This PDF file is an excerpt from the EPA guidance document entitled *National Management Measures to Control Nonpoint Source Pollution from Urban Areas* (November 2005, EPA-841-B-05-004). The full guidance can be downloaded from http://www.epa.gov/owow/nps/urbanmm/index.html.

National Management Measures to Control Nonpoint Source Pollution from Urban Areas

Introduction

November 2005

INTRODUCTION

The nation's aquatic resources are among its most valuable assets. Although environmental protection programs in the United States have improved water quality during the past several decades, many challenges remain. Of special concern are the problems in our urban streams, lakes, estuaries, aquifers, and other water bodies caused by runoff that is inadequately controlled or treated. These problems include changes in flow, increased sedimentation, higher water temperature, lower dissolved oxygen, degradation of aquatic habitat structure, loss of fish and other aquatic populations, and decreased water quality due to increased levels of nutrients, metals, hydrocarbons, bacteria, and other constituents.

The *National Water Quality Inventory: 2000 Report to Congress* identified urban runoff as one of the leading sources of water quality impairment in surface waters (USEPA, 2002b). Of the 11 pollution source categories listed in the report, "urban runoff/storm sewers" was ranked as the fourth leading source of impairment in rivers, third in lakes, and second in estuaries (Table 0.1).

Table 0.1: Leading sources[b] of water quality impairment related to human activities for rivers, lakes, and estuaries (USEPA, 2002b).

Rivers and Streams	Lakes, Ponds, and Reservoirs	Estuaries
Agriculture (48%) [a]	Agriculture (41%) [a]	Municipal point sources (37%)[a]
Hydrologic modifications (20%)	Hydrologic modifications (18%)	Urban runoff/storm sewers (32%)
Habitat modifications (14%)	Urban runoff/storm sewers (18%)	Industrial discharges (26%)
Urban runoff/storm sewers (13%)	Misc. nonpoint source pollution (14%)	Atmospheric deposition (24%)

[a]Values in parentheses represent the percentage of assessed river miles, lake acres, or estuary square miles that are classified as impaired. States assessed 19% of stream miles, 43% of lakes, ponds, and reservoirs, and 36% of square mileage of estuaries.
[b] Excluding unknown, natural, and "other" sources.

0.1 Purpose and Scope of the Guidance

National summaries, such as those shown in Table 0.1, are useful in providing an overview of the magnitude of the problems associated with urban runoff. Solutions, however, are usually applied at the local level. State and local elected officials and agencies, landowners, developers, environmental and conservation groups, and others play a crucial role in protecting, maintaining, and restoring water resources. Their efforts, in aggregate, form the basis for changing the status of urban runoff from a local problem to a national problem.

This document provides guidance to states, territories, authorized tribes, and the public regarding management measures that can be used to reduce nonpoint source pollution from urban activities. This document refers to statutory and regulatory provisions that contain legally binding requirements. This document does not substitute for those provisions or regulations, nor is it a regulation itself. Thus, it does not impose legally binding requirements on the U.S. Environmental Protection Agency (EPA), states, territories, authorized tribes, or the public and may not apply to a particular situation based upon the circumstances. EPA, state, territory, and authorized tribe decision-makers retain the discretion to adopt approaches that differ from this guidance on a case-by-case basis. Interested parties are free to raise questions and objections about the appropriateness of the application of the guidance to a situation, and EPA will consider whether or not the recommendations in this guidance are appropriate in that situation. EPA may change this guidance in the future.

This guidance document *is* intended to provide technical assistance to state and local program managers and other practitioners on the best available, most economically achievable means of managing urban runoff and reducing nonpoint source pollution of surface and ground waters from urban sources. It describes how to develop a comprehensive runoff management program that deals with all phases of development—from predevelopment watershed planning and site design, through the construction phase of development, to the operation and maintenance of structural controls. It also provides information for other situations such as retrofitting existing development, implementing nonstructural controls, and reevaluating the runoff management program. Figure 0.1 presents the components of a comprehensive runoff management program.

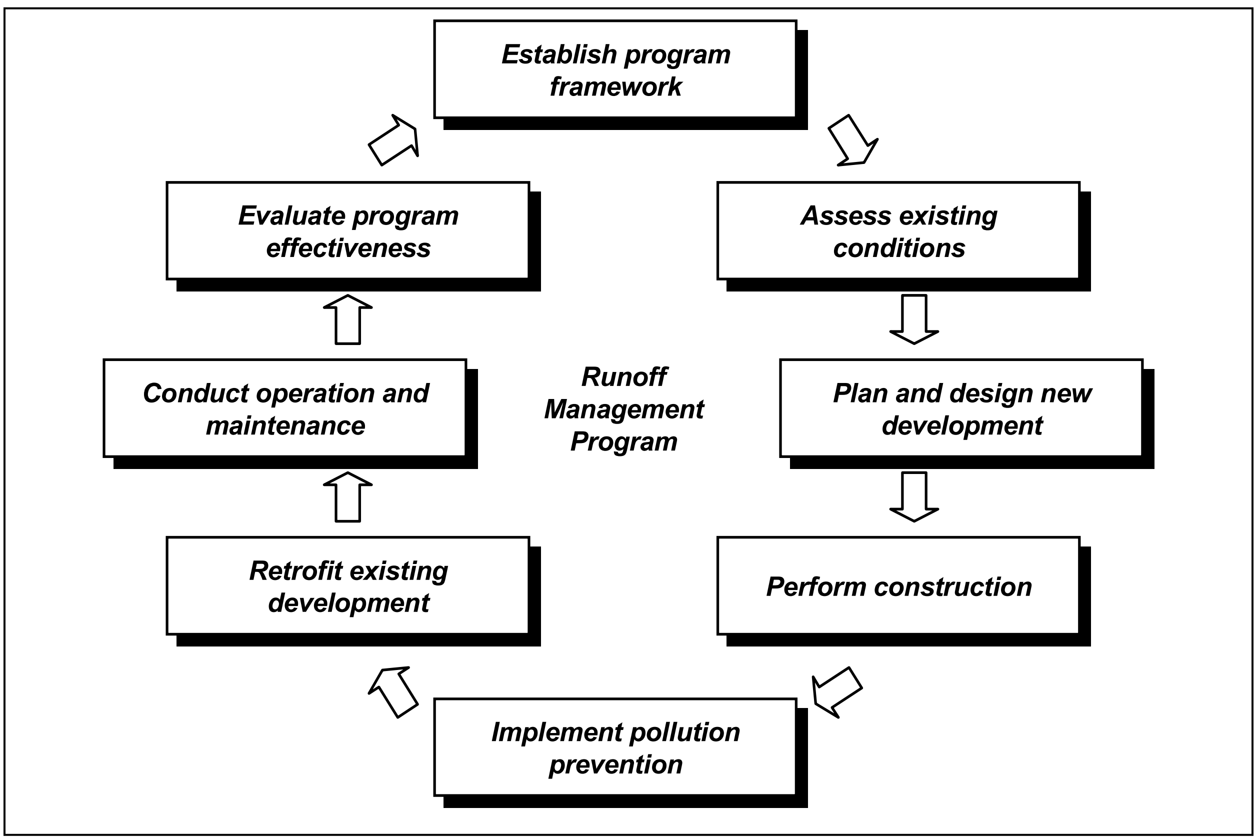


Figure 0.1: Components of a comprehensive runoff management program.

This document is intended to provide guidance for all urban areas, not just those covered by National Pollutant Discharge Elimination System (NPDES) phase II requirements. While the document can serve as a resource for meeting NPDES phase II requirements, there are still a number of smaller jurisdictions that are not regulated by the NPDES program and that can benefit from guidance in developing an urban runoff program.

0.1.1 Management Measures

Management measures can be used to guide the development of a runoff management program. They establish performance expectations and, in many cases, specify actions that can be taken to prevent or minimize nonpoint source pollution or other negative impacts associated with uncontrolled and untreated urban runoff. Twelve management measures have been included in this guidance. Figure 0.2 groups these measures within the context of the runoff management program cycle.

Each management measure listed in Figure 0.2 deals with an important aspect of the runoff management cycle. For example, Management Measure 8 focuses on construction site erosion, sediment, and chemical control. Local officials and developers should address these issues because if exposed soils are allowed to erode and move off construction sites as sediment, they can clog storm drains, streams, and other water bodies, harm habitat, and impair water quality.

This management measure has four elements:

- Prior to land disturbance, prepare and implement an approved erosion and sediment control plan or similar administrative document that contains erosion and sediment control provisions.
- Reduce erosion and, to the extent practicable, retain sediment on-site during and after construction.
- Use good housekeeping practices to prevent off-site transport of waste material and chemicals.
- Minimize application and generation of potential pollutants, including chemicals.

Note that specific actions or practices for achieving the performance expectations are not included in the management measure statement. This is by design. Local officials and other practitioners need the flexibility to choose management practices that best achieve the management measure's performance expectations given their own unique circumstances. To aid in their decision, however, this guidance presents several management practices that can potentially be used to achieve each management measure.

The components of the runoff management program shown in Figure 0.2 are organized in a cycle that can be followed stepwise if desired. The elements are meant to work together, but each can stand alone. The elements of the cycle do not have to be implemented consecutively.

The cycle begins with establishing a program framework that provides legal authority, funding, and staffing for watershed initiatives (Management Measure 1). Once this framework is established, watershed managers can commence an assessment of existing conditions (Management Measure 2) to identify areas in need of protection or restoration. This assessment also provides stream channel and water quality baselines (i.e., environmental indicators) against which the success of watershed initiatives can be compared (Management Measure 12: Evaluate Program Effectiveness).

Management Measures 3 through 7 address issues associated with new development. The watershed protection management measure (3) focuses on siting development and establishing

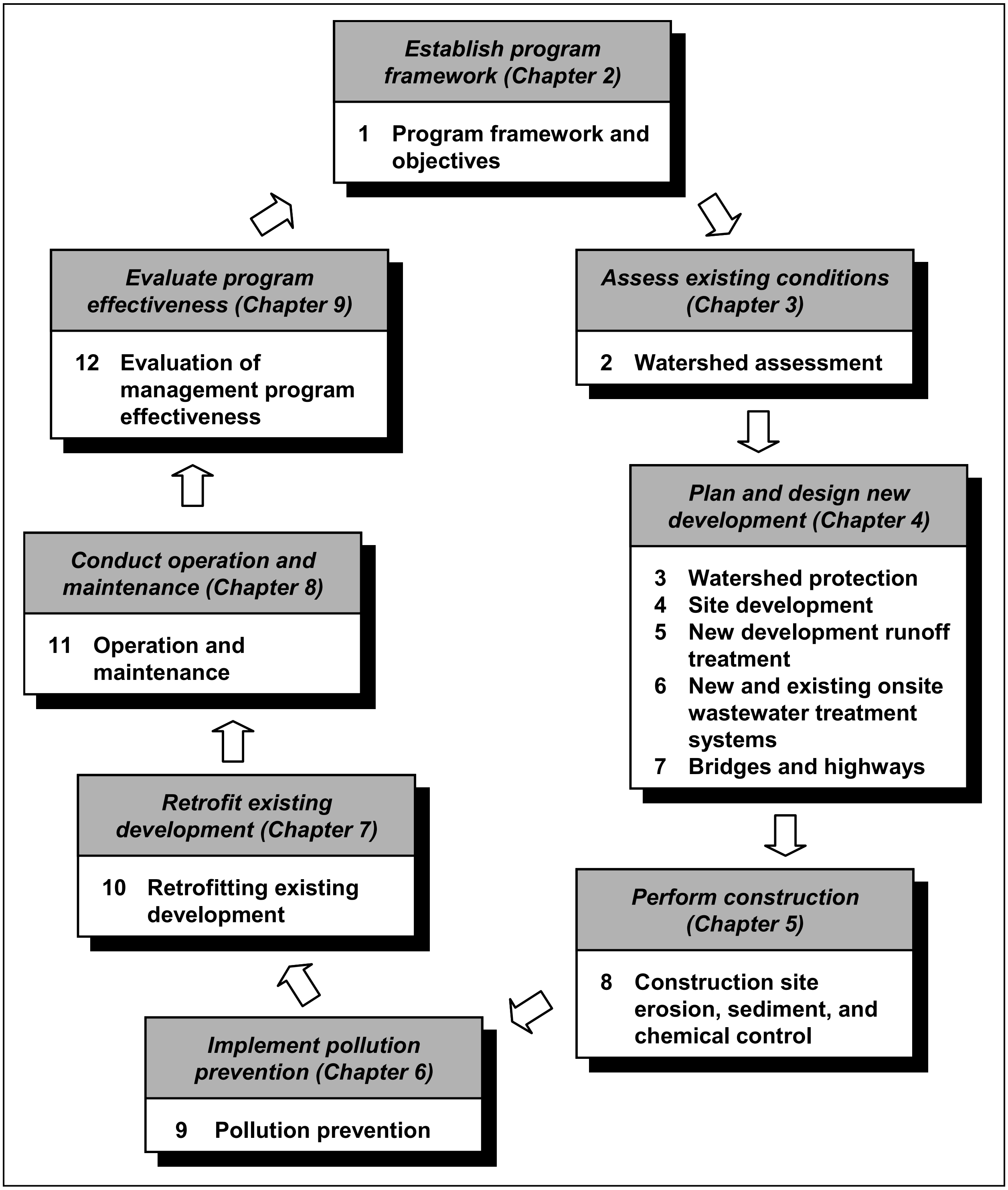


Figure 0.2: Twelve management measures associated with the runoff management program cycle.

actions to protect areas identified as sensitive or ecologically valuable. The Site Development Management Measure (4) provides guidance for planning development on the site scale with alternative, low-impact site layouts and infrastructure options that protect sensitive areas and reduce the quantity of runoff leaving the site. The New Development Runoff Treatment Management Measure (5) details practices that can be identified to prevent pollutants in runoff generated from newly developed areas. The onsite wastewater treatment systems management measure (6) provides guidance on how to reduce pollutant loadings from both new and existing on-site systems. Finally, the Highways and Bridges Management Measure (7) addresses pollutants generated from activities related to new and existing transportation infrastructure.

