NONSTRUCTURAL URBAN BMP HANDBOOK

A GUIDE TO NONPOINT SOURCE POLLUTION PREVENTION AND CONTROL THROUGH NONSTRUCTURAL MEASURES

Prepared by the
Northern Virginia Planning District Commission

Prepared for the
Department of Conservation and Recreation/
Division of Soil and Water Conservation

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ABSTRACT

TITLE: Nonstructural Urban BMP Handbook – A Guide to Nonpoint Source Pollution Prevention and Control through Nonstructural Measures

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SUBJECT: Information, recommendations, and programmatic design aids for the implementation of urban nonstructural Best Management Practices to improve surface water quality by preventing pollutants from entering local water courses.

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SUMMARY: The purpose of the Nonstructural Urban BMP Handbook is to provide watershed managers, planners, and the consulting engineering community with practical guidance on how to effectively implement nonstructural BMPs as a means of reducing or controlling the introduction of nonpoint source pollution into the environment.

The benefits of nonstructural BMPs to local and regional water resources are widely acknowledged. However, it has often been the case that nonstructural techniques are overlooked because it is difficult to assign a level of pollutant removed or prevented as a result of their implementation. Therefore, in addition to providing design and implementation guidance, it is also the aim of this Handbook to enable the planner to reasonably estimate the amount of pollution prevented or controlled as a result of implementing nonstructural BMP techniques, and to evaluate their potential to complement structural BMP programs in the context of an integrated watershed management plan.

Nonstructural techniques investigated in this Handbook include pollution prevention measures and control measures. Pollution prevention measures addressed are (1) land use management and improvement techniques (land use controls, watershed protection during site design, urban reforestation and riparian buffer restoration, and landscaping strategies) and (2) public education and volunteer measures (public education, storm drain stenciling, animal waste controls, lawn and garden care education, and reducing the generation of automotive pollutants).

The Handbook operates under the premise that no water quality program should be implemented in a vacuum and that an understanding of the sources and pathways of nonpoint source pollution is essential to the comprehensive, effective, and efficient control and prevention of nonpoint source pollution. Preparing an integrated watershed management plan requires that the planner screen the universe of pollution sources and mitigation techniques and target a combination of nonstructural and structural techniques where they will be most effective. To aid in this integrated approach, the Handbook is divided into five chapters, including: (1) Introduction; (2) Tackling the Nonpoint Source Pollution Problem; (3) Choosing Appropriate Nonstructural Approaches; (4) Pollution Prevention Measures; and (5) Control Measures.

UPDATES: The Handbook is designed to be a living document and updates will be periodically provided as the understanding of nonstructural BMP technology continues to evolve. Contact NVPDC at the above address to inquire about periodic updates or to relay information for potential publication.

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1. INTRODUCTION

The purpose of this Handbook is to provide watershed managers, planners, and the consulting engineering community with practical guidance on how to effectively implement nonstructural BMPs as a means of reducing or controlling the introduction of nonpoint source pollution into the environment.

The benefits of nonstructural BMPs to our water resources are widely acknowledged. However, it has often been the case that nonstructural techniques are overlooked because it is difficult to assign a level of pollution removed or prevented as a result of their implementation. This is particularly the case with the Chesapeake Bay Preservation Act, which requires that the developer demonstrate a no-net-increase in nutrient loadings from new development (from an average jurisdictional baseline) and a 10 percent reduction in nutrient loadings from existing site conditions for redevelopment.

Therefore, in addition to providing design and implementation guidance, it is also the aim of this Handbook to enable the planner to reasonably estimate the amount of pollution prevented or controlled as a result of implementing nonstructural BMP techniques, and to evaluate their potential to complement structural BMP programs.

Chapter 1 is organized in the following manner.

- **Nonpoint Source Pollution and Best Management Practices**
- **Institutional Responsibilities**
- **The Need for Additional Guidance on the Design of Nonstructural BMPs**
- **A Survey of Nonstructural Urban BMP Techniques**
- **Organization of this Handbook**

SECTION 1.1 ....

Nonpoint Source Pollution and Best Management Practices

The linkage between nonpoint sources of pollution and poor surface water quality has received increasing attention over the past decade. The term **nonpoint source (NPS) pollution** is used to describe pollution whose specific point of generation cannot be readily defined. Nonpoint source pollution is distinguished from point source pollution, or pollution which can be traced to a specific outfall such as effluent flowing from a single pipe.

Before the mid-1980s, State and federal water quality management efforts emphasized the control of point source pollution under the 1972 Clean Water Act. Increasing concern for and a greater understanding of the impacts of NPS pollution, however, resulted in the enactment of the Water Quality Act (WQA) of 1987 which significantly increased federal involvement in NPS pollution control. Section 319 of the WQA requires states to prepare NPS pollution problem assessment reports and four-year NPS pollution management programs.

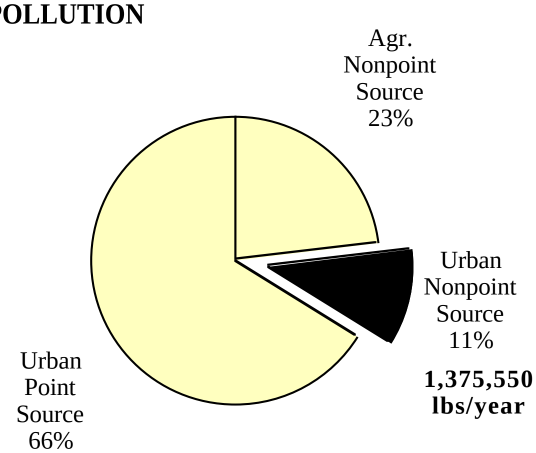
NPS pollution is now recognized as a significant contributor to local and regional water quality problems. For example, the Commonwealth of Virginia estimated that in 1985, 34% of controllable nitrogen pollution and 84% of controllable phosphorus pollution in the Northern Virginia region of the Potomac River basin originated from agricultural and urban *nonpoint sources*. Nitrogen and phosphorus are only two of the most important NPS pollutants of concern.

This Handbook deals explicitly with the urban portion of nonpoint source pollution (see Figure 1.1).

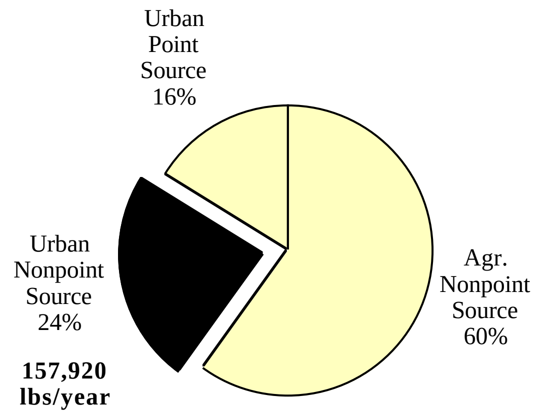
In addition to nutrients, other urban NPS pollutants of concern are sediments, heavy metals, synthetic organic compounds (SOCs), petroleum hydrocarbons, and pathogens (bacteria). These pollutants are introduced

FIGURE 1.1
The Relative Contribution of Urban NPS Nutrient Pollution in Northern Virginia

CONTROLLABLE NITROGEN POLLUTION



CONTROLLABLE PHOSPHORUS POLLUTION



Source: Virginia Department of Conservation and Recreation, *Summary of Nonpoint and Point Source Calculations – Northern Virginia*. 1996.

into the water primarily through stormwater runoff, atmospheric deposition, streambank erosion, and direct introduction.

Best Management Practices, or BMPs, are structural or nonstructural practices, or a combination of practices, designed to act as effective, practicable means of minimizing the impacts of development and human activities on water quality. Traditional structural BMPs, including extended detention dry ponds, wet ponds, infiltration trenches, and sand filtration systems, are now common elements of most new development projects. Structural BMPs rely heavily on gravitational settling and/or the infiltration of soluble nutrients through a porous medium for pollutant removal.

Nonstructural BMPs, which may be used independently or in conjunction with structural BMPs, rely on a much wider breadth of mechanisms to prevent or control NPS pollution. Nonstructural BMPs range from programs that increase public awareness to prevent pollution, to the implementation of control-oriented techniques (such as bioretention and stormwater wetlands) that utilize vegetation to enhance pollutant removal and restore the infiltrative capacity of the landscape.

SECTION 1.2 ....
Institutional Responsibilities

In Virginia, the Department of Conservation and Recreation (DCR), Division of Soil and Water Conservation (DSWC), has primary responsibility for implementing the State-wide NPS pollution management program (regulated under various federal programs) and for coordinating with other agencies and individuals dealing in NPS pollution control.

The Department of Environmental Quality, Water Division (DEQ-WD), retains responsibility for point source water pollution management and establishing water quality standards for surface and ground water and for monitoring water quality. The DSWC works closely with the DEQ-WD to ensure that nonpoint source control programs are consistent with the State's water quality standards.

The Chesapeake Bay Local Assistance Department (CBLAD) is responsible for the implementation and coordination of the Chesapeake Bay Preservation Area Designation and Management Regulations.

SECTION 1.3 ....
The Need for Additional Guidance on the Design of Nonstructural Techniques

As federal, State, and local regulation of NPS pollution has increased, design parameters and pollutant removal efficiencies for "conventional" methods of stormwater quality control have been examined more closely than non-conventional, and especially nonstructural, approaches. Reliance on conventional BMPs stems from the fact that such approaches facilitate the engineering calculations necessary to demonstrate compliance with numerical stormwater quality standards or criteria such as the "water quality volume" (first 0.5 inch of runoff) requirement under the Virginia Stormwater Regulations, or the "no-net-increase" criteria under the Chesapeake Bay Preservation Act.

Reliance on engineering calculations has resulted in a regulatory environment which provides little incentive to investigate nonstructural NPS pollution control approaches that have a wider range of variability in design and efficiency. Many of these nonstructural measures are widely recognized by scientists and watershed managers to have clear utility in an integrated NPS management program. However, the lack of credible data, site screening for applicability, and specific design parameters, may result in these measures being neglected, both in research and in jurisdictional NPS program development, under federal, State, and local stormwater management initiatives.

The *Nonstructural Urban BMP Handbook* outlines a range of nonstructural NPS pollution control approaches and provides watershed managers with a variety of tools to implement a successful integrated NPS pollution control program.

Nonstructural Techniques and the Need to Retrofit Existing Development

One of the most engaging reasons for recent interest in nonstructural BMP design is the growing pressure to "retrofit" existing urban areas with measures to reduce NPS pollution. Urban retrofit can meet requirements to reduce the impacts of existing development on water quality by assimilating BMPs into the developed landscape. Due to the fact that retrofit requires squeezing BMPs into existing and often diverse urban development, retrofit often must assume a wider range of forms than conventional water quality BMPs installed during new development.

While most regulatory efforts to-date have been aimed at holding the line against NPS pollution, more recent programs, such as the Virginia Tributary Strategies, seek to *reduce* the levels of pollution entering local and regional water courses. The expressed need for NPS pollution reduction in urban areas, and the non-regulatory nature of Tributary Strategies, provides an impetus for the establishment of experimental and unconventional BMPs, and especially nonstructural BMPs.

Pollution prevention also includes practices that restore the infiltrative capacity of the landscape and subsequently its ability to absorb and break-down pollution. Figure 1.3 demonstrates the differences between a purely structural approach to stormwater quality and a combination nonstructural/structural BMP approach.

FIGURE 1.2
Typical Structural BMP – Wet Pond

Structural BMPs, while efficient, are particularly difficult to integrate into the existing urban environment.

SECTION 1.4

A Survey of Nonstructural Urban BMP Techniques

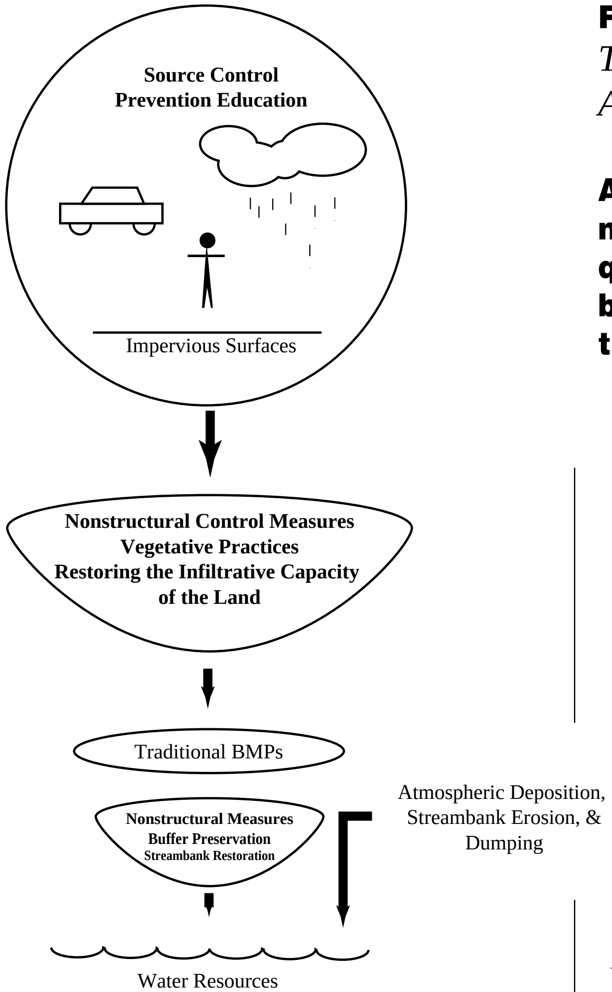
In general, nonstructural BMPs mitigate the impacts of urbanization on surface waters in either one of two ways – post-contamination removal of pollutants or pre-contamination prevention. The former is commonly referred to as a "control measure" and operates much like a structural technique by cleaning already polluted stormwater. The latter term is commonly referred to as "pollution prevention" or "source reduction."

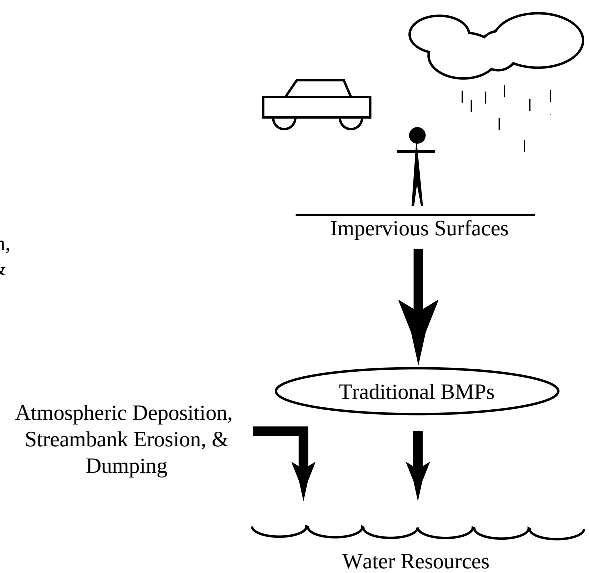
While source reduction of pollutants is considered to be the more environmentally sound and economically efficient means of protecting surface water quality, control measures are more generally quantifiable and thus more conducive to demonstrating pollutant removal.

The following is a survey of the range of nonstructural BMPs found in this Handbook and a brief de-

FIGURE 1.3
Traditional versus Nonstructural Approaches to NPS Pollution

A watershed-wide, targeted, nonstructural approach to water quality protects water resources better than relying solely on control triggered by new development.





A combination of pollution prevention and vegetative and nonvegetative control practices reduces reliance on traditional stormwater quality BMPs by preventing pollution in the first place and increasing the infiltrative capacity of the landscape.

Traditional BMPs rely primarily on settling of solids from stormwater and infiltration through the soil horizon for pollution removal. Because many pollutants have a sizeable soluble component, a large proportion of urban pollutants go uncontrolled.

scription of each BMP's principles of mitigating surface water quality impacts.

▶ Pollution Prevention Measures

Pollution prevention, or source reduction, is any technique that: (1) prevents runoff from occurring and/or prevents the generation of pollution before it enters a storm drain system, and/or (2) preserves the natural infiltrative capacity of the landscape, through the protection of natural resources by conservation, thus reducing the generation of pollutants and allowing any pollutants generated as a result of land uses to be assimilated without reaching the water environment.

Based on this dichotomy, pollution prevention techniques discussed in this Handbook fall under either one of two headings – land use management and improvement or public education and volunteer measures. The following is a brief description of the pollution prevention measures covered in this Handbook.

Land Use Management and Improvement

- **Land Use Controls** – Land use controls as a BMP covers a wide variety of techniques which encourage patterns of development that produce less, or more readily controlled, NPS pollution. Land use controls included in this Handbook include purchase of development rights (PDRs), transfer of development rights (TDRs), redevelopment/infill development, and down zoning/up zoning.

- **Watershed Protection During Site Design** – The primary goal of these techniques is to minimize the impacts of new development by planning to reduce impervious surfaces and maximize vegetated areas through innovative site design. Maximizing the infiltrative capacity of the landscape serves to minimize stormwater runoff and consequently the amount of NPS pollution that is washed to local streams.

  Practices include conservation (cluster) development, alternative street and parking area design, and the use of alternatives to impervious surfaces.

- **Urban Reforestation and Riparian Buffer Restoration** – The goal of urban reforestation and riparian buffer restoration as a BMP is to increase the infiltrative capacity of the urban landscape, protect stream reaches from runoff from adjacent land uses, and reduce or eliminate sediment- and nutrient-generating streambank erosion.

- **Landscaping Strategies** – The goal of this technique is similar to watershed protection during site design but targets home and business landscaping practices. Applying water-wise landscaping strategies serves to preserve the landscape's natural infiltrative capacity, conserve water, and keep stormwater onsite.

Public Education and Volunteer Measures

- **Public Education** – Public education is a general programmatic term which can be applied to almost any pollution problem which requires a specific change in human behavior.

- **Storm Drain Stenciling** – In most urban areas, storm drains are the primary conduit connecting human activities with local water courses. Unfortunately, storm drains are often a convenient way to dispose of used oil, paint, and household cleaners. In addition to those items intentionally dumped down storm drains, other pollutants are picked up by runoff from some distance away and end up going down the drain as well (for instance, fertilizers, pet waste, sediments, etc.). Many people do not make the connection between these actions and water pollution – assuming that storm drains lead to a local wastewater treatment facility. Storm drain stenciling is a means of educating the public that anything that is dumped in a storm drain or any activity that is connected by impervious surfaces to a storm drain, ends up in the region's water resources.

- **Animal Waste Controls** – Pet and animal waste is a significant contributor to urban NPS pollution and especially nutrient and bacteria (fecal coliform) pollution. Animal waste control practices include a combination of public education about the problem and enhanced enforcement measures to discourage violation of local ordinances concerning pet waste.

- **Lawn and Garden Care Education** – With turf acreage increasing throughout all tributary basins within Virginia, programs aimed at educating home and commercial turf care providers on good landscape management practices are becoming increasingly important. Lawn and garden care management practices include education programs which address proper fertilizer and pesticide application and promote integrated pest management.

- **Reduction of Automotive-Generated Pollutants** – Most of the petroleum hydrocarbons and many of the trace metals found in urban stormwater are the result of poor vehicle maintenance or improper disposal of used automotive fluids. Nonstructural remedies include used oil recycling programs, carpooling, and public education efforts.

▶ Control Measures

Control measures are very similar to traditional BMPs in that they remove NPS pollution after it has entered the environment. Control measures discussed in this Handbook are generally those which rely on the strategic placement of vegetation to capitalize on their pollution removal capabilities. Because control measures have a measurable input and output, arriving at an NPS pollutant removal efficiency is usually possible.

- **Vegetative Controls** – Vegetative controls discussed in this Handbook include vegetated buffer areas, vegetative filter strips, and grassed swales.

- **Bioretention/Rain Gardens** – Bioretention is very similar in concept to the traditional infiltration trench but incorporates the benefits provided by biological uptake and activity. In essence, bioretention attempts to mimic the biological and chemical conditions found on an upland forest floor. The soil underneath the plantings must have an adequate infiltrative capacity. In many instances, *in situ* soil must be excavated and replaced by more appropriate soil.

- **Stormwater Wetlands** – Stormwater wetlands have received increasing attention in recent years as a means of controlling urban pollutants while enhancing urban wildlife habitat. Wetland plants are noted as being particularly effective in slowing stormwater runoff, promoting settling of particulate pollutants, and nutrient uptake.

- **Street Cleaning** – Street cleaning as a BMP practice, as opposed to an aesthetic practice, is a fairly recent innovation. Using wet-vacuum or regenerative air vacuum equipment at the correct frequencies, street cleaning can be effective at removing particulates which have been deposited on urban street surfaces.

