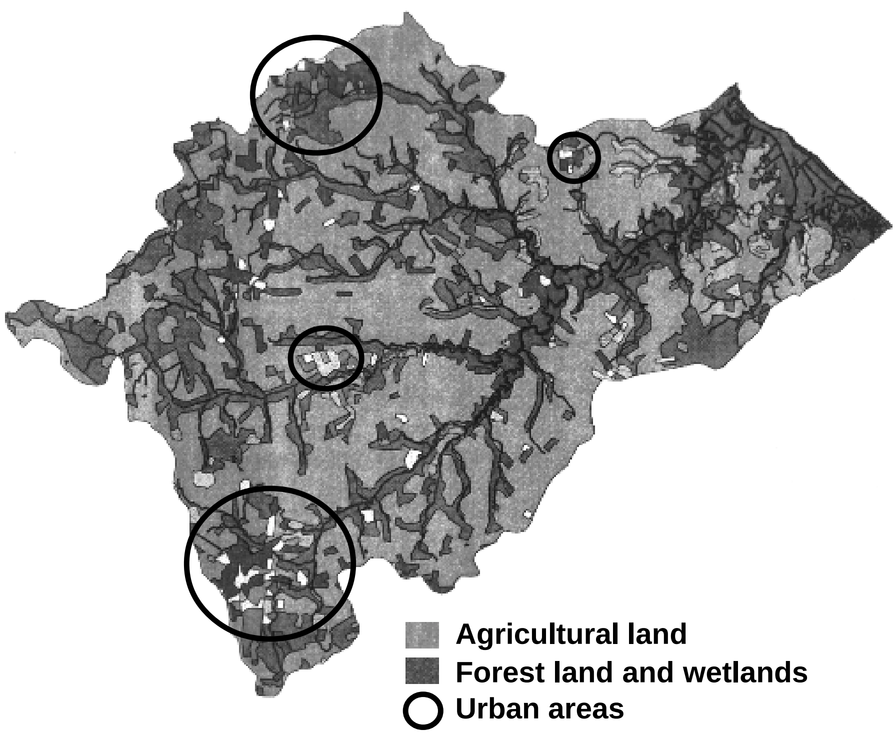
Ecosystem function increases as the size of the natural area gets larger.

Tract Size and Fragmentation

Ecosystem function increases as the size of the natural area gets larger. The underlying premise of the National Park system is that large tracts of land are required to preserve the function and value of the ecosystem as a whole. The inverse is, therefore, also true and is particularly relevant to urban design. As natural areas are bisected and fragmented by roads, buildings, and utility lines, ecosystem function is reduced (Harris, 1984).

Much of the region was covered in forest prior to European settlement. It has been said that during this period a squirrel could travel from the Atlantic Coast to the Mississippi River without touching the ground. These contiguous woodlands had maximum ecosystem function due to its age, size, and complexity. Man's influence on the land has shrunk (Figure 2-1) this network of connected woodlands to a fraction of its former size. Wetlands in the floodplains and along stream channels are the last remaining large natural areas left relatively undisturbed in Delaware. For this reason, floodplains are of critical importance in conservation design.

Figure 2 - 1
Land use of Murderkill River watershed showing riparian corridors



What makes floodplains particularly valuable ecologically is their connection to water and the natural drainage systems of wetlands, streams, ponds, lakes, and estuaries.

The many benefits that floodplains provide is partly a function of their size and lack of disturbance (e.g., age). But what makes them particularly valuable ecologically is their connection to water and the natural drainage systems of wetlands, streams, ponds, lakes, and estuaries. The water quality and water quantity functions provided by the floodplain overlap with the landscape functions of tract size and ecosystem complexity to make them exceptionally valuable natural resources.

Even back in the 1700's, scientists observed that large tracts of undisturbed woodlands and wetlands supported more species than smaller tracts.

Even back in the early 1700's, scientists observed that large tracts of undisturbed woodlands and wetlands supported more species than smaller tracts. This was quantified in a more recent study that found a twofold (2x) increase in animal diversity (total number of different animal species) for every tenfold (10x) increase in the area of undisturbed woodlands (Darlington 1957). Current studies confirm these early observations.

Fragmentation has its greatest effect on large mammals such as fox and deer because these animals require large home ranges to find food and shelter. Reptiles and amphibians are also especially sensitive to the affects of fragmentation due to their slow movement and their need to travel in response to changing seasons and rainfall conditions. The placement of a road can eliminate these animals from an area by cutting off their travel routes to water. The removal of understory vegetation and decayed logs from urban parks and suburban yards also eliminates the habitat needed for the breeding and overwintering of many salamander species. Small woodlots in urban and suburban areas are generally lacking large mammals, reptiles, and amphibians.

Birds are the most resistent to the adverse effects of fragmentation due to their ability to fly over and through urban barriers on the ground. Some of the best places to view migratory birds in this region are small wooded parks in heavily urbanized areas. These forest birds are concentrated in these "urban islands" during their migrations (Wilds 1983).

But even birds are affected by fragmentation. Certain bird species such as the wood thrush and ovenbird require undisturbed interior forests to feed, nest, and reproduce. Other species such as the Rock Dove, Starling, House Sparrow, American Robin, Cardinal, and House Finch prefer a mixture of open and wooded areas; i.e., "edges" of woodlands. It's no surprise that these "edge species" are common in urban areas.

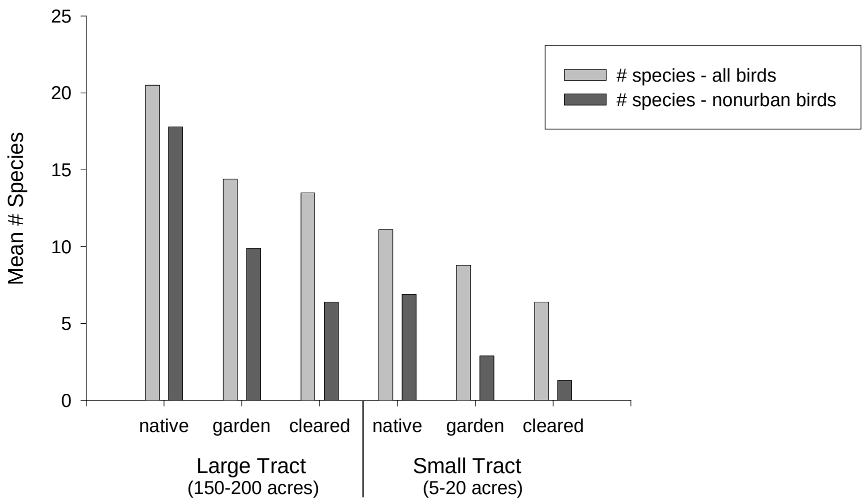
In a study of urban parks in Seattle Washington, a small undisturbed native forest (20 acres) contained half the bird species found in a forest 10 times larger (Figure 2-2). The smaller native forest tract also had a smaller proportion of nonurban birds indicating that tract size affected both the total number of species and the types of birds (Figure 2-2).

In the Seattle study, the human alteration of the physical structure of the forest (e.g., removal of the underbrush) had an even greater impact on the bird community than tract size. Conversion of native forest to gardens and parks eliminated almost all of the nonurban birds (Figure 2-2). Interestingly, birds were more abundant in the small cleared forest than the large native forest. This explains the observation that birds are common in urban areas, but that the ones seen are limited to a few species.

The effect of tract size on ecosystem function is simply a matter of geometry; the various dimensions of the tract change in proportion to the area of the tract. A tract reduced in area by a factor of one hundred

Figure 2-2

Effect of tract size and human disturbance on the diversity of birds in urban parks of Seattle, WA; native (unaltered forest), garden (garden with landscaped trees and shrubs), cleared (park with trees and grass).



(from Gavareski 1976)

reduces by one-tenth the distance to the center of the tract and increases ten times the dominance of the perimeter habitat (edge/area ratio). Tract size has important implication for species that require interior habitat. The tract can become so small that the interior habitat and the species that depend on it are eliminated (Figure 2-3).

Both the area and the shape of the tract effect ecosystem function and value. In simple terms, square and round shaped tracts are more valuable than rectangular or irregularly shaped tracts because they contain a greater proportion of interior habitat (Figure 2-3).

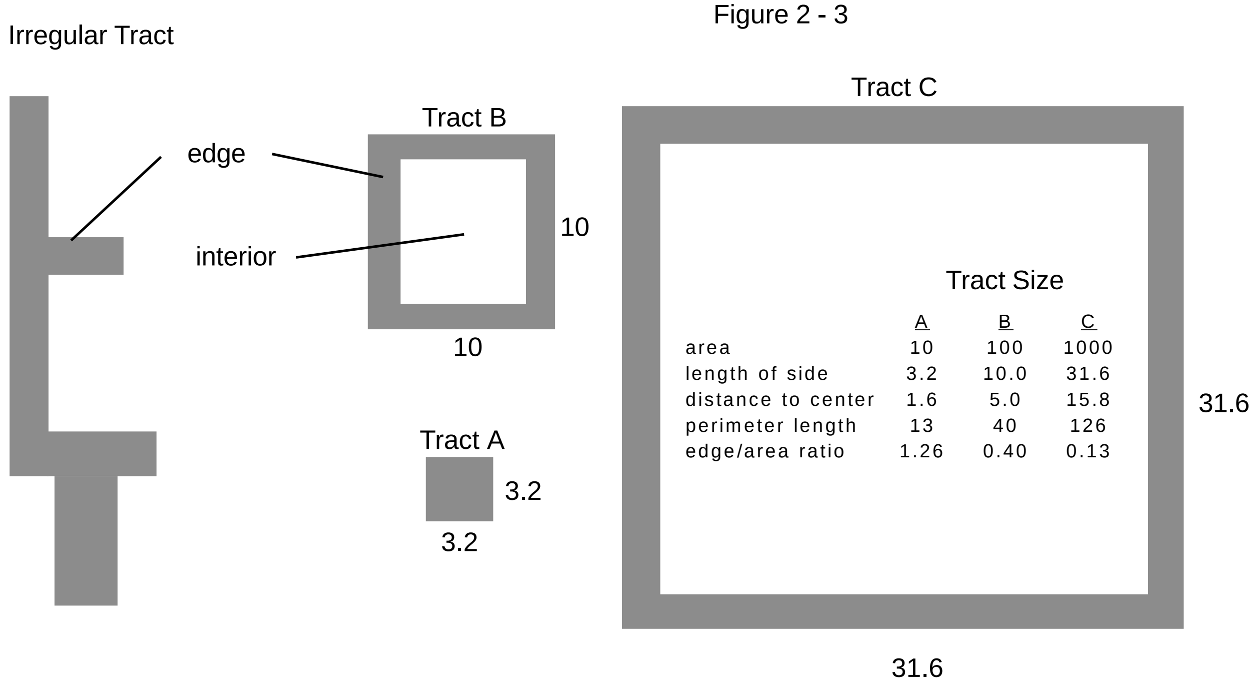
As discussed in Chapter 1, urbanization causes a shift in the aquatic community (macroinvertebrates and fish) from one dominated by pollution sensitive species to one dominated by pollution tolerant species. This ecological principle also applies to the terrestrial environment where the condition of living resources is driven principally by the size, age, and position of natural features in the landscape.

In the terrestrial environment, the condition of living resources is driven principally by the size, age, and position of natural features in the landscape.

Importance of Small Headwater Riparian Areas

There is one important exception to the rule that small areas are less valuable than large areas. Where these small areas are connected to a larger area, they acquire and enhance the ecological functions of the larger area. For example, the undeveloped riparian areas (e.g., wetlands, meadows, forests, etc.) at the headwaters of nontidal streams are connected to the floodplain system downstream. These headwater

Figure 2 - 3



	A	B	C
area	10	100	1000
length of side	3.2	10.0	31.6
distance to center	1.6	5.0	15.8
perimeter length	13	40	126
edge/area ratio	1.26	0.40	0.13

areas protect and enhance water quality and provide migratory corridors for wildlife.

The difficulty in placing great value on headwater riparian areas is indicated by the lack of regulatory control that has been placed on them. The U.S. Army Corps of Engineers has regulatory authority over activities in wetland, but where these activities occur in headwater wetlands, the process is simplified and the activity almost always permitted. The State of Delaware has no laws or regulations controlling activities in nontidal wetlands, much of which are in headwaters.

The ecological and water quality values provided by headwater riparian areas are also related to the total area they cover within a watershed or region. First and second order streams make up 73% of the nontidal stream resource in the United States (Table 2-1). With an average floodplain width of 3 meters (10 feet), the floodplains of first order streams cover an area approximately equal to that of any other stream order. They cover an area almost twice as large as the largest stream order; the Mississippi River is the only 10th order stream in the lower 48 States (Table 2-1).

Headwater riparian areas are a critically important, natural resource of Delaware.

Delaware has predominantly 1st through 3rd order streams. Therefore, the smallest first order riparian areas, only 3 meters wide, make up roughly one-third of the total floodplain area for most of the watersheds in the State (Figure 2-4). Taken together, headwater riparian areas are a critically important, and often under appreciated, natural resource in Delaware. Almost any development site in Delaware will be within only a few hundred meters (300 -600 feet) of a first order riparian area.

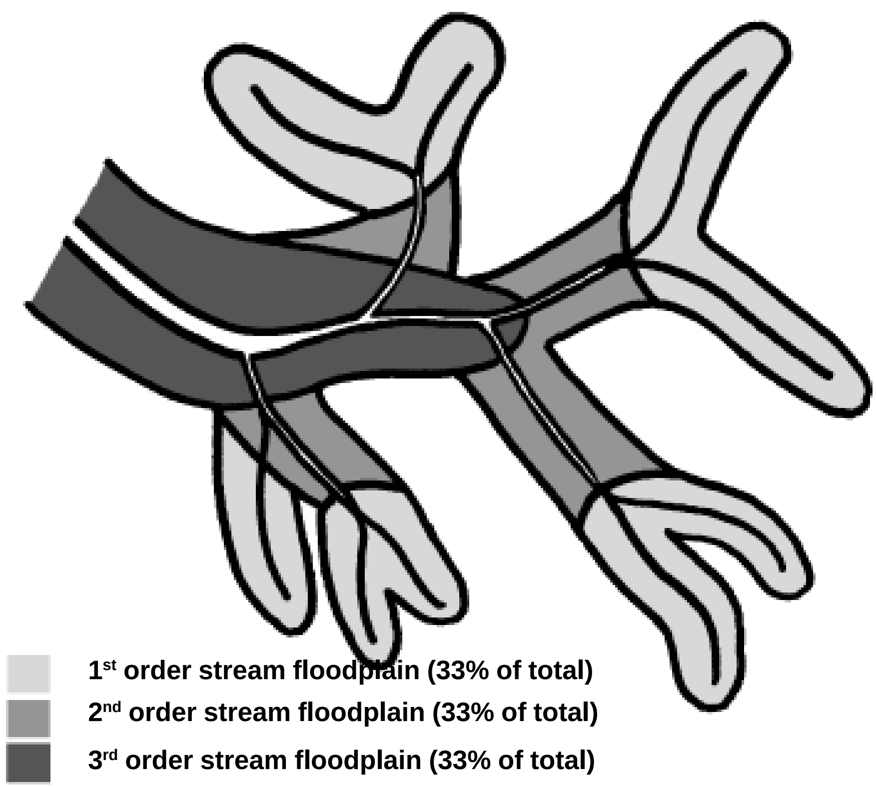
Table 2-1

Relationship between stream order and other stream and floodplain measures for nontidal streams of the United States; meters (m), kilometers (km).

stream					floodplain	
order	number	length(km)	%	cum %	width(m)	area(km2)
1	1570000	2526130	48.4	48.4	3	7578
2	350000	1295245	24.8	73.2	6	7771
3	80000	682216	13.1	86.3	12	8187
4	18000	347544	6.7	92.9	24	8341
5	4200	189218	3.6	96.5	48	9082
6	950	97827	1.9	98.4	96	9391
7	200	47305	0.9	99.3	192	9083
8	41	22298	0.4	99.7	384	8562
9	8	10002	0.2	99.9	768	7682
10	1	2896	0.1	100.0	1536	4448

(from Brinson 1993)

Figure 2 - 4
Watershed showing stream order and floodplain limits



The smallest first order riparian areas, only 3 meters wide, make up roughly one-third of the total floodplain area for most of the watersheds in the State

It is easy to ignore or place less importance on elements of ecosystem function which are not visible. Much of the information presented in this Chapter are understood visually (e.g., comparison of a mature forest and a farm field). But there are many other important elements of ecosystem integrity that are not so readily apparent: water cycle (humidity, soil moisture, runoff), chemical factors (nutrients, organics, pH), energy flow (production and use of plants), and biotic interactions (feeding, reproduction, predation).

It is also easy to underestimate the value of rare species. Most people will never, in their lifetime, see a rare species. River otter are rarely seen along the floodplains of Delaware streams, but they are there. The evidence of beaver have become more commonplace (flooding, fallen trees, chewed stumps), but the animals themselves are rarely seen because they are reclusive.

Rare species reflect the highest degree of ecosystem complexity and function and are the most sensitive to impact. Thus, they are good indicators of ecosystem health. Unfortunately, their rarity makes them impractical for use with most assessment studies done as part of development projects.

In 1933, the new concept of the "edge effect" was introduced by Aldo Leopold in his classic text Game Management. He proposed that woodland edges were the sites of greatest species diversity and function because they contained the overlapping functions of both woodlands and open fields. This led to a basic tenet of wildlife management during the 1940's and 1950's - the way to increase wildlife populations was to increase edge habitat through the fragmentation of large woodlots. But it was soon discovered that fragmentation lead to the local extinction of species that required large forests tracts and interior habitat. In the 1960's, forest management took a turn toward keeping large forests intact. The spotted owl in the Pacific Northwest is a recent example of the new knowledge now surfacing on the importance of large tracts of undisturbed forest.

Safety factors are used in engineering to account for uncertainty and ensure that "the bridge does not fail". This concept is even more applicable to natural resources that are considerably more complex and less well understood.

Obviously, we don't have all the answers. The degree to which the landscape is permanently changed as a result of urban development places great importance on the need to consider this uncertainty in conservation design. Safety factors are used in engineering to account for uncertainty and ensure that "the bridge does not fail". This concept is even more applicable to natural resources that are considerably more complex and less well understood. Examples of safety factors that might be applicable to conservation design might include larger buffer strips along wetlands, streams, and mature upland forests, the use of constructed wetlands to polish the discharge from traditional stormwater treatment systems (e.g., retention basins), and reducing the size of the development footprint.

Much of the large scale alteration of natural resources has obviously already taken place in Delaware. Thus, urban development projects will have much less overall impact. But the basic principles of ecology and landscape ecology still apply to minimize the impacts of future projects. Much of our knowledge of the functions and values of natural resources has developed in just the last 30-50 years. Mans' intellectual capacity to substantially alter natural features for hundreds of years carries with it the responsibility to make allowances for what we do not understood. In just a few decades, we will look back on how little we knew in 1997.

Much of our knowledge of the functions and values of natural resources has developed in just the last 30 - 50 years.

Wetlands

Wetlands are characterized by the presence of water during some, most, or all of the year. They are in areas that are saturated or where shallow surface or groundwater depths preclude the ability of upland plants to live due to their need for aerobic conditions. Wetland plants are adapted to growing in seasonally or continuously flooded soils resulting in anaerobic or low-oxygen conditions. They form a zone of transition from upland lands to permanently flooded water bodies. Wetlands occur naturally in the landscape with Delaware having approximately 223,000 acres of wetlands or 18% of the total State area, with approximately 56% being nontidal. (Tiner, 1985)

Wetlands, in their natural state, provide a number of benefits (Mitsch

Example of a nontidal wooded wetland

and Gosselink, 1993). A generalized grouping of these benefits, includes the following:

<u>Fish and Wildlife</u>

Wetlands benefit fish and wildlife by providing needed habitat. Wetlands are among the most productive ecosystems on the earth. Populations can include invertebrates, fish, amphibians and reptiles, birds, and mammals. All of these organisms are consumers and their relationship to primary producers (plants) is very complex.

Fish and wildlife utilize wetlands in a variety of ways. Some animals are totally wetland dependent, spending their entire lives in wetlands. Others use wetlands only for specific reasons, such as reproduction and nursery grounds, feeding, and resting areas during migration. Many upland animals use wetlands for drinking water. Almost half (42%) of the total U.S. threatened and endangered species depend upon wetlands for survival (Mitch and Gosselink, 1993).

Nearly all of the approximately 190 species of amphibians in North America are wetland dependent, at least for breeding.

Nearly all of the approximately 190 species of amphibians in North America are wetland dependent, at least for breeding. Frogs occur in many freshwater wetlands and many salamanders use temporary ponds or wetlands for breeding, although they may spend most of the year in uplands. The number of amphibians, even in small wetlands can be astonishing.

Water Quality

Wetlands provide water quality values through filtering and recycling of pollutants. Table 2-2 provides a summary of input/output studies. The data are taken from empirical studies of natural wetlands or entire watersheds. Results are reported as the range and mean percent retention of the contaminant in wetlands. These data show that wetlands acted as a sink for sediment and total nitrogen at all sites tested. The range of values illustrates the variability of the results and the complexity of the relationships between wetlands and water quality.

Table 2-2
Range and median % retention of sediment, total nitrogen, and total phosphorus by natural wetlands

Contaminant	# of Sites			Net Retention (%)	
	Total	Sink	Source	Range	Median
Sediment	8	8	0	23 to 93	76
Total N	28	28	0	14 to 100	77
Total P	34	25	9	-171 to 98	44

(from Shaver and Maxted, 1993)

Water quality performance is accomplished primarily by the following processes:

- Settling/burial in sediments
- Incorporation of contaminants into plant biomass
- Filtration
- Adsorption
- Bacterial decomposition
- Volatilization

Socioeconomic Benefits

Wetlands provide societal benefits including flood control, erosion control, and ground water recharge. Wetlands temporarily detain floodwaters and attenuate flood peaks. Watersheds with a large percentage of their area in wetlands generally have lower high-magnitude flows than those watersheds with less wetland area. Wetlands also desynchronize flood peaks. In a watershed with a variety of water retention systems, including wetlands and ponds and upland areas maintained in natural vegetation, each area of retention releases water at a different rate. Wetland losses can result in the loss of flood storage and can increase downstream flooding. This statement must be considered in conjunction with the following:

Watersheds with a large percentage of their area in wetlands generally have lower high-magnitude flows than those watersheds with less wetland area.

- size of the wetland,
- its location within the watershed,
- the character of the individual storm in terms of intensity and duration, and
- season of the year.

The storage capacity of wetlands reduces peak flows and velocities during small runoff events. The attenuated peak flows and velocities minimize erosional forces within the stream channel and further protect and maintain downstream receiving systems.

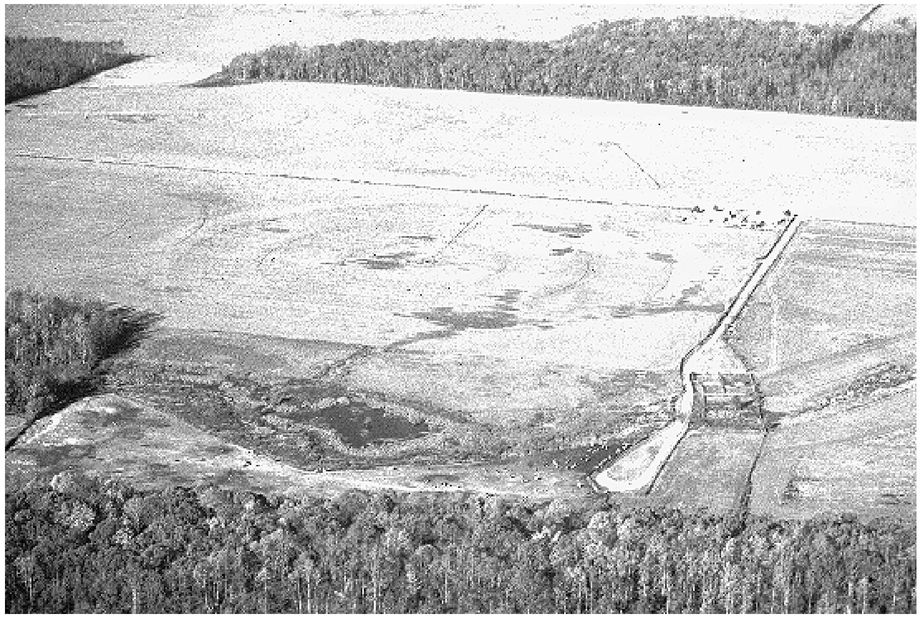
In terms of groundwater recharge, organic matter accumulates in wetlands primarily through the growth and decay of vascular plants and algae. Organic soils have a lower density and higher water holding capacity than do mineral soils. This is due to the high porosity of organic soils or the percentage of pore spaces. This porosity allows wetlands soils to store more water than mineral soils. This water would then be released over a long period of time augmenting stream baseflow and enhancing groundwater recharge.

Restoration

Delaware has lost 54% of the wetland resource it had prior to European settlement (circa 1780) (Tiner 1985). Much of this wetland resource has been converted to various human uses (principally agriculture and urbanization). It is estimated that today there are approximately 190,000 acres of cropland in Delaware that used to be wetlands, referred to as “prior converted cropland”. This is larger than the area of nontidal wetlands (130,000 acres) that exist today (Tiner 1885). This 190,000 acres (15% of the total area of the State) represents the area of the State that could be restored to wetlands for the purpose of stormwater treatment. For the first time in 200 years, the total acreage of wetlands in Delaware could begin to increase under the auspices of stormwater management.

The distinction between upland and wetland forests is necessary to understanding the functions and values of site resources and how those resources will be affected by the development project. For example, a

Example of an agricultural wetand



forested area might be identified as a suitable site for a stormwater retention basin before it is determined that the area includes forested wetlands. These wetlands are already providing important water resource benefits. Locating stormwater treatment systems in forested wetlands achieves one objective (i.e., stormwater treatment) at the expense of another (i.e., aquifer recharge, ecosystem diversity). The change in hydrology could further stress the forest community already under stress due to saturated soils.

Locating stormwater treatment systems in areas that were wetlands before conversion to their present use (e.g., prior converted cropland) have the greatest opportunity for success.

Locating stormwater treatment systems in areas that were wetlands before conversion to their present use (e.g., prior converted cropland) have the greatest opportunity for success. Locating them in areas already impacted by past land use practices also serve to provide for the greatest net environmental improvements and achieve multiple objectives. Guidance has been developed on how to construct wetlands for the purpose of stormwater treatment (Shaver and Maxted 1993).

Floodplains

Floodplains are the relatively low and periodically inundated areas adjacent to rivers, lakes, and oceans. Floodplain lands and adjacent waters combine to form a complex, dynamic, physical, and biological system that supports a multitude of functions and resources for the following:

- Water resources,
- Living resources,
- Water filtering processes,
- A wide variety of habitats for flora and fauna,
- Places for recreation, and
- Historic and archeological sites.

They are also the focus for a variety of human activities, including commerce, agriculture, residence, and infrastructure.

The preservation of floodplains provides protection to adjacent properties by allowing periodically occurring flood waters to safely be conveyed downstream. It should be noted that most jurisdictions in the state participate in the FEMA flood insurance program.

Floodplains provide a wide range of benefits to both human and natural systems. The previous list of floodplain functions and resources can be loosely placed in three categories.

<u>Water Resources</u>

Floodplains provide for flood storage and conveyance during periods when flow exceeds the channel boundaries. In their natural state they reduce flood velocities and peak flow rates by out of stream bank passage of stormwater through dense vegetation. They also reduce sedimentation and filter pollutants from runoff. In addition, having a good shade cover for streams provides temperature moderation of stream flow. Maintaining natural floodplains will also promote infiltration and groundwater recharge, while increasing or ensuring the duration of low surface stream flow. Floodplains provide for the temporary storage of floodwaters. If floodplain areas are not protected, development would, through placement of structures and fill material, reduce the ability of floodplains to convey stormwater when that need occurs. This, in turn, would increase flood elevations upstream of the filled area and increase the velocity of water traveling past the reduced flow area. Either of these conditions could cause safety problems or cause significant damage to private property.

If floodplain areas are not protected, development would, through placement of structures and fill material, reduce the ability of floodplains to convey stormwater when that need occurs.

This, in turn, would increase flood elevations upstream of the filled area and increase the velocity of water traveling past the reduced flow area.

The following Table 2-3 provides values of roughness coefficients that have been established for floodplain areas and indicate the value that

Out of bank floodplain flow

vegetation has on flood flow. The higher the value, the greater the retardance to flow.

Table 2-3
Values of the roughness coefficient *n* floodplains

Type of Ground Cover	Normal *n*
a. Pasture, no brush	
1. Short grass	0.030
2. High grass	0.035
b. Cultivated areas	
1. No crop	0.030
2. Mature row corps	0.035
3. Mature field crops	0.040
c. Brush	
1. Scattered brush, heavy weeds	0.050
2. Light brush and trees, in winter	0.050
3. Light brush and trees, in summer	0.060
4. Medium to dense brush, in winter	0.070
5. Medium to dense brush, in summer	0.100
d. Trees	
1. Dense willows, summer straight	0.150
2. Cleared land with tree stumps, no sprouts	0.040
3. Same as 2. with heavy sprout growth	0.060
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.100
5. Same as 4. with flood stage reaching branches	0.120

Natural floodplains support a high rate of plant growth and maintain biological diversity. They provide breeding and feeding grounds for fish and wildlife. In addition, they create and enhance waterfowl habitat and protect habitat for rare and endangered species.

As can clearly be seen from Table 2-3, the denser and taller the vegetation, the greater the frictional resistance to stream flow.

Living Resources

Natural floodplains support a high rate of plant growth which supports and maintains biological diversity. They provide breeding and feeding grounds for fish and wildlife. In addition, they create and enhance waterfowl habitat and protect habitat for rare and endangered species.

Floodplains are often wetlands and thus provide the same water quality functions as wetlands do. Ground cover in natural floodplains tends to be composed of leaf and dense organic matter. As mentioned in the wetlands discussion, organic soils have a lower density and higher water holding capacity than do mineral soils. This is due to the high porosity of organic soils or the percentage of pore spaces. This porosity allows floodplain soils to store more water than mineral soils.

Example of a stream and its natural floodplain

Societal Resources

Floodplains provide areas for active and passive recreational use. They increase open space areas, and provide aesthetic pleasure. They also contain cultural resources (historic and archaeological) and provide opportunities for environmental and other studies. The State has embarked on a program to increase greenways areas adjacent to streams, which would provide potential for hiker/biker trails and increase public use of floodplain areas. This increased use would allow the public to get closer to streams and rivers and increase their awareness and appreciation of environmental systems. This in turn would increase support for greenways and protection of floodplain areas.

Riparian Buffers

Riparian buffers are natural forested areas adjacent to streams and wetlands, as opposed to grassed areas which do not provide the same water quantity or quality benefits.

The word riparian is used to describe an area "adjacent to a river, stream, or other body of water". Thus, riparian buffers can be a variety of natural resources adjacent to aquatic resources. The wetlands within the floodplain serve both as the buffer area that protects the stream system and as an aquatic resource itself, also in need of protection from human activities. Development right up to the edge of floodplain wetlands can impact the wetland and its ability to protect the stream. The functions and values provided by wetlands and floodplains have been discussed in the previous sections and are not discussed further here. For the context of this section, riparian buffers include upland forests adjacent to aquatic resources including wetlands (e.g., floodplains), streams, ponds, and estuaries. Riparian buffers are forested areas adjacent to streams and wetlands, as opposed to grassed areas which do not provide the same water quantity or quality benefits (see discussion on "Meadows"). Riparian buffer functions include the following:

- control of stream temperature
- light quantity and quality reaching the stream (shading)
- contribute to habitat diversity
- contribute to maintaining channel morphology and stability
- contribute to food webs and species richness

Benefits are derived as a result of the buffer's proximity to a stream channel and include the following.

Shade and Temperature

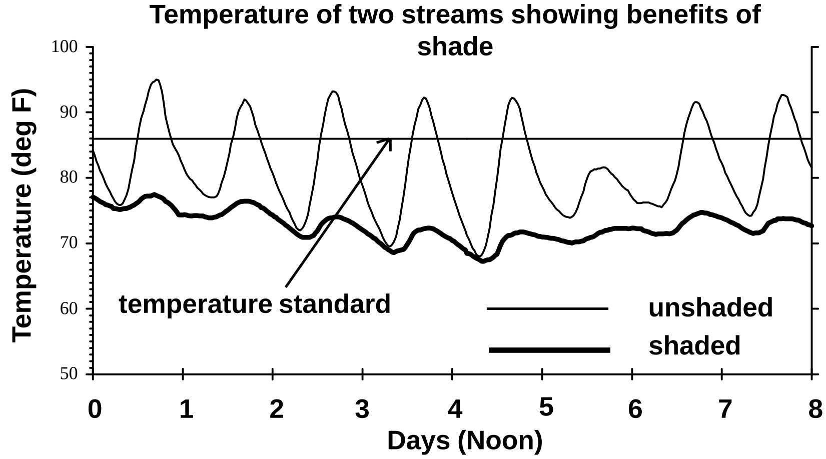
The shade provided by a riparian forest buffer moderates stream temperatures and levels of dissolved oxygen. These factors are critical for fisheries but also have water quality implications. Temperature increases the rate at which nutrients attached to sediments are converted to readily available (soluble) forms. As stream temperature increases above 60° F significant increases in phosphorus release from sediments occurs. In this way, the loss of forest shade may exaggerate nonpoint pollutant effects by reducing the streams' ability to assimilate organic wastes and inducing algae blooms and low oxygen levels.

The loss of forest shade may exaggerate nonpoint pollutant effects by reducing the streams' ability to assimilate organic wastes and inducing algae blooms and low oxygen levels.

In a recent study in Delaware, unshaded streams exceeded the temperature standard of 30° C (86° F) regularly during the daytime, while shaded sites showed no exceedences of the criteria (Maxted et al., 1995). Figure 2-5 is typical of the results found at 10 sites over a 40 day period during the summer of 1993. These wide daily variations in temperature also resulted in exceedences of dissolved oxygen criteria. The woody vegetation along stream channels and the shade it provides leads to multiple ecological benefits including moderation of temperature and DO extremes, stability of the stream bank, and increased complexity and stability of aquatic habitat

Habitat

Figure 2 - 5
Temperature of two streams showing benefits of shade



(Maxted et al., 1995)

Natural riparian buffer adjacent to a stream channel

A great variety of habitats are found in structurally diverse riparian forested areas. In many cases, their value to wildlife and fish alone may be substantial enough to justify forest buffers. Forested corridors function as connectors between isolated blocks of habitat and provide shelter for insects beneficial to control of agricultural pests. Fallen and submerged logs and the root systems of woody vegetation provide cover for fish and invertebrates while forest detritus is the basis of the food web for the stream. Energy cycles in the aquatic system are often critically dependent on interaction with streamside woody vegetation. As such, fish habitat is an important indicator of acceptable water quality. In many agricultural and urbanized areas, forest buffers can be essential to the survival for many important species. Riparian buffers in urban areas provide a unique linkage between people and the environment.

Forested buffer strips have an indirect effect on streambank stability by providing deep root systems which hold the soil in place more effectively than grasses, and by providing a degree of roughness capable of slowing runoff velocities and spreading flows during large storm events.

Stream Channel Stability

Streams are dynamic systems that are prone to change. Instream stability and streambank erosion at a given point are heavily influenced by the land use and condition in the upstream watershed. However, vegetation is essential for stabilizing stream banks, especially woody vegetation. Forested buffer strips have an indirect effect on streambank stability by providing deep root systems which hold the soil in place more effectively than grasses, and by providing a degree of roughness capable of slowing runoff velocities and spreading flows during large storm events. While slowing flood velocities may increase flood elevations upstream of the buffer, downstream flood crest and damage may be significantly reduced. These processes are also critical for building floodplain soils.

Restoration

On almost any development site in Delaware, there will be an opportunity to restore riparian areas as a major component of site design.

As discussed in Chapter 1, the physical habitat of 90% of the streams in Delaware has been disturbed either through channelization or urban development (see Figure 1-13). In the majority of cases, the impact was caused by a lack of native vegetation along the stream channel. In addition, much of the wetlands that are now prior converted cropland are adjacent to existing wetlands, ponds, or streams. On almost any development site in Delaware, there will be an opportunity to restore riparian areas as a major component of site design.

Most of the nonurban land in Delaware is in some form of open vegetation due to past human uses; e.g., cropland and pastureland. Thus, there will be many opportunities to use these meadows as riparian buffers in urban development projects. Where these areas are set aside as riparian buffers, in most cases they should be allowed to evolve naturally into forests.

Forests

There are no pristine upland forests in the Eastern United States. The Pleistocene glaciers, fire, insect and fungal infestation, and of course man have dramatically altered forest resources. Truly “old-growth” or “virgin” stands of forests exist in the lower 48 States only in the Pacific Northwest away from the influence of glaciers and where abundant rainfall has essentially eliminated the influence of fire.

At the front edge of European settlement, Delaware’s upland forests have been affected principally by man over the last 10,000 years. Delaware was almost completed covered in trees prior to settlement. It is estimated that today 30% of Delaware remains in forest land use. (Dept. of Agriculture, 1984) The forests that we see today can best be described as being in a constant state of change as a result of mans’ activities.

Delaware’s forests tend to be in the category of temperate deciduous forests. These forests once covered most of the eastern United States. These forests, historically, consist of four different strata which consists of an upper canopy of dominant trees, a lower tree canopy, a shrub layer, and the ground layer which consists of herbs, ferns, and mosses.

In Delaware, these forests have generally been clear cut at some time and are more often even-aged. This results in one or more of the natural strata being poorly developed. This may result in a thin low tree or shrub strata with the ground cover often being poorly developed. The diversity of animal life is associated with the stratification of and growth forms of plants. As a result the wildlife benefits of forested areas are very dependent on the site specific situation.

The dominant tree species found in upland forest in Delaware are summarized in Table 2-4. The size of the trees, the age, and complexity of the forest are dependent upon drainage characteristics, soil type, physiographic region, and past land use practices.

It is difficult to separate forest resources from wetland resources in a State like Delaware where 90% of the nontidal wetlands are forested (Tiner 1985). Several tree species are adapted to a wide range of drainage conditions. For example, two common tree species in Delaware, Red Maple (*Acer rubrum*) and Sweetgum (*Liquidamber styraciflua*), are found in both well drained and poorly drained soils. Other tree species are found only in wetlands such as Atlantic White Cedar (*Chemaecyparis thyoides*) and Bald Cypress (*Taxodium distichum*), and are therefore used as wetland indicators. Generally the Oaks (*Quercus sp.*) and American Beech (*Fagus grandifolia*) require well drained upland soils. The mapping of wetlands is an important step in characterizing the forest resources of a site.

Table 2-4

Dominant tree species typically found in Delaware for two stages of upland forest succession; by region and drainage condition.

Region	Drainage	Early Succession	Late Succession
Piedmont	upland - well drained	Black cherry Bigtooth aspen Sassafras Virginia pine	American beech Hickory White oak Northern red oak Black oak
	upland - poorly drained	Eastern red cedar Yellow poplar	Green ash White ash White oak
	wetland - intermittently flooded	Sweetgum Black gum Black birch	Green ash Red maple
	wetland - permanently flooded	River birch	Red maple
Coastal Plain	upland - well drained	Virginia pine Black locust Sassafras Yellow poplar Eastern red cedar	American beech Hickory White oak Red oak
	upland - poorly drained	Loblolly pine Eastern red cedar Flowering dogwood Red maple Sweetgum	Green ash American holly
	wetland - intermittently flooded	Loblolly pine Red maple Sweetgum	Swamp chestnut oak Swamp white oak Willow oak
	wetland - permanently flooded	Swamp cottonwood Atlantic white cedar	Bald cypress Black gum

The mapping of wetlands is an important step in characterizing the forest resources of a site.

Trees in poorly drained soil found in floodplains and wetlands are smaller than trees grown in well drained soil for several reasons. First, the wet soil cannot support the weight of larger trees. Second, saturated soil causes anoxia (insufficient oxygen) that inhibits growth and the downward movement of roots. This in turn limits the rate of growth and the size of trees. A 100 year old red maple that has grown in poorly drained soil may be the same size as a 25 year old one grown in well drained soil.

Since virtually all of the upland forests in Delaware have been modified by man, understanding the succession process and recognizing the various stages is a critical step in evaluating forest resources.

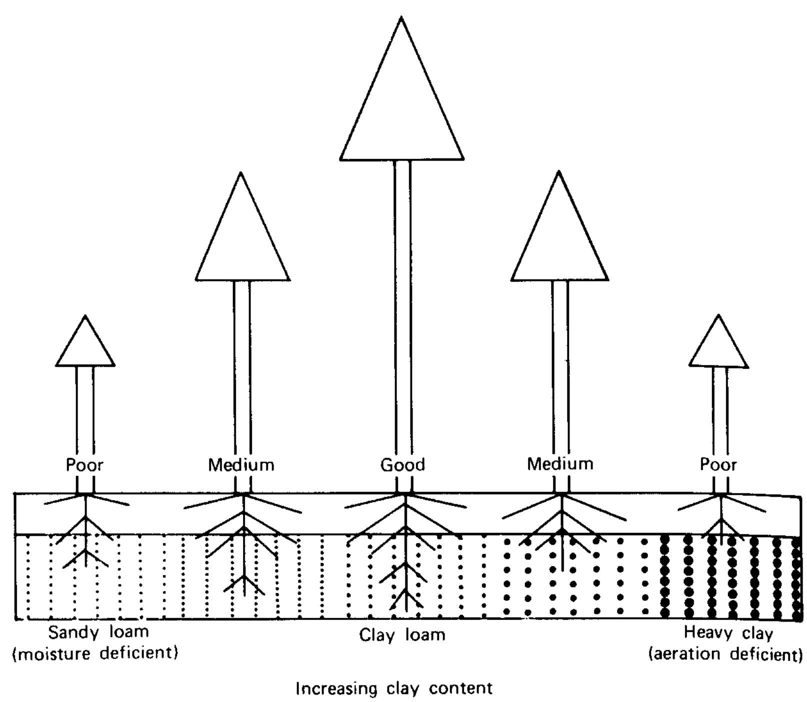
These factors help to explain why trees in the floodplain are often moderate and uniform in size (no more than 3 - 4 feet in diameter) even though they may have undergone minimal disturbance. Therefore, tree size is not a good indicator, by itself, of forest age or function.

In addition to drainage, tree size is also affected by the characteristics of the soils. Tree growth is highest in well drained soil that has a mixture of sand, clay and organic material (i.e., loam) and lowest in poorly drained soil that is either mostly clay or mostly sand (Figure 2-6). These characteristics can be determined from soil maps and wetland maps.

Since virtually all of the upland forests in Delaware have been modified by man, understanding the succession process and recognizing the various stages is a critical step in evaluating forest resources.

Succession depends upon two principle factors; (1) the type of initial disturbance (e.g., row crop cultivation, selective logging, or clear-cutting) and (2) drainage characteristics. Cultivation, often combined with drainage practices, removes seed sources, changes hydrology, and

Figure 2-6



(from Spurr and Barnes, 1980)

changes soil characteristics while selective cutting often retains seed sources and soil structure. Understanding the degree to which a tract has been logged or managed for silviculture will affect succession. Historical research of past land use practices is an important step in understanding upland forest succession

Cultivation, often combined with drainage practices, removes seed sources, changes hydrology, and changes soil characteristics.

Benefits of forests

Forested areas have many benefits. As used in this manual, those benefits relate to water quantity and quality. Those benefits will be briefly discussed, but there are benefits to forested areas that go beyond water quantity and water quality. Additional benefits can include:

- Increased privacy, both personal and community
- Reduced air pollution
- Energy savings by summer cooling and shade
- Reduction in noise
- Reduction in glare
- Wind reductions in excess of 90% from open areas
- Forests are natural air cleaners, removing carbon dioxide
- Reduction in rainfall energy striking the ground
- Food and shelter for wildlife

A forest land has three basic components whose characteristics determine it's effectiveness in terms of water quantity and quality. Those characteristics include:

Soil Structure

Example of a mixed strata forest adjacent to a stream

Forest soils are generally regarded as effective nutrient traps. The ability of a forest soil to function in removing nutrients in surface and groundwater is partially dependent upon the soil depth and position in the landscape, permeability, extent and duration of shallow water table, and it's function as a groundwater discharge zone.

Organic Litter Layer

A mature forest can absorb as much as 14 times more water than an equaivalent area of grass.

The absorptive ability of the forest floor develops and improves over time.

The organic litter layer in a forest buffer provides a physical barrier to sediments, maintains surface porosity and high infiltration rates, increased populations of soil mycorrhizae (a mutualistic relation of plant roots and the mycelium of fungi - aids in decomposition of litter and translocation of nutrients from the soil into the root tissue), and provides a rich source of carbon essential for denitrification. The organic soil provides a reservoir for storage of nutrients to be later converted to wood biomass. A mature forest can absorb as much as 14 times more water than an equivalent area of grass. The absorptive ability of the forest floor develops and improves over time. Trees release stored moisture to the atmosphere through transpiration while soluble nutrients are used for growth.

Vegetation

Trees have several advantages over other vegetation in improving water quality. They aggressively convert nutrients into biomass. They are not easily smothered by sediment deposition or inundation during periods of high water level. Their spreading root mats resist gullying and stimulate biological and chemical soil processes. They produce high amounts of carbon needed as an energy source for bacteria involved in the denitrification process. A forest's effectiveness in pollution control will vary with the age, structural attributes and species diversity of it's trees, shrubs and understory vegetation.

To consider performance of a forested area in water quality treatment, there are a number of functions that define that performance. These functions can be broadly defined as physical and biological functions and include the following:

Sediment Filtering

The forest floor is composed of decaying leaves, twigs, and branches which form highly permeable layers of organic material. Large pore spaces in these layers catch, absorb, and store large volumes of water. Flow of stormwater through the forest is slowed down by the many obstructions encountered. Suspended sediment is further removed as runoff flows into the vegetation and litter of the forest floor. These sediments are readily incorporated into the forest soil. With a well developed litter layer, infiltration capacities of forest soils generally exceed rainfall and can absorb overland flows from adjacent lands.

Nutrient Removal

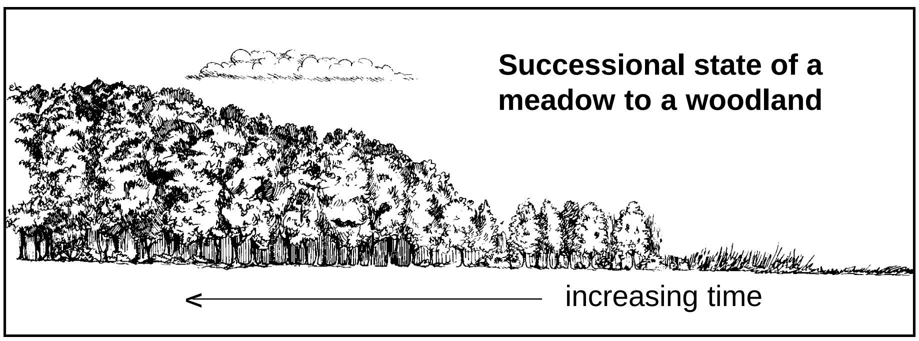
Forest ecosystems serve as filters, sinks, and transformers of suspended and dissolved nutrients. The forest retains or removes nutrients by rapid incorporation and long term storage in biomass, improvement of soil nutrient holding capacity by adding organic matter to the soil, reduction in leaching of dissolved nutrients in subsurface flow from uplands by evapotranspiration, bacterial denitrification in soils and groundwater, and prevention from erosion during heavy rains.

Meadows

Meadows are defined by dictionaries as a tract of grassland, either in it's natural state or used as a pasture. In the mid-Atlantic region meadows are not a natural evolutionary state. The abundance of rainfall and the presence of significant amounts of woody vegetation would necessitate active maintenance of a meadow to maintain it in that state. Natural meadows or grasslands generally occur when annual rainfall is between 10 and 30 inches per year, too much rain to encourage a desert but too little to encourage heavy forest growth.

Meadows, when used in the context of this manual, are called vegetative buffer strips.

Meadows, when used in the context of this manual, are called vegetative buffer strips. They can provide a very important water quality function, but their implementation and function will require maintenance to assure continued appearance and performance.



There are three main processes by which vegetated buffers provide for water quality treatment:

<u>Settling</u>

Suspended solids, primarily sediments, settle out of stormwater runoff as velocities of stormwater flow through the buffer are decreased, as a result of frictional resistance of the grass slowing the water down. Slow moving water causes solids to settle out by gravity. The more gentle the slope, the more sediments are removed from the runoff. This settling also serves to remove other pollutants such as nutrients, metals, and organics. These pollutants have an affinity and adhere to solid particles. As the suspended solids settle out, they take with them these other pollutants, further improving water quality.

Meadow in an urban environment designed for stormwater management

Biofiltration

Biofiltration removes pollutants by incorporating trapped materials into the plant structure. This is particularly true for nutrients (phosphorus and nitrogen) and trace metals. These pollutants are bound up in the plant biomass for long periods of time (100's to 1,000's of years), well after the plant has died and decayed. The organic sediments in meadows provide for the long-term storage of pollutants both through biofiltration and settling.

One disadvantage of grassed buffer areas is the fate of the pollutants that have been taken up within the structure of the plant when periodic mowing is done. To effectively remove the pollutant from the buffer and prevent downstream movement of the pollutant, the mowed clippings should be removed from the site for disposal.

Prolonged contact of the stormwater traveliing through the buffer will allow a portion of the stormwater to enter the soil profile and be conveyed to groundwater.

Infiltration

Infiltration is a major process by which vegetated buffers provide for water quantity and water quality benefits. Prolonged contact of the stormwater traveling through the buffer will allow a portion of the stormwater to enter the soil profile and be conveyed to groundwater. Infiltration of stormwater runoff is the only process that reduces the overall volume of stormwater exiting a developed site. Infiltration is maximized on very slight slopes and where underlying soils are very permeable (sands and gravels).

The pollutant removal effectiveness of vegetative buffers is greatest for smaller storms. With a traditional drainage system, pollutants are washed from impervious surfaces directly into storm sewers with no opportunity for infiltration or pollutant filtering. If impervious surfaces were disconnected from traditional storm drains and directed across vegetated buffers, small storms would be literally soaked up in the soil and significantly improving pollutant removal.

Ultimate pollutant removal efficiency depends on the length and slope of the buffer, the permeability of the soils, the contributing drainage area, the health and density of the vegetation and the prevention of concentrated flow through the buffer.

Soils

Major soil processes affecting water quality include physical, chemical, and biological processes as detailed in Table 2-5.

Table 2-5
Soil processes affecting water quality

Soil Processes	Impact on Water Quality
Soil Erosion	Transport of dissolved and suspended sediments in surface runoff
Leaching	Movement of nutrients, chemicals, and dissolved organic carbon in percolating water
Macropore flow	Rapid transport of water and pollutants from surface to subsurface and into a drainage system
Mineralization of humus	Release of readily soluble compounds that are easily washed away or leached out

Physical processes are set in motion by a decline in soil structure with resulting decreases in water infiltration capability and increases in surface runoff.

Important among physical processes are compaction, crusting, and accelerated soil erosion. Physical processes are set in motion by a decline in soil structure with resulting decreases in water infiltration capacity and increases in surface runoff.

Leaching, with transport of chemicals from surface into the subsoil with percolating water, is another major process affecting water quality. Concentrations of soluble nutrients may be several orders of magnitude higher in seepage water than in surface runoff. Leaching is generally more severe during times when plants are dormant. Leaching can be accentuated by macropore flow or bi-pass flow. This involves rapid transport of water and chemicals from surface into the subsoil through large pores made by biological activity, e.g. worm holes, root channels, burrows by larger animals.

The process of humification (plant decay into humus) releases plant nutrients immobilized in organic matter and makes them readily soluble and mobile. The biomass, active and dead, is a major buffer against nutrient loss (by erosion and leaching) out of the ecosystem. Therefore, decrease in total biomass, activity and species diversity of soil fauna can have serious adverse impact on water quality.

Water Movement

The passage of water through the soil is commonly referred to in two different terms which are often interchanged and misused. For the purposes of this chapter, the following definitions are provided:

Infiltration: The downward entry of water through the soil surface into the soil.

Permeability: The specific soil property designating the rate at which gases and liquids can flow through the soil.

It is important to recognize the difference between these two terms. Infiltration refers to the passage of water into the soil surface while permeability refers to the rate which water passes through a specific soil. Infiltration rates can be significantly reduced as a result of structural damage to the soil surface by traffic across that surface. The permeability of a specific soil may be high but the infiltration rate into the soil significantly reduced by sealing of the surface due to imperviousness or compaction. Compaction can result from construction equipment traveling across the surface of the soil during the construction process with the resultant infiltration rate being significantly reduced, thereby increasing overland flow and surface runoff.

The ability of soils to accept rainfall is an essential component of the hydrologic cycle, and activities on the surface of the ground have a profound impact on what happens within the watershed.

Soil particles are in contact with one another and the spaces between the particles are called pores and contain air and water. These pore areas are of critical importance to support plant and animal life and to provide drainage of water into the ground. The more water that drains into the ground means that less water will travel overland and carry pollutants into streams. The ability of soils to accept rainfall is an essential component of the hydrologic cycle, and activities on the surface of the ground have a profound impact on what happens within the watershed.

The process by which water moves into and over soil is generally the following:

- Rain strikes the ground. Some of the rainfall stays on the vegetation and eventually is evaporated. The rest of the rainfall comes in contact with the soil. If the rate of rainfall exceeds the ability of the soil to accept it, water runs across the top of the soil surface, eventually into a receiving drainage system.

- The rainfall that soaks into the ground remains in the ground until it evaporates, is used by plants, or travels laterally or vertically through the ground. The ground can become saturated with water where all available pore spaces are filled with water. This will also cause water to pond on the soil surface and cause runoff of the water.

The rate that soil accepts water is it's infiltration rate. The infiltration rate is determined by forces which include gravity and a water suction (or tension), where water is driven from areas of small suction (wet) to soils having a large suction (dry). When soils become completely saturated, gravity is the only force which determines the infiltration rate.

As the level of development increases, impervious acreage in the watershed increases, and compaction of site soils occurs.

Urban development will have a significant impact on the total volume of water running off the land. As the level of development increases, impervious acreage in the watershed increases, and compaction of site soils occurs.

One approach to considering the soils ability to accept water is described in a Natural Resources Conservation Service (NRCS) document titled "Technical Release #55 - Urban Hydrology for Small Watersheds". That document classifies soils into hydrologic soil groups to indicate the minimum rate of infiltration obtained for bare soils after prolonged wetting. The values given to soils are to place the individual soils into either A, B, C, or D categories. Soils fit into one of the four categories depending on the rate at which the water moves within the soil.

- Group A soils have low runoff potential and have high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission (greater than 0.3"/hour)

- Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 - 0.3"/hour)

- Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine texture. These soils have a low rate of water transmission (0.05 - 0.15"/hour).

- Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly imperious material. These soils have a very low rate of water transmission (0 - 0.05"/hour)

Stability of Soils

Soil erodibility is determined by four major factors. These factors include:

- particle size and proportion
- plant and animal litter
- soil aggregation
- permeability
- slope

Particle Size and Proportion

Litter acts as a mulch cover for the soil, reduces raindrop impact, and also reduces overland flow velocities. As such, raindrop and sheet erosion are reduced in the presence of a mulched soil surface.

