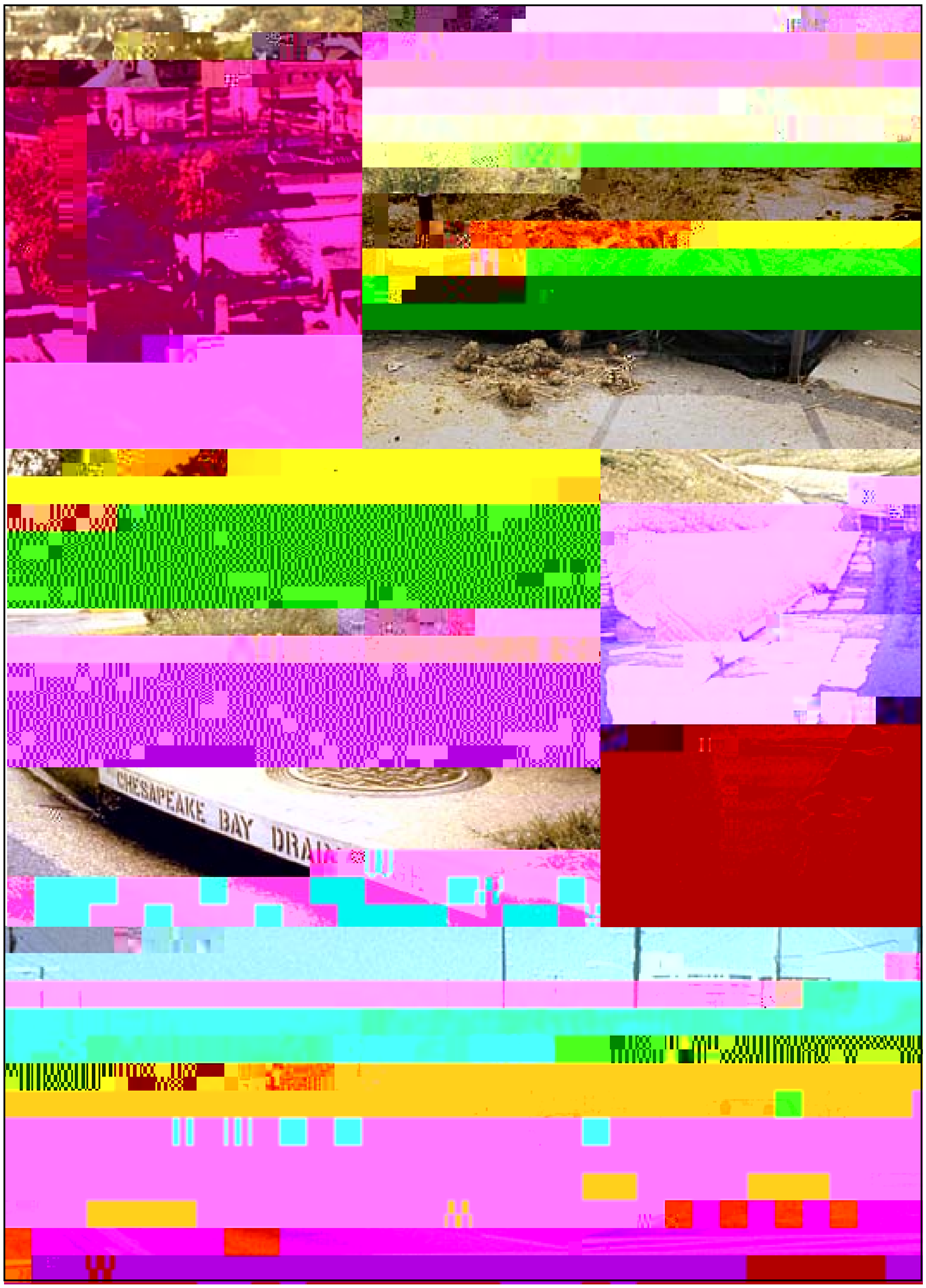
National Management Measures to Control Nonpoint Source Pollution from Urban Areas



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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Disclaimer

This document provides guidance to States, Territories, authorized Tribes, and the public regarding management measures that may be used to reduce nonpoint source pollution from urban areas. This document refers to statutory and regulatory provisions which contain legally

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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 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

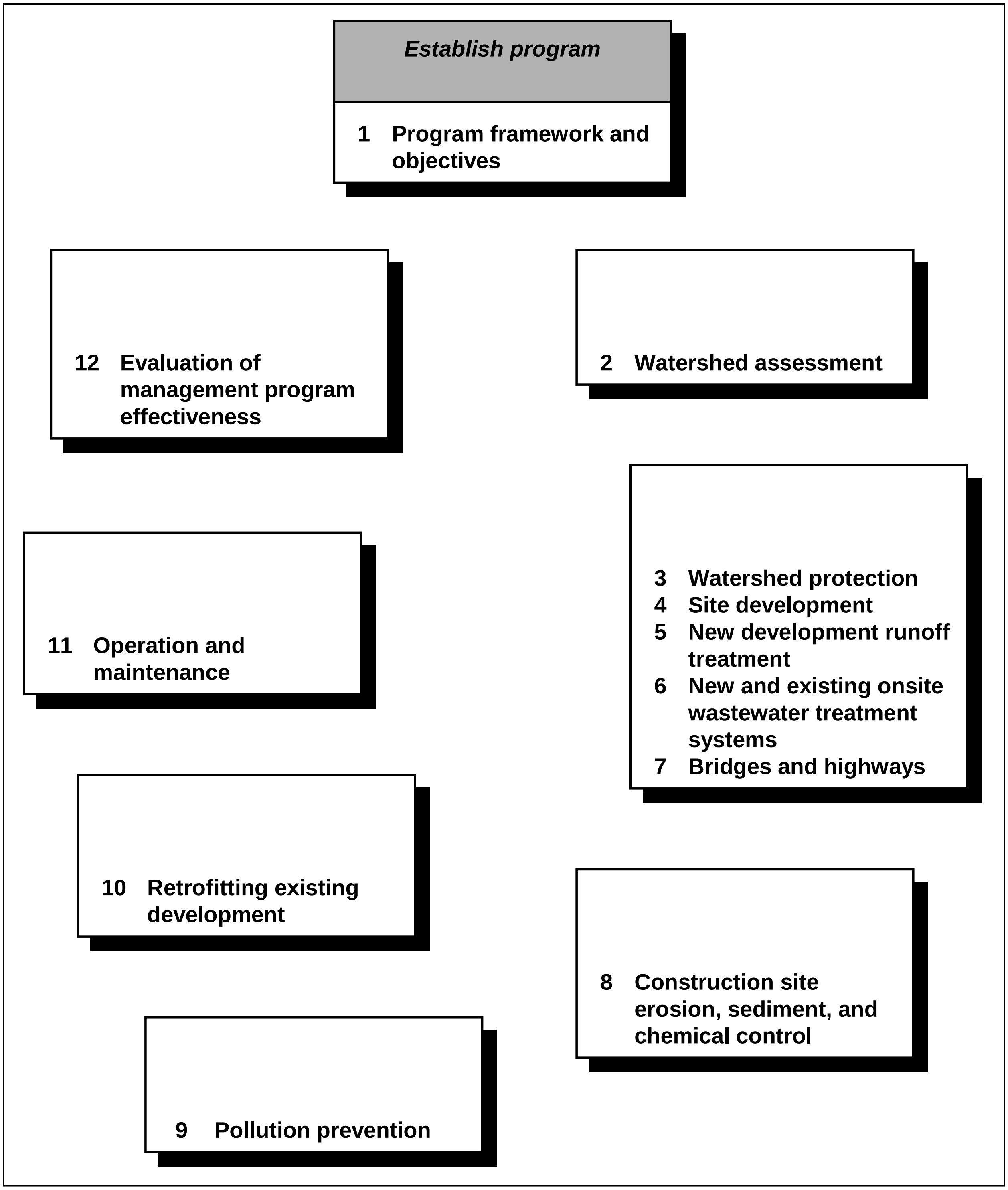
0.1.1 Management Measures

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.


Establish program
1 Program framework and objectives
2 Watershed assessment
3 Watershed protection
4 Site development
5 New development runoff treatment
6 New and existing onsite wastewater treatment systems
7 Bridges and highways
8 Construction site erosion, sediment, and chemical control
9 Pollution prevention
10 Retrofitting existing development
11 Operation and maintenance
12 Evaluation of management program effectiveness

practices is included in the discussion, as are case studies that illustrate how select management

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

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

	Public Education	Public Involvement	Illicit Discharge

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					V	
Soil Bioengineering and Other Runoff Controls for Highways					V	
Structural Runoff Controls for Bridges					V	
Bridge Operation and Maintenance Controls						V
Nonstructural Runoff Control Practices						V
Construction Site Erosion, Sediment, and Chemical Control						
Erosion and Sediment Control Programs				V		
Erosion Control Practices				V		
Sediment Control Practices				V		
Develop and Implement Programs to Control Chemicals and Other Construction Materials				V		
Pollution Prevention						
Household Chemicals	V	V				V
Lawn, Garden, and Landscape Activities	V	V				V
Commercial Activities	V	V	V			V
Trash	V	V				V
Nonpoint Source Pollution Education for Citizens	V	V				
Existing Development						
Identify, Prioritize, and Schedule Retrofit Opportunities					V	
Implement Retrofit Projects as Scheduled					V	

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.
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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

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Since 1991, EPA has promoted the watershed approach as the key framewf-09lrk or lda waith 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 plannin0 Td[(an p appl7(rs)-1t)10(theci)-14(a3(obja)-7(gemenJ-0.0006 Tc 0.0006 Tw 19.20 Tdd[(be)-1to

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):

0.3.3.2 Pervious surfaces

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

- Forests and wetlands
-

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

Table 0.6: Characteristics of aquatic integrity in urban watersheds.