SECTION 1.5 ....

Organization of this Handbook

This Handbook is organized under the premise that any nonstructural BMP program, in order to most effectively address NPS pollution, must start with an understanding of the how NPS pollution enters the water and what NPS pollutants need to be addressed in a particular watershed. This is the case no matter how large, or small, the particular area to be controlled.

Chapter 2, **Tackling the Nonpoint Source Pollution Problem**, takes the watershed or site planner through the steps necessary to successfully identify NPS pollution sources and a specific set of priority NPS pollution problems.

Once this needs assessment has been conducted, it is then possible to utilize the nonstructural BMP screening criteria identified in Chapter 3, **Choosing Appropriate Nonstructural Approaches**. Chapter 3 allows the watershed planner to tailor a nonstructural BMP program based on a practice, or combination of practices, that best addresses sources and problems identified in Chapter 2.

Chapter 4, **Pollution Prevention Measures**, provides explicit guidance on the design and implementation of pollution prevention techniques. When appropriate, each technique is accompanied by suggestions for how to quantify the impacts of implementing the technique.

Finally, Chapter 5, **Control Measures**, provides explicit guidance on the design and implementation of control-style nonstructural BMPs. Similarly, the pollution removal efficiency of each technique is discussed.

◆ ◆ ◆

2. TACKLING THE NONPOINT SOURCE POLLUTION PROBLEM

Nonpoint source (NPS) pollution is defined as pollution which is generated from diffuse sources. While all pollution may be traced to an originating source, the term nonpoint source pollution is meant to recognize that it is often impossible, or impractical, to hold any one party responsible for a single act of polluting. This is in contrast to more readily identifiable (and controllable) "point sources" of pollution, such as an industrial wastewater outfall.

The purpose of Chapter 2 is to discuss the nature of NPS pollution as it relates to nonstructural BMPs and to outline the steps that are necessary to successfully identify NPS problems within a watershed or a particular site. Identifying priority NPS pollutants of concern allows the stormwater manager to more effectively and cost-efficiently implement nonstructural BMP techniques and to utilize the nonstructural BMP screening criteria identified in Chapter 3.

Chapter 2 is organized in the following manner.

- **The Pathways of Nonpoint Source Pollution**
- **Types of Nonpoint Source Pollution, their Sources and Consequences**
- **Identifying the Water Quality Problem**
- **Controlling NPS Pollution through Regulation**

SECTION 2.1

The Pathways of Nonpoint Source Pollution

Under natural conditions, the infiltrative capacity of the land allows most pollutants which collect on the surface to be neutralized through biological uptake, chemical break-down, and soil infiltration. Urbanization, however, introduces new pollutants into the environment and significantly alters the land's ability to assimilate existing pollutants – leaving water resources defenseless.

There are many pathways by which NPS pollution can enter the water. However, three pathways in particular serve as conduits for a great bulk of nonpoint source pollution in urban and suburban areas. These include:

- **urban stormwater runoff**
- **streambank erosion**
- **atmospheric deposition**

Understanding how these pathways serve to *introduce* NPS pollution into water resources is integral to implementing a nonstructural BMP program that will *prevent* stormwater contamination in the first place. Along with an understanding of what specific pollutants are likely to cause local and regional water quality problems and where they come from (discussed in Section 2.2), it is possible to effectively target the implementation of nonstructural BMPs to reduce the introduction of NPS pollution to local water resources.

▶ Urban Stormwater Runoff

Urban stormwater runoff, and particularly the first half inch known as the "first-flush," can be severely polluted. The concentration of pollution in stormwater runoff drops off significantly after the first half inch of runoff, which is why most structural BMPs are sized to treat only the first-flush.

In general, urban stormwater runoff contributes a wider array of pollutants to local streams than both atmospheric deposition and streambank erosion.

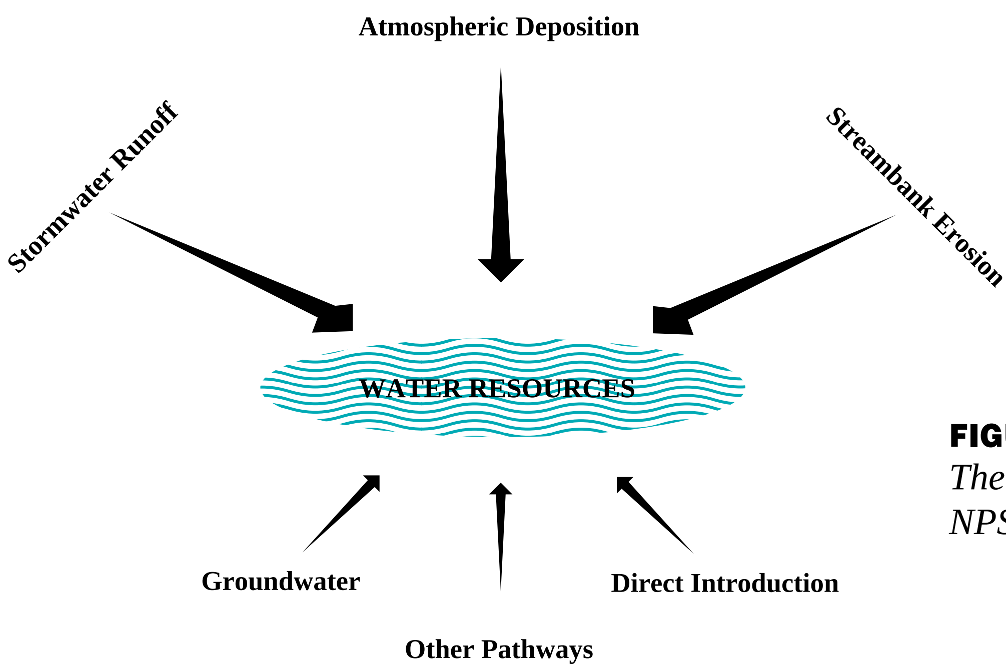


FIGURE 2.1
The Pathways of Urban NPS Pollution

TABLE 2.1

Pollutant Concentration Statistics for General Urban Runoff and Highway Runoff

CONSTITUENTS	GENERAL URBAN RUNOFF		HIGHWAYS RUNOFF		LIMITS FOR PROTECTION OF AQUATIC LIFE**
	MEAN	RANGE*	MEAN	RANGE*	
Suspended Solids (mg/l)	150	2-2,890	220	14-522	10 if background ≤ 100 mg/l. 10% of background if background > 100 mg/l.
BOD (mg/l)	9 (1)	0.41-159	•	•	•
COD (mg/l)	65 (1)	<10-1,031	124 (3)	34-1,291	•
Lead (µg/l)	140 (1)	3-28,000	550 (3)	10-3,775	34
Copper (µg/l)	34 (1)	4-560	43 (7)	13-288	6.7
Zinc (µg/l)	160 (1)	10-5,750	380 (3)	40-25,500	30
Cadmium (µg/l)	0.7 (8)	0.7-30	•	•	0.2
Chromium (µg/l)	7 (8)	<10-110	•	•	2
Nickel (µg/l)	12 (8)	<2-126	•	•	25
Arsenic (µg/l)	13 (8)	10-130	•	•	50
Organic Pesticides (µg/l)	•	0.002-0.35 (8)	•	•	•
Phthalate Esters (µg/l)	•	0.06-160 (8)	•	•	4-DBP, 0.6-DEHP, 0.2-all other PAEs
Phenols (µg/l)	•	8-115 (8)	•	•	•
Oil & Grease (mg/l)	7.8 (4)	up to 35.7	30 (6)	•	•
Total Hydrocarbons (mg/l)	3.7 (5)	1.8-43	•	•	•
Polynuclear Aromatic Hydrocarbons (µg/l)	•	<0.01-12	3.7 (6)	•	0.01 BaP
Total Nitrogen (mg/l-N)	1.5 (1)	0.34-20	2.72 (3)	up to 3.4	•
Total Phosphorus (mg/l)	0.33 (1)	0.01-4.3	0.59 (3)	up to 0.7	0.005-0.015***
Alkalinity (mg/l)	38.2 (4)	5.5-87	•	•	recommend >20
pH	•	6.2-8.7	•	6.6-8.0 (6)	6.5-9.0

Source: Terrene Institute, *Fundamentals of Urban Runoff Management*: 1994.
• No data reported.
* Range of actual values reported in literature from various studies unless otherwise indicated.
** Maximum concentrations for the protection of freshwater aquatic life as reported in "Approved and Working Criteria for Water Quality," British Columbia Ministry of Environment (1989), when receiving water hardness is 50 mg/l CaCO3.
*** For lakes with salmonids as predominant fish species.
(1) U.S. Nationwide Urban Runoff Program database.
(2) U.S. EPA database.
(3) Median of U.S. Federal Highways Administration database.
(4) Light industrial catchment in British Columbia.
(5) General urban catchment in Philadelphia.
(6) Highway runoff in England.
(7) Highway runoff in Washington State.
(8) Data from Metro Seattle.

TABLE 2.2

Common Sources of Pollution in Urban Stormwater Runoff

POLLUTANT CATEGORY SOURCE	SOLIDS	NUTRIENTS	BACTERIA	DISSOLVED OXYGEN DEMANDS	METALS	OILS (PAHs)	SOCs
Soil Erosion	■	■		■	■		
Cleared Vegetation	■	■		■			
Fertilizers		■					
Human Waste	■	■	■	■			
Animal Waste	■	■	■	■			
Vehicle Fuels and Fluids	■			■	■	■	
Fuel Combustion		■				■	
Vehicle Wear	■			■	■		
Industrial/Household Chemicals	■	■		■	■	■	■
Industrial Processes	■	■		■	■	■	■
Paints and Preservatives					■	■	■
Pesticides				■	■		■

Adapted by NVPDC from Terrene Institute, *Fundamentals of Urban Runoff Management*: 1994.

Urban runoff is caused when rainfall is prevented from infiltrating into the soil by impervious surfaces such as parking lots, streets, rooftops, sidewalks, and driveways. Impervious surfaces in urban areas tend to collect all types of pollutants from a range of sources (see Table 2.2). When runoff occurs, these pollutants are flushed into urban stormsewers and gutters, which often discharge directly into local streams.

National surveys of urban stormwater have detected more than half of the U.S. EPA's list of 126 priority pollutants that are either acutely toxic or known or suspected carcinogens in runoff. About one-half dozen exceed safe levels for aquatic life in some of the samples taken.

Heavy metals such as copper, lead, and zinc are the most prevalent priority pollutant constituents found in urban runoff. Oil and grease, which contain a variety of hydrocarbon compounds, are also commonly found in urban runoff. Some polynuclear aromatic hydrocarbons (PAHs) are known to be toxic to aquatic life at low concentrations.

The U.S. EPA has determined that construction activities also add to NPS pollutant loadings in stormwater runoff. The pollutants generated by such activities include: sediment and particulate organic solids; toxic metals and hydrocarbons (deposited from onsite equipment); and, nutrients (naturally occurring and those applied to promote revegetation and site stabilization).(1)

Research has shown that urban runoff also contributes oxygen-demanding substances to nearby waters. Decomposition of organic matter by microorganisms depletes dissolved oxygen (DO) levels in receiving waters, and especially in large estuaries such as the Chesapeake Bay.

In general, there is greater knowledge about stormwater runoff from impervious surfaces in highly urbanized areas than chemical and nutrient runoff from the rapidly-growing lawn acreage of Virginia's tributary basins. However, this is slowly beginning to change.

FIGURE 2.2
Urban Stormwater Runoff

Of particular concern is the home environment where the application of fertilizers and other chemicals tends to be performed by a vast number of amateurs. For example, there are home lawns spread across more than 500,000 acres of the Chesapeake Bay watershed with a multitude of potential fertilizer and pesticide applicators.(1) A poorly timed application just before a storm event, or an accidental application on an impervious surface, are only two ways that lawn care practices may affect local water quality.

The need to ensure that increasing home application of fertilizers and chemicals does not contribute to water pollution highlights the utility of developing strong prevention-oriented public education programs.

▶ Streambank Erosion

Streambank erosion is a natural source of both sediments and nutrients. However, urban land development can greatly accelerate the process of streambank erosion. As large areas of once pervious land are urbanized, the amount of impervious surface area draining to local stream networks greatly increases. The result is that during a storm event, a greater volume of stormwater is directly discharged into local waterways and at a much higher velocity (See Figure 2.3). The greater volume and velocity of water overwhelms the natural carrying capacity of the stream network and results in excessive streambank erosion.

Signs of stormwater erosion include undercut streams and fallen banks, felled bushes and trees which once lined the banks, and exposed sewer and other utility pipes. Suspended sediments choke and muddy local waterways making then uninhabitable to local species of aquatic life. In addition, nutrients and other pollutants attach themselves to sediment particles and contribute to eutrophic conditions in local lakes and reservoirs. Suspended sediments are deposited in slower moving portions of the stream course, causing buildup, destruction of benthic life forms, and a decreased stream capacity for floodwaters, thus resulting in greater potential for further erosion and even property damage.(1)

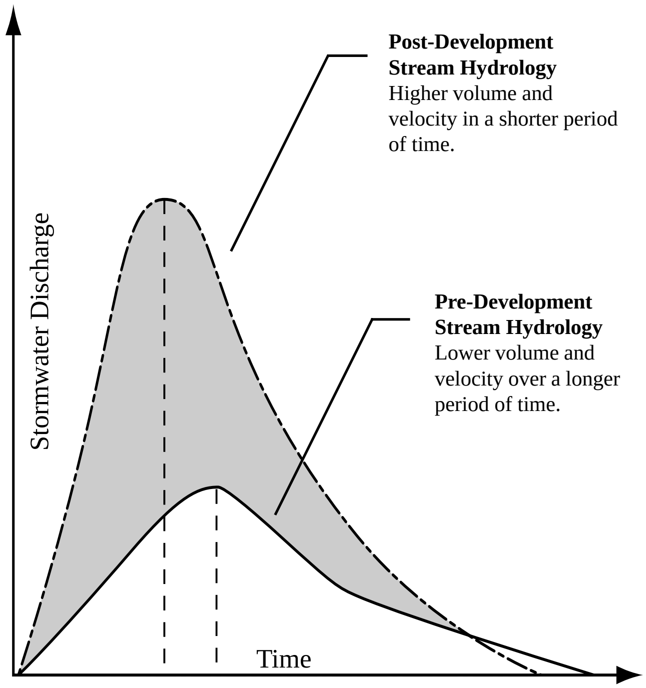
While implementation of structural stormwater controls helps to alleviate velocity problems in urban streams, long-term stormwater volume problems may only be effectively controlled through the implementation of nonstructural techniques that increase the land's ability to retain and infiltrate stormwater.

▶ Atmospheric Deposition

The air we breathe contains pollutants generated from a number of sources. As particulates settle from the atmosphere or are washed from the air by precipitation onto the earth's surface, the atmosphere becomes a major source of NPS pollution. Automobiles, power

FIGURE 2.3

The Effects of Stormwater Runoff on Urban Stream Hydrology

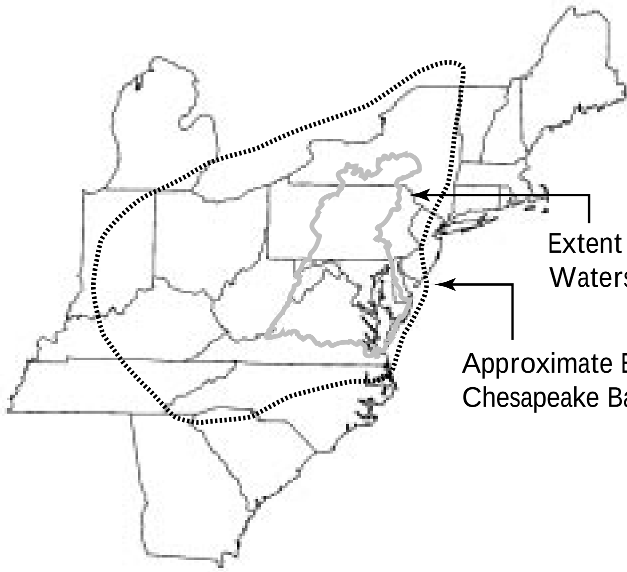


generation plants, and gasoline powered lawn mowers are among the largest producers of airborne pollutants.

Atmospheric deposition of nitrogen, in particular, is recognized by most east-coast estuarine programs as either a significant contributor to eutrophic conditions or a mechanism of possible concern. In 1988, an Environmental Defense Fund report estimated that atmospheric deposition of nitrogen from the burning of fossil fuels may contribute up to 25 percent of the nitrogen entering the Chesapeake Bay. Since that time, other studies have raised similar concerns. Officials at the Chesapeake Bay Program are now exploring how air pollution control can be a part of their strategy to reduce nutrient loads to the Chesapeake Bay and other water bodies.

A major hurdle to the control of atmospheric deposition is that the airshed which contributes to Virginia's water quality problems is much larger than any of its watersheds. The Chesapeake Bay airshed for example, according to many researchers, is up to 600,000 square miles in area (over 9 times larger than the Bay watershed) and is affected by emissions from as far away as North Carolina, Upstate New York, and the highly industrialized Ohio River Valley.[1] Therefore, reductions in atmospheric nitrogen to local and regional water resources require the cooperation of all jurisdictions located within the airshed. (See Figure 2.4)

FIGURE 2.4
Airshed versus Watershed – Atmospheric Deposition as a Super-Regional Management Concern



Adapted by NVPDC from East Coast Atmospheric Resource Alliance, *Airsheds and Watershed – the Role of Atmospheric Nitrogen Deposition*. Warrenton, Virginia: 1995.

▶ Other Pathways of NPS Pollution

While most NPS pollution finds its way to local water courses through stormwater runoff, streambank erosion, and/or atmospheric deposition, these are by no means the only ways by which NPS pollution travels.

Direct Introduction

Direct introduction of pollution into the water through dumping or carelessness is a significant cause of water quality degradation. Again, while any individual act may be considered a point source of pollution, the sheer number of very small events makes the problem nonpoint source in nature.

Direct introduction, because it often defies or overwhelms efforts to trap pollutants that are swept up from impervious surfaces, can only be controlled, in many instances, through nonstructural means.

Common examples of direct introduction include:

- dumping used oil into a local storm drain;
- careless use of petroleum products on boats or at a marina site;
- litter or dumping in or near the water;
- release of septage from a failing septic system or the purposeful discharge of pump-out into a local estuary from a residence, business, or boat;
- discharge of chlorinated pool water into a local stream; and,
- deposition of pesticide spray onto the water's surface due to inappropriate application near the water resource.

These represent only a few examples of the many ways that NPS pollution may enter the water through direct introduction.

Groundwater

Another means by which NPS pollution is introduced to surface water is through groundwater. Groundwater contributes to baseflow in many of Virginia's streams and rivers. Because groundwater is highly dynamic, contaminated groundwater is likely to result in contaminated surface water. Common examples of how groundwater may become polluted include:

- saturation of the soil with fertilizers;
- improper application of highly leachable pesticides on permeable soils;

- malfunctioning septic systems; and,
- leaking underground storage tanks.

These pathways of NPS pollution are no less important than previously discussed pathways and must be considered in order to develop a comprehensive water quality management plan.

SECTION 2.2

Types of Nonpoint Source Pollution, their Sources and Consequences

The principle pollutant categories of concern for urban water quality managers include nutrients, soil sediments, bacteria, heavy metals, synthetic organic compounds, and hydrocarbons. Each of these pollutants affect the natural environment in different ways and different nonstructural techniques are more efficient at controlling for different pollutants.

The following is a brief description of the most common pollutant categories and how each impacts the water environment.

Nutrient Pollution

For many water bodies, including the Chesapeake Bay, the pollutants of greatest concern are nutrients. Water bodies react to different types of nutrients in different ways. In general, phosphorus is the controlling nutrient in fresh water systems such as lakes and reservoirs while nitrogen is the controlling nutrient in brackish systems such as the Chesapeake Bay.

High concentrations of these nutrients can lead to excessive algae growth in quiescent waters. Excessive algae growth can cloud the water, thereby blocking sunlight to submerged aquatic vegetation (SAV). SAV serves to filter nutrients and pollutants from the water and provides needed habitat for aquatic species. As the algae die and decay, they consume large quantities of dissolved oxygen (DO) supplies that are necessary for the survival of fish and other aquatic species. This results in "dead zones" which are devoid of significant life.