Once development plans have been made, watershed managers can refer to Management Measure 8: Construction Site Erosion, Sediment, and Chemical Control. This measure presents practices that reduce pollutant loadings from land-disturbing activities.

Throughout the runoff management program cycle, watershed managers can use the Pollution Prevention Management Measure (9) to target municipalities, businesses, and individual citizens with education and awareness programs to reduce pollutants generated from day-to-day activities. Managers also can use the practices presented in the Existing Development Management Measure (10) to address areas in need of restoration or retrofitting of existing management practices. Additionally, the Operation and Maintenance Management Measure (11) describes activities needed to maintain and extend the life of new and existing management practices.

Once programs have been established and management practices implemented, managers can evaluate their effectiveness using program and administrative indicators (Management Measure 12). This evaluation involves reassessing conditions in the watershed to determine whether the implemented practices effectively reduced nonpoint source pollution. This evaluation also identifies areas where additional restoration or preservation activities are needed, guiding future watershed initiatives and thereby restarting the management cycle.

North Branch of the Chicago River Demonstration Project

Through the North Branch of the Chicago River Demonstration Project, the Friends of the Chicago River, and the Lake County Storm Water Management Commission joined to develop a plan to address NPS pollution and flooding while educating and involving citizens and community leaders in the process (USEPA, 2000a). The result was an urban watershed planning model, similar to the one presented in this guidance, that any city can use to protect its water resources.

This 96-square-mile watershed was affected by storm water runoff from two counties and 24 towns. The partners in the North Branch of the Chicago River Demonstration Project divided the project into four tasks—developing a watershed plan, conducting an information and education campaign, developing a handbook to guide them through the process, and conducting a series of demonstration projects. For more information, contact Friends of the Chicago River (http://www.chicagoriver.org).

0.1.2 Document Organization

Chapters 2 through 9 of this document consecutively focus on the eight components of the runoff management program cycle (Figure 0.2). Each chapter describes a component, introduces one or more management measures that define the performance expectation(s) for that component, and presents a range of management practices that potentially can be implemented to achieve the management measure(s). When available, information concerning effectiveness and costs of practices is included in the discussion, as are case studies that illustrate how select management practices have been implemented within communities.

0.2 Origin and Regulatory Context

0.2.1 Origin of This Guidance

This document is an update of the urban management measures and practices provided in Chapter 4 of an EPA manual entitled *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (USEPA, 1993). That document, referred to hereafter as the Coastal Management Measures Guidance, was published in January 1993 for the specific purpose of providing state and territorial officials with management measures to incorporate into their coastal nonpoint source (NPS) pollution control programs.

Through the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), Congress mandated that EPA develop the Coastal Management Measures Guidance, and that every state and territory with an approved coastal zone management program develop an NPS pollution control program, including enforceable policies and mechanisms to implement all of the specified management measures. The programs were submitted to EPA and the National Oceanic and Atmospheric Administration (NOAA) for approval. All were subsequently approved, some with conditions. The Coastal Management Measures Guidance functions as a blueprint for the coastal states and territories in their efforts to put together their NPS control programs.

The Coastal Management Measures Guidance included management measures for urban areas (Chapter 4), agriculture (Chapter 2), silviculture (Chapter 3), marinas (Chapter 5), and hydromodification (Chapter 6). It also addressed protection of wetlands and riparian areas from NPS pollution impacts and the use of vegetative treatment systems, such as constructed wetlands, as management practices to control runoff (Chapter 7).

Of all the NPS pollution sources identified in the Coastal Management Measures Guidance, none has experienced the rapid technical advancement that has occurred in the areas of urban NPS pollution control. Many communities have set their sights beyond simple NPS pollutant reduction targets and are now seeking ways to achieve balance and integration of many quality-of-life factors, including economic growth, community livability, and environmental protection.

Based on these changes, EPA perceived a need to update and expand the information in Chapter 4 of the Coastal Management Measures Guidance to help local urban officials in both coastal and inland areas remain current with state-of-the-art management measures and practices. Readers should note, however, that this guidance does *not* supplement or replace the 1993 *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* for the purpose of implementing programs under CZARA. It simply serves as an additional resource guide for local officials seeking to develop or improve their urban runoff management programs.

Fundamental differences between this guidance and the Coastal Management Measures Guidance are presented in Table 0.2.

Table 0.2: Key differences between the *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* (USEPA, 1993) and *National Management Measures to Control Nonpoint Source Pollution from Urban Areas*.

	Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters	National Management Measures to Control Nonpoint Source Pollution from Urban Areas
Date	1993	2005
Target audience	*Primary:* state and territory officials *Secondary:* all others interested in NPS pollution	All persons interested in urban NPS pollution and control practices
Focus	NPS management measures and control practices in coastal areas	NPS management measures and control practices in coastal and inland areas
Use	Required under CZARA	Voluntary
Organization	Management measures and practices presented by source category	Management measures and practices presented in the context of a comprehensive watershed program

0.2.2 Regulatory Context

During the first 15 years (1972–1987) of the national program to abate and control water pollution, EPA and the states focused most of their activities on traditional point sources. These point sources have been regulated by EPA and the states through the NPDES permit program established by Section 402 of the Clean Water Act. The NPDES program functions as the primary regulatory tool for ensuring compliance with water quality standards. NPDES permits, issued by either EPA or an authorized state, contain discharge limits designed to meet water quality standards and national technology-based effluent regulations.

In 1987, in view of the progress achieved in controlling point sources and growing national awareness of the increasingly dominant influence of NPS pollution on water quality, Congress amended the Clean Water Act to focus greater national efforts on nonpoint sources. Under this amended version, referred to as the 1987 Water Quality Act, Congress revised Section 101, “Declaration of Goals and Policy,” to add the following fundamental principle:

> It is the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this Act to be met through the control of both point and nonpoint sources of pollution.

The Water Quality Act of 1987 also included language that required comprehensive storm water regulation using a two-phased approach. (Detailed information on both phases of the NPDES Storm Water Program is available at http://www.epa.gov/npdes/stormwater.) Phase I, in place since 1990, required operators of medium and large municipal separate storm sewer systems (MS4s) located in incorporated areas and counties with populations of more than 100,000, certain industrial activities, and construction activities disturbing 5 acres or more to obtain an NPDES permit to discharge storm water runoff. In October 1999 EPA expanded the federal storm water program with the promulgation of the Phase II rule.

Phase II requires operators of small MS4s (non-Phase I regulated MS4s) in “urbanized areas” (as defined by the Bureau of the Census) and small construction activities disturbing between 1 and

5 acres of land to obtain an NPDES permit. Further, the NPDES permitting authority may require operators of small MS4s not in urbanized areas and small construction activities disturbing less than 1 acre to obtain an NPDES permit based on the potential for contribution to a violation of a water quality standard. NPDES permitting authorities are required under the rule to assess for potential designation all small MS4s located outside an urbanized area that are in areas with a population of at least 10,000 and a population density of 1,000 per square mile. The Phase II rule also includes a revised conditional no-exposure provision for industrial facilities, which provides for a waiver from the permit program if the storm water pollutant sources at a facility can be demonstrated to be isolated from precipitation and runoff.

For small MS4 permits, Phase II prescribes a set of six minimum control measures, as well as requirements for evaluation and assessment efforts. The minimum measures are: (1) public education and outreach on storm water impacts; (2) public involvement/participation; (3) illicit discharge detection and elimination; (4) construction site runoff control; (5) postconstruction storm water management in new development and redevelopment; and (6) pollution prevention/good housekeeping for municipal operations. The regulated operators must choose and implement appropriate best management practices (BMPs) and define measurable goals for each measure. The operators must also periodically evaluate and assess program compliance, the appropriateness and effectiveness of their chosen BMPs, and progress toward achieving their identified measurable goals. This guidance is expected to be consistent with any guidance issued for regulated small MS4 operators to meet the requirements of Phase II NPDES storm water discharge permits. Therefore, the management measures and practices herein can serve as a resource in developing a community’s storm water management program. It is important to note, however, that additional requirements not addressed in this guidance may be imposed under an NPDES storm water permit. Table 0.3 specifies how the management measures relate to each of the six minimum control measures.

Table 0.3: Comparison of management measures to the six minimum control measures of NPDES Phase II.

	Public Education	Public Involvement	Illicit Discharge	Construction Site ESC	Post Construction	Pollution Prevention
Program Framework and Objectives						
Establish Legal Authority			✓	✓	✓	✓
Develop an Institutional Structure						
Provide Adequate Funding and Staffing						
Foster Input From Technical Experts, Citizens, and Stakeholders		✓				
Establish Intergovernmental Coordination		✓				
Develop Training and Education Programs and Materials	✓	✓				
Watershed Assessment						
Characterize Watershed Conditions	Measurable Goals					
Assess Cumulative Effects						
Estimate the Effectiveness of Treatment Programs						
Establish a Set of Watershed Indicators						
Establish Water Quality Indicators						
Establish Physical and Hydrological Indicators						
Establish Biological Indicators						
Establish Programmatic Indicators						
Develop a Suite of Social Indicators						
Watershed Protection						
Resource Inventory and Information Analysis					✓	
Development of Watershed Management Plan					✓	
Implement the Plan					✓	
Land or Development Rights Acquisition Practices					✓	
Site Development						
Site Planning Practices					✓	
On-Lot Impervious Surfaces					✓	
Residential Street and Right-of-Way Impervious Surfaces					✓	
Parking Lot Impervious Surfaces					✓	
Xeriscaping Techniques					✓	
New Development Runoff Treatment						
Infiltration Practices					✓	
Vegetated Open Channel Practices					✓	
Filtering Practices					✓	
Detention and Retention Practices					✓	
Other Practices					✓	
New and Existing Onsite Wastewater Treatment Systems						
Permitting and Installation Programs			✓			✓
Operation and Maintenance Programs			✓			✓

Table 0.3 (continued).