Integrity Rating	Low	Moderate	High
Riparian Habitat Characteristics	–		

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

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.*

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

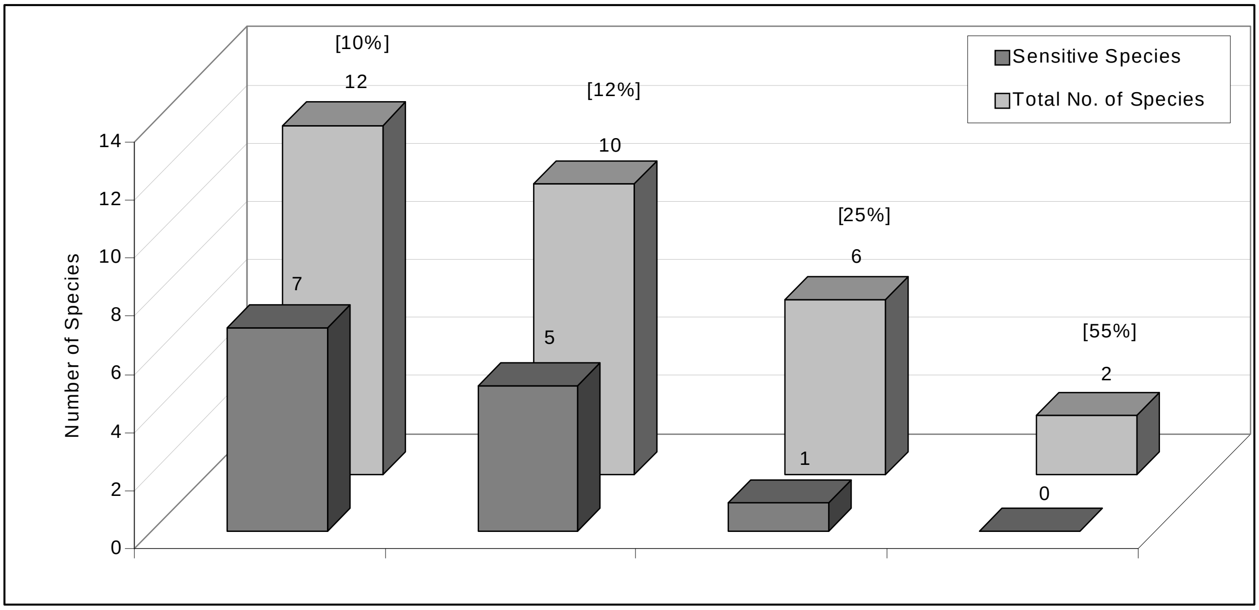

Figure 0.8: Fish diversity in four subwatersheds of different impervious cover in the Maryland Piedmont (Schueler and Galli, 1992, as cited in Schueler, 1995).

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.

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 depositop in spawning habitat or riffle-runs
- Increase in sediment oxygen demand, which can deplete dissolvop oxygen in lakes or streams — Significc/nt contributing facBor in the rapid decline of freshw/Ber mussels
- Reducop channel capaciBy, exacerbatin
- Reducop 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 be/ches
- Changes in the compositiox of bottom substrate
- Coral reef degrad/BBox in tropical and subtropical coastal areas
- Deposits th/B dimn ish the scenic and recre/BBoxal value of w/Berways

Additioxal chronic effecBs may occur where sediments rich in organic matter or clay are present. These enriched depositioxal 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 sediment/BBox, some ecological problems c/n result from insufficient sediment in a w/Ber body caused by hydrological modific/BBoxs. Too little sediment c/n lead to channel scour and destructiox of h/bit/B dependent on an optimum level of sediment. In lakes, reservoirs, and estuaries, insufficient total suspended sediments c/n lead to increased light levels, resulting in the growth of nuis/nce algae.

The term *sediment* is broadly usedd Tc 02[(Dred)Dompositas csusp

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 inb-13(3riten)-11(g)9(l)-23(y)19(seri)-13(ous pathog
parasites that can pose health risks to humans and wildlife. Fr more information, refer to the discussion of microbial contamination in Management Mriture atershed Assessment, and the discussion of pet waste in Management Mrasure 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 Northritt and Midwest. Nationally, an estimited $10 million are sp ent annually by stite and local governments to remedy road salt contamination. The Northeastern Illinois Planning Commission (undited) estimites that 18 million tons of deicing salt, primirily sodium and calcium chlorides, ire used

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, y.0001ded 9Ii pe017 T sohabns7 -1.1

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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

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MANAGEMENT MEASURE 1

consistency. States should maintain the authority to intervene if necessary. The following is a list of regulatory elements that might be included in a state's runoff legislation, or in rules and regulations to help guide local program implementation (WMI, 1997b):

- Criteria for local program implementation or delegation
- Types of activities that require runoff control
- Waivers, exemptions, and variances
- Plan approval and inspection fees, including construction or maintenance performance bonds
- Authority for a local storm water utility
- Specific design criteria
- Permit application and approval process
- Operation permit requirements and time frames
- Development and implementation of mandated educational programs related to site inspection of active and completed storm water management systems
- Requirements for any other educational programs
- Inspection requirements, including certification of inspectors
- Maintenance requirements for postconstruction runoff control facilities
- Penalty provisions in the event of noncompliance with requirements for the design, construction, or operation of storm water management systems

1.2.1.3 Role of regional authorities

Regional authorities often share some of the duties of state agencies but customize their services to fit the needs and attributes of the region. They provide a link between local communities and the state, and often work with state officials to establish region-based performance standards and design criteria for runoff controls. They also serve as a focal point for coordinating issues and interests among communities in the region, especially in terms of implementing the watershed approach, developing watershed plans, ensuring consistency of storm water runoff master planning, and resolving situations that affect downstream communities.

1.2.1.4 Role of local government

Counties and municipalities integrate local runoff management planning with land use and regional watershed management plans, floodplain management, wastewater planning, and other programs that affect the management of urban runoff. They are involved with the day-to-day administrative, operational, and technical aspects of runoff management and are responsible for performing inspections, enforcing compliance, performing operation and maintenance, identifying and removing illicit connections, and coordinating program funding.

The primary focus of the management practices discussed below is on how local governments can increase their ability to manage runoff by developing new ordinances or regulations, or modifying existing ones. It should be noted that many of these practices could also be adopted at the state level to ensure statewide consistency of runoff management practices.

1.3.1.1 Examine existing laws and regulations

The first step in crafting ordinances to improve runoff management controls at the local level is to examine all the existing mandates, authorities, laws, regulations, codes, ordinances, review processes, and so forth that pertain to environmental review in the community. By comparing current rules and practices with the rules needed to achieve the goals and objectives of the runoff management program, a community can identify gaps and weaknesses that need to be addressed.

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Revision of Development Rules for the City of High Point, North Carolina

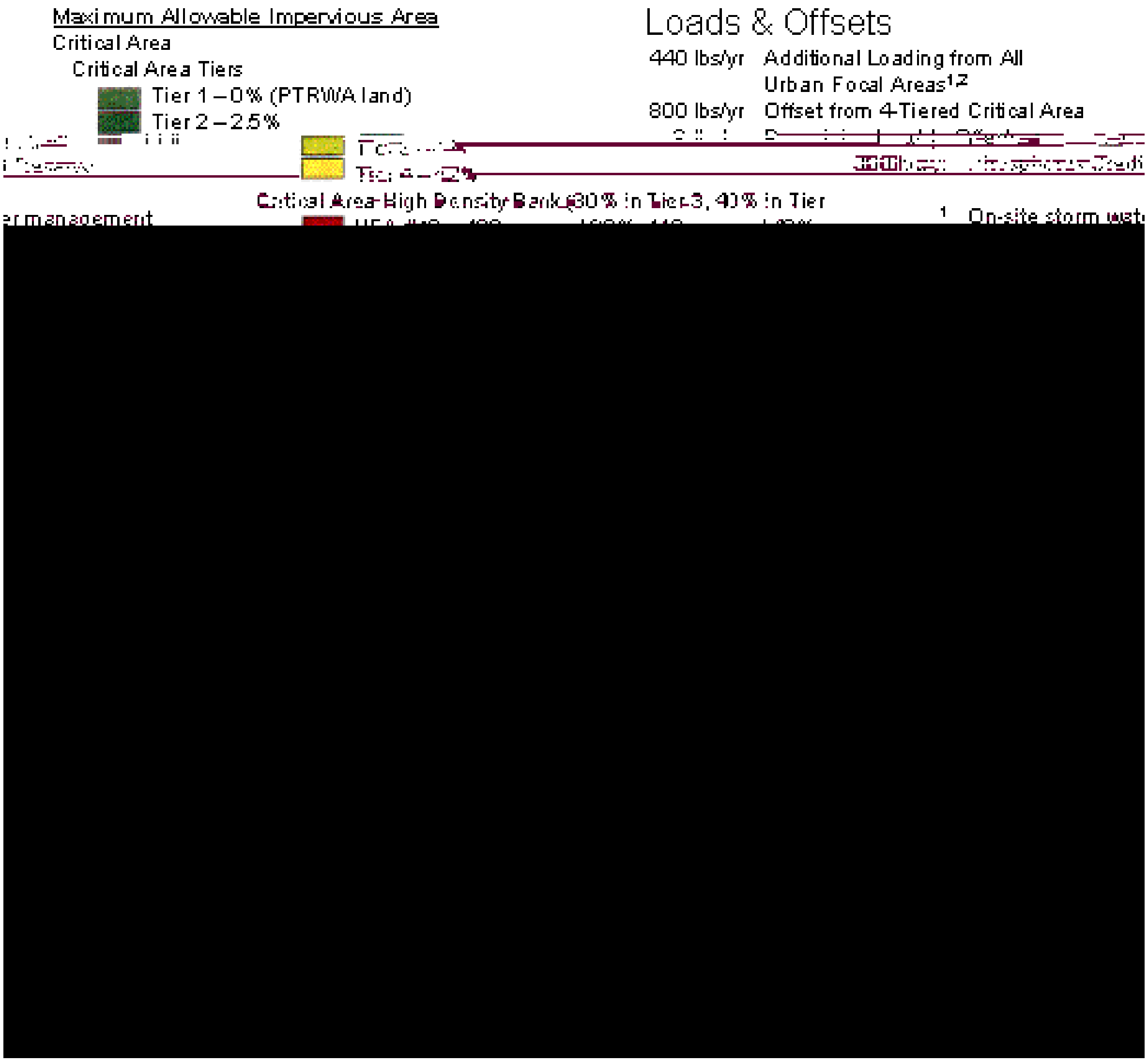

Figure 1.1: Adopted watershed protection plan for the City of High Point, North Carolina.