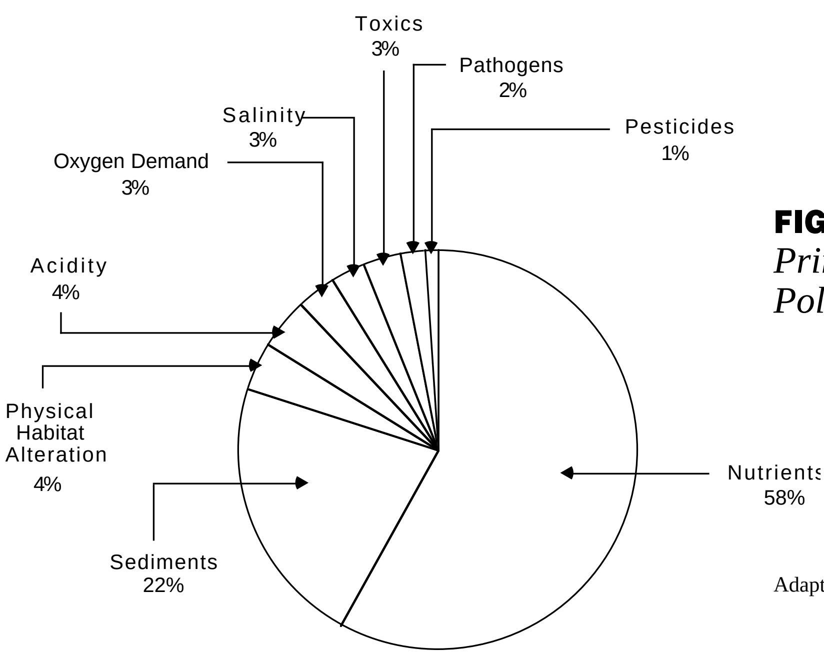


FIGURE 2.5
Primary Types of Nonpoint Source Pollution in U.S. Lakes

Adapted from USDA: 1991.(2)

Phosphorus has been identified by the Chesapeake Bay Local Assistance Department (CBLAD) as the "keystone pollutant" from which the pollutant loading reduction calculations of the Chesapeake Bay Preservation Act are made when designing stormwater quality management facilities. Thus, phosphorus, as a pollutant, occupies an elevated role in stormwater quality management.

According to CBLAD, "The major attribute of a keystone pollutant is that it shares the general characteristics of most other urban pollutants. Thus, by removing the keystone pollutant, one will simultaneously remove other important pollutants in urban runoff."[(3)]

However, the differences among pollutants often outweigh the similarities. Therefore, the stormwater manager must be cognizant of how each pollutant affects the ecosystem, where it is coming from, and how it is best controlled.

Like many pollutants, phosphorus and nitrogen exist in two physical forms – particulate and dissolved. This dichotomy affects what techniques will be most effective in the removal of nutrients from the water. The particulate form accounts for 40 to 50 percent of total phosphorus while it accounts for only 20 to 30 percent of total nitrogen. For structural BMP devices which rely primarily on settling, phosphorus and nitrogen removal is often limited to the percentage of particulate matter since only the particulate form will settle out. However, nonstructural techniques can prevent the introduction of phosphorus and nitrogen into the water system altogether or allow for enhanced removal efficiency through biological uptake and chemical breakdown by vegetative cover and soils.

NUTRIENT GENERATION AND TRANSPORT

Nutrients are generated naturally across landscapes. However, human activities usually magnify the levels at which nutrients are introduced into nearby waters.

Land use activities such as fertilizer applications, removal of vegetation during land clearing, and storm runoff channeling are major sources of nutrients generated in urban and suburban settings. When a nutrient management plan is not being utilized, nutrients applied to the land can exceed the carrying capacity of the soil and vegetation. In turn, these nutrients infiltrate into the groundwater or are carried in runoff from the land into nearby waterways during storm events. Ill-timed application of nutrients immediately before a storm event and the misapplication of nutrients on impervious surfaces (such as gutters or sidewalks) are two additional ways that these pollutants may enter stormwater runoff.

Soil erosion is a primary cause of nutrient transport to local waterways. Nutrients, and phosphorus in particular, tend to cling to soil particles that are washed off the land into surface water.

Nutrients are also introduced to stormwater through atmospheric deposition. Automobile exhaust and power generation plants are the largest producers of airborne pollutants. While only a small proportion of nutrients are directly deposited on water bodies, a much greater proportion of nutrients are deposited on impervious surfaces where they can be flushed into local waterways during subsequent storm events.

Finally, nutrients may be introduced into the water through fecal matter in runoff. Curbing pets, where fecal matter will be washed directly into the storm drain, is a particularly acute problem in many urban areas. Golf courses or other public open spaces which attract wild fowl are also major sources of fecal matter. In some aging urban and suburban areas, leaking sanitary sewer lines, which usually follow low lying areas associated with stream beds, have also been identified as a major source of nutrient pollution.

A prime indicator that nutrients are being introduced into the water through fecal matter is the elevated presence of another pollutant – fecal coliforms, or bacteria pollution.

▶ Sediment Pollution

A certain amount of sediment is necessary for the health of most waterbodies. Sediment is a source of nutrients and silica needed for plankton growth, and some of it is captured by tidal marshes to keep them built up against storm surges and tidal inundation. However, large volumes of sediment decreases flow capacity in drainage ways, takes up storage volume in reservoirs, and blankets the bottom of waterways, killing oxygenproducing plants and ruining spawning grounds. Soil in runoff may also have other pollutants attached such as pesticides, nutrients, or oxygen-demanding substances. These pollutants may exert an immediate stress on receiving waters or may settle out and exert their effects over a period of time.

The U.S. EPA has stated that suspended sediments comprise the bulk of urban NPS pollutants. This has both short and long-term impacts on receiving waters. Immediate detrimental impacts of high sediment loadings include increased turbidity, impaired respiration of fish and aquatic invertebrates, and reduced fecundity and impairment of commercial and recreational fishing. High sediment concentrations may also cause long-term effects. Sediments tend to bind and transport nutrients, toxic substances, and trace metals. These enriched depositional sediments may present a continued risk to aquatic and benthic life, especially where sediments are disturbed and resuspended by tides, storms, and winds.

SEDIMENT GENERATION AND TRANSPORT

Sediment pollution is a result of excessive soil erosion. When precipitation in the form of rain strikes the ground, its kinetic energy can dislodge and mobilize soil particles, resulting in erosion of the land. The dislodged soil particles cause a net downslope movement of soil called "rainsplash erosion." In areas where rainfall exceeds the absorption capacity of the soil, water accumulates and travels downslope, carrying the soil particles in an irregular sheet flow. In a process known as "sheetflow erosion," the force of this water flow can dislodge more soil particles as it continues to make its way downslope. Soil eroded by both rainsplash and sheetflow erosion can be carried to a receiving waterbody where it becomes sediment.

The primary sources of sediment in urban areas are from construction activities and streambank/shoreline erosion. Soil erosion rates on construction sites generally range from 10 to 100 tons/acre/year and more. Sediment loadings from construction sites may be as much as 100 times greater per acre than those from agricultural lands and perhaps 2,000 times greater than from undisturbed forestland. Exposed, disturbed, and stockpiled soils are extremely susceptible to erosion and transport off-site. In general, downstream suspended sediment levels are greatest during the advanced stages of construction when sediment delivery conditions are optimal.(1)

Streambank erosion is also a major source of sediment in urban areas. Urban stream beds are subjected to much higher velocities and volumes of water than under natural conditions. The increased "flashiness" of stormwater discharges causes the natural channel to be overwhelmed and results in stream bank erosion and undercutting.

▶ Bacteria Pollution

Bacterial levels in undiluted urban runoff exceed public health standards for water contact recreation almost without exception. Because bacteria multiply faster during warm weather, it is not uncommon to find a twenty-fold difference in bacterial levels between summer and winter.(4)

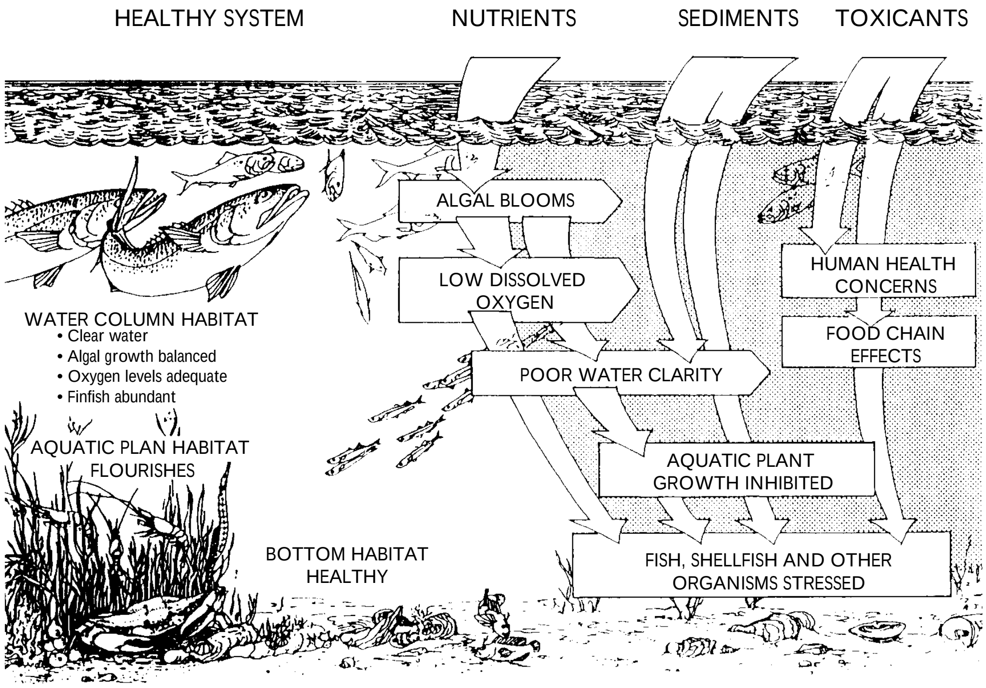
Under the federal Clean Water Act, all State waters are expected to be maintained to support recreational use and the propagation and growth of all aquatic life reasonably expected to inhabit them. One of the key indicators used to measure these "swimmable and fishable goals" is the level of fecal coliform bacteria. Fecal coliforms are also an important indicator from a human health standpoint. These indicator organisms, while not necessarily harmful in themselves, are found in the intestinal tracts of warm-blooded animals, including humans, and therefore can be indicative of fecal contamination and the possible presence of pathogenic organisms. Under the CWA guidelines, fecal coliform counts should not exceed 1,000 mg/l in any one instance and should not exceed 200 mg/l over the geometric mean. In addition, the presence of fecal coliforms may also indicate that excessive nutrients are being discharged into the water body.

BACTERIA GENERATION AND TRANSPORT

The most common sources of fecal coliforms are domestic and non-domestic animal droppings, malfunctioning septic systems, and antiquated or failing sanitary sewer lines.

Although nearly every urban and suburban land use exports enough bacteria to violate health standards,

FIGURE 2.6
The Effects of Nonpoint Source Pollutants on Water Resources



From U.S. Fish and Wildlife Service, Chesapeake Bay Field Office: 1994.

older and more intensively developed urban areas produce the greatest export.(4) The reason is that older urban areas tend to have a greater proportion of antiquated sewer lines than newer suburbs. In addition, suburban areas tend to have more grassy areas where the deposition of animal waste is more easily absorbed into the soil horizon. In more urban areas, where the land surface is impervious, it is common to “curb” pets so that fecal matter is directly flushed through the storm drain and into the local water body.

Areas where wild fowl or other animals congregate are also major sources of bacteria pollution. Particularly where the presence of such animals kills the vegetative cover and packs the soil, animal waste is readily flushed to local water courses during storm events.

▶ Trace Metal Pollution

Trace metals are primarily a concern because of their toxic effects on aquatic life and their potential to contaminate drinking water supplies. While a certain background quantity of trace metals may be found in almost all surface waters, increased industrialization and urbanization have raised the levels of trace metals in some areas to dangerous levels. Trace metals common to urban stormwater runoff include arsenic, beryllium, cadmium, chromium, copper, cyanide, mercury, nickel, lead, selenium, thallium, and zinc. Trace metals are toxic to stream life in certain situations. This is particularly true for the more soluble metals such as copper and zinc.(4)

Trace Metal Generation and Transport

Most of the metals found in urban runoff come from "leakage" in the urban landscape and from atmospheric deposition. One of the most dangerous metals to human beings – lead – has been dramatically reduced since its use in gasoline and paints has been banned.(4)

A large fraction of trace metals are attached to sediment. This effectively reduces the level which is immediately available for biological uptake and subsequent bioaccumulation. Metals associated with sediment rapidly settle out of the water column and accumulate in soils and aquatic sediments.(1)

Common sources of trace metals on the street surface include atmospheric deposition, wear of vehicle and metal parts, wear of clutch and brake linings, and tire wear.

▶ Synthetic Organic Compounds

Synthetic organic compounds (SOCs) are any carbon-based chemical created by artificial means. Most modern pesticides are SOCs; however, other groups of SOC's, such as phthalates, PAHs, and PCBs are used for other purposes. Over 20,000 pesticide-containing products, representing approximately 6,000 SOCs, are currently available on the market in the United States. Despite the abundance and availability of pesticides, data on both the chronic toxicity of pesticides and the extent of public exposure to them is still limited. Even low concentrations of some of these chemicals over a long period of time have the potential to pose severe health risks to humans and the living resources of streams and waterways, especially through the process of bioaccumulation.(5)

SOC Generation and Transport

The three most common vehicles for the diffusion of SOCs in the environment are spray drift during application, groundwater contamination, and stormwater runoff. Since many SOCs chemically decay and become inert over a short period of time, there is less risk of water contamination from the first two modes of SOC transport. However, some SOCs with longer decay periods are particularly susceptible to leaching through the groundwater. In addition, SOCs with

TABLE 2.3

Source of Urban Nonpoint Source Pollution

Pollutants	Sources
Nutrients	▶ Soil particles from erosion ▶ Overapplication or misapplication of fertilizers ▶ Fecal matter from animals or sanitary sewers ▶ Vegetative matter ▶ Power plant emissions and automobile exhaust
Sediments	▶ Construction activities ▶ Urban streambank erosion
Bacteria	▶ Antiquated sewer lines ▶ Fecal matter from domestic and non-domestic animals ▶ Malfunctioning septic systems
Trace Metals	▶ Soil particles from erosion ▶ Wear of vehicle parts including clutch, brake linings, and tires ▶ Leakage from vehicular fluids ▶ Atmospheric deposition from automobile emissions
SOCs	▶ Spray drift, groundwater contamination, and stormwater runoff as a result of pesticide application ▶ Dumping household/ industrial chemicals.
Petroleum Hydrocarbons	▶ Leakage from automobile crank cases on impervious surfaces ▶ Illegal dumping of used oil by home car maintenance ▶ Underground and above ground storage tank malfunction
Chlorides	▶ Roadway deicing chemicals

longer decay periods may pose a threat to local streams if they are applied to impervious surfaces and subsequently flushed by stormwater runoff.

Most modern pesticides are water soluble, and as a result, can be carried in solution in runoff after a storm event into local streams and waterways. An increase in impervious land area due to development has made toxic contamination of stormwater runoff a potentially increasing problem. The ramifications of an improper or ill-timed pesticide application have correspondingly become more severe because imperviousness increases the opportunity for toxins to be discharged directly to the water course without a chance for infiltration through the soil or for biochemical uptake by plants.[5]

▶ Petroleum Hydrocarbons

Oil and grease contain a wide array of hydrocarbon compounds. The toxicity of petroleum hydrocarbons to aquatic biota is species-specific and also specific for the type of petroleum entering the system. Many types of petroleum hydrocarbons are known to be acutely toxic to aquatic species at very low levels.[4]

Petroleum Hydrocarbon Generation and Transport

The major nonpoint sources of hydrocarbons in urban runoff are through leakage of crankcase oil and other lubricating agents from the automobile. As might be expected, hydrocarbon levels are highest in the runoff from parking lots, roads, and service stations.[4] While residential land uses generate less hydrocarbon export than commercial or industrial land uses, illegal disposal of waste oil into the storm drain during "do-it-yourself" automobile repair may result in a severe local problem.

Other point sources of petroleum hydrocarbons which may be considered nonpoint sources due to their abundance and dispersion are leaking underground and above ground storage tanks.

SECTION 2.3

Identifying the Water Quality Problem

In many instances, such as is the case with urban development under the Chesapeake Bay Preservation Act and the Erosion and Sediment Control Law, the need to control for particular pollutants is well established. (See discussion in Section 2.4.)

Notwithstanding these and similar regulations, it is extremely worthwhile to identify pollutants of concern in local streams, lakes, and reservoirs prior to the implementation of a nonstructural BMP approach to water quality. This is because different nonstructural BMPs are more effective than others in preventing the entry of certain pollutants into local streams. For instance, it does not make sense to develop an educational program about used oil disposal practices if bacteria contamination is the actual primary reason for local water quality decline.

By keying in on the actual water quality problem, it is possible to more effectively target the use of nonstructural BMPs.

An analysis of local water quality is an excellent starting point for any nonstructural BMP program. However, it is also just the beginning. Often times, an individual pollutant can come from a multitude of sources and it is necessary to do some further investigating in order to pinpoint an exact cause.

The water quality analysis is abridged when planning for a specific site, as it is easier to determine what pollutants require being addressed. However, when looking to reduce the incidence of NPS pollution on a watershed-wide or jurisdictional basis, the analysis may become as complex as it is necessary.

Pollutants versus Indicators

The most common pollutants of concern for localities are identified in Section 2.2 and include nutrients, sediments, bacteria, heavy metals, SOCs, and petroleum hydrocarbons. However, each of these "categories" may contain a vast array of specific pollutants. For

TABLE 2.4
NPS Pollution Categories and their Specific Measures

CATEGORY	SPECIFIC MEASURES
Solids	Settleable Solids (SS) Total Suspended Solids (TSS) Turbidity (Turb)
Oxygen Demanding Substances	Biochemical Oxygen Demand (BOD) Chemical Oxygen Demand (COD) Total Organic Carbon (TOC)
Phosphorus (P)	Total Phosphorus (TP) Soluble Reactive Phosphorus (SRP) Biologically Available Phosphorus (BAP)
Nitrogen (N)	Total Nitrogen (TN) Total Kjeldahl Nitrogen (TKN) (Ammonia + Organic) Ammonia - nitrogen (NH3-N) Nitrate + Nitrite - Nitrogen (NO3+NO2-N)
Metals	Copper (Cu), Lead (Pb), Zinc (Zn), Cadmium (Cd), Arsenic (As), Nickel (Ni), Chromium (Cr), Mercury (Hg), Selenium (Se), Silver (Ag)
Pathogens (Bacteria)	Fecal coliform bacteria (FC) Enterococcus bacteria (Ent) Viruses
Petroleum Hydrocarbons	Oil and Grease (O+G) Total Petroleum Hydrocarbons (TPH)
Synthetic Organics	Polynuclear Aromatic Hydrocarbons (PNAs) Phlathalates Pesticides Polychlorobiphenols (PCBs) Solvents

Source: Terrene Institute, *Fundamentals of Urban Runoff*: 1994.

instance, there are over 6,000 testable SOCs currently available on the commercial market.[5] (See Table 2.4.)

Pinpointing a specific pollutant as a water quality problem provides the water quality planner with the best chance to address it through nonstructural means. However, it is often the case that the resources are not present to test for a full contingent of pollutants. If this is the case, the water quality planner may wish to limit testing to a certain number of specific, and common, NPS pollutants.

Another solution is to test the water for quality indicators. Indicators reflect, but are not the cause of, poor water quality. The most common indicators which can be tested for include:

- temperature;
- dissolved oxygen content;
- chlorophyll*a*; and,
- pH.

By identifying indicators of concern, it is possible to more clearly identify which pollutants need to be monitored. A low dissolved oxygen content, for example, may indicate that excess nutrients are being introduced into the water through stormwater runoff. However, if other indicators are normal, and temperature is high, this may indicate that the problem is not a pollutant, but excessive clearing along stream banks. In either case, the number of pollutants that need to be tested for is reduced.

In addition to these "testable" indicators are:

- **visual indicators;**
- **biological indicators; and,**
- **pollution potential indicators.**

Trash, an oily sheen on the water surface, or felled trees along a stream bank are examples of visual indicators. These indicate litter problems, petroleum hydrocarbons, and sediment and nutrient problems respectively.

Biological indicators are revealed through a "biological community assessment." By performing an assessment of the health of the existing biological community, it is possible to determine to what degree the aquatic system is impaired as well as establish a baseline for future comparisons.

Pollution potential indicators are those indicators which show a relatively high potential that a particular pollutant is or will be an NPS pollution problem. An example of this approach would be an examination of the age and quantity of above ground heating oil tanks within a census tract. A high concentration of above ground tanks in an area of relatively older housing may suggest that there is the potential for significant leakage into the environment.