	Public Education	Public Involvement	Illicit Discharge	Construction Site ESC	Post Construction	Pollution Prevention
Bridges and Highways						
Site Planning and Design Practices					✓	
Soil Bioengineering and Other Runoff Controls for Highways					✓	
Structural Runoff Controls for Bridges					✓	
Bridge Operation and Maintenance Controls						✓
Nonstructural Runoff Control Practices						✓
Construction Site Erosion, Sediment, and Chemical Control						
Erosion and Sediment Control Programs				✓		
Erosion Control Practices				✓		
Sediment Control Practices				✓		
Develop and Implement Programs to Control Chemicals and Other Construction Materials				✓		
Pollution Prevention						
Household Chemicals	✓	✓				✓
Lawn, Garden, and Landscape Activities	✓	✓				✓
Commercial Activities	✓	✓	✓			✓
Trash	✓	✓				✓
Nonpoint Source Pollution Education for Citizens	✓	✓				
Existing Development						
Identify, Prioritize, and Schedule Retrofit Opportunities					✓	
Implement Retrofit Projects as Scheduled					✓	
Restore and Limit the Destruction of Natural Runoff Conveyance Systems					✓	
Restore Natural Streams					✓	
Preserve, Enhance, or Establish Buffers					✓	
Redevelop Urban Areas to Decrease Runoff-Related Impacts					✓	
Operation and Maintenance						
Establishing an Operation and Maintenance Program					✓	✓
Source Control Operation and Maintenance					✓	✓
Treatment Control Operation and Maintenance					✓	✓
Evaluate Program Effectiveness						
Assess the Runoff Management Program Framework	Measurable Goals					
Track Management Practice Implementation						
Gauge Improvements in Water Quality Resulting from Management Practice Implementation						
Develop and Implement a Schedule to Improve the Management Program Framework						

The Clean Water Act establishes several reporting, funding, and regulatory programs that address pollutants carried in runoff that is not subject to confinement or treatment. These programs relate to watershed management and urban NPS control. Readers are encouraged to use the information contained in this guidance to develop nonpoint source management programs/plans that comprehensively address the following EPA reports and programs:

- *Section 303(d) Lists and TMDLs*. Under section 303(d) of the Clean Water Act, states are required to compile a list of impaired waters that fail to meet any of their applicable water quality standards or cannot support their designated or existing uses. This list, called a "303(d) list," is submitted to Congress every two years, and states are required to develop a Total Maximum Daily Load (TMDL) for each pollutant causing impairment for water bodies on the list. More information on the TMDL program and 303(d) lists is provided at http://www.epa.gov/owow/tmdl.
- *Section 305(b) and the National Water Quality Inventory: Report to Congress*. Every two years, states are required to submit a report to Congress detailing the health of their waters. These periodic reports allow Congress to gauge progress toward meeting the goals of the Clean Water Act and to help identify priorities for future pollution control funding and activities. More information on the 305(b) program and the National Water Quality Inventory is provided at http://www.epa.gov/owow/305b.
- *Section 319 Grant Program*. Under Section 319 of the Clean Water Act, EPA awards funds to states and eligible tribes to implement NPS management programs. These funds can be used for projects that address urban sources of pollution. More information about the Section 319 program is provided at http://www.epa.gov/owow/nps/cwact.html.
- *Section 404 Discharge of Dredged and Fill Material*. Under Section 404 of the Clean Water Act, persons planning to discharge dredged or fill material to wetlands or other waters of the United States generally must obtain authorization for the discharge from the U.S. Army Corps of Engineers (Corps), or a state approved to administer the Section 404 program. Such authorization can be through issuance of an individual permit, or may be subject to a general permit, which applies to certain categories of activities having minimal adverse environmental effects. Implementation of Section 404 is shared between the Corps and EPA. The Corps is responsible for reviewing permit applications and deciding whether to issue or deny permits. EPA, in consultation with the Corps, develops the Section 404(b)(1) Guidelines, which are the environmental criteria that the Corps applies when deciding whether to issue permits. EPA also has authority under Section 404(c) to "veto" Corps issuance of a permit in certain cases. More information about the 404 program is provided at http://www.epa.gov/owow/wetlands.
- *Clean Water State Revolving Fund*. EPA established the Clean Water State Revolving Fund (CWSRF) to provide states with low- or no-interest loans for projects that improve water resources. These funds can be used to support urban NPS pollution programs and projects. To receive CWSRF loans from EPA for water quality projects, states must develop annual Intended Use Plans that outline the expected use of these funds. More information on the CWSRF program is provided at http://www.epa.gov/OWM/finan.htm.
- *National Estuary Program.* Under the National Estuary Program, states work together to evaluate water quality problems and their sources, collect and compile water quality data,

and integrate management efforts to improve conditions in estuaries. So far 28 estuaries have been accepted into the program. Estuary programs can be an excellent source of water quality data and can provide information on management practices. More information on the National Estuary Program is provided at http://www.epa.gov/owow/estuaries/nep.html.

Two excellent resources for learning more about the Clean Water Act and the many programs established under it are *The Clean Water Act: An Owner's Manual* (Elder et al., 1999) and *The Clean Water Act Desk Reference* (WEF, 1997).

Safe Drinking Water Act. Many urban areas, especially urban fringe areas, need to maintain or improve the quality of surface and ground waters that are used as drinking water sources. This act requires states, among other things, to develop Source Water Assessment Reports and implement Source Water Protection Programs. Low- or no-interest loans are available under the Drinking Water State Revolving Fund Program. More information about the Safe Drinking Water Act and Source Water Protection Programs can be found at http://www.epa.gov/safewater/protect.html.

0.3 Key Concepts

0.3.1 Watershed Approach

Since 1991, EPA has promoted the watershed approach as the key framework for dealing with problems caused by urban runoff and other sources that impair surface and ground waters (USEPA, 1998). Five principles guide the watershed approach:

- *Place-based focus*. Activities are directed within specific geographic areas known as management units. When surface runoff is the primary issue, these management units are defined by watershed boundaries. Other types of boundaries can also be used to define management units in special circumstances. If ground water is an issue, for example, ground water recharge areas might be a logical designation.

- *Stakeholder involvement and partnerships*. The people most affected by management decisions are involved throughout the process. Stakeholder participation helps to ensure that local quality of life, economic stability, and other important community issues are incorporated into planning and implementation activities. Partnerships among public agencies and private groups at all levels are also crucial for long-term success.

- *Environmental goals and objectives*. The success of watershed initiatives is measured by improvements of the water resource rather than by programmatic objectives. For example, reestablishing the pool and riffle structure in a stream channel to increase aquatic insect and fish populations might be an objective. Local goals and objectives need to be consistent with all applicable state, tribal, and federal statutes and regulations, including water quality standards.

- *Problem identification and prioritization*. Sound scientific data and methods are used to identify and prioritize threats to human and ecosystem health. This process usually begins with the assessment and characterization of current natural resource and community conditions within the management unit(s). Problems, including their causes and sources, are also documented. Stakeholders and partners then work jointly to set priorities among the various water resource concerns, taking into account priorities already established at scales above and below the management unit.

– *Integration of actions*. Stakeholders and partners take actions in a comprehensive and integrated manner. Results are then evaluated and actions are adjusted as needed.

A key attribute of the watershed approach is that it can be applied with equal success to large- and small-scale watersheds. Federal agencies, states, interstate commissions, and tribes usually apply the approach on watersheds of approximately 100 square miles. Local agencies and urban communities, however, can apply the approach to watersheds as small as 1 square mile. Although specific objectives, priorities, actions, timing, and resources might vary from large scale to small scale, the basic goals of the watershed approach remain the same—protecting, maintaining, and restoring water resources.

Local runoff management program officials must be especially conscious of watershed scale when planning and implementing specific management practices. Nonstructural practices, such as stream protection ordinances and public education campaigns, are usually applied community-wide. Consequently, the results benefit many small watersheds. In contrast, structural practices, such as infiltration basins and sand filters, usually provide direct benefits to a single stream. Regional structural management practices such as retention ponds for larger watersheds can be used, but they do not protect smaller contributing streams. Given limited resources, runoff program officials must often analyze costs and benefits and choose between large- and small-scale practices. Often, a combination of nonstructural and structural practices is the most cost-effective approach.

British Columbia's Watershed Approach

The Province of British Columbia has taken a watershed approach in planning for water quality protection through runoff volume management. Program officials have recognized the link between surface water volume and watershed health, and are incorporating land use planning into urban runoff management efforts. The Water Balance Model is a decision support tool developed to assist in the integration of land use planning and urban runoff management by simulating the effects of source controls within the watershed. This tool allows the province to establish priorities and efficiently evaluate the potential effectiveness of management efforts (Stephens et al., 2003).

0.3.2 Stream Network

The size of a watershed is closely related to the network of streams contained within its borders. Streams with no upstream tributaries are designated as first-order streams down to their first confluence. A second-order stream is formed when two first-order streams meet. A third-order stream is created by the confluence of two second-order streams, and so on.

Headwater streams are defined as first- and second-order streams. What they lack in individual size and length, they make up through sheer numbers. Headwater streams dominate the landscape, accounting for roughly 75 percent of the total stream and river mileage in the United

States (Table 0.4). Because they are the dominant drainage feature, headwater streams also directly receive the bulk of runoff from construction sites, developments, parking lots, highways, and other features of the urban landscape. In most communities, runoff is collected by a storm sewer system and discharged with no treatment. Increases in the volume and rate of storm water runoff have historically resulted in construction of concrete channels and drainage pipes, eliminating many headwater streams.

Table 0.4: National stream order statistics (Leopold et al., 1964).

Stream Order	Number of Streams	Total Length of Stream Miles	Mean Drainage Area (square miles)
1	1,570,000	1,570,000	1
2	350,000	810,000	4.7
3	80,000	420,000	23
4	18,000	220,000	109
5	4,200	116,000	518
6	950	61,000	2,460
7	200	30,000	11,700
8	41	14,000	55,600
9	8	6,200	264,000
10	1	1,800	1,250,000

0.3.2.1 Watershed scales

Any number of watersheds can be defined by the streams within the network. Larger watersheds encompass progressively smaller watersheds in a hierarchical manner. Larger watershed scales, or national scales, are classified using the Hydrologic Unit Code (HUC), a system of hierarchical codes used by federal agencies, states, interstate commissions, tribes, and others to identify watersheds at the national level. Smaller local watersheds, existing at scales below the smallest HUC scale, are identified more informally.

The U.S. Geological Survey (USGS) has developed the National Hydrography Dataset (NHD), which is a comprehensive set of digital spatial data derived from USGS digital line graphs and EPA's reach file 3 that contains information about surface water features such as lakes, ponds, streams, rivers, springs, and wells. Within the NHD, surface water features are combined to form “reaches,” which provide the framework for linking water-related data to the NHD surface water drainage network. These linkages enable the analysis and display of these water-related data in upstream and downstream order. More information about the NHD is provided at http://nhd.usgs.gov.

0.3.2.2 National-level scales

USGS developed the HUC system for the purpose of inventorying all “national scale” watersheds in the United States. To accomplish this objective the agency first divided the country into 21 regions that account for the watersheds of 21 major river basins. Within those major river basins the agency identified a total of 222 watershed subregions. The subregions, in turn, were classified as 352 accounting units. The accounting units were further broken down into 2,262 smaller watersheds called cataloging units.

Each level, or scale, in the watershed hierarchy is identified by a numerical code. The cataloging unit, the smallest scale in the hierarchy, has an eight-digit code that uniquely identifies its location. The region where the cataloging unit resides is designated by the first two digits of the code, the subregion by the second two digits, and so on until the four scales are identified. For example, the watershed of the Upper Mississippi River at Hasting, Minnesota, has a HUC code of 07010206. This code breaks down as follows:

Major River Basin ID	07
Subbasin ID	0701
Accounting Unit ID	070102
Catalog Unit ID	07010206

0.3.2.3 Local-level scales

The hierarchy established by the HUC system identifies scales useful for watershed planning and management by national, regional, state, and multi-state jurisdictions. In many instances, a municipality or urban community is part of a larger team and undertakes activities in a large-scale context. However, because even the smallest scale, the cataloging unit, usually describes watersheds of 100 to 1,000 square miles, local practitioners of runoff management typically find the HUC-designated scales simply too large to be of practical use. This is especially true when designing and implementing runoff control practices for individual developments and sites. Consequently, the watershed hierarchy must be extended to include smaller-scale management units. A national effort is under way to designate 14-digit HUCs.

The Center for Watershed Protection (Caraco et al., 1998) proposed three progressively smaller scales in the watershed hierarchy below the subbasin cataloging unit (Figure 0.3):

- *Watershed*. The scale encompassed by the cataloging unit. Generally, this is the largest management unit that falls within the local land use planning authority. A community might have one or more watersheds within its borders, depending on its size.

- *Subwatershed*. The scale encompassed by the watershed. Its boundaries include all the land area draining to the point where two second-order streams come together to form a third-order stream. In most regions, subwatersheds are a few square miles in area and are drained by a stream several feet in width.

- *Catchment*. The smallest scale in the hierarchy. The Center for Watershed Protection defines it as the area that drains an individual development site to its first intersection with a stream. In some cases this intersection is in the form of a pipe outfall. Depending on the size of the development site, the catchment might also include some off-site drainage.

