BETTER SITE DESIGN

An Assessment of the Better Site Design Principals for Communities Implementing Virginia's Chesapeake Bay Preservation Act

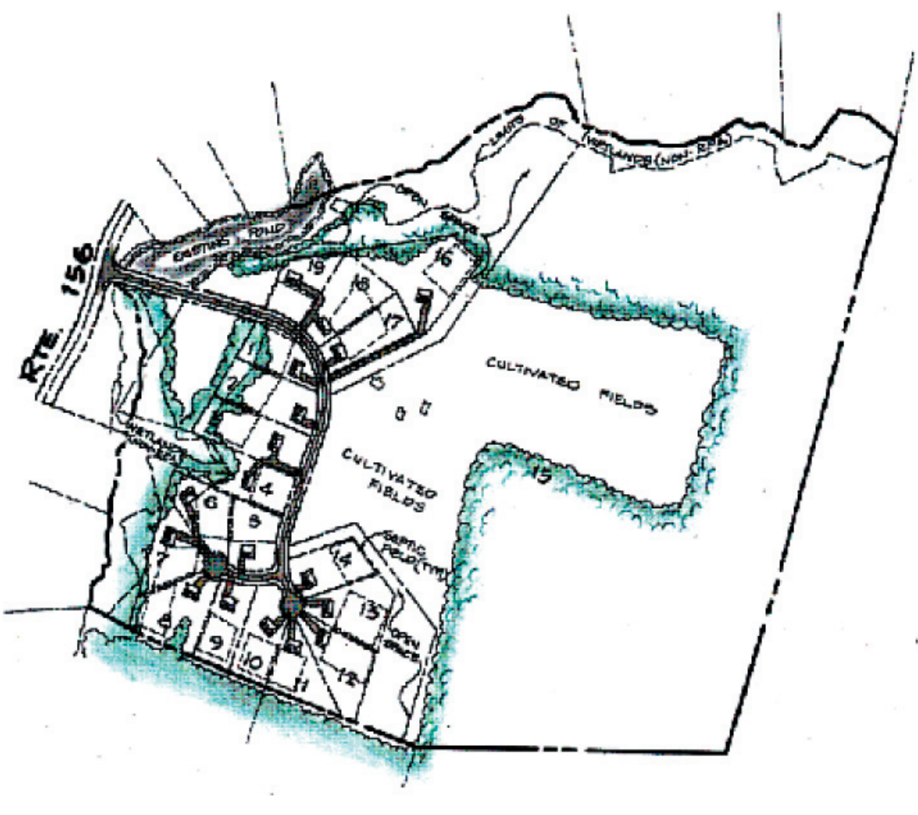

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TABLE OF CONTENTS

I. INTRODUCTION

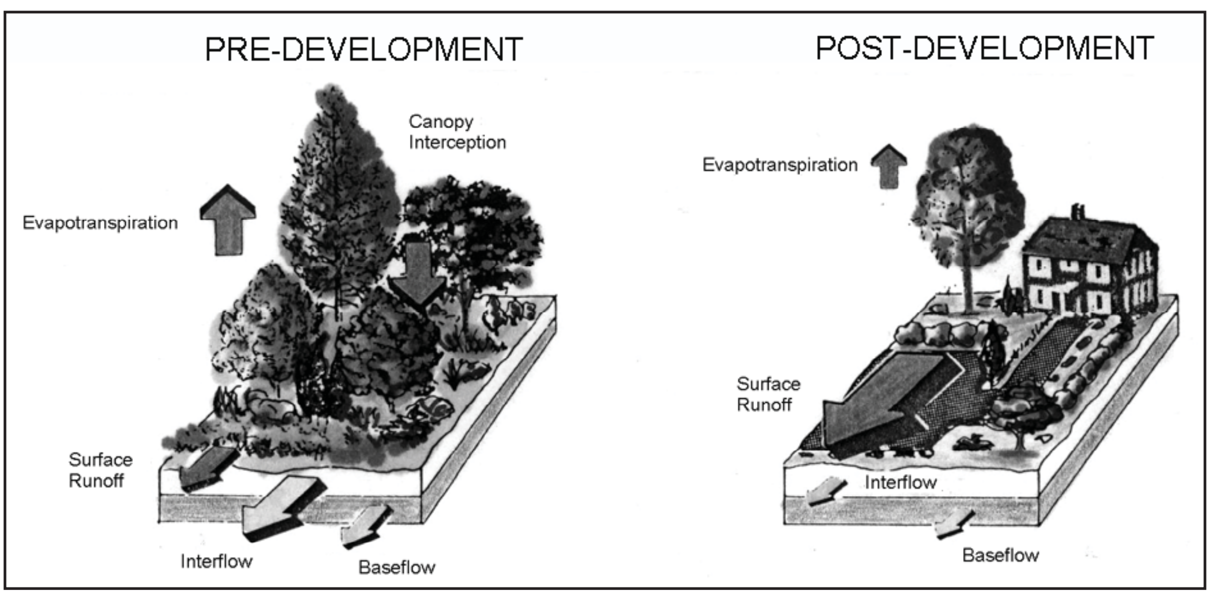
Development patterns in most Virginia communities are the result of numerous individual site planning decisions made over long periods of time. The cumulative effects of these decisions have dramatically transformed the landscape. Development alters the surface of the land by replacing natural cover and native vegetation with rooftops, roads, parking lots, driveways, and sidewalks. These hard surfaces are impermeable to rainfall and are collectively known as impervious cover.

Urbanization can have a negative impact on the quality of our waters and aquatic resources. For instance, the increased impervious cover in a watershed, in conjunction with the loss of natural cover, alters hydrology by preventing the infiltration of water into the soil and increasing the frequency and volume of stormwater runoff that flows to a watercourse (Figure 1.1). The land disturbance that occurs during the development process also adds excess sediments that can choke streams and cloud tidal waters. In turn, these fundamental changes impact both the water quality and habitat of receiving waters. A summary of the cumulative impacts of urbanization on water resources is presented in Table 1.1 on page 3.

More and more communities are struggling to achieve the goal of economic growth that also protects the local environment. Unfortunately, many communities have found that their own development codes and standards can actually work against this goal. For example, local codes and standards often create needless impervious cover in the form of wide streets, expansive parking lots, and large-lot subdivisions and require excessive clearing and grading. At the same time, local codes often give developers little or no incentive to conserve natural areas that are important for watershed protection.

This publication is intended to enhance a community's ability to improve water quality during the site design process by providing an assessment of various techniques aimed at

Figure 1.1: This diagram shows how development and the corresponding increase in impervious cover disrupts the natural water balance. In the post-developed setting, the amount of water running off the site is dramatically increased.



Specifically, this publication will look at ways in which Virginia's Chesapeake Bay Preservation Act and the performance criteria of the Chesapeake Bay Preservation Area Designation and Management Regulations can be used as a vehicle to improve water quality through better site design.

Reducing the Impacts of Urbanization Through Virginia's Chesapeake Bay Preservation Act

Land can be used and developed in ways that minimize impacts to water quality. The first sentence of the Chesapeake Bay Preservation Act, enacted in 1988, states that "Healthy state and local economies and a healthy Chesapeake Bay are integrally related; balanced economic development and water quality protection are not mutually exclusive." The Chesapeake Bay Preservation Act was designed to enhance and protect water quality while still allowing reasonable development to continue.

The Chesapeake Bay Preservation Area Designation and Management Regulations, adopted by the Chesapeake Bay Local Assistance Board, address nonpoint source pollution by identifying and managing certain lands called Chesapeake Bay Preservation Areas (CBPAs) -- lands where development has the potential to impact water quality most directly. Land in a CBPA is categorized as either a Resource Protection Area (RPA) or a Resource Management Area (RMA). RPAs are sensitive lands at or near the shoreline or along the banks of perennial streams that have an intrinsic water quality value due to the ecological and biological processes they perform. RMAs are lands that, without proper management, have the potential to significantly degrade water quality or to damage the protective features of the RPA. Development within RPAs is restricted to water dependent uses or redevelopment.

Land use within RMAs, on the other hand, is not limited by the Chesapeake Bay Preservation Act. Any development permitted by local zoning is allowed to occur within an RMA, but must be accomplished using the 11 performance criteria from the Chesapeake Bay Preservation Area Designation and Management Regulations, which work to reduce nonpoint pollution at its source. While all 11 performance criteria must be met for all development and redevelopment within CBPAs, the focus of this publication is on the three general performance criteria listed below. The following three general performance criteria are perhaps more subjective than the others, but equally important for protecting water quality. These three general performance criteria provide the broad objectives to be met through better site design and are the focus of the Model Development Principles described in this publication:

No more land shall be disturbed than is necessary to provide for the desired use or development. (9VAC 10-20-120.1)

Indigenous vegetation shall be preserved to the maximum extent possible consistent with the use and development allowed. (9VAC 10-20-120.2)

Land development shall minimize impervious cover consistent with the use or development allowed. (9VAC 10-20-120.5)

The Site Design Process

All too often, the application of these three general performance criteria has focused only on nutrient control and has been relegated to a technical exercise of engineering a site for stormwater control. The use of Best Management Practices (BMPs) to mitigate the increased runoff and to treat the pollutants it contains is typically the result. Good site design provides a more appropriate, and cost effective, approach to meeting the performance criteria. The key to successfully incorporating these criteria into development plans is simply to use them at the beginning of the site design process, rather than at the end. The same three questions should be asked when considering each element of a design: Does this minimize land disturbance? Does this preserve vegetation? Does this minimize impervious cover?

As a first step, sensitive features should be evaluated and preserved to the greatest extent possible. This may be accomplished by concentrating development in the most suitable portions of a site. At a minimum, steep slopes, non-RPA wetlands, intermittent streams, and stands of mature forests should be considered as features worthy of preservation. Once the most suitable areas of a site have been determined, the design process should focus on how to meet the needs of the proposed development within these areas. This phase includes such design work as laying out lots and locating structures, roads, driveways, and parking areas. Included in this phase is consideration of specific issues related to impervious cover such as necessary road widths. When this process is followed, and the techniques described below are used, the result should be less need for stormwater management in the form of expensive BMPs because less stormwater runoff is generated, and more filters into the ground. In addition to the costs savings derived from fewer structural BMPs (and their ongoing maintenance headaches), development costs are minimized because better designs require less clearing, grading, and pavement.

About the Model Development Principles

The Model Development Principles outline 16 areas for consideration by local planners, developers, citizen groups, design professionals, and policy makers to change the standard approach to site design. The result can be more environmentally sensitive, economically viable, and locally appropriate development.

In many ways, our communities are a mix of three habitats. The first habitat includes the open spaces and natural areas that are relatively undeveloped. The second is the habitat where we live and work, including our yards and homes. The third habitat is devoted to the automobile, and includes roads, driveways, and parking lots. The size, appearance, location, and design of all three areas are determined in large part by local subdivision, zoning, clearing and grading, and landscaping ordinances and state road and utility standards.

Each of the Model Development Principles falls into one of the following three areas:

- Conservation of Natural Areas. Principles 1 and 2 address codes and ordinances that promote (or impede) protection of existing natural areas and incorporation of open spaces into new development.
- Lot Development. Principles 3 through 6 focus on the regulations which determine lot size, lot shape, housing density, and the overall design and appearance of our neighborhoods.
- Residential Streets and Parking Lots. Principles 7 through 16 focus on those codes, ordinances, and standards that determine the size, shape, and construction of parking lots, roadways, and driveways in the suburban landscape.

The Model Development Principles set forth in this document were adapted from a series of 22 nationally- endorsed principles developed by the Site Planning Roundtable, a national cross-section of diverse planning, environmental, home builder, fire, safety, public works, and local government personnel.

To promote more widespread implementation of the Model Development Principles, the Center for Watershed Protection developed a comprehensive handbook entitled Better Site Design: A Handbook for Changing the Development Rules in Your Community. This handbook details the technical support for the 22 Model Development Principles and outlines current and recommended practices along with research data on the economic, market, legal, safety, and social benefits of better site designs. Also featured is a codes and ordinance worksheet designed to help communities target the development rules most in need of change in their localities. Finally, the handbook guides users through the process of coordinating the local site planning Roundtable consensus process necessary to actually change development rules to promote better site design.

Table 1.1: Cumulative Impacts of Land Development on Aquatic Resources
A Summary of Research

- Higher peak discharge rates and greater flooding
- Reduced groundwater recharge and lower stream flow during dry weather
- Greater streambank erosion and enlargement of the stream channel
- Decline in stream bed quality due to embedding, sediment deposition, and turnover, resulting in degradation of stream habitat structures and loss of pool and riffle structure
- Fragmentation of the riparian forest cover
- Increased nutrient loadings that cause algal blooms and areas of inadequate oxygen supply
- Increased sediment loadings that cloud tidal waters and prevent submerged aquatic vegetation (SAV) from growing and choke benthic organisms such as oysters
- Increased bacteria loadings may result in levels that exceed recreational contact standards
- Lower diversity of plant, aquatic insects and native fish species, loss of sensitive fish species, and lower spawning success of anadromous fish
- Warmer stream temperatures

The Model Development Principles

Conservation of Natural Areas

1. Conserve trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Wherever practical, manage community open space, street rights-of-way, parking lot islands, and other landscaped areas to promote natural vegetation.

(Photo Courtesy: Randall Arendt)

2. Clearing and grading of forests and native vegetation at a site should be limited to the minimum amount needed to build lots, allow access, and provide fire protection. A fixed portion of any community open space should be managed as protected green space in a consolidated manner.

Lot Development

(Photo Courtesy: Randall Arendt)

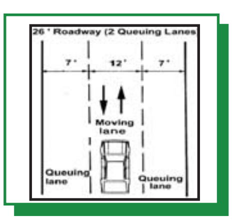
3. Promote open space development that incorporates smaller lot sizes to minimize total impervious area, reduce total construction costs, conserve natural areas, provide community recreational space, and promote watershed protection.

4. Relax side yard setbacks and allow narrower frontages to reduce total road length in the community and overall site imperviousness. Relax front setback requirements to minimize driveway lengths and reduce overall lot imperviousness.

5. Promote more flexible design standards for residential subdivision sidewalks. Where practical, consider locating sidewalks on only one side of the street and providing common walkways linking pedestrian areas.

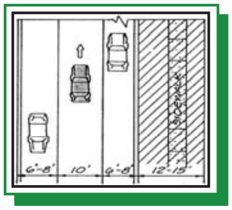
6. Reduce overall lot imperviousness by promoting alternative driveway surfaces and shared driveways that connect two or more homes together.

Residential Streets and Parking Lots



7. Design residential streets for the minimum required pavement width needed to support travel lanes; on-street parking; and emergency, maintenance, and

8. Reduce the total length of residential streets by examining alternative street layouts to determine the best option for increasing the number of homes per unit length.



9. Residential street right-of-way widths should reflect the minimum required to accommodate the travel-way, the sidewalk, and vegetated open channels. Utilities and storm drains should be located within the pavement section of the right-of-way wherever feasible.

10. Minimize the number of residential street cul-de-sacs and incorporate landscaped areas to reduce their impervious cover. The radius of cul-de-sacs should be the minimum required to accommodate emergency and maintenance vehicles. Alternative turnarounds should be considered.

11. Where density, topography, soils, and slope permit, vegetated open channels should be used in the street right-of-way to convey and treat stormwater runoff.

12. The required parking ratio governing a particular land use or activity should be enforced as both a maximum and a minimum in order to curb excess parking space construction. Existing parking ratios should be reviewed for conformance taking into account local and national experience to determine if lower ratios are warranted and feasible.

13. Parking codes should be revised to lower parking requirements where mass transit is available or enforceable shared parking arrangements are made.

(Source: Wells, 1995)

14. Reduce the overall imperviousness associated with parking lots by providing compact car spaces, minimizing stall dimensions, incorporating efficient parking lanes, and using pervious materials in the spillover parking areas where possible.

(Source: ULI, 1997)

15. Provide meaningful incentives to encourage structured and shared parking to make it more economically viable.

16. Provide stormwater treatment for parking lot runoff using bioretention areas, filter strips, and/or other practices that can be integrated into required landscaping areas and traffic islands.

Relationship to the Chesapeake Bay Preservation Area Designation and Management Regulations Performance Criteria

The table below shows how incorporating the Model Development Principles into a site design can help address the three general performance criteria of minimizing land disturbance, preserving indigenous vegetation, and minimizing impervious surface. The Model Development Principles are not intended to serve as numerical performance standards, or to establish specific design parameters, but rather to provide general guidelines for better implementation of the performance criteria. It is important to keep in mind that these principles are only a set of tools to use in the process of site design. Simply incorporating a principle from the list does not imply that the performance criteria of the Chesapeake Bay Preservation Area Designation and Management Regulations have been met.

Table 1.2: Model Development Principles and the Chesapeake Bay Preservation Area Designation and Management Regulations Performance Criteria

Model Development Principle	Minimizes Land Disturbance	Preserves Indigenous Vegetation	Minimizes Impervious Surface
1. Native Plant & Tree Conservation	T	T	
2. Minimized Clearing & Grading	T	T	
3. Open Space Design	T	T	
4. Shorter Setbacks & Frontages	T	T	T
5. Common Walkways			T
6. Shared Driveways			T
7. Narrower Streets	T	T	T
8. Shorter Streets			T
9. Narrower Right-of-Way Widths	T	T	
10. Smaller & Landscaped Cul-de-Sacs			T
11. Vegetated Open Channels			T
12. Reduced Parking Ratios	T	T	T
13. Mass Transit & Shared Parking			T
14. Less Parking Lot Imperviousness	T	T	T
15. Structured Parking	T	T	T
16. Treated Parking Lot Runoff	T		

II. Implementation of the Model Development Principles

Applying the Model Development Principles Throughout the Design Process

As a first step towards applying the better site design principles, sensitive features should be evaluated and preserved to the greatest extent possible by concentrating development in the most suitable and appropriate portions of a site. At a minimum, Chesapeake Bay Resource Protection Area (RPA) features and their buffer area are to be retained. In addition, steep slopes, non-RPA wetlands, intermittent streams and stands of mature forest should be considered as features worthy of preservation. Once the most suitable areas of a site have been determined, the design process should focus on how to meet the needs of the proposed development within these areas. This phase includes locating roads, driveways, parking, structures and laying out lots. Also included in this phase is consideration of specific issues related to impervious cover such as necessary road widths. When coupled with the model development principles, this better site design process should result in less need for stormwater BMPs because less stormwater runoff is being generated, and more is filtering into the ground. Furthermore, in addition to the cost savings derived from fewer BMPs (and their ongoing maintenance headaches), development costs are minimized because better designs require less clearing, grading, and pavement.

Randall Arendt (1994) has advanced a two-phase process that simplifies the design of open space developments. The first phase of this process deals with the collection and analysis of basin information, and the second organizes this information while making judgements about the shape of the development. The Model Development Principles go hand-in-hand with this process, described in Table 2.1. Appendix A also provides a detailed list of Better Site Design resources to help incorporate the Model Development Principles into the site design process.

The Model Development Principles and the Development Review Process

The Chesapeake Bay Preservation Area Designation and Management Regulations (Regulations) require that local governments make provisions, as necessary, to ensure that any development of land within Chesapeake Bay Preservation Areas is accomplished through a plan of development procedure to ensure compliance with the Act and the Regulations. The Regulations also state that a water quality impact assessment shall be required for any proposed development with a Resource Protection Area (RPA) and for any other development in Chesapeake Bay Preservation Areas that may warrant such assessment because of the unique characteristics of the site or intensity of the proposed use or development.

The requirements of the Regulations provide a statutory framework through which localities can institutionalize consideration of the Model Development Principles in the development review process. At present, most localities review development for compliance with the Regulations at the end of the review process (e.g., with plan check of engineered drawings for structural BMPs). As suggested above, consideration of the Model Development Principles can result in the preservation and enhancement of water quality and reduce development costs by eliminating, or reducing, the need for structural BMPs.

Accordingly, development review should occur in three stages. The first step is when a rezoning is sought and the use and intensity (density) of development is being proffered. Information required at this step should address the "Background Stage" described in Table 2.1 and result in the identification of areas most suitable for development and those areas most appropriate to be preserved or used in an open-space context. The resulting density and a development concept (sketch) plan should then become a part of the proffer. The second step is the local plan of development review process. It is at this step that the Model Development Principles are most applicable.

The third step of the process is the technical review of the development plans for compliance with the stormwater management criteria, including the calculations of impervious cover and pollutant mitigation requirements, along with the selection and design of the most appropriate BMP for the situation.

Table 2.1: An Overview of the Steps Involved in Designing Open Space Developments
(Arendt, 1994)

Background Stage

Understand the locational context
- Site's proximity to traditional small towns or villages
- Relationships between dwellings and streets

Map special features
- New development should be based on an analysis of the site's special features, both those offering opportunities and those involving constraints
- Include soils, wetlands, floodplains, slopes, significant wildlife habitats, woodlands, farmland, historic, archaeological, and cultural features, views into and out from the site, and aquifers and their recharge areas

Integrate the information layers
- Once pertinent features have been identified, located, and evaluated in terms of their significance, they need to be drawn on overlay sheets and looked at together
- A composite map can eventually be prepared by looking at all information areas together to see the overall pattern of potential conservation areas
- All buildable lands will clearly emerge

Prioritize objectives
- "Primary Conservation Areas" may include wetlands, floodplains, slopes, and significant wildlife habitats
- "Secondary Conservation Areas," a second broad category of open space, may include woodlands, farmland, historic, archaeological, and cultural features, views into and out from the site, and aquifers and their recharge areas

Design Stage

Identify all potential open space areas
- Conservation land that should potentially be protected
- Unbuildable wetlands, floodplains, steep slopes – "Primary Conservation Areas"
- Buildable uplands that are most sensitive environmentally, most significant historically or culturally, most scenic, or which possess unusual attributes that cause them to stand out from the rest of the property as areas that the average observer would miss most if they disappeared under new houselots and streets – "Secondary Conservation Areas"

Locate the house sites
- Maximize the number of "view lots"
- Ensure that usable open space is located within convenient walking distance from other houses in the subdivision and, whenever possible, lots should front on open space areas
- Incorporate smaller parcels of open space to increase the number of "view lots," such as a small neighborhood common or village green, or trees and grass around ponds doubling as stormwater management facilities
- No clearing of reserve drainfields

Design road alignments and trails
- Avoid crossing wetlands and minimize the length of streets
- Avoid large trees, mature tree stands, or wildlife habitat
- Avoid long, straight street segments
- Minimize dead ends

Draw in the lot lines
- Reduce both the width and area of lots where houses are located off-center (i.e., closer to one side line, thereby maximizing one side yard) and where lots abut open space behind them

III. The Model Development Principles in Practice: Four Virginia Case Studies

The better site design techniques represented by the Model Development Principles are, in most cases, not new. In fact, the use of some of these principles can be found in many residential and commercial developments throughout Virginia. Where they have been used, there has often been a concurrent reduction in impervious cover, less clearing and grading, and greater preservation of indigenous vegetation than is typically found in more conventional development patterns. As a result, these sites typically have less stormwater runoff and nutrient export, an increase in on-site stormwater infiltration, and often, a reduction in infrastructure costs. Unfortunately, as it seems that only a few recent developments projects in Virginia employ many of the Model Development Principles, opportunities to reduce impervious cover, minimize clearing and grading, and preserve native vegetation have been lost.