Soils are generally composed of clay, silt, and sand materials, and their size and proportion vary accordingly. Sands are considered as being coarse textured and have a greater proportion of their volume being porous. Being porous, water passes through the soils quickly, but sands also have a greater erosion potential. Clay soils are smooth textured and have a greater binding potential. This binding potential limits the passage of water through the clay and reduces it's erodibility. Silts are classified between sands and clays in terms of it's water passage ability and erodibility.

Plant and Animal Litter

Plant and animal litter, or organic matter, improves soil structure and increases permeability, the ability of the soil to hold water, and the fertility of the soil. Litter acts as a mulch cover for the soil, reduces raindrop impact, and also reduces overland flow velocities. As such, raindrop and sheet erosion are reduced in the presence of a mulched soil surface. It's benefits can be seen in the use of straw mulch as an erosion control practice during construction.

Soil Aggregation

Aggregation affects the soil's ability to absorb water. When the soil surface is compacted or crusted, water will run across the soil rather than infiltrating into it. Soils with poor aggregation tend to be compacted or suffer significant disturbance. The better the aggregation of a soil, the better it's infiltration and reduced runoff potential.

Permeability

Soils with high permeability allow water to pass through the profile more easily than do soils having a poor permeability. Good permeability means less water running overland and less erosion. Conversely, soils having poor permeability rates have increased potential for surface water flow, and thus, increased erosion potential.

<u>Slope</u>

Steeper slopes also increase the erosion potential of the soil. The equation most commonly used to estimate sheet and rill erosion potential from a parcel of land is the Universal Soil Loss Equation. It is based on forty years of experimental field observations gathered by the Agricultural Research Service of the U.S. Department of Agriculture. (Wischmeier and Smith, 1965)

A=(R)(K)(LS)(C)(P)

Where

A	=	calculated soil loss (tons/ha)
R	=	rainfall energy factor
K	=	soil erodibility factor
LS	=	slope-length factor
C	=	cropping management (vegetative cover) factor
P	=	erosion practice factor

There is a direct relationship between slope and calculated soil loss. The greater the slope, the greater the soil loss. In computing the LS term, LS is based upon the length of a given slope and the steepness of the slope. If the slope length is kept constant, the doubling of the slope (log-log relationship) causes the LS factor to approximately double. This means that a slope of 2% (100 m. length) has an LS factor of 0.29, where a slope of 4% has an LS factor of 0.6. A slope of 16% has an LS factor of 5. A slope of 16% has 17 times the soil loss of a 2% slope, all other factors being equal. Disturbance of steep slopes has a dramatic impact on site soil loss.

A slope of 16% has 17 times the soil loss of a 2% slope, all other factors being equal. Disturbance of steep slopes has a dramatic impact on site soil loss.

By identifying erodible soils in the project planning phase of a new land development, portions of a site having increased potential for erosion can be identified. This process would allow for site development to occur in a less destructive manner or would allow for more stringent erosion and sediment control practices to be implemented during site development.

Other Natural Features

There are other natural conditions which exist on sites beyond those discussed to this point. Those discussed earlier are the primary ones in terms of overall importance but there are others and consideration of their importance is in order.

<u>Depression Storage</u>

Of the precipitation which reaches roofs, pavements, and pervious surfaces, some is trapped in the many shallow depressions of varying size and depth present on practically all ground surfaces. The specific magnitude of depression storage varies from site to site. Depression storage commonly ranges from 1/8 to 3/4 inch for flat areas and 1/2 to 1.5

inches for cultivated fields and for natural grass lands or forests. Significant depression storage can also exist on moderate or general slopes with some estimations for pervious surfaces being between 1/4 to 1/2 inch depth of water and even more on natural meadow or forest land. Typical depths on moderate slopes can be 0.05 to 0.10 inches for impervious surfaces, 0.1 to 0.2 inches for lawns, 0.2 inches for pastures, and 0.3 inches for forest litter. Steeper slopes would obviously have smaller values.

When using traditional hydrologic procedures such as the Natural Resources Conservation Service Technical Release #55, depression storage is contained in an initial abstraction term. That term includes all losses before runoff begins. It includes water retained by vegetation, evaporation, and infiltration. It is highly variable, but generally is correlated with soil and cover parameters.

Prior to urbanization, watersheds have a significant depressional storage factor. Driving through agricultural or wooded areas after significant rainfall clearly demonstrates the existence of depressional storage. The urbanization process generally reduces that storage in addition to significantly modifying the lands surface. The combination of site compaction, site imperviousness, and reduced depression storage causes dramatic increases in downstream flood potential and channel erosion.

Natural Drainage Systems (streams and wetlands)

Natural site drainage features exist on every site. The most common of these features is having an existing flow path for stormwater runoff. Water doesn't usually travel in a straight line, as is evidenced by this picture of a stream in Colorado. Straight lines are something that humans have developed to accelerate the passage of water downstream as quickly as possible. During site development, the tendency is to place water in conveyance systems, open and enclosed, which follow the shortest distance to site outfalls.

Shortening the flow distance effectively increases the slope that water travels on, accelerates the flow of water, and increases the ability of the water to scour downstream receiving systems.

Shortening the flow distance effectively increases the slope that water travels on, accelerates the flow of water, and increases the ability of the water to scour downstream receiving systems. When water travels over a meandering flow path, energy is dissipated which reduces the erosion potential. Shortening flow lengths reduces energy expended and increases the available erosion producing energy. Stream channels will meander regardless of the degree of human alteration. Replicating existing flow paths and lengths, to the extent possible, promotes channel stability and increases function and value.

The additional functions provided by meandering channels over straight channels is also simply related to the length of the aquatic resource and the time that the water is in contact with the various biotic and abiotic processing mechanisms. In two studies in Iowa (Bulkley, 1975) and Oklahoma (Barclay, 1980), channel straightening reduced channel length by 45 percent and 31 percent, respectively. The additional length of

Stream meander pattern

meandering channels also provides a greater total quantity of aquatic resource, and the associated functions and values they provide.

Clearing and grading of areas which will remain pervious results in significant compaction of thse pervious areas. This compaction reduces expected infiltration rates and increases overland flow.

Uncompacted Open Space

A common approach to site development is to clear most, if not all, of the site being developed. Open space areas are cleared along with essential site development areas. Clearing and grading of areas which will remain pervious results in significant compaction of those pervious areas. This compaction reduces expected infiltration rates and increases overland flow. Using the NRCS soil classification system, of A, B, C, and D soils, TR-55 has a paragraph on Disturbed Soil Profiles which reads as follows:

"As a result of urbanization, the soil profile may be considerably altered and the listed group classification may no longer apply. In these situations, use the following to determine hydrologic soil grouping (HSG) according to the texture of the new surface soil, <u>provided that significant compaction has not occurred</u>.

HSG	Soil Textures
A	Sand, loamy sand, or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay"

Obviously, the key issue with respect to urban development is the issue of significant soil compaction. The travel of heavy earth moving equipment around a construction site could cause significant compaction of soils whose surface is to remain pervious. There are three scenarios to address this concern:

1. Where cuts or fills <u>of at least two feet</u> are intended to facilitate site development, A, B, or C soils in those areas of cut or fill should be downgraded one soil classification from an A to a B, B to C, or C to D. Stormwater management computations which detail post construction hydrology would use this modified approach to soil classifications.

2. In areas of significant site disturbance, and where there is less than two feet of cut or fill, soil classification groupings are not reduced, but the approved plans should contain a construction requirement that significantly disturbed soils in areas where those soils remain pervious should be chisel plowed. Chisel plowing will break the surface crust of the disturbed soil and allow for a greater infiltration rate.

3. Avoid compaction altogether by keeping equipment out of areas preserved for open space.

Linkage with Site Development

The only way that site development can occur in a manner which integrates existing site resources is to identify those site resources present on the site prior to initiation of site design. The first step in site resource integration is conducting an inventory of site resources and detailing them on a plan. A simple checklist can be developed which is based on the items discussed here. The checklist could include the following items which were presented throughout this Chapter:

The only way that site development can occur in a manner which integrates existing site resources is to identify those site resources present on the site prior to initiation of site design.

- Wetlands
- Floodplains
- Forested areas
- Meadows
- Riparian buffers
- Soils and steep slopes
- Other natural features

This plan should be included as a part of the stormwater management plan submittal which is provided to the appropriate plan review and approval agency. A narrative should also be submitted to detail what steps have been considered and/or provided to integrate existing resources into the stormwater management plan.

Plan designers and developers should also be aware of other jurisdiction specific criteria which may overlap with the natural site features items detailed above. Examples of other criteria include but are not limited to:

- natural resource protection areas
- water resource protection areas

Credits and design considerations for individual conservation practices are presented in Chapter 4.

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Chapter 3
The Conservation Design Approach:
Nonstructural Conservation Techniques Defined

This new approach to stormwater management focuses on utilization of natural systems and processes to achieve stormwater management objectives where feasible .

Stormwater management throughout Delaware (and elsewhere) can be markedly improved by approaching stormwater differently than has been the practice in the past, where "stormwater management" has been defined largely as stormwater disposal. This different perspective is based on a conceptual understanding of stormwater which is more comprehensive in scope and addresses the full array of stormwater issues. These issues are so important to maintain and protect Delaware's water resources, including recharging groundwater and maintaining balance in the hydrologic cycle, preventing flooding, and maintaining water quality and the ecological values which characterize Delaware waters. This different perspective further challenges us to maximize prevention, even before stormwater becomes a problem, and to avoid highly engineered structural solutions, expensive to build and expensive to maintain. In their place, this new approach to stormwater management focuses on utilization of natural systems and processes to achieve stormwater management objectives where feasible.

At the same time, this new approach is intended to work with site re-

Example of a stream with a riparian buffer

sources, as discussed in Chapter 2, and to enhance their functioning. The end result is site design which enhances existing wetlands, promotes the critical functions of floodplains, builds onto riparian buffer systems, even as stormwater requirements are satisfied. Dual function—double bang for the buck.

In short, the point of this approach is to do more with less.

In short, the point of this new approach to stormwater management is to do more with less. We have defined this different perspective as Conservation Design which includes an array of more areawide approaches (Conservation Design Approaches or CDAs) as well as more specific practices (Conservation Design Practices or CDPs). The purpose of this Chapter is to define these Approaches and Practices.

Conservation Design Principles

Common to all of these Approaches and Practices comprising Conservation Design are several basic principles:

Achieve multiple objectives. Stormwater management should be comprehensive in scope, with management techniques designed to achieve multiple stormwater objectives. These objectives include both peak rate and total volume control (i.e., balance with the hydrologic cycle), as well as water quality control and temperature maintenance. Comprehensive stormwater management involves addressing all of these aspects of stormwater. Complicated "treatment train" configurations with multiple structural techniques may be required in some situations in order to achieve comprehensive objectives. However, the objective in Conservation Design is simplicity. Try to achieve multiple comprehensive objectives with simpler, rather than more complex, management systems.

Integrate stormwater management and design early into the site planning and design process. Stormwater management tacked on at the <u>end</u> of the site design process almost invariably is imperfect. For comprehensive stormwater management objectives to be <u>optimized</u>, stormwater must be incorporated into site design from the outset, integrated into concept/sketch plan phase development up front, just as traffic and circulation are integrated. Stormwater impacts may even be a factor in determining <u>type</u> of use and <u>how much</u> of a use is to be developed at a site, if the issues are serious enough. Land planners need to consider incorporation of Conservation Design practices into the overall site design process and not engineer them after the fact.

Prevent rather than mitigate. The first objective in stormwater management strategizing is <u>prevention</u>. Approaches to site design which can reduce stormwater generation from the outset are the most effective approach to stormwater management, although such areawide planning actions are typically not thought of as stormwater management per se. For example, effective clustering significantly reduces length of roads, when compared with conventional development. Arrangement of units with minimal setbacks reduces driveway length. Reduction in street width and other street accommodations further subtract from total impervious cover. These important elements of site design are rarely thought of as conventional stormwater management practices, yet they achieve powerful stormwater quantity and quality benefits.

Manage stormwater as close to the point of origin (generation) as possible; minimize collection and conveyance. From both an environmental and economic perspective, redirecting runoff back into the ground, as close to the point of origin as possible, costs less money and maintains natural hydrology. Pipes, culverts, and elaborate systems of inlets to collect and convey stormwater, work against management objectives by definition and generally worsen the stormwater management challenge in most cases. Such systems increase flows and increase rate of flows, all worsening erosive stormwater forces. Structural collection and conveyance systems are increasingly expensive both to construct and then to maintain. Furthermore, these systems, almost without exception, suffer from failures and therefore should be avoided if at all possible. A corollary principle is to avoid concentrating stormwater flows, which is achieved when stormwater is not conveyed long distances, but recycled into the ground at or near the source.

A corollary principle is to avoid concentrating stormwater flows, which is achieved when stormwater is not conveyed long distances, but recycled into the ground at or near the source.

Rely on natural processes within the soil mantle and the plant community to the maximum. The soil mantle offers critical pollutant removal functions through physical processing (filtration), biological processing (various types of microbial action), and chemical processing (cation exchange capacity, other reactions). Plants similarly provide substantial pollutant uptake/removal potential, through physical filtering, biological uptake of nutrients, and even various types of chemical interactions. Where something ends up is important. Pollution is often just a resource out of place—too much of a good thing in the wrong location. Natural processes can work effectively to minimize these types of pollution problems.

Conservation Design is based on a philosophy—a vision for the environment—that is neither pro-development or anti-development. Conservation Design is grounded on the positive notion that environmental balance can be maintained as new communities are developed throughout our watersheds, if basic principles are obeyed. Conservation Design means understanding our natural systems such as our essential water resources and making the commitment to work within the limits of these systems whenever and wherever possible. As stated above, Conservation Design is grounded on the recognition that stormwater is ultimately a precious resource to be utilized carefully, rather than a waste in need of disposal.

Importance of Natural Processes in Conservation Design

Before describing specific aspects of Conservation Design, a quick review of the nature and extent of the natural systems and processes referred to above and which are so important to the success of the Conservation Design is in order. Keep in mind that the sections below are very much condensed summaries and that numerous details have been omitted for the sake of user friendliness. Refer back to Chapter 2 for additional discussion of soils and vegetation.

Soil-Linked Processes for Water Quality/Quantity Management

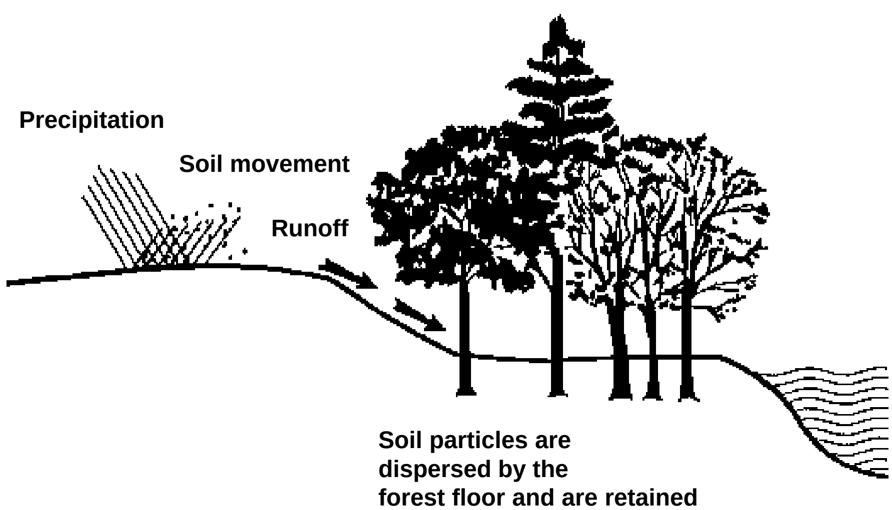
Conservation Design, as with other Best Management Practices, relates in important ways to the soil mantle and the manner in which water moves across and through this soil. Understanding how much of what type of soil is in place is essential when assessing stormwater impacts and stormwater management needs. Soil may turn a management problem into an opportunity. For example, soil type influences how much water can be infiltrated per time period, based on soil permeability. Soil permeability rating, therefore, is a critical variable in Conservation Design. Soil type will affect pollutant removal potential. Soil erodibility is an important factor as well. Factors such as depth to bedrock and depth to seasonal high water table also have important ramifications for Conservation Design.

Conservation Design, as with other Best Management Practices, relates in important ways to the soil mantle and the manner in which water moves across and through this soil.

Soil surveys done typically by county provide a considerable amount of information relating to all relevant aspects of soils. More detailed discussion of soils occurs in Chapter 2. Soil with a coarse texture (i.e., having large particle size such as sand) has a high rate of infiltration. Soil with extremely small particle size (clayey soil) has a low permeability rating. Understanding these soil characteristics is an essential first step in Conservation Design.

When dealing with structural BMPs which rely on infiltration (basins, trenches, dry wells), HSG rank and permeability rating is crucial for BMP success. Typically a permeability of at least approximately 0.5 inches per hour is required for structural BMPs. Because Conservation Design often does not involve the type of soil disturbance and potential com-

Figure 3-1
Streamside forests
filter sediments from runoff



paction problems which can occur with structural BMP design, somewhat lower permeabilities, perhaps as low as 0.27 inches per hour (HRPDC, 1991 and 1992), can be tolerated and put to good use. When permeabilities are so poor, extreme care must be taken when undertaking Conservation Design.

At the same time areas of such poor permeability but with good stands of vegetation may function quite satisfactorily and offer opportunity which should not be ignored at a site (a well-developed root zone associated with established vegetation can significantly improve poor soil infiltration and permeability). For example, an otherwise questionable HSG C soil, if not disturbed and if reasonably well vegetated, may offer surprisingly good opportunity for receiving and infiltrating stormwater created by new impervious surfaces elsewhere at on the site. Presence of stems and roots can substantially enhance infiltration and permeabilities. Conversely, even seemingly good soils (HSG B), <u>if substantially disturbed and compacted</u>, can become far less permeable. As discussed elsewhere in this Manual, in these cases permeability ratings should be reduced (it should be noted that sandy HSG A soils may be able to withstand disturbance problems more readily than heavier soils with clay content and therefore may not experience this same kind of loss of permeability).

Soils are very important for their ability to remove pollutants entrained in stormwater, through a complex of physical, chemical, and biological mechanisms.

Although reliance on the published soils data is acceptable for most feasibility studies and conceptual planning, detailed Conservation Design stormwater management planning should be accompanied by soil field sampling verification. Bore holes are drilled and then under saturated conditions, rate of infiltration is determined. Size of site, geologic complexity, and other factors will determine the number of bore holes necessary site-by-site.

Soils are very important for their ability to remove pollutants entrained in stormwater, through a complex of physical, chemical, and biological mechanisms. Above all, the soil mantle must be understood to be a vast and complex system, a rich and diverse community of organisms—thousands, even millions of organisms per cubic inch—all of which have complex functions which can become the basis of impacts if damaged or destroyed, or become mechanisms for treatment if understood and properly utilized. The various types of processes which occur as the result of soil microbe action and the other essential elements of the soil community, when fully understood, can be utilized quite effectively for stormwater management purposes. <u>Soil constitutes an extremely valuable resource.</u> Documenting the complete array of these soil-based processes is a manual in itself. Soil microflora are abundant and diverse, including innumerable species of bacteria, fungi, actinomycetes, algae, and viruses (Table 3-1). These species process organic material, certainly a stormwater-linked pollutant, as food and energy sources in different ways (Gray and Williams, 1971). Physically, particulate form pollutants are caught and filtered by the soil mantle as well. Many of the soil-based functions which are chemically-oriented (adsorption, others) occur through the mechanisms of cation exchange driven by surface area of soil particles, amongst other factors. Such functions are especially important for their ability to remove soluble pollutants such as nutrients. Even in large particle sandy soils where surface area is low (72 sq cm per gram), significant pollutant reduction can occur through these chemical mechanisms. Cation exchange capacity (CEC), as discussed in Chapter 1, is used as a measure of pollutant reduction potential.

Table 3-1
Relative number and biomass of soil flora and fauna commonly found in soils[a]

Organisms	Number per m^2	per gram	Biomass[b] Kg/HFS	(lb/AFS)
Microflora				
Bacteria	10^{13} - 10^{14}	10^{8} - 10^{9}	450 - 4500	400 - 4000
Actinomycetes	10^{12} - 10^{13}	10^{7} - 10^{8}	450 - 4500	400 - 4000
Fungi	10^{10} - 10^{11}	10^{5} - 10^{6}	1,120 - 11,200	800 - 8000
Algae	10^{9} - 10^{10}	10^{4} - 10^{5}	56 - 560	50 - 500
Microfauna				
Protozoa	10^{9} - 10^{10}	10^{4} - 10^{5}	17 - 170	15 - 150
Nematoda	10^{6} - 10^{7}	10 - 10^{2}	11 - 110	10 - 100
Other fauna	10^{3} - 10^{5}		17 - 170	15 - 150
Earthworms	30 - 300		110 - 1100	100 - 1000

[a] Generally considered 15 cm deep, but in some cases (earthworms) a greater depth is used.
[b] The biomass values are on a live weight basis. Dry weights are about 20-25% of these values

Pollutant removal potential often varies indirectly with permeability.

Pollutant removal potential often varies indirectly with permeability. For example, soils which are extremely sandy (large particle) can be expected to have excellent permeability. Yet CEC values may be borderline. In fact extremely sandy soils may have such low CEC values that they should be deemed unacceptable certainly for any type of stormwater runoff which can be expected to be reasonably laden with nonpoint source pollutants, particulate or soluble. In no way should "hot spot" runoff from roads or fast food parking lots be cycled through sandy infiltration systems without being pretreated through some sort of filtering mechanism. Conversely, heavy clayey soils may have limited permeability, yet typically do an excellent job of removing a wide variety of pollutants through their high CEC ratings.

Vegetation-Based Processes for Water Quality and Quantity Management

As discussed in Chapter 2, vegetation provides a host of useful functions which are vital to Conservation Design Techniques. In so many cases, these functions reflect the close connection between water quantity and water quality issues:

- Vegetation absorbs energy of falling rain, promoting infiltration, minimizing erosion, etc.

As with soil, vegetation provides a host of useful functions which are vital to Conservation Design Techniques.

- Roots hold soil particles in place, preventing erosion.
- Vegetation (blades, stems, trunks, etc.) slows runoff velocity; as this velocity slows, not only is the erosive force reduced, but sediment already entrapped will begin to settle out, as will other pollutants. Reduced velocity means increased opportunity for infiltration.
- Vegetation provides for a richer organic soil layer which improves soil porosity and structure, maximizing the absorptive capacity of the soil and promoting infiltration, etc.
- Vegetation "consumes" many different types of stormwater-linked pollutants through uptake from the root zone. In addition to the positive effects on sediment and sediment-bound phosphorus, even solubilized nitrogen is taken up through a series of complex processes and transformations, as are some other metals and compounds.

These processes are discussed below in more detail, technique by technique.

Conservation Design: Approaches and Techniques

As the understanding of stormwater management has grown more sophisticated, there has been a proliferation of guidance documents and manuals developed by federal, state, and local agencies throughout the country. In some cases, the special environmental values prompting special stormwater management actions may seem to differ somewhat from the values characterizing Delaware (i.e., the focus may be different bays or estuaries or high quality stream systems and the like), nevertheless, the objective of most of these manuals is similar to the objective here—to establish better approaches to new land development which minimize impacts on water resources. Additionally, many of these manuals may seem to be water quality focused, though the techniques presented often accomplish quantity management objectives as well. These manuals have been reviewed and generously borrowed upon in the course of preparing this Manual.

Of these available sources, the *Urban Stormwater Best Management Practices for Northeastern Illinois*, is especially useful. This manual includes its own set of principles similar to those offered in this manual, in this case called the Runoff Reduction Hierarchy.

Also useful is the more summary *A Watershed Approach to Urban Runoff: A Handbook for Decisionmakers (March 1996)* developed by the Terrene Institute. *Fundamentals of Urban Runoff Management: Technical and Institutional Issues* (1994) is an excellent compendium of material which ranges from an overview of the field to technical methodologies and equations to insightful discussion of institutional and overall program development issues (published through the Terrene Institute).

Site Planning for Urban Stream Protection, published by the Center for Watershed Protection and the Metropolitan Washington Council of Governments (MWCOG), is another recent manual which offers useful information for the Conservation Design approach. The Hampton Roads Planning District Commission has prepared a *Vegetative Practices Guide for Nonpoint Source Pollution Management* (1992) which is extremely useful, highlighting natural functions provided by vegetative practices; this group also offers other information sources. The massive manual from EPA and NOAA, Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters also contains useful information, although its scope goes well beyond new land development controls being discussed here. Most recently, the Chesapeake Bay Program agencies have published the *Chesapeake Bay Riparian Handbook* (1997), an excellent manual which provides a wealth of information relating to riparian buffer and other stormwater management techniques.

In short, the information base for comprehensive stormwater management has proliferated in recent years. At the same time, it must be acknowledged that the extent of research studies focusing on the performance of the many different techniques presented here as well as other structural BMPs remains deficient. Data relating to effectiveness is often times lacking.

Conservation Design: Preventive and Mitigative versus Structural and Nonstructural

Conservation Design can be thought of in different ways. In the discussion here, we make a broad distinction between those Approaches which tend to manage stormwater largely through <u>preventive</u> strategies, versus practices which are largely <u>mitigative</u> in nature. Examples of preventive approaches would be reduction in imperviousness, as accomplished through a variety of mechanisms discussed in the section below. In such cases, the generation of stormwater itself is prevented, or at least minimized. This reduction in stormwater quantity in most cases translates into a reduction in stormwater-related pollutant loadings as well. Furthermore, the cost savings associated with preventive Approaches are obvious and compelling (though not always easily calculable). In sum, although <u>total</u> prevention of stormwater generation may not be possible, a stormwater management system which is designed to maximize prevention is going to achieve both quantity-related and quality-related management objectives much more cost-effectively than other approaches.

Conservation Design can be thought of in different ways. In the discussion here, we make a broad distinction between those Approaches which tend to manage stormwater largely through <u>preventive</u> strategies, versus those techniques which are largely <u>mitigative</u> in nature.

Mitigative practices, on the other hand, are designed to manage stormwater after it has been generated. As such, mitigative practices logically have to collect and control stormwater, typically with some type of structure or even a series of structures. Mitigative practices can be designed to manage both peak rate and volume discharges as well as remove as many pollutants as possible.

This differentiation between preventive and mitigative stands in contrast to the more customary distinction so often made between structural and nonstructural practices for managing stormwater. Although the structural vs nonstructural differentiation may be helpful to think of in terms of some aspects of what we are defining in Conservation Design, the structural vs nonstructural break out also can be confusing. For example, considerable attention has been given to nonstructural approaches to stormwater management which can include "program"-types of management efforts, such as street sweeping and others, not the subject of this Manual. Conversely, equating preventive and nonstructural practices also gets problematic, in that some preventive approaches such as use of natural areas/forested zones with level spreaders or minimum disturbance/minimum maintenance (all discussed below) may seem to have structural, rather than nonstructural, qualities to them.

Therefore, because the structural/nonstructural breakout can confuse rather than clarify the Conservation Design discussion, we use the preventive vs mitigative differentiation more frequently here.

Conservation Design: Best Management Approaches (BMAs) and Practices (BMPs)

Given the importance of this preventive vs mitigative concept, we have taken the further step of sorting out Conservation Design recommendations into these preventive and mitigative categories. Along with the categories comes some terminology.

Conservation Design Approaches: The term Conservation Design Approach (CDA) we apply to the list of stormwater management recommendations which <u>tend</u> to be preventive and may be viewed as nonstructural in nature, although such is not always the case. Approaches tend to be broader in geographical scope than other techniques and typically may involve the entire site—a site-wide strategy for new land development. Site design/clustering is one such broader approach which transcends the concept of a BMP. Reduction in imperviousness, and all that is involved with this approach, transcends the more focused stormwater management practice concept. The tentative list of approaches included in this manual includes:

Approaches may even transend the site itself, involving an entire planning jurisdiction or area, or even an entire region.

- Planning/Zoning (Building)
- Clustering/Lot configuration
- Reduced imperviousness
- Minimum Disturbance/Maintenance

Approaches may even transcend the site itself, involving an entire planning jurisdiction or area, even an entire region. For example, we know that configuring 10,000 persons in a concentrated neo-traditional "village" translates into significant reductions in land area requirements and significant reductions in total impervious area, all of which generates significant reductions in total stormwater being generated and significant reductions in nonpoint source pollutant generation as well—when contrasted with the low density/large lot suburban mode which so frequently characterizes new land development in Delaware and beyond. Typically, we have not thought in such “global” or “macro” terms when considering stormwater management. Such issues relate to an entire county or municipality in its total watershed setting within the total context of the state. But increasingly, a more complete understanding of the linkages between land and water compel us to consider stormwater management on this broader level. Ultimately, the water management issues merge into total growth management issues—how much growth is reasonable and by when? How is this growth best distributed across Delaware and its watersheds? This Manual makes the optimistic assumption that a broader planning framework will be developed properly and that issues will be resolved with maximum sensitivity to water resources.

Ultimately, the water management issues merge into total growth management issues—how much growth is reasonable and by when?

We emphasize that Conservation Design as defined here avoids the basic issue of how much of what type of use is to occur at any particular site—in other words, essential planning and zoning issues. Although there is a summary discussion of these planning issues at the beginning of the next section, the issues are not treated in any detail here. Nevertheless, these questions are critical and have profound importance for overall water resources management—both quantity and quality. The emphasis of this Manual is to define what we can do to improve stormwater management primarily on a site-by-site basis, assuming that development continues to occur. We do note that in those cases where conventional development programs cannot be accommodated with Conservation Design, density reduction is an option. Though development at maximum allowed density has come to be the assumed norm in many cases, certainly development at reduced densities may provide economic use while balancing water and other ecological needs.

Conservation Design Practices: The second type of Conservation Design technique which we define is the conceptually more conventional Conservation Design Practice (CDP). CDPs include mitigative techniques which often are more structural in nature. CDPs encompass a rapidly growing array of biofiltration and bioretention methods such as vegetated filter strips with an ever-growing number of variations in sizes and configurations. Similarly vegetated swales are included as another important category of CDP, again with a long list of variations is size and configuration. We also include here a CDP defined as Terracing/Berming/Terraforming, as well as use of natural areas/reforestation/revegetation. The list of practices used in this manual includes:

- Vegetated swales, use of natural drainageways
- Vegetated filter strips including riparian buffers
- Grading, berming, terraforming
- Use of natural areas with level spreading, with reforest-

ing and revegetation

All of these CDPs can be used in conjunction with CDAs and with one another to good effect. Sometimes its difficult to see where a CDA stops and a CDP starts. In most cases it's not all that important to focus on the category distinction. The point here is to incorporate the critical functions of Conservation Design which we have discussed in the preceding chapters into overall stormwater management planning. Variations on the themes developed here may emerge. We expect, in fact we hope, that this Manual gives rise to creative thinking which expands our lists of CDAs and CDPs on all sides.

We must move beyond the approach to stormwater management where the site plan is defined and then the BMP list is brought out to do whatever it can.

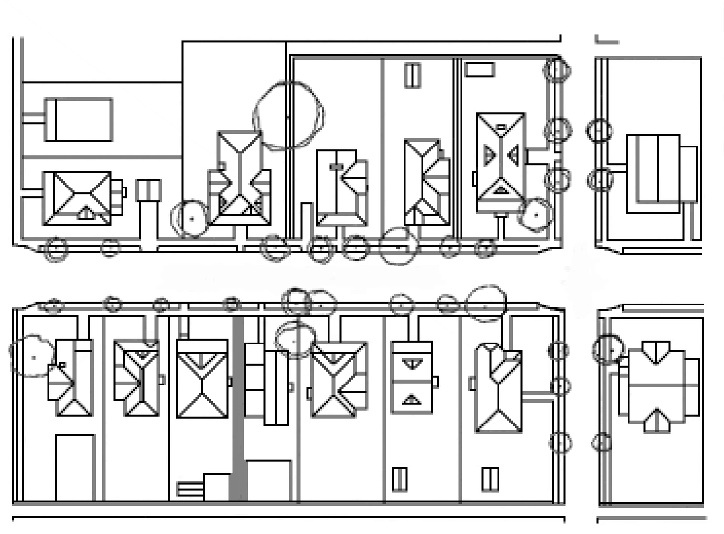
We must move beyond our lists of Best Management Practices, as defined in the past. We must move beyond the approach to stormwater management where the site plan is defined and then the BMP list is brought out to do whatever it can. We can do it better, as the discussions of CDAs and CDPs below and their application in the case studies makes clear.

Conservation Design Approach: Comprehensive Planning/ Zoning (Macro/Areawide)

Description: This Manual has been developed for stormwater management purposes. Comprehensive planning throughout the state, its counties and municipalities, is the purview of other agencies and other efforts. It would be inappropriate for DNREC to exceed its legislated bounds and to presume to interfere with broader planning initiatives. At the same time, the linkages between land and water—land use planning and water resources management and, in particular, stormwater management—are extremely important.

Comprehensive planning concepts, though not discussed in any detail

Figure 3-2
Street Layout for Concentrated Development Typical of a Village



in this Manual, should be addressed when considering a total program of stormwater management, and deserve direct discussion from the outset. As we advance to a better understanding of water quantity and water quality from the larger system or watershed perspective, there has also been increased recognition that application of BMPs site-by-site, though extremely important, simply does not—cannot—optimize water quantity/quality objectives, as watershed and sub-watershed units begin to build-out. Our "toolbox" of BMPs includes practices that in the field may give us a varying reduction in pollutant loads (sometimes a bit higher, sometimes lower). Such a variable level of performance can be tolerated relatively easily in areas of modest development where total loadings are not great. But as development increases, these loads start to mount, and stream systems begin to show signs of stress. If we really want to keep high quality systems, broader planning strategies <u>optimizing</u> quality and quantity management objectives must be put in place. More "macro" planning strategies are essential, if water resources are to be fully protected.

Assuming that land development impacts water resources as described in earlier discussions, then one planning and management response might be to simply limit growth. For any number of economic and social and political reasons, such a strategy is not a practical alternative, at least in terms of a state-wide or county-wide broad-based approach. Furthermore, such a strategy <u>technically</u> is not required either. The simple issue of <u>number</u> of people and <u>number</u> of dwelling units and office spaces per se is not the accurate measure of water resource impacts—not necessarily. A vibrant economic future with considerable growth can be achieved <u>even as water resources are managed carefully.</u> We can develop in ways which are far less harmful to water resources.

If we really want to keep high quality systems, broader planning strategies <u>optimizing</u> quality and quantity management objectives must be put in place.

More "macro" planning strategies are essential, if water resources are to be fully protected.

Fortunately, these new directions for watershed management happen to coincide quite compatibly with principles which have emerged for overall growth management as is being discussed elsewhere across the State.

The theme is simple. Concentrate growth. Make far more happen on far less land area. Minimize disturbance watershed-wide. Don't just zone out a few overlay zones of sensitive areas for special protection and then let the bulk of the watershed build-out with suburban sprawl. "Consume" substantially less watershed area person-by-person and not just in terms of one particular site, but from a total areawide perspective. We might imagine concentrations of development, carefully positioned in the least environmentally sensitive zones, all tied together with transit systems—Transit Oriented Development (TOD), which minimizes automobile trips and nonpoint source pollutant loadings as well. In such a scenario, the required land area disturbance becomes a small fraction of what is occurring today. Such centers of development would be surrounded by a landscape dotted with clustered village development separated by large expanses of open area, with stormwater and wastewater recycled locally back into and through natural systems. In short, the complete planning "vision" requires a planning focus which extends well beyond the site-specific level.

Ultimately, all of these issues translate into how much of what type of use is to be developed, parcel by parcel - in other words, the building program.

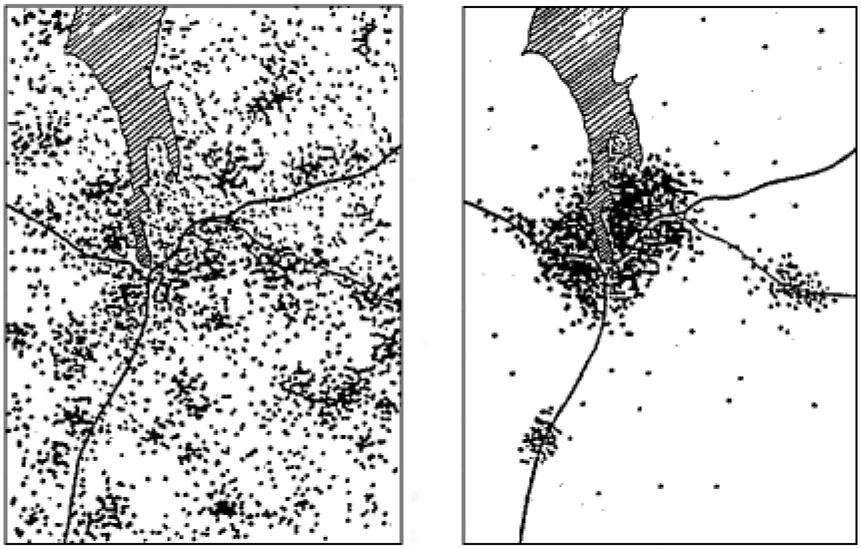
Performance of conventional structural stormwater management practices can be quite partial in nature. Often times not much more than 50 percent of a particular pollutant is removed as the result of our best efforts.

Performance: Performance of conventional structural stormwater management practices can be quite partial in nature. Often times not much more than 50 percent of a particular pollutant (especially pollutants in soluble form) is removed as the result of our best efforts. Even with Conservation Design Practices such as filter strips and vegetated swales, pollutant removal is not complete. The macro comprehensive planning strategies as described above offer the possibility of significantly limiting those pollutant loads which cannot reasonably be expected to be eliminated through site-specific practices.

Studies of the effects of these areawide measures in terms of water quantity and water quality watershed-wide are quite limited. In fact, because the linkages between stormwater and growth management have only recently come to be recognized, research findings are relatively sparse. Hydrologic modeling using TR-55, TR-20, and a variety of other statistical models typically targets flooding; their use such as in Pennsylvania's Act 167 stormwater management program demonstrates that land development, even with detention controls, can translate into worsened flooding downstream. It is often reported anecdotally that developing watersheds experience not only worsened flooding as defined in terms of peak 100-year flood elevations, but also are impacted by far more frequent out-of-bank flooding events even as rainfall events are held constant. In other words, a 1-year storm <u>before</u> development ends up producing a 2-year or even worse flood after development - or even worse.

From a somewhat different perspective, interesting work has been done in Washington State by the City of Olympia and adjacent city and county governments, where watershed analysis has indicated the need to reduce imperviousness for water quality and quantity objectives to be achieved (*Impervious Surface Reduction Study: Final Report*, 1995). Holding projected population to 2015 constant, two dramatically different scenarios of land development (the current baseline pattern of low density sprawl vs. a growth management strategy of concentration in developed urban areas) were defined and tested for imperviousness. The concentrated pattern with its mixed use zones, connected roads, intensified city centers (Figure 3-3) demonstrated less impervious area per capita in total, less impervious cover in outlying rural and low density areas, and more efficient use of impervious areas in the existing urban areas, in contrast to the current baseline low density pattern of separated uses, strip commercial, with lesser developed downtowns. Although the Olympia analysis itself does not report on stormwater, we can further conclude that these different land development scenarios would have roughly comparable differences in their stormwater quantity (and quality) impacts as well.

Figure 3-3
Two Development Scenarios Used in Impervious Surface Reduction Study



Current Pattern

Future pattern if the growth management strategy is implemented

Work has been done in Washington State by the City of Olympia and adjacent city and county governments, where watershed analysis had indicated the need to achieve reduced imperviousness for water quality and quantity objectives to be achieved.

Moving from flood flows to low flows, we are not aware of modeling studies which specifically focus on watershed-wide impacts resulting from reduced volumes of groundwater recharge, reduced stream baseflow, and the like. The Brandywine Conservancy's recently developed Water Based Land Use Regulation (WBLUR) program, based on a Modified Climatic Water Budget Model, is designed to assess these types of water quantity impacts of land development. This program enables patterns of land use to be formulated for a site, for a municipality, and for a watershed which optimize water resources.

More model application and overall study has focused on water quality issues, typically on use of one or more BMPs at a site or series of sites. For example, in *Managing Watersheds: Combining Water Quality Protection and Community Planning* (1996), the Regional Plan Association (RPA)in the New York metropolitan area has completed studies for New York City Department of Environmental Protection (NYCDEP) which demonstrate that overall community planning concepts taking the form of villages and hamlets in the appropriate locations produce a water quality result which is better than water quality related to conventional low density development. The critical objective of this RPA/NYCDEP work was to figure out how to "save" the largest public water drinking system in the world—a remarkable surface water system in the once undeveloped Catskill Mountains in New York State, where new development threatens the quality of the water resource. RPAs analysis of different approaches to future land development has triggered a campaign to replan development in very different ways in order to maintain water quality.

Costs: When compared with the costs of site-specific BMPs multiplied dozens, perhaps hundreds of times across a municipality or watershed, the actual costs of developing better planning strategies at hypothetically $20,000-50,000 becomes virtually trivial. An entirely new comprehensive plan for a county may cost $50,000. The recent round of comprehensive planning in Delaware's three counties provides an excellent basis for cost analysis. Although we do not have these cost figures at hand, we would be surprised if the total spent on this entire effort were to be more than $250,000 for all three counties for comprehensive planning, which encompasses all aspects of life, transportation, housing, all aspects of the environment, economics, and so forth.

From a cost effectiveness perspective, therefore, even very modest improved performance from better areawide planning across the many different development sites involved yields tremendous benefits. We have heard complaints from developers contending that elaborate stormwater management systems in residential developments can exceed $10,000 per lot or dwelling unit. If a better county-wide plan can have a real impact on stormwater performance, a tremendous amount of money can be saved.

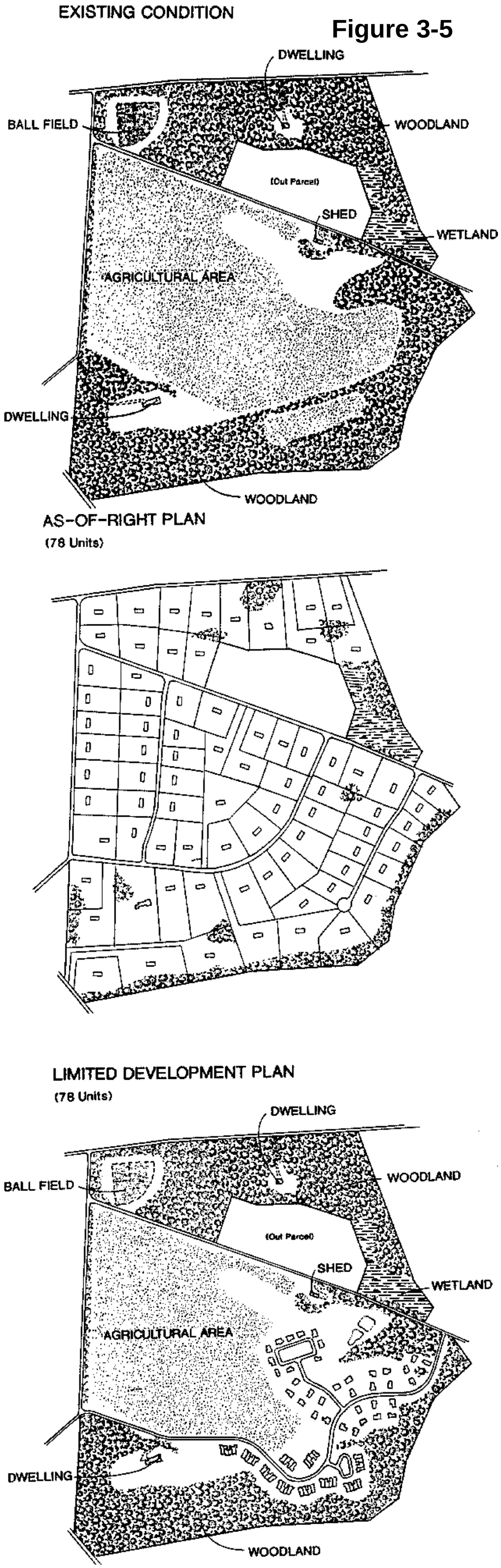
From a cost effectiveness perspective, therefore, even very modest improved performance from better areawide planning across the many different development sites involved yields tremendous benefits.

Conservation Design Approach: Clustering/Lot Configuration

As stated earlier in the Manual, stormwater management is optimized when stormwater objectives are integrated into site planning from the earliest possible stage. In many if not most cases, the process translates into concentrating or clustering development so that the most environmentally sensitive areas of the site are left undisturbed, although there may be aspects of site design which cannot be readily incorporated within a conventional understanding of clustering per se. Most of the discussion here focuses on various aspects of clustering, as has evolved during recent years.

Figure 3 - 4
Example of traditional versus cluster development

Figure 3-5



<u>Description</u>

Many municipalities have included various types of clustering provisions within their zoning ordinances, typically as an option to conventional subdivision development. Rarely is clustering mandated, often a reflection of its overall lack of popularity with existing residents who worry that reduced lot size will lower land values and create a deteriorated neighborhood.

Clustering offers tremendous potential in terms of stormwater benefits and overall resource protection. Nevertheless, clustering does have limitations. Obviously clustering by definition does not—cannot address important issues of areawide or watershed-wide growth patterns which have important stormwater implications. Clustering in most cases is parcel-specific (it should be noted here that clustering programs <u>are</u> growing more sophisticated. Randall Arendt's Conservation Design process is designed to make clustering provisions relate to larger systems of open space by connecting the open space areas generated, cluster by cluster; in this manner, more meaningful open space corridors can be cre-

Clustering offers tremendous potential in terms of stormwater benefits and overall resource protection.

ated).

Although some density bonuses may be offered which increase density, clustering in a strict sense usually begins after the basic determination of how much of what type of use—a certain number of single-family residences, for example—already is to be permitted parcel-by parcel. In some cases, parcels may be combined to produce a broader development pattern, but a typical clustering set of regulations should understand and reflect the existing pattern of ownership if it is to function successfully. In some cases, the clustering concept may be structured to include different types of development, twin houses and townhouses and multifamily residences, blending into Planned Residential Development (PRD) and Planned Unit Development (PUD) and Unified Development Area (UDA) concepts.

From a stormwater management perspective, clustering minimizes stormwater and pollutant loading generation from the outset and therefore is preventive in nature.

As a Conservation Design Approach, clustering comes near the top of the list. From a stormwater management perspective, clustering minimizes stormwater and pollutant loading generation from the outset and therefore is preventive in nature. To maximize positive stormwater effects, clustering works well when used in conjunction with other Conservation Design Approaches and Practices. In many cases, a tight clustering approach to site design facilitates these other approaches and practices and even makes them possible.

Guidance on clustering is proliferating. The Center for Watershed Protection's new *Site Planning for Urban Stream Protection* devotes an entire chapter to clustering, going so far as to define a "stream protection cluster." Maryland Office of State Planning's *Clustering for Resource Protection* is another good source of guidance on clustering provisions and mechanisms to make clustering most effective from a water resource perspective. Metropolitan Washington Council of Government's *Cluster Development Strategies for Urban Watersheds* and many other references provide an excellent resource base.

In the region, both the Brandywine Conservancy and the Natural Lands Trust (NLT) have developed substantial expertise in clustering programs and are working with numerous municipalities in their implementation. Brandywine promotes an "open space design option" as defined in its *Environmental Management Handbook*, which typically consists of clustering provisions included in zoning, operationalized by conditional use provisions. NLT has developed the concept of open-space subdivisions accomplished in a four-step process:

- Identify conservation areas.
- Locate dwelling sites.
- Align streets and trails.
- Draw in lot lines

NLT's Randall Arendt has just recently completed work with Kent County where many of these principles have been applied. Clearly clustering is here to stay.

Almost without exception, benefits of clustering are maximized when clustering provisions can be made flexible. Clustering at one site often must respond to a different set of features than clustering at another site. If the prevailing density of an area is large lots of several acres, 1-acre lot clusters may be appropriate, whereas in a much more dense setting, effective clustering may mean going from half-acre lots to 6,500 ft^2 lots.

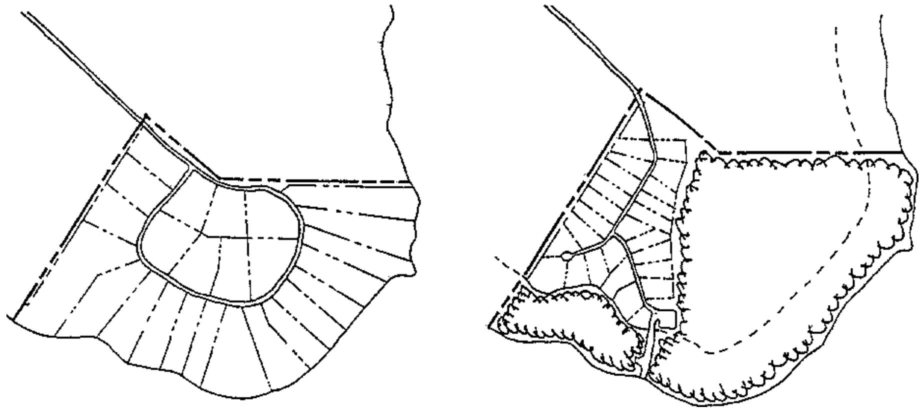
In order to achieve maximum benefit, substantial design flexibility must be maintained—a difficult objective to integrate into clustering ordinance regulatory language. Crafting effective clustering regulations to address all of these different situations is challenging. Clustering can be made to work effectively on a small site or a large site, but clearly the standards imposed on a 100-acre tract need to be different, possibly significantly different, than the standards imposed on a 10 acre tract. Clustering may involve lot design and arrangement only. Or clustering may transcend lot design and even involve changing types of residences, as discussed above. The challenge is to create a clustering system which maximizes clustering benefits such as open space preservation even as developer incentives are maximized as well.

The challenge is to create a clustering system which maximizes clustering benefits such as open space preservation even as developer incentives are maximized as well.

If clustering is not mandated, incentives must be provided to encourage its use. In many cases, clustering provisions have given rise to <u>dis</u>incentives. For example, in many clustering ordinances, the underlying zoning district base density is held constant, such that clustering doesn't affect the maximum number of units allowed. Because many developers perceive clustered units on smaller lots as less valuable, some sort of density bonus provision is needed if the option is to be used. Adding to the problem is the fact that the clustering option typically requires all sorts of special processing requirements, which invariably requires more time, energy, and resources on the part of the developer. Some special clustering provisions effectively subtract out additional environmentally constrained site areas, not subtracted out with conventional development, such that the net building program with clustering is reduced. Assuming that clustering is optional, such density reductions, however well-intentioned, virtually guarantee rejection of the concept by developers, who are the real implementers of any and all of these concepts.

Furthermore, clustering may well require that a variety of provisions elsewhere in the subdivision/land development ordinance be modified. Setback provisions may have to be amended, as can be the case for any number of other dimensional requirements predicated on large-lot conventional subdivision design. Required street frontage, setback of the structure from the street, side and even rear yard setbacks become very different for Traditional Neighborhood Development than for large-lot development. For clustered single-family residential units with a standard structural footprint, minimum lot size tends to be around 10,000 sq ft, although if unit type can be varied and if zero lot line and other more creative approaches to the single-family home are included, further lot reductions are possible.

Figure 3-6
Conventional Development Versus Conservation Design Cluster



Other important issues to keep in mind when considering clustering include:

- Are meaningful open space requirements established? Do these open space requirements properly vary with site size, type of use allowed, etc.?

- How is open space controlled and managed over the long term?

- Have water supply and wastewater provisions been incorporated by the locality (i.e., are the "centralized" systems for wastewater and water supply reasonably achievable? Are onsite systems so much easier to develop and approve that infrastructure dictates the conventional development approach?)

- Have homeowners' management systems been incorporated to the extent feasible? Does the need for a homeowners' association itself discourage use of a clustering option?

All of these factors can determine success of a clustering program.

<u>Performance</u>

Benefits achieved from clustering can be considerable:

- reduction in imperviousness
- reduction in pollutant loads
- preservation of special values and sensitive features
- habitat protection
- aesthetics
- passive recreation and open space maintenance
- reduction in costs, both development and maintenance, as well as reduced community costs

- increased property values

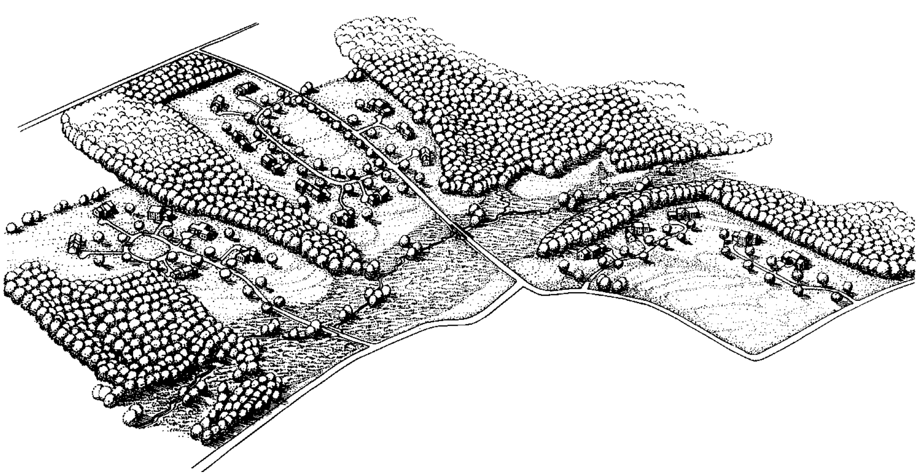
The Maryland Office of State Planning has completed one of the more in-depth comparative studies of the benefits of clustering in contrast to conventional large-lot subdivision (*"Environmental and Economic Impacts of Lot Size and Other Development Standards"*, 1988). Although non-stormwater-related benefits, as listed above, have not been detailed in this Manual, they are extremely important as well.

Although reduced imperviousness is dealt with separately below, reduced imperviousness is such an important benefit from clustering that it deserves special mention. Holding all other aspects of the development constant (number of units, types of units, etc.), clustering may reduce impervious cover by 50 percent or more, if the development is proposed for an otherwise large-lot (over 1 acre per unit) development. In a comparative study of four different 100-lot subdivisions each having 100 houses on one-eighth, one quarter, 1.4, and 5-acre lots respectively, the Maryland Office of State Planning calculated total impervious surfaces ranging from 7.4 acres to 18.3 acres, an increase of 147.3 percent when going from the one-eighth-acre to 5-acre configuration. Imperviousness increased by 30 percent when moving from the one-quarter-acre to 1.4-acre configuration. Imperviousness reduction is achieved mostly through reduced road construction and reduced driveway lengths (note that these percentage reductions are extremely difficult to define precisely, due to the tremendous variation in site size and shape as well as other factors which affect clustering design in any one instance). Given the direct relationship between imperviousness and stormwater generation, reduction in imperviousness can be expected to result in comparable reduction in stormwater generation, both total volume and rate.

Given the direct relationship between imperviousness and stormwater generation, reduction in imperviousness can be expected to result in comparable reduction in stormwater generation, both total volume and rate.