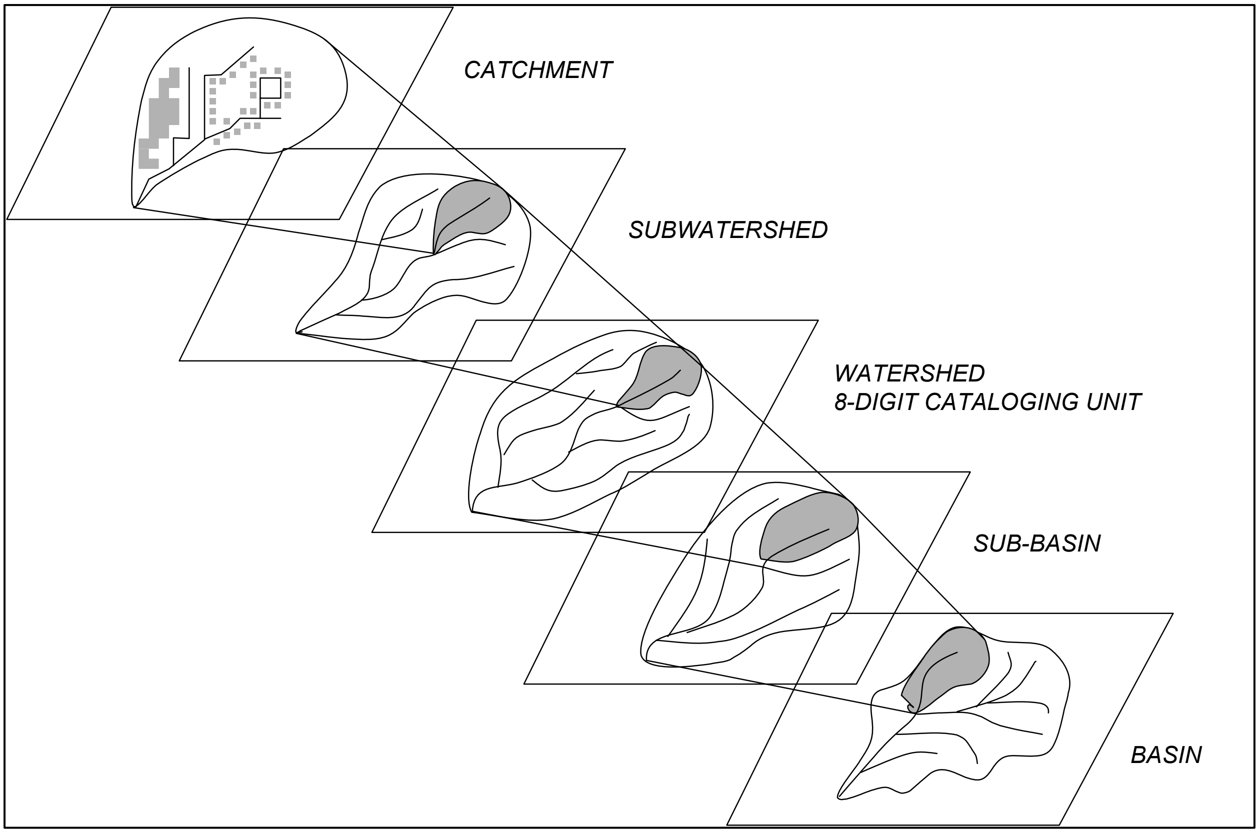


Figure 0.3: Scales of watershed management units (Schueler, 1995).

0.3.3 Impervious and Pervious Surfaces in the Urban Landscape

The term impervious surface refers to land cover, both natural and human-made, that cannot be penetrated by water. Consequently, precipitation that falls on impervious surfaces does not infiltrate into the soil. Instead, it runs off to a pervious area where all or a portion infiltrates into the soil, or it continues to travel down-slope on impervious surfaces including saturated soils until it is eventually conveyed to a ditch, a storm drain network, a stream, a lake, a wetland, an estuary, or some other type of surface receiving water. For additional discussion on the water quality impacts of imperviousness, see Section 1.3.5, Changes in the Watershed Due to Increased Imperviousness.

Most of the impervious cover in an urban watershed or subwatershed can be organized into three main categories:

- *Rooftops*. Impervious cover created by buildings, homes, garages, stores, warehouses, and other structures with roofs.

- *Transport systems*. Impervious cover created by structures such as roads, sidewalks, driveways, and parking lots. Most of these structures are associated with transportation of people or materials, hence the name transport systems.

- *Recreational facilities*. Impervious cover created by tennis and basketball courts, playgrounds, decks, and swimming pools.

In most areas the transport systems component covers a larger percentage of land than the rooftops component. A study in the city of Olympia, Washington, for example, revealed that transport system imperviousness constituted 63 to 70 percent of the total impervious cover at 11 sites of varying land use, including residential, multifamily, and commercial areas (City of Olympia, 1995).

0.3.3.1 Total and effective impervious surface

The amount of impervious cover in a watershed or subwatershed is reported in two basic ways:

- *Total (or mapped) impervious area*. Includes all impervious cover in a watershed or subwatershed—rooftops, transport systems, and recreational facilities. It is usually expressed as a percentage of the total watershed or subwatershed area. It can be calculated by direct measurement or by percentage estimation based on land use, road density, population density, or another indicator.

- *Effective impervious area (EIA)*. The portion of total impervious cover that is directly connected to the storm drain network (Sutherland, 1995). These surfaces usually include street surfaces and paved driveways and sidewalks connected to or immediately adjacent to them, parking lots, and rooftops that are hydraulically connected to the drainage network (e.g., downspouts running directly to gutters or driveways). EIA also is usually expressed as a percentage of the total watershed or subwatershed area. It is the preferred statistic for use when estimating runoff volumes because it is the portion of the impervious cover that generates direct runoff.

Subtracting EIA from the total impervious area yields the amount of impervious area that is not directly connected to the storm drain network, or the ineffective impervious area. Residential rooftops are an example of possible ineffective impervious areas because downspouts can direct runoff to yards and other pervious landscaping areas, where a portion of the water can infiltrate the ground. Rooftops in some residential and most commercial areas, however, will likely be classified as effective impervious areas because their downspouts typically will be tied directly to the storm drain network. Filtration, infiltration, evaporation, and biological uptake of pollutants can substantially reduce runoff volume and improve water quality when runoff is directed over vegetated areas. For further discussion on downspout disconnection, see Management Measure 4: Site Development and Management Measure 10: Existing Development.

Both the amount of impervious area and the relationship between total and effective impervious areas varies according to land use (Caraco et al., 1998). For example, work in the Puget Sound area revealed that total impervious area in low-density residential sites averaged approximately 10 percent, with an effective impervious area of only 4 percent. In commercial and industrial areas, however, total impervious area averaged about 90 percent. Almost all of the total impervious area is also effective impervious area because of the lack of pervious areas to break up direct connections.

0.3.3.2 Pervious surfaces

The urban and suburban landscape has a variety of pervious surfaces, including

- Forests and wetlands
- Lawns and other private turf
- Public turf
- Intensively landscaped areas
- Vacant lands
- Runoff treatment areas

Although most of these areas are green, it would be a mistake to think of them as hydrologically equivalent to an undisturbed meadow, forest, or other natural pervious area, especially in terms of their ability to allow runoff to infiltrate. Soils in urban landscapes are usually highly disturbed and compacted, poor in structure, and low in permeability. In addition, they often receive runoff from adjacent impervious areas, resulting in water inputs many times greater than normal. These factors and others tend to decrease the ability of pervious urban areas to infiltrate runoff, which means an increased fraction of water moves off these areas to impervious areas and storm drainage networks. In extreme cases, the amount of runoff generated is close in volume to that generated from impervious surfaces. Consequently, some “pervious” areas function as impervious areas and cause analysts to underestimate peak flow, runoff volumes, and time of concentration. Refer to Management Measure 9: Pollution Prevention, for more information on runoff from lawns.

0.3.4 Impervious Cover Model

A simple tool, the *Impervious Cover Model*, can be used to project the current and future quality of streams and other water resources at the subwatershed scale based on impervious cover (Caraco et al., 1998). The objective of this model is to assist local officials and other watershed practitioners in devising realistic goals and objectives given present and future levels of development. The impervious cover model is a simple urban stream classification system that contains three stream categories based on the percentage of impervious cover present in the subwatershed. It is intended to help managers decide how to adapt and refine management measures given the intensity of urban development in their watersheds. The impervious cover model has some limitations. These are (Caraco et al., 1998):

- *Reference condition*. The model predicts potential, not actual, stream quality, so in some cases stream reaches might depart from the model’s predictions.

- *Scale effect*. The model should be applied only to small, first- to third-order streams because the influence of impervious cover is strongest at these spatial scales.

- *Statistical variability*. There is a moderate degree of scatter exhibited in individual impervious cover/stream quality indicator relationships, although the indicators show a general downward trend as imperviousness increases. The model predicts the average behavior of multiple indicators over a range of imperviousness, and the impervious cover thresholds are not sharp breakpoints but transitions.

- *Measuring and projecting impervious cover*. Accurately quantifying actual and projected impervious cover is important for the model. However, there is no standardized method for measuring total or effective imperviousness.

- *Regional adaptability*. The model has been tested mostly in the mid-Atlantic and Puget Sound ecoregions but little research has been conducted to determine the applicability of the model in western, midwestern, and mountain streams.

- *Defining thresholds for nonsupporting streams*. More sampling and study are needed to more firmly establish the threshold for the transition between impacted streams and nonsupporting streams, projected to occur at 25 percent impervious cover for small urban streams.

- *Influence of management practices in extending thresholds*. The changes in hydraulic and pollutant loadings, and their effects on receiving streams, should be carefully considered when practices are used to extend the threshold of imperviousness.

- *Influence of riparian cover in extending thresholds*. Conservation or restoration of a riparian zone has been shown to extend the impervious cover threshold.

- *Pervious area*. Urban landscapes contain pervious areas, but many of them are highly disturbed and do not resemble pervious areas in non-urban landscapes. However, planners can integrate pervious and impervious areas to greatly reduce effective impervious area and reduce the impact of imperviousness on stream quality.

0.3.4.1 Subwatersheds as the primary management unit

The impervious cover model relies on the subwatershed as the primary management unit. Table 0.5 displays the influence of impervious cover in the context of a hierarchy of watershed-based management units. The subwatershed scale is ideal for planning purposes at the local level for many reasons, including:

- The influence of impervious cover on hydrology, channel stability, water quality, and biodiversity is most evident at the subwatershed scale because the receiving water body is typically a headwater stream.

- The smaller scale helps local officials more easily identify impacts of individual development projects and sources of pollutants.

- Subwatersheds are typically small enough to be within the borders of one or two jurisdictions. This eases the burden of establishing regulatory authority as well as keeping the number of stakeholders to a manageable number.

- Assessments and evaluations can be conducted more easily because most subwatersheds can be mapped on a standard 24-inch by 36-inch sheet with sufficient detail to provide useful management information. The smaller scale also allows assessments and evaluations to be completed more rapidly than similar efforts at larger scales. This creates the opportunity for phasing the development of subwatershed plans (or focusing on areas needing priority attention), making the best use of limited resources. Officials and local citizens can more easily recognize progress as plans are completed and implemented over a coordinated cycle.

Table 0.5: Idealized characteristics of five watershed management units with respect to size and the influence of impervious cover (adapted from Caraco et al., 1998).

Watershed Management Unit	Typical Area (square miles)	Influence of Impervious Cover
Catchment	0.05–0.50	Very strong
Subwatershed	1–10	Strong
Watershed	10–100	Moderate
Subbasin	100–1,000	Weak
Basin	1,000–10,000	Very weak

0.3.4.2 Classification levels

The impervious cover model designates three levels of classification based on impervious cover:

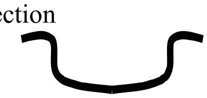
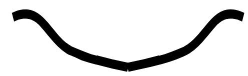
- *Sensitive subwatersheds*, which have less than 10 percent impervious cover. Streams found in sensitive subwatersheds are at, or close to, predevelopment conditions. Urban runoff management strategies, therefore, should focus on maintaining these conditions. New development and redevelopment should be discouraged or designed to have no impact to prevent any increase of impervious cover in subwatersheds of this type.

- *Degrading subwatersheds*, which have 11 to 25 percent impervious cover. Degrading subwatersheds have crossed the 10 percent imperviousness threshold, and have experienced degradation of key stream attributes or can be expected to experience such degradation over time. Some of the more sensitive organisms probably have disappeared or will disappear. Resource objectives consequently should focus more on maintaining or restoring key conditions than on resource protection as a whole. Structural and nonstructural practices that deal with, or counteract, increased urban runoff are recommended.

- *Nonsupporting subwatersheds*, which have more than 25 percent impervious cover. Streams in nonsupporting subwatersheds are well beyond the impervious cover thresholds and may never recover predevelopment conditions no matter how many management practices are implemented. Resource objectives are primarily aimed at reducing peak flows and preventing and removing urban pollutants so they will not be carried downstream. Limited restoration of some attributes such as increased biodiversity can sometimes be achieved given the right circumstances. Pollution prevention and retrofitting in existing urban areas are the most frequently used practices.

Table 0.6 describes channel stability, water quality, and biodiversity attributes, as well as general resource and water quality objectives associated with each category.

Table 0.6: Characteristics of aquatic integrity in urban watersheds.