If the aim of the water quality manager is to address a specific water quality problem through targeted nonstructural techniques, it is best to be as specific as possible in the monitoring effort. Likewise, ongoing monitoring of indicators is important to see if the control of a particular pollutant is having the desired affect or whether additional pollutants or sources need to be controlled.

Obtaining Water Quality Data

Depending on specific needs and availability, data on local stream water quality may be obtained in one of four ways:

- Use of existing stream water quality data or an existing water quality monitoring network.
- Establishment of a water quality testing station or network for a specific purpose or purposes.
- Performance of a "biological community assessment."
- Performance of a "pollution potential assessment" in order to gain insight into potential or existing pollution problems.

▶ Using Existing Water Quality Monitoring Data

The least costly (although not always most cost-efficient) means of assessing local water quality is through the use of an existing water quality monitoring network. Many county and city health departments in Virginia maintain extensive water quality monitoring networks. Colleges and universities are also excellent sources of water quality monitoring data.

The following are some readily available sources of water quality data in Virginia.

- County/city health departments.
- United States Geological Survey's annual *Water Resources Data Report*.(6)
- Virginia Department of Environmental Quality's annual *Virginia Water Quality Assessment* (305(b) report to EPA and Congress).(7)
- Special watershed protection districts/programs. Examples include the Occoquan watershed which is monitored through the Occoquan Watershed Monitoring Lab in Manassas, and Lake Barcroft (Falls Church), which is monitoring under the Lake Barcroft Watershed Improvement District (WID).
- Local civic and environmental organizations.

Existing data is essentially free and often readily available. In many instances, base conditions are already set and trend data is available. The primary drawback to such an approach is that the watershed planner may have little or no control over the placement of testing stations or the determination of testing parameters.

For instance, the Fairfax County Health Department maintains 72 sampling sites in 25 watersheds in Fairfax County. In 1995, each site was tested between 18 and 24 times. Testing parameters reflect the fact that the FCHD is primarily interested in human health issues and measuring compliance with the federal Clean Water Act. The FCHD tests for fecal coliforms, dissolved oxygen, nitrate nitrogen, total phosphorus, temperature, and eight heavy metals.(8)

By contrast, the primary purpose of the Occoquan Watershed Monitoring Lab's testing program (located in Manassas) is to protect a vital drinking water supply reservoir from contamination and eutrophication. Therefore, water collected from the program's 27 stations are tested for a more comprehensive array of specific pollutants. For instance, the OWML tests for 66 SOCs and 18 polyaromatic hydrocarbons.[9]

So long as these constraints are reconcilable with water quality management goals, using an existing stream water quality monitoring network is both economical and efficient.

▶ Establishing a Local Water Quality Monitoring Network

If existing water quality monitoring data is insufficient, one option is to establish a monitoring program for the area/stream in question. This is more time consuming and expensive than relying on established data, but in the long run may save time and money by enabling the watershed planner to better identify pollution problems and hot spots.

The Terrene Institute suggests that a five step analytical process be used to cost-effectively design a water quality monitoring program.[10] These steps include:

- Specify the monitoring program objectives;
- Determine the level of effort and financial resources that one has to devote to the analysis;
- Perform a systematic analysis appropriate to the problem and objectives;
- Specify monitoring program elements preliminarily; and,
- Evaluate the preliminary monitoring program for cost-effectiveness and finalize according to evaluation results.

Specify Monitoring Program Objectives

According to the Terrene Institute, "Establishing objectives is essential, even though they cannot always be specified in great detail. Objectives stem from the nature of the problem or decision making need that requires data collection."[10] In the context of controlling or preventing NPS pollution through the use of nonstructural techniques, the watershed manager is confronted with four common problems:

- Defining the water quality status of a waterbody.
- Identifying problem areas, their sources, or both.
- Selecting locations to apply problem abatement strategies.
- Evaluating alternative abatement strategies both prior to and after implementing control techniques.

Every monitoring program should, if possible, formulate objectives at two levels – general and specific. "General objectives describe what must be accomplished to solve the overall problem or meet the need. Specific objectives relate directly to measurements and produce results to meet the general objectives."[10]

Determine the Level of Cost and Effort

A monitoring program may range from simple and inexpensive to comprehensive and costly depending on the quantity and type of information that is desired. The watershed planner should determine early in the process how much time and effort that he or she is willing to spend on the monitoring program.

A simple cost accounting equation provided by the Terrene Institute is as follows:

$$TC = C_o + T * T * C_t * S * T * C_s + R * S * T * C_r$$

where:
- TC = Total cost;
- C_o = Fixed overhead cost;
- C_t = Fixed cost for each sampling occasion;
- C_s = Cost association with visiting each sampling station;

C_r = Cost to collect and analyze each sample;
T = Number of sampling occasions; and,
S = Number of sampling stations;
R = Number of replicates on each occasion at each station.

An important element to consider in this process is the amount of information that is currently available about the water quality problems of the area. If the purpose of the monitoring effort is to *locate* and respond to pollution "hot spots," it will probably be necessary to establish a network of testing stations. If, however, it is already known where hot spots are, and the purpose is to monitor the results of a nonstructural BMP program, then it may be possible to establish a few monitoring stations at key locations. As a general rule, the more information that is available from other means, the less expensive the testing program will be.

The cost of a monitoring program will depend on the number of samples taken, the parameters tested for, and the lab selected to perform the actual analysis. As a general guide, prices for testing any one parameter should range from $5.00 to $55.00 depending on the pollutant tested and the lab used. Appendix 2.1 provides sample lab fee ranges for testing common pollutants as well as a list of laboratories serving Virginia.

Perform a Systematic Analysis

As noted by the Terrene Institute, this step is the core of the evaluation process. This systematic analysis is also commonly referred to as a watershed analysis. A watershed analysis, depending on the needs of the water quality planner, may be as large or small as necessary. The watershed analysis involves surveying watershed characteristics, identifying the most critical potential problems and sources, and highlighting the most critical places, times, and biological units that manifest problems.

A watershed inventory involves collecting the appropriate level of data according to the needs of the project. While level of detail will vary, important elements include:

- developing a basin map;
- identifying features such as land uses, soils, topographic information, and hydrologic data; and,
- identifying potentially critical problem source locations (e.g., earth moving activity, industrial areas, major traffic concentrations) or areas potentially sensitive to problems (e.g., fisheries and other productive resource areas, rare or endangered resources, stream reaches vulnerable to major channel damage).

Once the watershed analysis has taken place, it is often a good idea to reevaluate the original goals of the monitoring program to assure their continued appropriateness.[10]

Specify Monitoring Program Elements Tentatively

According to the Terrene Institute, if performed properly, the systematic analysis in the last step should provide sufficient information to shape the monitoring program. At this stage, program elements which should be tentatively decided upon include:

- what to sample;
- where to sample;
- how many samples to take on each occasion (replicates);
- how to sample; and,
- what to analyze in samples.

The design should set objectives and identify potentially critical problems while considering cost-effectiveness. The objectives and analytical findings should dictate the media sampled, the locations and times of sampling, and the analysis to be performed. The program should be tailored to meet a specific level of effort and to meet stated goals and objectives.

Deciding when to sample should be a thoughtful process and not necessarily confined by a strict intervals, although it may be decided that this is desirable. For instance, one should consider whether it is more important to attempt to test immediately before and after major storm events or whether monitoring should be concentrated in the wet season when levels of runoff are greatest.(10)

Evaluate the Preliminary Monitoring Program and Finalize

The final step in the analytical process is to evaluate the previous step according to its number of samples. This is necessary because the number of samples directly affects the cost of the program and its probable effectiveness. According to the Terrene Institute, the basic task is to determine the number of samples needed to meet the objectives while considering variability and budget limits. Many otherwise flawless monitoring programs fail because the cost winds up being too high or variability in the runoff and natural aquatic system prevents the monitoring group from attaining a desired level of statistical confidence.(10)

▶ Determining if there is a Water Quality Problem

A very important question which must be answered before the decision to implement a nonstructural BMP as a result of water quality monitoring is "is there a water quality problem?"

To determine this question, one must examine not only water quality **standards**, but also water quality **trends**.

Water Quality Standards

Under the federal Clean Water Act, all State waters are expected to be maintained to support recreational use and the propagation and growth of all aquatic life reasonably expected to inhabit them. These are known as the CWA "swimmable and fishable" goals. The parameters used to determine these are minimum and daily average dissolved oxygen content (DO), pH, maximum temperature, and fecal coliform bacteria

TABLE 2.5a
CWA Fishable and Swimmable Water Quality Standards

CLASS	DESCRIPTION	DISSOLVED OXYGEN		pH	MAX. TEMP °C
		Minimum	Daily Average		
I	Open Ocean	5.0 mg/l	***	6.0 - 8.5	***
II	Estuarine (Tidal Water-Coastal Zone to Fall Line	4.0 mg/l	5.0 mg/l	6.0 - 8.5	***
III	Free Flowing Streams (Coastal Zone and Piedmont Zone)	4.0 mg/l	5.0 mg/l	6.0 - 8.5	32
IV	Mountainous Zone	4.0 mg/l	5.0 mg/l	6.0 - 8.5	31
V	Put and Take Lake Trout Waters	5.0 mg/l	6.0 mg/l	6.0 - 8.5	21
VI	Natural Trout Waters	6.0 mg/l	7.0 mg/	6.0 - 8.5	20
VII	Swamp Water	Case-by-case.	Case-by-case.	Case-by-case.	Same as I through VI as appropriate.

Maximum Fecal Coliform Bacteria (instantaneous count)	1,000 cells/100 ml
Maximum Fecal Coliform Bacteria (geometric mean of two or more samples collected within a 30 day period)	200 cless/100 ml

TABLE 2.5b

Selected Water Quality Standard Criteria

POLLUTANT	STANDARD
Nitrate Nitrogen	Seldom exceeds 10 mg/l in nonpolluted water
Phosphorus (Total)	No established limit. Increase over time may indidate contamination
Heavy Metals	U.S. EPA Preliminary Maximum Contaminant Level (PMCL)
Arsenic	0.05 mg/l
Barium	1.00 mg/l
Cadmium	0.01 mg/l
Chromium	0.05 mg/l
Lead	0.05 mg/l
Mercury	0.02 mg/l
Selenium	0.01 mg/l
Silver	0.05 mg/l

Fairfax County Health Department, 1996.

level. Fecal coliform levels are the most important from a human health standpoint. These indicator organisms, while not necessarily harmful in themselves, are found in the intestinal tracts of warm-blooded animals, and therefore can be indicative of fecal contamination and the possible presence of pathogenic organisms. Temperature, DO, and pH are the primary indicators of the health of the aquatic system. The presence of DO in the water is essential for aquatic life and the type of aquatic community is dependent to a large extent on the concentration of DO in the water. Strongly related to pH are biological productivity, stream diversity, metal solubility, and the toxicity of certain chemicals, as well as important chemical and biological activities. Temperature affects feeding, reproduction, and the metabolism of aquatic animals.

Average annual figures can be misleading; for example, a week or two of high temperatures each year may make a stream unsuitable for sensitive aquatic organisms, even though temperatures are within tolerable limits throughout the rest of the year.

The waters of the Commonwealth are divided into seven classes. CWA standards for each class are presented in Table 2.5a. Non-CWA surface water quality recommendations for selected pollutants are presented in Table 2.5b. General water quality recommendations for certain pollutants as they relate to aquatic health are presented in Table 2.1.

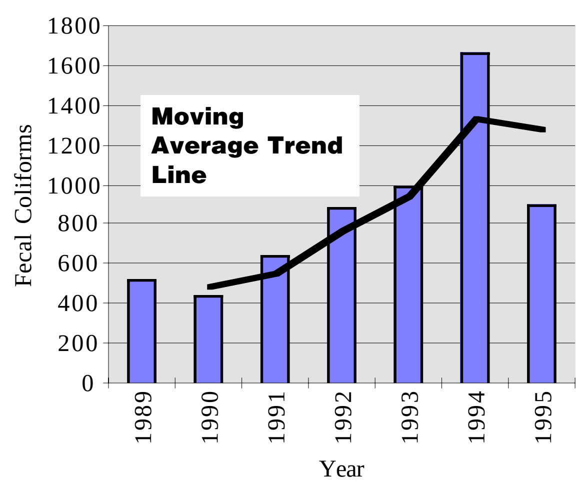
Water Quality Trends

In addition to water quality standards, trends in local water quality are also important measures of a potential problem.

Trends may be measured over the short term or the long term. In either instance it is important that sea-

FIGURE 2.7

Example Trend Analysis for Fecal Coliforms



Fairfax County Health Department, 1996.

sonal variations are recognized and taken into consideration. Measures of trends include:

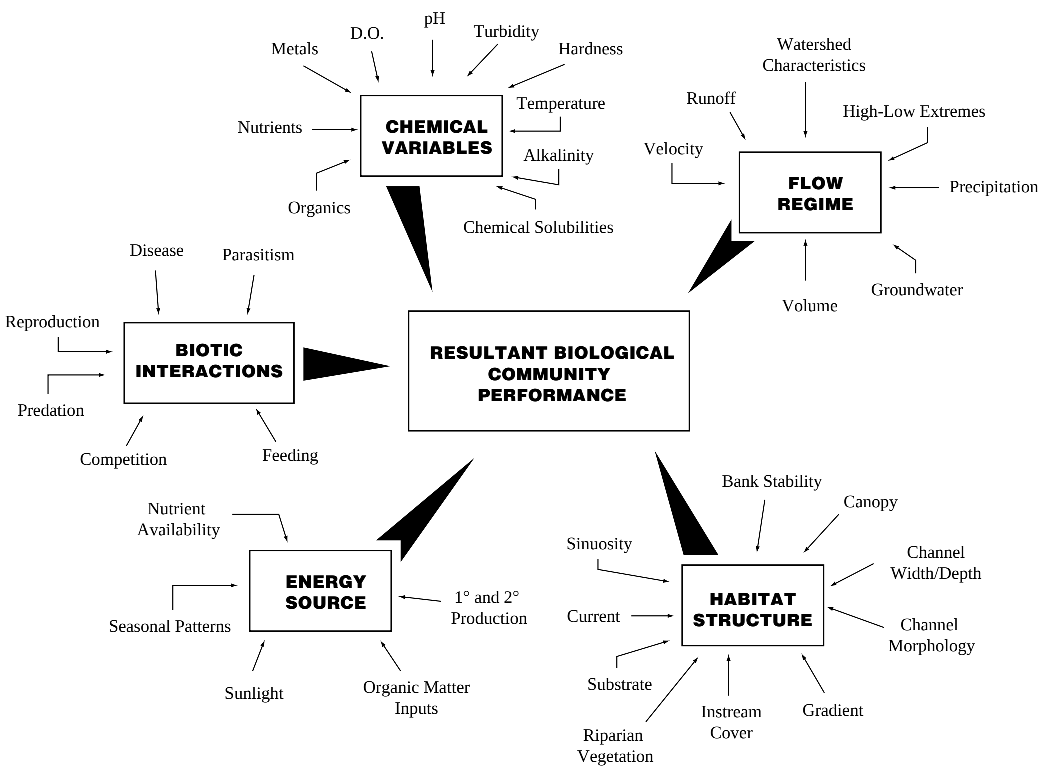
- **Simple histogram** – A histogram is simply a bar graph which spans over the course of a number of years. The watershed manager may visually determine the general trend.
- **Time series analysis** – Time series analysis represents a broad range of analytical methodologies for not only assessing trends, but for predicting future trends within some range of accuracy. More complicated time series analysis allows the watershed manager to account for seasonal variations in making forecasts.

These are only two of the more common ways to assess water quality trends. Others may be more appropriate in particular instances. Trends analysis may be performed on almost any commercially available spread sheet software. In addition, there are several commercially available statistical packages which can perform a broad range of statistical analysis on water quality data. Figure 2.7 provides an example of an analysis of trends in fecal coliform counts in the Accotink watershed of Fairfax County.(11)

▶ Biological Community Assessment

The biological well being of a stream system is the ultimate goal of any water quality program. A multi-

FIGURE 2.8
Factors that Influence Aquatic Biological Community Performance



Adapted by NVPDC from Terrene Institute, *Fundamentals of Urban Runoff Management*: 1994.

tude of factors affect biological well being, many of which are, of course, influenced by human activities. (See Figure 2.8) Performing a “biological community assessment,” or “biological monitoring,” on a watershed is recognized as a reliable indicator of water quality and the general health of a stream. Biological monitoring is also a particularly good screening tool when deciding where to target resources. If the biological community assessment indicates good stream health, or the presence of endangered or threatened species, the watershed planner may wish to implement more prevention style nonstructural BMPs. (See sidebar for more information on how to locate critical habitat or endangered species.) Likewise, evidence that the watershed is highly impaired may warrant further investigation to the root cause or that resources be diverted to a different watershed altogether.

The general health of a stream can be measured by evaluating the biological populations and diversity of species. Insects and fish, because they represent a wide array of species, are particularly good for conducting a biological assessment. For example, the presence of Mayfly nymph in a stream generally indicates good water quality (See Figure 2.9).[11]

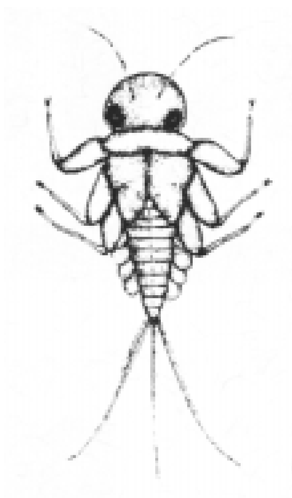


FIGURE 2.9
Mayfly Nymph

A major benefit of biological monitoring is that it can be easily performed by individuals, communities, environmental groups, and school groups without the need for expensive equipment. Because monitoring requires that someone physically go out to a stream site, individual monitors can play an important role in alerting officials to problems in local streams and yet unidentified pollution sources (See Appendix 2.2 for an example of a volunteer monitoring form).

Some other advantages to biological monitoring cited by the Terrene Institute include:

Obtaining Biological Data from Virginia’s Fish and Wildlife Information Service

The Virginia Department of Game and Inland Fisheries (VDGIF) maintains several biological databases which may be useful in identifying sensitive watersheds or stream reaches or the presence of endangered or threatened species. Databases include:

Breeding Bird Atlas – A cooperative project between VDGIF and the Virginia Society of Ornithology that evaluated the status and distribution of breeding birds in the Commonwealth.

Breeding Bird Survey – An ongoing cooperative program with the main goal of estimating population trends of birds that nest in North America north of Mexico and that migrate across international boundaries.

Biota of Virginia – Species Information System – A Virginia-specific information system that contains a variety of information on over 1,300 faunal species.

Collections – A database originally developed in 1991 for storing and reporting information provided by researchers under the Scientific Collection Permit program and expanded to include specific location data from miscellaneous reports, staff field activities, follow-up of the Breeding Bird Atlas project, and data from VDGIF’s warmwater stream survey, JFISH (Jenkins Fish) database, and HERPS database.

Waterbirds – Colonial Waterbird Database – Contains information on the distribution, abundance, and habitats of Virginia’s breeding water bird species.

Coldwater Stream Survey – A trout stream survey containing biological and physiochemical data about each classified stream reach or specific collection location.

Databases may be queried by geographic region, locality, by point and radius, or by stream reach. VDGIF maintains theses filed in Richmond. They are also available via the Department’s Fish and Wildlife Information On-Line Service.

Requests for information should be directed to:

FWIS Coordinator
Virginia Department of Game and Inland Fisheries
4010 West Broad Street
Richmond, Virginia 23230
(804) 367-1000

- Biological communities reflect overall ecological integrity.
- Over time, biological communities integrate the effects of different stressors, providing a measure of fluctuating environmental conditions.
- By assessing the integrated response to highly variable pollutant inputs, biological communities provide a practical approach for monitoring runoff source impacts and the effect of BMPs.
- The public is generally interested in the status of biological communities as measures of environmental health.
- Biological communities offer a practical way to evaluate habitat degradation typically associated with urban runoff discharges.(10)

Biological monitoring can be relatively simple or fairly complex depending on the overall purpose of the assessment. The U.S. EPA has developed a series of protocols which may be used as the basis for the collection of biological communities and comparison. In general, a more simple assessment is known as a "stream quality survey" (see Appendix 2.2). A more detailed assessment (which examines a broader, and more detailed range of indicator species and subspecies) is known as a "rapid bioassessment." More stringent training of volunteer water quality monitors is usually required to conduct a rapid bioassessment.