Water quality benefits as well. Reduced quantities of stormwater typically translate into reduced pollutant loadings for a variety of reasons. Clustering means, in most cases, a tremendous reduction in vegetation removal and soil mantle disturbance, all of which becomes a source of erosion-driven sediment. Schueler and Lugbill cite sediment concen-

Figure 3-7
Open Space Design Subdivision



trations of 4,000 mg/l at some construction sites, with typical instream concentrations at 200-300 mg/l, in their *Performance of Sediment Controls at Suburban Maryland Construction Sites* for the Maryland Department of the Environment and MWCOG, 1991. They contend that percentage reduction in sediment quantity translates into comparable percentage reductions in total pollutant loads, based on use of Schueler's Simple Method of estimating stormwater pollutant loads. This finding is corroborated in Maryland Office of State Planning's *Environmental and Economic Impacts of Lot Size and other Development Standards* (1988), shown in Table 3-2,where a variety of pollutants were estimated based on several different estimating methodologies and where total pollutant loads declined dramatically as lot size declined, <u>holding the number of dwelling units constant</u>:

Table 3-2
Stormwater pollutant loads for varying units/acre

Pollutants in lbs/year	**Lot Sizes in Acres**			
	1/8	**1/4**	**1.4**	**5**
BOD5	326	427	792	1837
Suspended solids	4595	6014	11165	25904
Phosphorus	17	22	40	94
Nitrogen	128	167	311	721
Fecal coliform*	35294	46122	85627	198673

*Millions of bacteria /year

When <u>total</u> growth and development is taken into account and held constant, then the positive effects of clustering and other Conservation Design Techniques emerge.

Almost without exception, pollutant loads, like so many other types of impacts, have meaning only when viewed on a per house or per household or per capita basis, <u>in contrast to per acre measures</u>. If we assume that the counties and municipalities and watersheds of Delaware are developed at lower densities based on a small fraction of projected growth and total development, then many per acre impact parameters decrease as density declines. However, when <u>total</u> growth and development is taken into account and held constant, then the positive effects of clustering and other Conservation Design Techniques emerge.

The Maryland Office of State Planning further evaluated a variety of measures relating to vehicle miles traveled and air pollutants generated, again relating to the four different density patterns combined with a variety of other assumptions. As expected, total mileage increased significantly as lot size increased, as did generation of hydrocarbons, carbon monoxide, and nitrogen oxides. These air emissions settle out on land surfaces and then become nonpoint source pollutants in the watershed.

Costs: Clustering reduces costs considerably through reduced land clearing, reduced road construction (including curbing), reduced sidewalk construction, fewer street lights, less street tree planting/less landscaping, reduced sanitary sewer line and water line footage, reduced storm sewers and reduced need for costly stormwater basin construction. Based on James Frank's *The Costs of Alternative Development Patterns: A Review of the Literature* (1989) and the CH2MHILL/Chesapeake Bay Program's *Cost of Providing Government Services to Alternative Residential Patterns* (1993), costs of infrastructure (streets/roads, sewer and water lines, storm sewers and management systems, sidewalks) move from $10,200 per unit (1992 dollars) in a cluster at 5 units per acre to $33,700 per unit at 1 unit per acre (with an adjustment to 1996 dollars, the difference approaches $25,000 per unit).

Clustering reduces costs considerably through reduced land clearing, reduced road construction (including curbing), reduced sidewalk construction, fewer street lights, less street tree planting/less landscaping, reduced sanitary sewer line and water line footage, reduced storm sewers and reduced need for costly stormwater basin construction.

There are numerous studies from highly reputed organizations where significant (over 25 percent) cost savings are achieved with clustering when densities are relatively low (i.e., at 1 acre or larger lots; when base densities start out at half-acre or less, cost savings with clustering diminishes; see Land Ethics/Dodson Associates' Rappahannock Views 1994; National Association of Homebuilders *Cost-Effective Site Planning—Single Family Development,* 1986) In Northeastern Illinois Planning Commission's *Reducing Impacts of Urban Runoff*, the NAHB 1986 study results are reviewed in detail (see Table 3-3). The analysis indicates that total site development costs for a clustered 166-acre subdivision were 66 percent of total costs for a conventional nonclustered site plan with tremendous savings resulting from reduced grading, water and sewer line construction, and especially the stormwater management system.

Table 3-3
Conventional versus cluster site development costs ($)

	Conventional		**Cluster**	
Site Improvement	Total Costs	Costs/DU	Total Costs	Costs/DU
Street pavemnt	862,165	1,827	540,569	1,145
Curbs and Gutters	433,872	919	----------	-------
Street trees	412,496	874	374,640	794
Driveways	743,400	1,575	527,715	1,213
Storm drainage	696,464	1,476	278,295	590
Water distribution	746,044	1,581	492,792	1,044
Sanitary sewer	1,142,647	2,421	1,009,601	2,139
Grading	332,044	703	220,755	468
Clearing/grubbing	156,915	332	109,785	233
Sidewallks	209,250	443	197,775	419
Subtotal	5,735,297	12,151	3,751,927	8,045
Engineering fees	332,647	705	217,612	467
Total	**6,067,945**	**12,856**	**3,969,539**	**8,512**
Actual difference on a per lot basis		4,344		
Percent of conventional lot cost		100%		66%

In *Cost of Providing Services to Alternative Residential Patterns*, a variety of different residential densities and configurations are evaluated in terms of "intraneighborhood," "interneighborhood," and various "regional" services; results indicate consistently large cost reductions as density increases, holding total amount of development constant:

- In one analysis, costs varied from $50,700 per unit at a density of one dwelling unit per acre to $27,500 per unit with clustered single-family dwellings at a density of five units per acre (p. 4-7;

all in 1992 dollars).

- "The costs of alternative development patterns shows that the total neighborhood capital costs/du (Frank's definition—includes the costs of schools) declines from $36,300/du (1992 dollars) for a single family du on a 1 acre lot to $15,500/du for cluster housing at 5 dus/acre." Furthermore, these figures excluded certain services which, when included, would serve to increase the range even more.

- "Windsor in his recalculation of *The Costs of Sprawl* showed infrastructure costs/du decreasing from $17,600/du (1992 dollars) for a single family du to $12,800 for clustered townhouses.

Table 3-4
Cost of development infrastructure as a function of density: Cost per lot, 1992 dollars

Land use category	Schools & Utilities*	Subdivision Infrastructure**
SFR (1 DU/acre)	$16,500 per lot	$33,700 per lot
SFR (3 DU/acre)	$17,300	$17,500
SFR Cluster (5 DU/acre)	$18,900	$10,200
Townhouse (10 DU/acre)	$15,600	$ 7,200
Garden Apts. (15/acre)	$14,700	$ 4,600
Hi Rise Apts. (30 dus)	$ 6,400	$ 2,200

SFR = single family residential
* includes primary and secondary schools, and gas, electric and telephone
** includes all streets and roads; sidewalks, sewer, water, and storm drain/management systems

In sum, the Maryland study convincingly demonstrates the powerful cost reduction potential associated with basic clustering approaches.

Cost reductions do vary with factors other than density and dwelling unit type. Furthermore, density has a much greater effect on certain types of services such as the more localized neighborhood level services such as streets, sanitary sewers and water lines, storm sewers, and the like. These relationships have been demonstrated in earlier studies such as The *Costs of Sprawl* (1974).

The Maryland Office of State Planning in their study integrated data from the Suburban Maryland Building Industry Association, based on analysis of developments in Montgomery and Prince George's Counties. Detailed cost comparisons have been developed, and although these figures should be adjusted to current dollars, results are extremely useful for comparison purposes. For example, total site improvement costs varied from $14,661 (1/8th-acre lots) to $37,774 (5-acre lots), again on a per unit basis, even when sidewalks and other amenities were included in the higher density options and curbing/guttering and other features were subtracted from the lower density options. In sum, the Maryland study convincingly demonstrates the powerful cost reduction potential associated with basic clustering approaches.

A further point to be made is that clustering results in enhanced— not reduced—land values. The increase in housing values was 13 percent in Lacy and Arendt's *An Examination of Market Appreciation for Clustered Housing with Permanently Protected Open Space* (1990), and values increased from 5 to 32 percent in the Land Ethics 1994 study. In Heraty's 1992 study for the MWCOG, *Results of Cluster Survey*, clustering's positive valuation effect was documented as well. To the extent that this positive value impact occurs, local real estate tax revenues benefit, assuming that taxes properly reflect real market value. Furthermore, the local fiscal impact is benefitted by clustering because many local services costs can be reduced as well. Whereas certain services such as schools and libraries are not especially sensitive to clustering, other municipal services (e.g., trash removal, street maintenance, water/sewer line maintenance, lighting, etc.) are reduced with clustering, as described earlier.

Conservation Design Approach: Reduction in Setbacks

The issue of setbacks relates to Conservation Design in important ways. Standard building setbacks and yard requirements, which can be found in most land development ordinances, must undergo significant change, if the kinds of village and hamlet and other concentrated "configurations" as strongly advocated above are to be accommodated, or if clustering is to be implemented. Although the precise requirements vary from municipality to municipality, most municipalities have required structures, especially residences, to be set back from streets and highways. Structures typically must be set back from lot lines on the side and rear as well, all of which effectively requires lots to be quite large. Similarly, yard requirements (front, side, and rear) often are comparably overstated. Typically, street frontage requirements lot-by-lot are excessive, again making concentrated development configuration an impossibility. From this perspective, such setbacks must be viewed as contrary to the goals and objectives of Conservation Design.

Because reduction in setbacks is so integrally related to other Approaches such as Clustering/Lot Configuration and Reduction in Imperviousness, this Manual does not treat setbacks separately. Reduction in setbacks is integral to clustering, as discussed above, as well as to many of the provisions discussed below in Reduction in Imperviousness.

Imperviousness is an essential factor to consider in stormwater management, both quantitatively and qualitatively.

Conservation Design Approach: Reduction in Imperviousness

Imperviousness is an essential factor to consider in stormwater management, both quantitatively and qualitatively. Site-by-site and watershed-by-watershed, increased impervious cover means increased stormwater generation with increased pollutant loadings as well. Consequently, actions which can be taken that reduce impervious cover become important stormwater management strategies. Although such measures may appear to be structural in nature from one perspective (i.e., they may relate to streets and parking areas and sidewalks), the strategies which call for reduced street width and decreased parking ratio requirements also can be viewed as nonstructural "program" approaches.

A variety of specific strategies to reduce imperviousness are described in this section. In many cases, ways to reduce imperviousness relate to new approaches to planning, the so-called neo-traditionalism or new urbanism discussed above, as well as to clustering. In these cases, planning for new street systems is often based on a hierarchical system where the function and use of the particular roadway can be linked to width and other characteristics relating to imperviousness. These Conservation Design Approaches in most cases can stand alone and be used development-by-development, although reduction in imperviousness also can be used in tandem with other approaches and practices. As noted above, reduction in imperviousness also is achieved through other Conservation Design approaches, such as clustering.

A major variable in considering imperviousness is the consideration of transportation which includes roads and sidewalks:

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<u>Roads</u>

In many developing areas, minimum street widths have been established which are excessive and which do not reflect functional needs now or in the future. Access streets in subdivisions often are wider than the collector and "higher order" streets which receive their traffic. In some cases the intent almost seems to be to inflate development costs in the hope that development itself will be discouraged. Another explanation might be that as we watch our arterials grow more and more congested, we grow frustrated and somehow hope that making the local streets bigger, regardless of need, will solve these larger road congestion problems.

Several time-honored sources of highway specifications such as the American Association of State Highway and Transportation Officials (AASHTO) and the Institute of Transportation Engineers (ITE) have established minimum pavement width and right-of-way width specifications which are unnecessarily large, especially when applied in zones of lower density where average lot size is large and traffic generation even at build-out is much less than traffic anticipated by such specifications. Even AASHTOs minimum pavement width of 26 feet is sometimes exceeded; some municipalities have standards which are even greater. For the type of "first order" street system designed to service low density residential subdivisions, this width is excessively costly to construct, requires expensive real estate, and creates far more stormwater than otherwise would be necessary. Because of the way in which so much development is configured, these streets are often times just networks of cul-de-sacs specifically designed to exclude through traffic; in most cases such streets will not receive significantly increased traffic as an area builds out. Consequently, traffic levels will never increase much beyond the traffic generated by the 15 or 20 houses (often times even fewer) lining the street. Ironically, excessively wide streets encourage excessive speeds as well.

Table 3-5
Condensed summary of national design standards for residential streets

Design Criteria	AASHTO	ITE	MWCOG
Residential Street Categories	1	3	4 depending on ADT
Minimum Street Width	26 ft min.	22-27 ft.>2du 28-34 ft. 2-6 du 36 ft. < 6 du	16 ft. (>100 ADT) 20 ft. (100 -500 ADT) 32 ft. (.6 du/ac)
Additional right of way	24 ft.	24 ft.	8 to 16 ft.
Design speed, level terrain	30 mph	30 mph	15 to 25 mph
Curb and gutter	generally required	generally required	not required on collectors
Cul-de-sac Radii	30 ft.	40 ft.	30 ft.
Turning Radii in Cul-de-sac	20 ft.	25 ft.	17 ft.

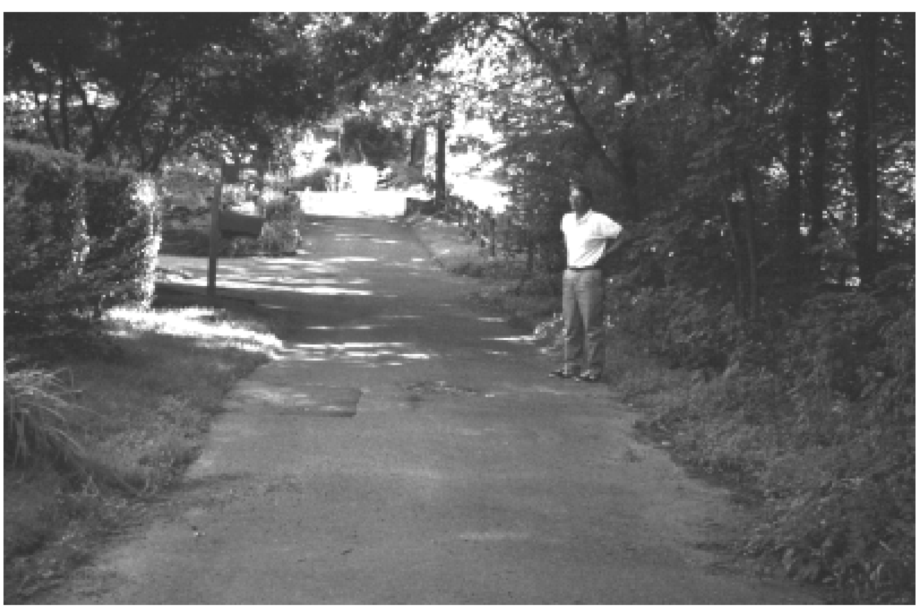
AASHTO - American Association of State Highway and Transportation Officials
ITE - Institute of Transportation Engineers
MWCOG - Metropolitan Washington Council of Governments, 1995

Width reduction offers considerable potential benefit in terms of stormwater reduction. For the very smallest access street or lane with fewer than 100 vehicle trips per day (15 homes), decrease width to 16 feet. Increase width as the traffic increases (20 feet for 100-500 trips per day, 26 feet for 500-3,000 trips per day, and so forth). In conventional developments with conventional lots and house design, there is no need to provide onstreet parking, although if tightly clustered configurations are used, onstreet parking may be a desirable option and included in the design (add another 8-foot lane).

Width reduction offers considerable potential benefit in terms of stormwater reduction.

Road length also is an important issue. Road length should first be

Narrow Subdivision Street With Reduced Impervious Surface



Overall dense patterns of development result in dramatically less road construction than low density patterns, holding net amount of development constant.

addressed from a macro level planning perspective. Obviously overall dense patterns of development result in dramatically less road construction than low density patterns, holding net amount of development constant. High density development and vertical development contrast sharply with the low density sprawl which has proliferated in recent years and which has required vast new highway systems throughout urban fringe zones. Furthermore, if the critical mass of density is achieved, other forms of transportation such as transit may be enabled. **In other words, concepts such as Transit Oriented Development (TOD) which has been discussed in a variety of different contexts around Delaware recently has extremely important stormwater benefits as well.** Although TOD is hardly the focus of a DNREC stormwater manual (obviously TOD and variations on the theme are a manual unto themselves), the point to be made is that there really is an important connection. Flows of all types—from stormwater to traffic—can be managed much better.

Furthermore, the issue of concentration of development through increased density—while holding total amount of development constant—plays itself out on less macro levels of planning as well. As mentioned in the clustering discussion, road length is significantly reduced as tighter clustering occurs site-by-site, although an area—a watershed—built out with such tight clusters will still require more road length than would be the case if a TOD-type of concentration were to be achieved. The point is to downsize streets, both their length and width, wherever possible.

<u>Turnarounds</u>

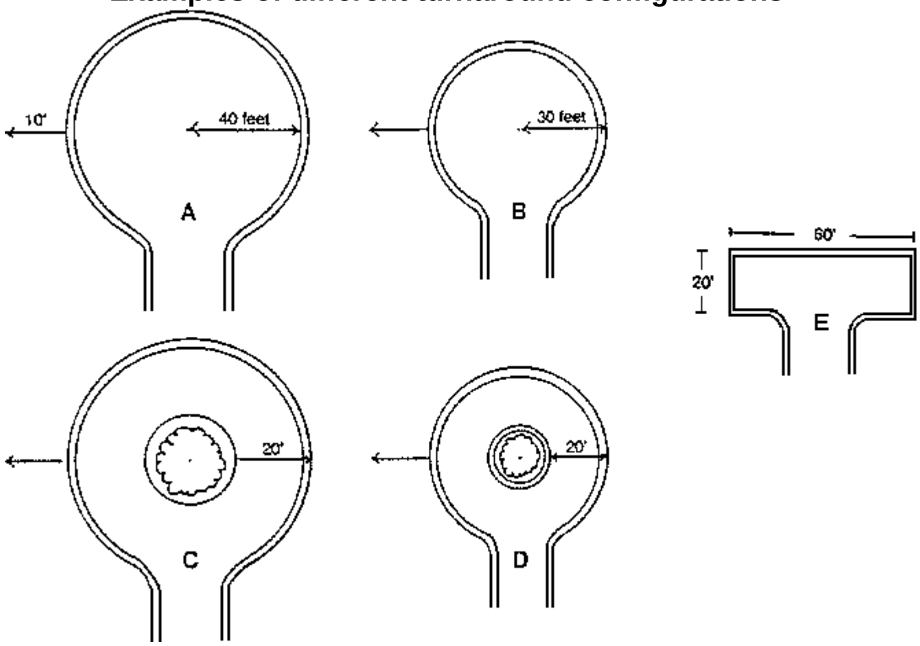
Imperviousness can be limited in turnarounds as well. Large diameter circles at the ends of low density cul-de-sacs simply make no sense and create much more impervious area than is necessary. Figure 3-8 indicates turnaround options, culminating in the least impervious hammerhead turnaround appropriate for low density cul-de-sacs where traffic flows are not great.

<u>Parking</u>

Many different aspects of parking relate to the stormwater problem, including parking ratio requirements as well as the design of parking spaces and their dimensions.

A complete discussion of all of the relevant parking/stormwater issues links to larger macro planning issues quite quickly. Parking requirements in total communities—total watersheds—where low density development has sprawled throughout the countryside forcing maximum reliance on the automobile means that more trips will be generated on a per resident or per capita basis, when contrasted with a TOD or TND (Traditional Neighborhood Design) approach, where the total number of auto trips is reduced as the result of walking or biking or even transit of some sort. “Business as usual” with low density residential development and widely scattered office parks and job centers along major roadways and

Figure 3-8
Examples of different turnaround configurations



at expressway interchanges means even greater reliance on the automobile, even greater need for parking spaces as more and more trips are generated in the future.

Furthermore, the <u>mixture of uses</u> as found in these neo-traditional TOD/ TND configurations further means that opportunity for creative "sharing" of spaces can be devised so that daytime spaces can be utilized for nighttime parking demand as well, minimizing the suburban separation of uses with its vast zones of single-purpose parking lots. Additionally, this blending of uses and sharing of parking spaces can help to deflect the peak demand factor (i.e., the shopping mall at Christmas) that has determined so many municipal parking requirements. In short, the broader planning level is where to start.

But there are also Conservation Design Approaches available which are not so far-reaching and which can minimize parking-related imperviousness even where more conventional development modes are still utilized. Many localities rely on parking ratio standards prepared by recognized agencies or authorities. The trend in recent years has been to increase these ratios, perhaps reflective of the general increase in land development and traffic and congestion and the concern on the part of most municipalities to err on the conservative side (or perhaps to serve as a negative incentive to development). These ratios have grown larger and larger, often times not reflecting local experiences and not necessarily the result of actual experience. In many cases, vast zones of parking area go unutilized, or perhaps used one or two days each year. For example, some cities have studied their parking requirements and discovered that parking ratios were substantially inflated, even during peak periods (see *City of Olympia Impervious Surface Reduction Study: Final Report 1995*). In some cases, minimum parking ratios are even ex-

In many cases, vast zones of parking area go unutilized, or perhaps used one or two days each year.

ceeded by the developer, interested in promoting business. Municipalities typically establish minimum parking ratios, but rarely specify maximum parking ratios.

It should be noted that adjustment of ratios must be done with care. Some office parks, for example, are experiencing "employment intensification" which is certainly compatible with many growth management principles being espoused in this Manual. As companies grow, more employees typically are hired (downsizing excepted); ratios of employees per square foot area in these cases increase. Cars increase, and need for parking increases as well.

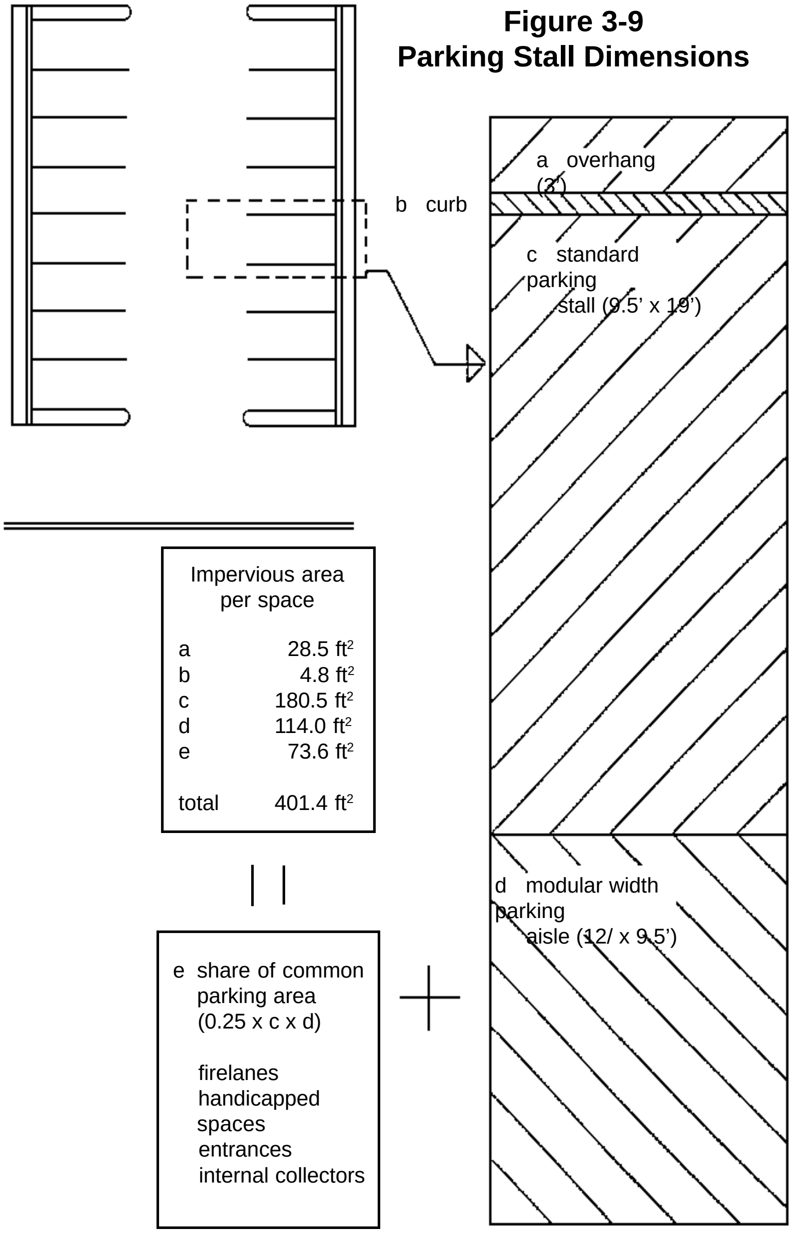
In terms of parking stall design standards, parking stall size can be reduced without compromising performance of the parking lot. A standard dimension in years past has been approximately 10-by-20 ft, borne out of the large car era years ago. Schueler, assuming a 9.5-by-19 ft space dimension further points out that with the typical overhang zone provided plus the appropriate share of the parking aisle, this parking space impervious area increases to 400 sq ft, nearly twice the area of the parking stall itself (Figure 3-9). With the downsizing of vehicles, even full size vehicles, a reasonable size adjustment to the parking stall would be 9-by-18 ft, nearly a 20 percent reduction in impervious area lot by lot, or even 7.5-by-15 ft for compact stalls (a reduction of nearly 50 percent). A fixed percentage of these compact lots should be specified (20 to 35 percent of the total number of lots, depending upon use, local experience, etc.).

A variety of other design-linked techniques should be evaluated, including altered approaches to spillover parking where pervious pavement approaches can be used. Gravel in these rarely used zones should be considered, or perhaps some version of grid pavers (several types now available). Even grass may be a possible option. At the other extreme is structured parking—an excellent option, although costs typically are excessive in most suburban development contexts. Note however, that if neo-traditional TND/TOD concepts are operationalized, densities can be increased sufficiently so that structured parking can make economic sense. Another simple technique is 1-way angled parking lot configurations which allow for a reduction in parking aisle widths (for example, from 24 to 18 ft). Depending upon the size and configuration of the parking lot, total impervious area of the parking lot may decrease by 10 percent.

Depending upon the size and configuration of the parking lot, total impervious area of the parking lot may decrease by 10 percent.

In sum, the first parking-related objective of Conservation Design is to avoid inflated parking ratios. All parking requirements should be revisited, compared with neighboring municipalities, compared with actual experience. In the ideal, a study of actual developments and their respective experiences should be undertaken (elaborate studies can be circumvented by quick phone calling and other creative ways to assess the local situation). Ratios such as the typical 3 spaces per 1,000 sq ft of gross leasable floor area should be downwardly adjusted as much as possible. Depending upon the specific use involved, ratios driven by

Figure 3-9
Parking Stall Dimensions



Schueler, 1997

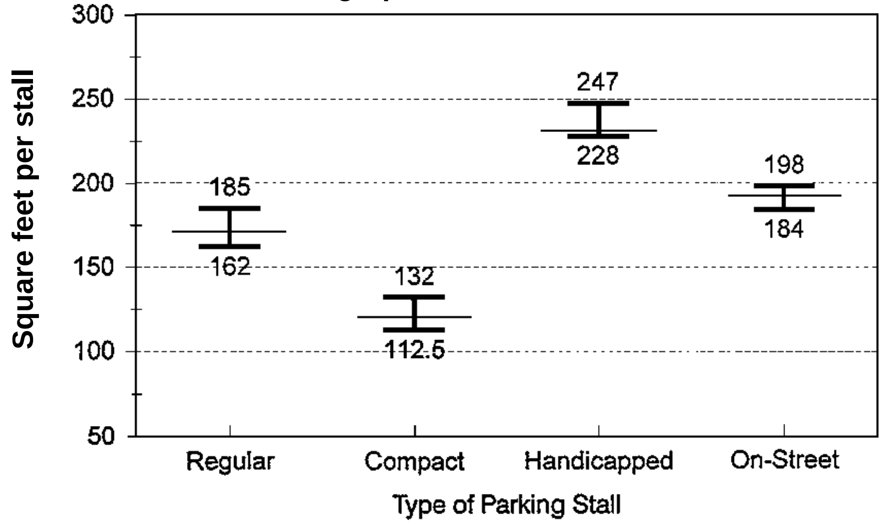
peak demand such as for shopping centers may be able to be further reduced if combined with special parking overflow provisions.

Secondly, maximize sharing of parking areas by creative pairing of uses wherever possible. Developers don't even attempt such sharing because of the perception (probably well-based) that officials would simply reject such a concept. Municipalities need to incorporate such sharing concepts into their requirements (there are straightforward guidelines which can be used to make the system operate reasonably). Municipalities should even provide positive incentives for developers to utilize sharing options.

Depending upon the specific use involved, ratios driven by peak demand such as for shopping centers may be able to be further reduced if combined with specifal parking overflow provisions.

Driveways

Figure 3-10
Variation in Parking Space Sizes Across the U.S.



As houses have grown larger, as car per house ratios have increased, greater accommodation has been required for the automobile, which translates into increased impervious surface of different types.

Driveways are very much linked to configuration of the development. Conventional low density subdivisions typically have setback requirements as well as front yard/side yard ratio requirements and street frontage requirements. All of these specifications together translate into a development mode which is familiar to all of us. Driveway length clearly must be equal to the house setback, plus required right-of-way allowance. Furthermore, as lots have grown larger, sometimes much larger than 1-acre, specifications for minimums are well exceeded. Houses often sit back considerable distances; driveways and total impervious cover increase tremendously. As houses have grown larger, as car per house ratios have increased, greater accommodation has been required for the automobile, which translates into increased impervious surface of different types. A standard 20-ft wide driveway will fan out into a three-car garage. Turnaround aprons will be increased in size accordingly. More aesthetic side-loaded garages mean longer driveways. The end result has been a substantial increase in the amount of impervious area created per person or per dwelling. Although reduced density of development on any one lot may give the appearance of some sort of improved environmental sensitivity and performance, the larger watershed builds out more rapidly and is impacted negatively with more net imperviousness resulting in order to accommodate the projected population growth. More stormwater problems are created.

Several strategies can be followed to reduce imperviousness from driveways. The most far-reaching driveway strategies dovetail with the macro planning strategies discussed above. Transit Oriented Development, for example, quickly solves the driveway problem. Traditional Neighborhood Development with its small lots and minimal setbacks (if alleys are used, driveways may be virtually eliminated as garages open onto the alley—the new common driveway—with a small apron). Similarly tightly clustered subdivisions also result in shorter driveways, possibly even shared driveways. In terms of driveway width, a standard 20 ft width can be reduced in most cases at least by 10 percent (i.e., 18 ft). Various types of pervious paving materials can be used as well.

Sidewalks

Sidewalks are an important element in community design. Although many low density developments have eliminated sidewalk requirements, sidewalks in the Tradition Neighborhood Development should not be ignored, their imperviousness notwithstanding. Nevertheless, sidewalks do not have to be located on both sides of the street. A minimum width of four feet should be provided (pursuant to the Americans with Disabilities Act). In the vast majority of cases, these sidewalks should be designed to discharge stormwater to adjacent yard areas.

Performance

Example of a Sidewalk Having a Reduced Impervious Surface

Reduction in imperviousness translates directly into stormwater quantities, both in terms of peaking and total runoff volumes. Although such provisions may not appear to be all that significant for one particular site or development, these reductions do become significant as they are totaled across entire municipalities or entire watersheds. In terms of water quality, benefits are not as directly related in that pollutant loadings are not just a function of paved area. Loadings are also a function of number of vehicle trips, comings and goings. Therefore, to the extent that a tightly clustered development may reduce vehicle miles traveled by, for the sake of example, 50 percent, but not have a significant effect on total number of trips, pollutant reduction will fall somewhere in between.

Reduction in imperviousness translates directly into stormwater quantities, both in terms of peaking and total runoff volumes. Although such provisions may not appear to be all that significant for one particular site or development, these reductions do become significant as they are totaled across entire municipalities or entire watersheds.

In terms of turnarounds, reducing radii from 40 to 30 ft halves impervious surface and therefore stormwater generation. Using the "T" shaped turnaround further reduces impervious area by nearly another 50 percent. Reduction in parking requirements similarly has direct stormwater reduction benefits. Quantitatively, half as much parking means half as much stormwater. Qualitatively it should be noted that eliminating unutilized parking spaces won't automatically produce the same direct reduction in pollutant loads, to the extent that the same vehicles and vehicle movements which are the primary pollutant sources will be accommodated by fewer spaces.

All of these various ways to accomplish the Conservation Design Approach must be viewed not just as a way to avoid negative impacts, but as a way to optimize positive functions as well.

Finally, all of these various ways to accomplish this Conservation Design Approach must be viewed not just as a way to avoid negative impacts, but as a way to optimize positive functions as well. What we mean here is that by reducing imperviousness in the various ways discussed, the same areas otherwise disturbed and paved can remain undisturbed and natural. These undisturbed natural zones then potentially can be used to promote and facilitate other Conservation Design approaches and practices (such as Use of Natural Areas)—a kind of double bang for your buck.

<u>Costs</u>

Parking lot costs are highly variable. Schueler (1995) cites a Maryland 1990 figure of $2.75 per sq ft, which can be expected to have increased to $3 or more by 1996 (NIPC cites a construction cost of $16.50 per sq yd as of 1996, excluding curbs and gutters). Assuming that the rough estimate of 400 total paved area sq ft per parking space is reasonable, pavement costs alone come to $1,200 per parking space, excluding costs of land, stormwater management, etc. If parking area requirements can be reduced as discussed above, cost savings clearly are considerable.

Road construction is more costly than parking lot construction, on a square foot basis and usually constitutes a major portion of the total site development budget. Delaware's Department of Transportation uses $150 and $100 per linear foot as an estimate of current road cost, assuming full gutters and curbs, at 30 feet and 20 foot widths. Eliminating curbs and gutters would reduce road costs by about $15 per linear foot. NIPC reports on construction costs as follows:

residential roads	\$20 per yd^2
driveways	\$13 per yd^2
sidewalks	\$3 per yd^2

Consequently, the substantial reductions in road construction achievable through tight clustering can have significant cost implications as well. Virtually all aspects of this approach translate into cost savings of one sort or another. Furthermore, all of these impervious surfaces must be maintained on an ongoing basis and even replaced over the longer run. Reduced street widths mean quicker deicing and less snow removal—reduction in paved area translates into cost savings.

Conservation Design Approach: Minimum Disturbance/Maintenance (Site Fingerprinting/ Footprinting)

Description

Minimum Disturbance/Minimum Maintenance (MD/M; termed site fingerprinting or footprinting elsewhere) is an approach to site development where clearing of vegetation and disturbance of soil is carefully limited to a prescribed distance from proposed structures and improvements. In most cases, the concept is appropriate for sites with existing vegetation in the form of tree cover, although existing vegetation can certainly take the form of any natural vegetative cover (including dunes and meadows and coastal grasses, etc.). Also, tree cover need not consist solely of stands of mature forest; so-called scrub vegetation provides very significant quantity and quality benefits as well. The concept can be operationalized at already cleared sites where revegetation/reforestation then is involved.

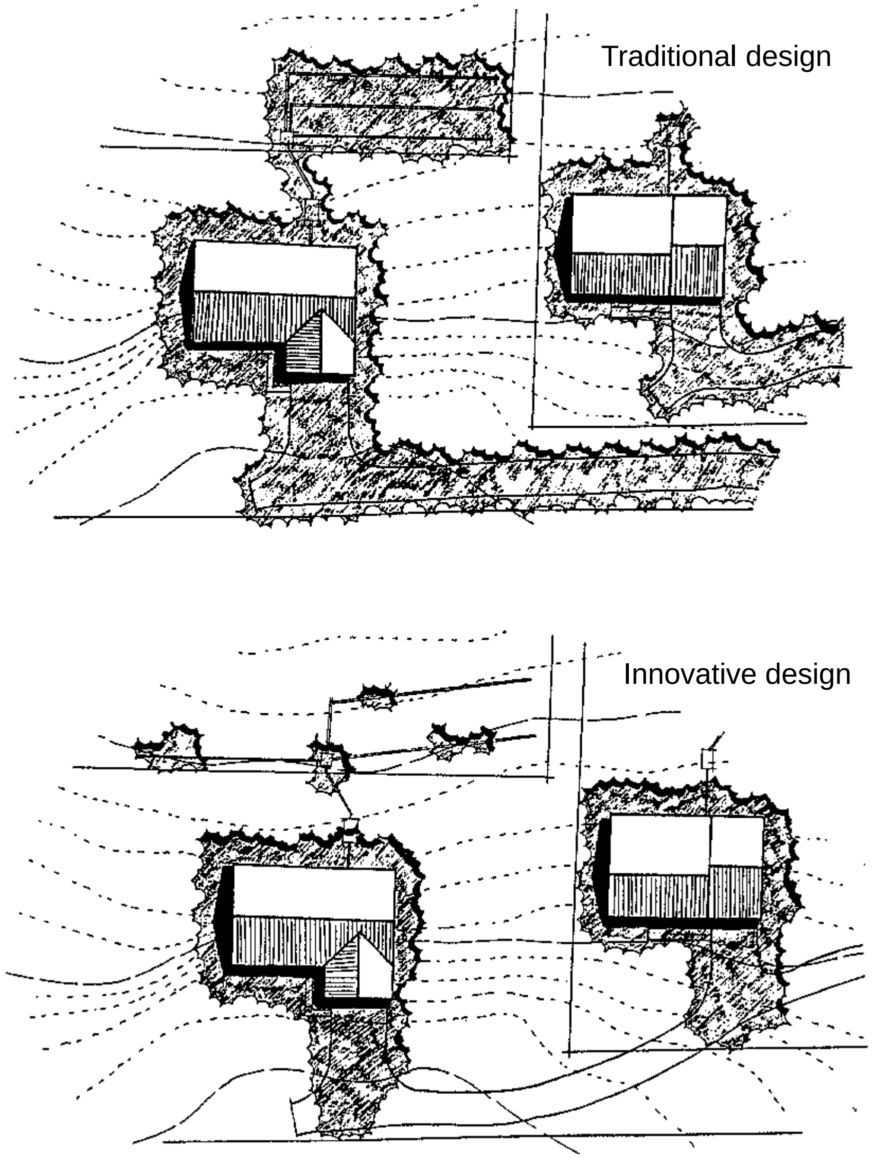
Minimum Disturbance/Minimum Maintenance (MD/MM; termed site fingerprinting or footprinting elsewhere) is an approach to site development where clearing of vegetation and disturbance of soil is carefully limited to a prescribed distance from proposed structures and improvements.

At issue here are both construction phase impacts as well as the long-term operation of the development. The focus in the case of MD/M is not so much the new impervious areas being created. The assumption is that the driveways and rooftops will be constructed (though hopefully with attention to the Reduction in Imperviousness above). Rather, at issue here is the new maintained landscape being created after land clearing occurs, together with the chemicals being applied year-after-year in order to maintain the new landscape that is installed. The objective with MD/M is to maximize existing (hopefully natural/native) vegetation and to minimize creation of an artificial landscape. MD/M is a classic example of the “double bang for the buck” benefit discussed above. Not only are the disturbed area impacts avoided as the result of substantial reduction in areas to be disturbed, but natural areas of vegetation are preserved, retaining all of their functions—possibly to be used for stormwater management purposes themselves (i.e., the Use of Natural Areas Technique).

The first step in developing a MD/M program is to establish a variety of standards and criteria which define the approach, although a degree of interpretation/judgement is often necessary:

- Establish a limit of disturbance (LOD) based on maximum disturbance zone radii/lengths; such maximum distances should reflect reasonable construction techniques and equipment needs, together with the physical situation such as slopes, together with building type being proposed (construction of a single-family home on an individual lot can occur within a much “tighter” zone of disturbance than a mid-rise office structure). For example, a 10-foot LOD distance may be workable in low density residential development, whereas a 25-foot limit may be more appropriate for larger projects where use of larger equipment is necessary.

Figure 3-11
Traditional versus innovative site development



The Limit of Disturbance should be established early on in the reviewing process.

LOD distances may be made to vary by type of development, by size of site, and by the specific development feature involved. For example, distances specified for drives and walks may be set at 10 feet, whereas distances from structures at 25 feet, given the varying equipment needs associated usually with these different elements of the development. A special exception procedure should be provided to allow for those circumstances with unusual constraints.

- Integrate MD/M requirements fully into the reviewing process; typically such an Approach requires modified language in the subdivision and land development ordinance. Procedurally, the Limit of Disturbance should be established early on in the reviewing process; this LOD should be shown clearly in the plans, as wetlands delineation might be shown.

- Require the Limit of Disturbance to be flagged in the field.

- Determine whether MD/M is required or optional. In some instances where water quality is extremely important, MD/M may be required. In watershed zones of highest quality designations, or perhaps in zones which flow into water supply lakes and reservoirs, MD/M may be a required mode of development, unless detailed pollutant impact and mitigation analysis can be successfully developed.

Minimum Site Disturbance in a Subdivision

Site disturbance can be minimized by locating buildings and roads along existing contours, orienting the major axis of buildings parallel to existing contours.

In addition, site disturbance can be minimized by locating buildings and roads along existing contours, orienting the major axis of buildings parallel to existing contours, staggering floor levels to adjust to grade changes, allowing for steeper cuts and grades provided that proper stabilization and erosions/sediment control measures are put in place, designing structures including garages to fit into the terrain, lot by lot (i.e., if structures must be located on slopes, then these structures should be required to adhere to slope design principles. For example, the Metropolitan Washington Council of Governments points out in their *Clearing and Grading Strategies for Urban Watersheds* that special trenching procedures for utility lines and systems can be used which literally reduce disturbance by 50 percent.

<u>Performance</u>

Because aspects of MD/M are quite different than some of the other techniques being discussed here (i.e., MD/M relates to the new landscape—not the new impervious cover—being created with new land development), performance must be gauged somewhat differently as

The natural zone which is retained as the result of MD/MM receives no chemical applications, which would occur if a conventional landscape were to be installed. Therefore, the water quality impacts which otherwise would have occurred from creation of a new maintained landscape are totally avoided.

well. The natural zone which is retained as the result of MD/M receives no chemical applications, which would occur if a conventional landscape were to be installed. Therefore, the water quality impacts which otherwise would have occurred from creation of a new maintained landscape are totally avoided. Furthermore, as discussed above, this retained natural area zone can then be used to receive runoff from other impervious portions of the development (see the Use of Natural Areas Practice), itself becoming part of the treatment solution rather than the treatment problem. In low density developments, this approach alone may be adequate to accommodate total site stormwater management needs, both in terms of quantity and quality.

Water quantity performance is variable. Development impacts often include a change in land cover condition from forest to lawn. Even if the predevelopment cover condition is not a mature forest—perhaps scrub growth or meadow, the post-development lawn runoff, both peak rate and total volume, as measured by Curve Number, is greater. Development impacts are worsened by the fact that the development process includes scraping and “stock piling” and then regrading (and sometimes more) such that decently permeable native soils become less and less permeable through compaction and manipulation. In *Small Storm Hydrology* (1992), Pitt found that one third of the soils he tested in Milwaukee urbanized areas had infiltration rates of nearly zero—about as impermeable as asphalt itself. Because such problems are avoided, the MD/M zone, even if having less than ideal permeabilities, can offer remarkably effective infiltration.

In terms of water quality, performance of MD/M must be compared to the landscape which it replaces. The Fall 1995 edition of *Watershed Protection Techniques* reports on recent research in the area of maintained landscapes. Water quality impacts vary, depending upon whether the maintained area would have become a “high input” vs “low input” landscape (lawn). Morton et al (1988) found nitrogen fertilizer application rates at 100 lbs/ac/year when applied by homeowners and up to 200 lbs/ac/year when applied by commercial maintenance companies (i.e., high input lawns). Bannerman (1994) in Wisconsin found phosphorus concentrations in urban lawns to be higher than in any other source. Studies on pesticides strongly indicate that compounds such as diazinon and chlorpyrifos are significant problems for aquatic biota (Connor 1995). All of these problems are avoided with MD/M.

The basic problem is that once conventional lawn areas are created, then chemical applications are highly likely, regardless of need. In recent studies in Virginia, Aveni determined that nearly 80 percent of all homeowners surveyed were applying chemicals to their lawns, although the vast bulk had not performed any soil testing whatsoever. Dindorf (1992) in Minnesota found that 85 percent of homeowners surveyed applied fertilizer; only 18 percent undertook any sort of testing prior to fertilizer application. Barth (1995) summarized recent findings in Maryland relating to chemical application in different settings. Schueler (1995) summarizes a variety of studies on pesticide use, indicating that a wide variety of pesticides are typically applied by individual owners and commercial services. If storm events occur shortly after chemical applications, runoff can be expected to contain significant pollutant loadings. Also, depending upon the specific chemical involved, some leaching through groundwater and then into surface water system may occur as well. Schueler (1995) summarizes a variety of studies which indicate that herbicides are routinely detected in urban streams. Wotka (1994) found powerful evidence of commercial weedkillers in residential watersheds in Minnesota. Insecticides diazinon and chloropyrifos similarly have been found widely, as have other compounds. These compounds have been found to be highly toxic to aquatic organisms.

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Costs

Accurate comparison of costs which includes all preventive and mitigative functions is challenging to undertake. As reported in MWCOG 1995, cost benefit evaluations have been developed which show significantly higher benefit to cost ratios than conventional structural BMPs and with superior performance. Costs can most readily be assessed in those situations where a MD/M concept can accommodate all stormwater management requirements, including peak rate control with the addition of level spreading devices and redirection of stormwater generated into zones of existing vegetation, possibly with the addition of berms (see Use of Natural Areas and Grading/Berming/Terracing/Terraforming discussions).

Although it is possible that a MD/M approach to site development may increase development/construction costs to some degree (through use of smaller-scale construction equipment, flagging and inspection, etc.), we would not expect this increase to be significant. In fact, the reduced amount of overall site work and rough and fine grading required as the result of MD/M, the reduced amount of clearing/grubbing, the reduced

Low Maintenance Lawn Reducing Chemical Application

amount of seeding/sodding and relandscaping all should more than balance any increased costs. To the extent that MD/MM facilitates the creation of natural areas which then can be used for stormwater management purposes, additional cost savings result.

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Furthermore, reduction in disturbed areas reduces the need for erosion and sediment control practices. Properly installed silt fence have been estimated to cost $5 per linear foot; due to their short half life, frequent and costly maintenance is usually required as well (based on 1993 cost calculations in the EPA Blue Book). Sediment traps and basins run about $1,100 per drainage acre, with storm drain inlets very conservatively estimated at $100 per inlet (in our experience this number can increase considerably) plus piping ($5 per linear foot). Proper construction site entrance/exit wash racks/sediment traps cost several thousand dollars to install and maintain. Obviously disturbance that is required will necessitate proper erosion and sedimentation controls.

From a long-term operation perspective, the MD/MM Approach yields much more compelling cost benefits. A variety of studies indicate that typical maintenance costs (from mowing to fertilization to pest-weed control) can easily range from $1,000-1,500 per year; if commercial services are used, costs can be considerably greater. Thus, a site development approach which eliminates the need for such costs can be tremendously desirable.

Conservation Design Practice: Vegetated Filter Strips and Buffers

Vegetated filter strips and buffers are zones of vegetation, either natural/existing or planted, which are used to receive runoff in the form of sheet flow from upslope impervious areas. Strips may include vegetation ranging from grasses to meadow to forested zones, although grassed filter strips are the most popular. Vegetated filter strips may utilize existing vegetation or may be planted during the course of development. Filter strips often must include some sort of level spreading device to ensure an even distribution of stormwater across the vegetated area.

Some guidance documents suggest that filter strips should be considered primarily as water quality BMPs, without particular attention to quantity issues such as infiltration. Other guidance acknowledges that volume control accomplished through infiltration can be significant if filter strips are properly designed and maintained. Filter strips also serve to slow the velocity of stormwater flows thereby increasing the time of concentration through the watershed.

If filter strips can be integrated into design so that small storms (less than one-half inch of rainfall) are controlled and properly distributed, with larger storms being redirected, the technique has excellent quantity and quality benefits. While a filter strip may not eliminate the need for a detention basin, it can often reduce the necessary size while adding many water quality benefits.

Redirecting stormwater runoff from impervious surfaces to filter strips could also be categorized as “hydrologic disconnection” where the objective is to minimize stormwater conveyance through widescale distribution close to the point of generation. In these cases, sidewalks and driveways and other impervious features are designed to drain evenly onto adjacent pervious, presumably vegetated zones. Such zones may be lawn areas or planted groundcover, possibly even preexisting vegetation. In cases where contributing areas are relatively small in size and estimated flows are not great, provisions can be simple (e.g., roof drains outletting onto splash blocks).

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In the discussion here, Vegetated Filter Strips and Buffers are combined, although some differences are highlighted below. A difference frequently cited is that filter strips often are created/planted whereas buffers utilize existing vegetation. Another distinction is that filter strips ideally are located as close to the source of the runoff as possible, and are carefully integrated into the development landscape design (i.e., grassed filter strips often receive runoff from adjacent parking areas). In contrast, buffers are typically recommended as a technique to protect sensitive environmental features such as wetlands or stream corridors. Conservation Design includes proper buffering of these sensitive features from impact-generating uses.

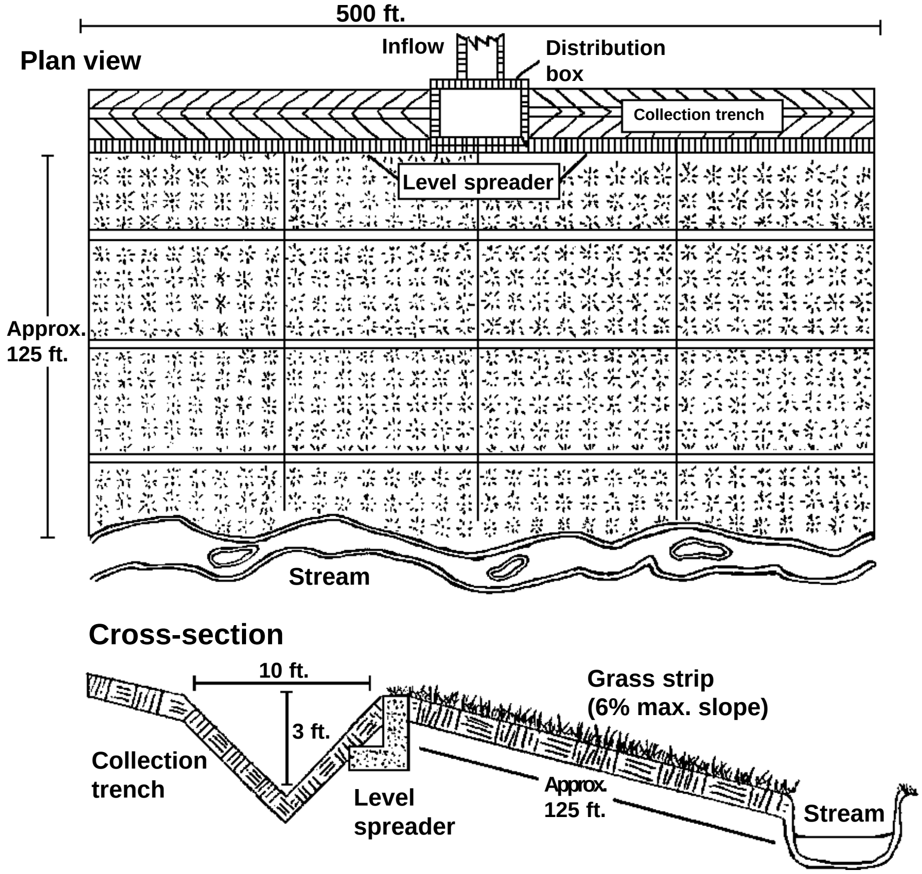
An excellent example of a buffer is the riparian buffer zone. The sensitive stream system is buffered from diffuse runoff from adjacent developed zones (including agriculture), with the now almost standard three sub-zone buffer of at least 75 feet. Such a buffer provides level spreading, particulate filtration/removal, and pollutant uptake functions, as well as temperature protection, aesthetic control, and preservation of habitat. Although the full range of functions provided by the riparian buffer zone are more complex than the filter strip, conceptually the riparian buffer zone is an elaborate filter strip, as would be buffers provided around wetlands or any other special resource value with fixed locations.

Description

The objective in filter strip design is to intercept stormwater flows before they have become substantially concentrated and then to distribute this flow evenly through the vegetated filter strip. As the water moves across the filter strip, a portion of the runoff can be expected to infiltrate. The reduced flows are slowed, and varying proportions of pollutants are removed through various mechanisms/processes (primarily settling, biofiltration, and infiltration) (Figure 3-12).

Most filter strips have limited stormwater management capabilities and therefore are best suited for relatively low density development (i.e., flows generated by higher density development may be too intense). Also, their functions are maximized when only smaller storm events are treated (i.e., larger event flows should bypass the filter strip to prevent

Figure 3-12
Schematic of a vegetated filter strip



erosion). In many cases, filter strips are designed to treat up to the half-inch rainfall, although both size of storm and density of development need to be taken into account.

Critical to the proper design of filter strips is consideration of the following elements:

Site Suitability: Ideal applications are residential developments and campus-type commercial and office developments offering expanses of grassed or otherwise vegetated zones distributed among the buildings and parking areas. To function effectively, broad zones of imperviousness must be designed carefully so contributing flows are evenly distributed along the filter strip. Filter strips may be placed between parking bays and integrated into overall design in other ways.

Slope: Studies indicate that filter strips function best when slopes are kept at 5 percent or less (slopes should never exceed 10 percent and should always be more than 1 percent, according to Dillaha and Hayes 1992). A width-to-slope ratio of 4:1 is recommended (i.e., for a slope of 5 percent, the strip should be 20 feet wide). Slope of the contributing area obviously is a factor which affects velocity of runoff. When level spreading devices are utilized to intercept and collect this accelerated runoff from more steeply sloping areas, such problems can be overcome. Slope of the filter itself also is a major factor in designing filters strips, although absolute slope prohibitions can be problematic. For example, sloping filter strips with established high quality vegetation may be able to receive limited quantities of runoff quite effectively.

Level Spreading: Concentration of flow is to be avoided at all costs when developing filter strip technology. Concentrated flows substantially reduce or eliminate pollutant removal functions of filter strips as well as reduce any infiltration of runoff which otherwise could occur. When flows are concentrated, as when water is discharged from a detention basin, they must be directed carefully into level spreading devices, such as gravel filled trenches, paralleling the filter strip. The water must be evenly distributed and allowed to flow onto and through the filter strip without concentration. The Northeastern Illinois manual suggests that a level spreader be at least 1 foot in width and 3 inches in depth, although actual dimensions may vary with flow (e.g., if significant concentrated flows are expected, then special energy dissipating provisions will have to be provided at the inlet point in some manner).

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Calculation of Filter Strip Dimensions: Appendix A, based on swale and filter strip design in the State of Washington provides a model for developing sizing requirements for filter strips. Design considerations can vary according to the main function of the filter strip. They can be sized for sediment or volume control or a combination of the two. Greater widths of filter strips reduce flow of water by spreading it across the a greater area. This also reduces the effective impervious length of the contributing area (i.e., the total contributing area divided by the contributing area width) which in turn reduces the needed flow path length of the filter strip. Various sources such as Dillaha and Hayes (1992) have recommended that the ratio of total contributing area to total area of the filter strip in general should not exceed 50 to 1.

Erosive Velocity: Appendix A also provides a mechanism for calculating maximum velocity of runoff flows across the filter strip. This velocity must be controlled in order to prevent destruction of the filter strip by channelization and highly erosive forces. Diverting the rare large storm flows away from the strips, and catching the frequent smaller events, which comprise the majority of average annual rainfall events, will result in the removal of the bulk of the annual pollutant loadings.

Infiltration: Although some experts caution against assuming significant rates of infiltration by filter strips, clearly it is often substantial with properly designed systems. Rate of infiltration

Care must be taken to avoid compaction of the filter strip area which reduces permeability of the soil as well as interferes with vegetative growth.

is a function of soil properties, vegetation, rainfall intensity, and antecedent soil moisture content (which is true for any infiltration-oriented technique). Wong and McCuen (1982) have calculated the volume of infiltration during the duration of flow to be equal to the product of the minimum infiltration rate, the overland flow travel time, and the length of the buffer strip.