Integrity Rating	Low	Moderate	High
Riparian Habitat Characteristics	– Riparian zone greatly reduced – Increased sediment deposition – Completely bare/exposed banks – Deeply incised and widened channel cross-section 	– Riparian zone partly cleared – Moderate sediment deposition, sand bar formation – Banks slightly exposed – Steep banks and widened channel cross-section 	– Mature riparian zone – Decreased sediment deposition, mostly rocky substrates – Bank well-vegetated and forested – Floodplain terrace channel cross-section 
Macroinvertebrate Community Characteristics	– Pollution-tolerant species – Tolerant of low dissolved oxygen (DO) levels – Reduced feeding and life history requirements – Decreased diversity and number of species	– Moderately pollution-tolerant species – Tolerant of moderate DO levels – Some general reduction in life history and feeding requirements	– Pollution-intolerant species – Intolerant of low DO levels – Unaltered life history and feeding requirements – Increased number and diversity of species
Fish Assemblage Characteristics	– Pollution-tolerant species – Exotic/introduced species – Reduced feeding and life history requirements – Decreased diversity and number of species	– Moderately pollution-tolerant species – Intermediate number of individuals and species – Some general reduction in life history and feeding requirements	– Pollution-intolerant species – Unaltered life history and feeding requirements – Increased number and diversity of species
Rehabilitation Process	Degraded		Improved

0.3.5 Changes in the Watershed Due to Increased Imperviousness

Watershed imperviousness plays an important role in determining the conditions in streams and other bodies of water. Impervious cover, however, is an inescapable attribute of development and a permanent part of the urban/suburban landscape. Figure 0.4 illustrates how four important components in the water cycle are affected by increasing levels of imperviousness (FISRWG, 1998). In natural landscapes, there is usually very little or no surface runoff. Water either percolates into the ground or is returned to the atmosphere by evaporation and transpiration. As imperviousness increases:

- Runoff increases because the surface area of rooftops and transportation systems is increased.
- Soil percolation decreases because pervious areas are reduced.

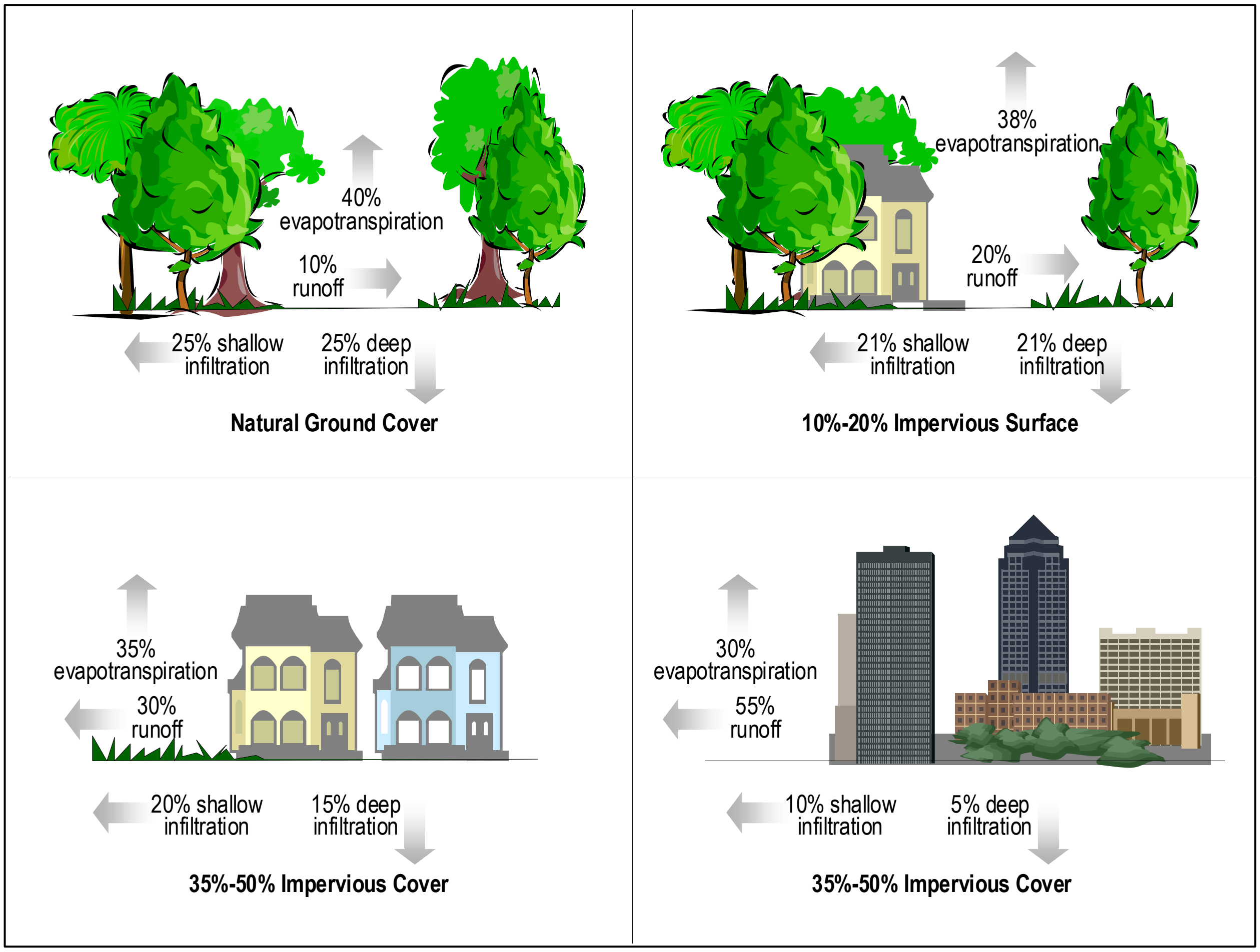


Figure 0.4: Impacts of urbanization on the water cycle (Adapted from FIRSWG, 1998).

- Evaporation decreases because there is less time for it to occur when runoff moves quickly off impervious surfaces.

- Transpiration decreases because vegetation has been removed.

As might be expected, there is a linear relationship between the amount of impervious surfaces in a given area and the amount of runoff generated. What is unexpected is what this means in terms of both the volume of water generated and the rate at which it exits the surface. Depending on the degree of impervious cover, the annual volume of storm water runoff can increase to anywhere from 2 to 16 times the predevelopment amount (Schueler, 1994). Impervious surface coverage as low as 10 percent can destabilize a stream channel, raise water temperature, and reduce water quality and biodiversity (Schueler, 1995). One recent study found that connected imperviousness levels between 8 and 12 percent represented a threshold region where minor changes in urbanization could result in major changes in stream condition (Wang et al., 2001).

Figure 0.5 shows a hydrograph comparing stream flow rates before, during, and after a storm under pre- and postdevelopment conditions (Schueler, 1987). As indicated, streams with developed watersheds have substantially higher peak flows, and these peak flows occur more quickly than under predevelopment conditions. This is reflective of typical urban conditions, where runoff moves quickly over impervious surfaces and drains into a channel.

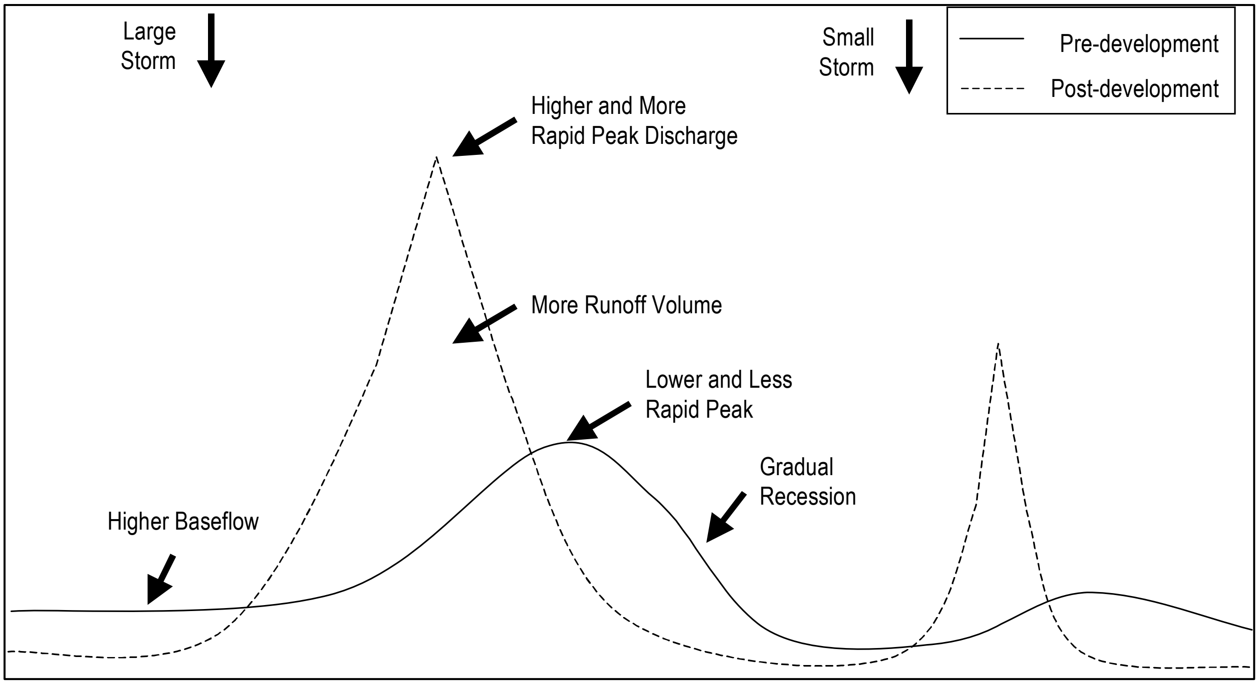


Figure 0.5: Changes in stream flow hydrograph as a result of urbanization (Schueler, 1987).

Development and increased impervious cover also lead to erosion and undercutting of streambanks, widening of channels, and depositing of in-channel sediment. In addition, decreased base flow occurs in dry weather because a greater portion of runoff flows off the

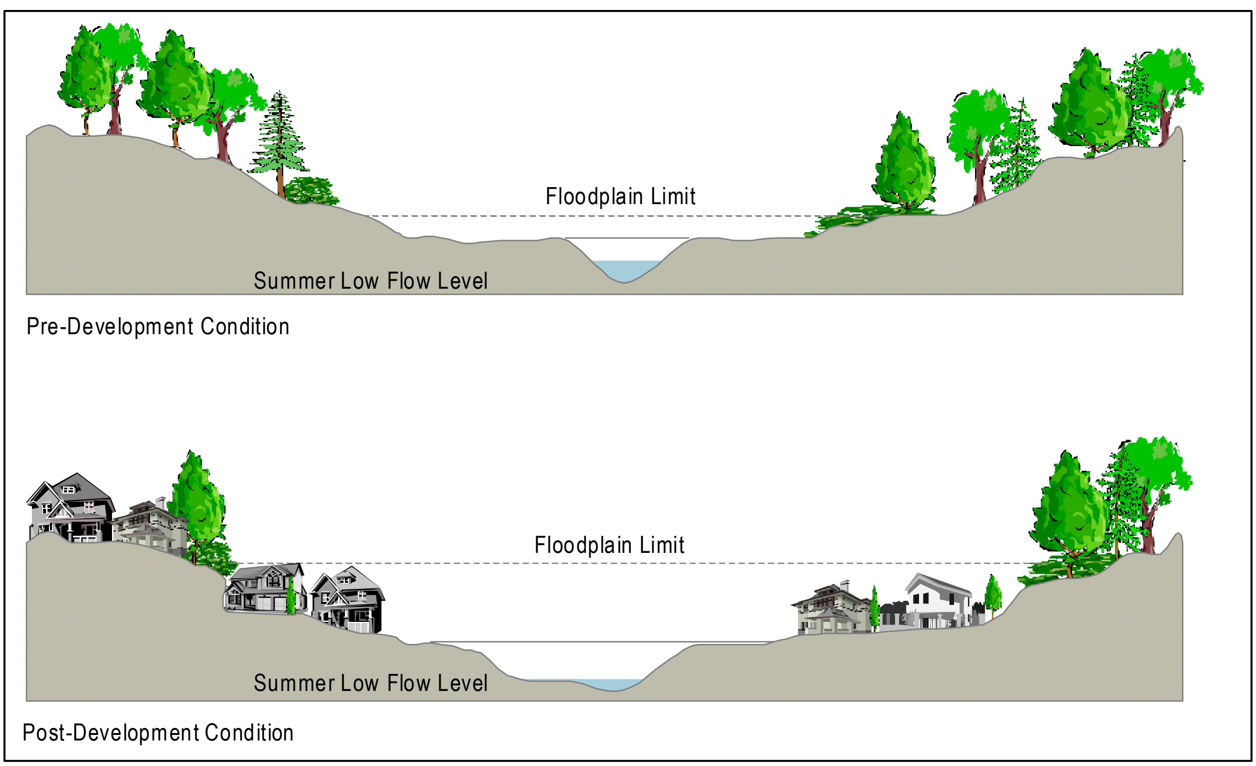


Figure 0.6: Response of stream geometry to urbanization (Schueler, 1987).

surface, resulting in less infiltration to ground water reserves that normally provide base flow to streams. Figure 0.6 shows changes to stream geometry in response to urbanization (Schueler, 1987).

EPA (1997) reviewed the literature for case studies that quantitatively examined the relationship between increased impervious surfaces and stream impacts. Table 0.7 lists these relationships, and Table 0.8 summarizes the case studies used to derive the relationships.

Table 0.7: Impacts from increases in impervious surfaces (USEPA, 1997).