To illustrate the potential benefits of better site design through real-world application, this section presents a summary of evaluations of four case study projects from across the Virginia Tidewater region. Each site employs a variety of the Model Development Principles and illustrates the point that on virtually every development project there are ways to limit impervious cover, provide better protection of sensitive areas, treat stormwater at the source, and still provide a marketable, cost-effective development. The evaluation includes a comparison of each project as-built to a hypothetical site plan where the model development principles were not utilized. This is referred to as the "status quo" site design and is more representative of the typical or conventional new development. In general, the status quo sites are assumed to have wider streets, larger setbacks, less open space, more cleared area, and more parking. The assumptions for each status quo site are presented in the text in Sections IV through VII. The purpose of the comparison between the two design variations is to quantify the relative reduction in impervious cover and clearing and to document the preservation of native vegetation.

The four sites used here were selected from a pool of more than 20 sites scattered throughout Tidewater Virginia. Local government staff, engineering consulting firms, watershed organizations, and the Chesapeake Bay Local Assistance Department were contacted to identify possible candidate projects that met the following general criteria:

- One site per jurisdiction, generally representative of a different physiographic region (coastal plain and Piedmont)
- Sites that incorporate measures to reduce impervious cover, preserve indigenous vegetation, and reduce clearing and grading
- Projects representing a range of land use (e.g., residential, infill and redevelopment, and commercial)
- Sites representing a range of land development intensity and impervious cover
- Land exhibiting a range of pre-developed vegetative and land cover (e.g. forest, meadow, wetlands, existing housing)

Table 3.1: Model Development Principles Applied In Virginia Case Studies					
Model Development Principle		Case Study Site Name			
		The Fields at Cold Harbor	Whittaker Island at Governor's Land	Rivergate	The Arboretum
1.	Native Plant & Tree Conservation	T	T		T
2.	Minimized Clearing & Grading	T	T		T
3.	Open Space Design	T	T	T	
4.	Shorter Setbacks & Frontages	T	T	T	
5.	Common Walkways	T	T	T	
6.	Shared Driveways	T			
7.	Narrower Streets	T	T	T	
8.	Shorter Streets	T			
9.	Narrower Right-of-Way Widths			T	
10.	Smaller & Landscaped Cul-de-Sacs		T		
11.	Vegetated Open Channels	T			
12.	Reduced Parking Ratios			T	
13.	Mass Transit & Shared Parking				T
14.	Less Parking Lot Imperviousness				T
15.	Structured Parking				T
16.	Treated Parking Lot Runoff			T	

The following four development projects were ultimately selected to help illustrate the application of several Model Development Principles in a variety of different development scenarios:

- The Fields at Cold Harbor: a low density residential development on private septic in Hanover County
- Whittaker Island at Governor's Land: a medium density residential site on public water and sewer in James City County
- Rivergate: an infill townhouse project in Alexandria
- The Arboretum: a commercial office park in Chesterfield County

Each case study, while very different in density, location, and type of land use, applies several of the Model Development Principles presented earlier. Table 3.1 illustrates the model development principles that apply to each of the case study sites. While a conscious attempt was made to identify the best examples of better site design in Virginia, it is certainly possible that better examples exist elsewhere in the Commonwealth. At least two of the selected case studies were planned and constructed before the Chesapeake Bay Preservation Act was fully implemented and therefore may contain elements that would have been handled differently had the projects been developed more recently. Finally, we would like to emphasize that the primary purpose of the following sections is to illustrate the benefits of applying better site design principles to representative real projects, and not to imply that these sites are perfect examples of sustainable development.

Each case study begins with a narrative description that introduces the site, describes the conditions of the parcel prior to development, walks the reader through the site design, and discusses specific ele-

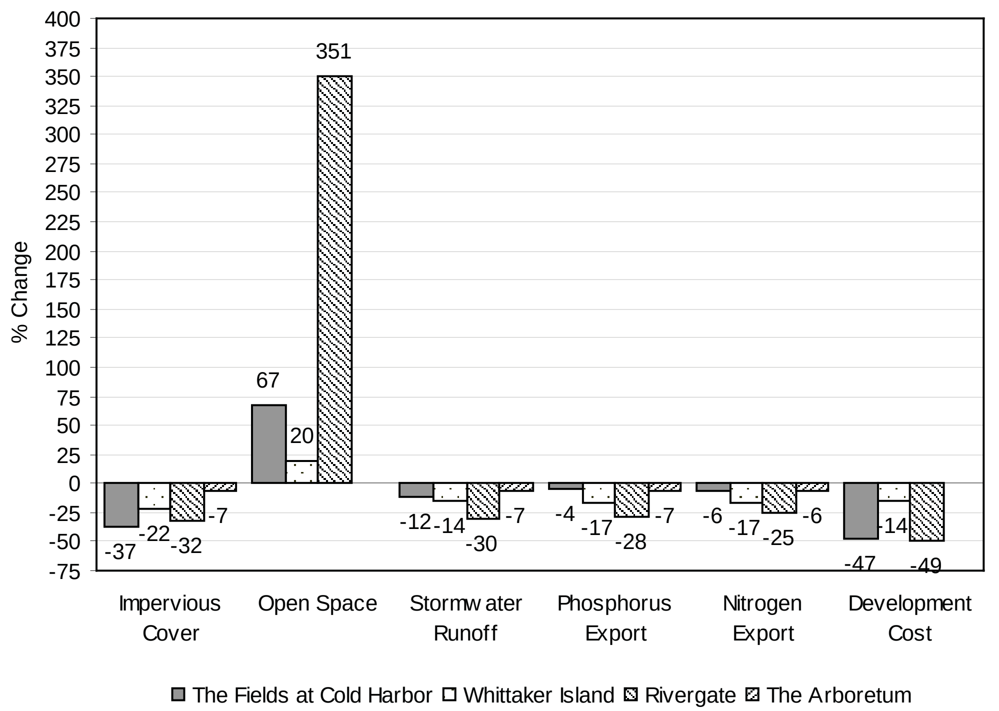


Figure 3.1: Percentage change in key site conditions from the status quo site design to the as-built design.

ments related to the local jurisdiction. Next, a table identifies the Model Development Principles incorporated into the site design. For each project a site plan and, where available, representative photos provide a graphical illustration of the site and highlight unique site design aspects.

Next, a detailed discussion of the site design is provided, organized by the applicable Model Development Principles. First, the specific design characteristics promoted by the principle are described along with the relative marketability. Then, the application of the principle is examined in the context of the local codes and ordinances under which the site was developed. Finally, a comparison to the status quo is presented. Here, the site design techniques typically employed in conventional development projects are tabulated and contrasted with the techniques employed at the actual case study site. The status quo design assumptions used in the comparative analysis are also presented.

For each principle, the benefits of applying the principle versus the status quo are analyzed in the context of the Chesapeake Bay Preservation Area Designation and Management Regulations' performance criteria. A table highlights the effects of employing the Model Development Principle in terms of impervious cover reduction, minimization of clearing and grading, or the preservation of indigenous vegetation.

The final section of each case study assesses the overall benefits of applying the suite of Model Development Principles by comparing the actual site design to the hypothetical status quo site. A simplified model, known as the Simplified Urban Nutrient Output Model (SUNOM), is used to compute the hydrologic budget, infrastructure cost, and nutrient export from each site design scenario. See Appendix B for a description, derivation, and relevant variables used by the model. For each case study site and the corresponding status quo site design, land cover, stormwater runoff and infiltration, nutrient loading, and infrastructure costs are calculated using SUNOM. Next, the changes in land cover associated with the development site as-built are compared to the status quo site. The results of these analyses are presented in detail in Sections IV through VII and summarized in Figure 3.1 (Note: open space and development costs were not calculated for the Arboretum).

As can be seen from Figure 3.1, the four case studies produce varied, but consistent, results. In general, all sites have reduced impervious cover, runoff, nutrient export, and development cost corresponding with an increase in open space. The largest reduction in imperviousness is achieved in the Fields at Cold Harbor at 37% but yields only a modest reduction in nutrient load export due to the retention of sizable cultivated areas in the case study. Perhaps the best overall performer is the Rivergate site where all variables are reduced by at least 25% with open space increasing by over 300%.

The overreaching conclusions of the case study exercises suggest that applying the Model Development Principles over a range of land uses yields measurable reductions in impervious cover and development costs, and increased preservation of natural vegetation in common open space. The decreased impervious cover results in less stormwater runoff and consequently less nutrient export.

IV. CASE STUDY #1: THE FIELDS AT COLD HARBOR, A RURAL RESIDENTIAL CASE STUDY

The Fields at Cold Harbor is a proposed 19-unit, rural residential development in Hanover County, Virginia near the Richmond National Battlefield Park. While approximately two-thirds of the existing parcel is forested, this 120.3-acre parcel also houses an existing farm and features a farmhouse and cropland along with historic military earthworks (man-made earthen hills usually marked by wooden posts dating back to the Civil War). There is no existing stormwater management of the site, but there is a pond and two wetlands within the parcel (Figure 4.1). The entire parcel is located within a Chesapeake Bay Resource Management Area (RMA) and was recently rezoned as a Rural Conservation District (RCD).

The purpose of the RCD zone is to preserve the rural characteristics of an area while permitting the development of these areas into low-density, single-family residential subdivisions. This consists of both residential lots and conservation areas in which existing buildings and agricultural uses are permitted. Not less than 70% of the "net acreage" must be devoted to conservation areas, which may include both preservation lots and common open space with restricted allowable uses. Preservation lots permit existing homes, stables, and agricultural uses that are not likely to generate noxious odors; natural or landscaped buffers; forests; passive/active recreational areas; facilities for utility service; and/or golf courses. Common open space may include natural or landscaped buffers, active and passive recreation areas, common wells, forests, wildlife reservations, and agricultural uses that do not generate noxious odors or sewage sludge. "Net acreage" is defined as the total area of the site minus the total of RPAs and areas

Table 4.1: Model Development Principles Incorporated into the Design of The Fields at Cold Harbor

Model Development Principle	Minimizes Land Disturbance	Preserves Indigenous Vegetation	Minimizes Impervious Surface
1. Native Plant and Tree Conservation	U	U	
2. Minimized Clearing and Grading	U	U	
3. Open Space Design	U	U	
4. Shorter Setbacks & Frontages	U		U
5. Common Walkways			U
6. Shared Driveways			U
7. Narrower Streets	U	U	U
8. Shorter Streets			U
11. Vegetated Open Channels			U

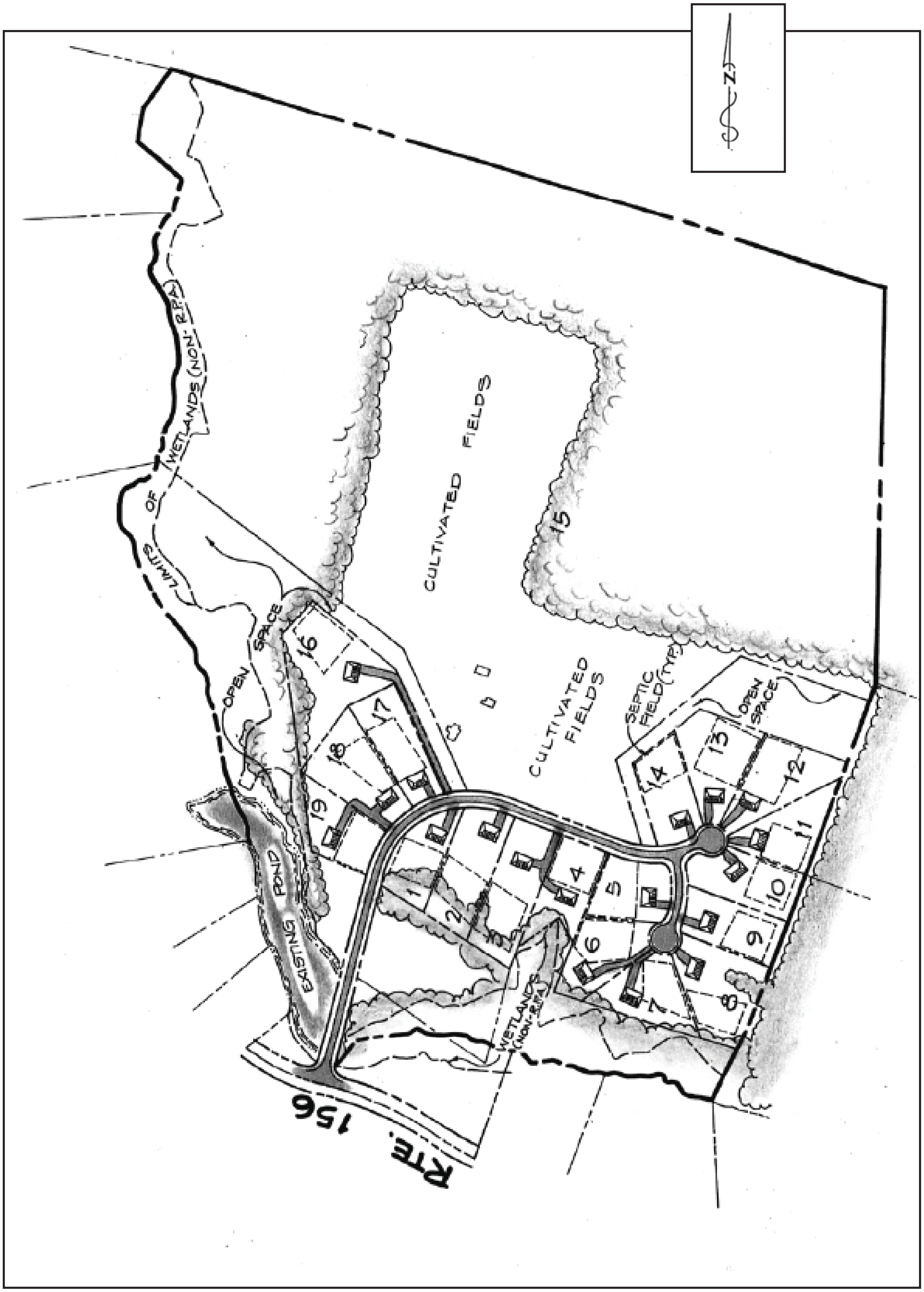


Figure 4.1: View of the proposed Fields at Cold Harbor, a rural residential development in Hanover County, Virginia.

of slopes greater than 25%. The RCD designation also requires that the parcel of land be no less than 25 contiguous acres.

The RCD zoning ordinance, as well as the Virginia Department of Transportation's residential street width requirements, codify some of the design features incorporated into the proposed site. The proposed development consists of lots that range from 1.0 to 1.4 acres. Approximately 96.7 of the 120.3 acres are provided as conservation area, with 22.2 of these acres in the form of common open space. Innovative features include the use of 18-foot roads, the preservation of existing trees and historic structures, and the inclusion of a walking trail.

At the time of publication, the design of The Fields at Cold Harbor was still in its early planning stages. While it is clear that the existing and proposed sites utilize on-site sewage disposal systems with wells as the water supply source, exact specifications on house sizes, prices, or placement on the lots were not available. Several assumptions were made based on available information, including house placement and driveway layout.

The Model Development Principles in The Fields at Cold Harbor

Nine of the Model Development Principles have been incorporated in the design of The Fields at Cold Harbor (Table 4.1). While rural areas are often zoned for larger lots, The Fields at Cold Harbor illustrates the application of Model Development Principles to minimize land disturbance, reduce impervious cover, and preserve indigenous vegetation in an area that would typically be designated for large-lot zoning. A detailed evaluation of each principle applied in the design of The Fields at Cold Harbor follows, including a discussion of the design characteristics, an outline of local codes and ordinances that allowed or required the design characteristics, and a comparison to the status quo site design techniques.

Principle 1. Native Plant and Tree Conservation

Much of the existing forest was preserved as contiguous open area. In addition, the preservation of trees of a five-inch caliper or greater in the side and rear yards was proffered by the developer in the rezoning of the property. Tree preservation can have a substantial influence on the marketability of the site, particularly if preserved as a greenway or buffer. A few of the numerous economic benefits include increased property values, lower air conditioning costs, retention of carbon dioxide and ozone, and reduced stormwater flows and management costs (CWP, 1998).

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

Regulations under the RCD require that no less than 70% of the net acreage be devoted to conservation areas with no less than 25 contiguous acres. While indigenous plants and trees are not specifically protected by local ordinances, preserving large tracts of land allows existing vegetation to be kept intact.

A Comparison to the Status Quo

Unlike the proposed development at The Fields at Cold Harbor, with many status quo subdivisions, complete clearing and grading of the site is common. In the status quo site design, none of the individual trees on lots were preserved and much more land was cleared and graded to allow for larger individual lots. This increased clearing and grading resulted in more impervious cover and increased infrastructure costs.

Principle 2. Minimized Clearing and Grading

Preservation of 80% of the site, along with retention of larger trees on the side and rear yards, significantly minimizes clearing and grading at The Fields at Cold Harbor. By keeping clearing and grading to a minimum, the area is also protected against possible increases in impervious cover and drastic changes in the rural character of the site. It also reduces the need for erosion and sediment control (ESC) measures, while increasing property values through tree and plant preservation.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

Regulations under the RCD allow only 30% of the net acreage to be cleared and graded for development, keeping most of the site preserved in its existing state. Net acreage is calculated after the steep slopes and RPAs have been deducted from the gross acreage of the site.

A Comparison to the Status Quo

Complete clearing and grading of a development site is common practice, and for the status quo site design at The Fields at Cold Harbor, a larger portion of the existing site was converted into individual lots. In addition, the farmland and historic features were eliminated, protection of wetlands was minimized, and an additional three acres of forest were cleared. As a result, an extra 6.8 acres of lawn were added to the site. The increased clearing and grading of the status quo site design resulted in a slight increase in overall impervious cover and infrastructure costs that were almost double.

Principle 3. Open Space Design

The lots at The Fields at Cold Harbor are clustered in the southwestern section of the development site. The proposed design also incorporates open space preservation, tree preservation, use of narrow and shorter streets, reduced setbacks, common walkways, shared driveways, and vegetated open channels. The application of these principles make up some of the basic elements of open space design.

Open space designs have many documented benefits, including increased marketability, reduced construction costs, and reduced stormwater runoff. One study estimated that the use of open space techniques saved $800 per home in a Davis, California development (Liptan and Brown, 1996). Other studies have shown that construction savings can be as much as 66% using open space designs (CWP, 1998).

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

Regulations under the RCD do not require a minimum lot size. However, there is a maximum density of one unit per 6.25 gross acres. In addition, open space cannot be less than 200 feet wide at any point. These regulations, combined with the 70% minimum preservation requirement, encourage the use of open space designs.

A Comparison to the Status Quo

Individual lots in status quo designs, especially in rural districts, are often generously sized and converted to lawns. For example, an agricultural district in Hanover County sets the lot size minimum at 10 acres per single family dwelling unit. Preservation of natural areas are rarely as generous as 80%, and while some developments may preserve small patches of common areas, contiguous and larger patches of common open space are not customary. In the status quo site design, lot size was a predominant feature of the development site and increased from about 1.2 acres to an average of 2.5 acres per lot. The increase in lot sizes directly influences the amount of conservation area and common open space. Table 4.2 compares the influence of open space design on land cover between the case study and the status quo site design.

Principle 4. Shorter Setbacks and Frontages

Since preliminary site plans did not include specific information about setbacks, setbacks were assumed to be the minimum that lot and septic field layout permitted in the proposed development of The Fields at Cold Harbor. For the most part, side yard setbacks were not an issue, since the lot lines were defined and lot sizes were large enough that addressing front yard setback minimums usually translated into side yard setbacks that were well beyond the minimum. Most of the driveways were less than 20 feet long, which met minimum front setback requirements, yet allowed minimization of driveway length.

Table 4.2: The Influence of Open Space Design on Land Cover

Scenario	Conservation Area (acres)	% of Total Site Area	Common Open Space (acres)	% of Total Site Area
Status Quo Site Design	68.9	57.3%	2.1	1.7%
As-Built	96.7	80.4%	22.2	18.5%
Difference	27.8	23.1%	20.1	16.8%

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
The minimum setback requirements for RCD zoning are significantly smaller than for Hanover County's agricultural residential district, which requires setbacks of up to 100 feet for the front yard, 25 feet for the side yard, and 40 feet for the rear yard. In the RCD, the minimum setbacks required are 15 feet for the front yard, 20 feet aggregate for side yards, and 25 feet for the rear yard.

A Comparison to the Status Quo
With the status quo site design, front yard setbacks were increased to 100 feet or more, requiring extended driveways to service the homes. The resulting 30% increase in driveway impervious cover in the status quo site design was primarily due to the increased front setback (see Principle 6). The houses were also placed far away from lot lines or other possible structures, which incrementally increased the street length required to service the houses.