The city has adopted a watershed protection ordinance for the Deep River 1 watershed that incorporates the strategies listed above and has modified its engineering specifications to allow bioretention facilities and to provide guidance for their design. In the coming year, the city will work to:

- Review local monitoring data and recommend additional monitoring protocols that can track the effectiveness of best management practices used, including new low-impact development design techniques. Possible funding sources for monitoring will be identified.
- Review and revise the city's development ordinance and engineering specifications to further allow and encourage low-impact design techniques.
- Plan and host a spring 2000 low-impact development design workshop for city staff, local contractors, and engineers.

1.3.1.2 Develop or improve ordinances for water quality enhancement

(1) *Aquatic buffer ordinance*. Aquatic buffers serve as natural boundaries between local waterways and existing development. They help protect water quality by filtering pollutants, sediment, and nutrients from runoff. Some other benefits of buffers are flood control,

compliance, the inspector may issue a permit violation, stop-work order, or fine, or take other steps to compel action.

Whether program authority is implemented at the state level or delegated to a local government, the ordinance should include goals, performance standards, and design criteria for both erosion prevention and sedimentation control. At a minimum, the ordinance should define the following erosion prevention design criteria:

- The threshold for disturbed areas at which regulatory action/compliance is required; and
- The maximum time frame for permanent site stabilization after final grading or temporary stabilization if construction ceases and the site is left dormant.

(3) *Open space ordinance*. Open space development, also known as “cluster development,” is a planning technique that concentrates dwelling units in a compact area and leaves the balance of the site as natural, open space. Lot sizes, setbacks, and frontage distances are minimized, thereby reducing the amount of impervious cover on-site. Open space development reduces the need for clearing and grading by 35 to 60 percent, and increases opportunities for using the reserved land for a variety of purposes such as conservation, recreation, habitat preserves, and storm water management15 Tcutp0mOl: PTmld w

The Center for Watershed Protection and EPA Present Model Ordinances on the Web

Communities can strengthen the language of their regulations and ordinances to better protect environmental resources by referring to examples of exemplary ordinances from across the country. The following is a list of ordinances available for download from http://www.epa.gov/owow/nps/ordinance.

Aquatic Buffers

– Language from Baltimore County, MD
– Coastal Zone Program, RI (an example of a buffer ordinance in a coastal region)
– Ordinance on Riparian Habitat Areas, Napa, CA
– Portland Metro Floodplain Preservation Ordinance
– Model Land Trust Agreement from the Natural Lands Trust

Erosion and Sediment Control

–

(4) *Storm water operation and maintenance ordinance*. The expense of maintaining most storm water management practices is relatively small compared to the original construction cost. Too frequently, however, maintenance is not completed, particularly when the practice is

(7) *Source water protection ordinances*. Source water protection involves preventing the pollution of the ground water, lakes, rivers, and streams that serve as source6pc5C of drC0volves thesou-0.0

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EPA's trading Web site (http://www.epa.gov/owow/watershed/trading.htm) provides a number of resources related to the current policy, new developments, case studies, and links to other trading programs.

1.3.2 Develop an Institutional Structure

The following practices follow the approach presented by the Center for Watershed Protection in the *Rapid Watershed Planning Handbook* (CWP, 1998c). This approach applies mainly to local efforts in small watersheds. State and regional agencies might need to conduct their efforts on a larger scale. Other resources that address establishing a watershed planning framework on a larger scales include *Framework for a Watershed Management Program* (Clements et al., 1996) and *Know Your Watershed* (CTIC, 2000).

1.3.2.1 Establish a watershed baseline

The first step in a watershed assessment process is to gather basic background information about the watershed and subwatersheds. This process can be used as a foundation for developing the rest of the watershed plan.

(1) *Define watershed and subwatershed boundaries*. Watershed and subwatershed boundaries need to be mapped on a good topographic map such as those produced by the U.S. Geological Survey. These maps, an example of which is shown in Figure 1.2, can help in identifying the political jurisdictions and citizens that should participate in the watershed planning effort, and the land use patterns in the watershed and each subwatershed (CWP, 1998c).

(2) *Identify "embedded" agricultural areas*. Livestock waste management is typically not considered an issue in urban areas. However, the urban/suburban landscape can build up around an existing agricultural area, or property owners can board animals on residential property, making animal waste management an important component of maintaining water

State/Local Agencies

- Environmental or wildlife agency
- Flood control district
- Water rights agency (primarily in the southwestern United States)
- Public works department
- Planning/zoning department or board
-

1.3.2.2 Set up an institutional structure

A successful runoff management

1.3.2.4 Project future land use change in the watershed/subwatershed

Land use in a watershed and individual subwatersheds has a strong influence on aquatic ecosystems. Current impervious cover should have been measured as a part of the watershed baseline analysis. The watershed manager needs to forecast the future impervious cover based on available land use planning information, such as existing zoning or master plans.

Impervious cover projection helps watershed managers determine if aquatic resources will degrade from current conditions (see Section 6 of the Introduction for more information about impervious cover). If the analysis indicates that impervious cover will increase to such an extent that it will cause subwatershed quality to decline, a watershed manager should consider shifting impervious cover to another watershed or limiting development.

Southeastern Delaware Whole Basin Management

The Delaware Department of Natural Resources and Environmental Control (DNREC) and Sussex County officials developed a phased process to manage the Inland Bays Basin that combines an assessment program with an implementation plan to solve water quality problems affecting Rehoboth, Indian River, and Little Assawoman Bays (Delaware DNREC, 2000). They identified excessive nitrogen and phosphorus as the most pressing water quality problems in the basin. They attributed the

- Failing or inadequate septic systems.
- Sewage treatment plant effluent.
- Fertilizer application for residential and commercial landscaping.
- Construction site sediment export.
- Exhaust emissions.
- Open burning.
- Field application of manure to crops.

They also assessed biological populations and identified priority communities and species that warrant special protection.

To begin implementing a whole basin management program, the Delaware legislature established the Center for the Inland Bays in 1994. In 1998 the Center initiated a Tributary Strategy Program that organized stakeholders into three Tributary Action Teams, which assist the Center in reducing nutrient inputs to the bays and restoring habitat. They are also assisting DNREC in developing pollution control strategies to meet TMDLs for nutrients. In 1999 the Delaware House of Representatives passed Resolution 32, which established a multijurisdictional committee to

- Assess progress toward implementation of the Land-Use Action Plan of the Inland Bays Comprehensive Conservation and Management Plan.
- To identify areas where implementation has not been achieved.
- To recommend changes to Sussex County's Comprehensive Plan and implement zoning and subdivision ordinances.

Finally, in 1999 the Delaware Legislature passed the Delaware Nutrient Management Law, which established the Delaware Nutrient Management Commission. The purpose of the Commission is to develop a program to address nutrient inputs from both agricultural sources and urban sources such as golf course landscape operations, residential inputs, and residential and commercial fertilizers.

Regardless of the forecasting option chosen to estimate future impervious cover, it is important to verify and adjust the estimate periodically. This adjustment helps ensure that land use planning tools for the watershed result in the desired level of impervious cover needed to maintain the management strategy of each subwatershed.

1.3.2.5 Develop subwatershed plan

Based on the information obtained in the preceding steps, the watershed manager should determine what goals and objectives are appropriate in the watershed and its individual subwatersheds. Goal-setting is among the most important steps in watershed planning, and the management structure should ensure full involvement from stakeholders at this stage.

A subwatershed plan is a detailed blueprint to achieve the established subwatershed objectives. A typical plan may include revised zoning, management practice regulations, proposed management practice locations, description of proposed new programs, estimates of budget and staff needed to implement the plan, stream buffer widths, or monitoring protocols.

The plan should target the subwatershed objectives with the combination of management practices that is most economical, effective, and feasible. Implementing management practices by planning on the subwatershed scale can increase cost-effectiveness and water quality benefits. A combination of nonstructural, on-site, regional, and channel stabilization practices specifically tailored to the subwatershed will help to maximize these benefits. Pollution prevention and nonstructural practices are key, as they can reduce the generation of pollution and its exposure to rainfall and runoff. In addition, implementing site-dispersed, low-impact development practices can help to control both runoff quality and quantity at the site level. Ensuring that drainage channels and floodplains are stable will provide protection against flooding and serve to buffer receiving waters. Finally, regional runoff control and treatment practices are a last line of defense to control flooding and reduce pollution. The following are descriptions of each type of practice

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practices only treat the first ½ inch to 1 inch of runoff, and the rest is bypassed. They are, however, good first practices in a system of storm water management practices.

– *Regional (off-site) practices*. Regional runoff control and treatment practices act as a last line of defense to control flooding and reduce pollution. The advantages of regional controls are that they are easier to maintain and do not require the actions of the property owner; they can provide aesthetic and recreational benefits; and they can be cost-effective due to the economy of scale. However, a regional pond offers no protection to upstream tributaries, and placement in low-lying areas may hurt natural wetlands. Communities may also have to address safety and liability considerations.

– *Stable drainage channels*. Stable drainage channels and floodplains are important for protection against flooding and as buffers for receiving waters by filtering pollutants and preventing erosion. Riparian areas can provide aesthetic and recreational benefits as well as wildlife habitat. Restoring stream channels and riparian areas can, however, be expensive, and is not feasible when development exists along drainage channels or restoration conflicts with landowner use of streamside property.

Regional vs. On-Site Development Regulations

In anticipation of dramatic growth in the next decade or two, the city of Seattle, Washington is considering the development of an integrated drainage plan to address storm water at the subwatershed level rather than on a project-by-project basis. One of the options being considered is the establishment of off-site mitigation programs in urban jurisdictions. These programs allow developers to meet on-site development requirements relating to storm water by compensating the municipality to provide equivalent mitigation in an off-site public facility. In a case study, Maupin and Wagner (2003) explore the costs and benefits of regional and onsite management practices. The authors determine that an offsite mitigation program might be beneficial if the municipality has storm water management obligations, has the authority to regulate development, requires on-site storm water management on new development or redevelopment projects, and cost, water quality, or community benefits may result from off-site treatment. Because it shifts the maintenance burden to the municipality, it may not be appropriate in all cases (Maupin and Wagner, 2003).