Avoidance of Compaction, Other Construction Provisions: As with any technique that offers infiltration potential, care must be taken to avoid compaction of the filter strip area which reduces permeability of the soil as well as interferes with vegetative growth. Construction should occur only when the soil moisture is low. If for some reason compaction appears to be a potential problem, either due to natural conditions or to those occurring during construction, a subsoiler or plow should be used to counter the effects of soil disturbance.

The special requirements for filter strips must be included in construction specifications, with serious attention given to requiring construction phase inspection. If filter strips are created, vegetation should be planted as early in the construction process as possible, provided that the filter strip can be properly protected from construction encroachment. Special attention should be given to erosion protection, including use of geotextile erosion blankets and special mulching, especially if the filter strip itself is sloping and/or substantial flows are anticipated.

<u>Performance</u>

Filter strip performance can be assessed in terms of both quantity and quality. Quantity performance is directly related to the infiltration capacity of the filter strip or buffer. As overland flow rates decrease as a result of water flowing through the vegetation of the strip, volume of runoff

Open Space Trail Allows Public Access to Natural Areas

infiltrated increases. As the length of the filter strip increases, infiltration volumes increase. The total volume of water infiltrated can be calculated and is equal to the area of the filter strip times duration of runoff, divided by the travel time (Hampton Roads Planning District Commission 1992).

Wong and McCuen (1982) also describe a simplified model for predicting how much water will infiltrate:

$$V_L = f_c \, t_c \, L$$

where
V_L = the volume infiltrated per width of buffer strip (ft^3/ft^3),
f_c = the minimum infiltration rate (ft/hr),
t_c = the overland flow travel time (hr), and
L = the length of the buffer strip (ft).

The minimum infiltration rate depends on the type of soil present. Wong and McCuen also provide graphical solutions that predict the volume of runoff infiltrated for a variety of vegetative covers and filter strip/buffer lengths. The volumetric capability of the filter strip can thereby be assessed. By using the minimum infiltration rate of the soils, this method provides a conservative estimate of the runoff that will infiltrate.

Thus, if designed properly, filter strips can be used to hold pre- to post-development runoff volumes constant. Practically speaking, this pre-to-post volume control is feasible only in relatively low density situations with the filter strip approach. Once runoff is concentrated and increases in rate and volume, the size of the required filter strip becomes quite large, often impractically large and provisions for increasing volume, such as use of subtle berming, should be considered.

Another important aspect of quantity is peak rate control. Filter strips help to control peak rate as volume is controlled. As runoff passes through the filter strip and is infiltrated, peak rate is reduced. Although filter strips and buffers can infiltrate a certain amount of the runoff, they are often not adequate to satisfy peak rate criteria, especially when the contributing area is quite large. In these cases, they can be managed most effectively when used in conjunction with other Conservation Design Practices and/or other stormwater BMPs.

In terms of water quality, filter strips, when properly designed, are reasonably successful at reducing suspended solids and pollutants, such as phosphorus, bound to soil particles. The pollutants moving with infiltrated stormwater undergo physical, chemical, and biological removal processes. As stormwater moves through surface vegetation, resistance slows overland flow, dissipates energy, and promotes deposition of settleable pollutants (especially the larger particles). Pollutants are also removed through uptake by the vegetation itself. Plants utilize nutrients and even some metals. Over time, the sediment deposited, if not excessive, is incorporated into the soil mantle, aided by plant growth

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and decay. In low density applications and for small storm events, pollutant removal of non-soluble pollutants can be excellent.

A variety of studies have been performed which document the pollutant removal effectiveness of different types of filter strips and buffers. Most of these studies have been performed in agricultural settings, where both sediment and nutrients have been pollutants of concern. Because these pollutants are also of concern in terms of urbanization, these studies are of interest. EPA's recent *Water Quality Functions of Riparian Forest Buffer Systems in the Chesapeake Bay Watershed* provides an especially informative summary of most of this work:

Cooper et al 1987: Researched forested buffer zones, large particle sedimentation occurred predominately at the forest edge at site studied.

Daniels and Gilliam 1995: Studied North Carolina piedmont sites and found relatively low TSS removal rates due to one specific "blow out" storm event. When that storm was excluded from the analysis, removal rates averaged approximately 80 percent for the 2-year study period.

Dillaha et al 1986 and 1989: Found in experimental 30- and 15-foot properly designed and functioning filter strips in Virginia, researchers found consistently high total suspended solids removal, varying with slope. For 30-ft strips, removal rates were at 93 percent (5 percent slope), 98 percent (11 percent slope), and 70 percent (16 percent slope). For 15-ft strips, removal rates were 83 percent (5 percent slope), 86 percent (11 percent slope), and 53 percent (16 percent slope). In the 1986 study, the 15-ft strip removed 81 percent and the 30-ft strip 91 percent of total suspended solids.

Magette et al 1989: Found in the Maryland coastal plain, a 15-foot Kentucky 31-fescue vegetated filter strip removed 66 percent total suspended solids and a 30-ft strip removed 82 percent.

Parson et al 1994: Researchers in both coastal plain and piedmont settings used 4.3 and 8.5 meter fescue buffers — sediment removal averaged 80 to 90 percent.

Peterjohn and Correll 1984: Found a 90 percent reduction in sedimentation from flow through a 19 meter riparian forest in the Rhode River in Maryland.

Woodard and Rock 1995: Used actual residential construction sites and a unusual sampling concept. These researchers generally confirmed buffer performance for actual residential development sites, although length of buffers was quite long (they recommend a minimum length of 50 ft). Results indicated the importance of maintaining the condition of the buffer.

Yu et al. (1993) described a test that compared the removal effectiveness of a 150 foot and a 75 foot filter strip. Both strips received stormwater runoff from an urban parking lot. The 150 foot strip significantly out performed the 75 foot strip and removed 84% of total suspended solids, 20% nitrate+nitrite, 40% total phosphorous, 50% extractable lead, and 55% extractable zinc.

In sum, properly designed and maintained filter strips and buffers can be expected to achieve the 80 percent total suspended solids reduction rate, as specified by Delaware regulation. Of course, the State's stormwater law is also intended to reduce other pollutants contained in stormwater flows and as indicated above, filter strips and buffers have the capability to remove an array of these contaminants and nutrients.

In sum, properly designed and maintained filter strips and buffers can be expected to achieve the 80% total suspended solids reduction rate, as specified by Delaware regulation.

It is possible to control how effective filter strips will be in accomplishing these pollutant removal goals by designing them based on a variety of factors (from Comerford et al 1992 and Karr and Schlosser 1978):

Velocity of Water Flow: Velocity is the single most important variable affecting sediment deposition. Researchers have demonstrated that the maximum particle size moved by water is related to the velocity of the water to the 6th power (i.e., if velocity is halved, then the maximum particle size carried by water flow is reduced by a factor of 64). This relationship is given by the equation for Competence:

$$\text{Competence} = CV^6$$

where

Competence	= the maximum particle size moved by water,
C	= a constant, and
V	= the velocity of water (Hewlett and Nutter 1969).

Thus, even small reductions in the stormwater flow velocity that occur as a result of passing through a filter strip translate into very substantial reductions in sediment loads.

Particle Size of Sediment: If sediment is composed primarily of large particles, filter strips are particularly effective. As particle size decreases and becomes colloidal in nature, filter strip functions decline. Generally, sediment loads should not be excessive when dealing with filter strip applications (they should not exceed 10 tons per acre per year from the contributing area, according to Dillaha and Hayes (1992)).

Slope and Length of Slope and Area of Contributing Zone: Slope and length of slope of the contributing area affect velocity of runoff and therefore are critical to filter strip and buffer design. Wong and McCuen (1982) site research utilizing sod buffer strips that suggests strips produce an effective "removal of medium silt sized sediment when the ratio of the slope length of the contributing area to the buffer strip length is 10 percent."

Slope and Length of the Filter Strip: Both the slope of the filter strip itself as well its length are critical, as they determine the potential for pollutant removal to occur.

The State of Ohio (Ohio DER 1966) has tabularized pollutant removal effectiveness of vegetated filter strips for different slopes and strips widths as shown in Table 3-6.

Table 3-6
Filter strip length as a function of slope and trapping efficiency

Slope of filter	Particulate trapping efficiency	
	70%	90%
1%	10 ft.	50 ft.
2%	30 ft.	120 ft.
3%	40 ft.	135 ft.
4%	60 ft.	170 ft.
5%	75 ft.	210 ft.

Overall, filter design should strive for a dense and deep-rooted vegetation mat which will serve to slow runoff flows as well as keep soils permeable.

Vegetation Characteristics: Clearly, type of vegetative cover is an essential consideration in developing filter strips and buffers. A high quality forest floor with a rich and highly absorptive humic layer or zone with thick, low understory performs quite well. High quality grassed buffers, when kept mowed so that blades are erect and not inundated by runoff also perform well. Turf grass should be kept at a minimum length of 3-5 inches and a maximum length of 12 inches. Overall, filter design should strive for a dense and deep-rooted vegetation mat which will serve to slow runoff flows as well as keep soils permeable. It is also important to choose vegetation based on the type of runoff expected from a particular area. For example, filters located near roadways and parking lots require vegetation, such as tall fescue, that can withstand salt and heavy metals.

Soil Characteristics: In general, as soil particle size increases, permeability increases, thereby promoting infiltration across the filter strip. For newly constructed filter strips, effort should be taken to minimize soil manipulation and compaction which reduce permeability.

While all these factors significantly contribute to filter strip effectiveness, it is important to recognize that the single greatest threat to filter strip performance is channelization and concentration of flows. Infiltration and pollutant removal occur as water flows through the vegetation. When flows are concentrated, this filtration system is short circuited. Concentrated flows can also cause significant erosion of soil and vegetation leading to filter strip degradation. Level spreaders at the top of the filter are designed to prevent these concentrated flows. This is also the reason it may be prudent to have a mechanism of bypassing the filter strip during heavy rainfall events.

Over time, successful filter strips may also accumulate sediment and other solids and clogging may occur (if this settling occurs at the beginning of the filter strip, berming begins to form, thereby providing some additional volume capacity). Frequent inspection can lead to early identification and treatment of such problems.

Costs

Filter strips are relatively inexpensive and typically are integrated into overall landscaping costs. If the Practice is integrated into development from the outset, existing vegetation may be used, further reducing costs. Filter installation may require the need for specialized lighter weight grading equipment. Cost items could include additional site grading, seeding/sodding/other special planting, added erosion protection, and development of level spreaders.

Maintenance requirements for filter strips typically are not great, especially if design and installation have been accomplished satisfactorily. Frequent inspection of the filter strips (particularly after major storm events) during and after installation is critical. It is important that any incipient erosion problems be identified and remedied without delay so as to prevent worsening of flow concentration and worsening of erosion. Periodic aeration of soils may be necessary if soils are heavy from the outset, if some compaction has occurred, and if sedimentation appears to be a problem. In some cases, reseeding or revegetation may even be necessary. Ideally, filter strips should be virtually self-maintaining. As sediment and other pollutants (e.g., nutrients) are incrementally deposited within the filter strip area, vegetative growth is expected to be stimulated, incorporating deposits over time.

Conservation Design Practice:
Use of Natural Areas including Reforestation and Revegetation

Description: This Conservation Design Approach involves utilization of existing zones of vegetation, from forested zones to scrub vegetation, and often is used with some sort of subtle berming or containment provision to be put in place in order to achieve volume control. An essential process in the approach is infiltration. Consequently soils characteristics are important, as with any infiltration-oriented practice. In this particular case, existence of vegetation can be expected to significantly aid in the infiltration process, enhancing the natural infiltration rates of the soils.

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The scale of this approach can be made to vary. In a micro sense, redirecting sidewalk and driveway stormwater onto adjacent grassed or otherwise vegetated areas, illustrates the concept at the smallest or most micro scale. All such opportunities should be exploited. At the same time, where such opportunity does not exist for one reason or another, stormwater can be collected and then conveyed at some distance to Natural Area zones designated elsewhere at the site (conceivably even offsite).

For those Conservation Design applications where vegetation such as wooded areas already exists, this practice really is a hybrid of Minimum Disturbance/Maintenance, often used in conjunction with berms, and in that sense does not need to be treated as a separate practice. However, this Natural Area practice does have meaning in those cases where Reforestation/Revegetation is occurring.

In brief, the Reforestation/Revegetation practice includes planting of appropriate tree species (small inexpensive saplings) coupled with quick establishment of an appropriate ground cover around the trees so as to stabilize the soil and prevent influx of invasive plants. This Reforestation/Revegetation practice can be used in conjunction with Terracing/Berming/Terraforming, and even vegetated filter strips and swales. The practice is highly desirable because, in contrast to so many other management techniques, Reforestation/Revegetation actually improves in its stormwater performance over time, rather than vice-versa.

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Reforestation/Revegetation closely relates to the literature on riparian stream buffer establishment. Although Reforestation/Revegetation is not linear in configuration as is the case for stream buffer specifications, the specifications for replanting are quite similar. Guidelines for Reforestation/Revegetation, summarized blow, are provided in Appendix ___, much

Riparian Buffer Providing Stream Protection

of which is based on the *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers* (1997).

Tree species selection should be undertaken carefully, matched to the four major indigenous forest communities which exist across Delaware and reflective of the combination of environmental factors which characterize these zones, in order to restore ecological health of streams and natural areas at the broad watershed scale.

Planting: To ensure high survival rates, reduce costs, minimize soil disturbance, and expand on the native vegetation found in and around the site, a mixture of young native trees and shrubs is recommended (see species list in Appendix __ Conservation Design Reforestation/ Revegetation Guidelines). 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 feet centers, with a total of approximately 430 trees per acre. Trees should b planted with tree shelters to avoid browse damage in areas with high deer populations, and to encourage more rapid growth. Initial watering followed by weekly watering of trees during dry periods is important during the first growing season. Planting should be done in spring or fall.

Management: Reforestation/Revegetation areas need periodic management, at least for the first five years, to ensure good survival rates for newly planted stock. The level of management decreases as the plantings mature. A carefully chosen cover crop should be installed immediately, requiring one annual mowing in early spring until the trees begin to shade the ground. The cover crop will also help to discourage invasive weed growth, while allowing buffer plantings to mature and natural regeneration to gradually occur. During the first 2-3 years, annual spot applications of herbicide glyphosate will be required around tree tubes to keep weeds from outcompeting the new trees for water and nutrients. If periodic mowing is not sufficient, invasive woody vegetation or vines may need to be managed by hand removal, by spot applications of gylphosate, or by selective cutting. A reinforcement planting of at least 50 trees should be included to replace failed saplings.

To the extent that vegetation of different types is already established, the already stabilized Natural Area offers various physical, chemical, biological mechanisms which should maximize pollutant removal as well as satisfy quantity-related management objectives. Assuming that all of this stormwater is infiltrated, pollutant discharge would be minimized.

It is important to point out that these Natural Areas certainly can be located in designated open space zones. From a stormwater management perspective, use of such open space, if satisfying all other criteria, is perfectly appropriate.

To the extent that vegetation of different types is already established, the already stabilized Natural Area offers various physical, chemical, biological mechanisms which should maximize pollutant removal as well as satisfy quantity-related management objectives.

Performance

As indicated above, reliance on properly designed Natural Areas can achieve excellent results in terms of both water quantity and water quality issues, especially if vegetation already is established. The discussion included under Vegetated Filter Strips and Berming applies to most of the Natural Area variations, both in terms of quantity control and quality control. In terms of Reforestation/Revegetation, stormwater performance, either quantity or quality, clearly is compromised in the early years of vegetation establishment. It should be noted that in the Case Studies presented in Chapter 5, areas which are disturbed are reduced a grade in terms of Hydrologic Soil Group. Furthermore, any revegetated area are further rated as being in “poor’ condition, all of which serves to raise the respective Curve Numbers and increase stormwater runoff calculations. The highly desirable aspect of Reforestation/Revegetation is that as this vegetation becomes more established, these areas will perform even more effectively in terms of stormwater management. Such enhanced performance in terms of both quantity and quality can be particularly beneficial as watersheds continue to undergo development.

Costs

Of all the Conservation Design Approaches available, this Approach can be one of the least expensive.

Of all the Conservation Design Approaches available, this Approach can be one of the least expensive. The technique of draining onto adjacent vegetated areas requires little expense. As a matter of fact, because curbing is clearly eliminated in such situations, cost savings may result. Modest cost may be involved if storm flows must be conveyed to a larger bermed Natural Area, both for the conveyance systems as well as for the berming. However, because this berming is to be kept quite subtle, installation expense should not be great (see berm discussion).

In terms of Reforestation/Revegetation, cost issues are more complex and particularly important. Installation costs have been calculated on an area basis as follows (much of this cost data is based on the *Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers* (1997):

$ 860/acre trees installed
$1,600/acre Tree Shelters/stakes installed
$ 300/acre (4 waterings)
Total Estimated Installation Cost: $2,925/acre

Where clearly the most costly item for Reforestation/Revegetation is the installation of the Tree Shelters. In those areas where deer populations are not great, eliminating the Tree Shelter requirement may be considered, thereby substantially reducing costs. Ongoing annual maintenance costs has been estimated (assuming an average old-field site needing mowing, herbicide application, and one reinforcement planting in Year 2.

$54/acre herbicide treatment

$12/acre mowing
$75/acre reinforcement planting

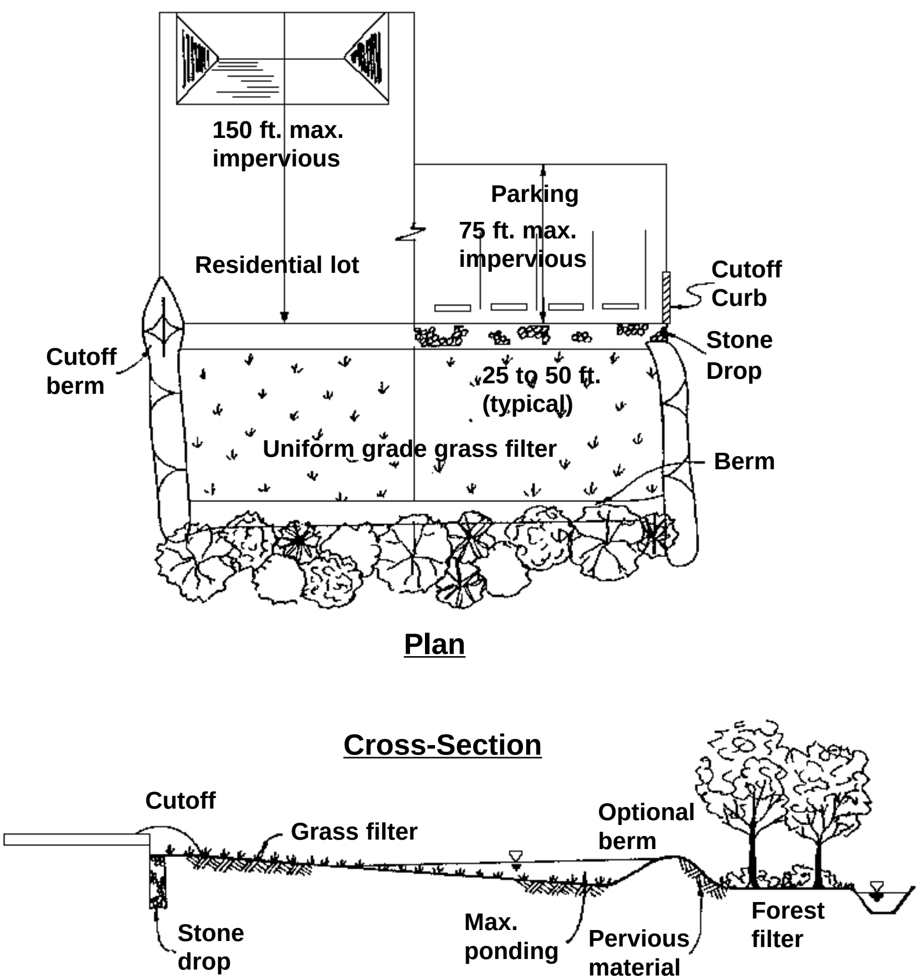
The total estimated cost for Year 1 would be $3,264/acre, with Year 2 costs at $141 and years thereafter at $66/acre.

Conservation Design Practice:
Terracing, Berming, Special Grading (Terraforming)

Although a basic principle of Conservation Design is to achieve an areawide watershed build-out "future" which has minimized total disturbance of natural vegetation and soil mantle to the extent possible, there are instances where grading itself can move from part of the problem to part of the solution. Disturbance of the natural vegetation and soil, if deemed necessary, can be accomplished carefully and with imagination so that natural processes can be exploited to the maximum, and the full range of stormwater management objectives can be achieved. This particular Conservation Design Technique, like so many others, is best used in conjunction with other techniques. Specific concepts range in scale and application from micro site-by-site terraformed saucers to cre-

Disturbance of the natural vegetation and soil, if deemed necessary, can be accomplished carefully and with imagination so that natural processes can be exploited to the maximum, and the full range of stormwater management objectives can be achieved.

Figure 3-13
Example of a filter strip with "terraform" berming



ative use of subtle earthen berms placed in zones of existing vegetation. In all cases, the objective is to achieve comprehensive stormwater management functions, including return of stormwater volumes, management of peak rates of discharge, and reduction of pollutant loadings. These objectives are accomplished as the stormwater is collected and infiltrated through the soil mantle and the vegetative root zone, enabling the full range of physical, chemical, and biological processes as discussed above to come into play.

Note from the outset that because this technique is very reliant on the process of infiltration, all those factors constraining use of infiltration-oriented structural BMPs come into play. Soil characteristics are critical. Tight soils with extremely poor permeability will suffer even worse compaction if graded and regraded and should not be considered for terraforming. Depth to bedrock and seasonal high water table must be considered. In those cases where berming is considered with existing vegetation, presence of vegetation and a developed root zone can be expected to significantly improve soil permeabilities and overcome some of these limitations.

Description

Terraforming is simply another term applied to a careful grading process designed to achieve specific objectives such as infiltration, rather than "disposal," of stormwater.

Terraforming is simply another term applied to a careful grading process designed to achieve specific objectives such as infiltration, rather than "disposal," of stormwater. Exact configurations resulting from this special grading may vary. For example, subtle, sometimes nearly imperceptible depressions or saucers can be integrated into the graded landscape to receive residential rooftop runoff or stormwater from the driveway and turnaround. Terraforming can be quite micro in its scale, replicated acre lot-by-acre lot, possibly relying on several signature concepts in a particular development to facilitate both installation and ongoing maintenance (e.g., rear yard depressions, use of the driveway or elevated roadway to create subtle upslope dams). Terraforming can also be integrated into larger scale site planning, such as at an office park.

Obviously, such an approach may not work for all developments. To the extent that neo-traditional concentrated development configurations can be successfully introduced, any lot-by-lot approach would be difficult to operationalize, although terraforming could be located elsewhere on the site. Nevertheless, for those developments which continue to have large lots (and in many cases these lots are well over 1 acre and offer ample space for onsite stormwater management), the feasibility of terraforming should be investigated.

Basic rules or principles must be respected. In extremely heavy clayey soils, soil compaction may be problematic, preventing infiltration. As with any infiltration-driven concept, avoid zones near structures, near drainage fields of septic systems, and so forth. Setback distances should vary with topography and other factors (infiltration downslope of basements requires less separation distance than infiltration upslope of basements). Furthermore, location of any terraformed areas should be evaluated from a user perspective. Ideally, the location should not interfere with uses of the site, such as recreation. In most cases, this is not difficult to accomplished.

To the extent that this micro scale site-by-site or grouped site approach can be implemented, the terraforming concept is quite similar to the drainage fields required for onsite septic systems or community onlot disposal systems. The objective is to define and reserve specific zones to accommodate these natural functions onsite, whether the need be wastewater effluent management or stormwater management.

The objective is to define and reserve specific zones to accommodate these natural functions onsite, whether the need be wastewater effluent management or stormwater management.

Berming

From small scale to large scale: listing berms as a variation on the theme of terraforming and grading may be pushing conceptual bounds a bit; nevertheless, berming does involve grading and earth movement in special ways. In most cases, berming is most effective when used in conjunction with other Conservation Design Practices discussed here.

Conceptually, the fundamental work of the berm is to block the passage of runoff, retain it, and allow it to infiltrate naturally into vegetated areas upslope. In the ideal, a berm would simply be an impermeable wall, the top of which would level spread any overflow from larger storms onto vegetated areas downslope. It is critical that areas upslope be able to infiltrate stormwater and that areas downslope be able to handle overflow. Although stormwater can be piped and conveyed down to the berm itself, the best use of berms for Conservation Design includes level spreading of runoff well upslope, allowing for sheet flow down to the berm itself. This approach maximizes opportunity for recharge enroute to the berm and minimizes any volumes which must be retained and infiltrated thereafter.

Not a lot of guidance/specification is available on berm construction. The USDA-NRCS has developed some specifications for agricultural applications, including diversion berms and terraces, which have some limited usefulness here, although these specifications in many cases need to be modified for Conservation Design applications.

Berm “literature” suggests that berm construction should include, first, channel excavation parallel to contours and then mounding of excavated material into berm formation at the lower edge of the channel (Figure 3-13). Upslope of the berm itself, a broad flat cleared area is created. This approach readily provides a storage volume. If excavation volume and berm fill balances, this approach is quick and easy. However, in Conservation Design berm development, such excavation for channelization is to be avoided, in order to minimize disruption and compaction of soils in the areas upslope of the berm where infiltration is so critical.

As a Conservation Design Practice, berming is defined to include residential and nonresidential applications, ranging from individual lots to broader sitewide installations. As discussed below under Vegetated Swales, berms can be incorporated with individual driveways, lot-by-lot, in order to grab and infiltrate runoff from roads and driveways. Such berm systems may intersect the vegetated swale, with the berms extending along the contours into the respective lot and providing volume control as necessary.

As discussed above under Natural Areas, berming can be carefully integrated into total site development by taking advantage of zones of existing vegetation.

As discussed above under Natural Areas, berming can be carefully integrated into total site development by taking advantage of zones of existing vegetation. Larger volumes of stormwater are directed to these natural area zones, where volume control is provided through placement of a berm. Depending upon the configuration of the development, some sort of level spreading device may be necessary for proper distribution of these larger flows to this natural area. It is important to note that slope becomes an important determinant in the approach used for this technique. If large areas of relatively flat land with existing vegetation (ranging from dense forest to scrub growth) are available to receive stormwater runoff, then such an approach is ideal and can be accomplished with minimal difficulty. If the stormwater initially is evenly spread upslope of the area, sheet flow will continue in this manner. Sheet flow not infiltrated from the larger storms will be dammed by the berm. Once contained, this stormwater will be infiltrated, aided and abetted by the enhanced permeability of the vegetated floor of the natural area.

Berms may be designed to detain and contain any sized storm, including up to the 100-year storm. If sizing of the area bermed area has been designed to contain the difference between predevelopment to postdevelopment for up to the 2-year storm (a reasonable recharge criterion), then larger storms will have to pass over the berm. In these cases, the berm itself becomes a level spreading device and reinforcement of the berm may be necessary for structural stability. Here, the berm top and sides can be reinforced through use of “geogrids” which significantly increase stability if significant erosive forces must be withstood. Of course, costs are increased significantly as well. Geogrids may be necessary when flows are substantial and slopes are considerable.

Based on review of guidance from other jurisdictions, a sequence of berm construction actions can be established for Conservation Design applications in Delaware (Table 3-7).

Table 3-7
Berm Construction Rules for Conservation Design Applications
(Based on London Grove Township, Chester County, PA)

Rule 1: Size the berm area, including the height of the berm, to detain the design storm of choice. Height should not exceed approximately 2 feet (if more volume is needed, additional berms should be considered). Because the reasonable design criterion for such infiltration practices is the 2-year storm (actually <u>differ-</u>

ence between predevelopment and postdevelopment runoff volume for up to the 2-year storm), this is a reasonable criterion for berm design as well. The ideal berm construction for Conservation Design is in moderately rolling terrain, rather than more severe slopes, where channelization upslope of the berm is not necessary in order to achieve storage volumes and where natural vegetation remains undisturbed up to the base of the berm.

Rule 2: Strip and stockpile topsoil carefully and save for replacement, using a small loader. It is important that organic material be stripped down to a solid mineral base in order to make sure that the interface between the placed berm fill and parent soil is tight.

Rule 3: Place berm granular fill, free of organic matter. Use appropriate construction equipment so as to prevent disturbance of upslope areas, also downslope areas (protection of upslope areas is most critical). Compact berm fill as necessary, as per State standards for fill material. Top soil should be replaced following berm compaction.

Rule 4: Berm slopes should be at least 3:1. Top of berm should be level so as not to concentrate any overflow during larger storms. Spillways with special non-erosive covering may be used at certain intervals as an alternative.

Rule 5: Berm top and downslope side should be stabilized with a nonerosive covering.

Rule 6: Width of berm top/thickness of berm itself should be a function of slope and stormwater volumes being handled and must be evaluated on a case by case basis in order to guarantee structural stability.

Rule 7: When side slopes are steeper than 5:1, then the lip of the berm should be stabilized with a light-duty geoweb type product.

Placement of the berm must be accomplished carefully. The objective is to avoid significant disruption of the Natural Area, whether in mature forest, dense scrub growth, or meadow. Berm dimensions have important bearing on extent of disruption created. The berm must be stable, but at the same time should be no taller and no larger in base area than is absolutely necessary for stability. Only the minimum volume of fill material should be utilized for the berm.

Placement of the berm must be accomplished carefully. The objective is to avoid significant disruption of the Natural Area, whether in mature forest, dense scrub growth, or meadow.

As the slope of natural area increases, berms become more challenging to construct. Berms can be stepped down hillsides; but the extent of disruption in such cases increases and becomes problematic.

Performance

In terms of quantity, stormwater storage volumes provided can be calculated as with any infiltration-oriented Technique. For subtle saucer depressions and other irregularly shaped depressions resulting from terraforming, calculation of exact volumes can be challenging, but of course can be calculated. Depending upon soil types, slopes, and a variety of other factors, the total volume for up to the 2-year storm usually can be maintained, pre- to post-development through terraforming in low density residential settings where lots are 1 acre or larger. Furthermore, in such situations peaking for large storms up to 100-year should be controlled as well, due to the relationship between impervious cover created and the larger areas terraformed for infiltration. In many cases, this same relationship will hold true for berming within Natural Areas, where the land area receiving runoff is relatively large in contrast to the impervious area generating the stormwater.

As with all infiltration techniques, water quality performance of these terraforming techniques is excellent.

Costs

In research conducted by Prince George's County MD, bioretention techniques were significantly less expensive than other far less effective water quality-oriented structural BMPs such as oil-grit separators (furthermore, these structural techniques do not provide any degree of infiltration of stormwater).

Sources have estimated grading and berming costs at varying levels. Costs can be expected to closely relate to the specific requirements of the specific application context. A simple earth dike without special constraints has been estimated by MWCOG to cost $5.50 per linear foot. Costs obviously will vary with size of dike. If the dike or berm is carefully located in existing vegetation and special care is taken to avoid excessive disturbance of this vegetation, costs can be expected to increase.

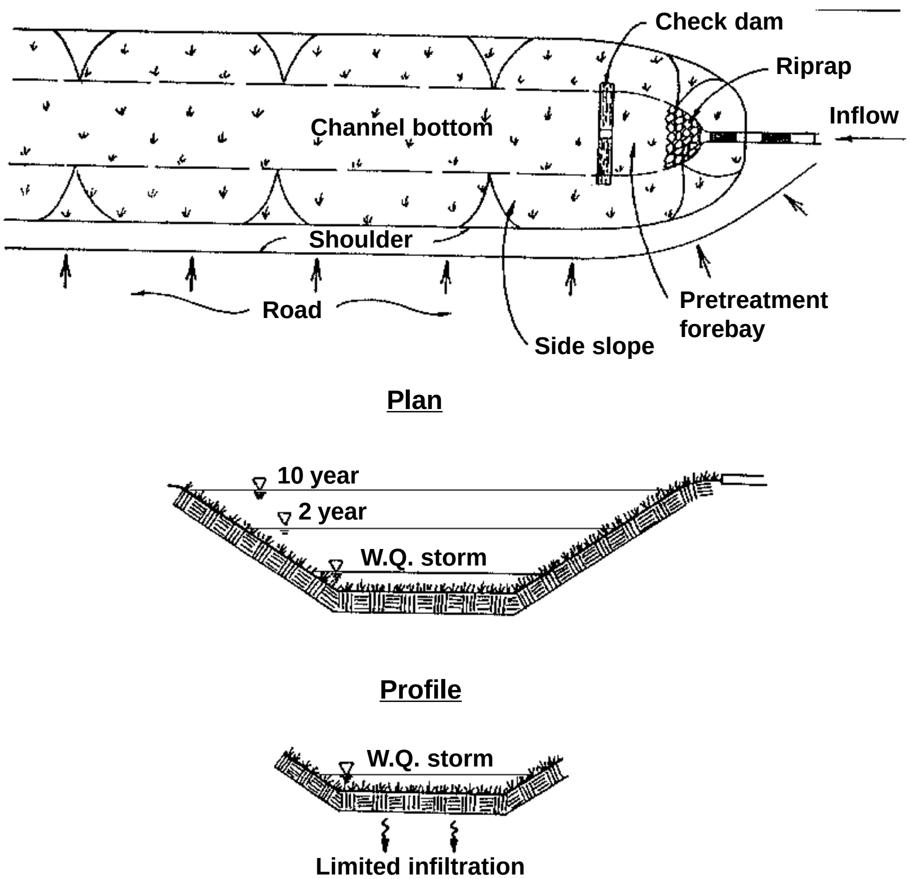
Grassed or vegetated swales are often used as storm water conveyance systems. They are vegetated channels and may be located in a variety of places such as along a roadside, in a highway median, or along the side or back of residential properties.

To the extent that geoweb/geogrid is included in the berm design, costs will increase. Furthermore, economies of scale are significant. Because specialized construction equipment is required, extensive berming reduces the unit cost of equipment. In the Chapter 5 Case Studies, a unit cost of $10 per linear foot has been applied.

Conservation Design Practice: Grassed/Vegetated Swales

Grassed or vegetated swales are often used as storm water conveyance systems. They are vegetated channels and may be located in a variety of places such as along a roadside, in a highway median, or along the side or back of residential properties. Stormwater is directed into these channels and then conveyed to a stormwater treatment area,

Figure 3-15
Schematic of a vegetated swale



often a basin. While their function is often only to direct stormwater flows, if designed properly, they can have significant water quantity and quality benefits and may eliminate the need for elaborate stormwater treatment structures.

Grassed or vegetated swales can take the place of conventional stormwater conveyance and piping systems. The conventional structural conveyance system in most cases provides no water quality management function and returns no stormwater back into the ground. Velocities and erosive forces of stormwater are actually worsened by such systems. Although vegetated swales vary in their intended objectives and design, the overall concept of a vegetated swale is to slow stormwater flows, capture some proportion of stormwater pollutants through biofiltration or bioretention, and hopefully infiltrate some portion of flow back into the ground.

Swales can act in two ways to affect stormwater flows. First, simple conveyance in a vegetated channel causes a decrease in the velocity of the flow. As the water passes over and through the vegetation, it encounters resistance. This resistance translates into increased times of concentration within the watershed and reduced peak rates. The result can be a reduction in the habitat destruction and bank erosion that often

Although vegetated swales vary in their intended objectives and design, the overall concept of a vegetated swale is to slow stormwater flows, capture some proportion of stormwater pollutants through biofiltration or bioretention, and hopefully infiltrate some portion of flow back into the ground.

is caused by peak flows of small storms (which comprise a majority of the rainfall events) (Price and Dreher 1993). Some of the flow will also infiltrate (depending on the design of the swale and the residence time). Secondly, water quality can be affected by passage through vegetation. All the physical, chemical, and biological processes previously described can significantly reduce the pollutant loadings in stormwater. For example, total suspended solids are often reduced as a result of decreased flow velocity. Vegetation can also directly absorb nutrients and utilize them in growth.

Vegetated channels can be designed to meet a broad array of stormwater management objectives and to accommodate a variety of site specific situations.

Vegetated channels can be designed to meet a broad array of stormwater management objectives and to accommodate a variety of site specific situations. They are commonly used in single family residential areas with low to moderate impervious cover in place of curb and gutter systems as part of a drainage easement (Hampton Roads Planning District Commission 1992). They are also often used along roadsides, in the medians of highways, or in recessed areas of parking lots.

Description: Swales can be designed for a number of purposes and in a number of situations. They can be dry grassed channels having slight slopes using vegetation to filter flows as shown in Figure 3-15. They can also be normally wet and rely on wetlands vegetation to provide water quality treatment.

Although a variety of swale types exist, extreme care must be taken to control volumes and rates in all design procedures so that destructive erosive velocities do not result. The overall slope of the system together with its bottom channel area and cross-sectional dimensions can be modified to slow and disperse flows so as not to exceed velocity limits. Some vegetation is more effective in accomplishing stormwater objectives. Checkdams can and should be integrated into the design to accomplish some degree of infiltration and provide for management of water quantity (both peak rate and total volume). In the right low density subtle-sloping circumstance, vegetated swales theoretically <u>can</u> be sufficient for peak rate management, given Delaware peak rate requirements.

Various vegetated swale principles have emerged as the result of research projects (see Kahn et al. *Biofiltration Swale Performance, Recommendation, and Design Considerations*,(1992):

- In design, keep the "roughness coefficient" (or Manning's n value) of the swale at least at 0.20, which means longer rather than shorter grass (within reason; note that swale design really can be equated with open flow channel design, which in turn is governed by Manning's Equation, an essential input factor of which is the Manning's n, a dimensionless coefficient which accounts for vegetational friction).

- Landscaping can be integrated into water quality swales, but precautions are needed to prevent shading and leaf drop, which can kill grass, and transport of soil from the planting beds into the swale.

- Uniform spreading of flow at the head of the swale is important for effective pollutant removal.

- Maximum design velocity should not exceed 0.9 feet per second to prevent exceedance of the treatment capability of the swale.

- A hydraulic residence time of 9 minutes is recommended for pollutant removals of about 80 percent of total suspended solids. If higher levels of performance are desired, longer residence times are recommended.

- Swale width should be limited to about 7 to 8 feet (the width of a typical backhoe loader) unless special measures are provided to assure an even level of swale bottom, uniform flow spreading, and management of flows to prevent formation of low-flow channels.

- No specific swale length is recommended, but the recommended hydraulic residence time and width will result in a minimum length for a particular set of geometric and vegetation characteristics.

- Swale slopes should be between 2 and 4 percent. Underdrains should be installed if slopes are less than 2 percent. If standing water is likely for prolonged periods (for example, several weeks) due to low gradients or interception of the water table or base flow, wetland vegetation should be used rather than grass.

- Water depth should be limited to no greater than one half the height of the grass up to a maximum of 3 inches of water depth. For taller grass, water depth should be less than or equal to one third the grass height.

- Regular mowing is strongly recommended. Not only does it encourage thicker, healthier grass, but leaves, litter, and other obstructions to good flow spreading are removed in the process of mowing.

- Regular maintenance of swales is key to assuring good water quality performance. It is recommended that mowing frequencies and inspection and repair schedules should be specified directly on the site plans. Establishing performance bonds retained through the first year of operation has also been effective in assuring that early problems are addressed.

The current literature provides a significant amount of guidance in designing swales for a broad variety of situations. Appendix A includes specific design specifications and procedures for the construction of grassed swales as outlined by "Biofiltration Swale Performance, Recommendations, and Design Considerations" by the Municipality of Metropolitan Seattle. Additional design specifications are available in the Hampton Roads Planning District Commission's (1991) *Best Management Practices Design Guidance Manual for Hampton Roads* and Schueler et al. (1992) *A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone.* In *Fundamentals of Urban Runoff Management: Technical and Institutional Issues* (Horner and Skupien 1994), an extremely useful set of steps is provided as guidance for designing both swales and filter strips. In the *Vegetative Practices Guide for Nonpoint Source Pollution Management*, the Hampton Roads Planning District Commission (1992) further indicates that vegetated swales are difficult to develop if peak discharge rates exceed 5 cfs or where average velocity exceeds 3 feet per second. Rather than the 0.9 feet per second as given above, they indicate that the upper limit for runoff velocity from the contributing area should be 1.5 feet per second.

Use of vegetated swales in tandem with micro contour berming in instances of low density large-lot residential development can be quite effective.

Use of vegetated swales in tandem with micro contour berming in instances of low density large-lot residential development can be quite effective. In such cases, berming parallel to the contours (see discussion in Terraforming/Grading) can be utilized to subtract excess flows from the vegetated swale, redirecting these flows to subtle bermed areas, lot-by-lot. In this manner flow volumes and velocities can be limited and properly controlled in the swale. Another mechanism to limit excessive flows is the flow bypass, accomplished by installing a parallel pipe connected to the inlet device such that larger storm flows are shunted out of the vegetated swale, thereby preventing excessive erosion and damage to vegetation.

Soils can be both a problem and an opportunity in terms of vegetated swale design. As soils become looser, sandier, greater infiltration will be accomplished, as is true of any Technique which relies on infiltration. Extremely sandy soils of course may interfere with actual formation of the swale and its maintenance over time. Tight clays on the other hand can be quite problematic, especially if during construction/development, construction vehicle traffic compacts soils even more tightly, a problem which is common.

Performance: In terms of water quantity performance, the record is not well developed. Price and Dreher (1993) report on a flow simulation study using the HSPF model calibrated to several watersheds in Illinois with average (i.e., reasonably tight) soils, where discharges to vegetated swales versus a conventional storm sewer system was evaluated. Results demonstrated that a surprising degree of volume reduction (defined both in terms of peak rate discharge and total volume) was achieved (Figure (Figure 5.2.1 Price and Dreher)) with the effect being most pronounced for the smaller and more frequent storms (from a groundwater recharge perspective, these smaller storms comprise the bulk of the rainfall, as discussed in Chapter 1). Perhaps one of the most important benefits to vegetated swale use is that, while achieving quantity criteria for peak rate and total volume may not be possible for all relevant storms, substantial quantity benefit can be achieved, sufficient to reduce the typical flashiness of urbanizing streams which in turn causes so much habitat disruption and stream bank erosion/undercutting.

Perhaps one of the most important benefits to vegetated swale use is that, while achieving quantity criteria for peak rate and total volume may not be possible for all relevant storms, substantial quantity benefit can be achieved.

Most of the research involving vegetated swales has focused on the issue of water quality. Properly designed vegetated swales have the potential to remove remarkably large percentages of stormwater-related pollutants. Wang et al. (1981) found that grassy channels were effective in removing metals from stormwater. In channels of 200 ft length, they found 80 percent removal of solids and lead, 70 percent of copper, and 60 percent of zinc. Harper et al. (1985) and Post et al. (1982) confirmed vegetated swale effectiveness, as did Oakland (1983) and Kercher (1983).

The City of Mount Lake Terrace in Washington State built a 200 foot long swale designed to test its pollutant removal capabilities (Reeves 1994). The trapezoidal filter had the following dimensions: 4% average slope, 5 foot bottom width, and 3:1 sideslopes. The residence time was found to be just under ten minutes. The contributing area consisted of a 15.5 acre residential watershed with 47% impervious cover. During the second phase of the study, the length was reduced to 100 feet and thus the residence time reduced to five minutes. Pollutant loadings were measured before entering the swale and at the outlet and the results are shown in Table 3-7. Infiltration was assumed to be low for this swale because of the soils underlying it. The swales achieved the following percentage reduction of pollutants:

Table 3-7

Pollutant	100 foot swale %	200 foot swale %
Suspended Sediment	60	83
Turbidity	60	65
TPH (Hydrocarbons)	49	75
Total Zinc	16	63
Dissolved Zinc	negative	30
Total Lead	15	67
Total Aluminum	16	63
Total Copper	2	46
Total Phosphorous	45	29
Bioavailable P	72	40
Nitrate-N	negative	negative
Bacteria	negative	negative

(Reeves 1994).

These results showed the marked improvement achieved by the longer residence time in the 200 foot swale. The study also revealed that the water quality in the shorter swale was not nearly as consistent as in the longer design.

Kahn et al. (1992) in *Biofiltration Swale Performance, Recommendations, and Design Considerations* report results of recent research on swales. The focus of this research was on water quality effectiveness with particular interest in length of swale and hydraulic residence time of the stormwater within the swale. If vegetated swale design specifications are maintained, 83 percent of suspended solids, 75 percent of oil/grease, 65 percent of total turbidity, and 63 to 72 percent of various metals was removed for the 200-ft swale with a hydraulic residence time of 9 minutes. Nutrient removal was variable with particulate phosphorus removed most effectively as one would expect. Soluble form nutrients, either ortho phosphorus or nitrate+nitrite-nitrogen, were not effectively removed by vegetated swales in this research.

The *Vegetative Practices Guide for Nonpoint Source Pollution Management* (HRPDC 1992), enumerates specific factors that can both positively and negatively affect swale pollutant removal performance.

Can cause an increase swale efficiency:

- check dams
- low slopes
- permeable subsoils
- dense grass cover
- long contact time
- smaller storm events
- coupling swales with plunge pools, infiltration trenches or pocket wetlands
- swale length greater than 200 feet

Can decrease swale efficiency:

- compacted subsoils
- short runoff contact storms
- large storm events
- snow melt events
- short grass heights
- steep slopes (6% or greater)
- runoff velocities (1.5 feet per second or more)
- peak discharge (5 cubic feet per second or more)
- dry weather flow

Most sources concur that construction costs of vegetated swales are less than costs for conventional storm sewer systems, including curbing, inlets, and conveyance piping to some ultimate basin or device.

Costs: Most sources concur that construction costs of vegetated swales are less than costs for conventional storm sewer systems, including curbing, inlets, and conveyance piping to some ultimate basin or device. To the extent that such a detention basin or some other receiving “device” can be totally eliminated or at least significantly decreased in extent, these total aspects of the stormwater management system must be included in the cost comparison.

Cost elements for the vegetated swale system are straightforward, including simple excavation and grading executed to minimize compaction. Erosion protection should be provided. Geotextile erosion blankets or special mulch protection such as fiberglass roving or straw and netting should be applied until the vegetation has a chance to become established. The vegetation itself must be planted. As slopes increase, planting of vegetation is modified (seeding procedures are replaced by sodding/staking at about a 4 percent slope). Provision for check dams increases costs, though not significantly in most cases. The installation process, as with many innovative techniques, benefits tremendously with provision for periodic inspection. Probably the best single cost objective should be the careful detailing of specifications during the design engineering process so that all aspects of this possibly unfamiliar Technique are specified in great detail in front of those responsible for construction.

Maintenance costs for swales are relatively low. The primary objectives are to keep a dense mat of vegetation growing and to keep the swale free of obstructions such as leaf litter and significant deposits of sediment. These objective can be accomplished by periodic mowing and inspection. Occasionally reseeding may be needed in areas that become bare. It is also necessary to discourage homeowners from cutting the grass too short and from applying fertilizers and pesticides to the swale vegetation. Both of these actions reduce the efficiency of the swale. The Hampton Roads Planning District Commission (1992) states that vegetated swales can last an indefinite time if they are properly designed and maintained according to these recommendations.

Maintenance costs for swales are relatively low. The primary objectives are to keep a dense mat of vegetation growing and to keep the swale free of obstructions such as leaf litter and significant deposits of sediment.

Schueler (1987) provides some cost estimates for swale excavation and vegetation establishment on a linear foot basis. For a fifteen foot wide swale with 3:1 side slopes, the cost for excavation and shaping plus planting of vegetation is as follows:

$4.50/linear foot	—	Seeding/Straw mulching
$8.25/linear foot	—	Seeding/Net anchoring
$7.75/linear foot	—	Sodding/Stapling.

MWCOG (1995) has estimated simple grassed swale construction at $3 per square yard of swale area plus another $1.25 per square yard for stabilization costs. Adding check dams to swales adds another $50 to $100 per dam, although clearly more elaborate dams with larger potential volumes can exceed these estimates.

Chapter 4
The Conservation Design Procedure

The overriding objective ultimately is to achieve a new way of thinking about site design.

Introduction

Although Conservation Design is an optional approach to land development and stormwater management in Delaware—at least until state program requirements are changed, the Department wants to encourage its use. That won't be easy. Conventional practices have developed over many years and are ingrained. Change won't come quickly, particularly when this change requires some fundamental rethinking of not only how <u>stormwater</u> itself is managed at a site, but even more far-reaching <u>site design concepts.</u>

In the last chapter we defined Conservation Design in terms of its substance—<u>the Approaches and Practices which comprise the heart of Conservation Design.</u> This chapter is intended to describe <u>how</u> we make it happen. A Procedure is needed. This Procedure should set out the steps to be followed in order to make Conservation Design a reality—what to use where and under what circumstances—how we can optimize Conservation Design applications. The Procedure itself can be thought of as a series of questions which must be asked as Conservation Design is applied to each site. If site designers rigorously address all of these questions, the Conservation Design Procedure will have been accomplished, and the "answers"—the Conservation Design Approaches and Practices which have been provided in Chapter 3—will be successfully identified for each site. The overriding objective ultimately is to achieve a new way of thinking about site design. Through use of this "question" approach, this new way of thinking hopefully will be understood and reinforced.

In the next section, the Conservation Design Procedure is presented, first in summary form and then in detail, Step-by-Step. Each of the detailed Procedure Steps, and the essential questions which are the basis of these Steps, is presented and discussed. The Procedure has been kept simple by intention. We have tried to avoid the temptation to make the Procedure more complicated in order to address the inevitable complexities of real world situations. Given the vast amount of variation encountered in the world of different sites, together with variation in development proposals, no amount of detailing in the Procedure would be adequate. We often learn by example. In the next chapter, Chapter 5, a series of case studies have been developed to demonstrate how this Conservation Design Procedure can be used in real world situations, applying Chapter 3 Conservation Design Approaches and Practices.

The Conservation Design Procedure in Overview

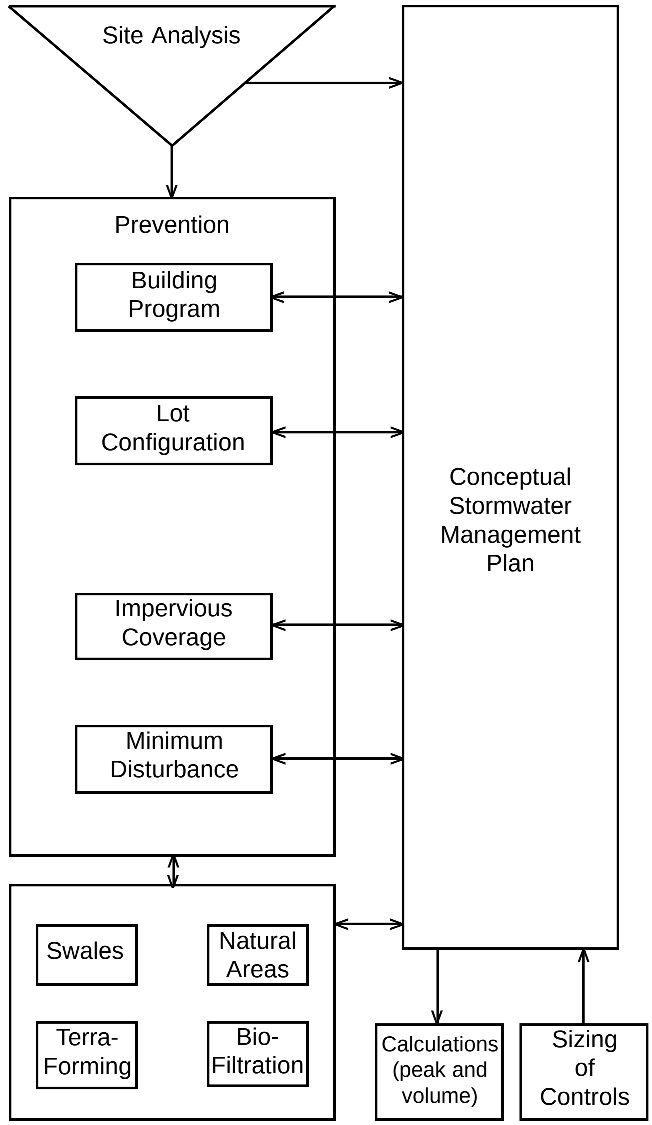
As procedures go, the Conservation Design Procedure is simple (Figure 4-1). As discussed throughout previous chapters, the Procedure is grounded in effective and complete Site Analysis, an upfront commitment by the site designers to inventory and evaluate the various "systems" which define the site and which pose both problems as well as opportunities for site development. These systems include the full range of natural systems—water, soil, geology, vegetation, habitat—as well as cultural resources and relevant socioeconomic factors. These systems range from the very macro in scale—resources of statewide importance, right down to micro-scale site-specific factors such as steep slopes and floodplains. The more this complex of systems is documented and understood from the start of the site design process—the better a building program can be fitted onto and into a site with minimal impact. The more clever the development "tinkering" can be, the more successful Conservation Design will become. Extra effort expended up front pays important dividends in the long run. Of all the stormwater management principles which have been articulated thus far in this Manual, we want to emphasize that Conservation Design requires a major departure from the conventional mindset of stormwater disposal—a reactive end of the line process forcibly imposed onto a development program. Conservation Design is proactive in the best sense of the word, based on understanding natural system opportunities which enable us to achieve essential stormwater quality and quantity management objectives integrated into the development design from the very beginning. Site Analysis makes it all happen.

Conservation Design requires a major departure from the conventional mindset of stormwater disposal—a reactive end of the line process forcibly imposed onto a development program. Conservation Design is proactive in the best sense of the word, based on understanding natural system opportunities which enable us to achieve essential stormwater quality and quantity management objectives integrated into the development design from the very beginning.

The second major point to be emphasized from Figure 4-1 is that the Conservation Design Procedure must first wrestle with a series of questions which, from a stormwater perspective, are <u>preventive</u> in nature. These questions are the basis of the major Best Management Approaches which have been described in detail in Chapter 3. If these questions are fully addressed, stormwater prevention can be maximized—a critical objective of Conservation Design.

Thirdly, some level of stormwater peaking and volume control will

Figure 4-1
Conservation Design Procedure



Probably the most important aspect of Figure 4-1 is its positioning of the Conceptual Stormwater Management Plan Step as a concurrent task in parallel with the entire site design process.

remain to be mitigated in most cases even with successful prevention. These corrective or mitigative needs should be met with an array of natural-system based Best Management Practices which also have been described in Chapter 3. Any remaining stormwater management needs can be met with conventional structural BMPS, such as detention or wet basins.

Probably the most important aspect of Figure 4-1 is its positioning of the Conceptual Stormwater Management Plan Step as a concurrent task in parallel with the entire site design process. All of the preventive and mitigative Steps set out in the Conservation Design

Procedure link directly to this stormwater conceptualizing process. Multiple feedback loops or iterations occur as the Procedure unfolds. The building program and then the site design for the building program and the stormwater management concept are integrated and adjusted and readjusted and hopefully optimized. Granted, other building program needs have to be included in the process. Nevertheless, this integration of stormwater needs from the start of the design process is essential to Conservation Design.

This integration of stormwater needs from the start of the design process is essential to Conservation Design.