Principle 5. Common Walkways
The proposed design of The Fields at Cold Harbor utilizes a walking trail that travels along the preserved forest, farmland, and other historic features. This trail, designed using a crushed brick material, helps divert pedestrians away from automobile traffic, provides access to recreational areas, and is much less expensive than concrete.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
RCD evaluates site plans for inclusion of a pedestrian circulation system linking off-road trails and open spaces, designed to assure that pedestrians can walk safely and easily.

A Comparison to the Status Quo
In the status quo design, safety concerns often lead to placement of sidewalks on both sides of the street. While safety is an important consideration, mobility, access, and service to common areas should also be considered. The crushed brick material used for the trail is slightly more pervious than concrete and costs about 3.5 times less than concrete. Despite the increased square footage of the longer trail path as compared to sidewalks on both sides of the street, the cost was still three times less for the crushed brick trail than for concrete sidewalks along both sides of the entire street length. Table 4.3 summarizes the influence of walkways on impervious area between the case study and the status quo site design.

Principle 6. Shared Driveways
Based on the layout of the proposed septic fields, the use of two common driveways serving two houses each was assumed. This reduced the amount of potential impervious cover by about a third for these four lots. While the final design could incorporate more shared driveways, only the two were assumed.

Table 4.3: The Influence of Walkways on Impervious Area

Scenario	Total Impervious Area (square feet)	% of Total Site Area
Status Quo Site Design	28,942	.6%
As-Built	24,960	.5%
Difference	3,982	.1%

Table 4.4: The Influence of Shared Driveways and Reduced Front Setbacks on Impervious Area

Scenario	Total Impervious Area (square feet)	% of Total Site Area
Status Quo Site Design	35,524	0.7%
As-Built	25,164	0.5%
Difference	10,360	0.2%

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
RCD does not encourage or discourage shared driveways.

A Comparison to the Status Quo
In the status quo site design, no shared driveways were used. While the amount of impervious cover reduced by using shared driveways was relatively small, when combined with increased front setbacks the total driveway impervious cover increased by 30% in the status quo site design. Table 4.4 compares the influence of shared driveways and reduced front setbacks on impervious area in the case study and status quo site design.

Principle 7. Narrower Streets
The Fields at Cold Harbor is designed using narrow 18-foot, shoulder and ditch streets. Since homes are designed with allowances for at least two parking spaces per house (usually with two additional driveway spaces), on-street parking was not assumed. The advantages of the narrower street design include reduced stormwater runoff, reduced motor vehicle speeds, and reduced asphalt costs.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
According to VDOT, the minimum width for a shoulder and ditch road that has up to 250 average daily trips (ADT) is 18 feet (see Appendix C for a discussion of VDOT's standards, requirements, and policies).

A Comparison to the Status Quo
In the status quo site design, the street widths were increased from 18 to 28 feet and a curb and gutter design was assumed. This would allow for parking on one side of the street with traffic in either direction. Many subdivision streets are designed to allow for quick passage of vehicles in either direction and parking on either side. This can quickly elevate the speed of traffic, promoting safety concerns for residents. Narrower streets are proven traffic calming devices and can help reduce motor vehicle speeds.

Principle 8. Shorter Streets
Clustering of houses in one section of the development site has allowed for reduced street lengths to service an equal number of houses. Similar to the benefits of narrower streets, shorter streets can also reduce stormwater runoff and result in construction cost savings. A comparison of street length in the case study and the status quo site design is summarized in Table 4.5.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
While street length is generally not addressed in codes or requirements, required frontage distances can dictate how wide a lot should be. The agricultural residential district zoning requires a 20-foot minimum street frontage. RCD does not require a minimum street frontage, allowing for flexibility in lot layout.

A Comparison to the Status Quo
In the status quo site design, the larger lots warranted longer street lengths, thereby increasing the impervious cover and the cost of street construction.

Principle 11. Vegetated Open Channels
Shoulder and ditch roads are often referred to as "open section roads" since they are not closed in by curb and gutters that border the edges of the street. At The Fields at Cold Harbor, the use of open section roads allows for the use of vegetated open channels to treat more stormwater on site. Vegetated open channels are sloped grassy areas designed to treat and retain stormwater runoff from the street. Vegetated open channels can help mitigate the need for larger, more expensive stormwater management

Table 4.5: The Influence of Shorter Streets on Impervious Area

Scenario	Street Length (feet)	Total Impervious Area (square feet)	% of Total Site Area
Status Quo Site Design	3,500	98,000	1.9%
As-Built	1,900	34,200	0.7%
Difference	1,600	64,800	1.2%

Table 4.6: The Influence of Vegetated Open Channels on Impervious Area*			
Scenario	**Street Width (feet)**	**Total Impervious Area (square feet)**	**% of Total Site Area**
Status Quo Site Design	28	98,000	1.9%
As-Built	18	34,200	0.7%
Difference	10	64,800	1.2%

* While VDOT regulations allow the use of open vegetated channels with narrower streets, the biggest benefits of vegetated open channels are reduced stormwater runoff and decreased nutrient loads.

controls, and can also eliminate construction costs associated with curb and gutters.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

While stormwater management is not required for The Fields at Cold Harbor, it is recognized as a design alternative. According to VDOT, they will be responsible for maintenance of drainage systems that fall within the dedicated right-of-way, but the system must be a "natural watercourse," as opposed to a swale. In addition, for an area with up to 250 ADT, pavement width for open section roads can be a minimum of 18 feet, but with curb and gutter, residential road width must be a minimum of 28 feet.

A Comparison to the Status Quo

With the status quo site design of The Fields at Cold Harbor, the use of curb and gutters was assumed. Curb and gutters can increase construction costs and do not allow for the infiltration of stormwater runoff that vegetated open channels can provide. In addition, according to VDOT, curb and gutters require a minimum street width of 28 feet, which increases the amount of impervious cover. Table 4.6 compares the influence of vegetated open channels on impervious areas. It is important to note that while reduced impervious cover is a benefit of vegetated open channels in Virginia, reduced stormwater runoff and decreased nutrient loads are two of the biggest benefits of vegetated open channels.

Conclusion

The Fields at Cold Harbor sharply contrasts with the typical rural residential development seen throughout Virginia and elsewhere. New rural residential development is often characterized by large-lot subdivisions with wide roads, large cul-de-sacs, and ample setbacks and frontages. Table 4.7 summarizes site characteristic differences between the pre-developed site, the status quo site design, and the case study site.

Due to the existing structures, the parcel was 3.3% impervious prior to development. The case study design has an impervious level of 7.4%, whereas the status quo site design resulted in slightly more imperviousness at 8.3%, primarily due to the increased width and length of streets and the inclusion of paved sidewalks.

The increased imperviousness in the status quo site design results in more annual stormwater runoff and nutrient loading from the site than in the case study design scenario. The status quo site design also results in a 6.4% higher infiltration rate. The difference was not as significant as in the other case studies, primarily due to preservation of a cultivated field. Cultivated fields have a lower infiltration factor than forest and wetlands, meadows, and lawn and landscaped areas.

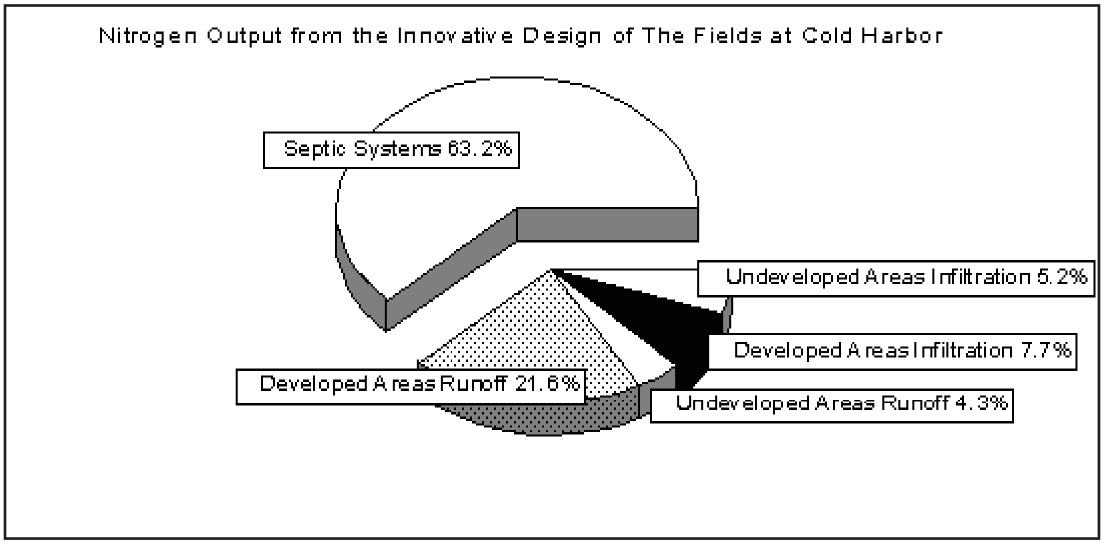
Nitrogen and phosphorous loads increase dramatically with development, and The Fields at Cold Harbor was no exception. With the status quo site design, nitrogen loads more than doubled and phosphorous loads increased by about 81% as compared to pre-developed conditions. While the increase in nutrient loads for the innovative site were not quite as high as the status quo site design, nitrogen loads were still 77% higher and phosphorous loads were 55% higher than pre-development rates. These calculations were computed without septic loads, which can further increase nutrient loading significantly. The impacts of septic loads are discussed in Box 4.1 on page 23, which details the influence of septic systems on nutrient loading on residential sites.

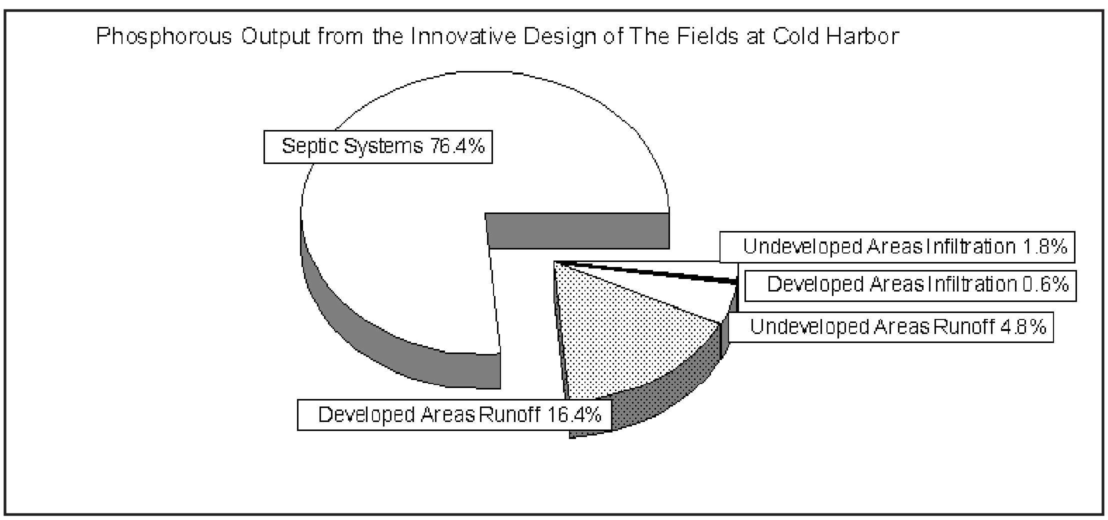
Table 4.7: A Comparison of The Fields at Cold Harbor to the Status Quo Design Scenario				
	Pre-Development	Status Quo	Case Study	% Difference[1]
Site Characteristics				
Site Area	120.3 acres	120.3 acres	120.3 acres	0%
Number of Units	1	19	19	0%
Average Lot Size (acres)	74.1[2]	1.2	2.5	108.3%
Land Cover and Disturbance				
Forest and Wetlands (acres)	79.7	54.9	57.9	5.5%
Meadow (acres)	7.9	10.4	4.0	61.5%
Lawn/ Landscaped Areas (acres)	1.4	46.2	39.4	14.7%
Cultivated Fields (acres)	27.6	0	12.0	100%
Site Imperviousness				
Rooftops (acres)	0.1	1.3	1.3	0%
Driveways (acres)	0.0	1.1	0.6	45.5%
Street (acres)	0.3	2.8	1.2	57.1%
Walkways[3] (acres)	0.0	0.7	0.6	14.3%
Equivalent Impervious Area[4] (acres)	3.6	4.4	3.8	13.6%
Total Impervious Area (acres)	*4.0*	*10.0*	*7.4*	*26%*
Total Imperviousness (%)	*3.3%*	*8.3%*	*6.2%*	*25.3%*
Stormwater Impacts				
Runoff (inches/yr)	3.4	4.9	4.3	12.2%
Infiltration (inches/yr)	7.1	7.8	7.3	6.4%
Nitrogen (lbs/yr) w/o BMP	176.9	777.2	727.5	6.4%
Phosphorous (lbs/yr) w/o BMP	23.1	124.6	119.8	3.9%
Infrastructure Costs				
Infrastructure Costs	N/A	$527,300	$278,300	47.2%
Landscaping/ Reforestation	N/A	$0	$120	100%
Total Infrastructure Costs	*N/A*	*$527,300*	*$278,420*	*47.2%*

1. % Difference is between the Status Quo and the case study design.
2. Existing farmhouse includes three existing structures.
3. The semi-pervious crushed brick trail was assumed to be 80% impervious.
4. Equivalent Impervious Area includes 1% imperviousness for lawn and cultivated areas and 100% imperviousness for pond surface.

Box 4.1: Nutrient Loading from Residential Septic Systems

Septic systems are often the single largest source of nitrogen and phosphorous output on rural residential sites where better site design techniques can only reduce the relatively small stormwater load. While failing septic systems can be a significant source of pollution to a stream, even properly functioning septic systems still remain the largest source of nutrient loading. The pie charts below show the sources of nitrogen and phosphorous loads for The Fields at Cold Harbor and the percentage that septic systems would contribute if they had been included in the site's nutrient loading calculations.





There are several alternatives to the conventional septic system capable of reducing pollutants that are not effectively treated by conventional systems and rely less on ideal site conditions to function. Most of these alternatives follow the basic design with certain modifications. One example is the recirculating sand filter which pumps waste water through a PVC pipe into a sand filter. The flow percolates through the soil where 75% of the effluent recirculates back to mix with anaerobic wastewater, resulting in increased denitrification. Where maximum nutrient removal is a goal for rural development, careful selection of septic systems alternatives should be considered.

Infrastructure costs nearly doubled in the status quo site design ($527,300) as compared to the case study site ($278,300). Since stormwater management was not proposed for the innovative site, the status quo site design was not evaluated using best management practices (BMPs). As a result, the bulk of the costs were attributed to added asphalt and concrete

V. Case Study #2: Whittaker Island at Governor's Land, A Medium-Density Residential Case Study

Figure 5.1: Whittaker Island is bordered by conserved forest and wetland areas and the James River to the south.

Whittaker Island is a 122.6 acre section within the medium-density residential subdivision of Governor's Land, a planned residential development in James City County, Virginia. Governor's Land covers 1,482 acres on a peninsula bordered by the James and Chickahominy Rivers, just a few miles from Jamestown and Williamsburg. Designed and developed through the 1980s and early 1990s, the site includes 734 homes, conservation areas, a golf course, a marina, and community recreational facilities. Homes border water, tidal marshlands, golf course fairways, meadowland, or mature forests. Approximately 70% of Governor's Land consists of permanent open space and conservation areas. Much of the design and development of Governor's Land predates the Chesapeake Bay Preservation Act. However, lots recorded after September 30, 1989 are subject to the requirements of the Chesapeake Bay Preservation Area Designation and Management Regulations.

Development within Governor's Land consists of several smaller residential "pods," including Whittaker Island (Figure 5.2). Whittaker Island, bordering the James River, employs several of the Model Development Principles typical of a well-designed open space subdivision (Table 5.1). Whittaker Island features 82 one-third to one and three-quarter acre lots on public water and sewer, bordered by conserved forest and wetland areas to the east and south (Figure 5.1), and a golf course fairway to the west. Instead of sidewalks, trails run through the common open space areas. In one location, a 10-foot wide paved bike trail connects Whittaker Island to the adjacent residential pod (Figure 5.3). The project incorporates relatively narrow streets

Table 5.1: Model Development Principles Incorporated into the Design of Whittaker Island

Model Development Principle	Minimizes Land Disturbance	Preserves Indigenous Vegetation	Minimizes Impervious Surface
1. Native Plant & Tree Conservation	U	U	
2. Minimized Clearing & Grading	U	U	
3. Open Space Design	U	U	
4. Shorter Setbacks & Frontages	U	U	U
5. Common Walkways			U
7. Narrower Streets	U	U	U
10. Smaller & Landscaped Cul-de-Sacs			U

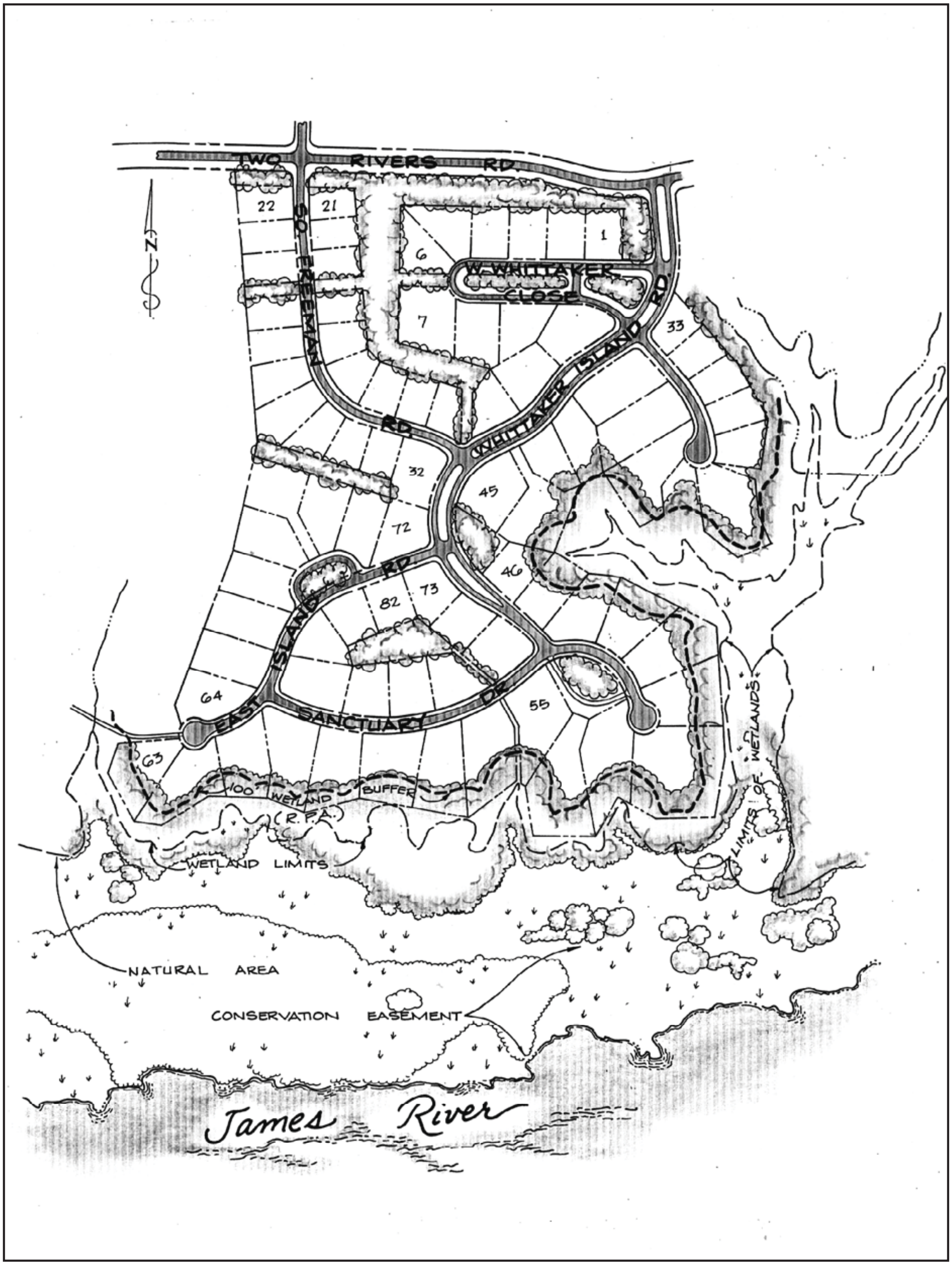


Figure 5.2: Whittaker Island is a section of Governor's Land, a planned residential subdivision in James City County, Virginia.

Figure 5.3: A 10-foot paved bike trail connects Whittaker Island to the adjacent residential pod.

and alternatives to the conventional cul-de sac. A 100-foot wetland buffer [which would now be designated as a Resource Protection Area (RPA)] runs along the back of several lots bordering the wetland preservation area. Clearing and grading by individual lot owners is prohibited within this zone.

When examining the unique design characteristics of Whittaker Island, it is important to do so in the context of the rules under which it was developed. The parcel was rezoned within James City County's Residential Planned Community District (R-4) zone in 1989. As part of the rezoning, wetland protection and trail and bikepath amenities were proffered by the developer. The R-4 zone provides the design flexibility for this type of planned residential community, which utilizes small lot sizes in exchange for larger open space areas. These communities are dominated by residential land uses and open space, but can also contain active recreation centers, fire stations, schools, and retail establishments that help make the community somewhat self-sufficient. An important feature of the development plan is the emphasis on site planning and the retention of large, open areas.

While Whittaker Island demonstrates several of the Model Development Principles, applying additional design techniques may have further reduced impervious cover along with the resultant stormwater runoff and nutrient loading. For instance, the average lot size is just over half an acre. Reducing this area may have allowed for greater preservation of contiguous open space in the uplands as well as in the forested wetland areas. The incorporation of shared driveways may have also contributed to a decrease in impervious coverage. More advanced stormwater management implementation would have certainly contributed to additional nutrient reduction.