Targeting Runoff Treatment Practices for Temperature Control

In the Token Creek Watershed in Dane County Wisconsin, a proposed 492-acre development for single-family homes posed concern for regulators regarding Token Creek, a cold water stream that is a major tributary to Lake Mendota. Managers identified three major goals for the watershed: reduce overall sediment and nutrient flows to Lake Mendota; protect the water quality in Token Creek, primarily regarding sediment and water temperature; and implement practices that will be aesthetically pleasing and increase property values. Managers recognized that traditional treatment practices such as storm water ponds and wetlands (for more information, see Management Measure 5) would not protect the stream from the potential thermal impacts of runoff from a highly developed area. Instead, the channel was lined with rock to provide infiltration, heat dissipation, and erosion control, and rock-filled gabion dams were installed. The Temperature Urban Runoff Model (TURM) was used to estimate water quality benefits. Modeling results predicted a 10.7 degree Fahrenheit increase in water temperature with the practices installed, as opposed to a predicted 21.6 degree increase without the practices (Dorava et al., 2003).

1.3.2.6 Adopt and implement the watershed plan

The best way to ensure that a plan is implemented is to incorporate the right stakeholders,

- – Construct lakes, detention basins, and sport fields.
- – Acquire land in key locations before development occurs.
- – Address existing problems in developed areas.

Other sources of revenue for the program include an annual $30 per home utility charge, a new development charge, and existing revenue sources such as a mill levy and Johnson County storm water funds.

The city's watershed management program will be implemented by constructing new facilities, improving the management of existing facilities, establishing development policies and processes, and

- Development and implementation of estuary comprehensive conservation and management plans under section 320 of the Clean Water Act

1.3.3.3 Leases

A municipal lease grants the lessee the option of applying lease payments to the purchase of the facility. The lessee is responsible for paying taxes on the property. Leases can be used to finance the purchase of environmentally sensitive areas, land for wetland restoration, or other projects. A sale/lease-back arrangement allows the owner of a facility to sell it to another entity and subsequently lease it back from the new owner. This arrangement can provide alternative financing for a facility and may limit a government's liability.

1.3.3.4 Intergovernmental transfers and assistance

Grants are awarded to state or local governments for assistance r assia rdbi-2(ca(t)-5)-2(e optl)-4(o)--5(v)-2(e2)T imsubs2 a-0,(g)un a2r.

– Identification of the parties involved in the process
– Vision statement
– Purpose of the MOU (issues to be addressed by the agreement)
– Pact to provide assistance to the partnership for coordination of planning efforts under a central management organization
– Resolution to use the watershed plan as guidance in future land use or water management decisions
– Signatures of all partners involved

Philadelphia's Office of Watersheds

[illegible]

Watershed citizens can and do play an important role in controlling nonpoint source pollution. Consequently, they need to acknowledge and be educated on pollution prevention issues and activities. Management practices concerning this topic are discussed in greater detail under the Management Measure 9: Pollution Prevention.

1.4 Information Resources

An Internet Guide to Financing Stormwater Management is a Web site presented by the Center for Urban Policy and the Environment (2001) at Indiana University-Purdue University Indianapolis. The site includes an annotated bibliography of existing storm water finance materials, an archive that contains selected previously published materials concerning storm water finance, a manual that discusses the financing options available to communities for storm water management programs, a set of case studies that describe successful finance mechanisms that have been used in seven communities around the country, and a group of links to other useful Web sites about storm water management. The site can be accessed at http://stormwaterfinance.urbancenter.iupui.edu.

The Center for Watershed Protection's *Rapid Watershed Planning Handbook* (CWP, 1998) describes techniques communities can use to more effectively protect and restore water resources. This document is available for purchase from the Center for Watershed Protection's Web site (http://www.cwp.org).

Framework for a Watershed Management Program (Clements, 1996) develops a specific watershed management protocol to increase the understanding of the critical components in watershed management programs. The publication is available for purchase from the Water Environment Research Foundation by calling 800-666-0206 and specifying publication order number D53016.

Building Local Partnerships, an Internet brochure published by the Conservation Technology Information Center (no date), provides an overview of local partnerships, including the types of partnerships that can be made, a how-to guide for forming partnerships, and caveats, as well as links to other resources pertaining to partnership-building. The publication can be accessed at http://www.ctic.purdue.edu/KYW/Brochures/BuildingLocal.html.

The Environmental Finance Center (2000) was created to assist local communities in finding creative ways to pay for environmental projects. The Center promotes alternative and innovative ways to manage the cost of environmental activities, provides training and development

1.5 References

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MANAGEMENT MEASURE 2
WATERSHED ASSESSMENT

2.1 Management Measure

Develop and implement a watershed assessment program to:

- Characterize watershed conditions
- Establish a set of watershed indicators

2.2 Management Measure Description and Selection

2.2.1 Description

Watershed assessment and monitoring are tools used to characterize water quality and to identify trends in water quality over time (USEPA, 1998c). This management measure describes methods that can be used to determine the health of water bodies by using watershed indicators that measure physical, chemical, and biological conditions.

2.2.2 Management Measure Selection

2.2.2.1 Overview

Watershed assessment is a critical component of a watershed-based approach to managing receiving waters. Watershed assessment is needed to develop both protection and restoration strategies, identify priorities, and adjust management prescriptions based on trend analyses. Both rapid and extensive assessments can be performed to determine water body status and trends. Numerous metrics, such as EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*; *Lake and Reservoir Bioassessment and Biocriteria*; and *Estuarine and Coastal Marine Waters:Bioassessment and Biocriteria Guidance,* are available for determining water body status. In general, the objectives, available funding, and expertise of the assessors will determine the level of assessment conducted.

An assessment and monitoring program is important for effective watershed management because it provides a basis for decisions and actions, and allows managers to continually reassess progress and redefine goals and priorities. Monitoring enables water quality managers to identify existing or emerging problems. Monitoring also facilitates responses to emergencies such as spills and floods, and helps water quality managers target specific pollution prevention or remediation programs to address these problems. Assessment and monitoring can be used to determine whether program goals, such as compliance with pollution regulations and implementation of effective pollution control actions, are being met. Monitoring programs should be established based on indicators of human health and aquatic life. A large number of documents and case studies are available to use as resources (see Information Resources at the end of this chapter).

2.2.2.2 Examples of monitoring and assessment programs and methodologies

State pollution control agencies, Indian tribes, local governments, and federal agencies typically are responsible for watershed assessment and monitoring activities. These entities monitor water quality and identify waters and watersheds that do not meet clean water documiedd fe4wsfedd fedd fe4d fedd fe4 -

- Implement nonpoint source pollutant removal methodologies
-

applicable, they produce a larger sample of unimpaired sites, and they allow more robust statistical comparisons.

The U.S. Geological Survey (USGS) developed a model for determining ecoregional background concentrations of nitrogen and phosphorus as a function of annual runoff, basin size, atmospheric nitrogen deposition rate, and region-specific factors. Background total nitrogen (TN) concentrations ranged from 0.02 mg/L in the western United States to more than 0.5 mg/L in the southeastern United States. Background total phosphorus concentrations ranged from less than 0.0006 mg/L in the western United States to more than 0.08 mg/L in the Great Plains (Smith et al., 2003).

2.3.1.2 Model pollutant sources and loads

Watershed managers can use models to estimate storm water pollutant loads in receiving waterbodies. Modeling of pollutant loadings can help watershed managers target specific areas for nonpoint source control. More specifically, runoff models can accomplish one or more of the following:

- Simulate the generation and movement of water and pollutants from their point of origin to a place of treatment or disposal into receiving waters
- Perform frequency analyses on water quality parameters to determine the return periods of concentrations or loads
- Provide input for an analysis of receiving water quality
- Determine the relative effects of pollution control options
- Determine optimal locations and combinations of management practices
- Provide input to cost-benefit analyses

Selecting the model that is most appropriate to fulfill watershed management goals requires careful consideration of trade-offs with respect to level of detail, data requirements, cost, and accuracy. For example, a high level of detail requires a more complex model. Data requirements are also important: a complex model might require more data than one has or is willing to collect. Sometimes published data can be substituted for field-collected data. The advantage of using published data is avoidance of costly, labor-intensive fieldwork. A major data source is the USEPA National Urban Runoff Program (NURP) database, which contains concentration values measured for 30 cities (USEPA, 1983). Information generally required for models includes the following:

Quantity Parameters

- Rainfall information
- Catchment area

- Imperviousness
- Runoff coefficient

Quality Parameters

- Constant concentrations (event mean concentrations or EMCs)
- Constituent median and coefficient of variation (CV)
- Regression relationships
- Buildup and wash-off parameters

Calibration/Verification Parameters

- Measured rainfall
- Measured runoff
-

– *Constant concentration or published yield values*. This method involves calculating loads as the product of the proportion of land area in a particular land use and the approach uses rating curves to relate pollutant loads or EMCs to flow rates or volumes, thereby allowing quantification of intra-storm variations in these measures.

- *Buildup and washoff.* This method is used to determine loadings by estimating the buildup of pollutants during dry weather and estimating washoff during rainfall events. This method quantifies intra-storm variations in pollutant loading and is good for comparing the relative effects of management practices. However, processes of sediment transport and erosion that are fundamental to this method are still poorly understood. Moreover, this method requires averaging the extent of pollutant buildup on heterogeneous urban surfaces. This averaging can result in erroneous predictions because actual values vary widely over relatively small areas. Assumptions include linear buildup and generic washoff coefficients that might or might not represent actual conditions. Estimates can be improved by using local monitoring data such as site-specific buildup and washoff estimates for model calibration.