Increased Imperviousness Leads to:	Resulting Impacts				
	Flooding	Habitat Loss	Erosion	Channel Widening	Streambed Alteration
Increased Volume	✓	✓	✓	✓	✓
Increased Peak Flow	✓	✓	✓	✓	✓
Increased Peak Duration	✓	✓	✓	✓	✓
Increased Stream Temperature		✓			
Decreased Base Flow		✓			
Sediment Loading Changes	✓	✓	✓	✓	✓

Table 0.8: Summary of case studies linking urbanization to hydrological impacts on streams (USEPA, 1997).

Case Study	Location	Documented Impacts	Inferred Impacts
East Meadow Brook	Nassau County, NY	– Increased peak flows	Flooding, habitat loss, erosion, channel widening, streambed alteration
Holmes Run Watershed	Fairfax, VA	– Frequent flooding – Severe streambank erosion – Sedimentation	Flooding, habitat loss, erosion, channel widening, streambed alteration
Kelsey Creek	Bellvue, WA	– Degradation of designated uses – Decreased base flow – Loss of fish populations	Habitat loss, channel widening
Patuxent River System	Maryland	– Increased instream sediment load – Changes in morphology of urban channels	Habitat loss, erosion, channel widening
Peachtree Creek	Atlanta, GA	– Increased bankfull events – Decreased base flow	Flooding, habitat loss, erosion, channel widening, streambed alteration
Pheasant Branch Basin	Middleton, WI	– Stream incision – Increase in bankfull events – Sedimentation	Flooding, habitat loss, erosion, channel widening, streambed alteration
Pipers Creek	Seattle, WA	– Increased peak flows – Loss of fish populations – Aesthetic degradation	Flooding, habitat loss, erosion, channel widening, streambed alteration
Several creeks	Dekalb County, GA	– Stream enlargement – Stream incision – Increased sediment transport	Habitat loss, erosion, channel widening, streambed alteration
Valley Stream, Pines Brook, Bellmore Creek, and Massapequa Creek	Nassau County, NY	– Decreased base flow	Habitat loss

Recent research has shown that streams in urban watersheds have a fundamentally different character from that of streams in forested, rural, or even agricultural watersheds. The amount of impervious cover in the watershed can be used as an indicator to predict how severe these differences might be. In many regions of the country, as little as 10 percent watershed impervious cover has been linked to stream degradation, with the degradation becoming more severe as impervious cover increases (Schueler, 1995).

Some key changes in urban streams that merit special attention are detailed below:

- *Bankfull and subbankfull floods increase in magnitude and frequency.* The peak discharge associated with the bankfull flow (the 1.5- to 2-year return storm) increases sharply in magnitude in urban streams. In addition, channels experience more bankfull and subbankfull flood events each year and are exposed to critical erosive velocities for longer intervals (Booth et al., 1996; Hollis, 1975; and MaCrae, 1996).

- *Dimensions of the stream channel are no longer in equilibrium with its hydrologic regime*. The hydrologic regime that defined the geometry of the predevelopment stream channel irreversibly changes, and the stream experiences higher flow rates on a more frequent basis. The higher-flow events of the urban stream are capable of moving more sediment than before.

- *Channels enlarge.* The customary response of an urban stream is to increase its cross-sectional area to accommodate the higher flows. This is done by streambed downcutting, channel widening, or a combination of both. Urban stream channels often enlarge their cross-sectional area by a factor of 2 to 5 depending on the degree of impervious cover in the upland watershed and the age of development (Arnold et al., 1982; Gregory et al., 1992; and Macrae, 1996).

- *Stream channels are highly modified by human activity.* Urban stream channels are extensively modified in an effort to protect adjacent property from streambank erosion or flooding. Headwater streams are frequently enclosed within storm drains, while other streams are channelized, lined, and/or "armored" by heavy stone. Another modification unique to many urban streams is the installation of sanitary sewers underneath or parallel to the stream channel.

- *Upstream channel erosion contributes greater sediment load to the stream*. The prodigious rate of channel erosion coupled with sediment erosion from active construction sites increases sediment discharge to urban streams. Researchers have documented that channel erosion constitutes as much as 75 percent of the total sediment budget of urban streams (Crawford and Lenat, 1989; Trimble, 1997). Urban streams also tend to have a higher sediment discharge than non-urban streams, at least during the initial period of active channel enlargement.

- *Dry weather flow in the stream declines*. Because impervious cover prevents rainfall from infiltrating the soil, less flow is available to recharge ground water. Consequently, during extended periods without rainfall, baseflow levels are often reduced (Simmons and Reynolds, 1982).

- *Wetted perimeter of the stream declines*. The wetted perimeter of a stream is the proportion of the total cross-sectional area of the channel that is covered by flowing water during dry weather, and it is an important indicator of habitat degradation in urban streams. Given that urban streams develop a larger channel cross-section at the same time that their base flow rates decline, it follows that the wetted perimeter will become smaller. Thus, for many urban streams, this results in a very shallow, low-flow channel that "wanders" across a very wide streambed, often changing its lateral position in response to storms.

- *Instream habitat structure degrades*. Urban streams are routinely scored as having poor instream habitat quality, regardless of the specific metric or method employed. Habitat degradation is often exemplified by loss of pool and riffle structure, embedding of streambed sediments, shallow depths of flow, eroding and unstable banks, and frequent streambed turnover.

- *Large woody debris (LWD) is reduced*. LWD is an important structural component of many low-order stream systems because it creates complex habitat structure and generally makes the stream carry more water. In urban streams, the quantity of LWD found in stream channels declines sharply because of the loss of riparian forest cover, storm washout, and channel maintenance practices (Booth et al. 1996; May et al., 1997).

- *Stream crossings and potential fish barriers increase*. Many forms of urban development are linear in nature (e.g., roads, sewers, and pipelines) and cross stream channels. The number of stream crossings increases in direct proportion to impervious cover (May et al., 1997), and many crossings can become partial or total barriers to upstream fish migration, particularly if the streambed erodes below the fixed elevation of a culvert or pipeline.

- *Riparian forests become fragmented, narrower, and less diverse.* The important role that riparian forests play in stream ecology is often diminished in urban watersheds as tree cover is often partially or totally removed along the stream as a consequence of development (May et al., 1997). Even when stream buffers are preserved, encroachment often reduces their effective width and native species are supplanted by exotic trees, vines, and ground covers.

- *Water quality declines*. The water quality of urban streams during storms is consistently poor. Urban storm water runoff contains moderate to high concentrations of sediment, carbon, nutrients, trace metals, hydrocarbons, chlorides, and bacteria (Schueler, 1987). Although considerable debate exists as to whether storm water pollutant concentrations are actually toxic to aquatic organisms, researchers agree that pollutants deposited in the streambed exert an undesirable impact on the stream community.

- *Summer stream temperatures increase*. The impervious surfaces, ponds, and poor riparian cover in urban watersheds can increase mean summer stream temperatures by 2 ºF to 10 ºF (Galli, 1991). Because temperature plays a central role in the rate and timing of instream biotic and abiotic reactions, such increases have an adverse impact on streams. In some regions, summer stream warming can irreversibly shift a cold-water stream to a cool-water or even warm-water stream, resulting in deleterious effects on salmonids and other temperature-sensitive organisms.

– *Reduced aquatic diversity*. Urban streams are typified by fair to poor fish and macroinvertebrate diversity, even at relatively low levels of watershed impervious cover or population density (Couch, 1997; Crawford and Lenat, 1989; May et al., 1997; Miltner, 2003; Schueler, 1995; Shaver et al., 1994). Declines in sensitive species have been observed at levels of impervious cover as low as 4 percent. Impervious cover in highly urbanized areas comprising greater than 25 percent of a watershed may even preclude the Clean Water Act goal of "fishable" waters (Miltner, 2003). The ability to restore predevelopment fish assemblages or aquatic diversity is constrained by a host of factors, including irreversible changes in carbon supply, temperature, hydrology, lack of instream habitat structure, and barriers that limit natural recolonization.

Figure 0.7 shows the relationship between impervious cover and aquatic insect diversity; Figure 0.8 shows the relationship between imperviousness and fish diversity. Both studies were conducted in Maryland streams (Schueler and Galli, 1992, as cited in Schueler, 1995).

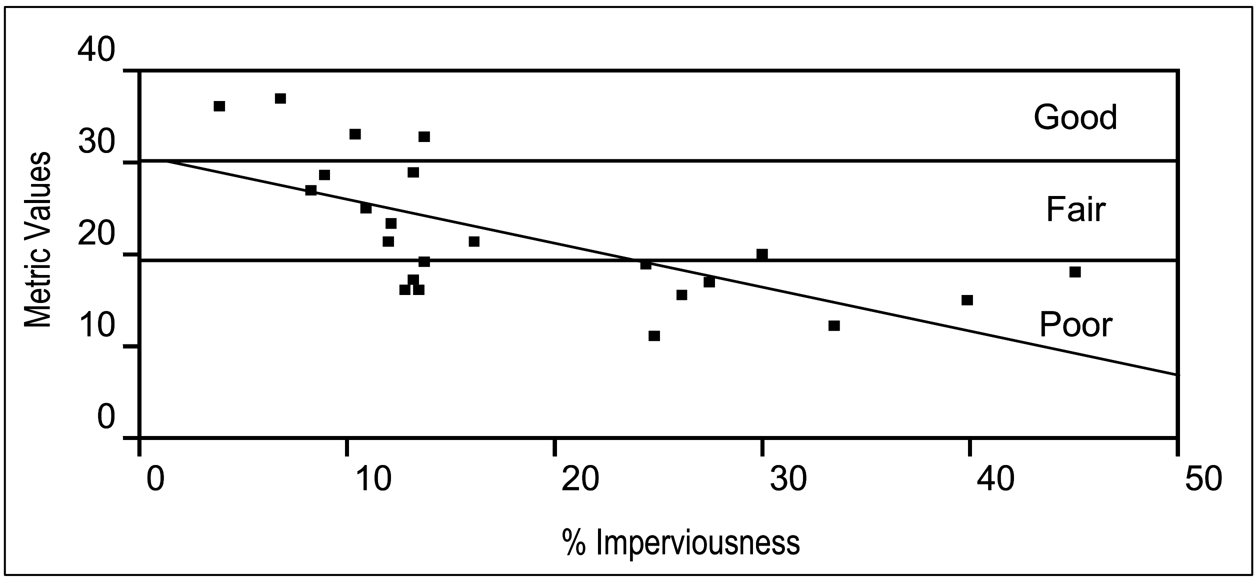


Figure 0.7: Relationship between impervious cover and aquatic insect diversity in Anacostia River subwatersheds (Schueler and Galli, 1992, as cited in Schueler, 1995).

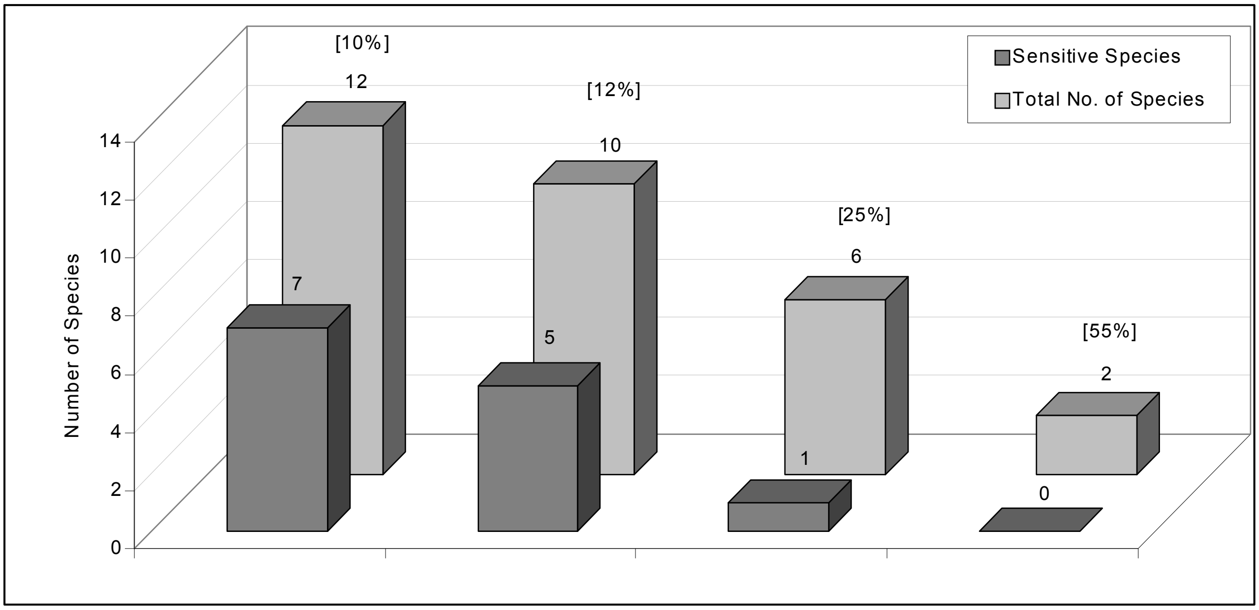


Figure 0.8: Fish diversity in four subwatersheds of different impervious cover in the Maryland Piedmont (Schueler and Galli, 1992, as cited in Schueler, 1995).