The Model Development Principles in Whittaker Island

Whittaker Island employs seven of the Model Development Principles, even though it was planned in large part in the late eighties (Table 5.1). As a medium-density project, the application of open space design techniques, coupled with good planning and reduced street width and setback requirements, afforded many opportunities to minimize clearing and grading, preserve natural vegetation, and minimize impervious cover.

Principle 1. Native Plant and Tree Conservation

The design of Whittaker Island preserved 60.5 acres, or approximately 49% of the site, as conserved forest and wetlands areas consisting of large contiguous land adjacent to the James River plus some common open spaces throughout the residential lots (the golf course fairway was excluded from these computations). This area is covered by a permanent conservation easement managed by a local land conservation trust. For lots that border on wetlands, the 100-foot buffer (again, what would now be considered an RPA) also serves as the clearing limit, thereby preserving some vegetation on private lots.

The conservation of native plants and trees goes hand-in-hand with an overall open space design objective. The individual smaller lots allow for more common open space and consequently less pressure on existing natural features. Conserving trees also makes economic sense by reducing clearing and grading costs while increasing market values. In fact, a study of 14 variables that might influence the price of suburban homes in Manchester, Connecticut and Greece, New York found that trees ranked sixth in influencing the selling price. Trees on individual lots increased sales prices by 5 to 15% (National Arbor Day Foundation, 1996). Other documented economic benefits of trees include reduced air conditioning costs, increased retention of carbon dioxide and ozone, and reduced stormwater runoff and management costs. (CWP, 1998)

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
The R-4 zone is intended to permit development in accordance with master planned, large, multi-use type projects that protect and preserve natural resources, trees, watersheds, and topographic features of the land. The R-4 zone dictates that the total area of the planned residential community may not exceed two dwelling units per acre. At least 40% of the total acreage of the community must be designated as open space, which may include parks, lakes, walkways, trails, playgrounds, and active recreational facilities (such as golf courses). The required open space must contain recreation areas in the amount of one acre or more per 350 dwelling units.

A Comparison to the Status Quo
The design of Whittaker Island differs significantly from most medium-density residential developments being built throughout Virginia and elsewhere. Many residential developments feature characteristics that conflict with the Model Development Principles, such as wider streets and larger cul-de-sacs; bigger setbacks and frontages; sidewalks along the street with little consideration given to pedestrian movement; and reduced preservation of indigenous vegetation. Several communities do not allow open space development, and many of those that do allow them offer few incentives to encourage their use. In fact, open space designs often require a special exception or zoning variance (i.e., they are not a by-right form of development). In Table 5.2, the amount of native vegetation preserved at Whittaker Island is compared with the hypothetical status quo site design. One benefit of preserving native vegetation can be seen in less stormwater runoff and consequently less nutrient loading to the James River and the Bay (see Table 5.6). In developing the comparative analysis it was assumed that the status quo site design only conserved delineated forested wetlands and utilized the entire remaining portion of the parcel for residential development.

Principle 2. Minimized Clearing and Grading
The application of Principle 2 goes hand-in-hand with the preservation of native vegetation and tree conservation. At Whittaker Island, the preservation of nearly 50% of the native vegetatation also necessitated limiting clearing and grading to less than half the total site area.

Limiting clearing and grading not only makes good environmental sense, but also contributes to the developer's bottom line. In a report prepared by the Delaware Department of Natural Resources and Environmental Conservation, minimized clearing and grading during the construction phase can reduce earth movement and erosion and sediment control costs by as much as $5,000 per acre (DEDNREC, 1997).

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
As stated previously, the protection of wetlands and other natural areas and consequent minimal clearing and grading was proffered by the developer in the rezoning of the property in 1989. In addition, since the development of lots recorded after September 30, 1989 are subject to James City County's adoption of the Chesapeake Bay Preservation Area Designation and Management Regulations, minimized clearing is also a regulated objective.

A Comparison to the Status Quo
Most development sites limit clearing and grading only in those areas protected by regulatory statute, such as wetland areas. In the status quo site design, only the areas designated as jurisdictional wetlands are protected from clearing and grading. Consequently, the amount of land disturbed goes from just over 50% for the Whittaker Island as-built design to

Table 5.2: The Preservation of Native Vegetation and Tree Conservation

Scenario	Conserved Vegetation and Trees (acres)	% of Total Site
Status Quo Site Design	46.0	37.5%
As-Built	62.2	49.3%
Difference	16.2	11.8%

approximately 62% for the status quo site design.

Principle 3. Open Space Design

The success of applying the previous two principles to Whittaker Island, or any other subdivision for that matter, is largely contingent on the planner's ability to leave large portions of the site as dedicated open space. The key to providing open space in developments are the provisions that allow smaller lots, narrower streets and rights-of way, smaller cul-de-sacs, and to a lesser extent, smaller setback requirements. All of these provisions were incorporated into the design at Whittaker Island.

As stated previously, the as-built lots in Whittaker Island range in size from a third of an acre to nearly one and three-quarters of an acre. The average lot size is approximately 0.63 acres. Houses are close to the street and each other, allowing for more preservation of community open space.

Some worry that the smaller lots of open space designs are not marketable, or that property values are less for these types of projects. However, the reality is that many independent studies have found that open space designs are highly desirable and have economic advantages that include cost savings and higher market appreciation (Arendt, et al., 1994; Ewing, 1996; NAHB, 1997; ULI, 1992; Porter, et al., 1988). In fact, a recent survey of new home buyers conducted by American Lives, Inc. noted that 77% of the respondents rated natural open space as extremely important (Fletcher, 1997). Whittaker Island is clearly a desirable place to live and there is no evidence that the smaller lot sizes limited initial sales, property value appreciation, or resale value.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

As stated previously, Whittaker Island was developed under the Planned Residential Community District (R-4) zone. One key provision of the R-4 zone allows for the establishment of minimum lot sizes and setbacks with the design and approval of the development plan. This is a common provision of many planned development zones that go by different names such as "planned neighborhood developments" (PNDs) or "planned unit developments" (PUDs).

A Comparison to the Status Quo

Again, many jurisdictions have strict zoning provisions that dictate minimum lot size, the size of setbacks and frontage distances, and the width of street rights-of-way, all of which contribute to the overall size of the net imprint of the developed portion of the site. In comparing Whittaker Island to its status quo site design counterpart it is assumed that the minimum lot size is half an acre, the number of lots maintained is 82, and setbacks are increased to 40 feet for the front yard and 12 feet for side yards. The Whittaker Island site design as-built provides approximately 51% of the site as open space, whereas the status quo site design option retains only 42% of the project in dedicated open space.

Table 5.3: Influence of Front Setback Requirements on Total Site Area and Total Impervious Cover

Scenario	Setback	Total Site Area Consumed		Total Impervious Area (acres)
		Area (acres)	% of Total Site	
Status Quo Site Design	40'	11.12	9.1%	1.27
As-Built	25'	6.29	5.1%	0.96
Difference	15'	4.83	11.8%	0.31

Table 5.4: Influence of Common Walkways on Total Impervious Cover

Scenario	Total Sidewalk Area (acres)	% of Total Site
Status Quo Site Design	1.66	1.4%
As-Built	0	0%
Difference	1.66	1.4%

Figure 5.4: A narrow, 12-foot private lane that included the preservation of mature trees in a landscaped island.

Principle 4. Shorter Setbacks and Frontages

While smaller lots sizes allow for more community open space, relaxed setback requirements have at least three tangible environmental benefits. First, shorter front setbacks allow for shorter driveways and consequently less impervious cover generated per household. Secondly, shorter side yard setbacks allow for narrower lots (assuming that house size remains reasonably constant). Narrower lots translate into shorter street lengths, and again, less overall impervious cover. Finally, moving houses closer to the street allows overall lot depths to be shorter, translating into less land devoted to lots and, in the case of Whittaker Island, more area in community open space preserved as forest and wetland. In addition, the net reduction in lot area translates into a net reduction in lot turf or lawn area. Reducing lawn area decreases nutrient loads, as less area is actively maintained and less fertilizer is applied to the overall site. Whittaker Island has a minimum front and rear yard setback of only 25 feet, and side setbacks of only five feet.

A Comparison to the Status Quo

Setbacks play an important role in the effectiveness of open space design. To demonstrate this, the land consumed as a result of front setbacks in Whittaker Island as-built is compared with that of the status quo site design. In the case study, the 25-foot minimum setback results in 273,985 square feet, or 5% of the parcel area, serving as front yards. This increases to 484,400 square feet, or roughly 9% of the site, in the status quo site design when front setbacks increased to 40 feet (Table 5.3).

Principle 5. Common Walkways

Many communities require that four to six foot wide concrete or asphalt sidewalks be placed on both sides of residential streets. While this helps keep pedestrians out of the street, this standard approach does little to facilitate pedestrian movement through a neighborhood. Designers do not consider these movements and instead rely on the standard road section for the placement of sidewalks. In Whittaker Island, a system of trails throughout the common open space is employed instead of sidewalks within the public street rights-of-way. A 10-foot wide bike path trail connects the site with the neighboring section of Governor's Land.

The issue of whether or not to have sidewalks seems to depend on owner preference. These types of preferences are logically resolved at the time buyers purchase the property. There appears to be no appreciable market difference between houses that are directly served by sidewalks (i.e., the sidewalk is on the same side of the street) and houses not directly served (i.e., sidewalk is on the opposite side of the street) (Woodsmall, 1998).

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

In general, James City County requires sidewalks to be provided for one block beginning at the entrance(s) on at least one side of all residential development entrance roads expected to serve more

Figure 5.5: Whittaker Island Road, the main entrance into the section, consists of two 16-foot travel ways separated by a 30-foot landscaped island.

than 500 vehicles per day, and on one side of all roads expected to serve more than 1,000 vehicles per day. The planning commission may modify this requirement if equivalent facilities have been provided that adequately provide for pedestrian access within the development and to abutting property, as is the case in Whittaker Island.

A Comparison to the Status Quo
Sidewalks contribute to a small but measurable fraction of a site's total impervious cover. In Whittaker Island, while there is impervious cover associated with the 10-foot wide bikepath leading to the neighboring section of Governor's Land, it is not considered to be within the limits of the site. In contrast, the status quo site design with five-foot wide sidewalks on both sides of the street adds over 70,000 square feet of impervious cover (Table 5.4).

Principle 7. Narrower Streets
Whittaker Island employs closed-section roads ranging from 12-foot wide private drives (Figure 5.4) to a 32-foot wide collector road. The main entrance road into the section, Whittaker Island Road, consists of two 16-foot travel ways separated by a 30-foot landscaped island (Figure 5.5). As stated previously, narrower streets serve at least two environmental design objectives. First, narrower streets produce less impervious cover and less stormwater runoff than their wider counterparts. Secondly, the smaller the street width, the less area required for the right-of-way. This translates into more flexibility to provide more open space.

Narrow streets also cost less than wide streets. Assuming that asphalt paving costs about $15 per square yard, developers can easily save as much as $3 per running foot for a paving width reduction of five feet. Moreover, this doesn't include the potential additional economic benefits of reduced clearing and grading costs; reduced water, sewer and storm drainage costs; reduced stormwater management costs; and equally important, reduced municipal maintenance costs for snow removal, street sweeping, or paving repair.

Figure 5.6: Instead of a traditional cul-de-sac, West Whittaker Close is a loop-de-lane -- a road with a 16-foot one-way travel lane and a 90-foot central landscaped area.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
The Virginia Department of Transportation's standard for a closed-section road less than half a mile long and with under 250 average daily trips is 28 feet. In addition, VDOT approved street width reductions for some streets in Whittaker Island.

A Comparison to the Status Quo
Many communities require residential streets to be up to 36 feet wide, even when they serve developments that produce small volumes of traffic. In Whittaker Island as-built, street widths are considerably narrower than this value and make up approximately 4.9 acres of impervious area. In contrast, the status quo site design is assumed to have 34-foot wide streets covering over 5.8 acres of the site. This increased imperviousness translates into increased stormwater runoff and, consequently, increased nutrient loading (see Table 5.6).

Principle 10. Smaller & Landscaped Cul-de-Sacs
Instead of traditional cul-de-sacs, Whittaker island in-

Table 5.5: Influence of Cul-de-Sac Size on Total Impervious Cover

Scenario	Total Cul-de-Sac Area (acres)	% of Total Site
Status Quo Site Design	0.44	0.4%
As-Built	0.27	0.2%
Difference	0.17	0.2%

Table 5.6: A Comparison of Whittaker Island As-Built to the Status Quo Site Design				
	Pre-Development	**Status Quo**	**As-Built**	**% Difference [1]**
Site Characteristics				
Site Area (acres)	122.6			N/A
Number of Units	N/A	82	82	0%
Average Lot Size (acres)	N/A	0.75	0.63	16.0%
Land Cover and Disturbance				
Area in Native Vegetation (acres)	122.6	46.0	60.5	24.0%
Residential Lawn (acres)	0	62.3	51.2	17.8%
Site Imperviousness				
Sidewalk Impervious Area (acres)	N/A	1.66	0	100%
Street Area (acres)	N/A	5.81	4.92	15.3%
Driveway Area (acres)	N/A	1.27	0.96	24.4%
Rooftop Area (acres)	N/A	3.76	3.76	0%
Equivalent Imperviousness[2] (acres)	N/A	1.08	1.12	3.7%
Other Impervious area[3] (acres)	N/A	1.76	1.24	
Total Impervious Area (acres)	*1.3*	*15.34*	*11.99*	*21.7%*
Total Imperviousness (%)	*1.0*	*12.5*	*9.8*	*21.7%*
Stormwater Impacts				
Runoff (inches/yr)	2.3	6.3	5.4	14.3%
Infiltration (inches/yr)	6.0	4.7	5.0	6.4%
Nitrogen Load (lbs/yr)	84.3	389.3	321.3[4]	17.5%
Phosphorous Load (lbs/yr)	10.6	43.9	36.3[5]	17.3%
Infrastructure Costs				
Infrastructure Costs	N/A	$1,780,000	$1,524,000	14.4%
Landscaping / Reforestation	N/A	$7,500	$4,500	40.0%
Total Infrastructure Costs	*N/A*	*$1,787,500*	*$ 1,528,500*	*14.5%*

1. % Difference is between the Status Quo and the As-Built.
2. Compacted turf and forest are assumed to be 1% impervious.
3. Other impervious areas equal lead walks, pools, patios, deck etc.
4. Nitrogen load for the case study represents a 281% increase above pre-developed conditions.
5. Phosphorus load for the case study represents a 240% increase above pre-developed conditions.

corporates three non-traditional looping roads. West Whittaker Close is a looping 16-foot-wide one-way travel lane with a 90-foot-wide central landscaped area (Figure 5.6). The three cul-de-sacs also have radii of 35 feet, which are smaller than average. Providing landscaped central areas in cul-de-sacs affords the opportunity to provide additional stormwater retention areas to help reduce stormwater runoff and nutrient loading.

Again, less asphalt means less cost. While the savings in paving will probably be offset by increased costs for stormwater management in the cul-de-sac, the net result, however, is still a savings over the traditional pipe-to-pond stormwater approach.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

Cul-de-sacs at Whittaker Island exactly meet the minimum requirements of VDOT at a 35-foot radius.

A Comparison to the Status Quo

Many communities require the cul-de-sac “bulb” to be 50 to 60 feet in radius. In Whittaker Island as-built, cul-de-sacs are significantly smaller and comprise only 0.27 acres of the site (Table 5.5). In the status quo site design, cul-de-sacs having a radius of 45 feet comprise 0.44 acres . While this seems to be a modest increase, this value represents only three cul-de-sacs. The real implication is that communities containing a large number of these cul-de-sacs can expect to see significantly less impervious cover with smaller turn-arounds.

Conclusion

In general, the use of smaller lots, smaller setbacks and narrower streets reduces the actual land disturbance area and allows for increased open space and consequently larger preservation of natural vegetation. The actual case study of Whittaker Island preserves over 62% of the original vegetation on-site, and much of this area is sensitive natural wetland and forested areas that is protected by a permanent conservation easement. In addition, common walkways, narrower streets, shorter front setbacks leading to shorter driveways, and smaller cul-de-sacs help to minimize total site impervious cover. These impervious surfaces consume about 4.8% of the total area of the actual site, but may have been as high as 7.1% had the status quo site design techniques been used instead. The remaining impervious coverage for both the as-built and status quo sites consisted of rooftops, which consumed roughly 3% of the total site area for both scenarios.

As a result of the reduced impervious cover and the increased open space, the case study design results in a lower volume of annual runoff and a higher volume of annual infiltration than the status quo site design. Reduced runoff and increased infiltration translate into decreased nutrient loading (Table 5.6). In fact, the nutrient load from Whittaker Island is reduced by approximately 17% without even considering the benefits of potential stormwater best management practices (BMPs). Other studies have shown that with the application of BMPs and better site design, nutrients can be reduced by as much as 45% for medium-density residential sites on public sewer (CWP, 1998). In addition, infrastructure costs for Whittaker Island as-built decrease from the status quo site design by nearly $260,000, or roughly 14%. Cost savings are greatest from the decreased street, driveway, and sidewalk areas. As discussed previously, while development costs are typically less for open space subdivisions, home sales prices, sales rates, and appreciation values tend to be the same or higher then those for status quo subdivisions.

On a final note, it is worth mentioning that both nitrogen and phosphorus loading increase over pre-development loadings by a substantial percentage for the Whittaker Island case study, even with the employment of the Model Development Principles described in this document. Employing the most effective best management practices, coupled with the principles of better site design, can minimize this increase substantially. Watershed managers and plan reviewers need to ensure that both effective BMPs and the better site design principles discussed here are employed at new development sites if nutrient loading is to be kept in check.

VI. Case Study #3: Rivergate, A Redevelopment Case Study

Rivergate is a 58-unit townhouse urban “infill” development in Alexandria that applies the Model Development Principles in a high-density, open space design. In densely developed communities such as Alexandria, infill and redevelopment projects like Rivergate are much more common than “greenfield” development. There are many benefits associated with this type of development. For example, from a watershed management standpoint, development that occurs within a previously developed watershed is more desirable than in an undeveloped or lightly developed one. Redevelopment tends to concentrate density and impervious cover in developed watersheds where infrastructure, such as sewer, water, and transportation facilities, is already in place. This helps to prevent new growth from encroaching on more distant and lightly developed watersheds. Although the Model Development Principles tend to focus on better site design for greenfield development, many of the principles are applicable to infill and redevelopment as well, and were incorporated into the design of Rivergate (Table 6.1).

Located on the banks of the Potomac River, the 4.2 acre parcel historically housed industrial facilities and was formerly the site of the Norton Rendering Plant. Prior to redevelopment, the site was vacant for several years, and site conditions consisted of the remnants of the rendering plant, a concrete slab, and gravel, with impervious cover estimated at about 95%. The soils on the site consist of fill material deposited within the last 10 years. The flag-shaped parcel is adjacent to a 0.4 acre piece of property owned by the City of Alexandria.

Developed in the early 1990s, Rivergate is an open space, high-density residential development clustered at one end of the site that retained a large portion of the parcel next to the Potomac River as parkland (Figure 6.2).

Within the 2.2 acre residential portion of the development, three-story brick townhouses line narrow, pri-

Table 6.1: Model Development Principles Incorporated into the Design of Rivergate

Model Development Principle		Minimizes Land Disturbance	Preserves Indigenous Vegetation	Minimizes Impervious Surface
3.	Open Space Design	U	U	
4.	Shorter Setbacks & Frontages	U	U	U
5.	Common Walkways			U
7.	Narrower Streets	U	U	U
9.	Narrower Right-of-Way Widths	U	U	
12.	Reduced Parking Ratios	U	U	U
16.	Treated Parking Lot Runoff	U		

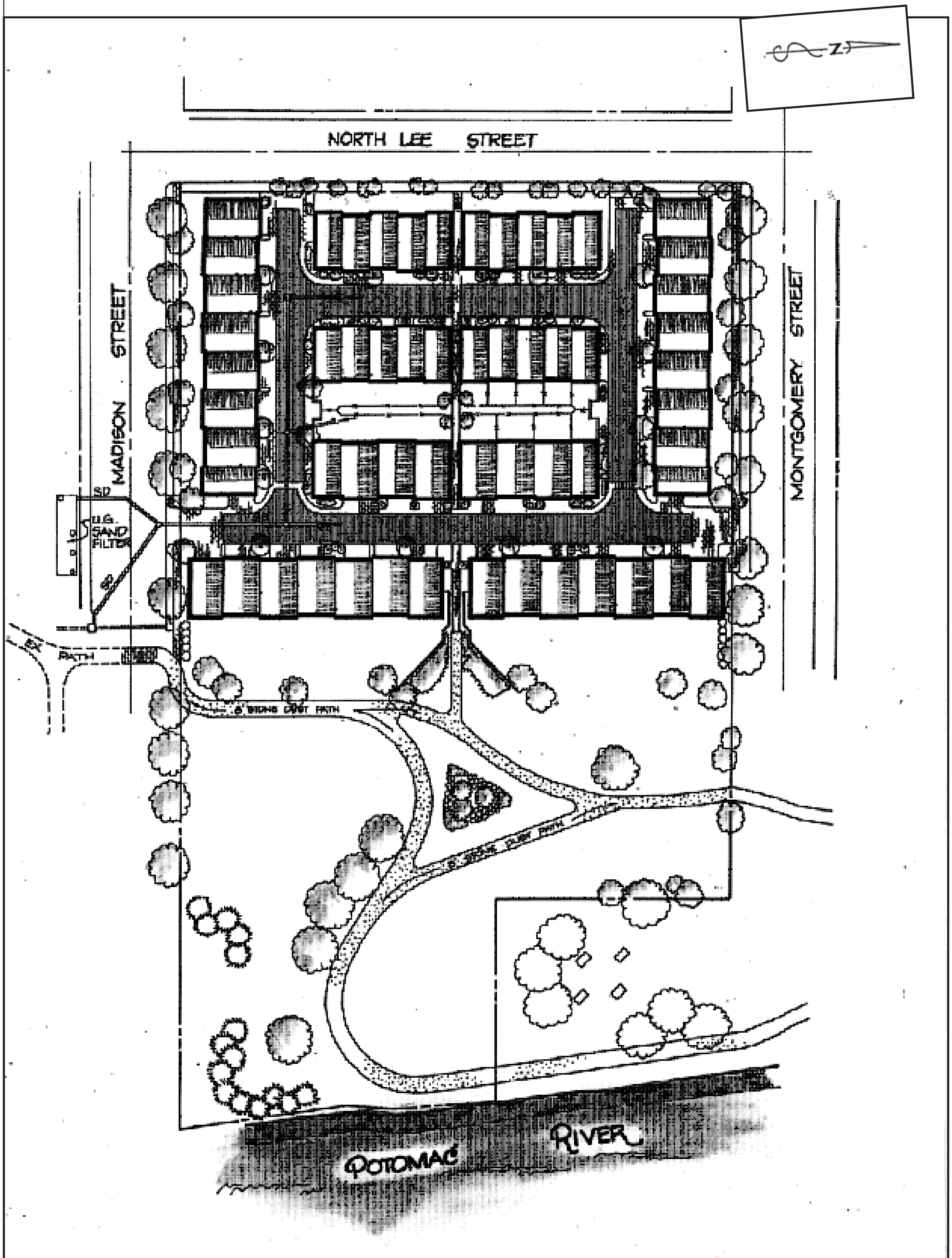


Figure 6.2: Rivergate is a townhouse "infill" development in Alexandria, Virginia.

vately- owned streets. The townhouses are garage units that accommodate one or two cars with stacked parking spaces in front of some units (Figure 6.3). There is a common walkway through the center of Rivergate leading to the river and park (Figure 6.4).