- *Mechanistic models*. Mechanistic models contain hydrologic and water quality components and use mathematical algorithms to represent the mechanisms that generate and transport runoff and contaminants. They are the most comprehensive models in that they incorporate many variables to produce the best estimations of the numerous mechanisms that affect pollutant loading. However, they require substantial local data to set and verify parameters, and they demand both skill and commitment from staff. Users must ensure that the models are documented, supported, and proven through the experience of other users. There are several commercially available mechanistic models, including STORM by the U.S. Army Corps of Engineers and SWMM and HSPF by EPA. (See Web references and resources below.)

The confounding factors for load estimation models are:

- Inputs from atmospheric deposition (H_2SO_4, NO_3, etc.)

- Ground water inputs

- Pervious surfaces that confound runoff estimates

- Sediment transport and erosion

- Pollutants adsorbed to solids. These pollutants, namely metals and organics, can be estimated as a proportion of the total suspended solids concentration or annual load.

- Point sources in the watershed (e.g., industrial and commercial sources and publicly owned treatment works)

All of these factors can be included in the surface runoff model at the expense of time and simplicity and can improve the accuracy of loading estimates. Before they are included, consideration should be given to the level of detail needed for the analysis.

– Keep track of hundreds of candidate management practice sites.
– Develop management scenarios using different combinations of management practices.
– Evaluate the practices' impact on water quality.
– Compare scenario results.
– Present the information to a wide range of people.

LORELEI provides decision support through data management, scenario development and evaluation, and enhanced involvement in and understanding of the watershed management process. LORELEI stores data about potential management practice locations and associated costs, practice types, and effectiveness data, as well as standard geographic information such as natural features, watershed

- USEPA Center for Exposure Assessment Modeling, Athens, Georgia
- US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi
- US Army Corps of Engineers, Hydrologic Engineering Center, Davis, California
- USGS, Reston, Virginia
- National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland—estuaries and bays
- Tennessee Valley Authority (TVA), Knoxville, Tennessee—rivers and reservoirs

Additional guidance regarding load estimation and receiving water quality modeling is provided in *Compendium of Tools for Watershed Assessment and TMDL Development* (USEPA, 1997a), which supports the watershed approach by summarizing available techniques and models that assess and predict physical, chemical, and biological conditions in water bodies. This document is intended to provide watershed managers and other users with information helpful for selecting models appropriate to their needs and resources. The *Compendium* includes information on the

EPA has assembled a Web site with information about and links to water quality models. This site includes basic information, EPA-supported models, other federal government-supported models, technical guidance for models, and model training and meetings. The Web site can be accessed at http://www.epa.gov/waterscience/wqm/.

2.3.2 Assess Cumulative Effects

A watershed assessment should include an evaluation of cumulative effects, which are combined effects of multiple activities over space or time. Such effects can be difficult to assess because a large number of resources can be affected and often there are multiple pathways through which these effects can occur. In addition, the appropriate spatial and temporal scales for the analysis usually are uncertain. Because many environmental assessments do not take cumulative effects into account, most likely because there is no explicit process for analyzing them, MacDonald (2000) developed a conceptual process to guide their assessment and management. The process is divided into three phases: the scoping phase, the analysis phase, and the implementation and management phase. Within each phase are a group of interrelated steps that, if followed, typically lead to a complete analysis of the cumulative effects on a watershed. The three phases and their steps are shown in Figure 2.1.

2.3.3 Estimate the Effectiveness of Treatment Programs

A useful tool to estimate the effectiveness of treatment practices on water quality is the Watershed Treatment Model (WTM), which was developed by the Center for Watershed Protection (Caraco, 2001). The WTM is a simple model for rapidly assessing how various management programs influence pollutant loadings and/or habitat quality in urban watersheds. It incorporates many simplifying assumptions that allow watershed managers to assess various programs and sources that are not typically tracked in more complex models. The WTM consists of two basic components: pollutant sources and treatment options. The pollutant sources component estimates the load from a watershed without

[illegible]

– *Water quality*: pollutant loadings for nutrients

– *Physical and hydrological*: acres of open space land protected from development

– *Socioeconomic*: inventory of public education efforts, such as number of publications produced and distributed, Web site hits, media campaigns, stream cleanup activities

– *Programmatic*: the following are programmatic indicators:

  – Number of approved erosion and sediment control plans and disturbed acreage
  – Number of inspections and enforcement actions for erosion and sediment controls
  – Number of citizen calls about flooding and drainage problems, and number of responses
  – Cost and number of flooding and drainage projects
  – Investigative and corrective actions for illicit discharge detection and elimination
  – Operation and maintenance activities
  – Number of approved site and subdivision plans, and acreage served
  – Number and type of BMPs installed, the number of acres served by each BMP, and installation and maintenance information

Under the Phase II Storm Water Rule, communities are required to go beyond chemical pollutant monitoring to track the implementation of storm water management programs. This database can serve as a useful tool in fulfilling this requirement and can be used as a model for the development of varied indicators of program success (Hillegass, 2003).

– Be monitored over a long enough period to establish observable trends

– Be compatible with available finances, personnel, and other resources. The cost of implementing the watershed indicator is an important consideration.

The Center for Watershed Protection and EPA published a reference to help municipalities select a suite of indicators that will most effectively measure conditions in their watershed (Claytor and Brown, 1996). This publication, *Environmental Indicators to Assess Stormwater Control Programs and Practices*, presents profiles with information such as advantages, disadvantages, cost, and applicability for 26 indicators, which include water quality, physical/hydrological, biological, social, programmatic, and site indicators. The document is available online at http://www.cwp.org.

2.3.5 Establish Water Quality Indicators

Conduct water quality monitoring. This type of monitoring involves measuring pollutants in both runoff and baseflow conditions. The most commonly measured constituents are oxygen demand, nutrients, metals, pH, temperature, flow or discharge, solids (e.g., total suspended solids or turbidity), fecal coliform, and a measure of oil and hydrocarbons (e.g., total petroleum hydrocarbons [TPH] or polycyclic aromatic hydrocarbons [PAHs]). Measurements can be taken at management facilities or in receiving waters. This method allows for the identification of trends in water quality over time and can identify areas that are degraded relative to low-impact reference sites. Changes in water quality that result from changes in land use or from the implementation of management practices can be detected to prioritize future conservation or restoration efforts. The specific constituents found in receiving waters can aid in identifying the source of the pollution problem and help target management practices effectively. The methodology for water quality monitoring is well-outlined in specific protocols, and results are quantitative and easy to present and compare to other monitoring databases. However, the monitoring effort must be long-term because of the high variability in constituent concentrations, and it might be expensive because of labor requirements or equipment costs for automation. Volunteer monitoring programs can reduce some of the expense of monitoring while providing the additional benefit of educating the public. EPA's Volunteer Monitoring Web site has more information about volunteer monitoring (http://www.epa.gov/owow/monitoring/volunteer).

(1) *Conduct toxicity testing*. These methods, often called whole effluent toxicity (WET) tests, involve exposing standardized freshwater, marine, and estuarine vertebrates, invertebrates, and plants to water samples to directly measure the adverse effects of effluents. Both acute and short-term chronic effects can be assessed. The test organisms can be either resident species or species that will be restocked or reintroduced. Toxicity reduction evaluation (TRE) can be used to identify the agent of toxicity, which helps to identify the pollutant source and indicates which management practices would be appropriate to treat the problem. Although this method allows managers to distinguish among a range of conditions and chemicals, species' responses vary substantially with respect to the choice of species, location (laboratory or in situ), and duration of the test. Also, chronic toxic effects, which may take a long time to manifest, are not measured with this type of testing. The TRE process can be expensive and is often used to specifically identify pollutants when receiving waters have previously been identified as impaired through other, less-expensive methods.

More information on WET methods is available at http://www.epa.gov/OST/WET. Descriptions and guidance on other analytical methods are provided at http://www.epa.gov/ost/methods (USEPA, 2000d).

(2) *Measure the frequency at which water quality standards are exceeded*. This method is usually based on chemical standards and can be derived from existing data or as part of the biennial 305(b) reporting process. It can identify long-term trends in water quality, storm water impacts, and the effectiveness of management practices. However, because the ability to detect exceedances is highly dependent on the frequency and timing of sample collection, brief periods of exceedance might be missed (during storm flow) and long-term conditions inaccurately represented. Also, exceedance frequencies provide little information about causes and sources of pollution. Costs associated with this method are minimal because data are usually collected through other programs. Guidance and information on EPA and state water quality standards and criteria can be found at http://www.epa.gov/ost/standards (USEPA, 2001c).

(3) *Determine sediment pollutant levels*. This type of monitoring involves the determination of pollutant load carried by sediments and deposited in slow-moving receiving waters. Analysis is usually conducted using spectrophotometry and chromatographic tests of samples from natural or artificial water bodies. The extent of toxicity in sediments can be determined by comparing sample results to reference samples that are known to be relatively unimpacted. Measured pollutant levels can also be compared to existing standards for typical contaminants in sediment (USEPA, 2000d). Using sediment contamination as an indicator of water quality is often confounded by uncertainty related to levels of concern and long-term impacts, the inability to identify pollutant sources, and lag time between discharge and settling. However, long-term trends in sediment pollutant loading can be detected if monitoring is conducted over a long period.

(4) *Measure microbial contamination*

Bacterial source tracking refers to a family of methods that can be used to distinguish among sources of fecal contamination and can aid in tracking illicit discharges to storm sewer systems. Bacterial source tracking requires development of a database of known sources against which samples can be compared (Zhang et al., 2003). The methods can be molecular (e.g. DNA fingerprinting, or more specifically, ribotyping, pulsed-field gel electrophoresis [PFGE], polymerase chain reaction, terminal restriction fragment length polymorphism) or non-molecular. Non-molecular procedures can be biochemical (e.g., antibiotic resistance analysis, carbon utilization, F-specific coliphage typing, cell wall fatty acid methyl ester) or chemical (e.g., caffeine detection, optical brightener detection). In general, molecular methods can offer the most precise identification of specific types of sources, but they also have the highest unit costs and the most time-consuming procedures. Biochemical procedures are simpler, less expensive, and faster, and allow a larger number of samples to be analyzed in a shorter period of time (USEPA, 2002). The technology in this subject area is constantly evolving and new procedures and more refined methods may be available as research progresses.