The Conservation Design Procedure in Detail

Site Analysis Background Factors: **How Do Background Site Factors Affect the CD Process?**

Hydrologic issues:

- ***Is the site above or below the C&D Canal?***
- ***Is the site tidally dominated?***
- ***Does the site flow to special waterbodies with special water quality needs?***
- ***Are there known downstream flooding problems?***
- ***The site is located in what watershed?***
- ***Does the site discharge into 1st, 2nd, 3rd order streams?***
- ***Is the site in the upper, middle, or lower part of the watershed?***

Discussion: Site Analysis (Figure 4-2) begins with an understanding of a variety of background factors which help to define site systems. Although there are a lot of systems which could be included here, inventorying should be focused on those questions which have most meaning for Conservation Design and stormwa-

Figure 4-2
Site Analysis

- What are the site's background considerations
  surrounding context
  location in watershed
  piedmont vs. coastal plain
  site size
  adjacent uses

- What are the site's critical natural features
  wetlands
  floodplains
  riparian buffers
  steep slopes
  special habitat areas

- What are the sites stormater
  opportunity problem areas
  soil characteristics
  land cover characteristics

ter management needs. Because state management criteria vary above and below the C&D Canal, obviously this summary indicator first needs to be addressed, followed by factors such as tidal influence (tidal influence means that peak discharge rate requirements should be either set aside or substantially modified—in most cases, the tidal system will be the controlling issue in terms of downstream flooding, which <u>will not be significantly affected by increased releases from specific sites—i.e., don't worry about them)</u>. Either of these factors—the Canal or tidal influence—have straightforward ramifications for stormwater calculations at a site.

Streams, particularly in the Piedmont portions of Delaware, where urbanization already has occurred have already been impacted by changes in their hydrology and therefore are particularly sensitive to further flooding impacts.

Also important is the extent to which the stream system to which the site discharges is characterized already by flooding problems. Streams particularly in the Piedmont portions of Delaware where urbanization already has occurred (Naamans Creek being an excellent example) have already been impacted by changes in their hydrology and therefore are particularly sensitive to further flooding impacts. The problem here is that there exists no convenient source of intelligence where all of this information has been technically developed, is organized and mapped, either on the state level or in the respective counties—at least to our knowledge (unfortunately the existing FEMA mapping doesn't begin to get at this type of issue). County agencies and possibly other sources may be able to indicate anecdotally the extent to which downstream flooding is a problem, in which case a cautionary flag should go up. Greater care should be taken in comprehensive floodplain management.

Another important question relates to a site's location within its watershed. All else being equal, sites located near the base of watersheds have a lesser degree of potential hydrologic impact in the watershed system (i.e., the longer the route or routing of whatever additional stormwater is generated, the greater the potential problem this stormwater may cause). Sites located farther up in watersheds closer to headwaters are potentially more problematic when additional stormwater is generated.

Another question which has not been detailed in this Manual but which may have increasing importance in the future is the issue of saltwater intrusion into Delaware's ground and surface water systems resulting from land development. To our knowledge, this issue has not been extensively addressed at this point, presumably because impacts have not yet been significant. Nevertheless, in coastal areas expected to experience significant development (e.g., portions of Sussex County), impacts may well grow more serious in the future. Zones of potential sensitivity should be identified. In these zones Conservation Design with its significant benefit for recharging groundwater and maintaining predevelopment hydrologic regimes becomes particularly critical. The question is deserving of attention by the state and certainly by the counties as well.

A variety of other background factors are also of interest due to their water quality importance. Does the site ultimately flow into a reservoir or other type of impoundment where special water quality sensitivities exist? Or perhaps other special fishery issues exist? Is the site linked to a special habitat system? For both water quality and temperature reasons, Conservation Design Approaches and Practices which achieve a higher order of protection become especially important.

Site Analysis Site Factors Inventory: What Site Physical Factors Affect Conservation Design?

Site size and shape:
- ***Does site size limit Conservation Design?***
- ***Does site shape, other factors limit Conservation Design?***

Natural features:
- ***What is the basic site hydrology?***
  - ***Perennial streams?***
  - ***Intermittent swales?***
- ***Describe site soils?***
- ***Describe site vegetation?***
- ***Describe site critical features***
  - ***Do wetlands exist?***
  - ***Are there floodplains?***
  - ***Are there riparian areas?***
  - ***Are natural drainageways present which are not perennial streams per se?***
  - ***Are there special habitat areas?***
  - ***Do special geological formations exist (i.e., carbonate)?***
  - ***Do steep slopes exist?***
  - ***Are there high water table, bedrock, other limitations?***

Built/developed features:
- ***Does the site have centralized sewer?***
- ***Does the site have centralized water?***

Site physical factors powerfully influence Conservation Design.

Discussion: Site physical factors powerfully influence Conservation Design. Most basic is site size and shape. As site size increases, ability to use different Conservation Design techniques increases. As size decreases, some aspects of Conservation Design may become more challenging to achieve, although in general the Conservation Design approach usually reduces site space requirements and therefore offers greater flexibility than the conventional site design approach (examples range from the clustering of dwellings in concentrated areas to elimination of conventional stormwater structural measures such as basins). Oddly shaped sites also usually can be better adapted with Conservation Design.

At the heart of the Conservation Design process is an understanding of the natural areas (systems) characterizing each site.

At the heart of the Conservation Design process is an understanding of the natural areas (systems) characterizing each site. As discussed in previous chapters, existing vegetation and soil have tremendous importance for Conservation Design and are key in so many different ways to understanding land development impacts on natural systems. **Careful accounting of existing vegetation is an important prerequisite for Conservation Design, followed closely by soils mapping, including classification by permeability rating into Hydrologic Soil Group categories, followed closely by basic site hydrology in order to understand natural predevelopment surface flow patterns.**

Equally important here is the understanding of critical natural areas which may exist. Critical areas include: special value areas and sensitive areas. Special value areas include wetlands, floodplains, riparian buffers and naturally vegetated swales and drainageways, for example—all areas distinguished by special positive functions which can be translated into real economic value or benefit. Elimination of/reduction in these functions through the land development process means real economic losses. Chapter 2 provides an overview of many of these special value areas—including wetlands and floodplains and riparian areas—and explains why it is so important that such features be conserved and protected during land development.

Critical natural areas also include sensitive areas, such as steep slopes, shallow bedrock, high water table areas, and other constraining features, where encroachment by land development typically creates increased negative impacts of one sort or another. Both types of impacts should be avoided. Critical areas should be directly avoided during the construction process.

Finally, site features also include built/developed features. Although the discussion here is cursory, the most important elements for Conservation Design are availability of centralized sewer and water service. With its focus on stormwater management, this Manual has not given detailed discussion of statewide and county-municipal-wide requirements for wastewater treatment, ranging from onsite systems to various types of centralized systems. These requirements are critical. Conservation Design must be able to harmonize with these wastewater programs. In many, if not most, cases, wastewater solutions are feasible. For example, in cases where no centralized treatment systems exist, a variety of land-based treatment approaches are available in addition to individual onsite septic systems. Different wastewater concepts have been conceptually tested for feasibility in the case studies, although no detailed analysis of wastewater treatment systems or other infrastructure has been undertaken.

The issues are similar for water supply, although wastewater tends to have greater significance for a variety of reasons. Agencies are actively developing additional guidance for improved approaches to wastewater treatment. DNREC will urge its sister state and county agencies to develop special wastewater treatment program elements specifically adapted for the Conservation Design approach.

Site Factors Analysis: What Site Factors Are Constraints and Opportunities in terms of Conservation Design?

Site Constraints:
- ***Where should building and roads be avoided?***
  - ***in terms of vegetation?***
  - ***in terms of soils?***
- ***Are areas off limits for all forms of disturbance?***

Site Opportunities:
- ***Where does most recharge occur?***
  - ***in terms of vegetation?***
  - ***in terms of soils?***

Discussion: This is the last step in the Site Analysis process. Site constraints and opportunities are grounded in the natural systems present at the site, as discussed above. Constraints and opportunities are not necessarily simple converses of one another, although these relationships often do hold. For example, certain types of critical natural areas should be viewed as constraints in terms of direct land disturbance and building construction, yet also provide significant opportunity in terms of Conservation Design stormwater provisions. Woodlands, which should be protected from direct land development, provide excellent opportunity for stormwater management, provided that the right Conservation Design practices are used. Vegetated riparian buffers should not be disturbed by building and road construction, yet can be used carefully with level spreading devices to receive diffuse stormwater runoff.

Woodlands, which should be protected from direct land development, provide excellent opportunity for stormwater management, provided that the right Conservation Design practices are used.

Similarly, soils with maximum permeabilities at the site should not be paved over with buildings and roads, but used for stormwater management where feasible. Conversely, buildings and other im-

Similarly, soils with maximum permeabilities at the site should not be paved over with buildings and roads, but used for stormwater management where feasible. Conversely, buildings and other impervious areas should be located on those portions of a site with least permeable soils.

pervious areas should be located on those portions of a site with least permeable soils.

Defined in this way, site opportunities have major linkages to site stormwater recharge potential. For the purposes of this Manual, DNREC's consultant, the Brandywine Conservancy, has applied its innovative Climatic Water Budget Model, WATBUG, to each of the case studies in order to assess runoff potential and recharge potential in a more quantitative manner. This WATBUG modeling, a geographic information system (GIS)-driven process which incorporates NRCS' soil cover complex method for runoff analysis, is linked directly to both the land cover or vegetation mapping as well as the soil mapping. For the purposes of this Manual, this modeling enabled the calculation of the actual recharge volumes occurring at a site before development, impacts by the conventional development approach, and then the benefit achieved through the Conservation Design approach. Lacking this modeling application in the future, site opportunities for recharge can be defined in terms of best vegetation types which minimize runoff as well as soil types with maximum permeabilities.

Site constraints also include features such as wetlands which should not be impacted by either building and road construction or stormwater management.

Use of Preventive Conservation Design Approaches

Building Program: How Do Building Program Factors Enter into the Conservation Design Procedure?

Can the proposed building program be reduced in terms of total number of units?
Can the type of units be modified (e.g., from single-family to townhouse)?
What is existing site zoning?
Are zoning options allowed?
Have building setbacks been made to be flexible?

Have innovative development concepts such as zero lot line been considered?
What does the comprehensive plan indicate for the site and adjacent areas?
What are the adjacent land uses?
Other Management/Regulatory issues:
What municipal/county requirements exist directly for stormwater?
Will some aspects of Conservation Design require waiv-

ers?

What other municipal/county requirements exist for land development?

Will some aspects of Conservation Design require waivers?

Figure 4-3
Building Program

- Can the program be modified in terms of total number of units?
  - Minimizing disturbance/maximiziing site's recharge areas
  - Reducing maximum zoned build-out
- To what extent can lot sizes be reduced and concentrated
  - Alteration to building type (single family to townhomes)
  - Reduction in lot sizes (e.g. zero lot lines)
  - Move towards clustering

Discussion: With Site Analysis completed, the next step in the Conservation Design Procedure is to address a series of questions, all of which focus on our ability to prevent the generation of stormwater from the outset.

First, we must ask whether the development or building program itself can be modified (Figure 4-3). Pivotal here are existing zoning requirements and maximum zoned densities. It has come to be a cardinal principle in real estate development circles that all parcels can and should be developed at maximum zoned densities. Some would even contend that any type of constraint which in some manner reduces the ability to achieve maximum zoned densities becomes a legal "taking," which is not the case. In all of the case study examples presented in Chapter 5, we have avoided this critical question by holding constant the number of dwelling units which have been proposed by developers in the conventional or baseline land development proposals. In most cases, these conventional development proposals appeared to very nearly approximate maximum zoned densities. Nevertheless, at the outset of the Conservation Design process, it is vital to address the issue of reducing the building program, particularly if the site is characterized by numerous critical features which are being impacted by conventional development concepts. In some cases, reducing the building program even moderately, may enable significant Conservation Design Approaches to be implemented, resulting in cost reductions which basically compensate for the reduction in profit.

Nevertheless, at the outset of the Conservation Design process, it is vital to address the issue of reducing the building program, particularly if the site is characterized by numerous critical features which are being impacted by conventional development concepts.

Secondly, an alternative to reducing a site's building program can be a change in the <u>type</u> of development being proposed, such as substituting townhouses for single-family development.

Secondly, an alternative to reducing a site's building program can be a change in the <u>type</u> of development being proposed, such as substituting townhouses for single-family development. This approach is illustrated in Chapter 5 by the Buckingham Greene Case Study, where moving from single-family dwellings to townhouses, even holding the total number of dwelling units constant, enables a highly successful Conservation Design concept to be developed. Achieving this same level of conservation of natural site features together with stormwater management needs would have required a significant reduction in the total number of dwellings being proposed, assuming construction of single-family dwellings on approximately the same size of lot.

In terms of modifying the <u>type</u> of development being proposed, DNREC cannot and should not propose any procedure which somehow is inconsistent with land use controls imposed by counties and municipalities. Furthermore, in many cases these more local controls usually contained within respective zoning ordinances do not provide for latitude in terms of type of dwelling, so that doing what we propose in Chapel Run or Buckingham may not be compatible with existing legal requirements (we have not inventoried and evaluated all of the existing ordinances in order to understand these provisions in detail). In some cases there may be some degree of flexibility in these ordinances. Certainly we would hope that clustering in some form would be allowed; we would hope that over time more flexibility of this type would be incorporated into the respective zoning ordinances. We would hope that setback requirements would be made to be flexible so that setbacks could be reduced. Also, we should take note that developers can always seek to do it differently through variance or special exception or zoning change processes which apparently are not uncommon. Advocacy of these approaches by DNREC will facilitate this Conservation Design process and indirectly lead to better developments throughout the state.

In terms of overall planning and management questions, of course, DNREC should be careful to make sure that whatever gets permitted and built relates to adjacent land uses and the community's plan for the area. DNREC may be hard pressed to bring this expertise to the table and may simply have to rely on reviewing by respective municipal or county planning organizations. After all, state permitting review or no review, <u>all</u> land developments are processed either through county level or municipal level land development ordinances which must be satisfied. Local zoning must be addressed. For the moment at least, alternative development concepts which achieve Conservation Design but which are not consistent with local zoning and other related requirements must:

- either seek a zoning change
- or obtain some other type of relief such as a variance or special exception or waiver (this issue is addressed in greater detail in Chapter 6).

Such a process is more than cumbersome and will serve as a major disincentive for the Conservation Design program where these conflicts exist. **Clearly, all counties and municipalities should be urged to modify their respective zoning and land development ordinances so that the provisions of these ordinances are compatible with Conservation Design requirements.**

Other issues of a regulatory nature also exist. As with the respective zoning ordinances, stormwater requirements as well as all other aspects of land development are directly regulated by municipal/ county ordinances. Numerous aspects of Conservation Design relate to these requirements, including landscaping requirements, building setbacks, pavement and parking specifications, all aspects of curbing and guttering, and a variety of others. As with zoning, DNREC will encourage these municipalities and counties to make their respective ordinances consistent with the provisions of Conservation Design.

Lot Configuration and Design: How Can Lot Configuration and Overall Site Design Prevent Stormwater Generation?

Have lots been reduced in size to the maximum degree?
Have lots/uses been clustered/concentrated to the maximum degree?
Have lots been configured to avoid critical areas?
Have lots been configured to take advantage of effective Conservation Design mitigative practices?

Discussion: As discussed in Chapter 3, Lot Configuration, relating to both the sizing of lots and their arrangement, has more potential benefits than any other single Conservation Design Approach or Practice (Figure 4-4). Lot size reduction is clearly related to the local zoning requirements, as discussed above. Local requirements must either be satisfied by straightforward compliance or by successfully obtaining a waiver of some sort or special exception to these existing requirements. It should be kept in mind that the important question of gross density should not be confused with minimum lot size. In other words, just because lot size is allowed to decrease does not mean that densities should be allowed to increase.

Lot Configuration, relating to both the sizing of lots and their arrangement, has more potential benefits than any other single Conservation Design Approach or Practice.

Figure 4-4
Lot Configuration

- How can sensitive and/or recharge areas be minimally disturbed
- Can the lots be concentrated/clustered
- How can lots be configured to provide for mitigative approaches

Once lots are reduced in size to the maximum, then these lots can be located on the total site in ways which avoid disturbance of critical site features such as wetlands and steep slopes and the like.

Lot size also is related physically to structural type (i.e., there are minimum lot sizes which "fit" different types of structures and different sizes of structures). As lot size decreases to less than one half acre for example, certain types of conventional structure types may be difficult to accommodate on the reduced size lot. The good news is that with the proliferation of "village" designs, there is ample documentation which demonstrates different designs for accommodating remarkably large homes on remarkably small lots.

Careful configuring—clustering—of these reduced size lots also is critical, first in order to minimize the total amount of site disturbance which is required and, secondly, in order to avoid critical areas such as wetlands, steep slopes, and riparian and floodplain zones. Once lots are reduced in size to the maximum, then these lots can be located on the total site in ways which avoid disturbance of critical site features such as wetlands and steep slopes and the like. This clustering further means that total road building and creation of other types of impervious cover can be minimized. Total site disturbance can be minimized.

Furthermore, if designed creatively, dwellings can be positioned so as to benefit from the open space which is allowed to remain as the result of clustering. Economists call this "internalizing the positive externality." This ability through clustering to maintain natural areas and special high quality viewscapes and other positive site features also allows dwellings to open onto these open space areas, which enhances values, rather than detracts from values. This finding has been confirmed by a variety of studies across the country (i.e., clustered singles on quarter-acre lots opening onto open space will be worth more than the same house located on a one-acre lot gridded out in a conventional manner). And furthermore, this clustering can also be designed to take advantage of stormwater opportunities, such as areas with the most permeable soils and with the best vegetation for stormwater management purposes.

Impervious Coverage: Have Impervious Surfaces Been Re-

duced as Much as Possible?

Have road widths been reduced to the maximum degree?
Have driveway widths and lengths been minimized to the maximum degree?
Have parking ratios and parking sizes been reduced to the maximum extent?
Has potential for shared parking been examined fully?
Have cul-de-sacs and turnarounds been designed to minimize imperviousness?
Have sidewalks been designed for adequate, though single-side movement?
Can porous surfaces be used for overflow parking, low impact shoulders, other applications?

Discussion: Although many of the Impervious Coverage questions (Figure 4-5) relate directly to the Lot Configuration and Design Step above, the questions listed in this Step also stand alone. Regardless of the decisions made in terms of Lot Configuration and Design, there are extremely important questions to be asked which relate to how and why we make the world impervious, as the result of the land development process—that relate to the building of roads, cul-de-sacs and turnarounds, parking lots, driveways, sidewalks, and even the structures themselves. As the discussion in Chapter 3 demonstrates, we can do it just as well, just as safely and effectively, and usually with much less imperviousness in many cases. Reducing imperviousness in any and all ways possible translates into a direct reduction in volume of stormwater runoff generated, in peak rate reduction, and in reduction of pollutants generated.

Reducing imperviousness in any and all ways possible translates into a direct reduction in volume of stormwater runoff generated, in peak rate reduction, and in reduction of pollutants generated.

Figure 4-5

How can Impervious Coverage be Reduced to Prevent Stormwater Generation

Cluster development
Minimize road lengths and widths
Reduce building set-backs
Minimize driveway widths and lengths
Evaluate parking ratios
Evaluate needs and sizes of walkways

Questions are tiered, based typically on the potential imperviousness reduction which can be achieved. In other words, in most residential development cases, the first issue to be addressed ought to be road width. All else being equal, a reduction in road width

All else being equal, a reduction in road width from 30 feet to 18 feet (if feasible) means an immediate 33.3 percent imperviousness reduction in roadway imperviousness, which typically comprises a large fraction of total site imperviousness.

from 30 feet to 18 feet (if feasible) means an immediate 33.3 percent imperviousness reduction in roadway imperviousness, which typically comprises a large fraction of total site imperviousness. Note that road length is not specifically dealt with here, simply because the Building Program and Lot Configuration and Design Steps will serve to dictate lengths of roads in most cases.

Next comes driveway width. Reduction achieved here may or may not be substantial, depending upon the lots being created, their size, and building setback requirements (i.e., large-lot developments with substantial setbacks mean that total driveway length added up across the development will be great. If driveway width in such situation can be reduced by 20 percent, imperviousness reduction can be expected to be substantial.)

Parking also is important, although the most interesting reduction in imperviousness to be achieved through parking strategies is with nonresidential development, where the sizes of parking stalls themselves can be reduced, where ratios of parking stalls per size of structure being built possibly can be reduced, where sharing of parking spaces may be possible. In residential applications, overflow or guest parking may be appropriately provided through use of porous pavement techniques.

Sidewalk construction may afford opportunity to reduce imperviousness, though not in all cases. Sidewalks should be provided for any number of reasons, though usually provided only on one side of the street (for example, sidewalks are essential to the concentrated village development concepts which are advocated here). At the same time these sidewalks should be reasonably wide, oftentimes up to 5 feet in width. Of course the width and hoped for use of sidewalks will vary according to each development, its characteristics, nature of development in adjacent areas, and so forth.

Minimum Disturbance/Maintenance: Has Disturbance of Site Vegetation and Soils Been Minimized?

Has maximum <u>total site area</u>, including both soil and vegetation, been protected from clearing and any other type of development disturbance?

Are zones of open space maximized?

Do these open space zones make sense internally, externally?

In terms of <u>individual lots</u>, has maximum lot area, including both soil and vegetation, been protected from clearing and other development-related disturbance?

Do structures correspond to site features such as slope,

both in terms of type of structure, placement on lot, elevation, and so forth?
Have revegetation opportunities been maximized throughout the site?
Have revegetation opportunities been maximized in critical areas such as riparian buffer zones?

Discussion: Minimum Disturbance/Maintenance, sometimes referred to as Site Fingerprinting or Site Footprinting, is the last, but by no means the least of the preventive Best Management Approaches (Figure 4-6). As discussed in earlier sections of this Manual, the undisturbed soil mantle with undisturbed vegetation—even if this vegetation is not a high quality mature hardwood forest—offers tremendous stormwater potential, quantitatively and qualitatively. The Minimum Disturbance/Maintenance Approach offers double-sided benefits in that a negative impact is avoided and a positive opportunity is created.

The Minimum Disturbance/ Maintenance Approach offers double-sided benefits in that a negative impact is avoided and a positive opportunity is created.

Figure 4-6
Minimum Disturbance

- Can limits of disturbance be placed to minimize total site disturbance
- Can disturbance of critical natural areas be minimized

Cluster development
Sensitive building siting
Reduced setbacks
No-disturbance buffers during construction

How are negative impacts avoided? Even if a disturbed area remains pervious and is converted to lawn or some other form of artificial landscape, soils have been manipulated and compacted and all of the stormwater opportunity benefits of existing vegetation have been eliminated as well (i.e., post-development lawns can be expected to generate significantly more stormwater runoff than pre-development vegetation of most types, including meadow or scrub vegetation and certainly forests).

How are positive opportunities created? At the same time, protected zones of vegetation and soil can be used actively for stormwater management purposes, offering areas where stormwater can be distributed and infiltrated, when used in conjunction with level spreading devices, berms, and other techniques.

Minimum Disturbance can be applied on several different levels. The Approach is most effective when applied on the total site or development basis, when lots are concentrated into the most compact areas and the maximum proportion of site area can be protected, free of disturbance of any sort. The Minimum Disturbance concept in such cases becomes comparable to open space provisions in clustering designs, assuming that clustering provisions do not allow for disturbance of any type to occur in this open space. Furthermore, the Minimum Disturbance concept can and should be extended beyond the site level to take into account adjoining sites with their open space areas, ideally all integrated to create even larger blocks of open space, all of which has greater and greater positive ecological effect. If possible, these open space areas can ultimately form open space systems designed to protect stream valleys, important habitat, and other critical features.

Conceptually, the real difference here is that the basic approach to the site is "flipped," moving from the conventional approach which assumes that wholesale clearance/ disturbance will automatically occur with some special critical areas flagged and protected. Versus the Minimum Disturbance Approach where the <u>entire site area</u> is considered important and disturbance zones are carefully defined—really the converse of how we typically go about land development.

Unfortunately, such a macro-scale, total site perspective for the application of the Minimum Disturbance Approach, however preferable, is not always achievable. In such cases, the Minimum Disturbance concept can be applied on the individual lot level, where, for example, larger lots of half-acre or more may be created and where through careful placement of structures, significant zones of existing vegetation can be preserved lot-by-lot, with undisturbed areas of adjoining lots forming larger open space massings. Zones of clearing—the required building footprint plus some modest apron needed for construction—can be designated and then flagged/ fenced onsite, not unlike a wetlands mapping process. Conceptually, the real difference here is that the basic approach to the site is "flipped," moving from the conventional approach which assumes that wholesale clearance/disturbance will automatically occur with some special critical areas flagged and protected. Versus the Minimum Disturbance Approach where the <u>entire site area</u> is considered important and disturbance zones are carefully defined—really the converse of how we typically go about land development.

As discussed in Chapter 3, the Minimum Disturbance Approach can be used most effectively when applied in conjunction with critical features identified during the Site Analysis Step. For example, although the general Minimum Disturbance principle is to protect as much natural vegetation as possible, protection of existing vegetation which happens to be in riparian zones, which happens to be adjacent to existing wetlands, which happens to be on steep slopes, which happens to be in and along the natural system of drainageways will maximize the positive functions which Minimum Disturbance provides. In other words, if Minimum Disturbance cannot be thoroughly and completely applied at a site, apply it with protection of these special value areas in mind.

Also, again as discussed in Chapter 3, the Minimum Disturbance

Approach also means that, if applied thoroughly and completely, types of structures themselves should be reevaluated and may have to be modified (i.e., more vertical with less building footprint). The conventional sprawling colonial with 2 or 3-stall garage at grade set well back on the lot to provide a formal front yard should be re-evaluated. Types of building practices may need to be modified in order to effectively reduce needed site disturbance. Standard modes of excavation and top soil stockpiling result in large-scale if not total site clearing and disturbance, which is simply not necessary in order to provide 2,500 square feet of dwelling space, for example. The design of the structure, placement on the site in terms of elevation, all should reflect existing topography. Can the elevation of the dwelling be changed so that less excavation is required (i.e., less excavation means less site disturbance)? In sloping topography, can the dwelling design itself be modified to fit the slope, with driveways/garages properly fitted to minimize excavation and grading?

The most ambitious, but possibly most important aspect of Conservation Design and the Minimum Disturbance Approach involves proactive reforestation as part of the stormwater management concept, again as defined in Chapter 3. Though sounding quite unusual in terms of stormwater management, reforestation can be made to happen cost-effectively, defined typically as distributing (level spreaders, swales, and so forth) stormwater onto areas where small trees with appropriate vegetative cover have been planted. Perhaps the most exciting aspect of reforestation is that although the short-term stormwater performance must be assumed to be that of a modestly vegetated land cover (i.e., whatever cover crop has been included along with the sapling trees), nevertheless the long-term stormwater performance will improve year by year. For the vast areas of the State which already have been cleared (though not necessarily developed as yet) and which are no longer naturally vegetated, incorporating reforestation techniques into the land development process actually offers the potential to return Delaware watersheds to a more natural condition—even as development occurs! The related environmental benefits of reforestation, many of which have been discussed in Chapter 2, are very significant and, although rarely quantified as such, serve to make cost benefit ratios overwhelmingly positive.

The most ambitious, but possibly most important aspect of Conservation Design and the Minimum Disturbance Approach involves proactive reforestation as part of the stormwater management concept.

Note that, as with the Minimum Disturbance Approach in general, reforestation done in conjunction with critical features such as riparian areas and natural swales is most important. If total zones cannot be reforested, at minimum reforestation of these most important zones should be undertaken as part of Conservation Design.

Use of Mitigative Conservation Design Practices: Which Practices Are Most Effective and How Can Their Positive Effects Be Maximized?

Are vegetated swales with check dams being used?
Are vegetated filter strips with level spreading devices being used?
Are berms and other terraforming technique being used in conjunction with zones of natural vegetation?

Having applied Conservation Design Approaches to the maximum, stormwater generation will be minimized to the maximum. Nevertheless, stormwater still will be generated and must be managed or mitigated most effectively through a variety of mitigative Conservation Design Practices.

Discussion: Having applied Conservation Design Approaches to the maximum, stormwater generation will be minimized to the maximum. Nevertheless, stormwater still will be generated and must be managed or mitigated most effectively through a variety of mitigative Conservation Design Practices, selection of which is the next Step (Figure 4-7). These Practices have been assigned to several groupings, although in many cases the lines of distinction are blurred. One technique blends into another. Virtually all of these techniques are actually structural in nature—they involve some building or construction of some type. Though at the same time, virtually all make maximum use of vegetation and soil functions, as discussed in other chapters, and therefore are quite “low profile” in terms of being “structures” per se.

Figure 4-7
Stormwater Mitigation Techniques

- Vegetated swales
- Use of Naturally vegetated areas
    - Level spreading
    - Riparian buffers
    - Filter strips
- Terraforming
    - Berms
    - Depressional areas/negative drainage
- Biofiltration/bioretention

Another point of potential confusion. Terminology can be misleading. Vegetated Swales and Vegetated Filter Strips both can be considered to be Bioretention/Biofiltration devices, the increasingly popular name given to just about any type of device which utilizes vegetation and soil—existing natural areas—to manage stormwater flows. In most cases, the inspiration for Bioretention/Biofiltration has been water quality—using vegetation to remove nonpoint source pollutants in one/all of the ways discussed in Chapters 2 and 3. At the same time, however, quantity objectives such as reduction in stormwater volumes through infiltration can also be very important here, given the right applications and given reasonable permeabilities in the existing soils and avoidance of compaction problems during development. Furthermore, there are also variations on the Bioretention/Biofiltration theme itself, such as Prince George's County "rain garden" concept. These variations, although not exact fits in either the Swale or Filter Strip concept, nevertheless are quite similar in their overall functioning. With imagination the number of variations is almost limitless!

Quantity objectives such as reduction in stormwater volumes through infiltration can also be very important here, given the right applications and given reasonable permeabilities in the existing soils and avoidance of compaction problems during development.

Also, it should be noted that although these Practices are defined and singled out, there is substantial overlap with the Minimum Disturbance/Minimum Maintenance Approach. Obviously, the use of existing naturally vegetated areas at a site with a Vegetated Filter Strip of some sort is in fact predicated on not disturbing these particular vegetated zones. So in a sense any Vegetated Filter Strip concept is linked to the Minimum Disturbance/Minimum Maintenance Approach.

In contrast to the tier of questions which has emerged for Preventive Approaches and which unfolds in a kind of sequence, the questions which relate to these mitigative Practices are less given to a particular sequence or order and must be addressed together in order to determine what to apply and where. Can Vegetated Swales be incorporated into site design? What are the opportunities for existing Vegetated Swales? Can they be utilized for stormwater that will be generated? Can existing swales be enhanced in their performance with the addition of check dams and additional vegetation in order to effectively manage additional volumes of stormwater? Can new swales be created which will collect and convey increased stormwater? Can these new swales be constructed in a broad and shallow configuration and then planted with vegetation that has maximum stem density in order to slow stormwater to the maximum and promote infiltration into the soil. Can check dams be used also to further slow flow rates and to maximize infiltration even as increased stormwater flows are conveyed?

Vegetated Swales do not perform well on steeply sloping sites, unless special provisions are made. Nor will Swales perform well in most cases if volumes of stormwater flow are large (i.e., swales can work nicely for residential applications, but are limited for higher density developments such as shopping centers where stormwater volumes are quite large).

Vegetated Filter Strips are another variation on the theme. Typically a Vegetated Filter Strip in some configuration involves the collection of stormwater and direction into a level spreading device for distribution of collected stormwater onto some area of existing vegetation (level spreaders may not be necessary if topography is quite gentle and even). This vegetated area may take the form of a nice neat strip (such as the grassed filter strips which farmers use to separate cultivated fields). Or the vegetated area may be an irregularly shaped zone of existing woods or some other vegetation. The concept is probably most easily implemented in areas adjacent to group parking facilities, where runoff from a large relatively flat parking area drains to a level spreading device along the edge of the lot and then overflows evenly across some expanse of vegetation, ideally an existing wooded area (although a meadow or scrub vegetation can work just fine as well). Or the concept can take the form of stormwater collected and even conveyed some distance to a riparian buffer area, distributed into a lineal level spreading device constructed parallel to the spine of the riparian corridor which then overflows evenly across the vegetated riparian buffer of some fixed width. Again the objective is certainly water quality protection, removal of nonpoint source pollutants accomplished through the physical and chemical and biological processes provided by the vegetation and soil. At the same time, Vegetated Filter Strips probably make infiltration and quantity reduction easier, than Vegetated Swales, for example. Filter Strips at least in theory should have more potential for infiltration than a swale, quite possibly serving to accommodate all required stormwater volumes, depending upon the proposed development.

The final Conservation Design Practice is Terraforming, the term loosely applied to any of several techniques such as use of berms, use of subtle depressions/negative drainage, and others to intercept and store stormwater. In these cases, both water quality and quantity are direct stormwater management objectives, with stormwater volume reduction actually able to be calculated. Important here is that site soils be reasonably permeable. Site slopes especially with berms should be moderate, with berms typically being placed along or parallel to the contour.

Important here is that site soils be reasonably permeable. Site slopes especially with berms should be moderate, with berms typically being placed along or parallel to the contour.

On the surface, Terraforming would appear to require soil clearing and disturbance and sometimes that is the case. At the same time this Practice can be used with other Approaches and Practices where disturbance is controlled carefully. The practice of berming can and should be used in conjunction with protecting existing vegetated zones such as wooded areas, where carefully developed berms of subtle height (2 feet) are threaded through wooded areas to provide the needed quantity control for the larger storm events. Here the objective is to minimize disruption of any type in the area behind the berm, so that infiltration rates are kept as high as possible.

On a small or micro scale, check dams placed in swales, as discussed above, can be thought of as a type of Terraforming. Along hilly roads, berms placed along the contours and integrated with fill placed for driveways may offer a mechanism whereby roadway runoff can be intercepted as driveways intersect the roadway lot by lot.

If lots are sufficiently large, lots also can be graded in subtle "saucer" fashion so as not to promote positive drainage and so as to retain stormwater volumes created lot by lot. Important here is to make sure that these depressions can be integrated into the overall site landscaping plan. Also important here is to make sure that infiltrated stormwater is kept away from building foundations. If volumes provided by these depressions are basically reserved for the largest 100-year storm, then these depressions should not be frequently filled and should not interfere with lot usage. This approach should only be used where widespread clearance and disturbance is going to occur (i.e., if there is the chance that Minimum Disturbance/Maintenance can be employed, then a Terraforming Practice which involves extensive grading probably should be reevaluated).

The Conceptual Stormwater Management Plan: How Can All Preventive Approaches and Mitigative Techniques Be Integrated into an Optimal Conservation Design Plan?

How has the stormwater plan been integrated into the overall site design?
Has prevention been maximized through Conservation Design Approaches?
Has mitigation been maximized through Conservation Design Practices?
What other benefits are achieved through Conservation Design (i.e., open space, enhanced marketability, cost reduction, habitat protection, stream water temperature, biota impacts, other stream impacts?

Discussion: As Figure 4-1 indicates, Conservation Design starts happening from the very beginning of the Site Analysis process and then continues to evolve with constant iterations—back-and-forth testing of different Approaches and Practices in order to develop the concepts which fit the best. A Conceptual Stormwater Management Plan emerges (Figure 4-8) as the result of this process. If the process of questioning has been honestly and rigorously followed and if the designers are reasonably familiar with Conservation Design concepts, then a successful, if not absolutely optimal Conservation Design plan should result. Of course, in many cases, different designers and engineers will produce different Conservation Design plans, which is to say that no one combination of

Conservation Design starts happening from the very beginning of the Site Analysis process and then continues to evolve with constant iterations—back-and-forth testing of different Approaches and Practices in order to develop the concepts which fit the best.

Approaches and Practices is necessarily going to result.

Figure 4-8
Conceptual Stormwater Management Plan

- How has stormwater plan been integrated into the overall site design
- Has prevention been addressed t the extent possible
- Has mitigation been maximized through vegetative and soil based practices
- What other benefits can be gained from conservation design approach (e.g., open space, marketability, cost reduction, etc.)

Conservation Design produces multiple benefits, including in many cases substantial reduction in costs, as demonstrated in the case studies presented in Chapter 5. Nevertheless, Conservation Design is not required per se and will need to be reinforced with as many incentives as possible. From the developer's perspective, the Conservation Design plan must be perceived to be favorable market-wise—more "green," more open space, better aesthetics—all translate into value for the developer. Additionally, of course there are a host of positive environmental features related to Conservation Design which are important, although developers tend to be less motivated by such intangibles.

To the extent that Conservation Design actually <u>saves</u> developers money, that's undoubtedly the greatest incentive for its use.

Perhaps most vital are the cost implications of Conservation Design planning itself. Chapter 5 case studies provide some basic comparative cost data, contrasting conventional stormwater systems with Conservation Design systems. To the extent that Conservation Design actually <u>saves</u> developers money, that's undoubtedly the greatest incentive for its use.

Additionally, DNREC is investigating ways to provide additional kinds of incentives to promote Conservation Design use. For example, there may be ways of modifying the standard way in which TR-55 is applied to Conservation Design applications which can facilitate the calculation process—an incentive in and of itself. Certain factors used in the calculation process may be able to be adjusted to more accurately address Conservation Design applications. During the course of this Conservation Design project, there has emerged widespread recognition that the stormwater calculation methodologies which have evolved over time, including TR-55 and others, are closely linked to the physical management schemes on which we have relied for stormwater management purposes—in other words, the detention basin. Better methodologies are needed to better evaluate the broader range of stormwater issues which are the focus of Conservation Design. All of this goes well beyond the scope of this manual. Still, the issues are very important.

Stormwater Calculations: How Has Conservation Design Affected Stormwater Calculations? What Conventional Stormwater Techniques Are Necessary to Manage Any Residual Stormwater Need not Mitigated by Conservation Design?

—How has impervious cover been reduced?
—What are the implications for Curve Numbers?
—How have total runoff volumes been affected?
—Has time of concentration been maximized?
—How has peak discharge rate been affected?
—How has recharge volume been affected?

Better methodologies are needed to better evaluate the broader range of stormwater issues which are the focus of Conservation Design.

Discussion: This nearly final Step in the process (Figure 4-9) actually should appear both <u>within</u> the Conceptual Stormwater Management Plan box as well as <u>after</u> the Plan has been developed. In a sense, this calculation process has been occurring <u>during</u> the Conceptual Stormwater Management Plan formulation process from the start. Locating and sizing mitigative Practices ranging from berms to swales is grounded on such calculations.

Figure 4-9
Stormwater Calculations for Peak and Volume Control

- Can time of concentration be maximized
- Can curve numbers be reduced
- Can impervious percentages reduced

All the Conservation Design case studies have been evaluated using the NRCS TR-55 Soil Cover Complex Method. Current regulations state that the peak runoff rate for the design storm (the 10 year storm below the Canal and the 100 year storm above the Canal) cannot increase pre to post development. The Conservation Design Approaches and Practices are located and sized to meet these criteria.

As the result of careful and detailed application of the TR-55 Soil Cover Complex Method with its Curve Number assignment, Conservation Design—<u>when contrasted with conventional design</u>—typically produces significantly reduced impervious cover with significantly lowered Curve Numbers with reduced total runoff volumes. Furthermore, because time of concentration of stormwater flow is typically extended (i.e., not reduced to the extent that it is with conventional design), peak discharge rates are not increased to the same extent as with conventional development. All of these results are benefits to the developer and translate into a lesser degree of management requirement at a lesser cost for the developer. In this sense, the use of Conservation Design is self-perpetuating or rewarding.

In some instances, the application of the Curve Number Method and TR-55 runoff calculations is straightforward and resembles the steps used for a conventional site plan. However, in many other cases, the application is not as standard. Conservation Design advocates alternative methods for the prevention and mitigation of stormwater runoff which often do not easily fit into the standard formulas and calculations. Many of these alternatives are designed to infiltrate stormwater. Because TR-55 cannot account for this infiltration, the calculations performed for the case studies using these techniques are conservative. The actual amount of stormwater generated on a site and the peak rates at the discharge point may be below the given figures. For example, stormwater level spread into a bermed area on good soils will significantly infiltrate. The current methodology has no way of accounting for this. TR-55 is more easily applied to sites with detention basins than it is to sites utilizing the Approaches and Practices advocated by this manual. However, until more accurate and flexible runoff models are designed and/or incorporated into regulations, the NRCS TR-55 runoff method will be used. It is therefore useful to describe how Conservation Design affects the values generated by this standard method.

Many of the Conservation Design Approaches and Practices discussed have the specific aim of reducing the Curve Number, and keeping it as close to the predevelopment number as possible. This is accomplished by reducing site imperviousness and site disturbance. These measures can considerably reduce the amount of runoff generated and thus reduce the mitigative/storage/detention need.

Curve Number: The Curve Number (NRCS method) is critical in determining how much runoff will occur from any given site. By minimizing the Curve Number (CN), runoff will be minimized. Curve Numbers are affected by both the Hydrologic Soil Group (A, B, C, or D) and the land cover type and condition (e.g., straight row crops with little residue, forest in good condition, open space/lawn). Development increases the CN by changing site conditions (i.e., compacting the soil and clearing the land) and most importantly by adding impervious surfaces.

Many of the Conservation Design Approaches and Practices discussed have the specific aim of reducing the Curve Number, and keeping it as close to the predevelopment number as possible. This is accomplished by reducing site imperviousness and site disturbance. These measures can considerably reduce the amount of runoff generated and thus reduce the mitigative/storage/detention need.

Techniques such as clustering and reduction in setbacks, road widths and driveway lengths can significantly reduce the amount of site imperviousness, as the case studies in Chapter 5 will illustrate. Impervious surfaces have a very high CN (98) and generate a significant amount of runoff. Minimizing these areas helps keep the overall site Curve Number closer to the predevelopment condition. To take advantage of the reduction in imperviousness that occurs as a result of Conservation Design, it is necessary to separate these surfaces when calculating the weighted Curve Number for a site. The assumptions used by NRCS in generating Curve Numbers and impervious percentages for developed areas may no longer hold true. For example, NRCS assumes 25% impervious coverage for 1/2 acre residential districts. If the building plan is altered or the setback and driveway length reduced, the impervious coverage may be less than 25%. For this reason, new categories (and new weighted Curve Numbers) must be generated based on the new conditions, or the amount of impervious surface for a site must be measured separately to get the most TR-55 benefit from Conservation Design.

Site disturbance affects stormwater runoff as well. In the case studies to follow, the Hydrologic Soil Group for all soils in disturbed areas was lowered one category to reflect the compaction that occurs during disturbance (e.g., an A soil becomes a B soil when disturbed). This increases the Curve Number even if the land cover does not change (which it usually does in disturbed areas). Conservation Design advocates minimizing these disturbed areas by setting strict limits of disturbance both for the entire site and on individual lots. Clustering lots, providing as much open space as possible, and retaining as much of the original site vegetation as possible, especially if woodlands and meadows are present, all significantly help reduce the impact of disturbance on any given site. When areas are left undisturbed with the original vegetation in place, Curve Numbers will invariably more closely approach the predevelopment condition.

Clustering lots, providing as much open space as possible, and retaining as much of the original site vegetation as possible, especially if woodlands and meadows are present, all significantly help reduce the impact of disturbance on any given site. When areas are left undisturbed with the original vegetation in place, Curve Numbers will invariably more closely approach the predevelopment condition.

Curve Numbers can also be reduced by reforestation/revegetation. Open space areas and even portions of individual lots may be reforested or revegetated as part of the site landscaping plan to both reduce the amount of stormwater generated and help mitigate the runoff that is created. Although it may take considerable time for reforested areas to actually become forests, they will still provide stormwater reduction especially if care is taken to plant a hearty ground cover. In the case studies, any areas that were reforested were assigned the Curve Number associated with a poor woods land cover condition for all calculations. In some cases this may be a conservative approach depending on the size of the trees planted and the ground cover condition. If a thick ground cover exists or is allowed to develop quickly (such as a meadow condition) the actual

Curve Number can be expected to be lower than that for poor woods.

The Conservation Design *Approaches* have the most significant impact on Curve Numbers. This is one of the main reasons stormwater calculations must be considered throughout the entire planning process. Decisions made early in the site planning process have significant effects on the final site Curve Number and thus the amount of stormwater generated.

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Time of Concentration: The time of concentration relates directly to the peak stormflow rate. Many factors affect the time it takes water to move through a site to a point of discharge including the initial amount of water (determined by the Curve Number), routing of the stormwater, and the surface the water passes over (grass, meadow, woods, concrete). All of these factors are important considerations in the Conservation Design procedure.

As discussed above, keeping the Curve Number as close to the predevelopment value as possible significantly aids in reducing the amount of stormwater generated. The less stormwater generated, the less need for mitigation.

The stormwater that is generated however, must be routed through the site to avoid flooding roads, houses and other important features. The longer the route, the longer the time it takes water to reach a discharge point. Conventional development plans often shorten the water routes through a site with piping and curb and gutter systems. Shortening the route increases the peak discharge. In Conservation Design these routes are kept as long as possible attempting to reflect the predevelopment flow paths. A longer path often will lower the peak rate of discharge.

Just as important as the route the water takes is the surface over which it flows. Vegetated surfaces slow water and may also infiltrate water and have water quality benefits, if designed properly. This is especially true during the smaller, most frequently occurring storms (such as the one year or less storms). The use of vegetated swales rather than paved channels can significantly increase the time of concentration, by both elongating the route and increasing the resistance of the surface (in channel flow this equates to increasing Manning's n). Conservation Design Practices such as swales, berms and filter strips can be used to reduce the time of concentration for particular flow paths and thus reduce the overall site peak rates of discharge for given design storms.

Curve numbers and time of concentration are the two major factors in determining the peak rate of discharge from a site and thus compliance of a site plan with current regulation. The above discussion addresses the ways in which Conservation Design Approaches and Practices can be used to meet the state criteria. However, these calculations do not fully reflect all the environmental and ecological benefits provided by Conservation Design. These benefits are discussed throughout the manual and need to be considered in the greater context of regional planning and the effects of development on the watershed and the ecosystem. To fully understand and fully quantify all the benefits achieved in using Conservation Design a new method of stormwater runoff calculation is needed.

Selection of Additional Stormwater Controls: If Conservation Design Has Not Fully Met All Stormwater Requirements, What Additional Requirements Must Be Provided?

Discussion: This final Step (Figure 4-10) in the Conservation Design Procedure in the ideal should not be necessary. In most cases, the goal is to make any sort of conventional structure unnecessary, although this might not be feasible in all cases. In most cases, the unmet management need will focus on satisfying peak rate control requirements for the larger storms (especially an issue north of the C&D Canal), such that some sort of detention basin would be most cost effective. However, these facilities will most likely be significantly smaller than with a conventional design and thus require less maintenance and land area. Certainly other types of structures such as infiltration trenches and basins also would be possibilities.

In most cases, the goal is to make any sort of conventional structure unnecessary, although this might not be feasible in all cases.

Figure 4-10
Additional Stormwater Controls

- Can unpreventable Stormwater be effectively mitigated
- How large do mitigative practices need to be
- If necessary, how large does detention basin need to be and what is desired routing

Chapter 5

Conservation Design Case Study Analysis

Conservation Design Approaches and Practices were presented and discussed in Chapter 3. A Conservation Design Procedure was established in Chapter 4, describing how to apply Chapter 3 Approaches and Practices. Chapter 5 is designed to illustrate through real world case study analysis how Conservation Design can be applied. The purpose of this chapter is to reinforce the instructions provided in the prior chapters and demonstrate how the Conservation Design Procedure can be made to happen successfully. It should be stressed that every bit as important as the results of the Conservation Design Procedure, however, is the learning of the process which needs to be undertaken in order to create these successful Conservation Design results.

Case studies have been defined as real world sites with real world development proposals, including conventional stormwater management designs. Some of the case studies have been constructed or are being constructed; others have not. Case study selection was undertaken by DNREC project managers and their consultant, the Brandywine Conservancy. Case studies were selected to provide a range of conditions, a range of site factors such as geomorphological conditions, watershed setting, and so forth, as well as a range of development context types, including both higher and lower densities. Case study selection factors included:

- Both Piedmont and Coastal Plain locations
- Locations in each of the three Delaware counties
- Locations with a range of soils types (i.e., both good and poor drainage)
- Locations with wetlands, floodplains, riparian buffers, other critical site features
- Locations with both lower density and higher density residential uses.

All case studies involved residential development proposals. Conservation Design certainly can be applied to nonresidential developments. Institutional uses, office parks, even shopping centers and other retail uses can integrate many Conservation Design Approaches and Practices successfully. Nevertheless, nonresidential applications tend to be more challenging, as impervious areas increase in size and extent, resulting in large increases in volumes and flows of stormwater. For the purpose of the case study evaluations here, however, the focus is exclusively on residential development, which happens to comprise the vast bulk of development proposals received and reviewed by DNREC and the three counties.

In some cases, sites have public water and sewer already provided; in other cases, onsite systems are assumed for Conventional Development, though not necessarily assumed for Conservation Design alternatives. Lack of centralized wastewater treatment facilities, however, has not necessarily been assumed to be a constraint on Conservation Design concepts. For example, where provision for a centralized sewer and water systems is integral to the Conservation Design, as in the Chapel Run Case Study 1, preliminary reconnaissance was given to this sewering need issue in order to assess the plan's overall feasibility.

A very important assumption in the case studies was that the building program count of dwelling units will not change as Conservation Design alternatives are developed. Although reduction in the building program is presented as a Conservation Design Approach itself back in Chapter 3, it is most instructive and beneficial to hold the building programs constant for all case studies, in order to make the testing and comparisons more rigorous and meaningful. The intent here is to demonstrate that Conservation Design is no "pie in the sky concept" and can peacefully—and profitably—coexist with levels of development occurring today.

In some cases the type of dwelling unit being proposed has been altered, which might have ramifications in terms of compatibility with local zoning (variances, zoning changes, other waivers might be necessary). Of importance here is the demonstration to state, county, and local officials that **flexibility in terms of type of dwelling can be extremely beneficial in decreasing stormwater and environmental impacts** (e.g., in the Buckingham Greene Case Study, holding density constant but moving to single-family detached "courtyard clusters" from conventional single-family dwellings resulted in a very significant reduction in environmental impacts at the site). Densities could even be increased, and environmental impacts of Conventional Development could be reduced!

A case study outline has been followed in the discussion below which reflects the Conservation Design Procedure as closely as possible. A variety of statistics have been developed for each case study, providing information relating directly and indirectly to stormwater management. Curve Number, total runoff volumes, peak runoff rates all have been developed, consistent with the TR-55 Soil Cover Complex Method methodology established by the USDA-NRCS (formerly SCS) and used by DNREC, consistent with State regulations, as well as most county permitting and reviewing agencies. In order not to belabor the case study discussions, more detailed information has been excerpted and included in appendix form in this Manual.

The caveat must be made that detailed engineering has not been undertaken for any of the case studies. Nor are detailed calculations developed and refined, given the project constraints. **The objective here was to perform calculations adequate to determine the basic feasibility of the Conservation Design Approaches and Practices being recommended.** Similarly, the discussion of costs should be understood to be approximate.

Also, it is important to note that a variety of assumptions had to be made in order to apply conventional stormwater methods. Effort was made to make these assumptions conservatively. For example, in all areas where disturbance was occurring, Hydrologic Soil Group ratings were dropped a level (i.e., A went to B, B went to C, and so forth) in order to take into account the problem of soil compaction which can be so limiting for any type of infiltration device. **Even more important, no effort was made as part of the peak discharge rate calculations to take into account infiltration occurring in the Conservation Designs. In reality, we would expect considerable volumes of stormwater to be infiltrated, further lowering peak discharge rates.**

Last and far from least, the one topic which has been included in these case study analyses but which is not normally part of stormwater regulations is the water budgeting analysis discussion. DNREC's use of the Brandywine Conservancy for this project was to some extent based on Brandywine's development of a unique water budgeting model, WATBUG, the technical engine upon which the Conservancy's innovative Water Based Land Use Regulation program is based. Harkening back to the discussion in Chapter 1, water budget issues which go beyond stormwater runoff—issue which get at volume of recharge maintained in order to replenish aquifers, maintain the water table, provide critical stream baseflow—all are critical. These issues bear close relationship to stormwater. Only that precipitation which does not runoff and become stormwater can be infiltrated and ultimately become recharge. Because of the importance of these water budget issues and the initial realization by DNREC that Conservation Design Approaches and Practices have the remarkable ability to both significantly reduce runoff as well as promote infiltration and recharge, the water budgeting model has been applied to further document the benefits of Conservation Design.

As part of the Conservancy's application of this water budgeting model to each of the case studies, the WATBUG model first evaluates critical water budget values before development, then assesses water budget impacts of conventional development, and finally evaluates water budget impacts of the Conservation Design alternatives. Although water budget results from predevelopment to post-development with Conservation Design are never going to be in perfect balance—development even with Conservation Design will result in some reductions to infiltration and recharge. The important comparison is between Conservation Design and Conventional Development. **As results presented here indicate, Conservation Design manages to make significant reductions in losses in recharge which otherwise would occur with Conventional Development.** This avoidance of/reduction in negative impact is important to keep in mind when weighing the benefits of Conservation Design Approaches and Practices.

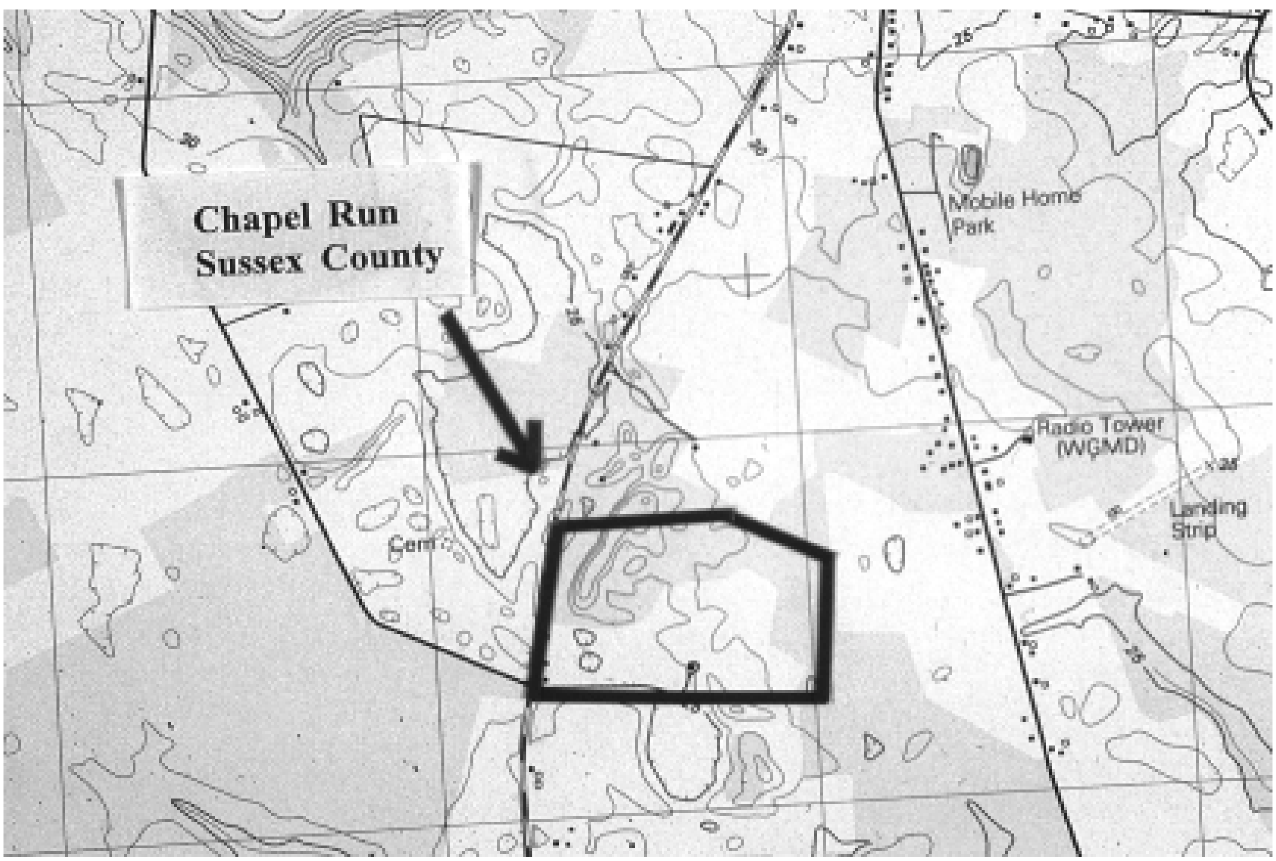
CONSERVATION DESIGN CASE STUDIES 1 AND 2: CHAPEL RUN

I. SITE ANALYSIS

Site Background

The Chapel Run case study is located in Sussex County, DE, not far from Rehoboth Bay as indicated on the USGS quadrangle for Fairmount, DE, Figure 5-1. This 96-acre site is in a rural area, several miles to the southwest of Belltown with about 2,000 feet of rural road frontage. In the new Sussex County Comprehensive Plan, the site is categorized as "Agricultural Residential" where agriculture is intended as the primary use, although low density residential is also permitted. In general, utilities are to be handled onsite in this category, although in some cases centralized water and sewer are provided. In reality, there are no centralized facilities serving the site at present. The site is adjacent to a large zone of "Agricultural Protection" immediately to the west, underscoring its rural nature.