When examining the unique design characteristics of Rivergate, it is important to do so in the context of the rules under which it was developed. The parcel is within Alexandria's Waterfront Mixed Use Zone (W-1). The W-1 zone is intended to promote mixed use development with suitable public amenities along appropriate portions of the City's waterfront by permitting a mixture of residential, commercial, cultural, and institutional uses and by allowing greater densities than would otherwise be permitted. In this zoning district, the maximum number of dwelling units allowed per acre is 30, and the minimum lot size is 1,452 square feet. The City encourages this higher density since property values are higher, and there is easy access to public transportation.

The Model Development Principles in Rivergate

In this case study, seven Model Development Principles are highlighted (Table 6.1). The design of Rivergate illustrates that even on infill and redevelopment projects, there are ways to limit impervious cover, reduce land disturbance, and still provide a marketable, cost-effective product. Following is a discussion, for each principle, of the design characteristics, local codes and ordinances that allowed or required the design characteristics, and a comparison of the case study to status quo design techniques.

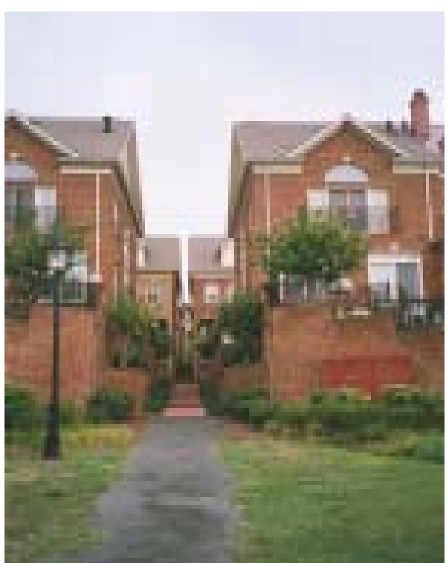


Figure 6.4: A common walkway through the center of Rivergate leads to the Potomac River and adjacent park.

Principle 3. Open Space Design

The residential portion of Rivergate is clustered at one end of the site, retaining 47% of the parcel next to the Potomac River as common open space. The two-acre landscaped park is open to public access and includes stone-dust paths and benches (Figures 6.5 and 6.6). Although this redevelopment site had no existing indigenous vegetation prior to development, the open space design and landscaped park contribute to the enhancement of indigenous vegetation, as several native species are incorporated into the landscape plan. The Rivergate Owners' Association pays for maintenance of the parkland.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

Three design considerations are particularly noteworthy in the open space design of the Rivergate site. First, within the W-1 zone, at least 300 square feet of open and usable space per dwelling unit must be provided. Next, the Alexandria Chesapeake Bay Preservation Ordinance has designated all land within the corporate limits of the City as a Chesapeake Bay Preservation Area. As such, the 100-foot buffer area along the Potomac River is a RPA and the rest of the parcel is a RMA. Finally, the Riverfront Agreement between the City of Alexandria and the U.S. Department of Justice (US DOJ) requires that each use, development, or project adjacent to the Potomac River provide a public access, open space walkway, and bikeway adjacent to the high tide watermark of the Potomac River. The US DOJ negotiates this public access with the property owners when development is proposed.

A Comparison to the Status Quo

A townhouse development, by its very nature, has open space. However, townhouse developments throughout Virginia often

Figure 6.5: The 2.4 acre park adjacent to Rivergate is open to public access.

Figure 6.6: Some habitat has been provided in the landscaping of the parkland, particularly for birds. The Rivergate Owner's Association pays for the maintenance of the park.

feature characteristics that conflict with the Model Development Principles, such as bigger streets, more on-site parking, and bigger setbacks, resulting in more land consumption. The basic features of the status quo site design include wider interior residential streets, increased front and rear setbacks, increased parking ratios and on-site surface parking, and wider sidewalks along interior residential streets. Assumptions made for this case study during the redesign analysis included a reduction in the parkland along the Potomac River and an increase in utilities in proportion to the increase in road length. The required 100-foot RPA buffer is maintained along the Potomac River.

Common open space covers a significant portion of Rivergate as-built, with 47% of the site preserved as parkland. In the status quo site design, however, more land is consumed by increased setbacks, frontages, and parking, and wider streets and easements, reducing the parkland to only 11% of the site.

Principle 4. Shorter Setbacks & Frontages

The short setbacks and frontages in Rivergate are one of the major elements allowing for the open space design described above. The frontages range from 18 feet to 36 feet; the front yard setbacks range from 16 feet to 20.5 feet; the side yard setbacks range from 0 feet to 18 feet; and the rear yard setbacks range from 8.5 feet to 18 feet. Since the interior streets are privately owned, each residential lot includes a portion of a street. All setbacks are from the edge of the lots, which equals the centerline of the road in some cases. This results in townhouses set only a few feet from the edge of the street.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

Frontage and setback requirements in the W-1 zone are as follows:

- Minimum frontage = lot width at building line = 18 feet for interior lots; 26 feet for end lots.
- Minimum front yard setback = none.
- Minimum side yard setback = 8 feet for end units only; 0 feet for interior units.
- Minimum rear yard setback = 8 feet.

A Comparison to the Status Quo

Smaller setback distances are typically not permitted, or require a zoning variance. For the purposes of the status quo site redesign analysis, all front yard setbacks were increased to 20 feet and all rear yard setbacks were increased to 18 feet.

In general, the use of shorter setbacks and frontages helps minimize land disturbance at Rivergate as-built. These features consume only about 14% of the total site area on the as-built project, as compared to 27% of the site in the status quo.

Principle 5. Common Walkways

Rivergate incorporates common walkways throughout the site instead of sidewalks adjacent to the streets. There are five-foot brick walkways down the center of the residential area leading to the parkland and along the perimeter of the site on Madison Street and Montgomery Street. In addition, there is an eight-foot stone dust, public access path in the parkland along the Potomac River.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

The Riverfront Agreement between the City of Al-

Table 6.2: The Influence of Walkways on Impervious Area

Scenario	Total Impervious Area (square feet)	% of Total Site Area
Status Quo Site Design	14,630	7.3%
As-Built	6,990	3.5%
Difference	7,640	3.8%

exandria and the US DOJ requires that each use, development, or project adjacent to the Potomac River provide a public access, open space walkway, and bikeway adjacent to the high watermark of the Potomac River.

A Comparison to the Status Quo
Most local codes require that sidewalks be placed on both sides of residential streets, be constructed of impervious concrete or asphalt, be four to six feet wide, and be placed two to 10 feet from the street. For the purposes of the status quo site redesign analysis, five-foot sidewalks are incorporated into the interior residential streets, within the 40 easements (see Principle 9).

Rivergate's common brick and stone dust walkways helped to minimize impervious cover (Table 6.2). These impervious and semi-pervious surfaces consume almost 4% of the total site area of the actual site, but may have doubled had the status quo site design techniques been used instead.

Principle 7. Narrower Streets
Rivergate's interior, private residential streets are 18 feet wide. To accommodate emergency vehicles, there is a 22-foot, two-way, perpetual emergency vehicle easement. Brick pavers line the interior residential streets within the emergency vehicle easement.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
At the time Rivergate was developed, the City of Alexandria did not have standards for private streets. The road widths were derived at the site designer's and plan reviewer's discretion. For public streets, the Virginia Department of Transportation's standard for a closed section road, less than half a mile long, with under 250 average daily trips, is 28 feet.

A Comparison to the Status Quo
Many communities require street widths up to 28 feet in townhouse developments. Rivergate's street widths in the status quo site design were widened to 28 feet.

The narrow streets in Rivergate as-built contributed the largest savings in impervious cover. These impervious surfaces consume about 8% of the total site area of the actual site, but may have been as high as 19% had the status quo site design techniques been used instead (Table 6.3).

Principle 9. Narrower Right-of-Way Widths
As the streets are privately owned, there are no rights-of-way. Instead, there is a 22-foot, two-way, perpetual emergency vehicle easement on the interior residential streets. In addition, all on-site sanitary sewers and water mains have 10-foot easements that fall within the emergency vehicle easement.

Table 6.3: The Influence of Street Width on Impervious Area

Scenario	Street Width (feet)	Total Impervious Area (square feet)	% of Total Site Area
Status Quo Site Design	28	37,520	18.8%
As-Built	18	15,948	8.0%
Difference	10	21,572	10.8%

Table 6.4: The Influence of Easement Width on Land Disturbance

Scenario	Easement Width (feet)	Area Consumed (square feet)	% of Total Site Area
Status Quo Site Design	40	52,000	28%
As-Built	22	16,346	9%
Difference	18	35,654	19%

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
As mentioned earlier, the City of Alexandria did not have standards for private streets at the time Rivergate was developed. For public, local residential streets, the City requires a 60-foot right-of-way.

A Comparison to the Status Quo
A public right-of-way is rare in townhouse developments, and many communities require private streets. In many communities that do require a right-of-way, a single width is applied to all residential street categories. For Rivergate, a 40-foot easement or right-of-way area is used for the status quo redesign analysis.

Like setbacks, the reduced easement widths in Rivergate as-built help to minimize land disturbance (Table 6.4). These features consume only about 9% of the total site area on the actual project, as compared to 28% of the site had the status quo site design techniques been used.

Principle 12. Reduced Parking Ratios
The developers of Rivergate provided two parking spaces per townhouse. Forty-two of the 58 units have a two-car garage, and the remaining 16 have a one-car garage with space for a second vehicle in front of the unit. Parallel parking is available for visitors on Montgomery Street and Madison Street adjacent to the property.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
The City of Alexandria requires two parking spaces per dwelling unit, and each space must be individually accessible. The 16 stacked parking spaces in Rivergate required a Special Use Permit. The developer requested a reduction in required parking equivalent to 16 individually accessible parking spaces in exchange for 16 stacked parking spaces.

A Comparison to the Status Quo
To account for visitor parking, many communities require up to 2.5 parking spaces per dwelling unit for townhouse developments. Another common requirement is one space per dwelling unit plus another half of a space per bedroom. Often, this is provided as surface parking in the form of driveways or parking lots, since many communities do not allow garage parking to satisfy residential parking requirements.

For the status quo site redesign analysis, the number of parking spaces is maintained at two spaces per townhouse. However, the increased front setback results in longer driveways for each townhouse.

Table 6.5: The Influence of Parking Ratios on Site Impervious Area

Scenario	Parking Spaces Provided in Driveways	Total Impervious Area (square feet)*	% of Total Site Area
Status Quo Site Design	116	23,200	12.7%
As-Built	16	6,400	3.5%
Difference	100	16,800	9.2%

* Assumes driveway width is 20 feet.

Table 6.6: The Influence of Site Design on Nutrient Loading

Scenario	Nitrogen (lbs/year)		Phosphorus (lbs/year)	
	without BMP	with BMP [1]	without BMP	with BMP [2]
Status Quo Site Design	49.4	37.8	6.0	4.3
As-Built	37.0	29.6	4.3	3.3
Difference	12.4	8.2	1.7	1.0

1. Underground sand filter removal efficiency of nitrogen = 44%
2. Underground sand filter removal efficiency of phosphorus = 51%

Figure 6.7: A disconnected downspout in Rivergate.

The case study provides driveway parking for 16 cars. In the status quo site design, the imperviousness resulting from the increased driveway length provides the equivalent of parking for two cars per townhouse, or 116 cars.

The reduced driveway lengths and parking ratios in Rivergate as-built help to minimize impervious cover (Table 6.5). These impervious surfaces consume about 4% of the total site area of the actual site, but may have been as high as 13% had the status quo site design techniques been used instead.

Principle 16. Treated Parking Lot Runoff

Principle 16 specifically refers to treating parking lot runoff. Rivergate displays an excellent example of a BMP applicable to a parking lot situation.

All of the rooftops have at least partially disconnected downspouts. Some discharge to a driveway, while others discharge to small garden plots and backyards (Figures 6.7 and 6.8). Catch basins and storm drains capture stormwater runoff on the residential portion of the site and direct the first half inch of runoff to an underground sand filter for treatment. The sand filter is not located on-site but is immediately adjacent to the property.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

The disconnected downspouts are included at the discretion of the site designer and plan reviewer. Sending rooftop runoff over a pervious surface before it reaches an impervious surface can decrease the annual runoff volume from a site. However, the City of Alexandria's codes have since been changed and now require that roof leaders be piped to storm sewers. The City of Alexandria requires treatment of half an inch per impervious acre.

A Comparison to the Status Quo

All communities within Tidewater Virginia are required to address stormwater management for new development. However, not all would result in BMP implementation as sophisticated as the underground sand filter used in Rivergate. Oil-grit separators are commonly used in space-restricted infill developments.

The underground sand filter as used at Rivergate was adapted for sites where space is at a premium. Designs will vary, but the sand filter displayed in Figure 6.9 is a three-chamber underground vault accessible by manholes or grate openings. The vault can be either on-line or off-line in the storm drain system.

Figure 6.8: Each townhouse in Rivergate has a small garden plot and backyard.

The first chamber is used for pretreatment and relies on a wet pool as well as temporary runoff storage. It is connected to the second sand filter chamber by an inverted elbow, which keeps the filter surface free from trash and oil. The filter bed is typically 18 inches in depth, and may have a protective screen of gravel or permeable geotextile to limit clogging. During a storm, the water quality volume is temporarily stored in both the first and second chambers. Flows in excess of the filter's capacity are diverted through an overflow weir. Filtered runoff is collected using perforated underdrains that extend into the third overflow chamber.

To demonstrate the influence of site design on nutrient loading, an underground sand filter was used for the status quo site design as well as for the case study. Table 6.5 displays the annual nutrient loading from the site under four scenarios: the status quo site design with and without a BMP, and the case study with and without a BMP. The influence of the previously discussed Model Development Principles becomes evident here. The phosphorus and nitrogen loads from the status quo site design with an underground sand filter are comparable to the loads from the case study design before the reductions of the BMP are even factored into analysis. This is due in large part to the reduction of impervious cover in the case study as compared to the status quo site design.

Figure 6.9: The underground sand filter used at Rivergate is an option for providing water quality volume where space or land prices are at a premium.

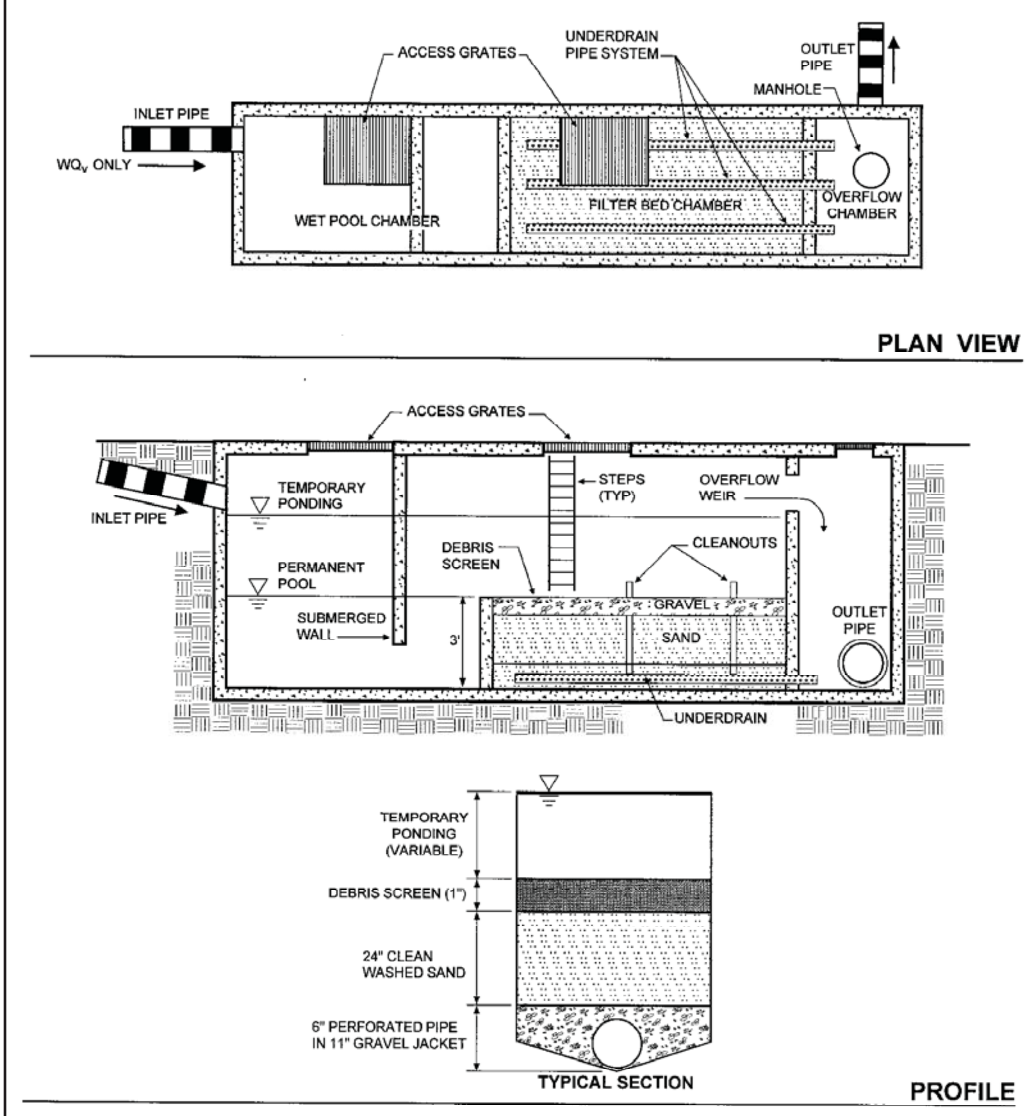


Table 6.7: A Comparison of Rivergate As-Built to the Status Quo Site Design					
		Pre-Development	Status Quo	As-Built	% Difference[1]
Site Characteristics					
Site Area		4.2 acres			N/A
Number of Units		N/A	58	58	0%
Average Lot Size[2] (sq ft)		N/A	2,822	1,648	42%
Land Cover and Disturbance					
Landscaped Parkland (sq ft)		N/A	17,834	80,400	351%
Residential Lawn (sq ft)		N/A	36,918	15,083	59%
Site Imperviousness					
Walkway Impervious Area (sq ft)		N/A	13,430	6,017	55%
Road Area (sq ft)		N/A	44,480	26,837	40%
Driveway Area (sq ft)		N/A	23,200	6,400	72%
Rooftop Area (sq ft)		N/A	47,258	47,258	0%
Equivalent Impervious Area[3] (sq ft)		N/A	548	955	74%
Total Impervious Area (sq ft)		*173,964*	*128,916*	*87,467*	*32%*
Total Imperviousness (%)		*95%*	*70%*	*48%*	*32%*
Stormwater Impacts					
Runoff (inches/yr)		32.8	24.8	17.4	30%
Infiltration (inches/yr)		0.6	2.9	5.1	76%
Nitrogen Load (lbs/yr)	without BMP	63	49.4	37	25%
	with BMP		37.8	29.6	22%
Phosphorous Load (lbs/yr)	without BMP	7.8	6.0	4.3	28%
	with BMP		4.3	3.3	23%
Infrastructure Costs					
Infrastructure Costs		N/A	$ 382,400	$ 190,000	50%
BMP Costs		N/A	$ 33,900	$ 21,900	35%
Landscaping / Reforestation		N/A	$ 1,600	$ 2,900	81%
Total Infrastructure Costs		*N/A*	*$ 417,900*	*$ 214,800*	*49%*

1. % Difference is between the Status Quo and the As-Built.
2. In both scenarios, roads are privately owned. Therefore, road area is included in average lot area.
3. Compacted turf is assumed to be 1% impervious.

Conclusion

In general, the use of shorter setbacks and frontages, as well as narrower easement widths, helps minimize land disturbance at Rivergate. These features consume only about 23% of the total site area on the actual project, as opposed to as much as 55% of the site had the status quo site design techniques been used. Although this redevelopment site had no existing indigenous vegetation prior to development, the open space design and landscaped park contribute to the enhancement of indigenous vegetation, as several native species are incorporated into the landscape plan. Finally, common walkways, narrower streets, and reduced surface parking help to minimize impervious cover. These impervious surfaces consume about 21% of the total site area of the actual site, but may have been as high as 44% had the status quo site design techniques been used instead.