Maryland's Environmental Indicators

EPA also provides guidance for lake

Development and Evaluation of Ecosystem Indicators for Urbanizing Midwestern Watersheds

Researchers at Purdue University are undertaking a study to develop predictive indicators of urbanization that are applicable to midwestern watersheds (Spacie et al., 2000). The objectives of this study are as follows:

- Quantify impacts on hydrologic regimes, water quality, and habitat structure of stream ecosystems using paired experimental watersheds.
- Develop linked models to accurately predict these impacts.
- Use the models to generate and test indicators of urbanization and hydrologic change with respect to biological responses to these changes.
- Use these indicators with the models to assess biological responses to alternative urbanization scenarios on larger scales.

Data from satellite imagery, intensive water quality and biological sampling, stream cross-section measurements, and physical habitat assessments will be used to develop and test the models. A dynamic hydrology model that can simulate cross-sectional averaged velocities, shear stress velocities, and water depth variability during storm peaks has been developed. Functional biological metrics and habitat quality indices will be correlated not only to land use but also to channel morphometry and flow variability.

For more information contact Anne Spacie, Department of Forestry and Natural Resources, Purdue University, 1159 Forestry Building, West Lafayette, Indiana 47907-1159; telephone 765-494-3621; e-mail aspacie@purdue.edu.

- Routine biological monitoring is inexpensive compared to chemical monitoring and toxicity tests.
- Biological monitoring is useful for evaluating impairment when criteria for specific ambient impacts do not exist.

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Also, standardized methods (biomass, chlorophyll) can be used to analyze and interpret algal communities without doing an extensive taxonomic evaluation, which requires specialized training. One problem with these indicators is that plankton populations vary seasonally and are highly transient, making them a poor indicator of site-specific conditions.

(2) *Assess macroinvertebrate assemblages*. Macroinvertebrates are relatively immobile and are good indicators of site-specific effects. They have a short life cycle and therefore are good indicators of short-term stress. Measurements of invertebrate populations are usually compared to populations from a reference condition to determine the severity of pollutant impacts. The presence or absence of particular species can be used to infer poor aquatic integrity because macroinvertebrate assemblages typically cover a broad range of trophic levels and pollution tolerances that allow interpretation of multiple effects. Macroinvertebrate sampling has some drawbacks, including the fact that populations are highly habitat-dependent and vary with season, stream flow, and region, which can confound results. In addition, taxa identification requires training and can be complex and time-consuming. Despite these drawbacks, volunteer monitoring programs can be used to collect macroinvertebrate data. Both *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (USEPA, 1999) and *Volunteer Stream Monitoring: A Methods Manual* (USEPA, 1997c) provide guidance on how to conduct benthic macroinvertebrate assessments.

(3) *Assess fish assemblages*. Measurements of fish diversity, species richness, species pollutant

(4) *Assess single species indicators*

2.4 Information Resources

USGS's NAWQA Data Warehouse provides online access for invertebrate community data from 1,700 stream sites in more than 50 major river basins across the nation. Data from more than 5,000 invertebrate community samples that were collected from 1993 through 2002 can be found here. The data warehouse also provides data on fish communities from more than 1,000 stream locations, as well as data from thousands of water quality samples from approximately 6,400 stream sites, 7,000 wells, and streambed sediment and aquatic animal tissue. Samples have been analyzed for a number of constituents. The NAWQA Data Warehouse can be accessed at http://water.usgs.gov/nawqa/data.

The Caltrans *Guidance Manual: Storm Water Monitoring Protocols* (Caltrans, 2000a) provides step-by-step descriptions of the processes used to plan and implement a successful water quality monitoring program specific to runoff from transportation-related facilities. Although the guidance manual emphasizes uniform policies and procedures for monitoring, the *Statewide Storm Water Management Plan* (Caltrans, 2000b) describes minimum procedures and practices Caltrans uses to reduce pollutants discharged from storm water drainage systems. These documents, along with other storm water-related documents, can be downloaded in PDF format http://www.dot.ca.gov/hq/env/stormwater/special/index.htm.

Donigan and Huber (1991), in *Modeling of Nonpoint Source Water Quality in Urban and Non-Urban Areas*, reviewed nonpoint source assessment procedures and modeling techniques for both urban and non-urban land areas. Detailed reviews of specific methodologies and models are presented, along with overview discussions focusing on both urban and non-urban methods and models. Brief case studies of ongoing and recently completed modeling efforts are described and recommendations for nonpoint runoff quality modeling are presented. This document can be ordered from the National Technical Information Service at *www.ntis.gov* or by calling 800-553-6847.

EPA has assembled a Web site with information about and links to water quality models. This site includes basic information, EPA-supported models, other federal government-supported models, technical guidance for models, and model training and meetings. The Web site can be accessed at http://www.epa.gov/waterscience/wqm/.

Patten et al. (2000) have undertaken a study to develop improved indicators and innovative techniques for assessing and monitoring ecological integrity at the watershed level in the western United States. Their objectives are to develop practical, scientifically valid indicators that span multiple resource categories, are relatively scale-independent, address different levels of biological organization, can be rapidly and cost-effectively monitored by remote sensing, and are sensitive to a broad range of anthropogenic and natural environmental stressors. More information about this project can be found at http://es.epa.gov/ncer_abstracts/grants/99/ecological/patten.html (NCER, 2001).

Compendium of Tools for Watershed Assessment and TMDL Development (USEPA, 1997a) supports the watershed approach by summarizing available techniques and models that assess and predict physical, chemical, and biological conditions in water bodies. The publication contains descriptions of three major categories of models: watershed loading, receiving water,

biocriteria derivation procedures. This document can be downloaded in PDF format at http://www.epa.gov/ost/biocriteria/States/estuaries/estuaries1.html.

The *Stressor Identification Guidance Document* (USEPA, 2000b) leads water resource managers through the process of stressor identification and evidence assembly. The guidance can be used whenever biological impairment is present in an aquatic ecosystem and the cause is unknown. The stressor identification process combines multiple methods to determine the causes of impairment, and the methods are presented in ordece mcostav(idene)-7(ecee use, from srit-)]TJ0 -1.15 Dd[spect models for TMDL development, assisting in da

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Table 3.1: Cost comparison of stream preservation vs. stream restoration (Michigan Department of Environmental Quality, no date).

	Bear Creek	**York Creek**
Type of nonpoint source project	Preservation	Restoration
Setting	Grand Rapids, MI, area stream	Grand Rapids, MI, area stream
Size	20,096 acres	2,110 acres
Level of urbanization	9.5% (1991)	19% (1993)
Stream category	High-quality trout stream	Former trout stream
Storm water ordinance	$10,000	$10,000
Decision-making GIS	$10,000	$10,000
Information/education program	$100,000	$80,000
Streambank stabilization	$15,000	$130,000
Storm water basin retrofits	–	$180,000
Additional storm water basins	–	$75,000
Other practices (habitat improvement, repairing road crossings, etc.)	$75,000	$190,000
Total cost	$210,000[a]	$675,000

Watershed Approach to Storm Water and Flood Management

Table 3.2: Types of lands that should be preserved for watershed protection (adapted from Caraco et al., 1998).

Conservation Area	Description	Examples
Critical habitat 	Essential spaces for plant and animal communities or populations	Tidal wetlands, freshwater wetlands, large forest clumps, springs, spawning areas in streams, habitat for rare or endangered species, potential restoration areas,

(4) *Purchase property or development rights*. This practice is meant to guarantee community control over the activities conducted on lands that contribute to aquifers or surface waters. This may involve outright purchase of the land or just surface-use rights (see section 3.3.5 for a discussion of land acquisition options). New funds from the Safe Drinking Water Act allow land trusts and other local organizations to work with state agencies and water suppliers to identify and acquire critical lands and conservation easements.

3.3.2 Development of Watershed Management Plan

The resource inventory and information analysis component provides the basis for a watershed

11. Set resource management goals and objectives. Before corrective actions can be taken, a resource management target must be set. The target can be defined in terms of water quality standards, attainment of beneficial uses, or other local resource management objectives.
12. Determine pollutant reduction for existing and future land uses needed to achieve water quality goals.
13. Select appropriate management practices for both point and nonpoint sources that can be used to achieve the goal. Evaluate pollutant removal effectiveness, landowner acceptance, financial incentives and costs, availability of land operation and maintenance needs, feasibility, and availability of technical assistance.
14. Develop a watershed management plan. Since the problems in each watershed will be unique, each watershed management plan will be specific. However, all watershed plans will include elements such as an existing and future land use plan; a master storm water management plan that addresses existing and future needs; a wastewater management plan, including septic tank maintenance programs; and an infrastructure and capital improvements plan.

Development of a watershed management plan may involve establishing general land use designations that define allowable activities on a parcel of land. For example, land designated for low-density residential use would be limited to a density of two hous

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3.3.3 Implement the Plan

Once critical areas have been identified, land use designations have been defined, and goals have been established to guide activities in the watershed, implementation strategies can be developed. At this point, the requirements of future development are defined. These requirements include, but are not limited to, permitted uses, construction techniques, and protective maintenance measures. Land development regulations may also prescribe natural performance standards, such as “rates of runoff or soil loss should be no greater than predevelopment conditions.”

prevent urban sprawl, and discourage the use of septic tanks where they are inappropriate (International City/County Management Association, 1979). Infill development may have the added advantage of municipal cost savings.

To discourage development in the environmentally sensitive East Everglades area, Dade County, Florida, has developed an urban services boundary (USB). In areas outside the USB, the county will not provide infrastructure and has kept land use densities very low. This strategy was selected to prevent urban sprawl, protect the Everglades wetlands (outside of Everglades National Park), and minimize the costs of providing services countywide. The area is defined in the county comprehensive plan, and restrictions have been implemented through the land development regulations (Metro-Dade Planning Department, 1988).