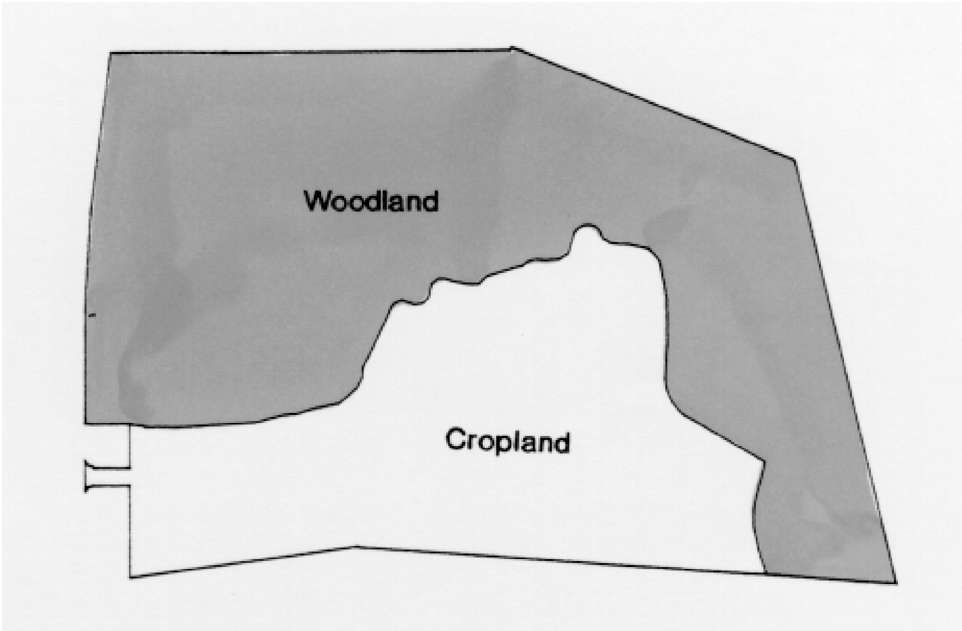
Figure 5-1
Chapel Run Quadrangle Map



Site Characteristics

Vegetation: Two different landcover types are present at this site: woodlands and cultivated crops. About 55 acres of high quality woodland occupy the northern portion of the site. The woodlands form a large contiguous stand along the northern, eastern and western borders of the site and become an

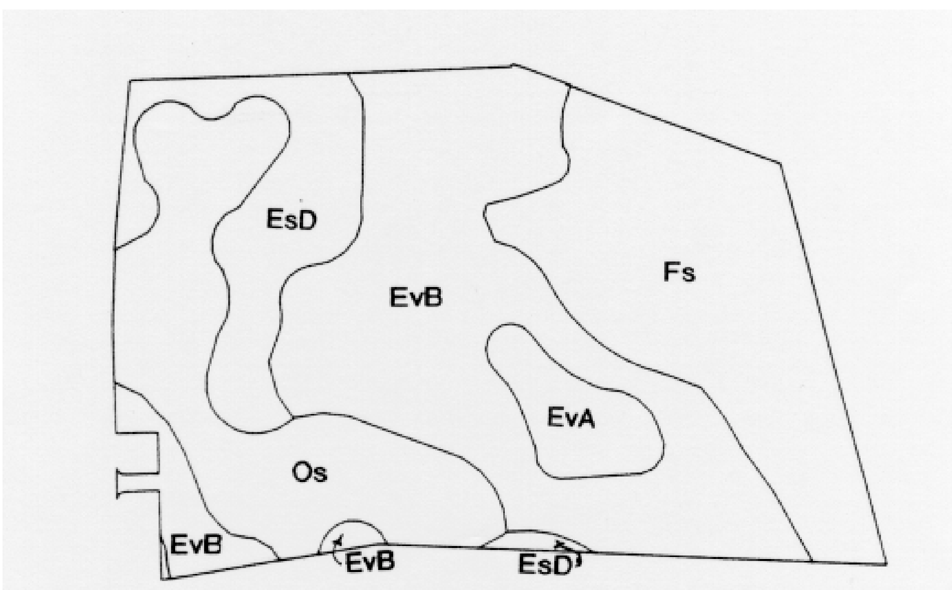
Figure 5-2
Predevelopment Land Cover



outstanding feature of the property. The southern portion of the site (approximately 41 acres) is cropland, as indicated in Figure 5-2.

Soils: The soils on this site are highly varied and offer decided differences in terms of their ramifications for stormwater management (i.e., their ability to infiltrate stormwater). Most of the site is Evesboro (Ev) soil, with the highest Hydrologic Soil Group (A) rating. Fallsington (Fa) and Osier (Os) soils are also present, both Hydrologic Soil Group D (worst rating). A small section of Woodstown soil is located in the southeastern corner of the site (Hydrologic Soil Group C). Figure 5-3 shows the distribution of the soils throughout the site.

Figure 5-3
Soils Distribution



Hydrology and Stormwater Recharge: Predevelopment surface water movement is determined by the topography, vegetative cover, and ability of the soil to infiltrate surface water. Figure 5-4 shows the natural drainage basins of this site. There are no perennial streams located on the property, although intermittent swales/drainageways do exist. Zones of high recharge, as analyzed by the Brandywine Conservancy's climatic water budgeting model, are designated in Figure 5-5. These high recharge areas are characterized by a combination of soils (the rapidly draining Evesboro) and land cover (the dense, mature woodlands) conditions.

Site Critical Features: The woodlands on this site constitute the major sensitive area needing protection. In the northeastern portion of the site, there is a small area that contains steep slopes. In addition to not having perennial streams on this property, there are no floodplains, wetlands, or sensitive

Figure 5-4
Natural Drainage Basins

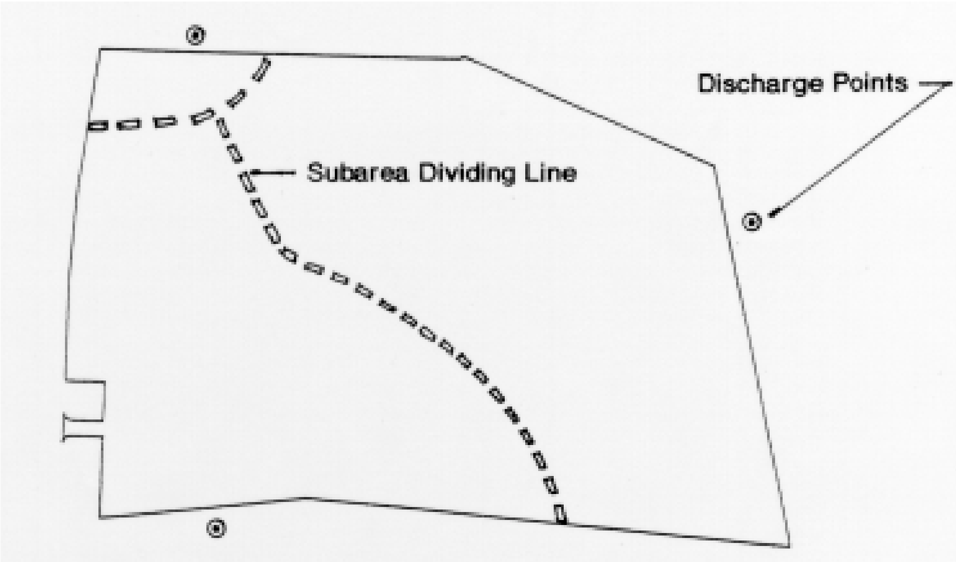
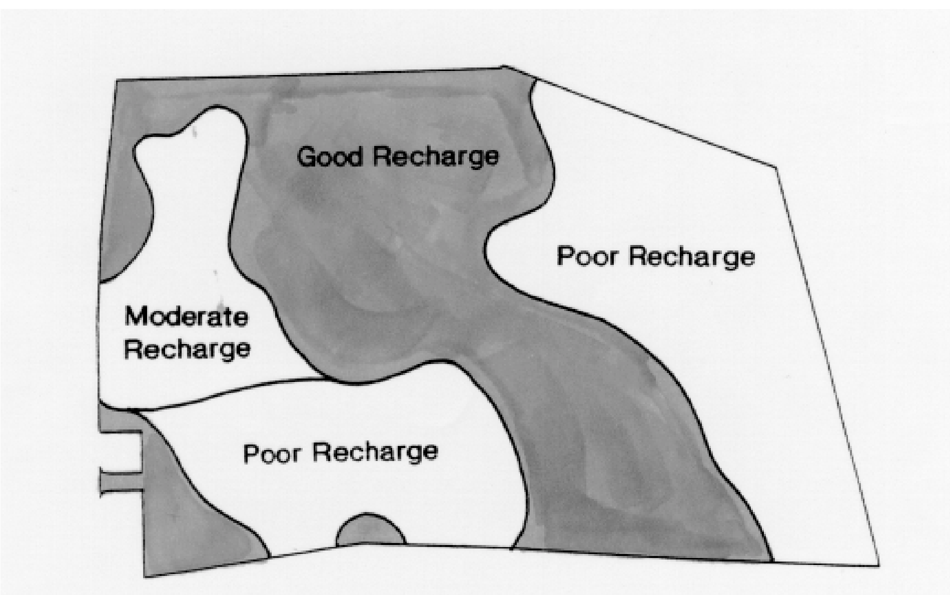


Figure 5-5
Zones of High Recharge



riparian zones present.

Site Constraints and Opportunities: The woodlands, especially those on well-drained soils, not only are critical site features, but also provide a unique opportunity for stormwater management if handled carefully. If left undisturbed, woodland areas reduce, if not eliminate, the generation of stormwater runoff. Secondly, woodlands provide an opportunity for the natural recharge of runoff created in other disturbed and developed areas of the site, if this runoff can be broadly distributed across the woodland floor. Maintaining the woodlands also provides significant water quality as well as overall ecosystem benefits, as per the discussions in Chapter 2.

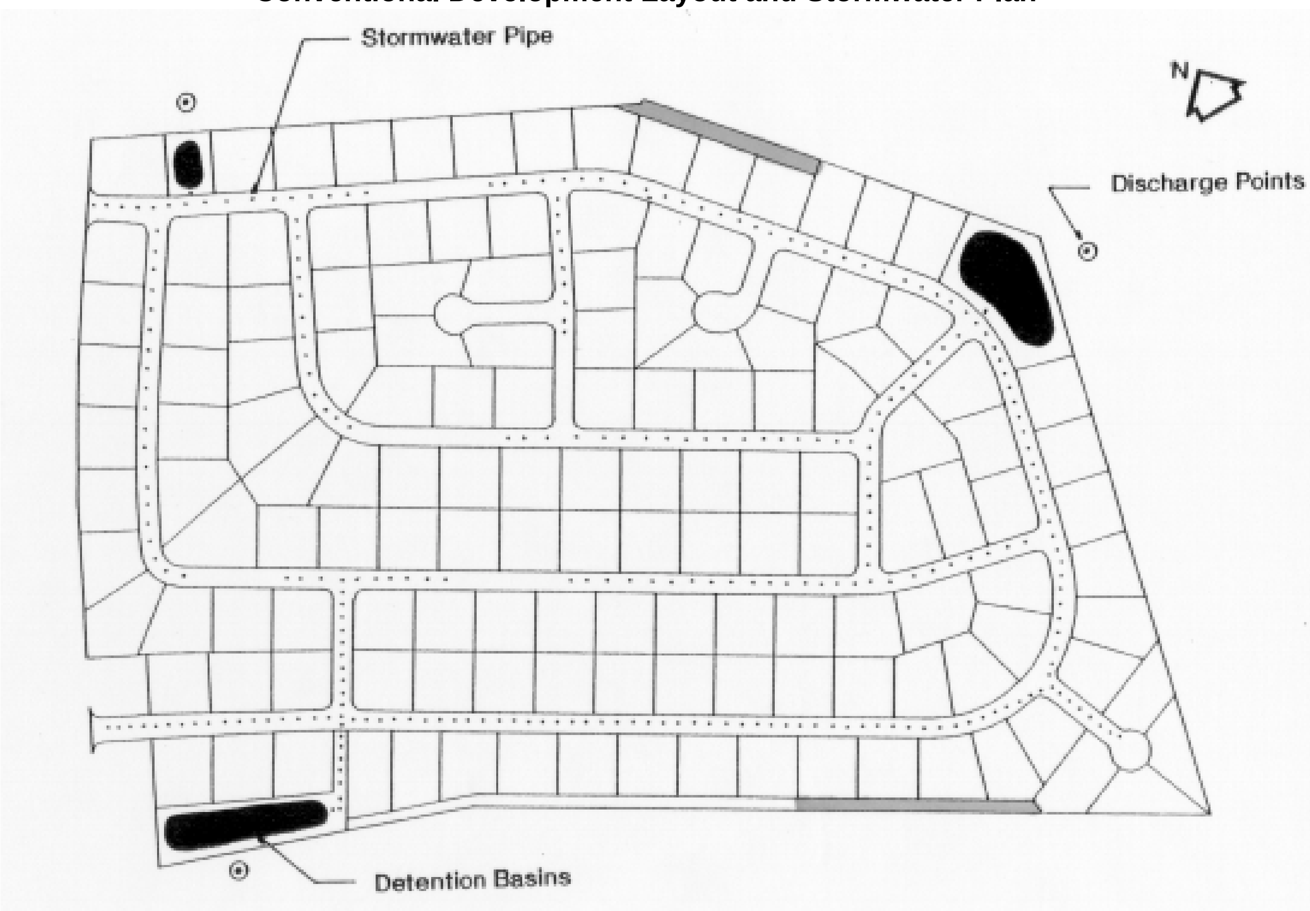
The soils with good permeability ratings also provide stormwater opportunities. Because the Evesboro soils infiltrate quite well, Conservation Design strives to take advantage of these soils by incorporating infiltration-oriented management techniques into the stormwater plan where such soils are present. Conversely, the poorly draining soils (Fallsington and Osier) do not offer much stormwater infiltration opportunity. Because of this, it makes sense to concentrate site disturbance in these poorly draining areas and use the most permeable soils for stormwater management.

II. PROPOSED CONVENTIONAL DEVELOPMENT

The proposed Conventional Development plan divides the 96-acre site into 142 half-acre lots, pursuant to local zoning, in a manner that is totally insensitive to woodlands, soils, or any other site feature. The site is totally disturbed. Onsite water and sewer are assumed, somewhat surprising at this half-acre density (we would expect septic systems at this density with these rapidly draining soils plus the inevitable lawn fertilization to create the substantial likelihood of nitrogen mounding and other groundwater problems over time). The site plan clears and grades virtually all of the property. No zones of undisturbed area remain. No zones of open space remain.

The proposed Conventional lot layout and stormwater management plan, including two stormwater management basins, are shown in Figure 5-6. An extensive road system totalling 13,388 feet is needed to serve the subdivision. Conventional road widths are assumed. Conventional Development results in an overall site imperviousness of 29 percent. It is assumed that the design includes a curb/gutter system with inlets to underground piping for stormwater conveyance to the two proposed stormwater detention basins.

Figure 5-6
Conventional Development Layout and Stormwater Plan

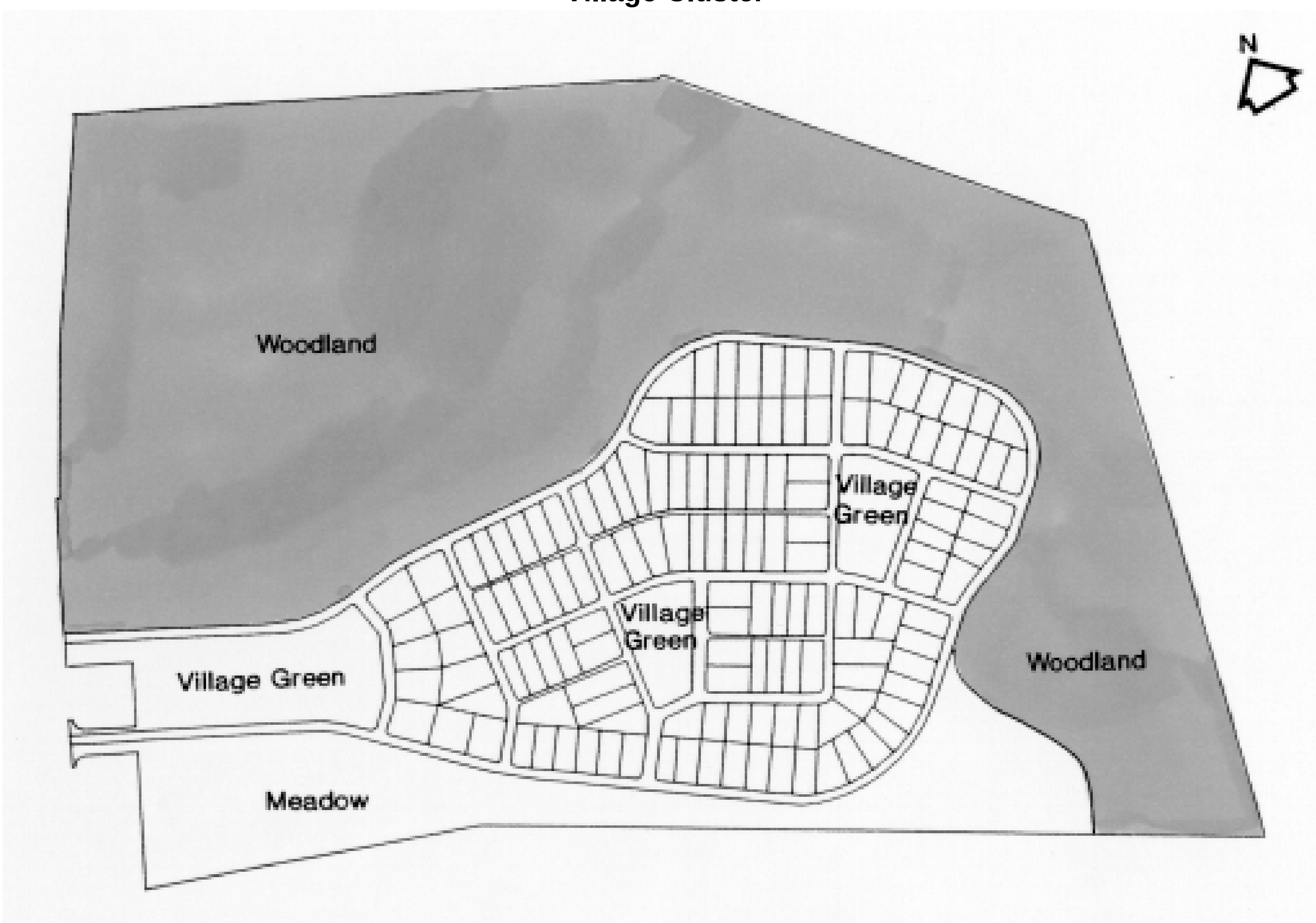


III. CONSERVATION DESIGN ALTERNATIVES

Case Study 1 : Village Cluster

Building Program: The principles of Conservation Design inspired two quite distinct case adaptations for Chapel Run. In an attempt to minimize site disturbance to the greatest extent possible, Case Study 1 reduces lot size from the 1/2-acre Conventional lot layout to an 1/8th-acre, village-like cluster, Figure 5-7. Of all of the Case Studies presented, Case Study 1 offers the most powerful evidence of the positive effects of lot size reduction. The lot sizes and building types have been altered to fit this more dense village pattern; however, the number of lots and house square footage have remained constant. This type of development, often dubbed a “neo-traditional” pattern, involves reduced setbacks, use of front porches, side-loaded garages, and in some cases alleys, in patterns that are being constructed now throughout the country with positive market response. These lot sizes will accommodate residences with approximately the same square footage as the Conventional Development design; however, the look of the Village Cluster is quite different. It would be expected that the prices of the dwellings in both cases would be roughly comparable, the difference in lot size notwithstanding.

Figure 5-7
Village Cluster



We do acknowledge that this Village Cluster concept in rural Sussex County may simply be too “unconventional” for this particular market—and many developers. Furthermore, one must ask whether a development such as the Village Cluster makes sense next to agricultural areas (as indicated above, adjacent land uses have not been addressed nor their zoning or any other broader planning issues). However, it is expected that other sites similar to this one will be developed where such higher densities would be appropriate. The objective of the case study is to make clear just how great the benefit from this Approach to Conservation Design can be.

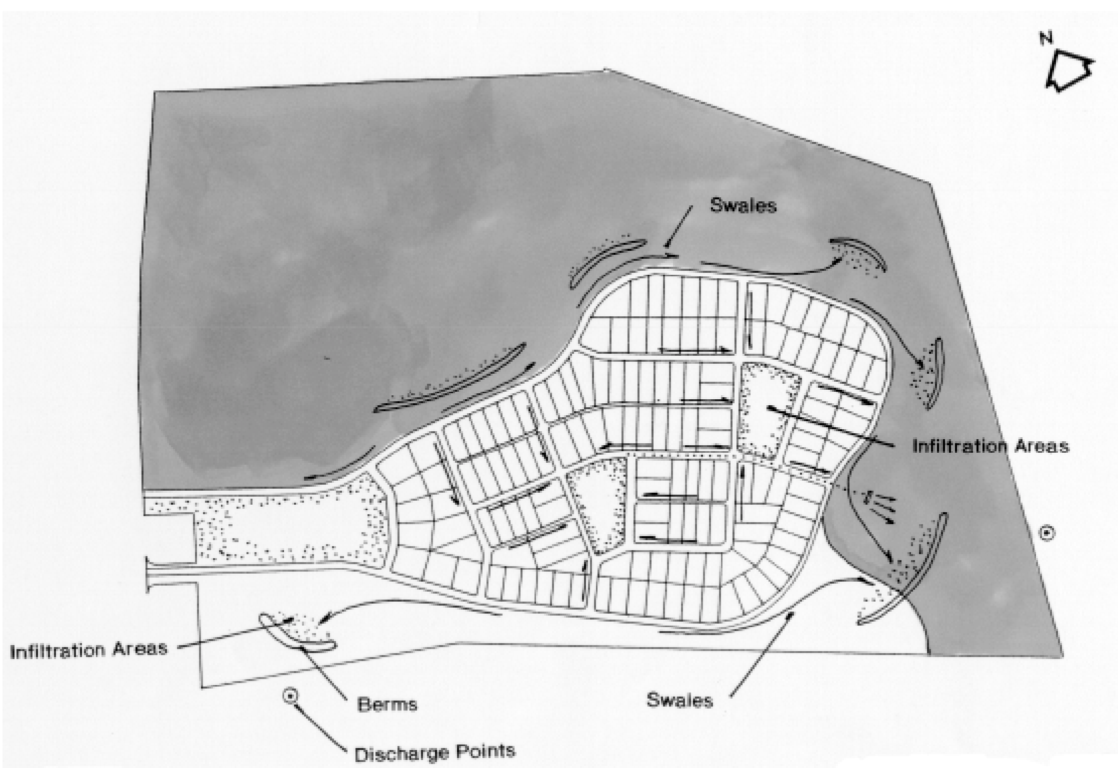
Lot Configuration: Case Study 1 Village Cluster alternative concentrates development in the open meadow portion of the site in an attempt to avoid the sensitive woodlands, especially those with good soils. With Conservation Design, this site maintains 69.9 acres or 72.7 percent of the site as open space—a remarkable achievement when contrasted with the virtual elimination of open space under Conventional Development. In addition, areas of high recharge within the center of the Village have been designated as two village greens (roughly 1.5 acres each). These small parks serve both recreational and stormwater functions, as described below. The formal entrance boulevard provides a site for a community wastewater treatment system (lagoons) with spraying of treated effluent to occur in the preserved woodlands.

Impervious Coverage: By concentrating development, reducing average street widths from 28 ft to 20 ft, and sharing drives where appropriate, the Village Cluster alternative achieves an impervious coverage of 17.7 percent (a 38 percent reduction in impervious surface from the Conventional Development). The total road length was reduced by 1,560 feet to 11,828.

Minimum Disturbance: As described above, by reducing lot size and concentrating these lots, a large portion of the site can remain undisturbed; 67.5 percent of the site or 64.8 acres (note that open space area does not equate with undisturbed area; some disturbed areas will become park open space areas). For the stormwater calculations, the entire development zone has been categorized as disturbed because of the concentrated building pattern. The Hydrologic Soil Group rating has been reduced one grade level for this zone.

Mitigation Practices: To manage the stormwater runoff which is created from the proposed Village Cluster, pursuant to state requirements, the Village Cluster alternative directs stormwater into two primary outflow points, utilizing the natural hydrology of the site to the maximum extent possible. Stormwater is conveyed through a vegetated swale system along the roadways. The swale system leads to several retention/infiltration receiving areas located throughout the development, Figure 5-8. These retention/infiltration receiving areas consist of level spreading devices with subtle berms. These berms are carefully constructed in the undisturbed forested zones having good soils (and therefore significant infiltration potential), as well as in the village greens which are designed to retain stormwater up to the ten

Figure 5-8
Stormwater Mitigation Plan



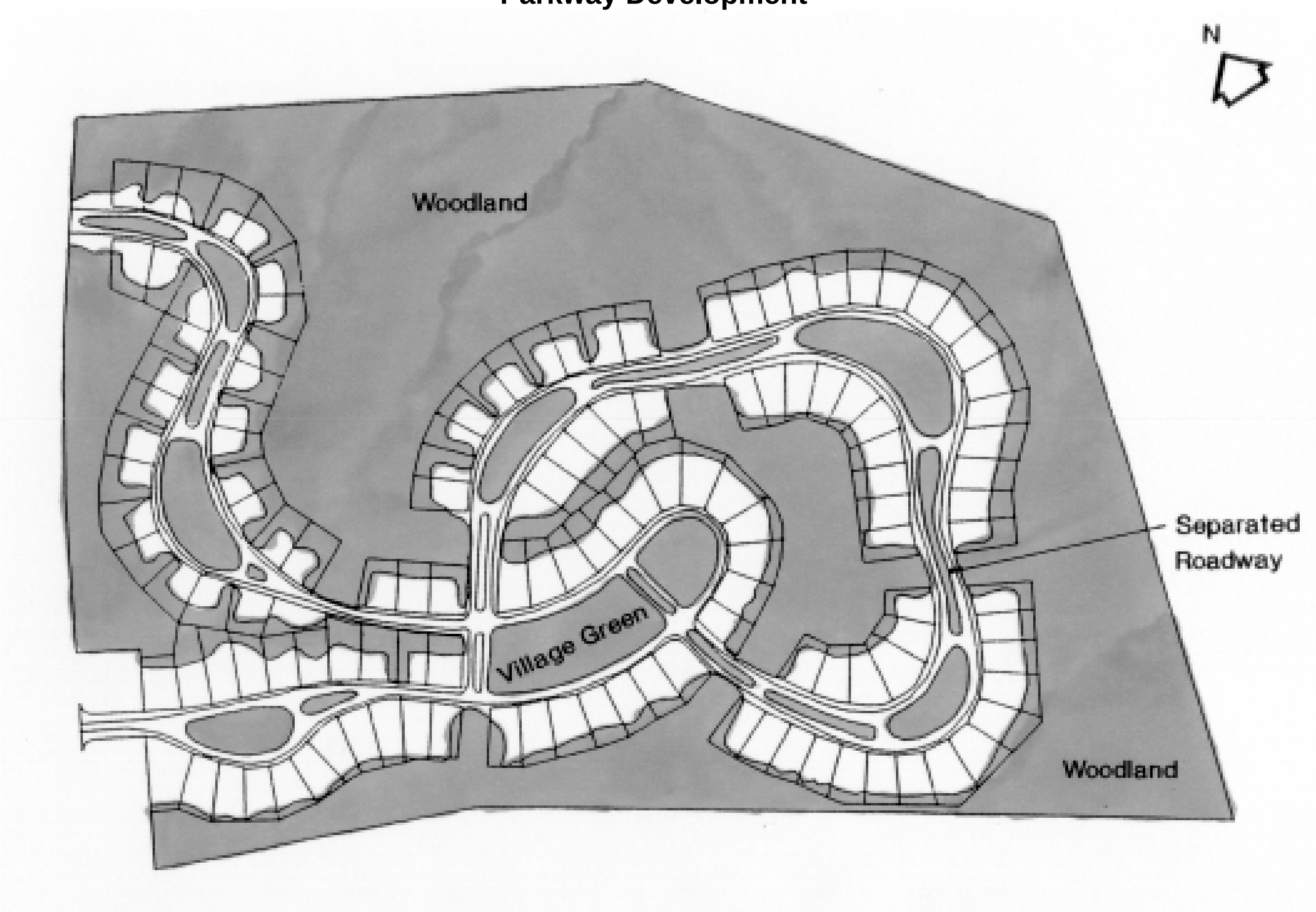
year storm. Some swales also discharge to meadows with good soils.

It also should be noted that the system of subtle berming constructed on the periphery of the development in the existing forested areas and meadows also could be integrated quite easily into a passive trail system for Chapel Run residents. Berm construction can be readily and inexpensively adapted to trail development (trail is simply placed on top of the berm). This Practice could have broad applicability in developments across Delaware and would add only marginally to total costs (it has not been formally included in this Case Study).

Case Study 2 : Parkway

Building Program: The Parkway alternative illustrates a significantly different approach to Conservation Design. This site design integrates the stormwater management system into the roadway infrastructure system, emphasizing the "woodland" theme in as many locations as possible, Figure 5-9. The original Conventional Development building program has been adjusted reducing lot sizes from the 1/2-acre Conventional to 1/4-acre. The size and number of dwellings has not been altered nor has the building type. The reduction in lot sizes still allows for a substantial reduction in overall disturbance of sensitive woodland areas, however, when compared with Conventional Development. This design also results in reduced impervious coverage.

Figure 5-9
Parkway Development



Lot Configuration: The Parkway alternative is intended to enhance the woodland sense throughout the development. The lots have been configured along a modestly elevated lane-separated roadway system that curves throughout the development. Each separated cartway within the parkway will be one-way, which will permit a minimum width of 12 feet of pavement. This parkway can be sensitively designed so as to minimally disturb the sensitive forested area, where woodlands already exist (carefully defined limits for vegetation disturbance/tree removal will be flagged in the field). Where woodlands are not extant, reforestation/revegetation will occur in the parkway center. In terms of stormwater management, stormwater from the roadways and in some cases even the adjacent dwellings will be directed into the parkway center, which will function to collect, store and infiltrate stormwater. It is important to note that the forested parkway concept is intended to become a unifying theme of the entire development, integrating the notion of the woodlands being preserved more directly into each individual lot. Quality of life as reflected ultimately in values of the dwellings themselves will be enhanced, in contrast to the Conventional Development with its monotonous and unaesthetic grid of lots.

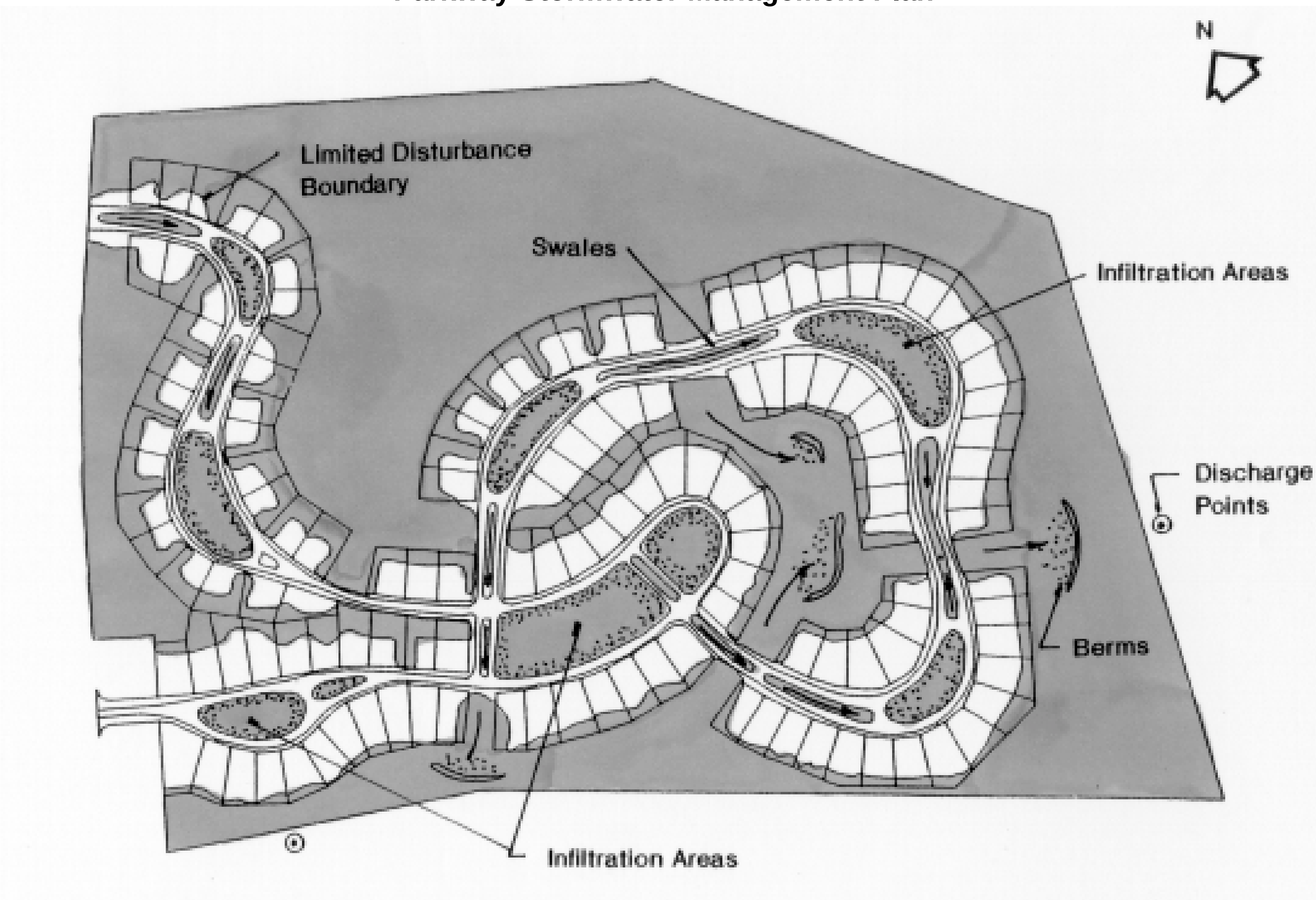
Overall, this design contains 47.8 acres of open space, or 49.7 percent of the total site. The six largest parkway center infiltration areas comprise roughly 5.8 percent of this open space. The parkway has been designed to fit within the natural drainage of the site, which permits a positive stormwater flow throughout the system. Finally, a large 2.3 acre park is located at the center of the community, offering recreation, stormwater management, and aesthetic benefits to the community.

Impervious Coverage: By reducing road lengths and widths, minimizing setbacks, and sharing driveways, the total impervious coverage in Case Study 2 has been reduced to 14.9 percent, a 48 percent reduction from Conventional Development and actually less than Case Study 1 as well. Although a separated parkway increases impervious slightly over a non-separated system, parkways do not require curbing and offer an interesting opportunity for stormwater mitigation (in fact, although this parkway concept is presented here as a variation on the theme of several Conservation Design Approaches and Practices such as Minimum Disturbance/Maintenance, Use of Natural Areas, and Berms/Terraforming, treating it as a Practice unto itself might make sense). Setbacks of dwellings have also been reduced so that driveways can be shortened. In many cases, driveways on adjacent lots have been designed as shared driveways, half on each lot, reducing impervious cover and costs significantly.

Minimum Disturbance: The goal in designing and constructing the parkway is to disturb as little of the existing woodland cover as possible, both in the parkway center areas as well as in the larger open spaces. This will provide a continuous theme of a green parkway threading throughout the development, both maintaining areas of existing recharge as well as creating opportunities for the recharge of stormwater generated elsewhere. In addition, because of the shared driveways and larger 1/4-acre lot size, the houses can be sensitively placed so as to minimize the soil disturbance on each lot through the Minimum Disturbance/Maintenance footprinting techniques described in Chapter 3. The total undisturbed area is 59.6 percent of the site, or 57.3 acres.

Mitigation Practices: As described above, the Parkway alternative integrates stormwater management early on in the site design process, Figure 5-10. The parkways are designed to mitigate stormwater as close to the source as possible in a "pay-as-you-go" fashion. The larger oval parkway centers are designed as de facto depressions of up to 2 feet in depth that can retain an average of 45,000 cubic feet of water during the largest storms. These depressions are created by the parkway construction itself (i.e., the slightly elevated roadway), such that the surface of the infiltration bed depressions is simply the natural and undisturbed vegetated surface. Where trees exist, trees are retained; if trees do not exist, they are planted. Although the calculations below do not reflect the infiltration potential of these areas, it is assumed that these vegetated areas will serve both water quality and quantity (infiltration) functions. In the narrower portions of the parkway system, these central areas are vegetated swales that convey the stormwater from the road and houses to these larger vegetated infiltration areas; some infiltration can be

Figure 5-10
Parkway Stormwater Management Plan



expected to occur in these areas as well. The mitigation system is designed with overflow piping in several locations to discharge the 100 year or greater storm and not flood the neighboring dwellings. Because the mitigation areas are proposed in community open space (rather than on private property), the management of the system becomes the responsibility of the homeowners' association or a contracted management agency, thus maintaining its long-term effectiveness.

IV. STORMWATER CALCULATIONS

Curve Number Calculations for Case Studies 1 and 2

Pursuant to state and local requirements for stormwater management, runoff volumes must be calculated, these volumes then routed or conveyed to points of discharge, and the peak rates of discharge calculated. To calculate runoff volumes, the commonly accepted method is the Soil Cover Complex or Curve Number method as set forth in TR-55 (USDA-SCS, 1986). Again, the higher the Curve Number, the greater the volume of runoff. The following Curve Numbers were computed using the USDA-NRCS (formerly SCS) Curve Number method and the TR-55 computer program:

Condition	Average Curve Number

Predevelopment	65
Conventional development	78
Conservation Design (Village)	66
Conservation Design (Parkway)	65

The lowering of the Curve Number from the Conventional Development to the Conservation Design alternatives reflects the strategies used to create these new designs.

First, overall site imperviousness was reduced significantly—by 38 percent for the 1/8th-acre lot Village Cluster alternative and 48 percent for the Parkway alternative. Because impervious surfaces have such a high Curve Number (98), reducing the area of imperviousness across the site by decreasing road widths, shortening driveways, reducing linear footage of streets, and so forth significantly reduces the overall site Curve Number. **This Curve Number reduction is an extremely important Conservation Design objective and a critical indicator of Conservation Design's overall success.**

Second, Conservation Design also strongly advocates minimizing site disturbance. The Conventional Development design requires total site clearance, replacing woodlands with pavement and lawns. The Curve Number increases dramatically. Not only is existing vegetation removed, but the soils are seriously disturbed and compacted by heavy construction equipment. Both of these practices decrease the infiltration capacity of the soils. In most cases, years are required to revegetate and restore the critical permeabilities of the soil mantle.

Conversely, both of the Conservation Design alternatives preserve a large portion of the existing woodlands. Strict limits of disturbance are established minimizing compaction of the soils. As described above, reforestation is also recommended in other areas which will be disturbed in order to restore permeabilities in the future. In parts of the southern area of the site, croplands are designated for reforestation. The Curve Number for even the poorest forest condition is lower than many of the cropland conditions. These practices lower the Curve Number by protecting as much of the site's original infiltration capacity as possible. By reforesting and revegetating portions of the site, these designs have made it possible for there to be little change in the predevelopment to post-development Curve Number.

One goal of Conservation Design is to create a stormwater management system that is as effective (or even more so) over time as it is in the initial stages.

Peak Runoff Rates

Using TR-55, the following runoff rates apply to the site.

Condition	Peak Rate (cfs - 10 year storm)
Pre-Development	79
Conservation Design (Village)	53
Conservation Design (Parkway)	51

Using Conservation Design it was possible to reduce the peak runoff rates for the 10 year storm (Chapel Run is located south of the C&D Canal) even below the predevelopment rate. The predevelopment cover condition in the southern half of the site consisted of cropland. Because of the high Curve Numbers of cropland, these areas discharge a significant amount of runoff—even before development occurs. The post-development landcover in Case Study 2 provides for revegetating/reforesting much of these areas thus reducing the amount of runoff generated.

The stormwater discharge peak rates are also reduced because the Times of Concentration of the runoff that was generated were extended as much as possible. In the Village alternative, a combination of infiltration areas (in the Village Greens) as well as berms and swales were used to slow the stormwater runoff and increase the length of the flow route, as well as infiltrate it. As explained above, the Parkway alternative used the road centers as vegetated conveyance systems and infiltration areas. Rather than collecting all the stormwater from the site in one or two large basins, both these approaches attempt to use smaller areas throughout the site to retain and infiltrate the water as well as convey it in vegetated channels. Using these smaller areas, however, requires dividing the site into numerous subareas for the TR-55 calculations. The Village alternative required 13 subareas. The Parkway design required 16 subareas. This increases the number of computations considerably, but can save time and money in the design and construction of the stormwater management facilities (i.e., through more careful and marginally more costly up front engineering, more substantial reductions in stormwater facility construction costs are achieved). Both approaches are successful in that they are able to satisfy the predevelopment to post-development peak rate control criteria without any additional detention basin facilities.

Water Budget

Annual Water Budget for Chapel Run (in gallons):

	Pre-Development	Conventional Development	Conservation Design Village	Conservation Design Parkway
Precipitation	114,082,682	114,082,682	114,082,682	114,082,682
Runoff	4,950,120	31,584,217	21,812,868	17,782,776
Recharge	40,732,744	31,280,103	34,001,079	35,502,938
Evapo-transpiration	68,408,227	51,223,261	58,208,796	60,802,278

The annual water budget for an average precipitation year shows the impacts of the different site designs in gallons over the entire site. A goal of Conservation Design is to alter site hydrology as minimally as possible, including both runoff and critical groundwater recharge. The Conservation Design alternatives approach the predevelopment levels of runoff, recharge, and evapotranspiration much more closely than the Conventional Development design. The Conservation Design alternatives generate significantly lower runoff volumes during the average year, in contrast to Conventional Development. These smaller runoff volumes mean reduced mitigation efforts are needed to satisfy the predevelopment to post-development requirement for stormwater management.

Although neither of the Conservation Design alternatives achieves predevelopment groundwater recharge levels, both are significantly better than Conventional Development. For example, the Village Cluster alternative reduces the Conventional Development recharge loss by nearly 30 percent; the Parkway alternative reduces the loss by almost half. Looking at the issue another way, the water budget model—a very conservative methodology—used by the Brandywine Conservancy indicates that Conservation Design results in a significant increase in recharge annually (10 percent or 2,720,976 gallons for the Village alternative and 13 percent or 4,222,835 gallons for the Parkway alternative), all based on Conventional Development. Nearly a quarter of the predevelopment recharge is lost by Conventional Development, and again, the conservative assumptions used in the water budget modeling make it quite likely that the losses generated by Conventional Development would be even greater, and the benefits achieved through

Conservation Design that much greater as well.

V. COSTS

In addition to the environmental and other benefits of Conservation Design, the total cost of Conservation Design often is less than that of Conventional Development. The problem here is that it is often extremely difficult to compare Conventional and Conservation Design alternatives in terms of costs because there are so many different elements which comprise Conservation Design. Comparison of the so-called stormwater systems typically makes little or no sense, because the stormwater system literally pervades the entire development in Conservation Design, such that the total development cost really becomes the valid basis for comparison. Furthermore, as discussed in Chapter 3, important cost issues exist not only for construction, but also for ongoing operation/maintenance (O&M) requirements. In most cases, Conservation Design Approaches and Practices translate into significantly reduced O&M costs, in contrast to structure-intensive conventional techniques.

Such difficulties notwithstanding, we have tried to gain some closure on costs in these Case Studies because the issue is so important. We have developed preliminary cost information and hope to be able to refine cost evaluations in the next phase of the project. Although it is difficult to pinpoint all of the costs associated with stormwater management, the array of costs in a Conventional Development plan typically includes stormwater piping, curbing, inlets, basin construction, grading and lot clearance, and other cost elements of conventional stormwater management. For Conservation Design, cost elements look quite different, including reforestation/revegetation, berm construction by highly-skilled operators, road construction and maintenance, to name a few. In this and the following case studies, we apply a variety of cost factors to roadways, swales, zones of reforestation, and bermed areas. In many cases, costs such as grading have not been taken into account, and because these costs will be much reduced in the Conservation Design alternatives, their omission serves to make our estimates quite conservative.

CONVENTIONAL DEVELOPMENT COSTS

13,388 ft of streets	@ $150/linear ft	2,008,200
3 detention ponds	@ $16,000/pond	48,000
16,000 ft of swm pipe	@ $22/linear ft	352,000
40 endwalls/inlets	@ $1,300/each	52,000
	TOTAL	**2,460,200**

CONSERVATION DESIGN COSTS: VILLAGE CASE

11,828 ft of streets	@ $85/linear ft	1,005,380
2,000 ft of swm pipe	@ $22/linear ft	44,000
5 endwalls/inlets	@ $1,300/each	6,500
1,050 ft of berms	@ $10/linear ft	10,500
22,570 ft of swales	@ $4.50/linear ft	101,565
90 check dams	@ $75/each	6,771
	TOTAL	**1,174,716**

CONSERVATION DESIGN COSTS: PARKWAY CASE

7,800 ft of streets	@ $85/linear ft	663,000
3,000 ft of swm pipe	@ $22/linear ft	66,000
10 endwalls/inlets	@ $1,300/each	13,000
100 ft of berms	@ $10/linear ft	10,000
20,600 ft of swales	@ $4.50/linear ft	92,700
82 check dams	@ $75/each	6,180
12.6 Reforestation (ac)	@ $2,925/ac	36,855
	TOTAL	**888,735**

Swales: Based on cost data listed in Chapter 3, the cost of swales is approximately $4.50 per linear foot assuming seeding and straw mulching. The total length of swales for the Case Study 1 Village design is 22,570 linear feet. At the suggested unit cost, the total cost for swales would be $101,565. The Parkway alternative has a total of 20,600 linear feet of swales, for $92,700. In Case Study 1 (as well as all subsequent Case Studies), swale design includes check dams to be located strategically (assumed here at an average of every 250 ft) in order to maximize flow retardance and infiltration. According to *Clearing and Grading Strategies for Urban Watersheds*, the cost of a check dam ranges from $50 to $100 with low maintenance costs.

Re-Forestation/Re-Vegetation: The Village has no reforestation required in the design. The Parkway has 12.6 acres of planned reforestation. At an estimated cost of $2,925 per acre of reforestation/ revegetation, the total reforestation cost for Parkways is $36,855.

Roads: The road lengths, listed earlier in this Case Study, are 11,828 linear feet for the Village alternative and 7,858 linear feet for the Parkway alternative. The average costs per linear foot of road construction is $150 for a conventional road with 30-ft width and curbing. Due to a reduced road width down to 20 feet and elimination of curbing (cost reduced to $85 per linear foot), the total cost for the roadways in Conservation Design alternatives are $1,005,380 for Village and $663,000 for Parkways.

Berms: The berms and related terraformed areas are relatively innovative techniques for stormwater management. Thus, the costs for berm construction/terraforming is estimated at $10 per linear foot. Therefore, the costs of berms/terraforming for the Village design is $10,500. The costs of berm construction/terraforming for the Parkway design is $10,000.

When considered from an individual lot perspective for 142 lots, cost per lot for conventional development is $17,325 while cost per lot using the village conservation design approach is $8,273 or $9,052 or 52% less. Considering the cluster option versus conventional development, the cluster option at $6,259 per lot is $11,066 or 64% less.

CONSERVATION DESIGN CASE STUDY 3: BUCKINGHAM GREENE

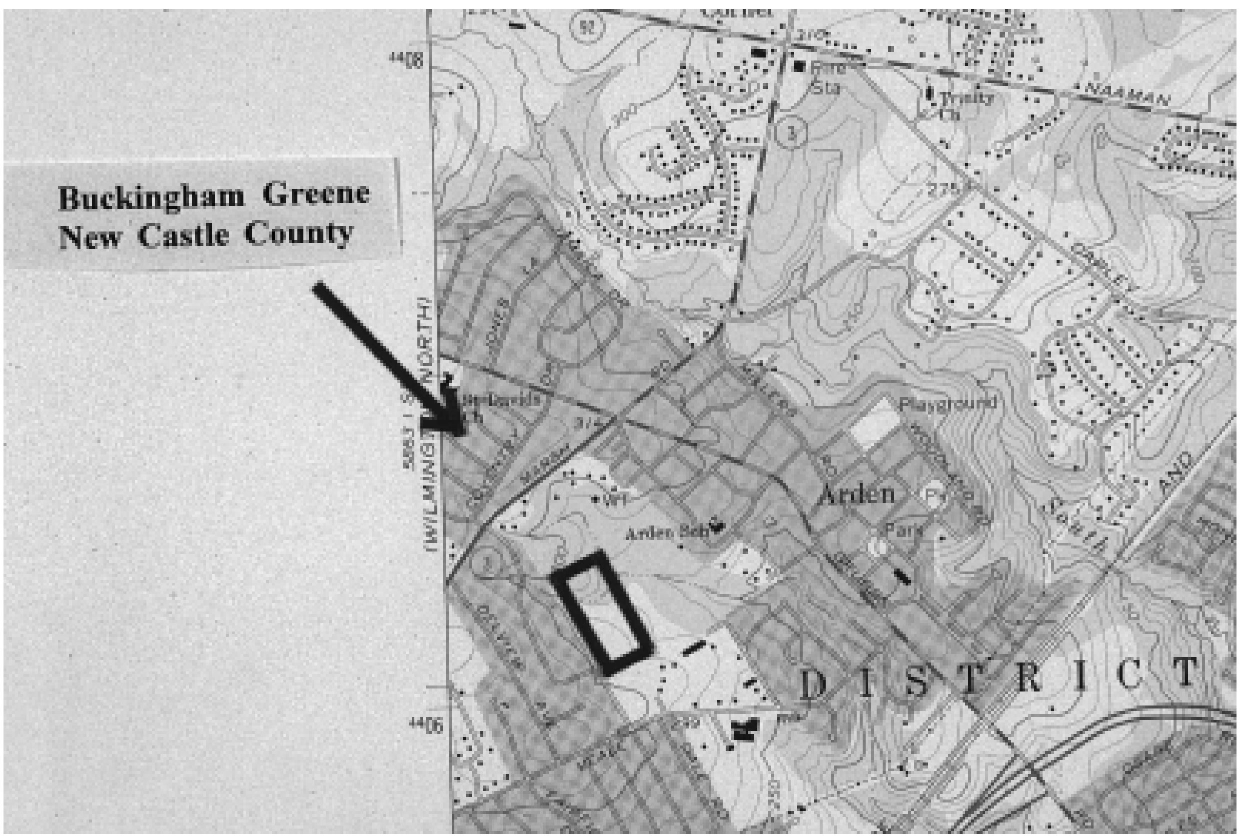
I. SITE ANALYSIS

Site Background

Buckingham Greene is located in the Brandywine Hundred of New Castle County, DE. It is located on the Marcus Hook, PA - NJ - DE USGS quadrangle, Figure 5-11. The site, zoned W-1-C, borders the community of Arden on the east, residential subdivisions to the north and has access off of Buckingham Road. The site includes about 19 acres and has been proposed for development into conventional single-family homes on small lots.

This is the only Case Study site which is found within the Piedmont Province, reflected in its rolling terrain. All other sites are within the Atlantic Coastal Province. The site is located in the Naamans Creek watershed.

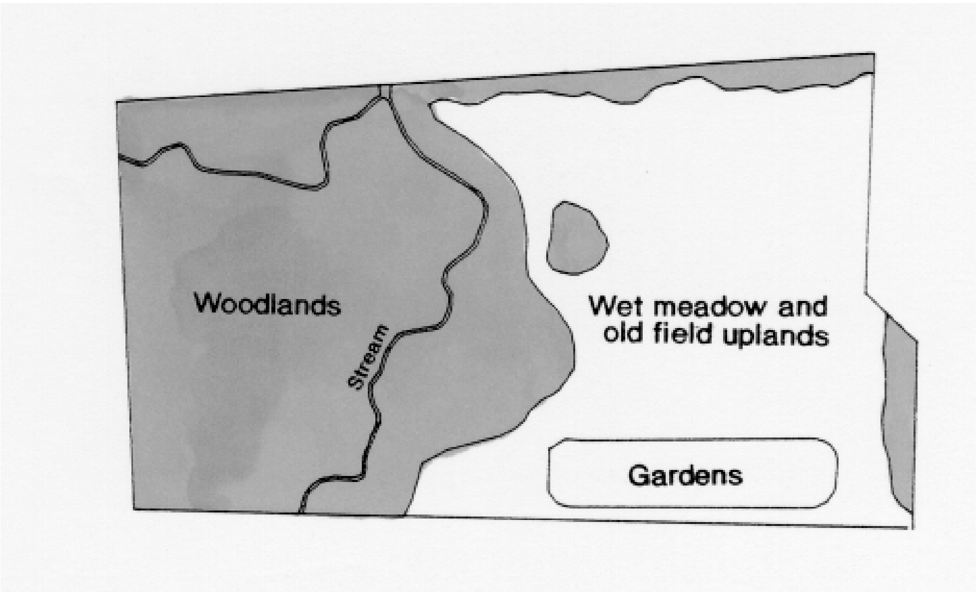
Figure 5-11
Buckingham Greene Quadrangle Map



Site Characteristics

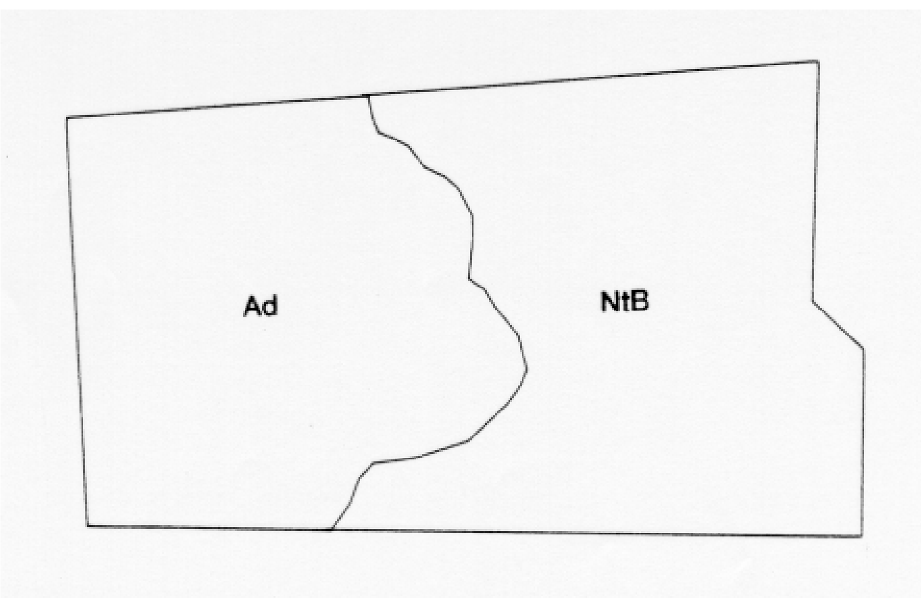
Vegetation: Predevelopment vegetation consists of mixed deciduous forests, wet meadows, and old field uplands. The forested area is located mostly in the northern half of the site encompassing a stream which runs through the property. There is also an area in the southwestern portion of the site that local residents have used for vegetable gardens, Figure 5-12.