Determining if there is a Water Quality Problem

The basis for determining the extent to which a watershed has been compromised as a result of human activity is based largely on comparison. This comparison is dependent on selecting an ecoregion "reference site" that allows one to approximate attainable quality by measuring the physical, chemical, and biological quality of uninfluenced streams draining the reference watershed.

According to the U.S. EPA, reference sites should be selected according to the following criteria.

- Specify environmental characteristics affecting water quality.
- Map areas that share similar characteristics.
- Identify watersheds from within those areas.
- Eliminate watersheds where access is prohibited.
- Eliminate watersheds affected by human influences. Since this will likely leave an insufficient number of watersheds, add those subject to the least human influences.
- Verify the site's suitability to ensure the accuracy of mapped information. Make use of a local expert.
- Collect physical, chemical, and biological data to generate reference data that define the range of regionally achievable quality.

Biological community monitoring will fail if proper training is not provided. Additionally, it is important, from a comparative standpoint, that data is collected in a similar manner. The U.S. EPA has developed a set of protocols, known as the "rapid bioassessment protocols," as common guidance for collecting biological data. *Rapid Bioassessment Protocols for Use in Streams and Rivers* (U.S. EPA, 1989)(12) contains more comprehensive discussion of this topic.

In Virginia, biological monitoring training, coordination, and information can be obtained from the Izaak Walton League's U.S. EPA approved Save Our Streams (SOS) program at:

Izaak Walton League
707 Conservation Lane
Gaithersburg, Maryland 20878
(301) 548-0150

The Izaak Walton League has State and regional coordinators in Virginia for the Save Our Streams Program.

▶ Potential Pollution Assessment

Different pollutant types, sources, and levels are associated with different urban land types and human ac-

Table 13. **Fuels and Equipment Characteristics: 1990**—Con.

[Data based on sample and subject to sampling variability, see text. For definitions of terms and meanings of symbols, see text]

State County County Subdivision Place		Percent with—						
		House heating fuel					Vehicles available	
	All occupied housing units	Utility gas	Bottled, tank, or LP gas	Electricity	Fuel oil, kerosene, etc.	Other or none	None	1
Charlotte County—Con.								
Roanoke district	733	–	3.7	12.5	43.4	38.4	4.1	32.2
Charlotte Court House town (pt.)	58	–	1.7	32.8	43.1	22.4	5.2	22.4
Phenix town	113	–	7.1	22.1	50.4	20.4	4.4	28.3
Walton district	973	–	4.9	23.7	43.3	28.1	11.3	28.6
Charlotte Court House town (pt.)	69	–	–	11.6	55.1	33.3	17.4	24.6
Keysville town	345	–	4.5	22.4	54.3	18.8	13.9	35.5
Chesterfield County	73 441	17.2	1.4	59.9	17.3	4.2	2.8	34.0
Bermuda district	12 131	18.8	2.6	44.8	28.8	4.9	6.4	32.8
Bellwood CDP	2 434	17.5	3.7	30.3	41.3	7.4	12.4	40.6
Bensley CDP (pt.)	1 796	8.1	1.2	54.6	34.9	1.3	8.1	47.2
Chester CDP (pt.)	4 623	14.7	2.6	50.6	28.5	3.7	4.7	24.0
Clover Hill district	18 631	12.6	.6	72.9	11.1	2.8	1.2	30.6
Dale district	12 965	19.3	1.1	59.7	17.0	3.0	2.3	26.5
Bensley CDP (pt.)	368	21.2	4.6	41.8	30.2	2.2	–	42.9
Matoaca district	14 075	8.3	2.7	65.4	14.9	8.7	3.7	23.1
Chester CDP (pt.)	882	12.0	.6	71.1	11.1	5.2	11.9	30.7
Ettrick CDP	1 455	10.8	3.1	57.0	24.9	4.1	8.8	38.6
Midlothian district	15 639	27.7	.5	51.1	18.4	2.4	1.7	19.8
Bon Air CDP	6 062	14.6	.1	47.6	35.7	2.0	2.9	26.2

FIGURE 2.10

Sample Datasheet for 1990 U.S. Census Data

Census data, such as that shown above, can be used to link what types of uses within a watershed may cause a particular pollution problem.

tivities. An analysis of population characteristics and land uses can aid in locating or preventing actual or potential sources of pollution in the urban environment.

Readily available tools which can be used to aid in this type of analysis include the following.

- **U.S. Census data** – U.S. Census data contains a vast array of information which can provide clues to potential sources of pollution. For instance, Census data provides information on the age of housing and the type of heating used for housing. A Census Block with a preponderance of older housing fueled by oil indicates that aging fuel tanks may pose a threat to local water quality (see Figure 2.10).

  Census data is also important in a number of other ways including the identification of potential language and cultural barriers. For instance, if a particular area is identified as having a high concentration of Spanish-speaking residents, the program manager should consider the use Spanish in any public education initiative.

- **Local land use maps** – Different land uses are known to produce different levels of pollutants in runoff. (See Appendix 2.3 for examples.) Much of this has to do with the level of imperviousness associated with the land use, but it also has to do with the type and level of human activities associated with the use.

  Because many nonstructural BMP techniques involve changing human behavior, it is important to take into account who is likely to live where. Additionally, many nonstructural BMP techniques require space for implementation. Local land use maps provide a good indication of the density of urban development and therefore the appropriateness of a particular BMP technique.

- **Department of Environmental Quality, Water Division, underground storage tank databases** – DEQ underground storage tank (UST) files, including leaking underground storage tank (LUST) files, provide a wealth of information on potential "hot spots" for leakage into the environment. These files should be analyzed to see where aging USTs are concentrated and where LUSTs have already been identified.

- **County/city health department records on failing septic systems** – County and city health departments keep records on the location and age of septic systems. Again, an analysis of these files allows the watershed manager to detect "hot spots" where there is the potential for leakage into the environment. Property owners in these areas may be targeted for public education efforts aimed at preventing septic failure.

TABLE 2.6

Sample Potential Pollution Sources Identification Matrix for use in a Directory Search

POLLUTANT OF CONERN	POTENTIAL SOURCE CATEGORY	CATEGORY SUBSETS
SOCs	Arborists	Tree Service
	Distribution (Agr.)	Agricultural Chemicals Agricultural Supply Stores Garden Centers
	Distribution (Commercial/Home)	Hardware Stores Insecticides Lawn and Garden Supplies Seeds and Bulbs Plants (Retail and Wholesale)
	Exterminators	Pest Control Pest Control Equipment and Supplies
	Institutional	Government Facilities Hospitals Schools
	Landscape/Lawn Maintenance	Landscape Contractors Lawn Maintenance Companies Weed Control Services
	Wood Preservation	Lumber Yards
	Marinas	Marinas
	Nurseries	Nursery
	Parks and Recreation	Golf Courses (Public and Private)
	Pool Maintenance	Pool Maintenance Pool Supplies
	Sod	Sod Farms Sodding Services

(In Northern Virginia, NVPDC has conducted two systematic septic studies; within the Occoquan watershed and in the Coastal Plain. Refer to the Chapter 2 bibliography for more information.)

- **Local and State directories and databases** – Many businesses, industries, and institutions are associated with particular NPS pollutants. Identifying these businesses and industries according to their potential NPS pollution hazard through State and local directories allows the stormwater manager to cost-effectively target business/industry-specific NPS pollution through public education, etc.

  An example of this type of potential pollution assessment was conducted for the Occoquan Reservoir watershed (Northern Virginia) in 1992.[5] The pollutants of concern in this instance were SOC's. A search of businesses, industries, and institutions that were potentially responsible for the application, storage, or manufacture of SOCs (see Table 2.6) revealed the presence of 210 confirmed and 102 potential sources of SOCs within the watershed.

  Databases used for the search included (1) Office of Pesticide Management Business License Lists, (2) Cooperative Extension Office Business Lists, and (3) the Telephone Yellow Pages. Once potential sources were identified, their locations were mapped and a pollution prevention brochure was sent to each.

These tools, among others, can be used to predict where pollution may already exist or has the potential to exist in the future. (Many sites using toxics are required to have separate nonpoint source NPDES permits.) This provides the watershed manager with the opportunity to prevent the pollution through nonstructural BMP techniques.

Many of the tools cited above are used to screen the appropriateness of using one nonstructural technique over another. To this extent, these tools are discussed in more detail in Chapter 3.

SECTION 2.4 ....

Controlling NPS Pollution through Regulation

In many instances, the need to control particular pollutants under specific circumstances has been well established. To account for this, federal, State, and local governments have implemented a wide network of programs and regulations to address rising public concern about the affects of NPS pollution on the environment.

A brief overview of these programs is useful since not all programs are implemented or required State-wide. In addition, programs differ their degrees of flexibility in implementation. Some regulations and programs address only certain types of NPS pollution. The Chesapeake Bay Preservation Act, for instance, applies specifically to the control of nutrients. Other regulations, such as the federal National Pollutant Discharge Elimination System (NPDES) Stormwater Permit Program, address a wider breadth of nonpoint source pollutants.

▶ Federal NPS Pollution Regulations

At the federal level, NPS pollution is regulated by the U.S. EPA under the National Pollutant Discharge Elimination System (NPDES) Stormwater Permit Program. In Virginia, this program is administered by Department of Environmental Quality, Water Division, under the Virginia Pollutant Discharge Elimination System (VPDES) Stormwater Permit Program.

The 1972 amendments to the federal Water Pollution Control Act prohibit the discharge of pollutants into the waters of the United States unless the discharge is authorized under a NPDES permit. The initial thrust of this program was to reduce point source discharges of pollution from industrial processing plants and municipal wastewater treatment plants. However, recognizing the need to comprehensively address the control of nonpoint source pollutants in addition to point source pollutants, Congress amended the Clean Water Act in 1987 to require phased NPDES requirements for municipal stormwater discharges.

Under the Act, an NPDES permit may be issued to a municipal government or a jurisdiction on a system-wide basis if:

(1) the municipality implements enforceable measures to prohibit non-stormwater discharges to the stormsewer; and,

(2) the municipality demonstrates that it has implemented stormwater management controls to reduce the discharge of pollutants to the *maximum extent practicable* (MAP).

The NPDES regulations require a two-part application process for discharges from systems serving large (500,000 or more people) or medium (100,000 to 500,000 people) municipalities. In general, Part I of the application requires identification of pollutant sources, compilation of existing precipitation and water quality data, and a field screening analysis for illicit connections and illegal dumping.

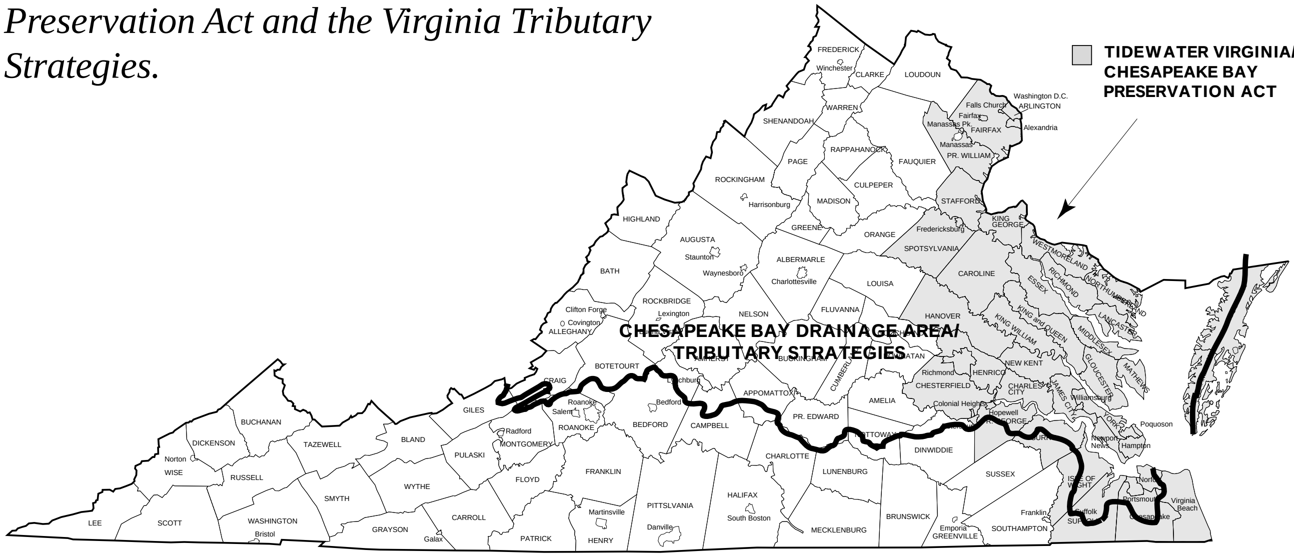
The core component of Part II of the application is the municipality's proposed stormwater management program. The program, in order to satisfy NPDES requirements, must include:

- a description of structural and source control measures, including maintenance activities and schedule;
- a description of planning procedures including a comprehensive master plan;
- a description of practices for maintaining public roadways (e.g., deicing practices) that discharge to storm sewers;
- a description of procedures that assure that flood management projects assess the impact on water quality and are retrofitted if necessary;
- a description of a monitoring program for runoff from operating or closed landfills; and,
- a description of programs, including public education, that will reduce the runoff of pesticides and fertilizers.

Also required under Part II are proposed programs to detect illicit discharges into the municipal stormsewer system as well as a proposed system to administer municipal stormwater permits for the discharge of stormwater from industrial facilities to the municipal

FIGURE 2.11

Physical Extent of the Chesapeake Bay Preservation Act and the Virginia Tributary Strategies.



separate stormwater system. Finally, the applicant must describe plans to implement and maintain structural and nonstructural best management practices to control pollutants throughout the storm drainage area.

▶ The 1983 Chesapeake Bay Agreement

The 1983 Chesapeake Bay Agreement, fostered through the U.S. Environmental Protection Agency, established a cooperative effort among Virginia, Maryland, Pennsylvania, and the District of Columbia to improve conditions in the Chesapeake Bay. The most widely known result of this agreement in Virginia is the Chesapeake Bay Preservation Act. Enacted in 1987, the Act is implemented and enforced through local ordinances. For a number of reasons, phosphorus removal was chosen as the keystone pollutant from which performance criteria are measured.

Also in 1987, the agreement was amended to include a goal of reducing the flow of nutrients into the Bay by 40 percent between the base year of 1985 and 2000. This initiative, known as Tributary Strategies, focuses on both nitrogen and phosphorus reduction. Figure 2.11 shows areas of Virginia subject to the Chesapeake Bay Preservation Act and the Tributary Strategies.

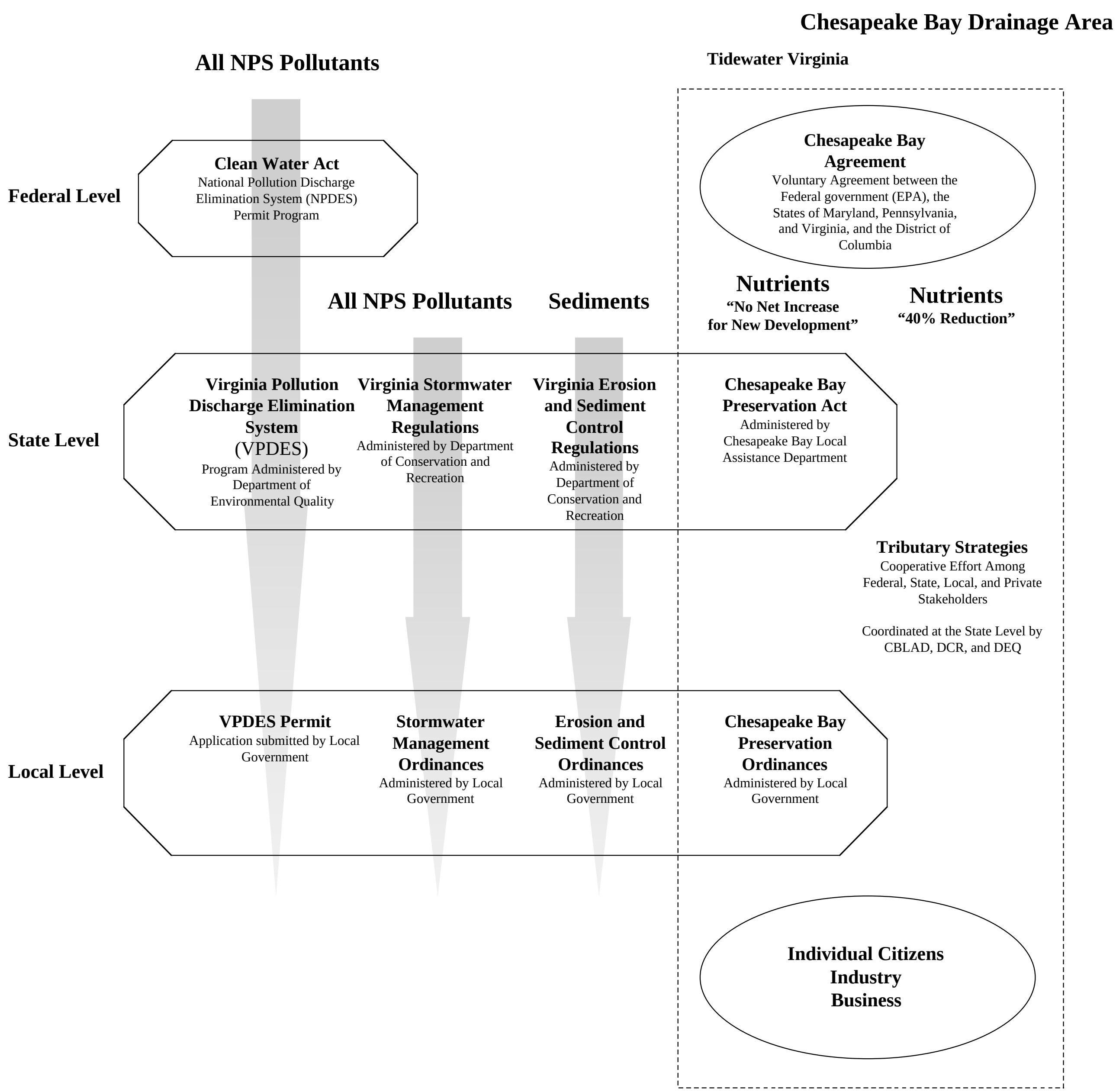
Chesapeake Bay Preservation Act

The Virginia Chesapeake Bay Preservation Act specifically addresses NPS pollution contributed to the Bay from the Tidewater portion of its Virginia watershed. The Act is administered through the Chesapeake Bay Local Assistance Department (CBLAD) and is implemented through 84 affected local governments.

The Regulations specify eleven performance criteria that apply to proposed development activities within sensitive lands designated by local governments as Chesapeake Bay Preservation Areas (or CBPAs). Local governments must designate two components of the CBPAs: Resource Protection Areas (RPAs) and Resource Management Areas (RMAs). RPAs include tidal shores, tidal wetlands, nontidal wetlands contiguous to tidal wetlands, other lands deemed to be significant in the protection of State waters, and a 100-foot buffer landward of these features, as well as along tributary streams. Development in the RPA is limited to water dependent facilities or the redevelopment of

FIGURE 2.12

Major NPS Pollution-Related Regulations



Source: NVPDC: 1996.

existing facilities, provided these activities adhere to the performance criteria specified in the Regulations.

RMAs are land types that, if improperly used or developed, have a potential for causing significant water quality degradation or diminishing the functional value of the RPA. The following categories must be considered by a locality for inclusion in the RMA: floodplains; highly erodible soils, including steep slopes; highly permeable soils; nontidal wetlands not included in the RPA; and other lands necessary to protect the quality of State waters.

The performance criteria have several objectives, two of which are the prevention of a net increase (based on average land cover conditions) in NPS pollution from new development, and the achievement of a 10 percent reduction in NPS pollution from redevelopment. General performance criteria for all development includes minimizing impervious cover, maximizing indigenous vegetative cover, and minimizing the construction footprint (area of land disturbance), among others.

Localities implement and enforce the program through their land use management tools such as the comprehensive plan, zoning ordinance, and subdivision ordinance.

VIRGINIA TRIBUTARY STRATEGIES

The Chesapeake Bay Agreement was amended in 1987 to include a goal of reducing the flow of controllable nutrients (phosphorus and nitrogen) to the Bay by the year 2000 from a 1985 baseline. Meeting this goal requires addressing both point source and nonpoint sources of nutrients from agricultural, forestal, and urban land uses.

The idea behind Tributary Strategies is to address water quality problems on a watershed basis as opposed to individual development sites. While individual jurisdictions are expected to play a major role in its implementation, the purpose of Tributary Strategies is to recognize that the protection of water resources requires a comprehensive, and flexible, approach and that some areas are controlled more cost-effectively than others.