Congress has enacted similar legislation for the protection of coastal barrier islands. In 1981, the availability of federal flood insurance for new construction on barrier islands was discontinued. In 1982, Congress passed the Coastal Barriers Resources Act, establishing the Coastal Barrier Resource System (CBRS), and t-5(em)-5rmd7rmd4(n)-ad t-5(ped)-10 vaarrid t-56(y)12( )TJ-0.0007 Tc 0.0007 T

provided at reasonable cost in a timely fashion. The potential impact of growth within the boundary on existing natural resources also needs to be determined. In the context of watershed planning, it is advantageous to use watershed boundaries or other natural features as urban growth boundaries. In this manner, key or sensitive watersheds can be protected from the impacts of development.

In Arizona, the 1998 Growing Smarter Act and its 2000 addendum, Growing Smarter Plus, were signed into law by Governor Jane Hull (Morrison, 2000). This legislation addresses the issue of development by strengthening the ability of communities in Arizona to plan for growth and to acquire and preserve open space. The Growing Smarter legislation requires communities to address growth and growth-related pressures by mandating general plans that identify growth areas, establish policies and strategies for new growth, identify open space needs, regionally plan for interconnected open space, and analyze the environmental impacts of the development anticipated by the general plan (City of Tucson, no date).

development, and it established a forest conservation fund for reforestation projects. In the first five years of implementation, the Forest Conservation Act has produced 22,508 acres of retained forest and 4,313 planted acres, while 12,210 acres of existing forest have been cleared (Honeczy, 2000).

Broward County, Florida, has an open space program and encourages cluster development to reduce impervious surface area, protect water quality, and enhance aquifer recharge (Broward County, Florida, 1990).

New Hampshire has a model shoreland protection ordinance that encourages grouping of residential units, provided a minimum of 50 percent of the total parcel remains as open space.

One way to increase open space while allowing reasonable development of land is to encourage cluster development. Clustering entails decreasing the allowable lot size while maintaining the number of allowable units on a site. Such policies provide planners the flexibility to site buildings on more suitable areas of the property and leave environmentally sensitive areas, such as wetlands or steep slopes, undeveloped. Criteria can vary. Advantages of cluster development include:

- Reducing the costs of infrastructure;
- Preserving sensitive areas;
- Increasing property values with proximity to open space; and
- Preserving ecological, aesthetic, and recreational values.

Planned unit development is a type of zoning that encourages the use of cluster development but does not require it. For example, a set number of units could be spread across the site under typical residential zoning, but under cluster zoning, the same number of units could be concentrated on smaller lots on only a portion of the site, preserving the other portion for common open space to protect sensitive features or for use as a recreation area.

3.3.3.5 Revitalize existing developed areas

Redeveloping existing areas can alleviate water quality impacts by reducing the strain of development on open space land and minimizing the amount of impervious surface added to the watershed. Existing impep hece as transformers that alter the chemical composition of compounds, as sinks that store nutrients for an extended period of time, and as a source of energy for aquatic life (USEPA, 1992). Setbacks or buffer zones are commonly used to protect coastal vegetation and wildlife corridors, reduce exposure to flood hazards, and protect surface waters by reducing and cleansing urban runoff (Mantel et al., 1990). The types of development allowed in these areas are usually limited to non-habitable structures and those necessary to allow reasonable use of the property, such as

plan approved by the local jurisdiction (Critical Area Commission for the Chesapeake and Atlantic Coastal Bays, no date).

3.3.3.6.2 Vegetative and use strategies within management zones

Buffers can be divided into three zones—the streamside, middle, and upland zones (Herson-Jones et al., 1995). Dense vegetation in the streamside zone (recommended to be approximately 25 feet wide) prevents excessive activity in this sensitive area, maintains the physical integrity of the stream, and provides shade, litter, debris, and erosion protection. The width of a grassed or mostly forested middle zone (minimum of 50 feet) depends on the size of the stream and its floodplain and the location of protected areas such as wetlands or steep slopes. The upland zone, typically 25 feet wide, is an additional setback from the buffer and usually consists of lawn or turf. Zones in the buffer should be delineated to determine the types of vegetation that should be maintained or established.

Allowable land uses in the three zones vary. The streamside zone is limited to footpaths, runoff channels, and utility or roadway crossings. The middle zone may be used for recreation and runoff control practices. The upland zone may be used for many purposes, with the exception of septic systems, permanent structures, or impervious covers. A depression incorporated into the design of the upland zone can detain runoff during storms. This runoff is released slowly to the middle zone as sheet flow, which is then transferred to the dense streamside zone, designed to have minimal to no discharge of surface water to the stream.

3.3.3.6.3 Provisions for buffer crossings

Stream crossings should minimize impacts on buffer integrity while providing crossing points for linear forms of development such as roads, bridges, golf course fairways, underground utilities, enclosed storm drains, and outfall channels (Schueler, 1995). They should also be designed to provide fish passage and to withstand overbank flows from the 100-year storm event. Design

The use of nonstructural and structural management practices described in this chapter for controlling nonpoint source pollution may be a condition of development approval.

Setbacks and limits on impervious areas may be clearly defined in a condition for development approval, as is being done in the programs discussed above.

Reduction in the use of pesticides and fertilizers on landscaped areas by encouraging the use of vegetation that is adaptable to the environment and requires minimal maintenance. (Xeriscaping techniques are described in Management Measure 4 and lawn and garden activities are described in Management Measure 9.)

3.3.3.10 Designate an entity or individual responsible for maintaining the infrastructure, including urban runoff management systems

The responsible party should be trained in the maintenance and management of urban runoff management systems. If desired, the local government could be designated to maintain urban

The Florida legislature funded the development of comprehensive programs and land development regulations required by the Local Government Comprehensive Planning and Land Development Regulation Act (1985). Distribution of funds was based on population according to formulas used for determining funding for the plan and land development regulations. A base amount was given to all counties that requested it. The balance of the monies was allocated to each county in an amount proportionate to its share of the total unincorporated population of all

Another resource is the Natural Lands Trust whose Web site, at http://www.natlands.org, provides information and resources pertaining to land preservation and land use planning.

The practices described below can be used to protect beneficial uses.

3.3.5.1 Fee simple acquisition/conservation easements

The most direct way to protect land for preservation purposes and associated nonpoint source control functions is fee simple acquisition, through either purchase or donation. Once a suitable area is identified for preservation, the area may be acquired along with the development rights. The more development rights that are associated with a piece of property, the more expensive it will be. Many state and local governments and private organizations have programs for purchasing land.

Conservation easements are legal restrictions on the present and future use of land. For preservation purposes, the easement holder, who is usually not the owner of the property, is able to control the rights of the property when the landowner might adversely impact resources on the property. In effect, the property owner gives up development rights within the easement while retaining fee ownership of the property (Mantel et al., 1990; Barrett and Livermore, 1983). The agreement between the easement holder and property owner is permanent, legally enforceable, and not subject to alteration unless permission is received in writing by the easement holder and all other cosigners (Arendt, 1997).

A conservation easement is a flexible tool that can be customized to set different levels of restrictions among different types of conservation areas in a parcel. In addition to protecting and maintaining environmental benefits in perpetuity, landowners who donate conservation easements to a government agency or nonprofit group typically realize substantial income, property, and estate tax benefits resulting from the charitable donations. Their property value might be lowered, however, because the development rights were removed. Consequently, tax and estate planning professionals need to be consulted when a conservation easement is being contemplated.

As an alternative, agricultural and forestry easements are specific types of conservation easements that allow continued use of land as farms or forests and prevent the land from being sold for commercial or residential development. The USDA Natural Resource Conservation Service currently manages the Farm and Ranch Lands Protection Program (FRPP), a voluntary program that provides matching funds to state, tribal, or local governments and non-governmental organizations with existing farm

Deed restrictions are included in deeds for the purpose of constraining use of the land. In theory, deed restrictions are designed to perform functions similar to those of conservation easements. In practice, however, deed restrictions have proven to be much weaker substitutes because unlike conservation easements, they do

- *Provide education and outreach*. The public should be familiar with the overall objectives of the program. Landowners and developers also need to be educated on how they will be affected.

- *Conduct an analysis of market conditions*. A successful program requires a market for TDR transfers.

- *Identify and designate TDR "receiving areas."* Receiving areas should be capable of supporting growth. Factors include adequate land area, infrastructure, public services, and consideration of environmental constraints.

- *Identify and designate TDR "sending areas."* Sending areas should support preservation and protection goals. Specific areas should be delineated to the parcel level.

- *Determine the nature of program*. Programs can be voluntary or mandatory. If mandatory, sending areas should be down-zoned to control growth.

- *Determine development potential and allocate TDRs*. Compute current allowable densities in both receiving and sending areas, and then allocate TDRs from sending areas based on desired densities. For example, down-zoning from a yield of 1 lot per 5 acres to 1 lot per 25 acres equates to 4 TDRs.

- *Consider a TDR Bank*. A TDR bank buys, holds, and sells TDRs. The bank can be either a government organization or a quasi-governmental entity.

Transfer of Development Credits Pilot Program, King County, Washington

King County, WashingtonTm 5n or a quas4T(, serion oTs)-11(rion lot)-117(e(enuntyt pot25ntialCrion ed12(Pn)- (ion T(, se

– *Provide adequate resources*. A TDR program does not run itself. It needs staff and resources to administer and manage the program.

3.3.5.4 Purchase of development rights

In this process, the rights of development are purchased while the remaining rights remain with the fee title holder. Restrictions in the deed make it clear that the land cannot be developed based on the rights that have been purchased (Mantel et al., 1990).

Howard County, Maryland, has the goal of preserving 20,000 acres of farmland. Development rights are acquired in perpetuity with $\frac{1}{4}^{th}$ of 1 percent of the local land transfer tax used as funding. There is no cap on the percentage of assessed value that may be considered development value, and payment for development rights may be spread over 30 years to ease the capital gains tax burden on the landowner (Jenkins, 1991).

3.3.5.5 Land trusts

Land trusts may be established as publicly or privately sponsored nonprofit organizations with the goal of holding lands or conservation easements for the protection of habitat, water quality, recreation, or scenic value, or for agricultural preservation. A land trust may also pre-acquire properties that are conservation priorities if it enters the development market when government funds are not immediately available by securing bank funding with the government as guarantor (Jenkins, 1991).