Table 6.6 compares the land cover associated with the site under three scenarios: pre-development, the status quo site design, and the actual Rivergate design. This information is used to compute the annual hydrologic budget, annual nutrient export, and infrastructure cost for each scenario.

As a result of the reduced impervious cover and the increased parkland, the case study design results in the lowest volume of runoff and the highest volume of infiltration per year over both the pre-development conditions and the status quo site design scenario. These site characteristics also result in reduced nutrient loading. As previously stated, the annual nutrient loads from the status quo site design with a BMP (an underground sand filter) are comparable to the loads from the case study design even when the BMP is eliminated from the analysis.

The Model Development Principles were developed to promote design techniques that are both environmentally friendly and economically sound. In Rivergate as-built, the larger parkland results in a higher landscaping cost. However, the increase in asphalt and utility lengths in the status quo site design results in a higher infrastructure cost than for the case study design. Also, the increased imperviousness of the status quo site design results in a higher volume of stormwater runoff to be treated, which in turn increases the BMP construction cost by 35%. Overall, the status quo site design is estimated to have total infrastructure construction costs that are about 50% higher than Rivergate as-built.

VII. Case Study #4: The Arboretum, A Commercial Case Study

Figure 7.1: Regional stormwater management facility with Arboretum I on the left, Arboretum III on the right, and the Arboretum III parking structure in the background.

The Arboretum is a commercial/office development complex located in Chesterfield County, Virginia. The development project, constructed in the late 1980s, consists of two buildings, Arboretum I and Arboretum III, and the associated infrastructure (Figure 7.1). Arboretum I is a three-story office building comprising 63,000 square feet of office space. Surface parking for this building is provided on the 4.81 acre site. Arboretum III is a six-story office building comprising 223,000 square feet of office space. Parking for this building is provided on the 7.96 acre site in a four-story, 272,000-square- foot parking structure and through additional surface parking. Stormwater management for the office complex and upstream development is provided by a regional stormwater management facility constructed between the two building sites. Figures 7.1 through 7.5 depict the layout and site features of the Arboretum complex. Prior to construction, the development site was predominately forested, with a small headwater stream flowing across it.

The Model Development Principles in the Arboretum

In this case study, five of the sixteen Model Development Principles are highlighted (Table 7.1). The principles highlighted on the Arboretum site include the conservation of native plants and trees, minimized clearing and grading, the use of mass transit and shared parking, reduced parking lot imperviousness, and the use of structured parking.

Table 7.1: Model Development Principles Utilized on the Aboretum Site

Model Development Principle	Minimizes Land Disturbance	Preserves Indigenous Vegetation	Minimizes Impervious Surfaces
1. Native Plant & Tree Conservation	T	T	
2. Minimize Clearing and Grading	T	T	
13. Mass Transit and Shared Parking	T		T
14. Less Parking Lot Imperviousness	T	T	T
15. Structured Parking	T	T	T

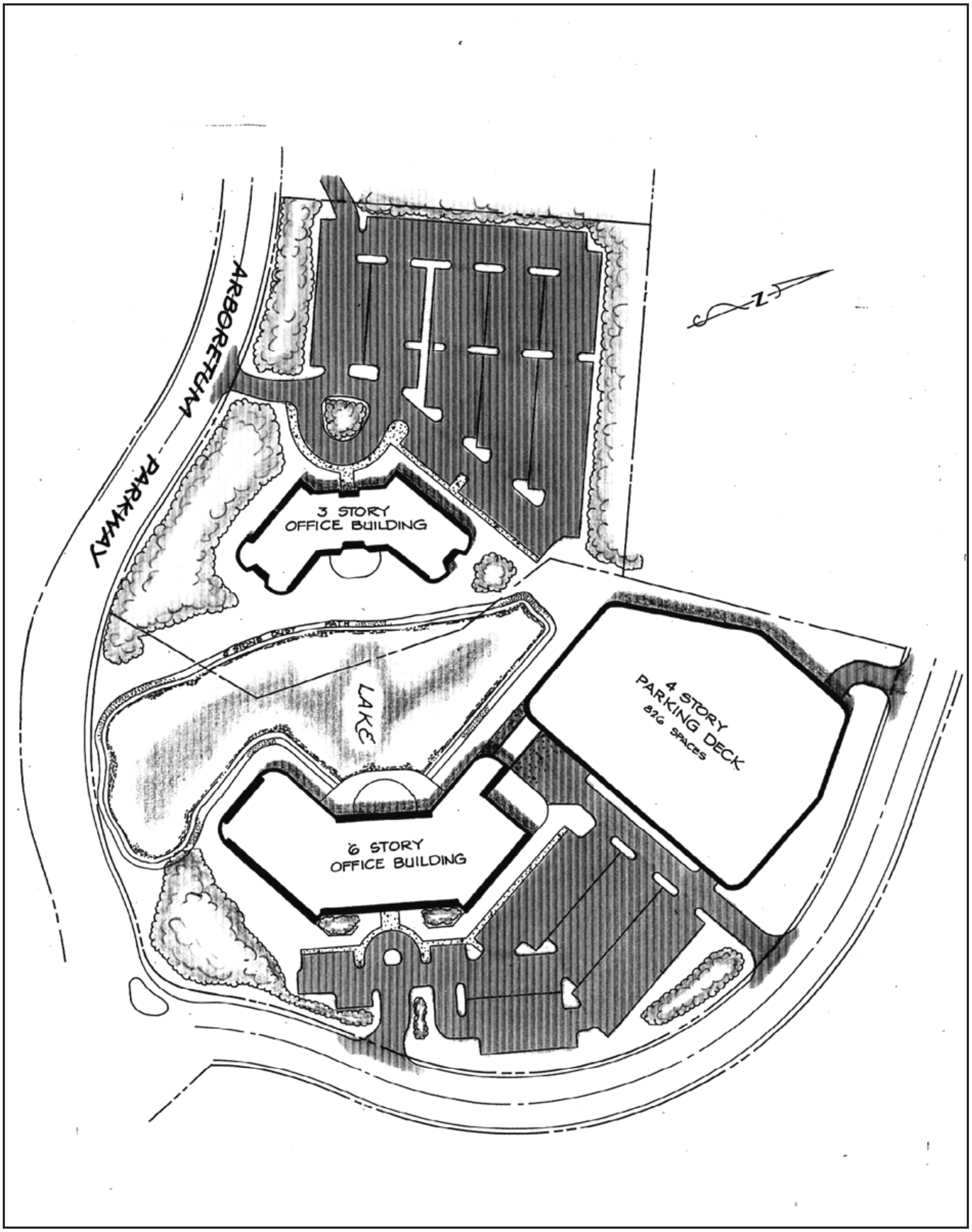


Figure 7.2: The Arboretum is a commercial office park in Chesterfield County, Virginia.

Figure 7.3: The Arboretum III on-site parking structure.

In this case study, the status quo site design consists of two redesign scenarios for the Arboretum III site. The redesign scenarios were limited to the Arboretum III site because the project incorporates a greater number of the Model Development Principles than does the Arboretum I project site.

There are two principal components in the design of a commercial office development: the size of the building, and the amount of parking required to serve the building. The as-built design of the Arboretum III building consists of a six-story 223,000 square foot office building with a four-story parking structure that provides 964 parking spaces. The status quo site design examines how the Arboretum III site would be developed without using structured parking.

The acreage of a building site controls the amount of area available for parking, and the amount of parking dictates the size of the building. When the Arboretum III site is redesigned to utilize only surface parking, there is not enough area on the site necessary to provide all of the parking required for the existing 223,000 square foot building. The first design scenario looks at constructing a smaller 124,200 square foot building that can be served by surface parking on the existing site. The second scenario looks at constructing the same size building as exists now, but increases the acreage of the site to allow enough surface parking to provide the required number of spaces.

Principle 1. Native Plant and Tree Conservation

Of the two building sites in the project, The Arboretum I site is significant in that 24% of the site is maintained in existing native tree cover. While the Arboretum III site preserved much less existing forest cover, (only 6% of the site), the development provides more than three times the office space and more than four and a half times the number of parking spaces on a site that is a little more than twice as large as the Arboretum I site.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

The Chesterfield County Code requires that "Preservation of existing trees and shrubs shall be maximized to provide continuity and improved buffering. Except when necessary to provide access, any trees that are eight inches or greater in caliper, located within the setback from a public right-of-way, shall be retained unless removal is approved through site, subdivision, or schematic plan review..." While this code does not stipulate a minimum amount of native plant and tree preservation, it does require that tree and shrub removal be justified on each site by the developer.

A Comparison to the Status Quo

Many communities throughout Virginia do not require that any existing trees or natural vegetation

Table 7.2: The Influence of Tree Save Requirements on Native Plant and Tree Conservation For the Arboretum III Site

Scenario		Area Conserved (square feet)	% of Total Site Area
Status Quo Site Design	Redesign 1	0	0%
	Redesign 2	0	0%
As-Built		20,804	6%
Difference		20,804	6%

be preserved during the land development process. The redesign scenarios for this case study include no requirements to preserve existing trees or native vegetation. Table 7.2 compares the area conserved on the Arboretum III site with the area that would have been conserved under a status quo site design.

Principle 2. Minimize Clearing and Grading

The minimization of clearing and grading goes hand and hand with native tree and plant conservation. On both the Arboretum I and III sites, any areas not required to be cleared and graded for the construction of buildings, parking, and other infrastructure were left undisturbed. This accounts for the 24% forest preservation on the Arboretum I site. While only 6% of the Arboretum III site was left undisturbed, it represents the maximum amount achievable in light of the intensity of development on this building site.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

While no specific local ordinance or code requires the minimization of clearing and grading, one of the main objectives of the locally adopted Chesapeake Bay Preservation Ordinances is to minimize clearing and grading.

A Comparison to the Status Quo

Most communities allow clearing and grading of an entire development site, except for a few specially protected areas such as jurisdictional wetlands, steep slopes, and floodplains. The status quo site designs for the Arboretum project assume that the building sites would be completely cleared and graded as part of the site development process. Table 7.3 compares the area disturbed on the Arboretum III as-built with the area that would have been disturbed under the status quo site designs.

Figure 7.4: The Arboretum III building as seen from across the regional stormwater management facility.

Principle 13. Mass Transit and Shared Parking

Shared parking is a strategy that reduces the number of parking spaces needed by allowing adjacent land uses to share parking facilities. The Arboretum III site provides a greater number of parking spaces than required by local codes without increasing impervious cover. Overflow parking on the Arboretum I site can be accommodated by the additional capacity in the Arboretum III parking structure.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics

Local code allows shared parking between adjacent businesses and between businesses with different peak usage times (for example, a church and a shopping center). Local code also allows multiple buildings to be combined for determining parking requirements when they share the same parking facility (parking requirements progressively decrease with

Table 7.3: The Effects of Minimizing Clearing and Grading on Land Disturbance on the Arboretum III Site

Scenario		Area Disturbed (square feet)	% of Total Site Area Disturbed
Status Quo Site Design	Redesign 1	346,738	100%
	Redesign 2	479,160	100%
As-Built		325,933	94%
Difference		325,933	6%

increasing building square footage).

A Comparison to the Status Quo
Although shared parking arrangements can significantly reduce the area needed for parking, only a few communities have actively encouraged such arrangements. The status quo site design assumes that there would be no shared parking allowed and that any overflow parking would have to be accommodated on the individual sites.

Figure 7.5: Tree save area at entrance to Arboretum III.

Principle 14. Less Parking Lot Imperviousness
Parking is the largest component of impervious cover in most commercial and industrial zones, but conventional design practices do little to reduce the impervious area associated with parking lots. For example, many communities require parking dimensions geared toward larger vehicles, despite the fact that smaller cars make up almost half of all cars on the road (ITE, 1994). The use of design practices such as compact spaces, efficient parking space layout and one-way traffic aisles can significantly reduce the impervious cover in parking lots.

Both the Arboretum I and the Arboretum III buildings incorporate means of minimizing parking lot impervious, but in different ways. The Arboretum I building utilizes a short entrance drive and an efficient parking space layout to maximize the numbers of spaces within the parking area. When examined in terms of the overall parking lot impervious area versus the number of parking spaces, the Arboretum I parking lot requires 364 square feet of impervious surface per parking space. In many instances impervious area per parking space exceeds 400 square feet (Schueler, 1995) making the Arboretum I parking efficient in terms of impervious surface utilization.

The Arboretum III building utilizes a four-story parking structure to minimize the amount of impervious surface attributed to parking. The advantages of utilizing parking structures will be discussed in the next section.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
At the time the Arboretum Buildings were approved, The local code required the construction of six parking spaces for the first 1,000 square feet of building space and one parking space for each additional 300 square feet of office space. Soon after, the parking requirement was revised to progressively reduce the number of parking spaces needed as a building grew larger. Had the new code been in place at the time the Arboretum III was approved, it would have required the construction of 82 fewer parking spaces on the site.

The new code required the following:

Table 7.4: Advantages of Minimizing Parking Lot Imperviousness on the Arboretum III

Scenario		Area Conserved (square feet)	% of Total Site Area
Status Quo Site Design	Redesign 1	139,391	40%
	Redesign 2	272,250	57%
As-Built		68,000	20%
Difference	Redesign 1	71,391	20%
	Redesign 2	204,250	43%

- One parking space for each 200 square feet of office space for the first 10,000 square feet
- Plus one parking space for each 250 square feet of office space for the next 40,000 square feet
- Plus one parking space for each 300 square feet of office space for the next 25,000 square feet
- Plus one parking space for each 400 square feet in excess of 75,000 square feet

The new parking code also allowed for impervious reduction measures such as angled parking and narrower aisle widths.

A Comparison to the Status Quo
In terms of parking lots, most communities only require that a minimum number of parking spaces be constructed, and often these minimums far exceed the number of spaces actually required. In addition, parking lot design and layout are rarely reviewed by planners in terms of efficiency or use of space. The status quo site design assumes that no measures have been taken to reduce parking lot imperviousness. Table 7.4 shows the level of impervious area reduction achieved on the Arboretum III site as-built as opposed to the status quo site design.

Principle 15. Structured Parking
In commercial and office developments, the use of multi-level parking structures can significantly reduce the impervious cover and pollutant load associated with parking lots. However, the use of structured parking is generally controlled by land values. In areas where land is abundant and land values low, structured parking is generally not economically feasible. In areas where land values are higher or where sites are limited in size, the use of structured parking may be more economical than surface parking.

The Arboretum III building utilizes a four-story, 272,000-square-foot structure for parking. A parking structure was utilized on the site because there was insufficient site area to provide the required number of parking spaces in a surface lot.

Applicable Codes/Ordinances Allowing or Requiring Design Characteristics
There are no specific codes that require the use of structured parking. Land values along with parcel and building sizes generally determine when structured parking is feasible.

A Comparison to the Status Quo
Had surface parking been utilized on the site, it would have required a parking lot approximately six acres in size. This is compared to the 1.5 acre footprint of the existing parking structure. Two scenarios were examined in the status quo site: one that utilized surface parking and a smaller building on the existing site, and one that utilized surface parking and the existing building on a larger site. Table 7.5 depicts the reduction in impervious area achieved through the use of structured parking on the site as-built.

Redesign Scenarios
The status quo site design scenarios focus on the Arboretum III building site, as the Arboretum III site incorporates a greater number of Model Development Principles. The most significant difference between the Arboretum III building and other similar office developments is the use of structured parking. The existing Arboretum III site utilizes a four-story parking structure to meet the parking

Table 7.5: Impervious Area Reduction Achieved Through the Use of Structured Parking

Scenario		Area Conserved (square feet)	% of Total Site Area
Status Quo Site Design	Redesign 1	139,391	40%
	Redesign 2	272,250	57%
As-Built		68,000	20%
Difference	Redesign 1	71,391	20%
	Redesign 2	204,250	43%

requirement. Of the total site (7.96 acres), only 3.08 acres of land were utilized for parking while providing 964 parking spaces. Had only surface parking been used to service the Arboretum III building, it would have required a parking lot of at least six acres in size. Not building a parking structure on the site would have required that either the building be downsized to accommodate the limited site area available for parking (Scenario 1), or that additional land be acquired to accommodate the existing building and provide sufficient surface parking (Scenario 2). Either one of these alternatives would result in an increase in impervious cover and pollutant loads. Table 7.6 depicts the impervious cover calculations and pollutant loads for the existing Arboretum III site.

Table 7.6: Impervious Cover Calculations and Pollutant Loads for the Existing Arboretum III Site

Arboretum III Project As-Built (7.96 ac. site, 223,000 ft^2 office space)		
Land Use	**Area (acres)**	**% of Site**
Pavement and Rooftops (acres)	4.2	52%
Semi-Impervious Area (acres)	2.1	21%
Forest and Wetlands (acres)	0.4	5%
Meadow (acres)	0.0	0%
SWM Pond (acres)	1.3	16%
Imperviousness 69%		
Hydrology		
Runoff (inches/yr.)	24.1	
Infiltration (inches/yr.)	3.1	
Nutrient Loads		
	Without BMPs	**With BMPs**
Nitrogen (lbs./yr.)	90.6	63.7
Phosphorous (lbs./yr.)	11.0	8.9

Status Quo Scenario 1

Assuming that 1) no structured parking was provided, 2) the existing site could not be expanded, and 3) a building with the same footprint was constructed, there is available land to create approximately 3.49 acres of surface parking on the Arboretum III site. The Arboretum I building utilizes a 1.78 acre parking lot to provide 213 parking spaces, for a parking lot area to parking space ratio of 364 square feet of total impervious area per parking space. Using this same parking space to parking lot area ratio, approximately 417 parking spaces could be created on the Arboretum III site. Based upon Chesterfield County parking requirements, this amount of parking would accommodate only 124,200 square feet of office space. This amount of surface parking would also result in the loss of the modest amount of tree save areas on the Arboretum III site (0.41 acres). The resulting development would be approximately 74% impervious, as opposed to the existing site's impervious cover of 69% (Table 7.9). Table 7.7 details the impervious cover and pollutant load increases of Scenario 1.

While this approach is feasible and would not significantly increase the pollutant load associated with this site, it would ultimately lead to the development of another site, of about the same size as the Arboretum I, in order to create the equivalent amount of office space that the current Arboretum III building provides. This would require additional road infrastructure to access a new site, an increase in sediment loss as an additional site was graded and constructed, and a doubling of impervious surfaces attributed to buildings and parking, all to create the same amount of office space. This would also result in a significant increase in the pollutant load that ultimately reaches local waterways.

Status Quo Scenario 2

The second scenario would be to build the Arboretum III building as it stands now and service it with surface parking only. This scenario would require the site area to be increased to approximately 11 acres. Using the parking space to parking lot area ratio discussed earlier, 6.25 acres of the 11 acre parcel would be dedicated to parking. The resulting site would be approximately 81% impervious as opposed to the existing Arboretum III impervious cover of 69%. In terms of pollutant loads, this scenario would result in a 50% increase in the nitrogen load and a 60% increase in the phosphorus load leaving the site, when compared to the as-built condition. Table 7.8 details the impervious cover and pollutant load increases of Scenario 2.

Summary of the Redesign Scenarios

The Arboretum III development site follows the philosophy of "build up, not out." There is no guarantee that the land saved by building up and not out on this development site would not simply be looked upon as creating more buildable land elsewhere. However, in reality, market forces and the demand for office space control the consumption of land. If market demand for office space can be satisfied on fewer or smaller development sites, then there will be less need/demand to consume additional land area. In terms of the economic benefits of the case study design, land, infrastructure, and construction/maintenance costs are minimized when the yield of office space per land area is maximized. Clearly, the construction of a taller building that incorporates structured parking has resulted in a significant net benefit to the local environment and the Chesapeake Bay.

Table 7.7: Scenario 1 - Impervious Cover Calculations and Pollutant Loads for the Arboretum III Building

Arboretum III Project with Surface Parking Only and Less Office Space on Existing Site (7.96 ac. site, 124,200 ft² office space)		
Land Use	**Area (acres)**	**% of Site**
Pavement and Rooftops (acres)	4.6	58%
Semi-Impervious Area (acres)	2.1	21%
Forest and Wetlands (acres)	0.0	0%
Meadow (acres)	0.0	0%
SWM Pond (acres)	1.3	16%
Imperviousness 74%		
Hydrology		
Runoff (inches/yr.)	25.8	
Infiltration (inches/yr.)	2.5	
Nutrient Loads		
	Without BMPs	**With BMPs**
Nitrogen (lbs./yr.)	96.5*	67.7*
Phosphorous (lbs./yr.)	11.8*	9.5*

* Does not account for the pollutant load from additional development site required to make up for reduction in office space.

In terms of comparing the marketability of the two status quo site design scenarios and the case study design, a park-like setting, the close proximity of the parking structure to the building, and the advantage of parking within an enclosed structure during inclement weather are highly marketable selling points. While the cost effectiveness of utilizing structured parking is a site specific matter and the subject of debate, it has proven itself in this instance as seen from the success of the Arboretum development.

Table 7.8: Scenario 2 - Impervious Cover Calculations and Pollutant Loads for the Arboretum III Site

Arboretum III Project With Surface Parking Only on Expanded Site (11.00 ac. site, 223,000 ft² office space)		
Land Use	**Area (acres)**	**% of Site**
Pavement and Rooftops (acres)	7.6	69%
Semi-Impervious Area (acres)	2.1	19%
Forest and Wetlands (acres)	0.0	0%
Meadow (acres)	0.0	0%
SWM Pond	1.3	12%
Imperviousness 81%		
Hydrology		
Runoff (inches/yr.)	30.0	
Infiltration (inches/yr.)	1.3	
Nutrient Loads		
	Without BMPs	**With BMPs**
Nitrogen (lbs./yr.)	141.6	98.4
Phosphorus (lb./yr.)	17.5	14.2

The Model Development Principles detailed here demonstrate a quantifiable improvement in the areas of impervious surface minimization, the preservation and enhancement of indigenous vegetation, and the minimization of land disturbance. Had there been no emphasis on preserving native vegetation, it is likely the entire site would have been cleared and graded.