On the State level, coordination of Tributary Strategies is a cooperative effort among the Department of Conservation and Recreation (DCR), the Department of Environmental Quality (DEQ), and the Chesapeake Bay Local Assistance Department (CBLAD). The DCR is the lead agency in the State regarding NPS pollution while the DEQ is the lead agency regarding point source pollution control. While they overlap, the Tributary Strategies covers a more extensive geographic area than the existing Chesapeake Bay Act boundaries.

Achieving a reduction in existing NPS pollution is a much greater challenge than controlling runoff from new development. The concept of controlling existing development is referred to as “retrofit.” Retrofit may be accomplished either structurally (through the establishment of regional BMPs or by modifying existing flood control facilities) or nonstructurally (through the implementation of source reduction programs such as public education, or through the implementation of vegetative BMPs such as buffer strips along stream banks).

▶ Other State Regulations

Two other major State regulations address the control of NPS pollution. The Virginia Stormwater Management Act of 1989 addresses primarily post-development stormwater volume control concerns although recently revised Regulations also incorporate the need for comprehensive water quality control. The Erosion and Sediment Control Law addresses the control of a particular type of NPS pollution – sediments – during development.

Additionally, a number of more specific, and lesser known, regulations and programs (outlined in Table 2.7) address various aspects of NPS pollution control.

STORMWATER MANAGEMENT ACT

In 1989, the General Assembly adopted the Stormwater Management Act enabling the establishment of comprehensive stormwater management programs. The Department of Conservation and Recreation adopted the Virginia Stormwater Management Regulations in 1990. The State stormwater management program addresses the permanent changes in storm-

TABLE 2.7

Virginia Urban NPS Pollution Management Measures

VIRGINIA REGULATION/ PROGRAM		New Development	Watershed Protection	Site Development	Construction Site E&S Control	Construction Site Chemical Control	Existing Development	New Onsite Disposal Systems	Operating Onsite Disposal Systems	Pollution Prevention	Developing Roads and Highways	Bridges	Construction Projects	Operation and Maintenance	Runoff Systems
Stormwater Management Act	DCR	■	■								■	■		■	■
Erosion and Sediment Control Law	DCR			■	■	■					■	■	■	■	
Chesapeake Bay Preservation Act	CBLAD	■	■	■	■		■	■	■		■	■	■	■	■
Sewage Handling & Disposal Regulations	VDH							■	■	■					
Virginia Department of Transportation	VDOT										■	■	■	■	
Nutrient Management Program	Various									■					
Pesticide Regulations	VDACS					■									
Solid Waste Management Regulations	DEQ-Waste					■									
Recycling Programs	DEQ-Waste					■				■					
Pollution Prevention & Waste Reduction Programs	DEQ									■					
Water Protection Permit Regulations	DEQ-Water			■							■	■			
Oil Spill Contingency Plans	DEQ-Water					■									
UST Regulations	DEQ-Water					■									
Virginia Marine Resources Commission	VMRC			■							■	■			

Adapted by NVPDC from Virginia Department of Conservation and Recreation, *Virginia Threshold Review Report – Review of Programs Applicable to Section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990*: May, 1994.

DCR = Department of Conservation and Recreation; DEQ = Department of Environmental Quality (Water or Waste Divisions); CBLAD = Chesapeake Bay Local Assistance Department; VDH = Virginia Department of Health; VMRC = Virginia Marine Resources Commission; VDACS = Virginia Department of Agriculture and Consumer Affairs.

water runoff that occur as a result of land development. The Regulations specify minimum technical and administrative requirements for local programs and State agency projects and are applicable to development projects that disturb one acre of land or more. The technical requirements include water quality and water quantity control criteria.

These Regulations require that local stormwater management ordinances include specific elements, including maintenance of post-development peak runoff rates at or below pre-development runoff rates for regulated development activities, and minimum technical criteria to control NPS pollution and localized flooding. Localities may reduce the one-acre threshold and may adopt criteria more stringent than the minimum requirements contained in the Regulations. Localities implement the program through the adoption of local ordinances.

Erosion and Sediment Control Law

The Erosion and Sediment Control Law of 1988 deals primarily with the control of erosion and sediment during the development process. However, many of the techniques required, such as the preservation of buffer strips along adjacent properties, may be applied as post-construction vegetative BMPs if proper care and maintenance techniques are followed to ensure that these buffers are not irreversibly degraded during the construction process.

The Virginia Erosion and Sediment Control Law is codified as Title 10, Chapter 5, Article 4 of the Code of Virginia. Section 10.1-562 addresses local erosion and sediment control program requirements which are to be consistent throughout the Commonwealth. The Regulatory program is implemented State-wide through 171 local erosion and sediment control programs and the Department of Conservation and Recreation. Minimum criteria, standards and guidelines are established in the *Virginia Erosion and Sediment Control Handbook*. The Regulations are applicable to land development projects disturbing 10,000 square feet or more, except in locally designated Chesapeake Bay Preservation Areas, where the Regulations are applicable at 2,500 square feet of disturbance.

As part of local program, each person engaging in land-disturbing activities must submit an erosion and sediment control plan prior to undertaking these activities. The local authority then must provide periodic inspections of the land-disturbing activity and may require monitoring and reports from responsible persons. General criteria for controlling erosion and sediment under this legislation includes measures for the stabilization of soil stockpiles and graded areas, as well as requirements for the establishment of permanent vegetation, for the preservation of buffer strips along adjacent properties, and for the installation of sediment traps, basins, diversion, and terraces. The general criteria also include stormwater management criteria for controlling off-site erosion.

▶ Local NPS Pollution Control Programs

Most federal and State nonpoint source pollution control programs are implemented at the local level. This is true for the federal NPDES program, the Chesapeake Bay Preservation Act, the Erosion and Sediment Control Law, and the Stormwater Management Act.

However, many localities have gone above and beyond federal and State initiatives and have implemented their own NPS pollution control programs, primarily in the form of source reduction and pollution prevention programs. Local nonstructural BMP programs include public education campaigns, tree ordinances, implementation of integrated pest management programs, proffers to maintain vegetative buffers along stream corridors, riparian reforestation, and various site plan requirements. Most of these programs are discussed further in this Handbook.

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◆ ◆ ◆

PREPARING AN INTEGRATED WATERSHED MANAGEMENT PLAN USING STRUCTURAL AND NONSTRUCTURAL TECHNIQUES

Chapters 2 through 5 provide information on how to implement nonstructural BMPs to reduce NPS pollution. It is easy to become focused on a particular site, source of pollution, or BMP technique. However, a prerequisite to planning and implementing a successful integrated watershed management plan using structural and non-structural techniques is to develop a program outline through a watershed assessment. Each chapter and section in this Handbook, in order for it to serve as an effective tool, should be viewed as a piece of a larger puzzle and not as an ends in themselves.

A watershed assessment enables the planner to determine the pollutants of greatest concern, visualize their pathways and sources, estimate each source's relative contribution, and make reasonable assumptions regarding the effectiveness of potential BMP techniques or combinations of BMP techniques. From this information, it is possible for the planner to map out alternative NPS pollution prevention and control scenarios, using combinations of structural and nonstructural techniques, to arrive at a cost effective and environmentally sound watershed management plan.

The graphic on the following page illustrates the importance of a watershed assessment. Because NPS pollution enters the water by countless means, it is necessary to constantly, and systematically evaluate and reevaluate a watershed for the types of nonstructural and structural BMPs that will most effectively address different sources of NPS pollution.

While each watershed is unique, the following provides some guidance for how to prepare an integrated watershed management plan.

1. Determine:

A. The pollutant(s) of concern (nitrogen, phosphorus, pathogens, toxics, heavy metals, petroleum, etc.) affecting water quality.
B. The regulatory standard or target by pollutant.
C. The total jurisdictional/watershed/site pollutant load and the controllable/non-controllable fraction of that load.
D. The pollutant budget (expressed as controllable load minus the target reduction).

2. Assess/Estimate Pollutants by Source

Assess spatially and temporally the sources of pollutants within the jurisdiction. Estimate the extent or level of pollution (for example, lbs/acre/year) from each of these sources. Make a planning scale map of the watershed showing areas of concern, whether pollutants are as a result of land use or are from point sources, etc.

3. Field Screen for Pollutant Sources Based on Known Pollutants of Concern

Based on data gathered on sources of pollutants or pollutant "hot spots," field screen the area for sources of pollution. If appropriate, previously nonpoint sources of pollution may be treated as point sources and responsibility for pollution prevention or reduction may be assigned.

4. Screen Each Watershed for Applicable BMP Technologies

Use the criteria outlined in Chapter 3 and elsewhere to determine which techniques are applicable to the watershed of concern. Criteria may include: developed versus developing land; public versus private funding; site, watershed, or jurisdiction oriented; physical constraints; and others.

5. Rank Available Technologies

Rank technologies by presumed efficiencies and by the level to which the total controllable pollutant load is covered by each technique.

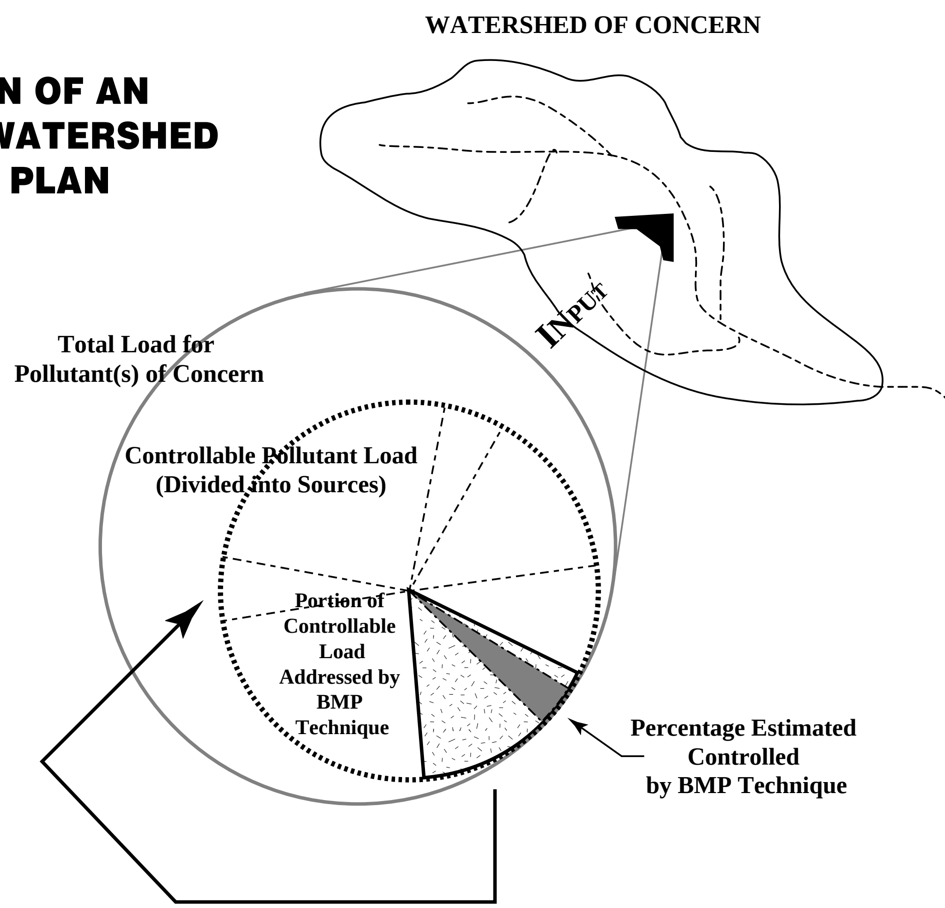
6. Conduct Sketch-Planning Level Scenarios

Conduct sketch-planning level scenarios using combinations of feasible techniques to determine maximum reduction and maximum cost-effectiveness.

7. Review Screening Outcomes

Review screening outcomes to determine if changed conditions (e.g., strong marketing for public education techniques) would improve pollutant reduction.

VISUALIZATION OF AN INTEGRATED WATERSHED MANAGEMENT PLAN



Systematically reassess what techniques will address the remaining sources and to what degree. Combine structural and nonstructural techniques as appropriate to achieve NPS pollution reduction goals.

3. CHOOSING APPROPRIATE NONSTRUCTURAL PRACTICES

Criteria for selecting nonstructural BMPs will be similar to, but have distinct variation from, structural, site-specific BMPs. Typically, criteria for selecting structural BMPs include assessing a site for physical constraints (space, soil suitability, etc.), watershed area to be served, maintenance and cost considerations, and required pollutant removal efficiency.

"**Screening**" a site for these considerations is still important in assessing the appropriateness of many nonstructural practices. However, implementing a nonstructural BMP program more often involves "**targeting**," rather than screening. Under many water quality regulations, a developer need only to consider pollution (and usually phosphorus and sediments) generated from that site. This approach is essential to maintaining overall water quality during watershed development, and certain nonstructural measures can be an important part of this strategy.

However, the highly flexible nature of nonstructural BMP techniques allows the watershed planner to holistically review a watershed for the presence of NPS pollution "hot spots" and for opportunities to control NPS pollution from older development that can not as efficiently be controlled through structural measures. Then, depending on the types of pollutants needing to be controlled, and their probable sources, a nonstructural BMP program can be organized.

Choosing an appropriate set of nonstructural BMPs, in compliment with a structural program, can be an involved, and ongoing process. However, the potential rewards for successful implementation can be far reaching and significant.

3. CHOOSING APPROPRIATE NON-STRUCTURAL APPROACHES

Once nonpoint source pollution problems are identified using the tools in Chapter 2, it is time to screen the universe of available tools for a technique, or combination of techniques, that will effectively and efficiently mitigate the problems. Applicable tools discussed in this Handbook include:

- **Vegetated Buffer Areas**
- **Vegetative Filter Strips**
- **Grassed Swales**
- **Bioretention**
- **Stormwater Wetlands**
- **Street Sweeping**
- **Land Use Controls**
- **Watershed Protection During Site Design**
- **Urban Reforestation and Riparian Buffer Restoration**
- **Water-Wise Landscaping Strategies**
- **Public Education**
- **Storm Drain Stenciling**
- **Animal Waste Controls**
- **Lawn and Garden Care Education**
- **Reducing the Generation of Automotive Pollutants**

Site developers may find that they only need to implement one or two of these techniques to meet applicable water quality and NPS pollution regulations. On the other hand, a *watershed manager* will find that a combination of techniques often serves to most effec-

FIGURE 3.1
Factors in Selecting an Appropriate Nonstructural BMP

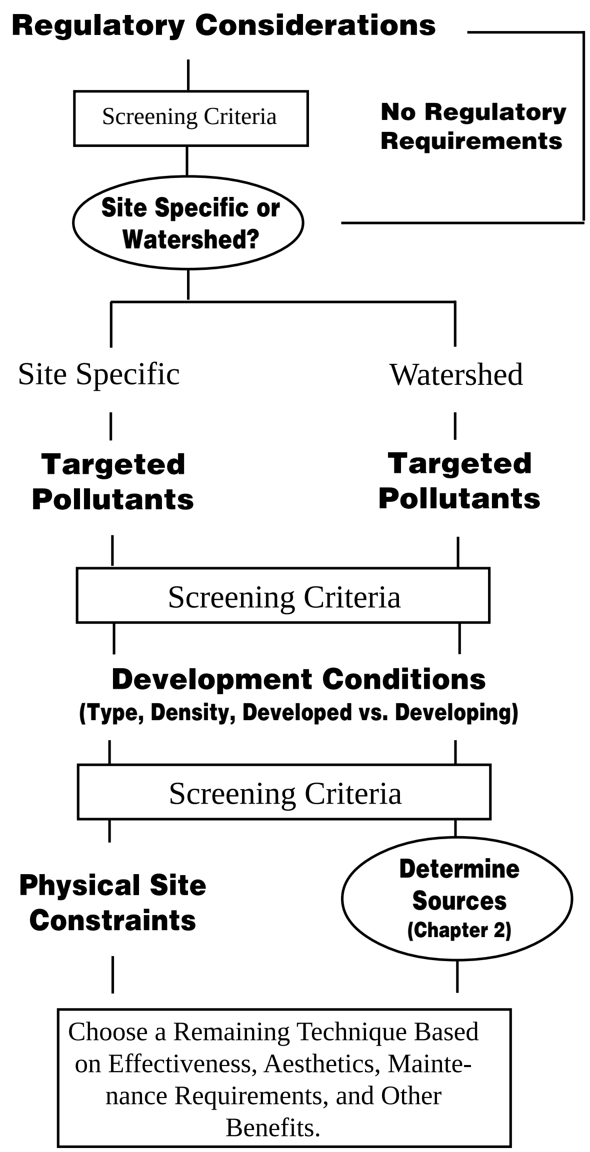


FIGURE 3.2
Screening versus Targeting BMP Techniques

A

Screening Approach – Onsite Control of Nutrients and Sediments

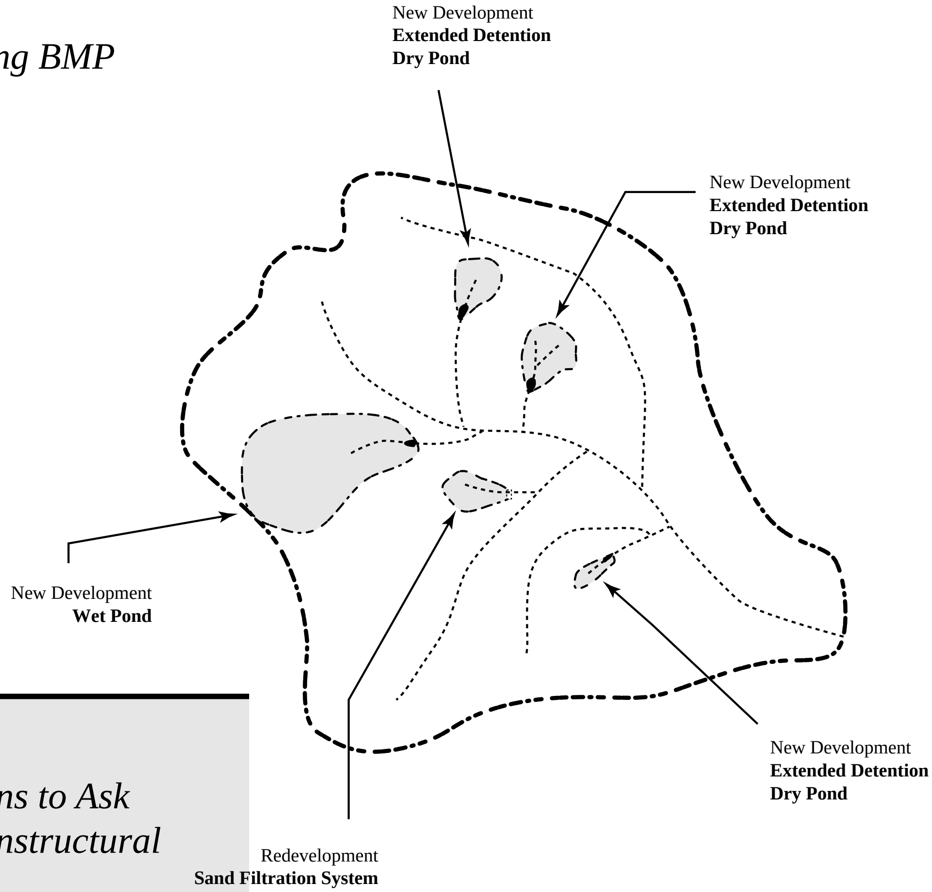


TABLE 3.1
Four General Questions to Ask When Considering Nonstructural BMPs

- Are the proposed BMPs effective enough?
- How much are the responsible parties likely to resist adopting the recommended BMPs?
- How likely is it that the BMP facility/program will be properly maintained once it is adopted?
- What other environmental costs or benefits may result from the adoption of the BMPs?

Source: The Conservation Foundation and National Audubon Society. *Controlling Nonpoint Source Water Pollution – A Citizen's Handbook*: 1988.