0.3.6 Nonpoint Source Pollutants and Their Impacts

Urban areas are a source for many different types of pollutants. Table 0.9 shows typical pollutant concentrations found in storm water. The following discussion identifies the principal types of pollutants found in urban runoff and describes their potential adverse effects:

0.3.6.1 Sediment

Excessive erosion, transport, and deposition of sediment in surface waters are significant sources of pollution in the United States, resulting in major water quality problems. Sediment imbalances impair waters' designated uses. Excessive sediment can impair aquatic life by filling interstitial spaces of spawning gravels, impairing sources of fish food, filling rearing pools, and reducing beneficial habitat structure in stream channels. In addition, excessive sediment can cause taste and odor problems in drinking water supplies and block water intake structures.

According to the *National Water Quality Inventory: 2000 Report to Congress* (required under section 305(b) of the Clean Water Act), states, tribes, and other jurisdictions surveyed water quality conditions in 19 percent of the nation's 3.6 million miles of rivers and streams (USEPA, 2002b). Some 39 percent of these surveyed waters were impaired by various pollution sources. Sediment was the second-leading cause of impairment, accounting for 31 percent of the impaired waters. Furthermore, sediment, especially its fine fractions, is the primary carrier of other pollutants such as organic components, metals, ammonium ions, phosphates, and toxic organic compounds.

Table 0.9: Typical pollutant concentrations found in urban storm water (adapted from MDE, 1999, and Terrene Institute, 1994).

Typical Pollutants Found in Storm Water Runoff	Units	Residential[a]	Mixed[a]	Commercial[a]	General Urban[b]
Total suspended solids	mg/L	101	67	69	80[c]
Total phosphorus	mg/L	383	263	201	0.30[c]
Total nitrogen	mg/L	–	–	–	2.0[c]
Total Kjeldahl nitrogen	mg/L	1.9	1.3	1.2	–
Nitrate + Nitrite	µg/L	736	558	572	–
Total organic carbon	mg/L	–	–	–	12.7[c]
Biological oxygen demand	mg/L	10	7.8	9.3	–
Chemical oxygen demand	mg/L	73	65	57	–
Fecal coliform bacteria	MPN/100 mL	–	–	–	3,600[c]
E. coli bacteria	MPN/100 mL	–	–	–	1,450[c]
Petroleum hydrocarbons	mg/L	–	–	–	3.5[c]
Oil and grease	mg/L	–	–	–	2 to 10[d]
Cadmium	µg/L	–	–	–	2[c]
Copper	µg/L	33	27	29	10[c]
Lead	µg/L	144	114	104	18[c]
Zinc	µg/L	135	154	226	140[c]
Chlorides (winter only)	mg/L	–	–	–	230[c]
Insecticides	µg/L	–	–	–	0.1 to 2.0[c]
Herbicides	µg/L	–	–	–	1 to 5.0[c]

[a] Source: USEPA, 1983.
[b] These concentrations represent mean or median storm concentrations measured at typical sites and may be greater during individual storms. Also note that mean or median runoff concentrations from storm water "hotspots" are 2 to 10 times higher than those shown here. Units: mg/L = milligrams/liter, µg/L = micrograms/l, MPN = most probable number.
[c] Source: MDE, 1999.
[d] Source: Terrene Institute, 1994.

A recent study of the economic impact of excessive erosion and transport of sediment in surface water systems estimates the annual cost of damage due to sediment pollution in North America at approximately $16 billion (Osterkamp et al., 1998). Sediment pollution costs can be measured in physical damages, chemical damages, and biological damages. Physical damages include harm to water conveyance, treatment, and storage facilities, and interference with recreational and navigational use. Chemical damages include deposition and storage of nutrients, metals, and pesticides associated with eroded sediments. Biological damages include harm to aquatic habitat from the movement and storage of sediment.

Potential sources of sediment pollution include agricultural erosion, deforestation, overgrazing, silvicultural erosion, urban runoff, construction activities, and mining activities. Sediments can also be dislodged and transported directly from the water body's shoreline, bank, or bottom. Atmospheric sources might also be a factor. In an informal study of atmospheric deposition of dust, Urbonas and Doerfer (2004) found that each 100 ft^2 of impervious surface can yield up to 1 to 1.2 pounds of solids in runoff on an average annual basis. Assuming that all of this dust enters storm water and that 30 percent of impervious surfaces are directly connected to the storm drain system, the authors estimate that 1 square mile of mixed-use urban development could yield 40 to 50 tons of total suspended solids in storm water each year.

The following is a summary of impacts of suspended and deposited sediments on the aquatic environment (adapted from Schueler, 1997):

Suspended sediments

- Abrasion of and damage to fish gills, increasing risk of infection and disease
- Scouring of periphyton from stream
- Loss of sensitive or threatened fish species when turbidity exceeds 25 nephelometric turbidity units (NTU)
- Shifts in fish community toward less-diverse, more sediment-tolerant species
- Decline in sunfish, bass, chum, and catfish when average monthly turbidity exceeds 100 NTU
- Reduction in sight distance for trout, with reduction in feeding efficiency
- Reduction in light penetration, resulting in a reduction in plankton and aquatic plant growth
- Reduction in filtering efficiency of zooplankton in lakes and estuaries
- Adverse impacts on aquatic insects, which are the base of the food chain
- Slight increases in stream temperature in summer
- Particles are a major vector for transport of nutrients and metals
- Turbidity, which increases probability of boating, swimming, and diving accidents
- Increased water treatment costs to meet drinking water standards of 5 NTU
- Increased wear and tear on hydroelectric and water intake equipment
- Reduction of anglers' chances of catching fish
- Diminishing quality of direct and indirect recreational experience of receiving waters
- Decreased submerged aquatic vegetation (SAV) populations

Deposited sediments

- Physical smothering of benthic aquatic insect community
- Reduced survival rates for fish eggs
- Destruction of fish spawning areas and redds

- Imbedding of stream bottom, which reduces fish and macroinvertebrate habitat value
- Loss of trout habitat when fine sediments are deposited in spawning habitat or riffle-runs
- Potential for elimination of sensitive or threatened darters and dace from fish community
- Increase in sediment oxygen demand, which can deplete dissolved oxygen in lakes or streams
- Significant contributing factor in the rapid decline of freshwater mussels
- Reduced channel capacity, exacerbating downstream bank erosion and flooding
- Reduced flood transport capacity under bridges and through culverts
- Loss of storage and lower design life for reservoirs, impoundments, and ponds
- Dredging costs to maintain navigable channels and reservoir capacity
- Spoiling of sand beaches
- Changes in the composition of bottom substrate
- Coral reef degradation in tropical and subtropical coastal areas
- Deposits that diminish the scenic and recreational value of waterways

Additional chronic effects may occur where sediments rich in organic matter or clay are present. These enriched depositional sediments may present a continued risk to aquatic and benthic life, especially where the sediments are disturbed and resuspended.

Although most concerns are due to excessive sedimentation, some ecological problems can result from insufficient sediment in a water body caused by hydrological modifications. Too little sediment can lead to channel scour and destruction of habitat dependent on an optimum level of sediment. In lakes, reservoirs, and estuaries, insufficient total suspended sediments can lead to increased light levels, resulting in the growth of nuisance algae.

The term *sediment* is broadly used to describe a problem associated with suspended solids, siltation, erosion, weathering, sedimentation, and other factors. Erosion, sediment transport, and deposition are natural processes caused by stresses placed on the earth's surface. Sediment movement is the result of water and air moving against the sediment (gravitation stresses) and natural weathering (molecular and chemical stresses). Because erosion is a natural process and significant quantities of sediments are being moved as a result of natural denudation, it would be unrealistic to expect complete control or elimination of sediment loads to receiving waters. However, it is feasible to control or manage excessive sediment loadings that have resulted from various land use activities and would be detrimental to the quality of the receiving bodies of water and to the aquatic and terrestrial habitat.

0.3.6.2 Nutrients

Nutrient overenrichment is especially prevalent in agricultural areas where manure and fertilizer inputs to crops significantly contribute to nitrogen and phosphorus levels in streams and other receiving waters. Urban streams have been shown to have the second-highest nitrate and total phosphorus levels, second only to agricultural streams (Barth, 1995). There are several nonpoint sources of nutrients in urban areas, mainly fertilizers in runoff from lawns, pet wastes, failing septic systems, and atmospheric deposition from industry and automobile emissions. Deposition of airborne pollutants is beyond the scope of this guidance. More information can be found at North Carolina State University's Web site, http://h2osparc.wq.ncsu.edu/wetland/aqlife/atmosdep.html.

Excessive nutrient levels in receiving waters can lead to exceedance of drinking water criteria (10 mg/L for nitrate-nitrogen), although monitoring data suggest that urban sources of nitrate are not high enough to pose a human health risk. However, moderately high concentrations of nutrients can result in eutrophication of sensitive receiving waters. These sensitive waters include oligotrophic or mesotrophic lakes where phosphorus is a limiting nutrient, or coastal or estuarine areas where nitrogen is limiting. Eutrophication can lead to changes in periphyton, benthic, and fish communities; extreme eutrophication can cause hypoxia or anoxia, resulting in fish kills. Surface algal scum, water discoloration, and the release of toxins from sediment can also occur.

0.3.6.3 Oxygen-demanding substances

Proper levels of dissolved oxygen (DO) are critical to maintaining water quality and aquatic life. Decomposition of organic matter by microorganisms may deplete DO and result in the impairment of the water body. Data have shown that urban runoff with high concentrations of decaying organic matter can severely depress DO levels after storms. The Nationwide Urban Runoff Program (NURP) study (USEPA, 1983) found that oxygen-demanding substances can be present in urban runoff at concentrations similar to those in secondary wastewater treatment discharges.

0.3.6.4 Pathogens

Urban runoff typically contains elevated levels of pathogenic organisms, including bacteria, viruses, and protozoa. The bacteria standard is one of the most commonly violated water quality standards in terms of both the number of water bodies and stream miles impaired. Approximately 50 percent of stream miles in Virginia are impaired due to bacteria contamination (Waye, 2002).

The presence of pathogens in runoff may result in water body impairments such as closed beaches and shellfish beds, and contaminated drinking water sources. Pathogen contamination related to onsite wastewater treatment systems (OWTSs) has been implicated in a number of shellfish bed closings. This problem may be especially prevalent in areas with porous or sandy soils and/or shoreline areas with a high concentration of OWTSs. Epidemiological studies have shown that pathogens can have significant effects on human health in contaminated marine swimming areas (Haile et al., 1999). While the most common effects of bathing in contaminated water are gastrointestinal illnesses, other conditions affecting the upper respiratory tract, ear, eye, and skin may also be contracted (USEPA, 2002a).

Indicator organisms have long been used to determine the level of risk for contracting illnesses from recreational activities in surface waters contaminated by fecal pollution. These organisms often do not cause illness directly, but have demonstrated characteristics that make them good indicators of harmful pathogens in water bodies. Until 1986, EPA recommended the use of fecal coliforms as an indicator for bacteria. However, after conducting epidemiological studies, EPA published *Ambient Water Quality Criteria for Bacteria*, which recommends that states use *Escherichia coli* (*E. coli*) for fresh recreational waters and enterococci for fresh and marine recreational waters because they are better predictors of acute gastrointestinal illness than fecal coliforms (USEPA, 1986). Some states and tribes have replaced their fecal coliform criteria with water quality criteria for *E. coli* or enterococci, but many other states and tribes have not yet made this transition (USEPA, 2002a).

Two protozoa of major concern as waterborne pathogens are *Giardia lamblia* and *Cryptosporidium parvum*. *Cryptosporidium* has become an increasingly serious pathogen problem in urban areas since the 1993 outbreak in Milwaukee, Wisconsin, when pathogens passed through a water treatment plant and left 400,000 people ill and almost 100 dead. Three major sources of pathogens in urban areas are human waste, pet waste, and anthropogenic wildlife. Anthropogenic wildlife includes raccoons, geese, pigeons, seagulls, and rats (Waye, 2002). Human waste can contaminate urban runoff through illicit connections of sanitary sewers with storm water systems, resulting in high bacterial counts and human health risks. These non-storm water sources are often a major contributor of pathogens to discharges from storm drain systems (Pitt et al., 2001).

While some types of waste can be treated before entering water bodies, others, such as feces from pets, should be disposed of properly. When pet waste is not properly disposed of, it can wash into nearby water bodies or be carried by runoff into storm drains. Since most urban storm drains do not connect to treatment facilities, but rather drain directly into lakes and streams, untreated animal feces can become a significant source of pathogens in surface waters.