Table 7.9: A Comparison of The Arboretum III As-Built to the Status Quo Site Design Scenarios					
		Pre-Development	**Status Quo Scenario 1**	**Status Quo Scenario 2**	**As-Built**
Site Characteristics					
Site Area		7.96 acres	7.96 acres	11.00 acres	7.96 acres
Office Space (sq ft)		0	124,200	223,000	223,000
Site Imperviousness					
Access Drive Area (sq ft)		N/A	12,632	12,632	12,632
Parking Area (sq ft)		N/A	139,391	272,250	121,532
Sidewalk Area (sq ft)		N/A	8,276	8,276	8,276
Rooftop Area (sq ft)		N/A	39,204	39,204	39,204
Lawn Area[1] (sq ft)		N/A	91,040	91,040	91,040
Forest Area[1] (sq ft)		346,737	0	0	17,860
SWM Pond Area [2] (sq ft)		N/A	56,192	56,192	56,192
Total Impervious Area (sq ft)		*3,468*	*256,605*	*389,664*	*238,925*
Percent Impervious		*1%*	*74%*	*81%*	*69%*
Stormwater Impacts					
Runoff (inches/yr)		2.1	25.8	30	24.1
Infiltration (inches/yr)		12.0	2.5	1.3	3.1
Nitrogen Load (lbs/yr)	without BMP	7.4	96.5[3]	141.6	90.6
	with BMP	NA	67.7[3]	98.4	63.7
Phosphorous Load (lbs/yr)	without BMP	0.7	11.8[3]	17.5	11.0
	with BMP	NA	9.5[3]	14.2	8.9

1. Turf and forest areas are assumed to be 1% impervious.
2. Pond area is considered 100% impervious.
3. Does not account for the pollutant load from additional development site required to make up for reduction in office space.

This would have resulted in the loss of all native vegetation on the site. Additionally, the use of structured parking on the Arboretum III site resulted in a significant reduction in impervious area, compared to utilizing only surface parking. Table 7.9 lists the improvements gained from utilizing the Model Development Principles in the as-built design.

VIII. How Do You Make This Happen in Your Community?

A community's planning, environmental management, or public works office typically administers its Chesapeake Bay Act program. However, staff members working within these offices need support from their directors and local governing bodies in order to ensure that the intent of the local program is met. Because the principles of better site design may differ from how a community has traditionally approached water quality protection, this calls for educational efforts that reach beyond the individuals who actually administer the local program on a day-to-day basis. Therefore, educational programs presenting the environmental and economic benefits of better site design should be developed to target the community's decision-making bodies, such as the County Board of Supervisors or City/Town Council and the local Planning Commission. Educational efforts targeted to these local governing bodies will help to ensure that the different authorities and levels of power within the community make well-informed, consistent decisions that take into account the water quality concerns of the locality.

A new approach to help evaluate and reform local development rules has been recently applied in a few communities in and outside of Virginia. The approach, referred to as a local site planning roundtable, relies on a consensus building process to help foster better site design at the local level. The program involves a systematic review of existing development rules and uses the model development principles as a basis for code reform. Those development codes and regulations that discourage or prohibit innovative site design are typically among those recommended for reform. Box 8.1 presents an overview of the local roundtable process. It is important to note that the roundtable is not a government sanctioned group with the authority to simply implement code reform, instead the roundtable should be viewed as an advisory board that develops a strategy for future regulatory action by the local government authority.

Table 8.1: Potential Members of a Local Roundtable

Local Government: • Planning Commission • Elected Officials • Public Works Department • Fire Department • Health Department • Planning Department	Residents/Land Owners: • Civic Associations • Homeowner Associations
State Government: • Department of Conservation and Recreation • Chesapeake Bay Local Assistance Department • Virginia Department of Transportation	Commercial Sector: • Site Design Consultants • Developers • Realtors • Real Estate Lenders • Chamber of Commerce
	Environmental Groups: • Watershed Advocates • Land Trusts
	Other: • Land Use Attorneys • Municipal Insurance

Some communities might decide that they have in place the political will and resources necessary to undertake a local site planning roundtable and that code reform is necessary in order to implement the principles of better site design. However, other communities might find that existing development rules allow for implementation of the better site design principles or that circumstances within the community make the roundtable process unrealistic. In either situation, education of all groups and individuals who impact the planning and physical development of the community is essential to ensuring that better site design is integrated into a community's water quality protection efforts.

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APPENDIX A. BETTER SITE DESIGN RESOURCES

This resources section provides a list of general Better Site Design resources as well as references that relate to specific principles. Each resource includes a brief description and contact information.

General Better Site Design Resources

Better Site Design: A Handbook for Changing Development Rules in Your Community (1998) by Center for Watershed Protection
Designed for local planners, engineers, developers, and officials, this guidebook outlines the culmination of research from a National Site Planning Roundtable process.

Center for Watershed Protection
8391 Main Street
Ellicott City, MD 21043
410-461-8323

Conservation Design for Stormwater Management (1997) by the Delaware Department of Natural Resources and Environmental Control and The Environmental Management Center of the Brandywine Conservancy
Provides guidance for site design that incorporates conservation into land development. Emphasis is on retaining natural features in the development process to reduce the need for structural stormwater management controls.

Delaware Department of Natural Resources and Environmental Control
Division of Soil and Water Conservation
Sediment and Stormwater Program
89 Kings Highway
Dover, DE 19901
302-739-4411

Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks (1996) by Randall Arendt
Discusses how to rearrange housing density so that no more than half of the buildable land becomes developed. Includes model zoning and subdivision ordinance provisions.

American Planning Association
Planners Book Service
122 S. Michigan Avenue
Suite 1600
Chicago, IL 60603
312-786-6344

Designing Open Space Subdivisions (1997) by Randall Arendt
Presents case studies of developments using flexible lot standards. Also includes more expansive discussion regarding large, Euclidean lots versus flexible, smaller lots.

Natural Lands Trust
Hildacy Farm
1031 Palmers Mill Road
Media PA 19063
610-353-5587

Guide to the Bay Act by Chesapeake Bay Local Assistance Department
This guidance pamphlet provides a general reference on the purpose and intent of Virginia's Chesapeake Bay Preservation Act Program.

Virginia Department of Conservation & Recreation Division of Chesapeake Bay Local Assistance
James Monroe Building
101 North 14th Street, 17th Floor
Richmond, VA 23219
1-800-243-7229

Land Development Manual (1995) by Virginia Department of Transportation
Includes information on the site plan review process, provides guidelines for traffic impact studies, and outlines standards, requirements, and policies.

Commonwealth of Virginia
Department of Transportation
1401 East Broad Street
Richmond, VA 23219
804-786-2576

Riparian Buffers Modification & Mitigation Manual (2003) by Virginia Department of

Virginia Department of Conservation & Recreation Division of Chesapeake Bay

Conservation & Recreation Division of Chesapeake Bay Local Assistance
This guidance provides information on the value buffers and on what modifications are allowed and what mitigation should be used within Chesapeake Bay Preservation Areas for the protection of water quality.

Local Assistance
James Monroe Building
101 North 14th Street, 17th Floor
Richmond, VA 23219
1-800-243-7229

Low Impact Development Design Manual (1997) by Prince George's County Department of Environmental Resources Division of Watershed Management and Maryland Department of Natural Resources Chesapeake and Coastal Watershed Services Watershed Restoration Division.
Provides guidance on hydrologic analysis, site planning, BMPs, permit processing, and public outreach programs.

Low Impact Development Center
3230 Bethany Lane, Suite 9
Ellicott City, MD 21042
410-418-8476

Rural by Design (1994) by Randall Arendt
Provides information on alternative neighborhood designs, including open space design, street design, greenways, zoning, and growth management.

American Planning Association
Planners Book Service
122 S. Michigan Avenue Suite 1600
Chicago, IL 60603
312-786-6344

Principle 1: Native Plant and Tree Conservation

Building Greener Neighborhoods: Trees as Part of the Plan (1995) by Jack Petit, Debra Bassert, and Cheryl Kollin
Demonstrates the environmental, economic, and aesthetic benefits of conserving and preserving trees in residential developments.

American Forests
PO Box 2000
Washington DC 20013-2000
202-667-3300

Forest Conservation Manual (1991) by Jennifer Greenfeld, Lorraine Herson, Natalie Karouna, Giselle Bernstein
Provides guidance in preparing forest stand delineations and forest conservation plans. Also provides guidance on reforestation or afforestation methods.

Maryland Department of Natural Resources
Tawes State Office Building
580 Taylor Avenue
Annapolis, MD 21401
410-260-8367

Forest and Riparian Buffer Conservation: Local Case Studies from the Chesapeake Bay (1996) by the Forestry Workgroup of the Chesapeake Bay Program's Nutrient Subcommittee
Cites examples demonstrating how buffer programs have been implemented on the local level.

USDA Forest Service
Northeastern Area State and Private Forestry
Chesapeake Bay Program
410 Severn Avenue, Suite 109
Annapolis, MD 21403
1-800-968-7229

The Wild Lawn Handbook: Alternatives to the Traditional Front Lawn (1995) by Steven Daniels
Guidance for creating and maintaining a non-conventional lawn.

Check your local public library for this book.

Principle 2: Minimized Clearing and Grading

Clearing and Grading: Strategies for Urban Watersheds (1995) by Kathleen Corish
Guidance report discussing problems associated with the clearing and grading activities that precede land development, and recommendations for minimizing impacts to receiving water bodies.

Metropolitan Washington Council of Governments
Information Center
777 North Capitol Street, NE Suite 300
Washington, DC 20002-4201
202-962-3256

Fire Protection in the Wildland/Urban Interface: Everyone's Responsibility (1994) by the National Wildland/Urban Interface Fire Protection Program
Presents five step method for assessing fire hazards in wildland/urban interface. Presents case studies demonstrating how local governments can reduce the risk for fires in the wildland/urban interface.

National Interagency Fire Center
Branch of Supply
3833 South Development Avenue
Boise ID 83705-5354
208-387-5542

Forest Conservation Manual (1991) by Jennifer Greenfeld, Lorraine Herson, Natalie Karouna, Giselle Bernstein
Provides guidance in preparing forest stand delineations and forest conservation plans. Also provides guidance on reforestation or afforestation methods.

Maryland Department of Natural Resources
Tawes State Office Building
580 Taylor Avenue
Annapolis, MD 21401
410-260-8367

Principle 3: Open Space Design

Conservation Design for Stormwater Management (1997) by the Delaware Department of Natural Resources and Environmental Control and The Environmental Management Center of the Brandywine Conservancy
Provides guidance for site design that incorporates conservation into land development. Emphasis is on retaining natural features in the development process to reduce the need for structural stormwater management controls.

Delaware Department of Natural Resources and Environmental Control
Division of Soil and Water Conservation
Sediment and Stormwater Program
89 Kings Highway
Dover, DE 19901
302-739-4411

Conservation Design for Subdivisions: A Practical Guide to Creating Open Space Networks (1996) by Randall Arendt
Discusses how to rearrange housing density so that no more than half of the buildable land becomes developed. Includes model zoning and subdivision ordinance provisions.

American Planning Association
Planners Book Service
122 S. Michigan Avenue
Suite 1600
Chicago, IL 60603
312-786-6344

Rural by Design (1994) by Randall Arendt
Provides information on alternative neighborhood designs, including open space design, street design, greenways, zoning, and growth management.

American Planning Association
Planners Book Service
122 S. Michigan Avenue
Suite 1600
Chicago, IL 60603
312-786-6344

Site Planning for Urban Stream Protection (1995) by Thomas R. Schueler
Chapter 3 examines how conventional zoning techniques relate to stream quality and how local

Center for Watershed Protection
8391 Main Street
Ellicott City, MD 21043
410-461-8323

governments can institute watershed-based zoning.

Principle 4: Shorter Setbacks and Frontages

Density by Design (1992) by James W. Wentling and Lloyd Bookout
Over 20 case studies of higher density communities, many achieved through the use of flexible lot designs and reduced setbacks and frontages. Focus on design of lot and marketing.

Urban Land Institute
1025 Thomas Jefferson Street, NW
Suite 500 West
Washington, DC 20007
800-321-5011

Designing Open Space Subdivisions (1997) by Randall Arendt
Presents case studies of developments using flexible lot standards. Also includes more expansive discussion regarding large, Euclidean lots versus flexible, smaller lots.

Natural Lands Trust
Hildacy Farm
1031 Palmers Mill Road
Media PA 19063
610-353-5587

Principle 5: Common Walkways

Pedestrian and Bicyclist Safety and Accommodation (1996) National Highway Institute
Course book that provides practical design information and an overview of laws and ordinances applicable to sidewalks.

National Highway Traffic Safety Administration
Federal Highway Administration
US Department of Transportation
To obtain a copy, call 301-577-0818 and ask for Publication No. FHWA-HI-96-028

Residential Streets (2nd Edition) (1990) American Society of Civil Engineers, National Association of Home Builders, and the Urban Land Institute
Includes discussion of design considerations for pedestrian walks and paths.

Urban Land Institute
1025 Thomas Jefferson Street, NW
Suite 500 West
Washington, DC 20007
1-800-321-5011
Also available from the American Society of Civil Engineers and the National Association of Home Builders

Principle 6: Shared Driveways

Density by Design (1992) by James W. Wentling and Lloyd Bookout
Over 20 case studies of higher density communities, many achieved through the use of flexible lot designs and reduced setbacks and frontages. Focus on design of lot and marketing.

Urban Land Institute
1025 Thomas Jefferson Street, NW
Suite 500 West
Washington, DC 20007
800-321-5011

Impervious Surface Reduction Study (1995) by Cedar Wells
Presents recommendations for pervious materials and shared parking. Based on results of study to identify strategies for reducing impervious surface in Olympia, Washington.

City of Olympia Public Works Department
PO Box 1967
Olympia, WA 98507
360-753-8454

Shared Parking Planning Guidelines (1995) by Institute of Transportation Engineers
Presents guidelines, research findings, and case studies of cities that actively promote shared parking.

Institute of Transportation Engineers
525 School Street, SW
Suite 410
Washington, DC 20024-2797
202-554-8050

Start at the Source (1992) by Bay Area Stormwater Management Agencies Association
Detailed discussion of permeable pavements and alternative driveway designs presented.

Bay Area Stormwater Management Agencies Association
2101 Webster Street, Suite 500
Oakland CA
510 286-1255

Principle 7: Narrower Streets

A Policy on Geometric Design of Highways and Streets (1994) by American Association of State Highway and Transportation Officials (AASHTO)
Provides guidance on highway design including shared use of transportation corridors and cost-effective highway design that reflects the needs of non-users and the environment.

AASHTO Publications
444 North Capitol Street, NW
Washington, DC 20001
888-227-4860

Performance Streets: A Concept and Model Standards for Residential Streets (1980) by Bucks County Planning Commission.
Presents model standards focusing on pedestrian as well as vehicular traffic and reducing overdesigned street networks.

Bucks County Planning Commission
Route 611 and Almshouse Road
Neshaminy Manor Center
Doylestown, PA 18901
215-345-3400

Report on New Standards for Residential Streets in Portland, Oregon (1994) by Portland Office of Transportation
Summarizes new residential street standards that encourage less costly street improvement with minimal impact on water quality and urban forests.

City of Portland
Office of Transportation
1120 S.W. Fifth Avenue
Room 802
Portland, OR 97204-1971
503-823-7004

Residential Streets (2nd Edition)
Includes discussion of design considerations for pedestrian walks and paths.

Urban Land Institute
1025 Thomas Jefferson Street, NW
Washington, DC 20007
1-800-321-5011
Also available from the American Society of Civil Engineers and the National Association of Home Builders

Subdivision Street Requirements (1996) by Virginia Department of Transportation
Specifies street design requirements for Virginia's subdivisions.

Commonwealth of Virginia
Department of Transportation
1401 East Broad Street
Richmond, VA 23219
804-786-2576

Principle 8: Shorter Streets

Best Development Practices: Doing the Right Thing and Making Money at the Same Time (1996) by Reid Ewing
Presents practices for developers and local governments regarding land use, transportation, the environment, and housing.

American Planning Association
Planners Book Service
122 S. Michigan Avenue, Suite 1600
Chicago, IL 60603
312-786-6344

Subdivision Street Requirements (1996) by Virginia Department of Transportation
Specifies street design requirements for Virginia's subdivisions.

Commonwealth of Virginia
Department of Transportation
1401 East Broad Street
Richmond, VA 23219
804-786-2576

Traditional Neighborhood Development Street Design Guidelines (1997) by Institute of Traffic Engineers.
Presents design guidelines that include street use by non-automobile traffic and the street's relationships to adjacent and future land use.

Institute of Transportation Engineers
525 School Street, SW
Suite 410
Washington, DC 20024-2797
202-554-8050

Principle 9: Narrower Right-of-Way Widths

Residential Streets (2nd Edition)
Includes discussion of design considerations for pedestrian walks and paths.

Urban Land Institute
1025 Thomas Jefferson Street, NW
Washington, DC 20007
800-321-5011
Also available from the American Society of Civil Engineers and the National Association of Home Builders

Site Planning for Urban Stream Protection (1995) by Thomas R. Schueler
Chapter 6 discusses right-of-way criteria and cites various ROW design standards currently in use.

Center for Watershed Protection
8391 Main Street
Ellicott City, MD 21043
410-461-8323

Principle 10: Smaller and Landscaped Cul-de-Sacs

Performance Streets: A Concept and Model Standards for Residential Streets (1980) by Bucks County Planning Commission.
Presents model standards focusing on pedestrian as well as vehicular traffic and reducing overdesigned street networks.

Bucks County Planning Commission
Route 611 and Almshouse Road
Neshaminy Manor Center
Doylestown, PA 18901
215-345-3400

Residential Streets (2nd Edition)
Chapter 2 discusses design considerations and vehicle turning requirements for cul-de-sacs.

Urban Land Institute
1025 Thomas Jefferson Street, NW
Washington, DC 20007
800-321-5011
Also available from the American Society of Civil Engineers and the National Association of Home Builders

Rural by Design (1994) by Randall Arendt
Chapter 11 discusses design alternative cul-de-sac design.

American Planning Association
Planners Book Service
122 S. Michigan Avenue Suite 1600
Chicago, IL 60603

312-786-6344

Principle 11: Vegetated Open Channels

Best Development Practices: Doing the Right Thing and Making Money at the Same Time (1996) by Reid Ewing
Chapter 5 discusses open vegetated channels and other stormwater management options. Developments that use these options are highlighted.

American Planning Association
Planners Book Service
122 S. Michigan Avenue
Suite 1600
Chicago, IL 60603
312-786-6344

Biofiltration Swale Performance: Recommendations and Design Considerations (1992) by Washington Department of Ecology

Washington State Department of Ecology
Olympia, WA 98507

Design of Stormwater Filtering Systems (1996) by Richard A. Claytor and Thomas R. Schueler
Presents detailed engineering guidance on ten different stormwater filtering systems.

Center for Watershed Protection
8391 Main Street
Ellicott City, MD 21043
410-461-8323

Start at the Source (1997) by Bay Area Stormwater Management Agencies Association
Detailed discussion of permeable pavements and alternative driveway designs presented.

Bay Area Stormwater Management Agencies Association
2101 Webster Street Suite 500
Oakland, CA
510-286-1255

Principle 12: Reduced Parking Ratios

Impervious Surface Reduction Study: Final Report (1995) by Cedar Wells
Presents recommendations for pervious materials and shared parking. Based on results of study to identify strategies for reducing impervious surface in Olympia, Washington.

City of Olympia Public Works Department
P.O. Box 1967
Olympia, WA 98507
360-753-8454

Flexible Parking Requirements (1984) by Thomas P. Smith
Discusses local parking policies, flexible parking requirements, and case studies of parking demand for four land uses.

American Planning Association
Planning Advisory Service
122 S. Michigan Avenue Suite 1600
Chicago, IL 60603
312-786-6344
Report No. 377

Parking Generation (1987) by Institute of Transportation Engineers
Provides parking data for 64 land uses and discusses three methods for determining average parking occupancy of a land use or building.

Institute of Transportation Engineers
525 School Street, SW
Suite 410
Washington, DC 20024-2797
202-554-8050

Site Planning for Urban Stream Protection (1995) by Thomas R. Schueler
Chapter 7 discusses downsizing parking areas, impervious cover associated with various parking ratios, and local experience with parking codes.

Center for Watershed Protection
8391 Main Street
Ellicott City, MD 21043
410-461-8323

Principle 13: Mass Transit and Shared Parking

Impervious Surface Reduction Study: Final Report (1995) by Cedar Wells

City of Olympia Public Works Department
P.O. Box 1967

Presents recommendations for pervious materials and shared parking. Based on results of study to identify strategies for reducing impervious surface in Olympia, Washington.

Olympia, WA 98507
360-753-8454

Parking Supply Management (1997) by Federal Transit Administration
Discusses mass transit use and its relationship to reduction in required parking through case studies of several communities.

Shared Parking Planning Guidelines (1995) by Institute of Transportation Engineers
Discusses shared parking issues and guidelines, including detailed case studies and results of local government survey.

Institute of Transportation Engineers
525 School Street, S.W., Suite 410
Washington, DC 20024-2797
202-554-8050

Principle 14: Less Parking Lot Imperviousness

Start at the Source (1997) by Bay Area Stormwater Management Agencies Association
Detailed discussion of permeable pavements and alternative driveway designs presented.

Bay Area Stormwater Management Agencies Association
2101 Webster Street Suite 500
Oakland, CA
510-286-1255

The University of Washington Permeable Pavement Demonstration Project (1997) by Derek B. Booth, Jennifer Leavitt, Kim Peterson
Reviews and provides information on types and characteristics of permeable pavements.

Center for Urban Water Resources Management
University of Washington
Civil and Environmental Engineering
Box 352700
Seattle, WA 98195-2700
Web address:

Parking Supply Management (1997) by Federal Transit Administration
Discusses mass transit use and its relationship to reduction in required parking through case studies of several communities.

Principle 15: Structured Parking

Guidelines for Parking Facility Location and Design (1994) by Institute of Transportation Engineers.
Detailed discussion of surface, structured, and handicapped parking design, including discussion of driveways.