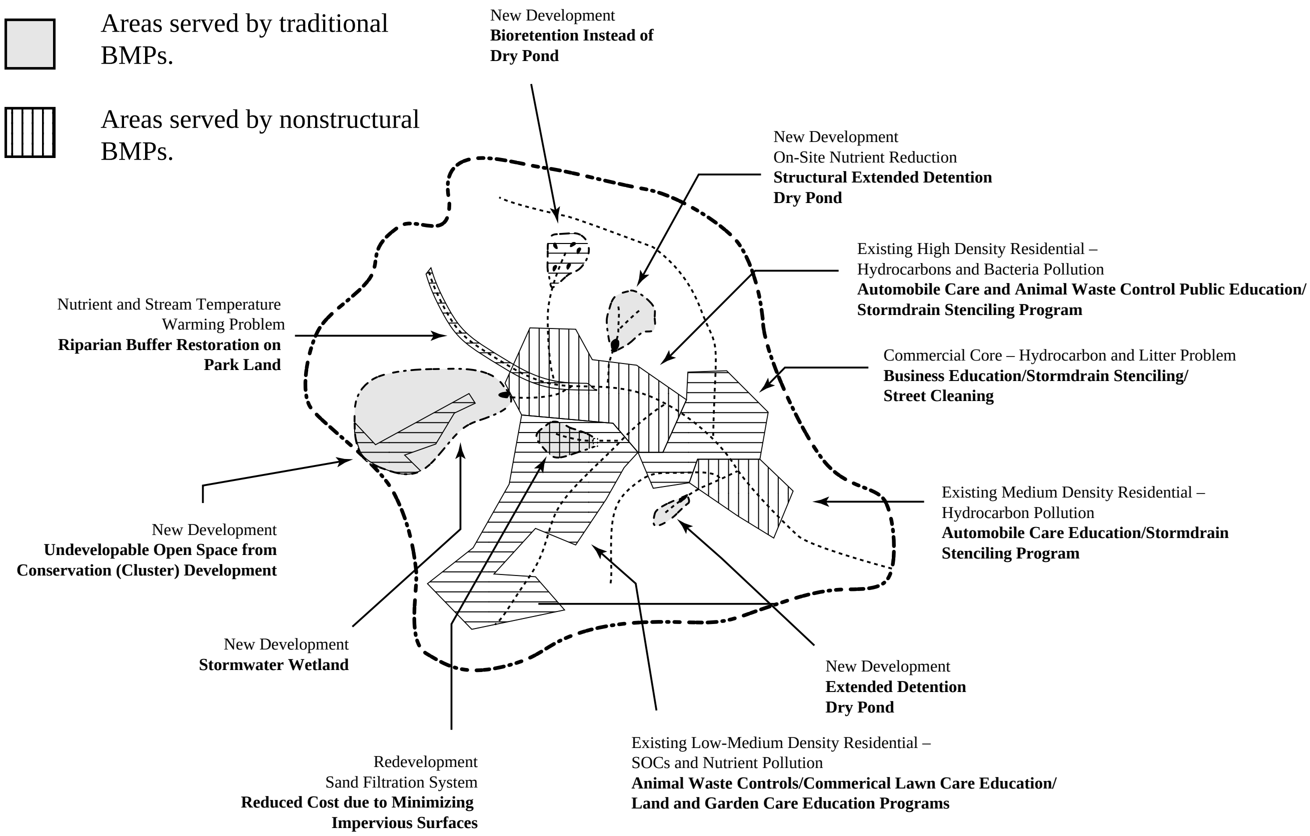
tively reduce the impacts of NPS pollution on the environment.

Selecting an appropriate nonstructural technique need not be a complicated process. However, some investigatory work is required for them to be defended in a plan and to assure that NPS pollution reduction goals and requirements are met. It is important to determine in advance whether the goal is to meet the requirements of a regulation, attack an overall watershed water quality problem, or address a particularly acute pollution problem of local concern.

A good general framework for selecting appropriate nonstructural techniques has been developed by the Conservation Foundation and National Audubon So-

B The Targeting Approach to an Integrated NPS Management Plan – Watershed-Wide and Onsite Control of Pollutants of Priority Concern

Key:



Source: NVPDC, 1996.

ciety and is outlined in Table 3.1. The watershed planner or site developer should be able to answer each of these questions during the BMP selection process.

Chapter 3 is organized in the following manner.

- **Regulatory Requirements and their Effect on Choosing BMP Techniques**
- **Selecting Techniques Based on Targeted Pollutants**
- **Selecting Techniques to Suit Density and Development Conditions**
- **Screening for Environmental Benefits and Public Concerns**
- **Summary of Targeting Criteria**
- **General Criteria for Selecting an Appropriate Public Education Program**
- **Screening Site-Specific BMPs Based on Physical Suitability**

The first question that needs to be asked is: "For what purpose is this nonstructural BMP technique being established." The immediate answer is to improve water quality; however, at this point in the screening process, **the more relevant answer relates to whether the BMP is being established to meet the requirements of an NPS pollution law, regulation, or ordinance, etc**. This subject is discussed in Section 3.1.

SECTION 3.1 ....

Regulatory Requirements and their Effect on Choosing BMP Techniques

If a nonstructural BMP is being considered to meet the requirements of a regulation, it is important to determine the degree of flexibility that is allowed in carrying out its mandate. Important considerations that will have a direct bearing on an appropriate nonstructural technique include:

- does the regulation require the **quantification** of pollution reduction;
- does the regulation require **site-specific compliance** from a developer or **jurisdiction-wide compliance** by the government; and,
- does the regulation focus on a **specific pollutant** or NPS pollution in general.

▶ Screening for Quantifiable Results

While some nonstructural techniques have established efficiencies (primarily vegetative controls), most pollution prevention techniques do not. This distinction does not necessarily reflect the effectiveness of a program; however, because some regulations require removal quantification, it may impact the applicability of certain techniques to meet regulatory requirements.

In order to receive credit for some nonstructural techniques, assumptions regarding their effectiveness would need to be made and defended. An effective pre- and post-project monitoring program could be useful in this regard.

▶ Site versus Watershed Compliance and Pollutants Targeted

It is important to recognize whether the regulation in question is aimed at site-specific compliance or jurisdiction-wide compliance and whether the regulation addresses a specific NPS pollutant or a broad range of NPS pollutants.

Some nonstructural techniques are more suited to site-specific applications (including vegetative controls, stormwater wetlands, watershed protection during site planning, and landscaping strategies), while others are more effective when implemented watershed-wide (including general land use controls, riparian reforestation, public education, animal waste controls, storm drain stenciling, reducing automotive generated pollutants, and street sweeping).

▶ The Impact of Chesapeake Bay Act and VPDES Requirements on BMP Screening

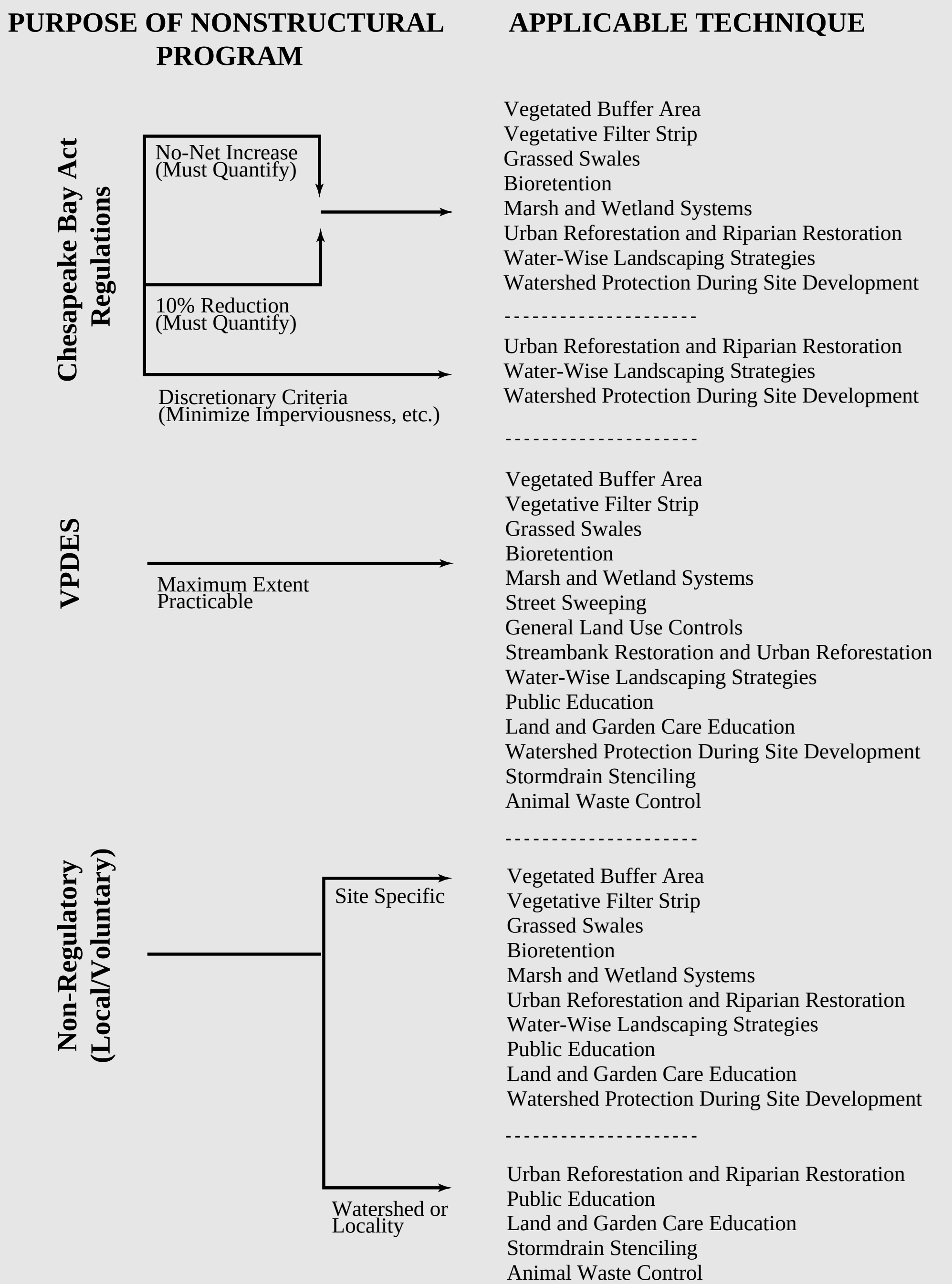
For the purpose of this Handbook, there are two State regulations/programs that have a direct bearing on screening nonstructural BMP techniques – the Chesapeake Bay Preservation Area Designation and Management Regulations (Chesapeake Bay Act regulations) and the Virginia Pollution Discharge Elimination System Permit Program (VPDES) under the federal Clean Water Act.

Figure 3.2 shows how regulatory requirements may affect the appropriateness of utilizing the nonstructural BMPs outlined in this Handbook.

CHESAPEAKE BAY ACT REGULATIONS

In general, meeting the Chesapeake Bay Act regulations require that a developer implement onsite NPS pollution controls. This is not always the case. Arlington County maintains a jurisdiction-wide NPS pollution prevention program as a means of meeting the requirements of the Act. Compliance with a State or locally implemented stormwater discharge permit (40 C.F.R. Parts 122, 123, 124, and 504, December 7, 1988) is also an acceptable alternative (see Section 4.2.8 of the Chesapeake Bay Preservation Area Designation and Management Regulations for additional details).

FIGURE 3.3
Regulations and their Impact on Screening Nonstructural BMPs



A similarly important screening criteria concerns *what* part of the Chesapeake Bay Act regulations are intended to be satisfied by the nonstructural technique. Under the regulations, nonstructural BMPs may be established to satisfy:

- the no-net-increase criteria for phosphorus from average land cover conditions as a result of new development;
- the 10% decrease criteria for phosphorus from a site as a result of redevelopment; and,
- the "discretionary" criteria of maximize vegetative cover, minimize impervious surfaces, and minimize building footprint.

While the first two criteria require nutrient removal calculations to demonstrate compliance, criteria three does not require removal quantification.

Techniques that Address Phosphorus Reduction as the "Keystone" Pollutant

The Chesapeake Bay Act regulations have designated phosphorus as the "keystone" pollutant. Therefore, any nonstructural measures selected to comply with the regulations must address phosphorus pollution.

Because phosphorus loadings from a site are calculated from the imperviousness of a site, any nonstructural BMP technique that effectively reduces impervious surface area (see Section 4.1) can be used to help meet the phosphorus reduction requirements of the Chesapeake Bay Act regulations.

Similarly, since most vegetative controls (Section 5.1) and stormwater wetlands (Section 5.2) are designed to filter and treat stormwater runoff from impervious surfaces, some localities may allow them to be proposed and utilized to meet the reduction requirements of the Chesapeake Bay Act regulations.

Some nonstructural techniques, for instance storm drain stenciling, control for the broad range of NPS pollutants that are washed into creeks and streams via the storm drain – including nutrients. This technique also controls for used oil, antifreeze, paints, plastics, paper, and pesticides. Other techniques which address phosphorus (as well as nitrogen) reduction include animal waste controls (Section 4.2.2) and lawn and garden care education programs (Section 4.2.3).

However, these latter nonstructural techniques, which rely on changes in human behavior for their effectiveness, do not presently have accepted nutrient reduction efficiencies, nor do they serve to reduce urban imperviousness. Therefore, while their implementation may reduce nonpoint sources of nutrients in a watershed, which may be demonstrated through long-term water quality monitoring, they are not generally applicable to meet *site specific* water quality goals.

▶ VPDES Requirements

The VPDES municipal stormwater permit program requires a comprehensive, jurisdiction-wide approach to NPS pollution and does not necessarily pertain to any single development site. Therefore, the implementing agency is given broad discretion in determining how to most effectively and efficiently place or implement nonstructural techniques throughout a watershed. Any combination of site-specific and watershed-wide measures may be implemented.

Furthermore, VPDES, for nonpoint source pollution, *uses a maximum extent practicable test* for compliance. In other words, it is not necessarily required that efforts be quantified. It is only necessary to document and demonstrate that the locality is controlling municipal stormwater discharges effectively and at a maximum level of effort to protect local water quality.

▶ Non-Regulatory/Local Programs

Localities that implement nonpoint source programs because they are "the right thing to do" are not beholden to quantifying results nor are they limited to a site or a particular watershed. Rather, a broad range of techniques may be used to protect water quality and to address identified pollution problems.

SECTION 3.2

Selecting a Technique Based on Targeted Pollutants

Determining what pollutants need to be controlled – either through a review of regulatory requirements (Section 2.4) or through the assessment process outlined in Section 2.3 – is an essential component of the screening process. Likewise, selecting nonstructural BMP techniques which are effective at controlling the identified pollutants is equally essential.

Traditional structural BMPs implemented to satisfy the requirements of the Chesapeake Bay Act regulations are generally designed to control for nutrients (and more specifically phosphorus) in the runoff. While it is assumed that other pollutants are also being removed, phosphorus is considered the "keystone" pollutant under the Chesapeake Bay Act regulations.

Many nonstructural techniques can be specifically designed to reduce nutrient pollution and some will effectively control the introduction of nutrient and/or non-nutrient nonpoint source pollutants. Still other techniques are designed to control NPS pollutants other than nutrients and may be ineffective at reducing nutrient NPS pollution

Major pollutant categories include nutrients, sediments, SOCs, bacteria, heavy metals, petroleum hydrocarbons, and solid waste (such as cigarette butts, plastic and glass bottles, paper waste, etc.). Table 3.2 provides a matrix that identifies nonstructural BMP practices according to the sources of pollutants controlled by each technique.

SECTION 3.3

Selecting a Technique to Suit Density and Development Conditions

Almost every watershed contains a mix of development density and type which will in turn affect the applicability of nonstructural BMPs. Similarly, most watershed areas have both developed and developing areas which contribute to NPS pollution. Therefore, it is important to screen techniques:

- In terms of whether the focus of the NPS pollution program is an **already developed** area or whether it is a **newly developing** area; and,
- In terms of the of **density** and type (residential, commercial, or industrial) of the targeted land use or uses.

The proactive converse to this approach is to look at different densities and stages of development within a watershed, identify potential pollutants, and implement practices to address them.

Developing versus Already Developed Areas

Developing areas provide considerably more opportunities to incorporate quantifiable land use-based and control-based structural and nonstructural BMPs into the landscape. Once a landscape is firmly established, room may not exist to implement these techniques, or public reaction to change may prevent their implementation. Fewer such constraints exist in newly developing areas where space can be set aside for the implementation of NPS pollution reduction measures.

In general, public education-style pollution prevention measures (Section 4.2) are the most applicable for "retrofitting" existing urban areas since they require no physical change in the landscape.

Street sweeping, as a control technique, is also highly applicable to existing urban areas and is often desir-

TABLE 3.2

Pollutants Controlled by Nonstructural BMP Techniques in this Handbook

Pollutants	Sources	Nonstructural BMP Techniques
Nutrients	▶ Soil particles from erosion	Landscaping strategies and *Virginia Erosion and Sediment Control Handbook*
	▶ Overapplication or misapplication of fertilizers	Public education (lawn and garden care)
	▶ Fecal matter from pets	Public education (animal waste controls)
	▶ Vegetative matter	Public education (lawn and garden care, stormdrai stenciling)
	▶ Power plant emissions	Not addressed in this Handbook
From Impervious Surfaces	▶ Human activities, atmospheric deposition, etc. All pollutants.	Landscaping strategies, watershed protection durin site development, land use controls, landscaping strategies
Sediments	▶ Construction activities	See *Virginia Erosion and Sediment Control Handbook*
	▶ Urban streambank erosion	Urban reforestation and riparian restoration
Bacteria	▶ Antiquated sewer lines	Not addressed in this Handbook
	▶ Fecal matter from domestic animals	Public education (animal waste controls)
	▶ Malfunctioning septic systems	Not addressed in this Handbook
Trace Metals	▶ Soil particles from erosion	Landscaping strategies and *Virginia Erosion and Sediment Control Handbook*
	▶ Wear of vehicle parts including brake, clutch, and tires	Public education (automotive maintenance)
	▶ Leakage from vehicular fluids	Public education (automotive maintenance)
	▶ Atmospheric deposition from automobile emissions	Public education (automotive maintenance)
SOCs	▶ Spray drift, groundwater contamination, and stormwater	Public education (lawn and garden care, integrated pest management)
	▶ Dumping household/industrial chemicals	Public education (stormdrain stenciling), dumping alternatives (drop-off centers, etc.)
Petroleum Hydrocarbons	▶ Leakage from automobile cran cases on impervious surfaces	Public education (automotive maintenance)
	▶ Illegal dumping of used oil by home car maintenance	Public education (stormdrain stenciling), educatio on dumping alternatives
	▶ Underground and above groun storage take malfunction	Not addressed in this Handbook
Litter	▶ Dumping and littering	Public education, stormdrain stenciling
Chlorides	▶ Roadway deicing chemicals	Not addressed in this Handbook

able for its positive aesthetic impact on the urban environment.

Less easily implemented than educational BMPs and street sweeping, but still applicable to already urbanized areas, are: land use controls including transferable development rights and redevelopment and infill (Section 4.1.1); impaired riparian buffer restoration (Section 4.1.3); and, home and business landscaping strategies (Section 4.1.4).

Restoring impaired riparian buffer areas is often difficult to accomplish in an already urbanized area. In some instances, reforestation would require demolishing existing structures or decreasing developable lot size. As a general rule, riparian buffer restoration is more easily accomplished during the development process; however, this should not be construed to imply that restoring buffers in existing urbanized areas when possible is not a worthwhile endeavor.

Vegetative controls and stormwater wetlands are most suited for incorporation into newly developing areas due to the space required for their implementation. However, there are often times that these controls may be retrofitted into the landscape where adequate space and conditions allow.

Finding suitable sites in an already built landscape to place NPS pollution control measures can be challenging. It requires that the watershed planner scan the environment for often hidden, underutilized land. Potential sites must:

- be large enough to accommodate a vegetative control or stormwater wetland facility (general not less than one acre);
- have a large enough drainage area to make control cost-effective; and,
- not be utilized for some other public purpose, the loss of which would create undue hardship or public opposition (for instance, an urban baseball field, etc.).

Other potential sites include:

- urban wetlands that have been degraded to the point where they no longer have significant habitat value; and,
- culvert area drainage depressions near street and road crossings.

A survey of the Four Mile Run watershed in Northern Virginia (1994) located 24 potential retrofit sites, providing coverage for 58% of the watershed. Retrofit locations were based on an inventory of underused or under-utilized parcels greater than one acre minus sites with insufficient drainage, wetlands, or public recreation areas (such as ball parks, etc.).

Some control measures, of course, are more aesthetically pleasing than others. Because of the sometimes dense nature of urban land use patterns, a more aesthetic retrofit option will increase the likelihood of public acceptance.

Density and Type of Land Use

The density of a land use, in conjunction with the type of land use (i.e. commercial, residential, or industrial) will have an affect on potential nonstructural BMPs as well. Arlington County, for instance, has developed a useful design standards matrix for use with its site-specific nonstructural BMP program (see Table 3.3).