As pet waste decays in a water body, it uses up oxygen, sometimes releasing ammonia. Low oxygen levels and ammonia combined with warm temperatures can be detrimental to fish and aquatic life. Pet waste also contains nutrients that promote weed and algae growth, which can cause eutrophication. Perhaps most importantly, pet waste carries bacteria, viruses, and other parasites that can pose health risks to humans and wildlife. For more information, refer to the discussion of microbial contamination in Management Measure 2: Watershed Assessment, and the discussion of pet waste in Management Measure 9: Pollution Prevention.

0.3.6.5 Road salts

According to a study by the Department of the Interior and USGS (1996), road salt has become a problem for both surface water and ground water quality, especially in the Northeast and Midwest. Nationally, an estimated $10 million are spent annually by state and local governments to remedy road salt contamination. The Northeastern Illinois Planning Commission (undated) estimates that 18 million tons of deicing salt, primarily sodium and calcium chlorides, are used each year in the United States. When the dissolved salts in runoff from highways and bridges enter soils, ground water, and surface waters, salinity levels increase and can become toxic to plants, fish, and other aquatic organisms. These impacts are especially pronounced in smaller water bodies adjacent to salted areas. Additionally, salt is corrosive and may cause damage to roadways, bridges, and vehicles. Deicing is very important for pedestrian and driver safety, and there are a number of new technologies available for reducing the threat to water quality from this activity. For a discussion of management practices to minimize the environmental impact of road salt application, see Management Measure 7: Bridges and Highways.

0.3.6.6 Hydrocarbons

The sources of oil, grease, and other petroleum hydrocarbons in urban areas include spillage and seepage of fossil fuels, discharge of domestic and industrial wastes, atmospheric deposition, and runoff. Atmospheric deposition is beyond the scope of this guidance (see North Carolina State University's Web site, http://h2osparc.wq.ncsu.edu/wetland/aqlife/atmosdep.html).

Runoff can be contaminated by leachate from asphalt roads, wearing of tires, deposition from automobile exhaust, and oiling of roadsides and unpaved roadways with crankcase oil (USEPA, 2000b). Also, many do-it-yourself auto mechanics dump used oil and other automobile-related fluids directly into storm drains (Klein, 1985). Petroleum hydrocarbons, such as polycyclic aromatic hydrocarbons (PAHs), can accumulate in aquatic organisms from contaminated water, sediments, and food, and are known to be toxic to aquatic life at low concentrations (USEPA, 2000b). Hydrocarbons can persist in sediments for long periods and result in adverse impacts on the diversity and abundance of benthic communities.

Hydrocarbons can be measured as total petroleum hydrocarbons (TPH), as oil and grease, or as individual groups of hydrocarbons, such as PAHs (see Management Measure 7).

0.3.6.7 Heavy metals

Heavy metals are typically found in urban runoff, with automobiles suspected to be the leading source (CWP, 1994). For example, Klein (1985) reported in a study of the Chesapeake Bay that designated urban runoff was the source for 6 percent of the cadmium, 1 percent of the chromium, 1percent of the copper, 19 percent of the lead, and 2 percent of the zinc.

Heavy metals are of concern because of toxic effects on aquatic life and the potential for ground water contamination. Copper, lead, and zinc are the most prevalent NPS pollutants found in urban runoff. High metal concentrations can bioaccumulate in fish and shellfish, and affect beneficial uses of a water body.

0.3.6.8 Toxic pollutants

Many different toxic compounds (priority pollutants) have been associated with urban runoff. The NURP studies (USEPA, 1983) indicated that at least 10 percent of urban runoff samples contained toxic pollutants. Methylene chloride and bis (2-ethylhexyl) phthalate were the most commonly reported and detected organic constituents in an ongoing evaluation of stormwater data from NPDES Phase 1 Municipal Separate Storm Sewer System permit holders. PAHs were also found in several hundred storm events (Pitt, 2004).

0.3.6.9 Temperature

Temperature changes result from increased flows, removal of vegetative cover, and increases in impervious surfaces. Impervious surfaces act as heat collectors, which heat urban runoff as it passes over them. Data indicate that intensive urbanization can increase stream temperature by as much as 5 to 10ºC during storms (Galli and Dubose, 1990). Elevated temperatures can be caused when streambeds become wider and shallower due to higher flows, removal of riparian vegetation along streambanks, and detaining water in runoff management facilities during warm weather. Elevated temperatures disrupt aquatic organisms that have finely tuned temperature limits, such as trout, salmon, and the aquatic insects on which they feed, by decreasing the amount of dissolved oxygen in the water column. Increased water temperatures can also lead to a shift in the algal community, disrupting the aquatic food chain (Galli, 1991).

0.3.7 Nonpoint Source Pollutant Loading

Nonpoint source pollution has been associated with water quality standard violations and the impairment of designated uses of surface waters. The *National Water Quality Inventory: 2000 Report to Congress* (USEPA, 2002b) reported the following:

Siltation, pathogens, oxygen-depleting substances, and nutrients are leading causes of water quality impairments in the nation's rivers and streams; and agriculture, hydromodification, habitat alteration, and urban runoff/storm sewers, all of which are nonpoint sources, were the leading sources of impairment.

The pollutants described previously can have a variety of impacts on coastal resources. Examples of water bodies that have been adversely affected by nonpoint source pollution are varied. The Miami River and Biscayne Bay in Florida have experienced loss of habitat, loss of recreational and commercial fisheries, and decrease in productivity partly as the result of urban runoff (SFWMD, 1988). Additionally, shellfish beds in Port Susan, Puget Sound, Washington, have been declared unsafe for the commercial harvest of shellfish in part because of bacterial contamination from OWTSs (USEPA, 1991). Also, impairment due to toxic pollution from urban runoff continues to be a problem in the southern part of San Francisco Bay (USEPA, 1992). Finally, nonpoint sources of pollution have been implicated in degradation of water quality in Westport River, Massachusetts, which discharges to Buzzards Bay. High concentrations of coliform bacteria have been observed after rainfall, and shellfish bed closures in the river have been attributed to loadings from surface runoff and OWTSs (USEPA, 1992).

0.3.8 Other Impacts of Urban Runoff

Other impacts not related to a specific pollutant can also occur as a result of urbanization. Salinity can be affected by urbanization. Freshwater inflows due to increased runoff can affect estuaries, especially if they occur in pulses, disrupting the natural salinity of an area. Increased impervious surface area and the presence of storm water conveyance systems commonly result in elevated peak flows in streams during and after storms. These rapid pulses or influxes of fresh water into saline receiving waters (i.e., bays, estuaries, and oceans) may be 2 to 10 times greater than normal (ABAG, 1991) This may lead to a decrease in the number of aquatic organisms living in the receiving waters (McLusky, 1989).

The alteration of natural hydrology due to urbanization and accompanying runoff diversion, channelization, and destruction of natural drainage systems have resulted in riparian and tidal wetland degradation or destruction. Deltaic wetlands have also been adversely affected by changes in historic sediment deposition rates and patterns. Hydromodification projects designed to prevent flooding can reduce sedimentation rates and decrease the marsh aggradation that would normally offset erosion and apparent changes in sea level within the delta (Cahoon et al., 1983).

0.3.9 Management Practices

Management practices are specific actions taken to achieve, or aid in the achievement of, a management measure. A more familiar term might be *best management practice* (BMP). The word "best" has been dropped for the purposes of this guidance (as it was in the Coastal Management Measures Guidance) because the adjective is too subjective. The “best” practice in one area or situation might be entirely inappropriate in another area or situation.

Four major runoff management themes dominate the management practices presented in this guidance document:

- Minimize the amount of impervious land coverage and disconnect impervious areas.
- Promote infiltration.
- Prevent polluted runoff by not allowing pollutants and runoff to mix.
- Remove pollutants from runoff before allowing it to flow into natural receiving waters.

The management practices can be grouped into two basic categories:

- *Nonstructural practices*. Nonstructural practices prevent or reduce urban runoff problems in receiving waters by reducing potential pollutants or managing runoff at the source. These practices can take the form of regulatory controls (e.g., codes, ordinances, regulations, standards, or rules) or voluntary pollution prevention practices. Nonstructural controls can be further subdivided:

    - *Land use practices*. Land use practices are aimed at reducing impacts on receiving waters resulting from runoff from new development by controlling or preventing land use in sensitive areas of the watershed. They can also be used to minimize total land used for development while accommodating growth.

    - *Source control practices.* Source control practices are aimed at preventing or reducing potential pollutants at their source before they come into contact with runoff or aquifers. Some source controls are associated with new development. Others are implemented after development occurs and include pollution prevention activities that attempt to modify aspects of human behavior, such as educating citizens about the proper disposal of used motor oil and application of lawn fertilizers and pesticides.

- *Structural practices*. Structural practices are engineered to manage or alter the flow, velocity, duration, and other characteristics of runoff by physical means (USEPA, 1993).

In doing so they can control storm water volume and peak discharge rates and, in some cases, improve water quality. They can also have ancillary benefits such as reducing downstream erosion, providing flood control, and promoting ground water recharge.

0.4 Information Resources

The Center for Watershed Protection is a non-profit organization that provides information concerning watershed restoration, planning, research, and training, storm water management, better site design, education, and outreach. Among other achievements, the Center has completed 20 plans to protect or restore local watersheds and 30 watershed research projects, responded to 5,000 requests for watershed advice, and trained more than 15,000 individuals through workshops. The Center for Watershed Protection's Web site (http://www.cwp.org) provides links to upcoming workshops, current and ongoing projects, surveys, and publications. Example publications available electronically include *Stormwater BMP Design for Cold Climates*, *Codes and Ordinances Worksheet*, and *Site Planning for Urban Stream Protection*. The Center for Watershed Protection also manages the Stormwater Manager's Resource Center Web site, which is designed to provide technical information to storm water managers.

Coordinated through the European Rivers Network, Rivernet is a multilingual service providing information concerning river ecological projects, river basins, and organizations currently working on problems associated with rivers. Access to newsletters, water policy and river management information, educational materials, international news related to rivers, and regional river basin news are available at the Rivernet homepage (http://www.rivernet.org/welcome.htm).

The Natural Resources Defense Council (NRDC), an organization with more than 500,000 members nationwide, seeks to protect and restore the natural environment. Information relevant to storm water management and pollution can be accessed at their Web site (http://www.nrdc.org/water/pollution). An example is *Stormwater Strategies*, which is a publication intended for municipal officials, local decision-makers, citizens, and environmental activists that provides examples of effective storm water management programs employed across the U.S. *Stormwater Strategies* can be downloaded at http://www.nrdc.org/water/pollution/storm/stoinx.asp.

The U.S. Geological Survey's Web site offers water quality and use data; publications, products, and technical resources; and links to water resource-related programs. Individual USGS case studies and reports of grants related to urban runoff programs are available through this site, which is located at http://water.usgs.gov.

Part of EPA's Office of Wetlands, Oceans, and Watersheds, the Nonpoint Source Control Branch provides information on many aspects of nonpoint source pollution. Resources include introductory information about nonpoint source pollution, nonpoint source publications and information resources, funding, information on the Clean Water Act and Coastal Zone Act Reauthorization Amendments, and educational information. More information and access to a full list of available resources can be found at http://www.epa.gov/OWOW/NPS/index.html.

EPA's Office of Wastewater Management (OWM), in cooperation with state and local agencies, administers the NPDES permit program, which includes regulating storm water discharges from municipal separate storm sewer systems. The OWM Web site provides technical and regulatory information on the NPDES Storm Water program as well as publications dealing with urban runoff. The OWM Web site can be accessed at http://www.epa.gov/npdes and information specific to the Storm Water program can be accessed at http://www.epa.gov/npdes/stormwater.

The Water Environment Federation (WEF) is a nonprofit technical and educational organization dedicated to the preservation and enhancement of the global water environment. The Water Environment Federation Web site contains a search engine for periodicals, newsletters, technical magazines, and other publications related to wastewater treatment and water quality protection. Members of the organization provide technical expertise and training on issues, including nonpoint source pollution, hazardous waste, residuals management, and groundwater; sponsor conferences and other special events around the world; and review, testify, and comment on environmental regulations and legislation. More information on WEF is available at http://www.wef.org.

The Sierra Club and American Rivers sponsored the publication of *Where Rivers Are Born: The Scientific Imperative for Defending Small Streams and Wetlands*, which provides an argument for protecting small, intermittent or "headwater" streams and wetlands based on the numerous environmental functions of these systems and their close connectivity with activities on land. The authors detail such functions as flood control, maintenance of water supplies, sediment trapping, and maintenance of biological diversity. The document can be downloaded in PDF format at http://iowa.sierraclub.org/Steve-Sierra%20web%20docs0526/WhereRiversAreBorn.pdf.

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