Figure 5-12
Predevelopment Land Use



Soils: The New Castle County Soil Survey describes two soils on this property, the Neshaminy-Talleyville-Urban complex and the Aldino series, Figure 5-13. The Neshaminy-Talleyville (NtB) complex is fairly well drained, has a Hydrologic Soil Group of B, and is present in the open areas of the property. The Aldino (Ad) series is less well drained with a HSG C, and is located in the northern portion of the site underlying the forests and along the stream.

Figure 5-13
Soils Distribution



Hydrology and Stormwater Recharge: Surface water flow on this site follows the natural topography and drains into the two unnamed tributaries of Naamans Creek in the northern portion of the property and into an existing drainage ditch in the southern portion of the site, Figure 5-14. One of the stream branches enters the site from the northeast and flows south while the other tributary enters the site from the northwest and flows east across the property. The two streams join just east of the property boundary. The Naamans Creek Watershed in general has experienced significant urbanization over the years. Flooding problems have occurred prompting a variety of actions to be taken, publicly and privately. This flooding in the larger watershed most likely is related to some degree to the ineffective manner in which stormwater has been managed in the past (i.e., allowing increased volumes of stormwater to be released site-by-site as development has occurred).

Groundwater recharge on this site is affected by the soils and vegetative land cover. The southern portion

Figure 5-14
Natural Drainage Basins

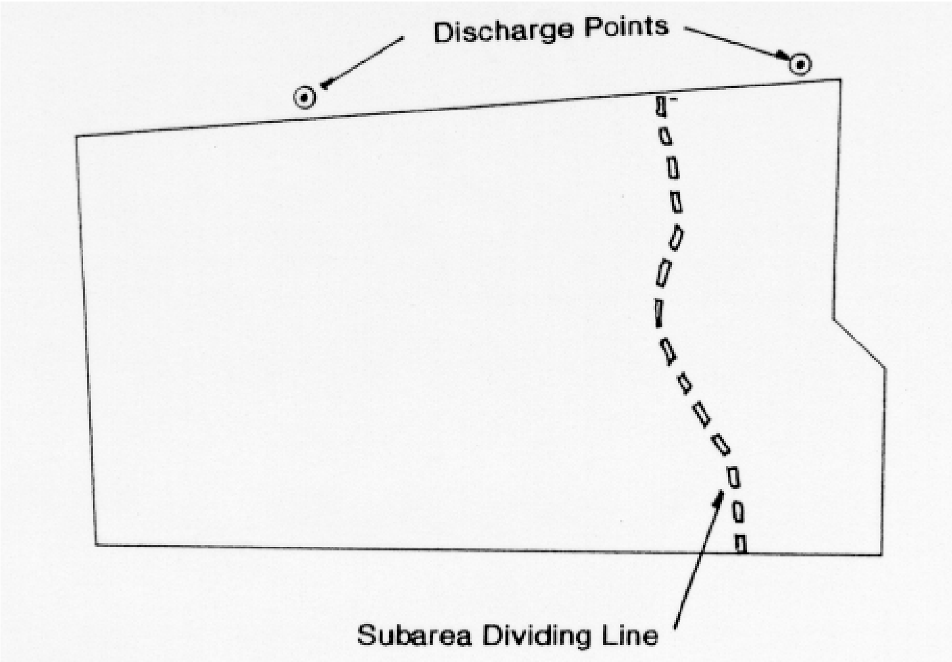
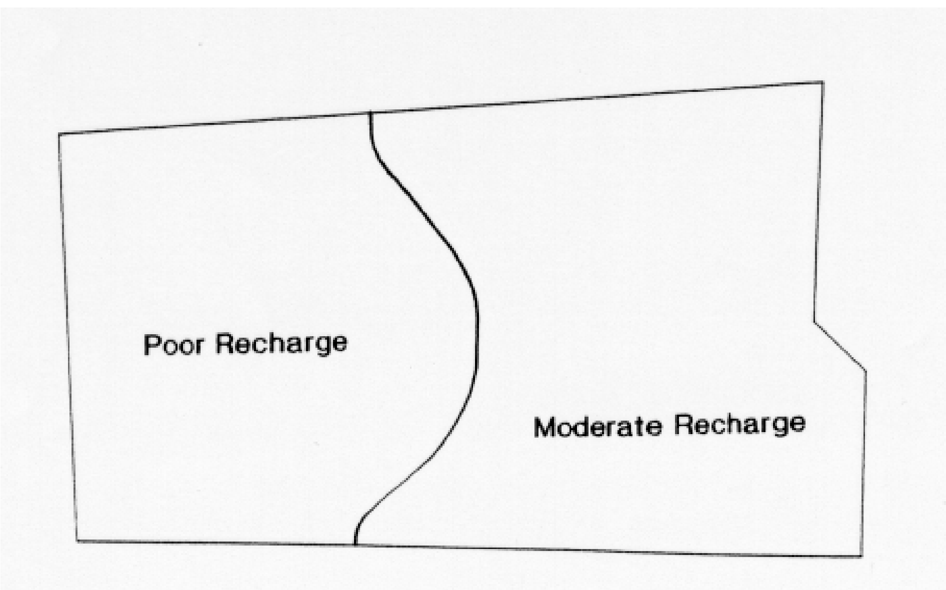


Figure 5-15
Zones of Recharge



of the site shows reasonable recharge rates, Figure 5-15, based on Brandywine Conservancy water budget modeling. The NtB complex soils drain fairly well and the meadow ground cover minimizes runoff. The northern portion of the site has less groundwater recharge. Although the woods provide a good groundcover and prevent excessive runoff, the Aldino soils do not drain as readily as NtB soils.

Site Critical Features: This property has a number of significant environmental features. Although not listed on the National Wetlands Inventory, two areas of wetlands were delineated on the property by a private consultant as part of the conventional development proposal. Mixed deciduous wetlands exist in the north along the streams. Wet meadow wetlands exist in the southeast portion of the site in a small pocket.

The stream system itself is a sensitive natural feature, as is the floodplain. The area surrounding the stream is currently forested and provides a stable, well vegetated riparian buffer. The wetlands and riparian buffer have an important positive impact on the water quality of the stream, as discussed in Chapter 2. Disturbance of these areas would have significant adverse ecological effects.

Site Stormwater Constraints and Opportunities: This site has both significant constraints and stormwater treatment opportunities. For the reasons discussed above, any sort of environmentally sensitive design should avoid disturbance of the wetlands, riparian buffer, and floodplain. These are also the areas of existing forests. Preserving the forests in the northern portion of the tract with its poorly draining soils will help to minimize runoff. The entire northern section of the site is less suited for development.

Conversely, the southern area of the property with its relatively well drained soils offers the opportunity for infiltration of stormwater.

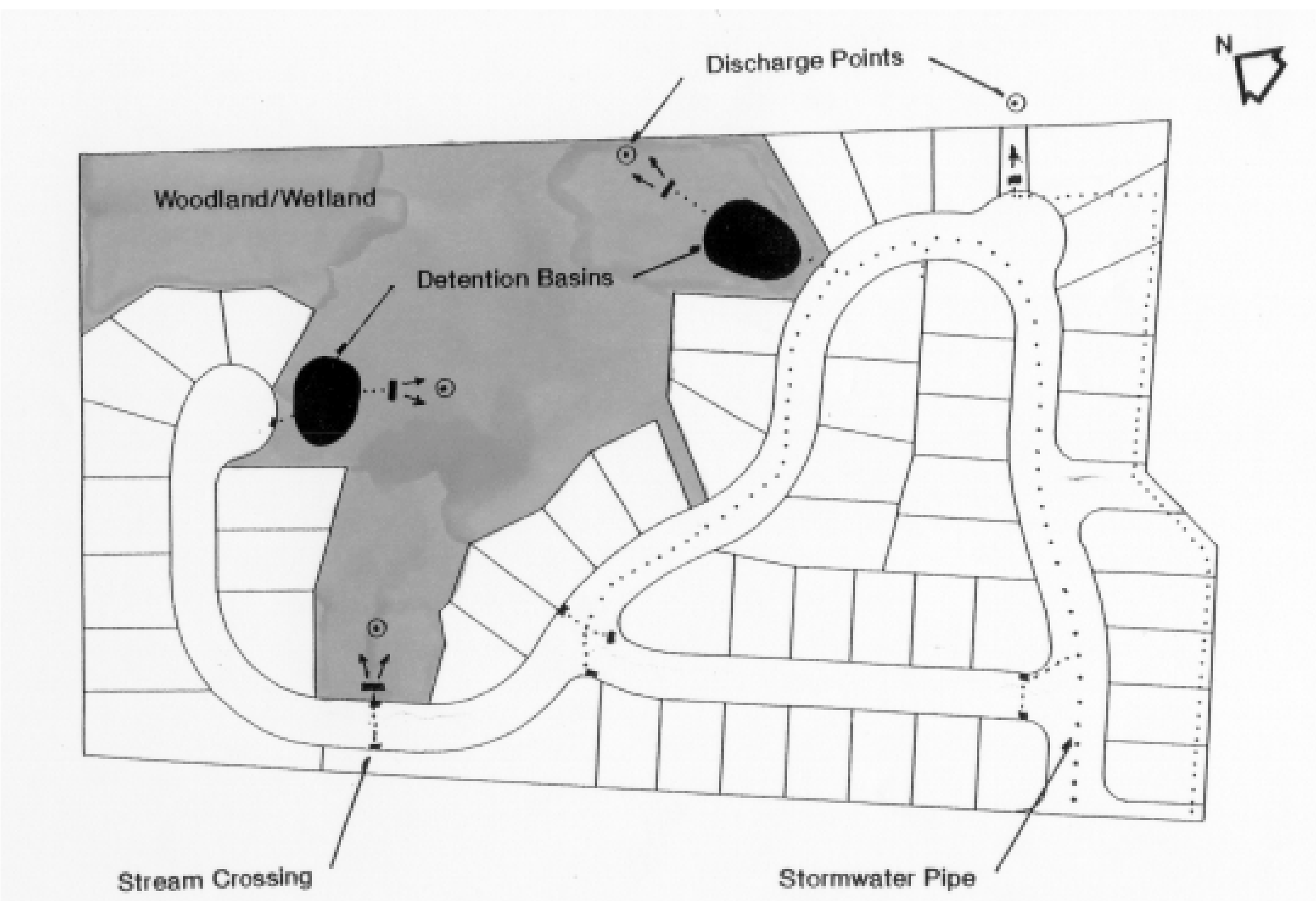
Early in the Site Analysis process, it became clear that, although the Conventional Development plan did respect stream, floodplain, and wetland boundaries, impacts could be significantly reduced if the northern section of the site was not disturbed, either directly by development or by the stormwater management basins to serve this development.

II. PROPOSED CONVENTIONAL DEVELOPMENT

The Conventional Development plan includes 55 lots of about 1/8 acre each (6,500 sq ft). The lots are arrayed throughout the site leaving the streams and most of the wetlands undisturbed, Figure 5-16. This design does, however, require a stream crossing in the west and also clearing of much of the northern forested area. Because of the manner in which the streams traverse the property from west to east, the 55 units are broken up into a northern section and southern section, separated by the stream corridor and other sensitive features. The open space provided by Conventional Development is 3.9 acres (20.5 percent of the site); undisturbed area is 3.6 acres (18.9 percent). Overall Conventional Development site imperviousness is 22.8 percent, including 2,700 linear feet of roadways.

Stormwater is to be conveyed by conventional storm sewers which discharge into two stormwater man-

Figure 5-16
Conventional Development and Stormwater Plan



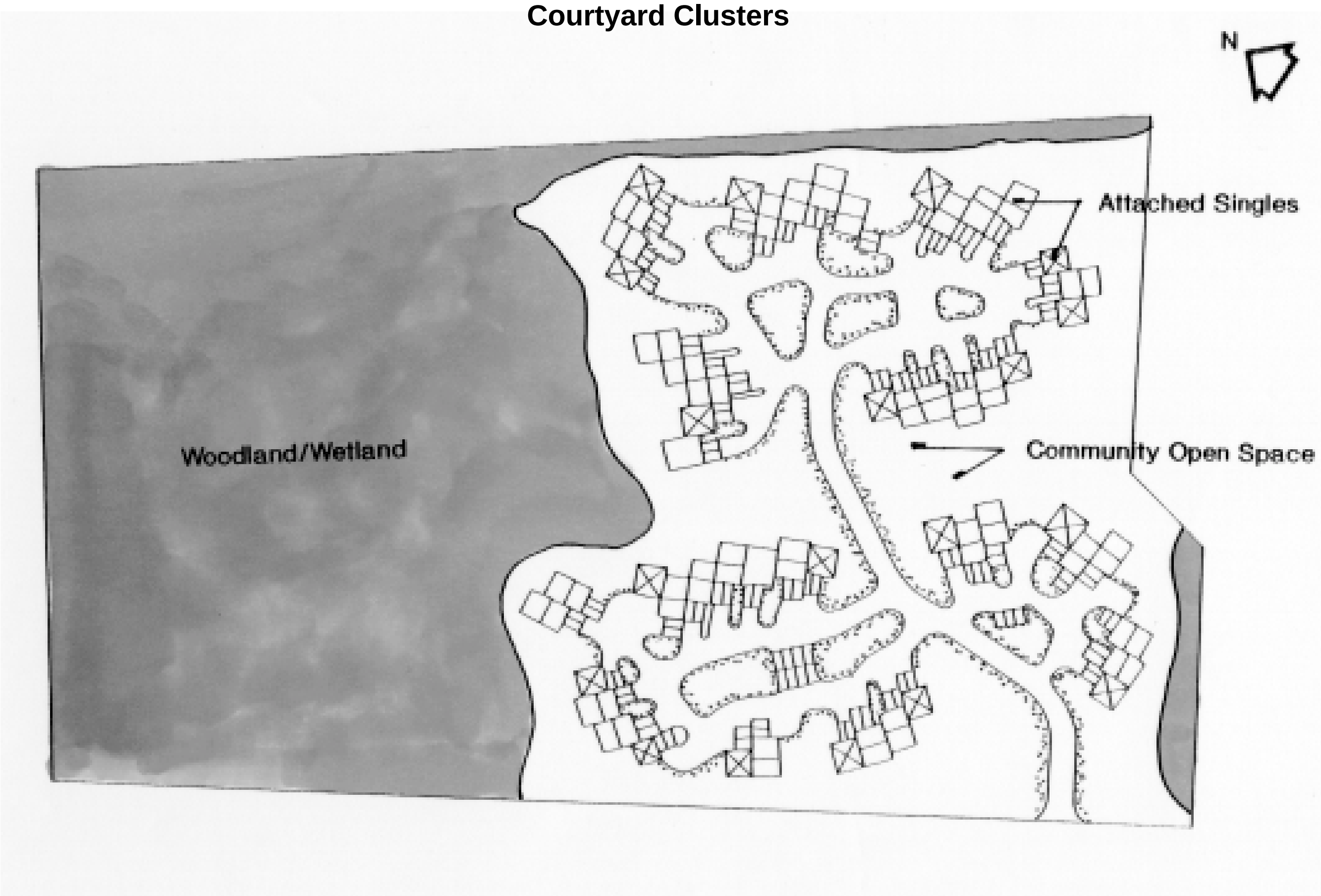
agement detention basins (dry) in the designated areas. Almost all the stormwater generated from the development will be routed to these basins. As detention basins, these structures slow or detain the release of runoff so that predevelopment <u>rates</u> of discharge are not exceeded, although these basins <u>release significantly increased total volumes of stormwater</u> over a longer period if time. Unfortunately, these detention basins require considerable intrusion into the natural riparian corridor, clearing of valuable vegetation, soil disturbance, aesthetic impacts and a broad range of other impacts which should be avoided if at all possible.

III. APPLICATION OF CONSERVATION DESIGN

Case Study 3 : Courtyard Clusters

Building Program: Case Study 3 provides an example of a building program which has been altered in order to minimize stormwater generation. This is the most dramatic of all the building program changes presented in this manual. The small, single family dwellings under Conventional Development are replaced by attractive attached single family units in courtyard clusters, with the number of dwellings held constant at 55, Figure 5-17. This change has been motivated by a desire to further compress the already small lots allowed under Conventional Development into a smaller total area, entirely within the southern section of the site. In order to achieve this, the design must either significantly reduce the building program and total number of units, or determine some way in which the area required per dwelling is reduced even beyond 1/8th acre. If such concentration is feasible, all development could be re-

Figure 5-17
Courtyard Clusters



stricted to the southern portion of the site, avoiding the northern natural sensitive areas and the costly and environmentally damaging bridging of the stream. Furthermore, development elements such as road length can be significantly reduced, resulting in more cost reductions.

This change allows the area of undisturbed area (9.9 acres or 52.1 percent of the site) to be significantly expanded—an increase of 175 percent over the Conventional Development plan. In addition, each courtyard dwelling has a two-car garage versus the one-car garages of the Conventional Development plan. This alteration in building program is based on the rationale that well-designed attached units can actually be more attractive and practical than small singles on 6,500 sq ft lots, with building separations of 10 to 20 feet, particularly if the units are carefully designed and open onto the preserved natural areas.

Lot Configuration: The courtyard cluster units are arranged in "organic" groupings to create a unique sense of place and exploit open space being preserved. This feature is not offered by the Conventional Development plan which lines up all of the small houses in rows. Conservation Design clusters occupy only the southern portion of the site, eliminating disturbance of the more sensitive northern site area and eliminating the stream crossing and reducing the disturbance of the existing forest. The courtyard dwellings are grouped into four clusters with large landscaped "islands" interspersed. These "islands" are designed as aesthetic features as well as infiltration facilities for stormwater management.

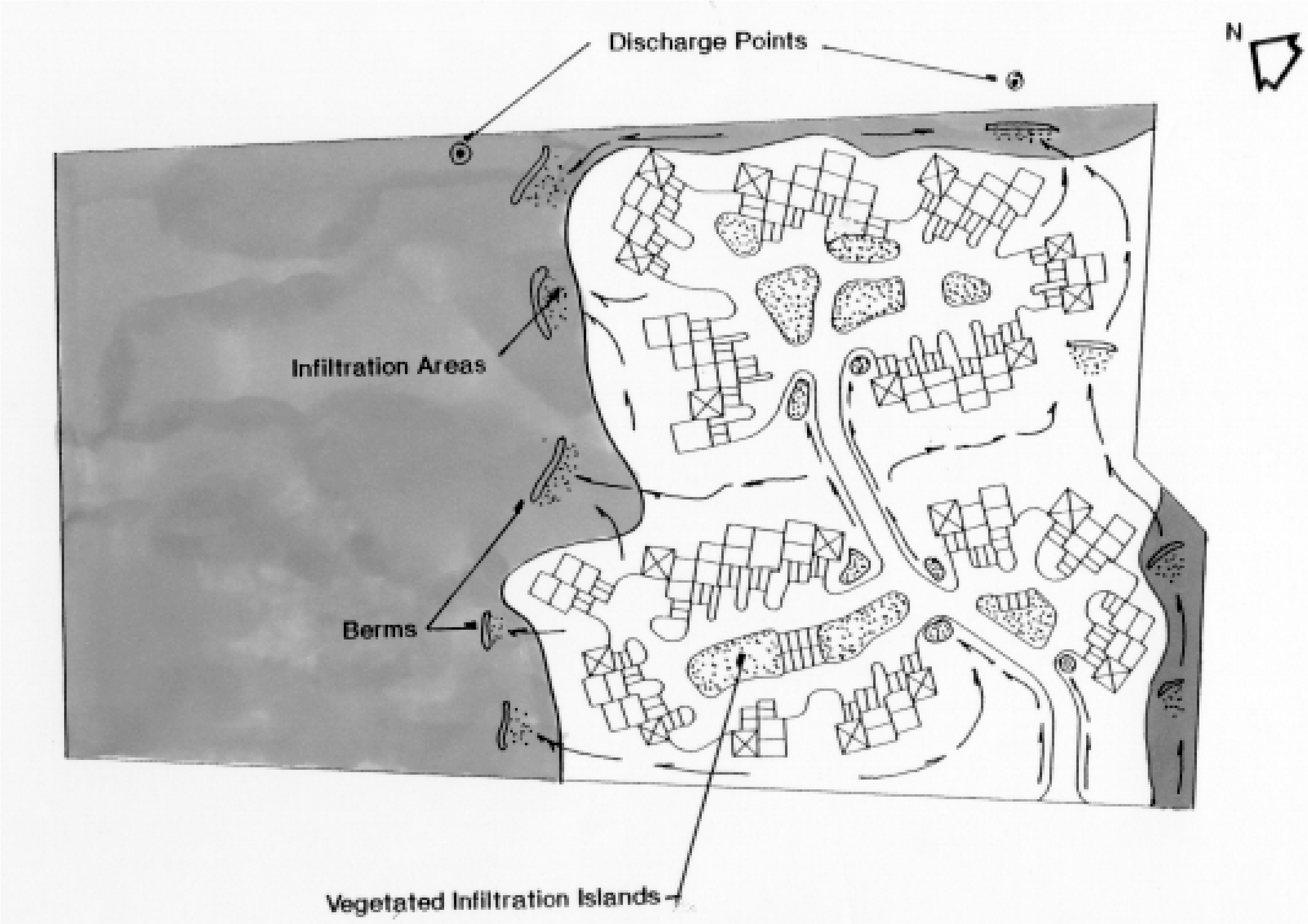
Impervious Coverage: With this Conservation Design alternative, the total site imperviousness is 21 percent. Although not dramatic, imperviousness is reduced about 6 percent, compared to Conventional Development design. The road length is reduced to 2,100 linear feet. The small decrease in impervious coverage is due in large part to the unconventional building arrangement, which is intended to minimize the number of unsightly front loaded garages and which requires slightly larger building footprints. Impervious coverage could be further reduced by designing the overflow parking areas with gravel or grass pavers.

Minimum Disturbance: Large forested areas and sensitive wetlands are left largely undisturbed by concentrating the buildings. As mentioned above, 52.1 percent of the site remains undisturbed, a significant increase from Conventional Development.

Mitigation Practices: The courtyard clusters are landscaped with a series vegetated "islands" within the parking lots and around the buildings, which are to be used for stormwater mitigation (both total volume and peak rate control), Figure 5-18. The theme of the development's design and landscaping, in fact, is centered around these vegetated "island" areas, landscaped with specially selected native species. These "islands" are to be located, flagged in the field at the outset of the development process, and maintained without disturbance to the extent feasible, in order to minimize soil compaction problems. Road and parking lot construction is to occur on adjacent filled areas, so that the "islands" are formed and effectively function as subtle depressions providing the needed stormwater volumes. Revegetation with native species properly selected for these contexts is the final step.

In addition to these proposed stormwater elements, vegetated swales will be used to convey stormwater flows where necessary. Vegetative swales connect either to these "islands" or to other areas where berms have been placed along existing contours and where additional stormwater control volumes are achieved. The vegetated "islands" are to function as zones of infiltration. As with all of the case studies, these infiltration zones are designed to efficiently drain during major storm events (storms greater than the 100-year). In such cases, stormwater ultimately flows through this system to the previous discharge points along the stream, although the bulk of the stormwater (virtually 99 percent) will be infiltrated prior to any discharge to the surface water system.

Figure 5-18
Stormwater Mitigation Plan



IV. STORMWATER CALCULATIONS

Curve Number

As with the other case studies, composite or weighted Curve Numbers were calculated for the site.

Condition	Curve Number
Pre-Development	61
Conventional Development	79
Conservation Design	78

As a result of Conservation Design, the Curve Number is lowered only slightly. The Case Study 3 court-yard cluster design is not able to reduce the amount of imperviousness by a significant amount. Nevertheless, keeping more of the forested area undisturbed helps to reduce the Curve Number, though only by a modest amount. This Conservation Design achieves its benefits by using other Conservation Design strategies. Most importantly, the stream and forested area remain undisturbed through the Conservation Design.

Peak Runoff Rates

Condition	Peak Rate (cfs - 100 year storm)
Pre-Development	15
Conservation Design	13

Conservation Design courtyard clusters is able to satisfy the peak rate requirement for the 100-year storm (it is located above the Canal). As in the predevelopment condition, stormwater is discharged during the largest storms (over 100-year) to two points off of the site: to the stream in the northeast and to a natural drainage area in the southeast. Berms, swales and infiltration areas are used to maximize the Times of Concentration and to retain and ultimately infiltrate most stormwater runoff. For the TR-55 calculations this site was divided into 21 individual subareas.

Water Budget

Annual Water Budget for Buckingham Greene (in gallons):

	Pre- Development	Conventional Development	Conservation Design Courtyard Cluster
Precipitation	21,917,200	21,917,200	21,917,200
Runoff	318,532	5,092,278	4,766,351
Recharge	7,394,415	5,327,105	5,497,774
Evapo-transpiration	14,204,617	11,512,227	11,656,293

The annual water budget results show a modest increase in recharge (170,669 gallons per year or 3.2 percent) and decrease in runoff (325,927 gallons per year or 6.4 percent) for the Conservation Design alternative, in contrast to Conventional Development. The changes are not as striking as in some of the other Case Studies. However, for such a small site with this number of units, even these small changes provide benefits.

The benefits of Conservation Design in this Case Study are somewhat different than for the other Case Studies. Although the Curve Number was not reduced significantly and the annual recharge increased only slightly, significant ecosystem benefits as well as cost savings are achieved. Preventing all disturbance in the wetlands, floodplain, and the riparian buffer zone in the northern section of the site has important water quality benefits for the stream system. In addition, the need for an expensive stream crossing is eliminated and the sensitive woodlands are preserved. This design also eliminates the two stormwater management basins which require an elaborate stormwater collection and conveyance system under Conventional Development.

V. COSTS

Costs of Conventional Development include the required streets and curbing, detention basins, stormwater piping, endwalls and inlets. Costs of Conservation Design include reduced-width roadways without curbing, swales, berms, and the vegetated infiltration “islands.” Various other costs are omitted for the purposes of this cost comparison, including cost elements such as grading which would serve to make the comparison even more favorable for Conservation Design.

CONVENTIONAL DEVELOPMENT COSTS

2,700 ft of streets	@ $150/linear ft	405,000
2 detention ponds	@ $16,000/pond	32,000
2,500 ft of swm pipe	@ $22/linear ft	55,000
38 endwalls/inlets	@ $1,300/each	49,400
	TOTAL	**541,400**

CONSERVATION DESIGN COSTS

2,100 ft of streets	@ $85/linear ft	178,500
175 ft of swm pipe	@ $22/linear ft	3,850
450 ft of berms	@ $10/linear ft	4,500
1,500 ft of swales	@ $4.50/linear ft	6,750
30,460 sq ft islands	@ $200/1,000 sq ft	6,092
	TOTAL	**199,692**

Swales: Again, to estimate the cost of swales we will use the unit figure of $4.50 per linear foot assuming seeding and straw mulching. The total length of swales for the Buckingham Greene Conservation Design is 1,500 linear feet. At the suggested price, the total cost for swales would be $6,750.

Roads: The road length for Buckingham Greene Conservation Design is 2,100 linear feet. Conventional Development road width is assumed to be 28 ft and includes curbing. Conservation Design road width is assumed to be 20 ft and does not include curbs. Costs per linear ft are $150 and $85, respectively.

Berms: As listed previously, the estimated costs for berm construction is $10 per linear foot. Therefore, the costs of berm construction for the Buckingham Greene Conservation Design is $ 4,500.

Vegetated Infiltration "Islands:" The bulk of these costs involves revegetation, which is estimated to cost $200 per 1,000 sq ft of area. This level of effort is to provide a mix of attractive native tree specimens as well as understory shrubs and ground covers, all selected for their texture, seasonal color, and so forth.

When considered from an individual lot perspective for 55 lots, cost per lot for conventional development is $9,844 while cost per lot using the conservation design approach is $3,631 or $6,213 or 63% less.

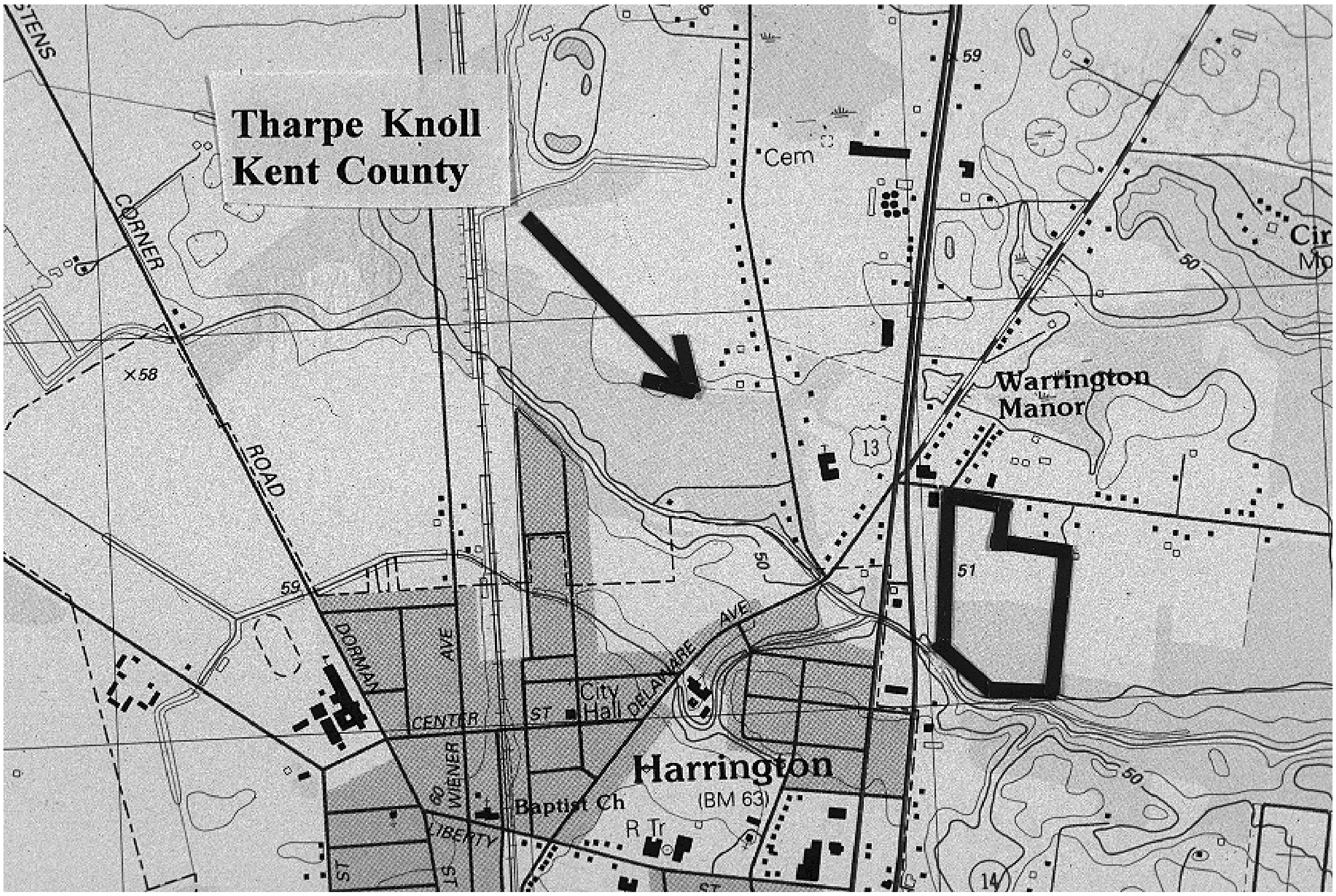
CONSERVATION DESIGN CASE STUDIES 4 AND 5 : THARPE KNOLL

I. SITE ANALYSIS

Site Background

Tharpe Knoll is located in Kent County, DE less than a mile from Harrington, DE on the Harrington, DE USGS quadrangle, Figure 5-19. The southern portion of the site is bordered by Browns's Branch. The 33-acre site is located in the Atlantic Coastal Plain Province.

Figure 5-19
Tharpe Knoll Quadrangle Map



Site Characteristics

Vegetation: Only two different land cover types are present at this site, Figure 5-20. The northern half of the site is in agricultural rotation for corn and soybeans. The southern portion, down to the stream, consists of volunteer indigenous deciduous and conifer species.

Soils: The soils on this site drain well and are mostly Hydrologic Soil Group B soils. Soils for this property are depicted in Figure 5-21. Rumford (Ru) and Pocomoke (Pm) soils are both Group B. There is a thin band of Woodstown (Wo) soils, HSG C, in the northern portion of the site and a small pocket in the south.

Figure 5-20
Predevelopment Land Cover

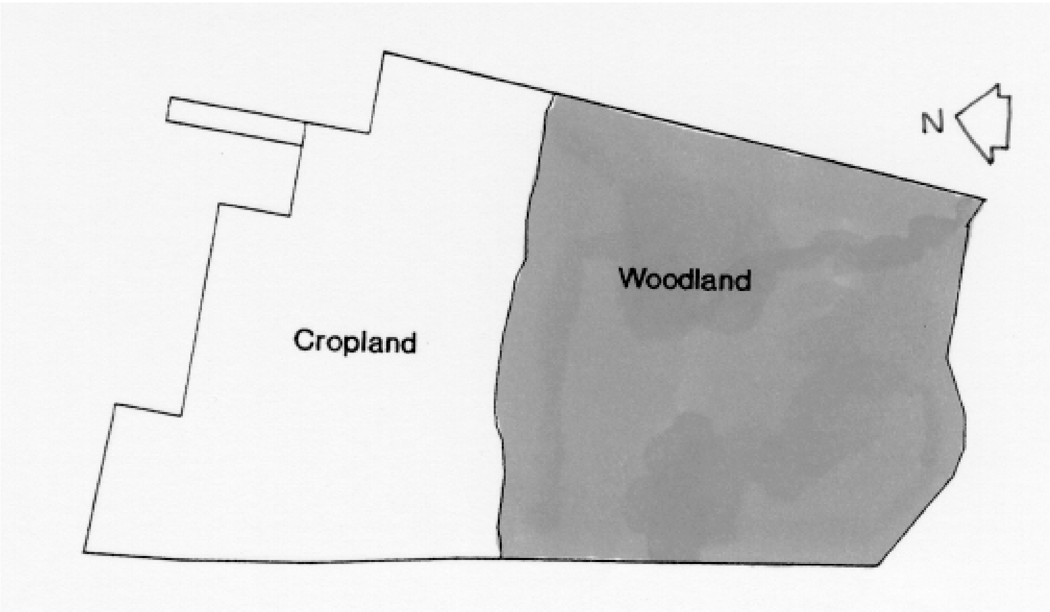
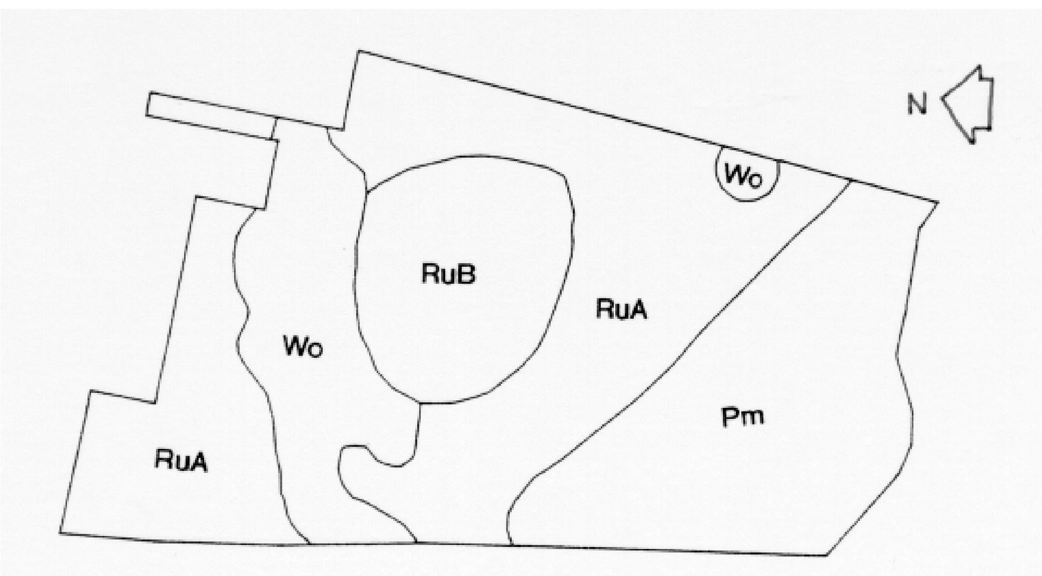


Figure 5-21
Soils Distribution



Hydrology and Stormwater Recharge: Predevelopment surface water movement on this site follows the topography and generally moves from the north to the south. There is a low area to the west of the property where much of the northern portion of the site drains, however. Figure 5-22 shows the natural drainage routes of the site. Most of the water from the site drains through the wetlands in the southern portion into Brown's Branch.

Figure 5-23 shows annual water recharge (on a per inch basis), applying the Brandywine Conservancy's climatic water budgeting model (based on average annual precipitation). The Rumford soils, especially those in the wooded areas, show the highest recharge rates. The northern Woodstown soil with a cropland landcover does not recharge nearly as well.

Site Critical Features: A site inventory for Tharpe Knoll shows some important sensitive areas relating to the stream along the southern border. Section 404 (i.e., Federally-regulated) wetlands, 100 to 300 feet wide, exist along the branch. In addition, the 100-year floodplain covers almost the southern third of the site. The wetlands and floodplain are forested with deciduous and coniferous species and constitute an especially valuable resource for downstream water quality and stream system flows, both flood flows and stream base flows. These areas are critical to the health and quality of the stream. The wetlands form a riparian buffer which performs the important functions described previously in this manual.

Figure 5-22
Natural Drainage Basins

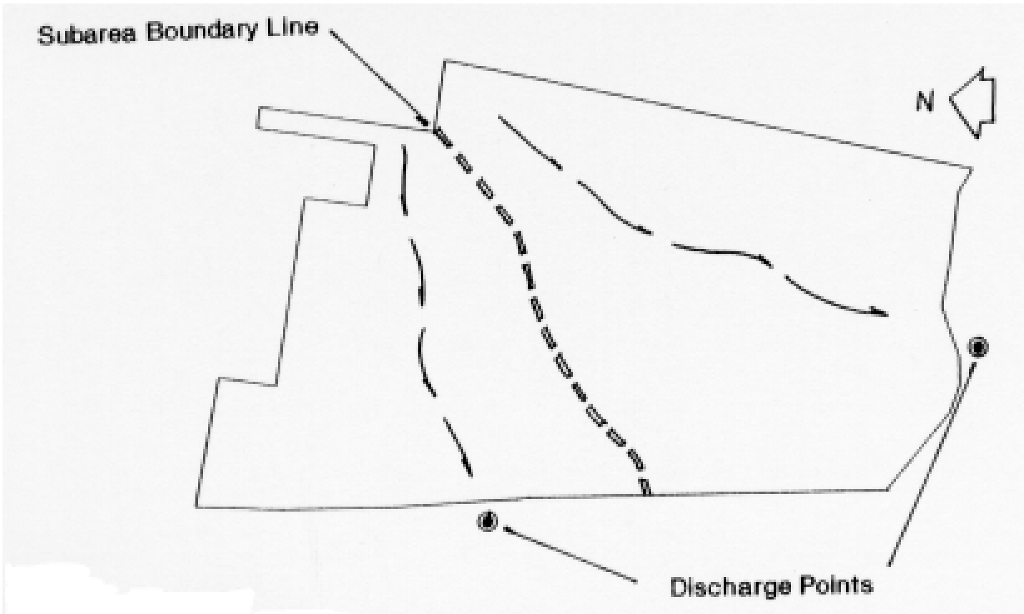
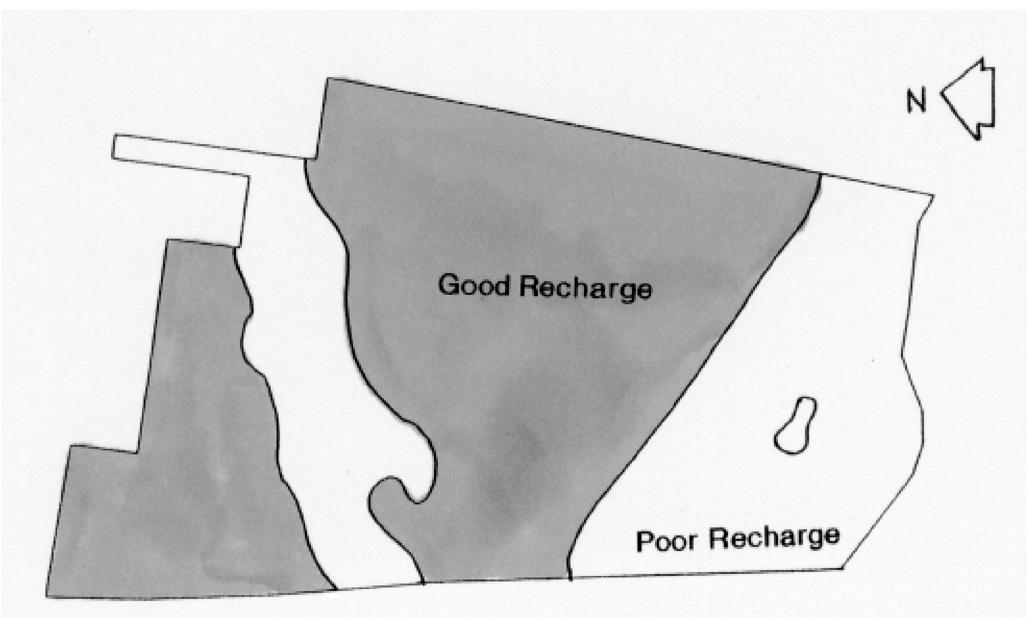


Figure 5-23
Zones of Good and Poor Recharge



Some regulations exist to prevent or at least discourage impacting this sensitive zone on the county, state and federal levels. Nevertheless, Conservation Design should strive to maintain, if not enhance this important portion of the site.

Site Stormwater Constraints and Opportunities: The soils, except for the small portion of Woodstown, drain well, provide good infiltration in the predevelopment condition, and therefore also should offer good potential for stormwater management practices which promote infiltration and groundwater recharge. In the southern half of the site, woodlands in combination with good soils provide an especially good opportunity for infiltration and recharge.

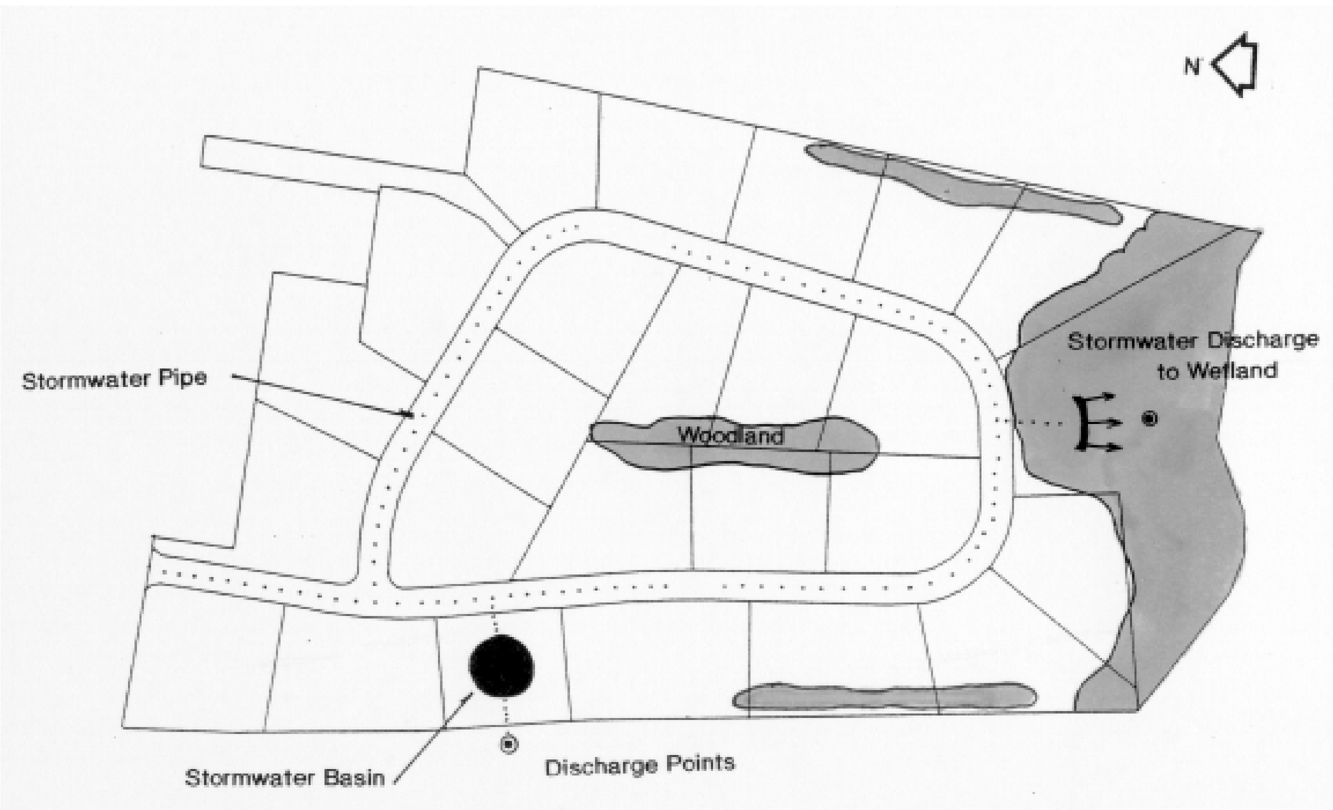
The wetlands are a critical natural area. These wetlands are to some extent supported and "fed" subsurface by precipitation which falls on the site upgradient, infiltrates into the ground, and then moves below the surface to points of discharge into the wetlands, as described in Chapters 2 and 3. Of course this hydrologic dynamic is occurring throughout the watershed and not just on this particular 33-acre site portion. Therefore, actions taken which interfere with, block, and reduce this natural infiltration and wetland "feed" undermine the vibrancy of wetland systems. At the same time, disturbance of the wetlands by directing stormwater flows directly from newly developed areas at the site into the natural wetlands can be expected to have negative impacts on the wetland communities and ultimately to the stream ecosystem. If stormwater volumes and discharge rates are properly managed before reaching the wetland, however, this natural wetland area will be supported hydrologically and will also help improve the quality of site runoff before it enters the stream through natural wetland water quality "polishing" functions.

II. PROPOSED CONVENTIONAL DEVELOPMENT

The proposed conventional development design for Tharpe Knoll consists of 23 lots averaging about one acre in size, gridded rather uniformly across the entire property, Figure 5-24. A significant amount of the woodland area would be cleared (85 percent of the total site area is disturbed), although 3.7 acres (11 percent) of undisturbed open space has been designated in the southern wetland/floodplain constrained portion. The total site imperviousness of Conventional Development is a relatively low 12.6 percent. Roadways total 3,097 linear feet in the Conventional Development design.

Two areas are designated for stormwater management. A stormwater detention basin would detain the runoff from the northern portion of the site. The southern area would drain through a water quality control device and then into the wetland.

Figure 5-24
Conventional Development Layout and Stormwater Plan

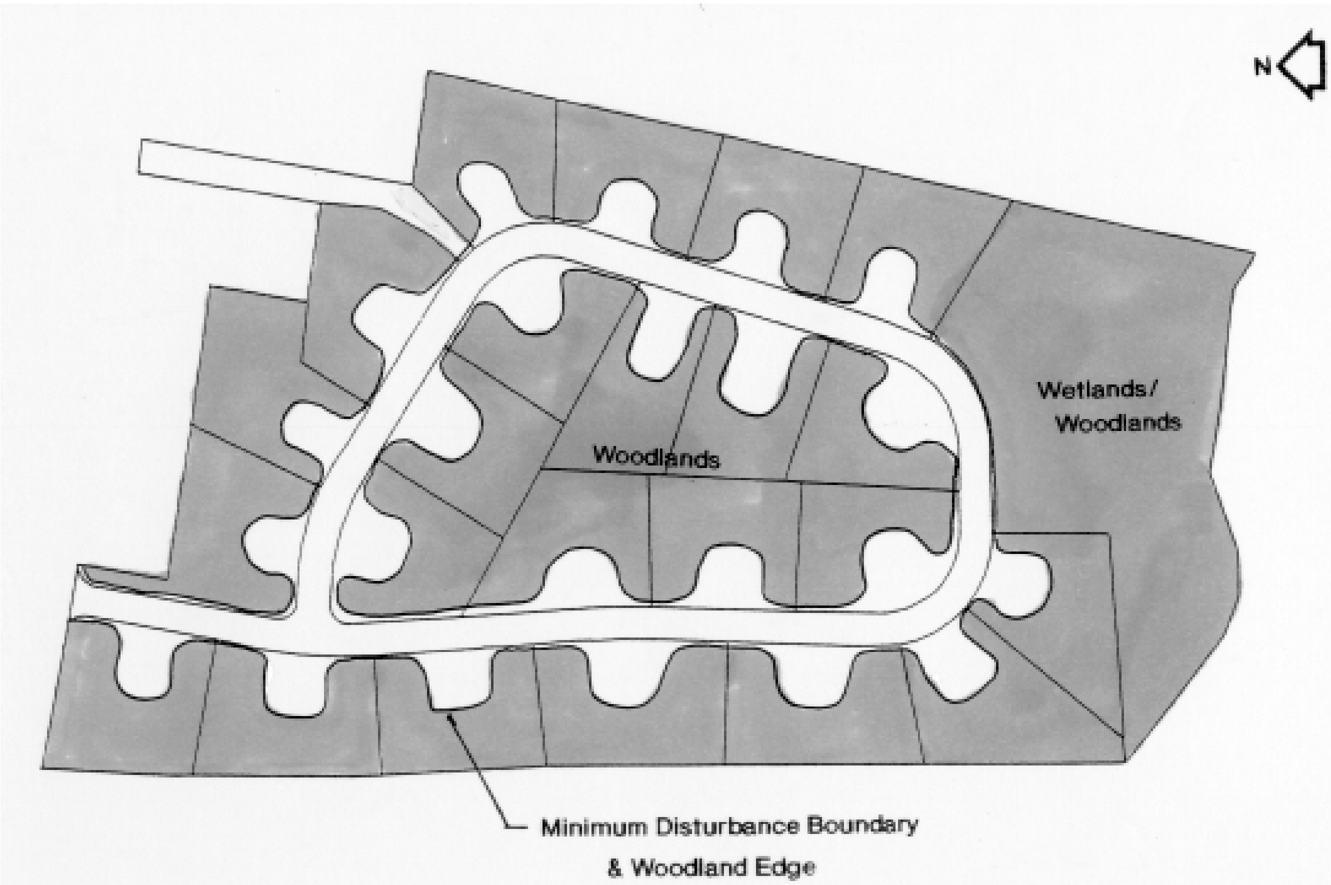


III. CONSERVATION DESIGN ALTERNATIVES

Case Study 4 : Large-Lot Conservation Design

Building Program: Of the six Case Studies, this large-lot development plan is the only one which does not alter the building program by reducing lot size. The lots remain roughly one acre, Figure 5-25, virtually identical to Conventional Development design. This decision to hold lot size constant was done specifically to provide an example of "low profile" Conservation Design Practices. **Even if lot size reduction and clustering cannot be used for some reason, Conservation Design can still provide important benefits.**

Figure 5-25
Large Lot Conservation Design



The large-lot Conservation Design plan leaves 35 percent of the land area undisturbed and 15 percent in open space. This undisturbed area includes the large natural area within the lot boundaries. In contrast to the undisturbed 11 percent in Conventional Development, even this "low profile" Conservation Design application almost triples the amount of area left undisturbed.

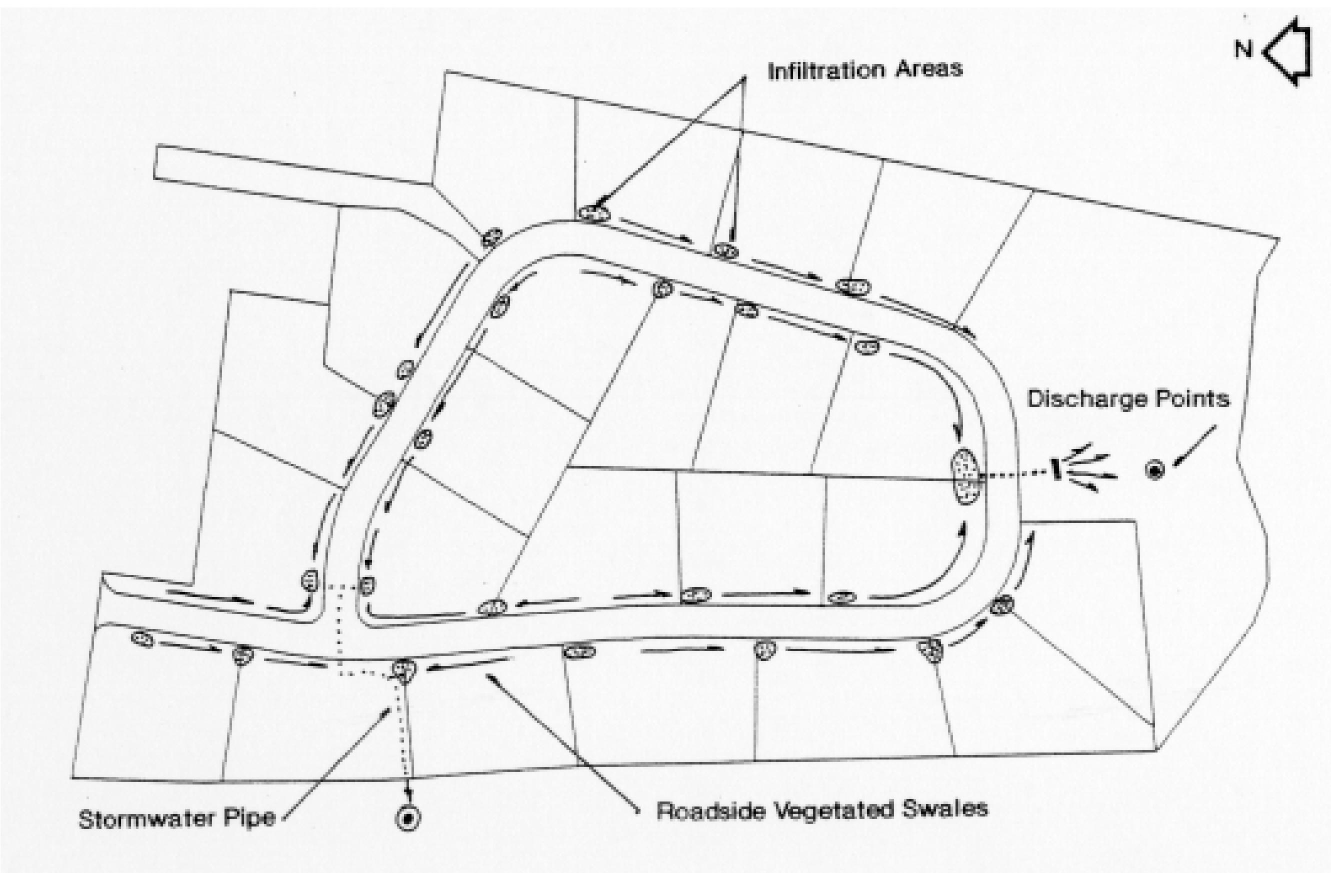
Lot Configuration: The lot configuration is not significantly altered in the large-lot Conservation Design alternative. By eliminating the stormwater basin closest to the entrance of the development, it is possible to shift the lots toward the entrance of the development, thereby reducing the impact on the wetlands and floodplain areas in the southern portion of the property.