Many vegetative controls and stormwater wetlands are particularly susceptible to damage from the high quantities of runoff from highly impervious surfaces. Therefore, their implementation should only be considered for low to mid density range development. Other techniques, such as street sweeping, require a certain level of density to be a cost-effective control technique.

In regard to the type of land use, most techniques discussed in this Handbook are more applicable to residential uses (and the various subsets of residential uses) and institutional uses. However, some, including landscaping and lawn care education programs, may be applied to businesses and industries as well.

Common sense will dictate that not all public education programs or landscaping measures are applicable to all residential uses. For instance, money spent on educating condominium dwellers on the benefits of integrated pest management (IPM) will most likely not be well spent.

An example of how consideration of density and land use type interact is in the use of animal waste controls for NPS pollution reduction. Animal waste control programs are primarily geared towards residential land uses (where pets are kept and walked). However, they are also aimed at those living in denser residential areas. This is because there is a greater chance that animal waste will be deposited on an impervious surface, where it may be flushed directly into the storm drain.

A storm drain stenciling program, on the other hand, may be applicable to any density and any land use where people have the opportunity to dump pollution onto impervious surfaces near a storm drain.

SECTION 3.4

Screening for Environmental Benefits and Public Concerns

Many nonstructural BMPs provide other benefits apart from water quality – including environmental benefits and aesthetic and recreational value. Likewise, many nonstructural BMPs are associated with public concerns – such as appearance or the creation of an attractive nuisance. While screening criteria must include whether the nonstructural technique will meet water quality goals, screening for environmental benefits and public concerns cannot be overlooked. This is particularly the case regarding potential public concerns since a negative public reaction to a misplaced (yet effective) technique may result in its discontinuation altogether.

TABLE 3.3
Arlington County Design Standards Matrix

CONTROL TECHNIQUE	LOW DENSITY (0-40% impervious)	MEDIUM DENSITY (40-70% impervious)	HIGH DENSITY (70-100% impervious)
Vegetated Buffers	Usually Appropriate	Usually Appropriate	Occasionally Appropriate
Flow Dispersion	Usually Appropriate	Often Appropriate	Seldom Appropriate
Parking Management	Seldom Appropriate	Occasionally Appropriate	Usually Appropriate
Multiple Stories	Seldom Appropriate	Usually Appropriate	Usually Appropriate
Porous Alternatives	Occasionally Appropriate	Occasionally Appropriate	Occasionally Appropriate
Alternative Landscaping	Usually Appropriate	Usually Appropriate	Usually Appropriate
Pavement Cleaning Programs	Occasionally Appropriate	Usually Appropriate	Usually Appropriate
Site Sensitivity	Always Appropriate	Always Appropriate	Always Appropriate

Source: Arlington County. *A Citizen's Guide to the Arlington County Chesapeake Bay Preservation Ordinance*: 1992.

Screening criteria discussed here include wildlife habitat creation, stream temperature stabilization, landscape enhancement and aesthetic value, recreational benefits, potential hazards, and public acceptance.

Wildlife Habitat Creation

Nonstructural techniques that rely on the use of vegetation for water quality often result in the creation of additional wildlife habitat. This is especially the case for techniques which rely on the establishment of trees, shrubs, and meadows.

Stormwater wetland creation and the establishment of riparian buffer areas are particularly effective at creating a diverse wildlife habitat. So too is the establishment of a more diverse, less yard intensive home landscape. Other vegetative controls, however, such as grassed swales and vegetative filter strips, provide considerably less valuable wildlife habitat.

Stream Temperature Stabilization/ Destabilization

Some nonstructural BMPs that rely on trapping stormwater runoff for pollutant removal have the side effect of potentially increasing stream water temperature immediately downstream of the practice. This is a particular concern for unshaded stormwater wetlands due to their shallow nature.

Other techniques, specifically those related to riparian buffers, have the ability to stabilize stream temperatures through shading in the summer and allowing sunlight to pass in the winter.

Landscape Enhancement and Aesthetic Value

Landscape enhancement and aesthetic value are purely subjective, yet important criteria to consider when choosing a BMP technique. While some may consider the semi-wild look of a bioretention facility in a parking lot to enhance the landscape, others may consider it to be an eyesore.

Well maintained vegetative BMPs typically have a positive aesthetic effect on the landscape. Stormwater wetlands, if properly designed, will also create an attractive community amenity. However, these techniques can become eyesores if proper maintenance does not take place regularly.

Street sweeping almost always has a positive affect on the landscape by removing trash, litter, and debris from roadways. Storm drain stencilling programs have a similar positive affect on the landscape; however, some people react negatively to the stenciling itself as unattractive. This is especially true if the project is not preceded by a vigorous public education campaign explaining the benefits of the measure.

Because these landscape enhancement and aesthetic value are subjective, it is important that the potential consequences of any particular technique on the landscape be shared with the affected community before implementation.

Recreational Benefits

Very few nonstructural techniques provide recreational benefits. However, the implementation of a riparian forest buffer system may be coupled with the implementation of hiking or biking trails, so long as their presence does not result in harm to the buffer itself.

Potential Hazards

Again, very few nonstructural techniques may be considered as potential hazards to surrounding communities. A key exception may be the use of stormwater wetlands. Stormwater wetlands may be considered an attractive nuisance and precautions to keep curious children away from the pool must be taken.

Public Acceptance

Nonstructural BMP techniques which have the potential to elicit a negative public reaction must be accompanied by public education as well as a commitment on the part of the local government to properly maintain the technique.

In so far as vegetative controls are concerned, and particularly stormwater wetlands, studies have revealed that they are generally accepted if regular maintenance is performed. Primary concerns often revolve around perceived nuisance conditions (such as odors, mosquitos, weeds, trash, etc.) most of which should not occur if the technique is properly maintained.

Three nonstructural BMPs for which public acceptance is generally an issue are storm drain stenciling, the use of density transfer techniques, and the use of cluster development.

Density transfer techniques may become controversial because it is often perceived that neighborhoods adjacent to density receiving areas will be negatively impacted. Cluster development, similarly, is often (and mistakenly so) associated with less attractive, and cheaper housing. Adequate public education about the nature and purpose of these two programs, as well as outreach and solicitation of comments from the community, will go a long way towards changing these public perceptions.

SECTION 3.5 ....

Summary of Screening Criteria

Table 3.4 presents an array of nonstructural BMP screening criteria based on the information provided in Sections 3.1 through 3.4.

SECTION 3.6 ....

General Criteria for Selecting an Appropriate Public Education Program

Public education has the potential to be among the most effective of all nonstructural BMP techniques for that component of NPS pollution that is affected by human behavior. Screening public education programs for applicability is an important consideration given the potentially enormous number of subjects that may be addressed. Too often, public education as a BMP fails because the messages generated by well meaning organizations do not reach those whose pollution-generating behavior must be redirected.

The following guidelines, taken in part from The Global Cities Project's (Study of Law and Politics, San Francisco, California) resource entitled *Building Sustainable Communities – An Environmental Guide for Local Government*, should be used when selecting a public education program.

- **Who should the program be geared towards, and what should the program accomplish?** Local government officials may know that they want to gear their program towards the residential sector in their communities, but who makes up this sector? Should school children be included? Many people feel that fostering an awareness and respect for nature (in this case, water quality) while children are young will help create life-long environmentally sound habits. Is there a group of water skiers, fishermen, and boaters who should be addressed? They may use the local lake, but are they careless about dumping power boat oil, garbage, picnic food wrappers into the lake? What about men between the ages of 16 and 40 that drive and often do their own automotive work? Where are they disposing their used oil?

- **What programs are available to address the pollution problem and how will they reach the targeted audience?** Using many of the screening criteria found in this chapter, a range of potential public education measures should be identified for potential implementation.

- **What resources are available to operate the program(s)?** Local governments should determine if staff has the time to operate each program. Another question that should be asked is whether staff members have the expertise to design and implement an education program or if template brochures for modification are available. (See Inset 3.1 for a list of public education and pollution prevention brochures that are available through various State agencies.)

TABLE 3.4

Array of Nonstructural BMP Alternatives for Water Quality

Letter Key:
H=Highly Appropriate/Yes
O=Occasionally Appropriate/Sometimes
S=Seldomly Appropriate/No
NA=Not Applicable
V=Variably Appropriate

Note:
Superscript numbers refer to explanatory notes on following page.

NONSTRUCTURAL BMP MEASURE	APPLICABILITY							CONSTRAINTS AND CONSIDERATIONS								
	Newly Developing Area	Existing Development	Low-Moderate Density	High Density	Site Specific Application	Area-Wide Application	Pollutant Reduction Quantification Method	Municipal Responsibility	Property Owner Responsibility	Wildlife Habitat Creation or Preservation	Stream Temperature Stabilization	Landscape Enhancement and Aesthetic Value	Recreational Benefits			
POLLUTION PREVENTION																
General Land Use Controls																
Purchase of Development Rights	H[1]	S	H	H	O[3]	H	A-B[8]	H	S	O	S	O	O	S	O[12]	S
Transfer of Development Rights	H[1]	S[2]	H	H	O[3]	H	A-B+C[9]	H	S	O	S	O	O	S	O[12]	O
Down Zoning	H[1]	S	O	H	O[3]	H	A-B	H	S	O	S	O	O	S	O[13]	S
Redevelopment and Infill	S	H	H	H	H	O	A-B	H	S	O[11]	S	O	S	S	O[12]	O
Watershed Protection During Site Development																
Minimizing Impervious Areas	H	S	H	O	H	H	A-B	H[14]	H	S	O	O	O	S	H	O
Maximizing Vegetated Areas	H	S	H	O	H	H	A-B	H[14]	H	O	O	H	O	S	H	O
Conservation Development	H	S	H	O	H	H	A-B	H[15]	H	H	H	O	H	S	O[12]	O
Urban Reforestation and Riparian Buffer Restoration																
Riparian Buffer Restoration	H	O[4]	H	O[4]	H	H	A-B	H[14]	H	H	H	H	H	S	H	O[4]
Landscaping Strategies																
Preserve Soil Permeability	H	S	H	O	H	O	A-B	H[14]	H	S	S	S	S	S	H	O
Design the Landscape to Keep the Water Onsite	H	S	H	H	H	H	A-B	H[14]	H	S	O	S	S	S	H	O
Minimize the Use of Turf Grass in the Landscape	H	O	H	S	H	O	A-B	H[14]	H	O	O	O	S	S	O-S[6]	O
Implement Planting Zones and Utilize Native Vegetation	H	O	H	H	H	O	A-B	H[14]	H	O	S	O	S	S	O-S	O

Continued on next page.

TABLE 3.4 (continued)
Array of Nonstructural BMP Alternatives for Water Quality

Continued from previous page.

Letter Key:
H=Highly Appropriate/Yes
O=Occasionally Appropriate/Sometimes
S=Seldomly Appropriate/No
NA=Not Applicable
V=Variably Appropriate

Note:
Superscript numbers refer to explanatory notes on following page.

NONSTRUCTURAL BMP MEASURE	APPLICABILITY							CONSTRAINTS AND CONSIDERATIONS								
	Newly Developing Area	Existing Development	Low-Moderate Density	High Density	Site Specific Application	Area-Wide Application	Pollutant Reduction Quantification Method	Municipal Responsibility	Property Owner Responsibility	Wildlife Habitat Creation or Preservation	Stream Temperature Stabilization	Landscape Enhancement and Aesthetic Value	Recreational Benefits			
Public Education																
Public Education	H	H	V	V[5]	O-S[6]	H	A-B	H	H	S	S	O[17]	S	S	O[18]	S
Stormdrain Stenciling	H	H	O	H	O	H	A-B	H	S	S	S	O[17]	S	S	O[19]	S
Animal Waste Controls	H	H	O	H	S	H	A-B	H	H	S	S	O[17]	S	S	O[18]	S
Land and Garden Care Education Programs	H	H	H	O	O	H	A-B	H	H	O	S	O[17]	S	S	O[18]	S
CONTROL MEASURES																
Vegetated Buffer Areas and Riparian Buffer Areas	H	O-S	H	O-S	H	H	A-%[10]	H	H	H	H	H	H	S	H	O
Vegetative Filter Strips	H	O-S	H	O-S	H	O	A-%	H	H	O	O	O	S	S	H	O
Grassed Swales	H	O-S	H	S	H	H	A-%	H	H	S	S	O	S	S	O	O
Bioretention	H	O	H	H	H	H	A-%	H	H	O	O	H	S	S	H-O	O
Marsh and Wetland Systems	H	S	H	S	H	H	A-%	H	H	O	S	H	O	H-O	O	H
Street Sweeping	O	H	O-S	H	O[7]	H	A-%	H	O[7]	S	S	H	S	S	H	S

TABLE 3.4 (continued)
Notes

(1) Applicable as a means of phasing or limiting the impacts of new growth.
(2) Technique requires both a sending area and a receiving area. However, the technique does not serve to reduce NPS pollution in the receiving area.
(3) Site specific application is possible, but much less effective and open to legal challenge.
(4) Riparian reforestation may be hindered in existing and high density development as a result of existing land use patterns and structures.
(5) Appropriateness depends on the demographic factors involved in the pollution problem.
(6) Site specific education is possible (and necessary in many instances) but is limited in its capacity to control NPS pollution.
(7) Site-specific applications may include parking areas, etc.
(8) "A-B" refers to "projected conditions prior to program implementation - projected conditions after program implementation." The difference is the amount of NPS pollution prevented.
(9) "A-B+C" is the same as superscript (8) but indicates the need to add the potential negative effects of redistributed density on other watersheds.
(10) "A-%" indicates that the pollutant removal efficiency can be expressed in terms of a percentage amount removed.
(11) Redevelopment and infill creates or preserves wildlife habitat only if it occurs in place of new development.
(12) Public acceptance may be affected by negative perceptions of increased densities.
(14) These practices require that the local government actively supports this program.
(15) The local government must provide for conservation development in its subdivision or zoning ordinances.
(16) This practice may contradict local home owner association covenants.
(17) Aesthetic value enhanced through decreased visible litter, waste, etc.
(18) These programs rely on the willingness of the citizenry to participate, which often requires significant changes in behaviors and perceptions.
(19) Some neighbors equate stenciling to be a form of graffiti and thus negatively react to it.

The potential for other groups to run certain programs should also be investigated. Other professionals may be willing to help educate the community. University extension professionals, local news reporters, environmentalists, school teachers, and Girl and Boy Scout leaders can all help "get the message out" in one form or another.

Similarly, where will the programs be run from? Will officials need to rent a meeting hall, or can the programs take place in schools, 4-H clubs, civic meeting halls, churches, or even outdoors.

- **Find sources of funding.** Public education can require additional permanent or part-time staff and the production of brochures, news releases, posters, etc. If the local government is not able to afford the program, it should scan the environment for potential sources of funding including local business sponsors, environmental groups, and State and federal grants.

- **Choose a BMP program.** It is now appropriate to select a technique or techniques to address the NPS pollution problem.

SECTION 3.7

Screening Site-Specific BMPs Based on Physical Suitability

Most *pollution prevention* techniques that are applicable to site-specific development (conservation development, landscaping strategies, etc.) *are not constrained by the physical suitability of a site*. However,

INSET 3.1

Public Education and Pollution Prevention Materials Available through State Agencies

Department of Conservation and Recreation

- Tips on Keeping Your Lawn green…And the Chesapeake Bay Clean
- We Would Like to Clear a Few Things Related to Lawn Care…Like Virginia's Rivers, Lakes, and Streams
- Treasure of Abundance or Pandora's Box?
- The Virginia Gardener Year Round Guide to Nutrient Management.
- Ecological Turf Tips…To Protect the Chesapeake Bay
- Classic Agronomic Principles Can Reduce Pesticide Need
- Nutrient Management for Golf Course Managers
- Nutrient Management for Lawn Care Services.
- Lawn Fertilization in Virginia
- Turfgrass Nutrient and Pesticide Management for Public Lands
- Save Our Streams Program, Izaak Walton League of America

Department of Environmental Quality

- BayScapes
- 25 Ways to Help Virginia's Environment
- Nonpoint Source Pollution…Be Part of the Solution

Virginia Cooperative Extension Service

- Guide to Water-Wise Landscaping
- It's Your Bay Protect It!
- Landscape Tips to Improve Water Quality
- Water Quality in Virginia
- Compost 'Em Leaf it Alone!
- BayScaping: A Ways to Benefit Lawns, Gardens…and the Bay!
- EASY Program
- Lawn Care Calendar
- Turf Tips Calibrating your Lawn Spreader
- Master Gardener Program
- Field Day and Workshop Flyers

Virginia Department of Agriculture and Consumer Services

- Pesticide Disposal Program
- Pesticide Container Recycling Program
- Virginia Department of Health
- Alternative Septic Systems for Virginia
- Groundwater Contamination and Your Septic System
- The Facts and Folklore of Septic System Maintenance
- Take the Mystery Out of Your Site Evaluation

Virginia Department of Transportation

- Adopt-a-Highway Program
- Storm Drain Stenciling Program

See Appendix 4.2 for agency contacts for more information on available publications and Appendix 4.3 for a listing of educational materials on environmental and NPS pollution related topics.

the site-specific use of vegetative controls or stormwater wetlands (because they rely primarily upon trapping or filtering stormwater, and/or soil infiltration for their water quality benefits) requires that the site be screened for any constraining physical properties, and may be rejected because they impinge on the zoning designation of the site.

Typical physical factors which must be considered include the watershed area to be served, soil type, slope, land consumption, and proximity to foundations, wells, bedrock, and water table. Some of these factors may eliminate the use of a technique altogether, while others will require that the design of the technique is modified.

Control techniques considered in this section include vegetative filter strips, grassed swales, bioretention, and stormwater wetlands.

Watershed Area to be Served

The size of the watershed area being served is an important consideration for nonstructural control techniques which serve to treat runoff collected from other areas of a site.

In general, vegetative filter strips should not be used in drainage areas of greater than 5 acres. Similarly, the contributing watershed area to a grassed swale system must be kept small, although the exact size of the contributing area will depend on the length and general slope of the swale system and whether or not check dams are used to impound stormwater runoff.

Based on information on other infiltration techniques, bioretention facilities should not be used for drainage areas greater than 10 acres, and are probably most effective for drainage areas less than 5 acres. Generally, bioretention has been applied to drainage areas of one (1) acre or less. The City of Alexandria indicates that bioretention is the preferred BMP for residential development projects with over two acres of impervious surface.

Stormwater wetlands may be designed to handle almost any sized watershed and are generally most appropriate as a multi-site BMP. However, it is recommended that a *minimum* watershed size of 5 acres be observed.

Soil Type

Many vegetative controls rely on infiltration into the soil horizon as their primary pollutant removal mechanism and therefore the permeability of the underlying soil will control BMP effectiveness. While the permeability of the soil may be increased through tilling or the addition of humus, there are limits to overcoming deficient soil permeability. In addition, other overriding factors, such as depth to bedrock, depth to water table, and the presence of fragipan, may make it impossible to make a soil suitable for infiltration measures.

For vegetative filter strips, grassed swales, and bioretention, a minimum permeability rate of 0.27 inches per hour is desirable.

Stormwater wetlands, on the other hand, rely on quite the opposite principle. It is difficult to establish wetlands on sites with sandy soils or soils with high infiltration rates.

Slope

The slope of a site will greatly limit the type of control-style nonstructural BMP facility which may be used for a particular site. Grassed swales and vegetative filter strips, in order to be effective, must not be situated on a slope of greater than 5%. Grading to a bioretention facility should not exceed a 3:1 ratio.

Land Consumption

Vegetative filter strips and grassed swales can often be incorporated into underutilized areas of the landscape where their spatial requirements can be minimized. Grassed swales, in particular, can be placed along the edges of roads, or along property lines, with little or no impact on usable space.

Bioretention, while occupying more space than vegetative filter strips or grassed swales, can often be effectively incorporated into the landscape as part of a jurisdiction's open space requirements.

Stormwater wetlands require considerably more space than other vegetative controls and can often occupy up to as much as 5% of a total development site due to their shallow depths.

Proximity to Foundations, Wells, Bedrock, and Water Table

Infiltration practices, and particularly bioretention, may be constrained by the proximity of foundations, wells, bedrock, and the water table. Figure 5.12 illustrates these site limitations for the implementation of a conventional bioretention facility. Any infiltration practice should be located far enough from foundations, fill slopes, retaining walls, and basements so that soil saturation does not imperil their structural integrity.

Distance to any potable water supply should be 100 feet or greater. Depth from the bottom of the facility to either the water table or bedrock should be no greater than 2 feet.

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