Institute of Transportation Engineers
525 School Street, SW Suite 410
Washington, DC 20024-2797
202-554-8050

Impervious Surface Reduction Study: Final Report (1995) by Cedar Wells
Presents recommendations for pervious materials and shared parking. Based on results of study to identify strategies for reducing impervious surface in Olympia, Washington.

City of Olympia Public Works Department
P.O. Box 1967
Olympia, WA 98507
360-753-8454

Shared Parking Planning Guidelines (1995) by Institute of Transportation Engineers
Discusses shared parking issues and guidelines, including detailed case studies and results of local government survey.

Institute of Transportation Engineers
525 School Street, S.W., Suite 410
Washington, DC 20024-2797
202-554-8050

Principle 16: Treated Parking Lot Runoff

Low Impact Development Design Manual (1997) by Prince George's County Department of Environmental Resources Division of Watershed Management and Maryland Department of Natural Resources Chesapeake and Coastal Watershed Services Watershed Restoration Division.
Provides guidance on hydrologic analysis, site planning, BMPs, permit processing, and public outreach programs.

Low Impact Development Center
3230 Bethany Lane, Suite 9
Ellicott City, MD 21042
410-418-8476

Design Manual for Use of Bioretention in Stormwater Management (1993)
Presents guidance for designing bioretention facilities.

Low Impact Development Center
3230 Bethany Lane, Suite 9
Ellicott City, MD 21042
410-418-8476

Design of Stormwater Filtering Systems (1996) by Richard A. Claytor and Thomas R. Schueler
Presents detailed engineering guidance on ten different stormwater filtering systems.

Center for Watershed Protection
8391 Main Street
Ellicott City, MD 21043
410-461-8323

Start at the Source (1997) by Bay Area Stormwater Management Agencies Association
Detailed discussion of permeable pavements and alternative driveway designs presented.

Bay Area Stormwater Management Agencies Association
2101 Webster Street Suite 500
Oakland, CA
510-286-1255

APPENDIX B. SIMPLIFIED URBAN NUTRIENT OUTPUT MODEL (SUNOM)

The Simplified Urban Nutrient Output Model (SUNOM) is a simple spreadsheet model that calculates the annual water balance, annual nitrogen and phosphorous export, and infrastructure costs for individual development sites. The model input includes basic site planning variables that can be directly obtained or measured from a typical development submittal to a land use authority, including total drainage area, length of sidewalks, total impervious cover, linear feet of roads, lawn cover, utilities (length and type), forest cover, size, type, and length of stormwater conveyance, riparian forest cover, size and type of stormwater practices, soil type(s), and method of wastewater treatment. Default data are provided for many parameters and many of these assumptions can be changed based on site specific information.

The product of SUNOM is a detailed estimate of the annual hydrologic budget, annual nutrient export and cost of development associated with each development site. Output of the model includes:

- Annual runoff
- Annual infiltration
- Annual phosphorus export
- Annual nitrogen export
- Estimated infrastructure costs

SUNOM provides watershed practitioners with the simple tool necessary to compare the costs and benefits of better site design. The model is not meant to be used as a method for determining actual stormwater runoff and nutrient loading from a development site, to obtain accurate numbers for this a more detailed model should be used or on-site monitoring should be conducted. The following write-up describes the hydrology, nutrient loading, and cost components of the model.

Hydrology

The basis for the nutrient output model is governed by the principles of a simplified water balance. Precipitation takes several different paths once it reaches the ground surface. A percentage runs off directly to receiving waters (known as surface runoff), some is infiltrated into the subsurface soils, and part is either recycled as evapotranspiration, supplies shallow ground water, a deeper aquifer, or is transported as interflow (below the surface, but above groundwater) to the receiving waters. Surface depression storage and tree canopy interception are neglected as they make up only a small percentage of the annual water balance.

At most development sites, additional factors will influence the water balance - namely, potable water consumption. Therefore, septic system impacts are incorporated into the model since they may play a significant role in the water balance, as well as be a significant contributor of nutrients, for a development site.

The following simple equation is used as the foundation for SUNOM:

$$P + I_s = R + E + I_{sw} + I_{BMP} \quad [1]$$

where:

P = annual rainfall (inches)
I_s = annual septic infiltration (inches)
R = annual surface runoff (inches)
E = annual evapotranspiration (inches)
I_{sw} = annual stormwater infiltration (including interflow) in inches
I_{BMP} = annual infiltration through stormwater BMPs

The annual runoff and infiltration are calculated by the model, and evapotranspiration is used to check the water balance, using available local data, or by comparing the data calculated to the results of more complex models. The land on a site is divided into three different categories to compute both runoff and infiltration, including:

- Impervious areas (A_i)
  A_i = rooftops, paving, sidewalks (square feet)

- Pervious areas
  A_{p1} = pervious cover for natural areas (forest, meadow, shrub, wetlands)(square feet)
  A_{p2} = pervious cover for managed areas (septic fields, landscaping, and turf) (square feet)

Runoff

Runoff is calculated using the Simple Method (Schueler, 1987). Runoff is calculated as:

$$R = 0.9 \bullet P \bullet (0.05+0.9Ia) \quad [2]$$

where:

R = Annual runoff (inches)
P = Annual Rainfall (inches)
Ia = Impervious Area Fraction
0.9 = Fraction of annual rainfall that does not produce runoff.

In the SUNOM model, runoff from managed and impervious areas is calculated separately from runoff from natural areas, primarily for the purpose of calculating nutrient loads as described in the next section.

$$R = R_n + R_m \quad [3]$$

where:

R_n = runoff from natural areas (inches)
R_m = runoff from managed and impervious areas (inches)

The values of R_n and R_m are determined by the following equations, which apply the Simple Method to the natural and managed areas separately, and normalize these quantities to runoff inches over the entire site.

[4]

[5]

where:

I_{p1}, I_{p2} = Impervious fraction associated with managed and natural areas.
A = Total Site Area (Acres)

The values of I_{p1} and I_{p2} are both 1% in the model (NVPDC, 1980), but can be changed to reflect local data or more detailed model results if available.

Infiltration

Total infiltration is the sum of stormwater infiltration (including interflow) plus septic infiltration.

Stormwater Infiltration
Stormwater infiltration is based on the amount of rainfall that is infiltrated into either the underlying soils, water table, or entering receiving waters as interflow and is related to the soil type.

Annual infiltration rates for various soil types are shown in Table B-1. These data represent a "base" infiltration rate, assuming good soil condition. Data are adjusted to reflect the condition of the land, by assigning a factor to each land use cover, as follows:

- For impervious cover, no infiltration occurs.
- For natural pervious cover, 100% of the value in Table B-1 infiltrates.
- For managed pervious cover, only 80% of the value in Table B-1 infiltrates due to soil compaction.

Table B-1. Annual Infiltration Rates

NRCS hydrologic soil group (HSG)	Annual base infiltration rate - I_B (inches)
A	18
B	12
C	6
D	3

Source: Horsley, 1996

As was the case for stormwater runoff, stormwater infiltration is calculated separately for managed and natural areas. They are determined as follows:

[6]

[7]

where:

I_{sw-n} = Stormwater infiltration from natural areas (inches)
I_{sw-m} = Stormwater infiltration from managed areas (inches)
I_{B-i} = Base infiltration rate for soil type I (Soil type from A to D) in inches
A_{p1-Ii} = Natural pervious area as soil type I.

Septic Infiltration
It is assumed that all water used is infiltrated into the ground through the septic system. The total infiltration, in site-inches, is determined by:

[8]

where:

N = Number of individuals on the septic system
W = Water Use (Gallons/person-day). This value is currently 46.5 gallons/day (US EPA, 1980)
586 = Conversion factor from gallons/ft^2-day to inches/year

Infiltration BMPs
Infiltration BMPs, as well as some vegetative BMPs, can increase the annual infiltration volume. The effectiveness of these BMPs is determined by the following equation:

$$I_{BMP} = R \bullet f_s \bullet f_p \bullet f_b \qquad [9]$$

where:

I_{BMP} = Stormwater runoff infiltrated by the BMP
R = Annual stormwater runoff (See Equations 3 through 5)
f_s = fraction of the site's impervious area draining to the BMP
f_p = fraction of the annual runoff volume treated through the volume provided
f_b = fraction of the treated volume infiltrated

In the final analysis, this value is added to total stormwater infiltration and subtracted from total stormwater runoff.

Nutrient Load

The total annual nutrient load is the sum of the surface stormwater load, the stormwater infiltration load, and the total septic load, minus the nutrient load reduced through the use of stormwater BMP practices. It is computed based on the following equation:

$$L = L_{isw} + L_{ssw} + L_s - L_{BMP} \qquad [10]$$

Where:

L = Total annual load (in pounds)
L_{ssw} = Total surface stormwater load (pounds)
L_{isw} = Total stormwater infiltration load (pounds)
L_s = Total septic load (pounds)
L_{BMP} = Nutrient load reduced through the use of stormwater BMPs (pounds)

Surface Stormwater Load

The surface runoff values obtained in the hydrologic portion of the model are used, along with assumed nutrient concentration values for natural and managed areas, to calculate the surface stormwater load. In the SUNOM model, stormwater from natural and managed areas are assigned a separate concentration so that:

$$L_{ssw} = (R_n \bullet c_{nsw} + R_m \bullet c_{msw}) \bullet A \bullet 5.20X10^{-6} \qquad [11]$$

where:

R_n, R_m = Annual runoff from natural and managed areas, respectively (inches) [See equations 4 and 5]
c_{nsw}, c_{msw} = nutrient concentration in surface runoff from natural and managed areas, respectively (mg/l) [See Table B-2]
A = Total Site Area (ft^2)
$5.20X10^{-6}$ = conversion factor from (inch/year)(ft^2)(mg/l) to lbs/year

Table B-2. Surface Runoff Concentrations		
Constituent	Natural Area Concentration (mg/l)[1]	Managed Area Concentration (mg/l)[2]
Nitrogen	0.8	2.0
Phosphorous	0.15	0.25
1. Source: NVPDC, 1978 2. Source: US EPA, 1983		

BMP Load Reduction

The surface nutrient load can be reduced with the use of stormwater BMPs. This reduction is determined by:

$$L_{BMP} = E \bullet L_{ssw} \bullet f_s \bullet f_p \qquad [12]$$

where:
- E = BMP Efficiency (fraction) [See Table B-3 for typical BMP efficiencies]
- L_{ssw} = Surface Stormwater load (lbs/year) [See Equation 11]
- f_s = fraction of the site treated by the BMP (based on sizing)
- f_p = fraction of the annual runoff volume captured by this BMP

Table B-3. Stormwater BMP Efficiencies Used in SUNOM

BMP	Total Nitrogen Removal (%)	Total Phosphorous Removal (%)
Dry Pond	31	19
Wet Pond	31	48
Wetland	21	51
Sand Filter/ Bioretention	44	51
Swale	49	29
Infiltration[1]	65	70
Oil/ Grit Separator[2]	0	0
Source: Schueler, 1997; except for 1: Schueler, 1987 and 2: Schueler, 1997a		

Stormwater Infiltration Load

Infiltrated stormwater transports nutrients to water bodies, although in smaller concentrations than surface runoff. The load from infiltration is also calculated separately for managed pervious surfaces versus natural areas:

$$L_{isw} = I_{swn} \bullet c_{in} + I_{swm} \bullet c_{im} \qquad [13]$$

where:
- L_{isw} = Total infiltration load (lbs/year)
- I_{swn}, I_{swm} = Infiltration from natural and managed areas, respectively (inches/year) [See equations 6 and 7]
- c_{in}, c_{im} = nutrient concentration in infiltrated stormwater from natural and managed areas, respectively (mg/l) [See Table B-4]

Table B-4. Infiltrated Stormwater Concentrations		
Constituent	Natural Area Concentration (mg/l)[1]	Managed Area Concentration (mg/l)[2]
Nitrogen	0.2	0.8[2]
Phosphorous	0.006	0.03[3]
1. Source: Omernik, 1977 2. Source: Modified from Petrovik, 1990 3. Source: Modified from Pitt *et al.*, 1994		

Septic Load

The load from septic systems is calculated using typical per person septic loads along with septic efficiencies. The total load is expressed as:

$$L_s = N \bullet L_{sn} \bullet (1-E_s)$$

where:

L_s = Site septic load (lbs./year)
L_{sn} = Per capita septic load (lbs./person/year), as follows:
Nitrogen Load: 8.4 lbs/person/year (US EPA,1980)
Phosphorous Load: 2.8 lbs/person/year (US EPA,1980)
N = Number of individuals on septic
E_s = Septic efficiency [See Table B-5]

Table B-5. Typical Septic System Efficiencies		
System Type	Total Nitrogen Removal (%)	Total Phosphorus Removal (%)
Conventional	28	57
Mound	44	??
Anaerobic Upflow Filter	59	??
Intermittent Sand Filter	55	80
Recirculating Sand Filter	64	80
Water Separation System	83	30
Constructed Wetlands	90	??
Source: US EPA, 1993		

Costs

The model also calculates the cost of development utilizing previously published unit costs and predictive equations for infrastructure, stormwater management, landscaping, and septic systems. The cost component of the model is computed as:

TC = IC + SWC + LC+SC

where:
TC = Total Cost ($)
IC = Infrastructure Cost ($)
SWC = Stormwater Management Cost ($)
LC = Landscaping Cost ($)
SC = Septic Cost ($)

Infrastructure

Infrastructure costs include the costs of paving, curb and gutter, sidewalk, and site construction. Typical infrastructure costs are included in Table B-6.

Table B-6. Infrastructure Costs Used in SUNOM

Infrastructure Element	Unit Cost
Paving (Asphalt)	$1.80/sf
Paving (Grid Pavers)	$2.50/sf
Curb and Gutter	$12.50/foot
Sidewalk	$2.45/sf
Water Pipe-6"	$30/lf
Water Pipe - 8"	$35/lf
Water Pipe - 10"	$40/lf
Sanitary Sewer	$40/lf
Storm Drain - 15"	$28/lf
Storm Drain - 18"	$35/lf
Storm Drain - 21"	$38/lf
Storm Drain - 24"	$45/lf
Storm Drain - 27"	$50/lf
Storm Drain - 30"	$55/lf

Stormwater Management

Stormwater management costs include the costs of stormwater BMPs used to improve water quality at a site. Often, these values can be calculated as a function of the BMP volume. Equations used in this model are included in Table B-7.

Table B-7. Stormwater Costs

BMP	Cost Equation ($)	Source, Notes
Ponds	$20.8V^{0.7}$	■ Brown and Schueler, 1997
Wetlands	$31.2V^{0.7}$	■ Brown and Schueler, 1997
Sand Filters	4.5V	■ Modified from Brown and Schueler, 1997 ■ Varies widely based on design choice
Bioretention	6.4V	■ Brown and Schueler, 1997
Designed Swales	4.25V	■ Brown and Schueler, 1997 ■ Assumes 80% of the cost of bioretention
Grassed Channels	0.50V	■ Modified from SWRPC, 1991
Infiltration Trench	4.4V+3250	■ Modified from SWRPC, 1991
Infiltration Basin	1.5V	■ Modified from SWRPC, 1991
Filter Strip	0 to 1.5V	■ Modified from SWRPC, 1991 ■ Varies based on method of establishment
Oil/Grit Separator	$15,000 per BMP	

Landscaping and Reforestation

Typical landscaping and reforestation unit costs based on area used in the model are displayed in Table B-8.

Table B-8. Landscaping and Reforestation Costs

Item	Unit Cost
Landscaping	$0.03/sf
Reforestation	$0.02/sf

Septic

Septic system costs vary depending on the type of system used. Interestingly, the most expensive options are not always the most efficient at removing nitrogen and phosphorous (compare data in Table B-9 with data in Table B-5).

Table B-9. Typical Septic System Construction

Costs	
System Type	**Typical Cost ($/house)**
Conventional	4,500
Mound	8,300
Anaerobic Upflow Filter	5,550
Intermittent Sand Filter	5,400
Recirculating Sand Filter	3,900
Water Separation System	8,000
Constructed Wetlands	710
Source: US EPA, 1993	

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APPENDIX C. A DISCUSSION OF THE VIRGINIA DEPARTMENT OF TRANSPORTATION'S STANDARDS, REQUIREMENTS, AND POLICIES

This appendix provides a list of the Virginia Department of Transportation's (VDOT) standards, requirements, and policies as they relate to the model development principles. Applicable principles are listed, along with information about how the VDOT standards, requirements, or policies influence application of that principle.

Principle 1. Native Plant and Tree Conservation

According to Virginia's Subdivision Street Requirements (SSR) (1996), vegetation should be "compatible with the surrounding area." Subdivision Street Requirements (1996) refers to a document entitled Guidelines for Planting Along Virginia's Roadways (1986) developed by the VDOT Environmental Division. This document provides a list of siting considerations for placement of plants and trees. Organized according to design speed, the document provides a list of trees deemed appropriate for planting. While the plant list does not specify native species, there are some native plants within the list. This document is due to be revised.

Principle 5. Common Walkways

Sidewalks are not required by VDOT. However, they may be eligible for maintenance by VDOT if the following criteria are met:

- within one mile from existing elementary schools
- one and a half miles from intermediate and high schools
- adjacent to or in the immediate vicinity of multiple community businesses or public facilities
- if on a cul-de-sac or loop, must be four or more dwelling units per acre
- minimum width of four feet
- approval through a special exception review
- specifies cement, concrete, or asphalt on open channels

VDOT will not accept responsibility for meandering sidewalks relative to roadway.

Principle 7. Narrower Streets

VDOT's street width requirements are dictated by average daily traffic (ADT), street length, parking requirements, and terrain. These are summarized for open section roads (shoulder and ditch design) and closed section roads (curb and gutter design) in Table C-1.

Table C-1. Minimum Local Street Width Requirements for Open and Closed Section Roads in Both Residential and Non-Residential Areas					
		Closed Section Roads			
		Residential		Non-Residential	
Average Daily Trips	**Open Section Roads**	less than .5 mile	.5 mile or more	Parking restricted	Parking allowed
Up to 250	18'	28'	30'	24'	30'
251 - 400	20'	28'	30'	24'	30'
401 - 1000	22' (20')*	36'	36'	N/A	38'
1001- 2000	22' (20')*	36'	36'	N/A	38'
2001- 4000	22'	38'	38'	N/A	40'
Over 4000	24'	40'	40'	N/A	40'

* Figures in ( ) refer to mountainous regions.
Source: SSR, 1996

Reduction in the residential curb and gutter roadway widths shown above may be approved. The reduction must be requested in writing by the governing body, and include a commitment to provide adequate off-street parking. At a minimum, three spaces per dwelling unit, exclusive of garage spaces, must be provided in the proximity of the dwelling unit they will serve. Under these conditions, optional street widths are as follows:

- for any residential street less than 0.5 miles long with a projected traffic of 250 ADT or less, a curb to curb width of 22 feet on a right-of-way not less than 30 feet may be approved
- for any residential street less than 0.5 miles long with a projected traffic of 251 - 400 ADT, a curb to curb width of 24 feet on a right-of-way not less than 30 feet may be approved
- for any residential street with a projected traffic of 401 - 4000 ADT, a curb to curb width of 30 feet on a right-of-way not less than 40 feet may be approved

Some additional facts about VDOT street requirements:

- Rules for parking only apply "in absence of local regulations that are deemed acceptable by the department" (Source: SSR, 1996).
- Street designs that restrict on-street parking must receive approval by the county official and resident engineer.

Principle 9. Narrower Right-of-Way (ROW) Widths

According to SSR (1996), ROWs include land required to accommodate the roadway surface plus utilities, sidewalks, and vegetated channels.

Table C-2. Minimum Local ROW Requirements for Open and Closed Section Roads in Both Residential and Non-Residential Areas							
	Open Section Roads			Closed Section Roads			
		Shoulder		Residential		Non-Residential	
Average Daily Trips	ROW	Fill w/Grade	Cut or Fill w/o Grade	less than .5 mile	.5 mile or more	Parking restricted	Parking allowed
Up to 250	40'	7'	4'	40'	40'	40'	40'
251 - 400	50'	7'	4'	40'	40'	40'	40'
401 - 1000	50'	7'	4'	44'	44'	N/A	46'
1001- 2000	50'	9'	6'	44'	44'	N/A	46'
2001- 4000	50'	9'	6'	46'	46'	N/A	48'
Over 4000	50'	9'	6'	46'	48'	N/A	48'
Source: SSR, 1996							

Principle 10. Smaller and Landscaped Cul-de-sacs

Various types of cul-de-sacs are approved and VDOT's regulations refer to the American Association of State Highway Transportation Officials (AASHTO) document "A Policy on Geometric Design of Highways and Streets." This book includes requirements for three-point turning areas, hammerheads, paved cul-de-sacs, cul-de-sacs with islands, and other slight variations of these basic designs. AASHTO's requirements suggest a 10 meter (32.8 feet) radius for paved cul-de-sacs.

VDOT's requirements for cul-de-sacs are:

- Minimum pavement radius = 30' to serve 25 or fewer dwelling units
- Minimum pavement radius = 45' to serve more than 25 dwelling units

Principle 11. Vegetated Open Channels

Stormwater management is not required on any subdivision streets but is recognized as a design option (SSR, 1996).

All drainage facilities must adhere to the *VDOT Drainage Manual* (1980).

The SSR encourages all drainage outfalls be directed to a natural watercourse as opposed to a swale. A swale is defined as "a broad depression within which stormwater may drain during inclement weather, but does not have a defined bed or banks." A watercourse is defined as "a definite channel with bed and banks within which water flows, either continuously or in season."

Principle 12. Reduced Parking Ratios

According to VDOT regulations, rules for parking only apply "in absence of local regulations that are deemed acceptable by the department." (Source: SSR, 1996) The VDOT regulations require the following:

- Minimum of two off-street parking spaces per dwelling unit for single family residential units
- Street designs for subdivision streets that restrict on-street parking must receive approval by the county official and resident engineer

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