Impervious Coverage: Although neither the building program nor the lot configuration are substantially altered, the impervious coverage for Conservation Design Large-Lot is reduced throughout the site by reducing road widths and driveway lengths and widths. Through these relatively simple measures, the impervious coverage is reduced to 9.7 percent (a 24 percent decrease from the Conventional Development plan).

Minimum Disturbance: With Conservation Design Large-Lot development, there comes an opportunity to use minimum disturbance on each lot more effectively as a stormwater prevention technique. The houses, drives, and roads can be sensitively sited and constructed on each lot so as to minimize disturbance and the accompanying soil compaction and vegetation disturbance. With minimum disturbance maximized on a lot-by-lot basis, the necessary lowering of the Hydrologic Soil Group rating in zones of disturbance has far less impact in contrast to Conventional Development. Through Conservation Design, 65 percent of the site area remains undisturbed.

Mitigation Practices: In order to mitigate runoff most effectively, the large-lot Conservation Design proposes to integrate a vegetated swale conveyance system combined with vegetated infiltration areas and check-dams, with the damming provided by the driveway crossing itself. These vegetated swales will be located along the roadways and in the rear and side yards of each lot, depending upon need, Figure 5-26. Runoff that does not infiltrate and "overflows" is conveyed via this system to two pre-existing drainage areas, one near the entrance road and one in the rear of the lots in the wetland area.

Figure 5-26
Stormwater Mitigation Plan



Incorporating vegetated infiltration areas within each individual lot requires significant attention to proper design and management. There is always the potential problem that individual homeowners who do not appreciate water collecting in portions of their yards may either fill the depressions, break the berms, or otherwise act to interfere with functioning of the Conservation Design system, even if deed restrictions exist. To avoid this scenario, this plan proposes that the vegetated infiltration areas be located at the intersection of the driveways and roadway, on the side away from the front yard, where possible. Thus each vegetated infiltration area has a clearly identifiable and accepted location and becomes a consistent theme throughout the development. The average vegetated infiltration area holds roughly 1,200 cubic feet of storage, with the driveway functioning as the berm or dam. Planting of these infiltration areas is to be carefully undertaken and includes native species which can thrive in conditions of variable hydrologic conditions. Also, it is important that these plant areas blend into the total landscaping, including the minimum disturbance areas, in a pleasing manner.

Re-Forestation/Re-Vegetation are also prescribed for areas in the northern part of the site previously in cropland. Stormwater generation is reduced by this Re-Forestation/Re-Vegetation. Under large-lot Conservation Design, each lot retains a small lawn area immediately adjacent to the structure, but otherwise the lots would be mostly forested.

Case Study 5 : The Clustered Alternative

Building Program: The Conservation Design Cluster alternative in Case Study 5 maintains the same lot number and home size as the other alternatives, yet reduces the lot areas from one acre to 1/2 acre, Figure 5-27. The Case Study 5 plan still calls for on-lot sewer and water, although given the small number of units involved, use of community wastewater treatment systems and use of community well(s) are possibilities and should be explored (although onsite septic systems are permitted at this density in certain parts of the state, we do not recommend septic systems at such densities). This reduction in lot area provides 17 acres of open space (50 percent of the site), a dramatic <u>increase</u> of 13.3 acres over Conventional Development.

Figure 5-27
The Clustered Alternative

Lot Configuration: The lots in Case Study 5 Conservation Design are configured based on two primary objectives: 1) remove as many houses as possible from the forest-floodplain-wetlands complex at the southern portion of the site; and 2) provide a central green area to serve aesthetic, recreational, and stormwater functions as well. The open space also provides areas of undisturbed vegetative cover, which further aids in the prevention of stormwater.

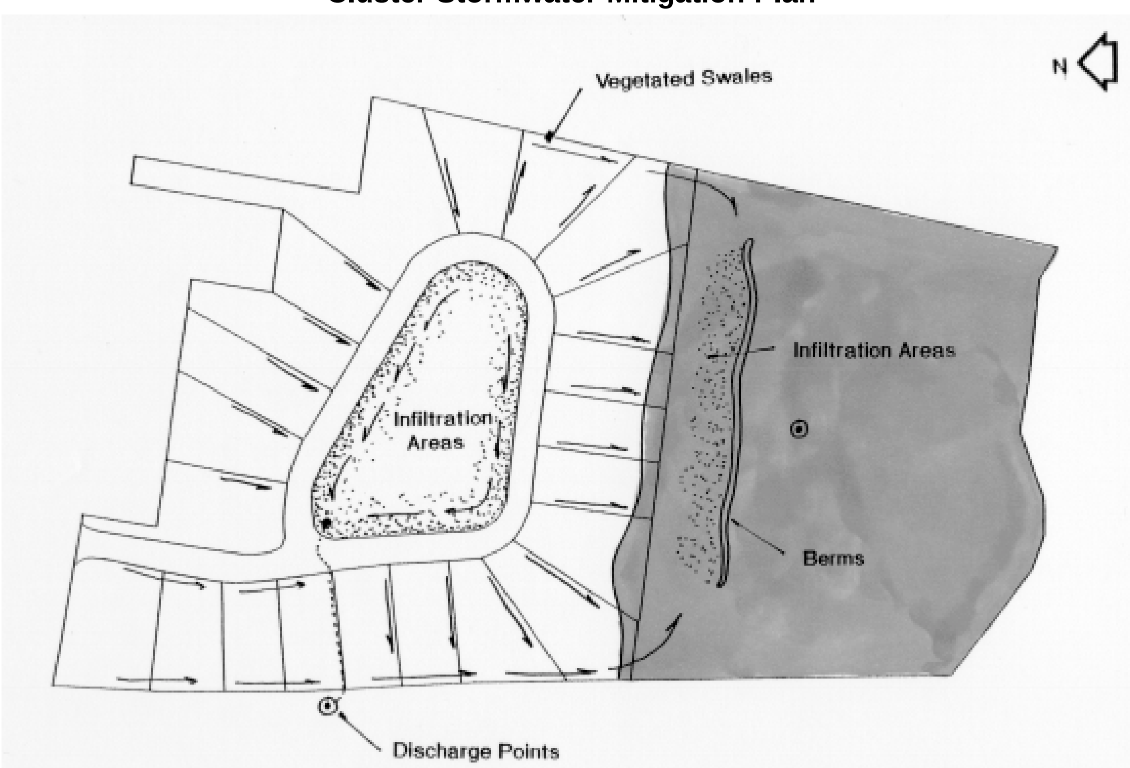
Impervious Coverage: With this Clustered option, the road length has been dramatically reduced to 2,065 linear feet (approximately 1,000 linear feet reduction from Conventional Development). Road widths, given the small number of dwellings involved, also can be reduced. Overall, the site impervious coverage is reduced to 7.4 percent in this Conservation Design alternative, a decrease of 41 percent from the Conventional Development design, which is impressive given the low percent imperviousness rating to begin with.

Minimum Disturbance: As mentioned above, the Conservation Design Case Study 5 is much less disturbed than under Conventional Development. The existing forest remains intact, thereby maintaining its current hydrologic functions. The proposed roadway is located completely on currently cultivated agricultural fields, thereby further minimizing forest disturbance. The total area undisturbed increases to 62 percent of the total site, or an additional 17.3 acres over Conventional Development design, a very large percentage increase.

Mitigation Practices: In order to mitigate the stormwater runoff which will be generated under this Conservation Design Clustered alternative, this stormwater management plan focuses on two themes:

- using the open space areas as mitigative zones
- using vegetated swales along the lot lines as conveyance mechanisms from roads and residences to these open space mitigative zones (Figure 5-28).

Figure 5-28
Cluster Stormwater Mitigation Plan



By forming the lot boundaries, the swales are located as far away from homes and more intensive yard use areas as possible, thereby reducing interference with individual users/homeowners. Stormwater is conveyed via this swale system to both the forested areas, where it is dispersed by using level spreading devices with ultimate volume control for larger storms provided by berms. In other cases, stormwater flows are directed to an open space "common green" where it is retained, level spread across existing vegetation, and infiltrated in most cases.

Case Study 5 also calls for the Re-Forestation/Re-Vegetation of a large area in the north of the site. For the Clustered alternative, this Re-Forestation/re-Vegetation occurs mostly in public open space behind or outside of individual lots.

IV. STORMWATER CALCULATIONS

Curve Number

Composite Curve Numbers were calculated for the Tharpe property according to the USDA-NRCS Curve Number method. Because the site has varied soils and landcover, weighted Curve Numbers were computed.

Condition	Curve Number
Pre-Development	69
Conventional Development	78
Large-Lot Development	69
Cluster Plan	68

The Conservation Design alternatives are able to decrease the Curve Number by reducing overall site imperviousness, maintaining existing vegetation, and reforesting/revegetating areas of the property. In the Case Study 4 alternative, the lot configuration remain the same as in the Conventional proposal. However, the driveways are shortened and road widths reduced, thereby decreasing the site imperviousness. Strict limits of disturbance are also set so that the most of the existing woodlands are maintained. This prevents/minimizes compaction of the soils on each lot and makes unnecessary the lowering of HSG rating for the soils where disturbance is occurring. Reforestation/revegetation is also prescribed for the northern portion of the site, an area that has previously been in crop rotation. As in the previous case studies, the reforested areas are assigned a Curve Number equal to a forest in poor condition. Close attention to impervious coverage, disturbance, and vegetation issues makes it possible to keep the Curve Number very close to the Pre-Development value even though the lot size and configuration do not change.

The Case Study 5 Clustered alternative goes a step further by clustering the lots and as a result, road length and overall site disturbance are reduced even further. Again reforestation/revegetation are prescribed for the northern portion of the site.

Peak Runoff Rates

As a result of reduced Curve Numbers, runoff amounts and peak rates are positively affected by using Conservation Design. For both Conservation Design Case Studies, predevelopment to post-development runoff peaks are maintained without the use of large stormwater detention basins.

Condition	Peak Rate (cfs - 10 year storm)
Pre-Development	35
Large-Lot Development	34.4
Clustered Plan	6

The systems of small vegetated infiltration areas combined with vegetated swales for the Conservation Design Large-Lot alternative adequately reduces the peak discharge rate. Because stormwater runoff on each lot is treated individually, it is necessary to divide the site into 32 subareas for the TR-55 calculations. This process is quite tedious and time-consuming and adds to "up front" engineering costs, though, as demonstrated below, is more than balanced by reduced total development costs. Furthermore, these calculation methodology issues once again underscore the need for a more accurate and appropriate methodology to calculate stormwater peaks and volumes, above and beyond TR-55.

The Clustered alternative (Case Study 5) is able to significantly reduce the peak rate below even the predevelopment rate. This is possible for a number of reasons. First, the reduction in impervious area and the reforestation/revegetation of areas reduces the Curve Number (the predevelopment condition in this area was cropland) and helps prevent the generation of stormwater runoff. The Clustered common green provides a large area for the retention and infiltration of stormwater runoff that is generated. During the larger storms, this area can hold up to 80,000 cu ft of stormwater, although this still does not require use of the entire common green area (this common green does not function as a basin, but rather as an appropriately landscaped area that holds 1 to 2 feet of water for a short period of time during the larger storms). Drainage overflow routes exist for the largest storms (100 - 500 year) to prevent flooding. Vegetated swales with check dams are used to convey the remaining runoff to the discharge point in the southern portion of the site. Because this Clustered alternative concentrates the development well north of the wetlands and the stream, it is also possible to construct a berm along contour in the woods a few hundred feet south of the swale discharge. This further retains/detains the stormwater and prevents any destructive releases into the wetlands and stream. The TR-55 calculations for this design require use of only 3 subareas.

Water Budget

Annual Water Budget for Tharpe Knoll:

	Pre-Development	Conventional Development	Conservation Design Large Lot	Conservation Design Clustered Plan
Precipitation	39,861,499	39,861,499	39,861,499	39,861,499
Runoff	1,368,474	5,863,616	4,113,807	3,302,438
Recharge	13,722,239	12,048,769	12,941,334	13,203,818
Evapo-transpiration	24,767,399	21,962,625	22,799,339	23,353,230

The water budget results show the impact of Conservation Design on the annual water cycle. While not eliminating runoff, both the Conservation Design alternatives significantly reduce the volume of runoff generated, by 33 percent (1,749,809 gallons) for Large-Lot and 46 percent (2,561,178 gallons) for Clustered.

Recharge improves as well when contrasted with Conventional Development. Of course all development alternatives experience a loss in recharge. However, the Brandywine Conservancy water budgeting model indicates that the loss experienced by the Large-Lot alternative is reduced by a factor of 53.4 percent when contrasted with Conventional Development. For the even better performing Clustered alternative, the recharge loss is reduced by a factor of 69.0 percent. Predevelopment, the soils on this site provide good recharge. The Conservation Design plans minimize disturbance of these soils to maintain drainage. Further, these designs direct stormwater to the areas of naturally high recharge.

The overall result of these strategies is to reduce the amount of runoff generated and to increase the amount of stormwater recharged once it has been created. As with the other Case Studies, the annual water budget for the site more closely resembles the predevelopment water budget through application of Conservation Design Approaches and Practices.

VI. COSTS

Like the previous Case Study, several of cost elements including swales, reforestation, roadways, berms, and bioretention areas are examined in this cost estimation.

CONVENTIONAL DEVELOPMENT COSTS

3,097 ft of streets	@ $150/linear ft		464,550
1 detention pond	@ $16,000/pond		16,000
2,800 ft of swm pipe	@ $22/linear ft	61,600	
15 endwalls/inlets	@ $1,300/each		19,500
	TOTAL		**561,650**

CONSERVATION DESIGN COSTS: LARGE-LOT

3,097 ft of streets	@ $85/linear ft	263,245	
200 ft of swm pipe	@ $22/linear ft	4,400	
600 ft of berms	@ $10/linear ft	6,000	
7,800 ft of swales	@ $4.50/linear ft		35,100
9.2 ac reforestation	@ $2,925/ac		26,910
13,800 BMP landscaping	@ $200/1,000 sq ft		2,760
1 endwall/inlet	@ $1,300/each		1,300
	TOTAL		**339,715**

CONSERVATION DESIGN COSTS: CLUSTERED

2,065 ft of streets	@ $85/linear ft	175,525	
400 ft of swm pipe	@ $22/linear ft	8,800	
900 ft of berms	@ $10/linear ft	9,000	
4,900 ft of swales	@ $4.50/linear ft		22,050
3.7 ac reforestation	@ $2,925/ac		10,825
56,000 BMP landscaping	@ $200/1,000 sq ft		11,200
300 ft of level spreaders	@ $10 /linear ft		3,000
4 endwalls/inlets	@ $1,300/each		5,200
	TOTAL		**244,800**

Swales: As listed earlier in this manual, the cost of swales is approximately $4.50 per linear foot, assuming seeding and straw mulching. The total length of swales for the Large-Lot design is 7,800 linear feet. At the suggested price the total cost for swales would be $35,100. The Clustered alternative has a total of 4,900 linear feet of swales with an estimate cost of $22,050.

Re-Forestation/Re-Vegetation: Reforestation/Revegetation is estimated to cost $2,925 per acre as indicated in Chapter 3. This cost includes planting of native tree saplings with protective shields at the recommended density, plus establishment of an appropriate groundcover to control invasives and minimize maintenance requirements. The Large-Lot design call for 9.2 acres of Re-Forestation/Re-Vegetation ($26,910). The Clustered alternative calls for 3.7 acres of Re-Forestation/Re-Vegetation ($10,825).

Roads: The road lengths are 3,097 linear feet for the Conventional Development as well as the Large-Lot alternative and 2,065 linear feet for the Clustered alternative. The width of the road was reduced to 20 feet from 28 feet for both of the Conservation Design alternatives, and curbing was eliminated for Conservation Design as well. The above road estimate costs have been produced by applying DelDOT multipliers for road lengths, as has been done in the other Case Studies.

Berms: Berms are relatively innovative techniques for stormwater management. The estimated costs for berm construction is $10 per linear foot, with the berms assumed to be a maximum of 2 ft in height and built according to the specifications set out in Chapter 3. Case Study 4 uses berming extensively, although in many if not most cases, these berms are integrated into the design of the residential lot along with its driveway (in a sense these become de facto berms and are not separate cost elements because they are part of the driveway construction). A limited number of berms (900 feet) are called for in Conservation Design Case Study 5.

BMP Landscaping: The “bermed” infiltration areas are to be revegetated with native landscaping species in Case Study 4. In Case Study 4 Large-Lot, a consistent landscaping theme is to be developed along the roads and driveways in these swale and infiltration areas. This landscaping will include a variety of different species selected for their texture, color, and other attributes in order to make this important landscaping component enhance the overall site appearance—not to mention the stormwater function—of the development. Different mixes of trees, shrubs, and ground cover species will be used, depending upon the specific context, although the intent is to achieve an integrated landscape theme throughout the development.

When considered from an individual lot perspective for 23 lots, cost per lot for conventional development is $24,420 while cost per lot using the large lot conservation design approach is $14,770 or $9,650 or 39% less. Considering the cluster option versus conventional development, the cluster option at $10,643 per lot is $13,777 or 56% less.

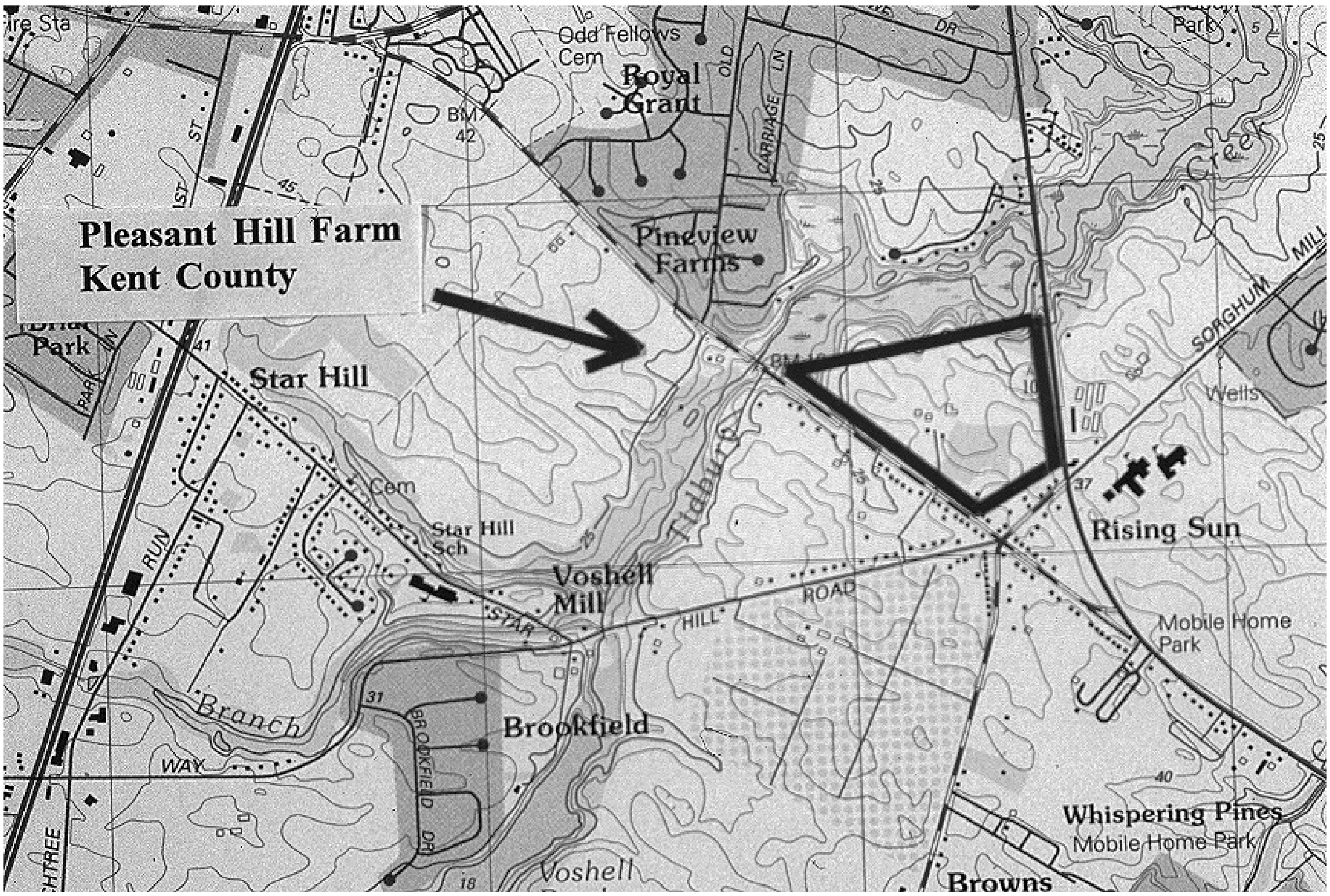
CONSERVATION DESIGN CASE STUDY 6 : PLEASANT HILL FARM

I. SITE ANALYSIS

Site Background

Pleasant Hill Farm is located in Kent County, DE in the northeast corner of the USGS Wyoming quadrangle, Figure 5-29. Tidbury Creek forms the northern border of the 84-acre property and is a significant site feature. The site is located in the Atlantic Coastal Plain Province.

Figure 5-29
Pleasant Hill Farm Quadrangle Map



Site Characteristics

Vegetation: Predevelopment landcover consists of woodlands, woods, grass mixtures and cropland, Figure 5-30. Along the stream and the northern boundary of the property, riparian woodlands dominate. Most of the southern area consists of straight row croplands with a small area of woods and grass.

Soils: Sassafras (Sa) soils dominate this site, Figure 5-31. These soils drain fairly well and have a Hydrologic Soil Group rating of B. In the northern portions of the site along the stream, Rumford (Ru) and Johnston (Jo) soils are also present. Rumford soils also drain well with a HSG of B, however the

Figure 5-30
Predevelopment Land Cover

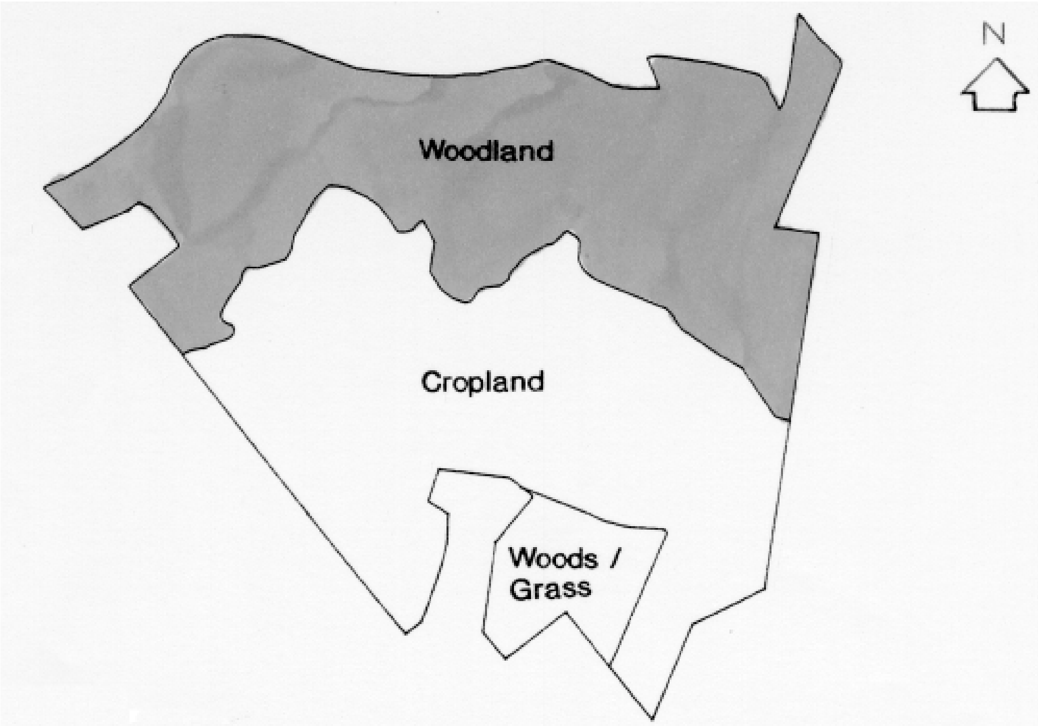
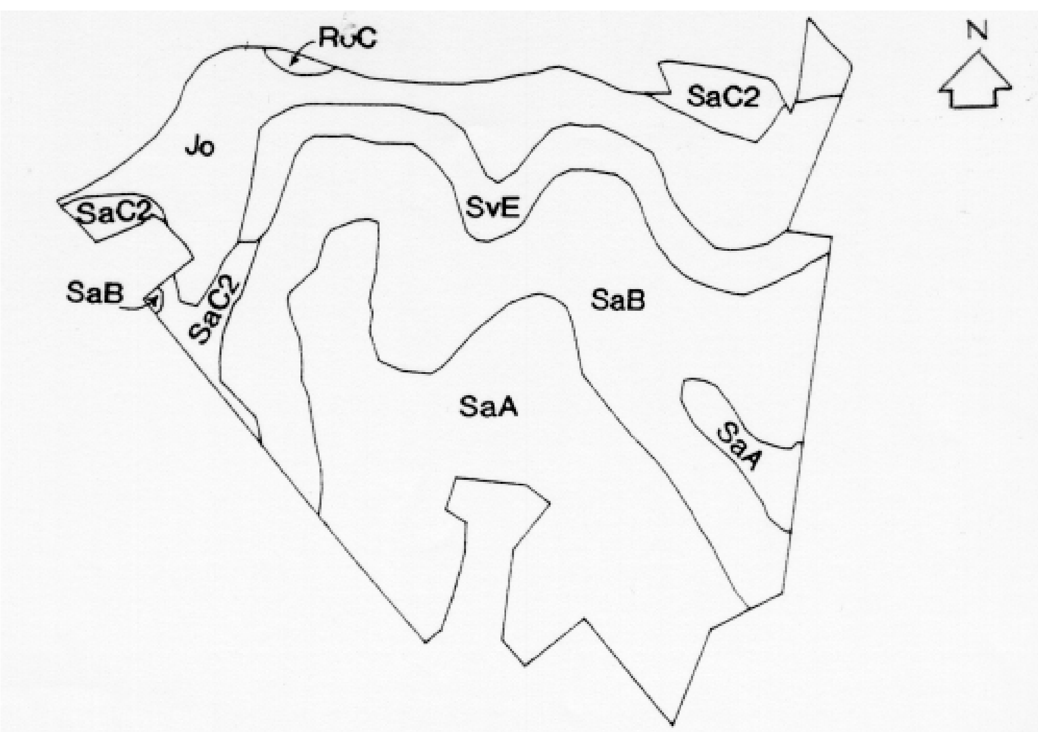


Figure 5-31
Soils Distribution



Johnston soils have a HSG of D and drain poorly.

Hydrology and Stormwater Recharge: Water moves from the south of this property toward the creek in the north. Five major drainage areas exist on this site predevelopment, Figure 5-32. These drainage areas reflect a system of natural swales or drainageways which thread through the lower portion of the site.

Figure 5-33 shows annual water recharge (on a per inch basis), applying the Brandywine Conservancy's climatic water budgeting model (based on average annual precipitation). The Sassafras and Rumford soils show the highest recharge rates. The northern Johnston soil does not recharge nearly as well.

Site Critical Features: Wetlands and floodplains form the most sensitive natural areas of this site. Woodlands, approximately 500 feet wide, extend along the length of the Creek on the north-

Figure 5-32
Natural Drainage Basins

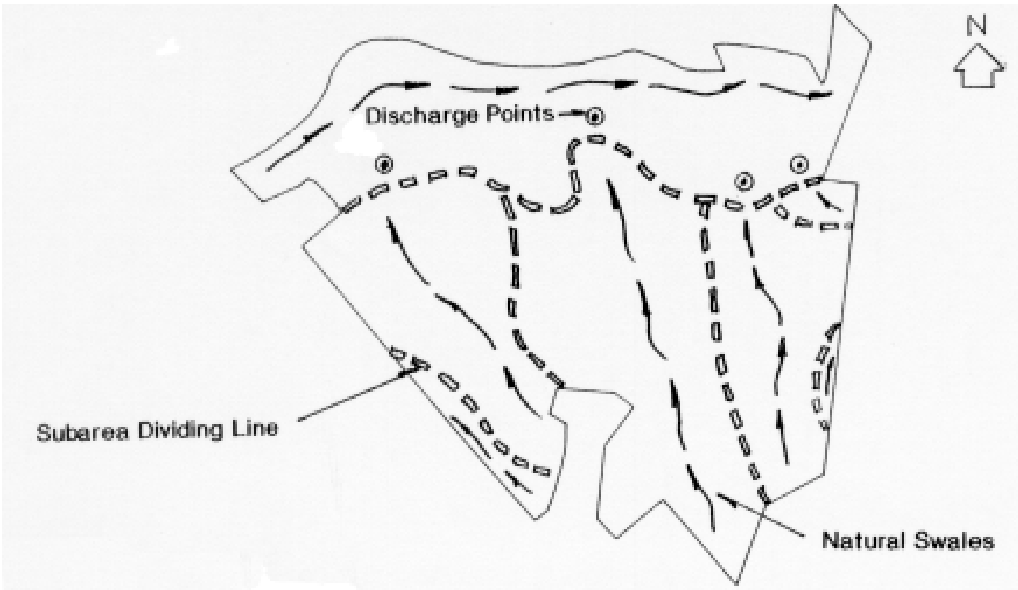
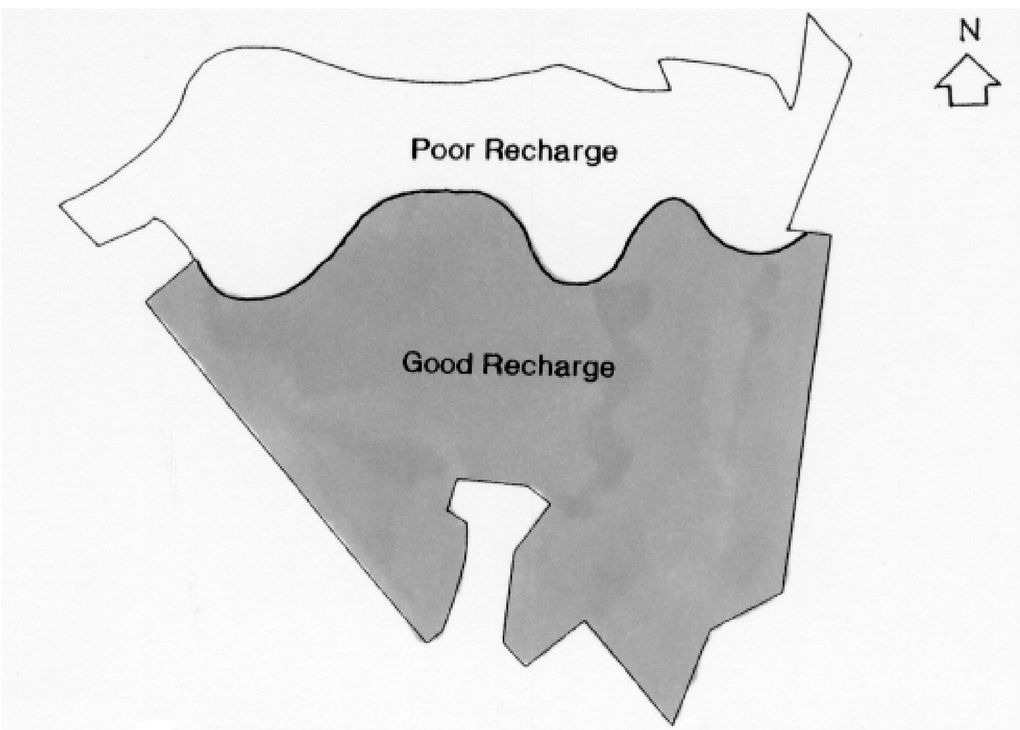


Figure 5-33
Zones of Good and Poor Recharge



ern border and form a broad swath. Steep slopes occur along the southern extent of the woods. The riparian buffer and wetlands along Tidbury Creek are wooded and provide significant water quality and quantity benefit to the stream.

Site Stormwater Constraints and Opportunities: The sensitive woodlands and wetlands along the stream constrain development and stormwater management on the site. Fortunately the existing buffer along the stream is fairly wide. Basic stormwater management needs, quantity and quality, should be met before stormwater reaches these wetland areas and the Creek itself, so water quality and wetland functions will not be impaired. Fortunately, with the exception of the Tidbury Creek riparian zone, the bulk of the site is not constrained.

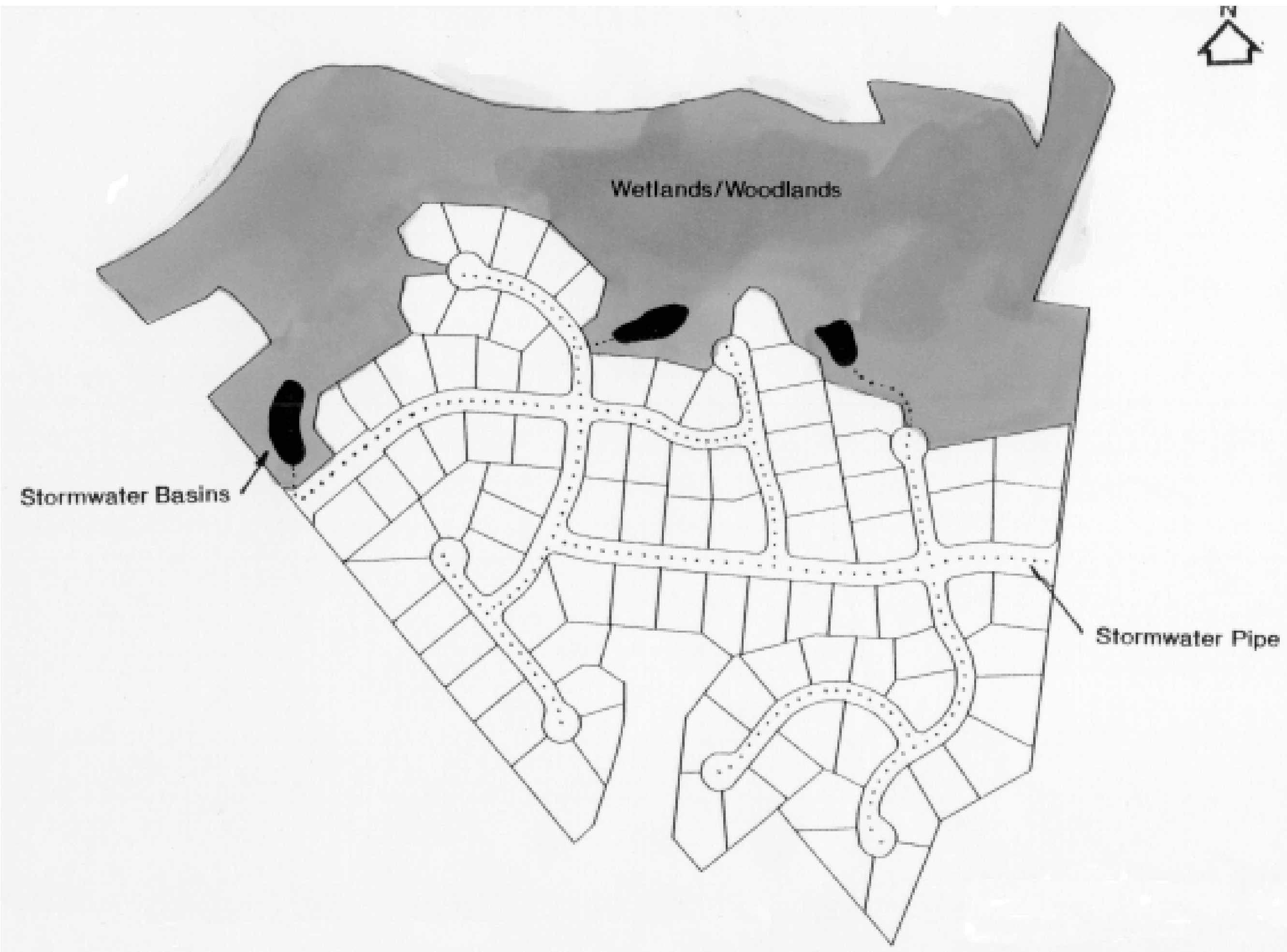
II. PROPOSED CONVENTIONAL DEVELOPMENT

The proposed Conventional Development incorporates 90 single family lots on about 50 acres (a large zone along the stream corridor has been shown as specially protected and not included in the development program, which accounts for the difference in total site acreage), with variable lot-sizes averaging 18,975 sq ft, Figure 5-34. The Conventional Development plan includes 7,579 linear feet of conventional roadways with a 28-foot width. The total impervious coverage for the site is 26.2 percent. The riparian forest to the north, consisting largely of undeveloped floodplain and wetlands bounded by steep slopes, has been offered to the County to add to their park system. Beyond this 35 acres of undeveloped forested area, no other open space has been proposed within this development.

The stormwater management plan includes a pipe collection system with stormwater inlets/gutters incorporated into the road system. This collection system discharges into three stormwater management basins constructed in the open space areas adjacent to Tidbury Creek. These basins are assumed to control peak rates of discharge through detention for up to the 10-year storm.

III. CONSERVATION DESIGN

Figure 5-34
Conventional Development Layout and Stormwater Plan



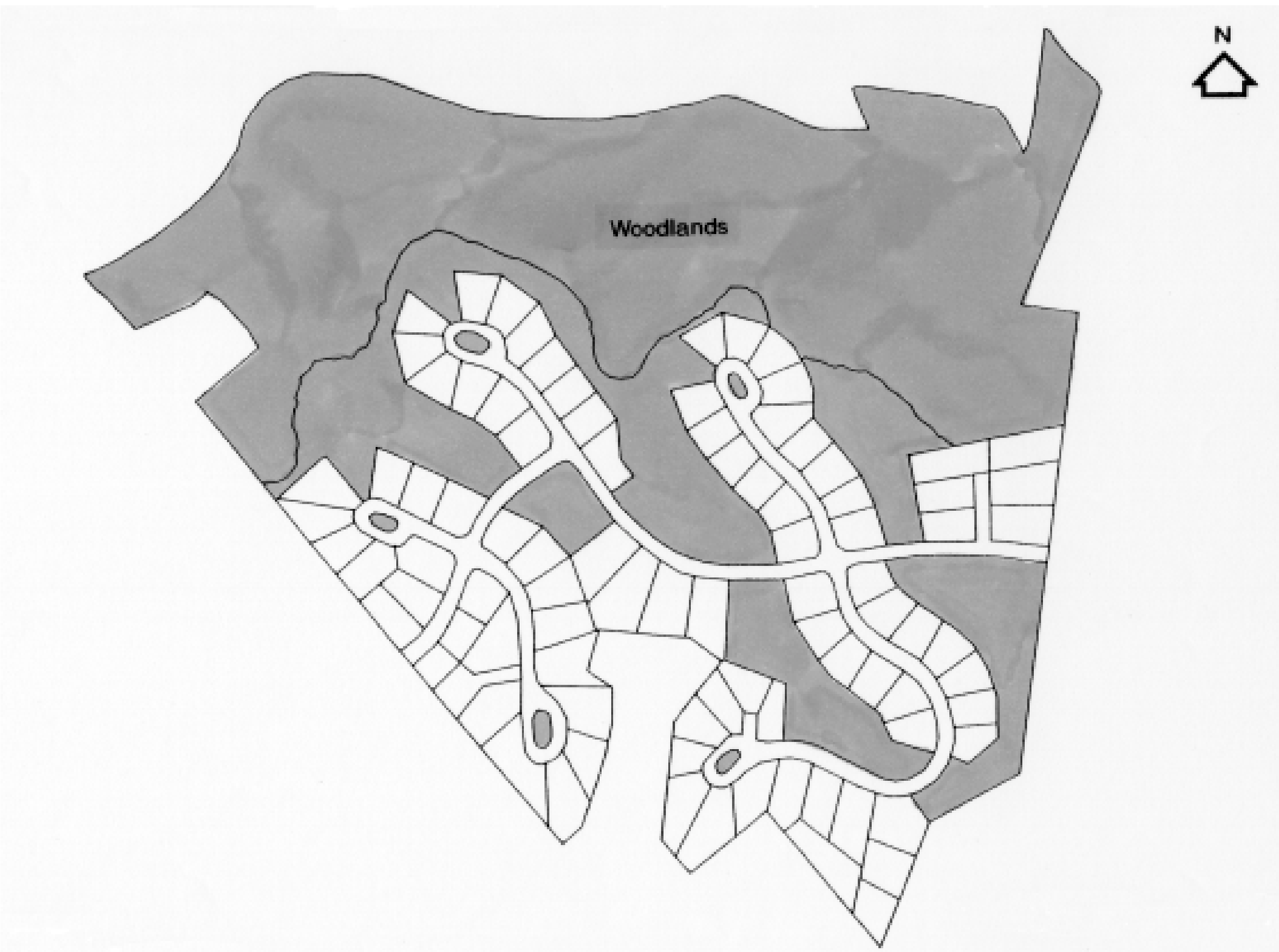
Case Study 6 : The Natural Swale/Open Space Corridor

This Conservation Design is largely based on application of the Minimum Disturbance/Maintenance Approach plus some Reforestation/Re-Vegetation, some Reduced Imperviousness, combined with Mitigation Practices such as vegetated swales and modestly sized berms. This stormwater management system is inspired by the existing natural system of swales and drainageways within the site as its basis. In a sense, the Conservation Design concept builds on the preservation of the Tidbury Creek corridor, carrying the theme of riparian area protection into the site's natural swale system which can be both ecologically beneficial and sensible from an engineering perspective, if done correctly. The swale system is designed to be an open space corridor for the site as well. Stormwater functioning of these natural swale "corridors" is enhanced through addition of native forest species (existing swales are already partially vegetated). Low berms constructed perpendicular to the swale axis provide the necessary stormwater retention volumes. The bulk of the natural swale area is not disturbed.

Building Program: The same number of dwellings are proposed. Lot sizes are reduced moderately. This Case Study represents a "middle ground" with respect to the clustering of lots, Figure 5-35. Of the 90 lots, roughly one-third of the lots have square footages similar to the Conventional Development plan. The remaining lots have been reduced in size to approximately 10,000 square feet, or one-quarter acre. With reduced road frontages, the house styles on the smaller lots must be altered; however, their size and number remain the same. Marketing implications of these changes should not be significant.

Perhaps most important, the vegetated swales/open space corridors are designed to provide meaningful open space "relief" for this relatively high density development, in some cases in rear yards, in some

Figure 5-35
Natural Swale and Open Space Corridor Approach



cases in front yards. As this additional vegetation matures and the open space benefits grow greater, this enhancement will increase and provide further benefit to the residents' quality of life and, hopefully, to value of the homes as well.

Lot Configuration: As stated above, lots are configured around open space corridors that are located along the site's natural drainage paths. These corridors serve several functions:

- they provide an aesthetic buffer between different clusters
- they minimize overall site disturbance
- they provide areas of natural drainage and recharge
- they become the primary stormwater management areas.

These corridors also permit the open space parkland to the north to extend into the development itself, thereby maximizing the ecological effectiveness of the Tidbury Creek riparian buffer corridor itself.

The development is concentrated in the open meadow portion of the site in an attempt to avoid the sensitive riparian woodlands. In all, this Case Study provides about 50 acres (60.1 percent of total site area) of open space, including the Creek corridor. Perhaps more meaningful is the fact that the 50 acres previously proposed for Conventional Development now is reduced to 35 acres of development with an additional 15 acres of open space integrated into the residential development.

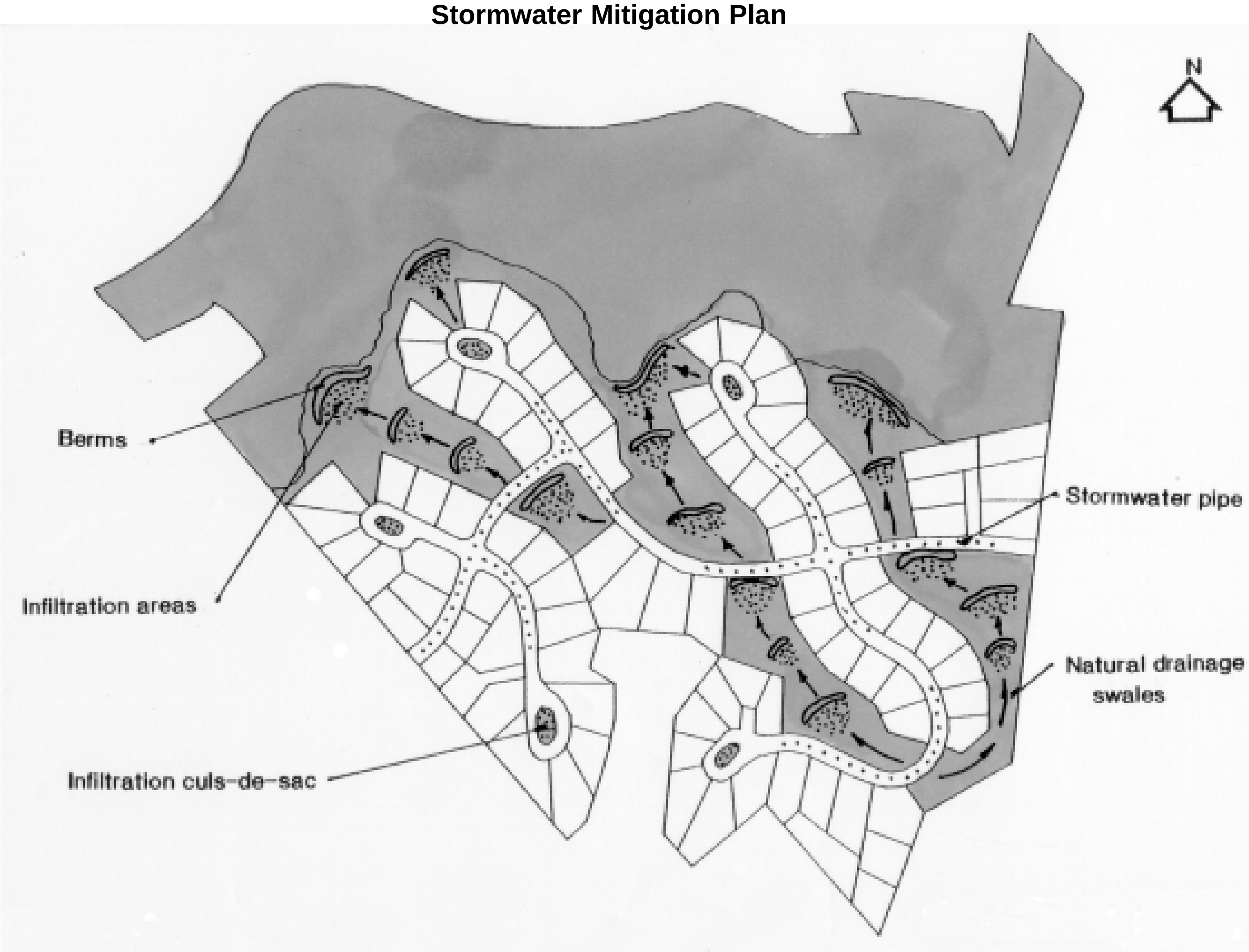
Impervious Coverage: By concentrating development, reducing average street widths from 28 ft to 20 ft, minimizing setbacks, and reducing road lengths to 6,333 feet (a 1,246 foot reduction from Conventional Development), this Conservation Design achieves an impervious coverage of 10.7 percent (a 59 percent <u>reduction</u> in impervious surface from the Conventional Development).

Minimum Disturbance: As described above, by reducing lot size and concentrating these lots, a large portion of the site can remain undisturbed. The open space corridors, with their highly permeable soils, will provide both very effective recharge and water quality filtering processes of different types, <u>if left largely undisturbed.</u> These open space corridors will be encroached upon minimally, with some careful berm placement and reforestation/revegetation to augment the natural water quantity and quality functioning (including peak rate control) of this important natural drainage system.

Mitigation: To manage the remaining stormwater runoff pursuant to DNREC requirements, the natural swale/open space corridor plan directs stormwater into a system of vegetated swales and bermed infiltration areas that follow the existing drainage paths, Figure 5-36. In this case, the roads will be curbed and guttered to direct stormwater to these open space corridor swale areas, minimizing the need for swales on these smaller residential lots. All of the stormwater system is integrated into common open space zones, thereby simplifying the management of the system.

This stormwater management plan also proposes reforesting/revegetating the natural swales/open space corridors, which will further reduce runoff and increase infiltration in the future, as well as enhance the overall aesthetics of the proposed development. Appropriate native tree species with ground cover to control invasives are planned for these open space corridors.

Figure 5-36
Stormwater Mitigation Plan



IV. STORMWATER CALCULATIONS

Curve Number

Condition	Curve Number
Pre-Development	68
Conventional	76
Conservation Design	71

The use of Conservation Design techniques makes it possible to decrease the Curve Number compared to the Conventional Development design. As with many of the other Case Studies, the reduction in impervious cover helps reduce Curve Numbers and the volume of stormwater being generated. This Conservation Design plan also avoids disturbing of a significant portion of the site and includes reforestation/revegetation of parts of the swale areas, all of which serves to keep the composite Curve Number lower than otherwise would be the case for Conventional Development.

Peak Runoff Rates

Condition	Peak Rate (cfs - 10 year storm)
Pre-Development	95
Conservation Design	67.3

The Conservation Design makes substantial impacts in reducing the Curve Number of the site over the Conventional Development. In addition, the peak rate is not only maintained, but actually lowered from predevelopment. The stormwater management plan closely follows the predevelopment drainage pattern in an attempt to maintain the Times of Concentration of stormwater flows. The berms proposed throughout the open space swale corridors are designed to handle the increased volume generated by the impervious surfaces associated with development. Because this design follows the natural drainage areas closely, the TR-55 calculations do not pose a significant problem in terms of performing calculations by subarea (a requirement for Conservation Design which has emerged as troublesome in some of the other Case Studies). The site is divided into only 5 subareas.

Water Budget

Annual Water Budget for Pleasant Hill (in gallons):

	Pre-Development	Conventional Development	Conservation Design Natural Swale/Open Space Corridor
Precipitation	99,630,858	99,630,858	99,630,858
Runoff	2,637,659	25,064,175	11,494,456
Recharge	33,921,626	25,108,208	30,491,589
Evapo-transpiration	63,056,866	49,454,425	57,640,772

Conservation Design succeeds in improving the stormwater drainage that would exist on the site under Conventional Development. Runoff is decreased by 54 percent (13,569,719 gallons), Conservation Design versus Conventional Development. This "improvement" (actually a reduction in the negative impact of development) occurs due to decreased impervious areas, including reduced road lengths and increased open space areas.

Another important objective of Conservation Design—to increase the recharge of stormwater while decreasing the runoff—is achieved in this Case Study. The recharge, calculated by water budget modeling, is improved by 17 percent (5,383,381 gallons) over the Conventional Design. This is achieved by designing the lots with the existing natural drainage areas in mind. It is very important to emphasize that the calculation methodology used here does not in any way directly take into account infiltration and recharge occurring in the natural swale/open space corridor system. In this study, as with the other Case Studies, we would expect these recharge volumes to be quite substantial, making the numbers given above by the Brandywine Conservancy's water budget modeling analysis extremely conservative. For the vast majority of storms, all those smaller than the 1-year storms, for example, we would expect the stormwater system in this Case Study to discharge virtually no stormwater flows to the surface water system and to infiltrate virtually all of these storms. Given the distribution of storm events, the positive water budget implications would be quite significant, adding in an equally significant way to the recharge quantities provided by Conservation Design.

V. COSTS

Costs including swales (both natural and constructed swales), reforestation/revegetation, roadways, berms, for the Conservation Design are examined in this section and compared to costs estimated for Conventional Development.

CONVENTIONAL DEVELOPMENT COSTS

6,800 ft of streets	@ $150/linear ft	1,020,000
3 detention ponds	@ $16,000/pond	48,000
7,400 ft of swm pipe	@ $22/linear ft	162,800
41 endwalls/inlets	@ $1,300/each	53,300
	TOTAL	**1,284,100**

CONSERVATION DESIGN COSTS

4,000 ft of streets	@ $100/linear ft	400,000
1,500 ft of streets	@ $85/linear ft	127,500
4,000 ft of swm pipe	@ $22/linear ft	88,000
22 endwalls/inlets	@ $1,300 each	28,600
1,900 ft of berms	@ $10/linear ft	19,000
3,900 ft of swales	@ $4.50/linear ft	17,550
16.2 ac reforestation	@ $2,925/ac	47,385
	TOTAL	**728,035**

Swales: The total length of swales for the Conservation Design is 3,900 linear feet; there are no swales in the Conventional Development. At the suggested price of $4.50 per linear foot, the total cost for swales would be $17,550.

Reforestation/Revegetation: As previously stated, Re-Forestation/Re-Vegetation is estimated to cost approximately $2,925 per acre. The design has 16.2 acres of Re-Forestation/Re-Vegetation planned. The total estimated Reforestation/Revegetation cost for the Conservation Design is $37,385.

Roads: The road length is 5,500 linear feet for this alternative, 4,000 ft of which is reduced width but with curb/gutter and 1,500 ft of which is reduced width without curb/gutter (thus the two cost categories). The width of the road was reduced to 20 ft in conservation Design. The total cost for the roadways in Conservation Design in this Case Study is $527,500.

Berms: The total costs of berm construction, estimating $10 per linear foot, is $— and $19,000 for the Pleasant Hill Conservation Design.

Costs for the Conventional Development design has been estimated at $1,284,100 versus the 728,035 for Conservation Design—a dramatic difference. **When considered from an individual lot perspective for 90 lots, costs per lot for conventional development are $14,268 while cost per lot using the conservation design approach is $8,089 or $6,179 (43%) less.** Although many cost details have not been included here for either the Conventional Development or the Conservation Design alternative, the substantial gap between the two cost estimates demonstrates conclusively that Conservation Design Approaches and Practices can be extremely cost effective.