3.3.5.6 Agricultural and forest districts

Agricultural or forest districting is an alternative to acquisition of land or development rights. Jurisdictions may choose to allow landowners to apply for designation of land as an agricultural or forest district. Tax benefits are received in exchange for a commitment to maintain the land in agriculture, forest, or open space.

Fairfax County, Virginia, taxes land designated as an agricultural or forest district based on the present use valuation rather than the usual potential use valuation. A commitment to agricultural or forestry activities must be shown, and sound land management practices must be used. The districts are established and renewed for eight-year periods (Jenkins, 1991).

3.3.5.7 Cost and effectiveness of land acquisition programs

The costs associated with land acquisition programs vary depending on the desired outcome. If land is to be purchased, the cost depend on the value of the land. An additional cost to be considered is the maintenance of the property once it is in public ownership. Easements and development rights are less expensive, and maintenance responsibility is retained by the owner. Depending on the size of the local government, implementation of these programs is usually part of the operating budget of the appropriate agency (planning department or parks and recreation department, for example).

The effectiveness of a land acquisition program is determined by the size of the parcel and the difference between predevelopmlow 7nt and potlopostdevelopment pollutant loading rates. In

3.4 Information Resources

The Center for Watershed Protection's *Rapid Watershed Planning Handbook*

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"Protecting Water Resources with Smart Growth" is intended for audiences such as communities, local governments, state and regional planners already familiar with smart growth who are now seeking additional ideas on how to protect their water resources. The document is a compilation of 75 policies designed to protect water resources and implement smart growth. The majority of these policies (46) are oriented to the watershed, or regional level; the other 29 are targeted for specific development sites. The document is available for download in PDF format at http://www.epa.gov/smartgrowth/water_resource.htm.

Getting to Smart Growth: 100 Policies for Implementation was produced by the Smart Growth Network. The document highlights and describes techniques to help policymakers put smart growth principles into practice. The policies and guidelines, which have proven successful in communities across the U.S., range from formal legislative or regulatory efforts to informal approaches, plans, and programs. The primer describes 10 smart growth principles, specific policies for each principle, illustrations of their application in a community, and additional resources to aid communities in implementation. The document is available online in PDF format at http://www.smartgrowth.org/pdf/gettosg.pdf g(t)4(pre)2(0.000+1.0 1416.5 1273help poro

The concept of creating and maintaining an interconnected network of protected land and water, called "G2oSc 0.0004 T qd l00.6 TM6nd ectiavailable feiw3h.orrtargeted fotoout 0 12c8BD 464artgro

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- Reforest areas within the same watershed in proportion to the acreage cleared of trees.
- Use porous pavements for areas of infrequent use (see section 5.3.2.3 in Management Measure 5).

The use of site planning and evaluation can significantly reduce the size of controls required to retain runoff and sediment on-site. Long-term maintenance burdens can also be reduced. Good site planning can attenuate runoff from development and can improve the effectiveness of the conveyance and treatment components of an ur mitigate basement flooding and CSOs (USEPA, 1999). Two communities in Indiana successfully implemented street surface storage of runoff to reduce the occurrence of CSOs in a cost effective manner while also reducing peak flows to wastewater treatment plants. The distributed storage controls also offered some water quality benefits by temporarily detaining runoff during storms (USEPA, 1999).

From a marketing perspective, studies have shown that lots abutting forested or other open space are initially valued higher than lots with no adjacent open space, and over time they appreciate more than lots in conventional subdivisions (Arendt, 1996). For example, lots in an open space subdivision in Amherst, Massachusetts, experienced a 13 percent greater appreciation in value compared to a conventional development after 20 years, even though the lots in the conventional development were twice as large (Arendt, 1996).

From a quality-of-life standpoint, site designs that incorporate pedestrian paths and common open space foster a greater sense of community among residents. House lots are closer together, encouraging communication among neighbors. Additionally, common open space provides recreational opportunities that further encourage community interaction.

Finally, better site design offers environmental benefits, including protection of ecologically significant natural resources, reduction of runoff, and preservation of open space and wildlife habitat. Maintaining open space also increases the opportunity for alternative sewage and wastewater disposal and treatment practices such as land treatment, spray irrigation, and reclamation and reuse. In addition, the flexibility of better site design allows designers to site these wastewater treatment systems in the areas of the development best suited for them.

Overall, the practices presented in this management measure provide many advantages over conventional developments and can be implemented in most communities. In some cases, however, outdated development rules can discourage or prohibit some of these practices. Watershed managers should review the local building codes and regulations that govern new developments to determine whether better site design techniques are allowed or encouraged and work with the appropriate authorities to remove these impediments.

The second edition of the Bay Area Stormwater Management Agencies Association’s *Start at the Source*, which was originally published in 1997, is an excellent resource on site design issues for watershed managers. This publication emphasizes the importance of considering runoff quality in the early stages of land planning and design. The new edition has been updated and expanded to include commercial, industrial, and institutional development, as well as a technical section that provides more detailed information on the characteristics, applications, design criteria, maintenance, and economics of the practices discussed in the document. More information about ordering this publication when it becomes available is provided on the Bay Area Stormwater Management Agencies Association’s Web site at http://www.basmaa.org/ (BASMAA, no date).

surface water bodies. Steep slopes and highly erodible areas need to be protected to avoid landslides and soil movement into water bodies.

The increase in storm water runoff that results from urban development can dramatically impact the ecology of wetlands and other areas by altering characteristics of hydrology, water quality, and soil (USEPA, 1996). Urban development can also result in ecological changes due to fragmentation and habitat destruction. If the development of a site changes runoff characteristics, measures should be taken to prevent negative impacts to wetlands and other features. For example, Pohlig Builders of Malvern, Pennsylvania, incorporated measures to protect wetlands into its building plan after homeowners opposed the construction of seven high-end homes adjacent to a wetland area. Pohlig designed a vegetative filter strip to buffer runoff from the homes and provide treatment before runoff reached the wetlands. The filter strip was designed to eventually grow into a wooded area to enhance aesthetics and benefit water quality. A level spreader was added to convert concentrated runof

Management Measure 3), zoning ordinances should not preclude the implementation of clustered development as an alternative to

Randall Arendt (1996), in his book, *Conservation Design for Subdivisions: A Practical Guide for Creating Open Space Networks*, presents a plain-language, illustrated guide for designing open space subdivisions. This publication is available from Natural Lands Trust, Inc., 1031 Palmers Mill Road, Media, PA 19063; phone 610-353-5587. The following topics are covered:

- Open space vs. conventional developments;
- Economic, social, and environmental benefits of open space designs;
- Roles and responsibilities of stakeholders in site development;
- A stepwise approach to designing an open space subdivision (discussed below);
- Ideas for creating an interconnected open space network;
- Seven case studies;
- Methods to modify existing regulations to encourage open space design;
- Management techniques for conservation lands;
- Sample house plans for open space subdivisions;
- Sample advertisements for developers to capitalize on open space design benefits; and
- Model ordinance provisions.

Arendt's multi-step process for creating conservation subdivisions involves two stages. The first, called the background stage, involves identifying the characteristics of the surrounding landscape and existing development and analyzing and delineating significant features of the site. The second stage involves integrating the site's feature information into a map and prioritizing conservation lands based on the features deemed most important, while maintaining the quantity of land necessary to develop the site to the desired density.

The background stage involves examining the surrounding landscape and existing development to identify conservation areas. It includes the following practices:

(1) *Understanding the locational context*. The layout of new dev

Comparison of Traditional and Low Impact Development Scenarios in Delaware

The Brandywine Conservancy and the Delaware Department of Natural Resources and Environmental Control presented a case study in *Conservation Design for Stormwater Management* (Delaware DNREC and the Brandywine Conservancy, 1997). The case study compares conventional site development to several alternative, low impact development scenarios at Chapel Run, a 96-acre site in Sussex County, Delaware. The Chapel Run site is located in a rural area and is categorized by Sussex County as a primarily agricultural area where low-density residential development is permitted. Conservation areas that were identified through a site investigation include a large area of woodland, much of which is on well-drained soils that generate little or no runoff, and a small area with steep slopes.

The proposed conventional design dictates dividing the site into 142 lots ½ acre in size. The conventional design does not take into consideration the sensitive areas identified in the site assessment and results in a site with 100 percent of the area disturbed after clearing and grading. Overall site imperviousness under conventional development would be 29 percent, assuming conventional road widths. On-site runoff management would be accomplished by a curb and gutter system that conveys runoff to two detention basins.

Two alternative designs were developed for the Chapel Run site: the parkway design and the village cluster design. Figure 4.4 shows lot layouts for the conventional and conservation designs. Table 4.1

Comparison of Traditional and Low-Impact Development Scenarios in Delaware (continued)

Table 4.1: Theoretical comparison of conventional and low-impact alternative designs for the Chapel Run site (DE DNREC and the Brandywine Conservancy, 1997). (Reductions are compared to the conventional design.)

Name	Conventional	Village	Parkway
Layout type	Conventional	Condensed cluster	Lots configured along curving road
Number of lots	142	142	142
			1/4-acre
			Woodland and high recharge areas
			49.7%
			14.9%
			48%
			Two one-way lanes 12 feet wide with a

4.3.2 On-Lot Impervious Surfaces

4.3.2.1 Reduce the hydraulic connectivity of impervious surfaces

Pollutant loading from impervious surfaces can be reduced by preventing the direct connection of the impervious area to an impervious conveyance system. This can be done in a number of ways, including:

(1) Routing runoff over lawn areas to increase infiltration;

(2) Discouraging the direct connection of downspouts to storm sewers, or the discharge of rooftop downspouts to driveways, parking lots, and gutters;

(3) Substituting swale and pond systems for curbs and gutters to increase infiltration; or

(4) Reducing the use of storm sewers to drain streets, parking lots, and backyards by routing runoff overland using curbless systems, curb cuts, sloped sidewalks, and bioretention cells.

If runoff is directed over lawns, care should be taken to alleviate soil compaction. Urban lawns that are highly disturbed and compacted do not necessarily function as pervious surfaces (for more information on managing runoff from lawns and landscaping, see Management Measure 9).

Figure 4.5 shows schematic representations of impervious areas that are directly connected and not directly connected (BASMAA, 1997).

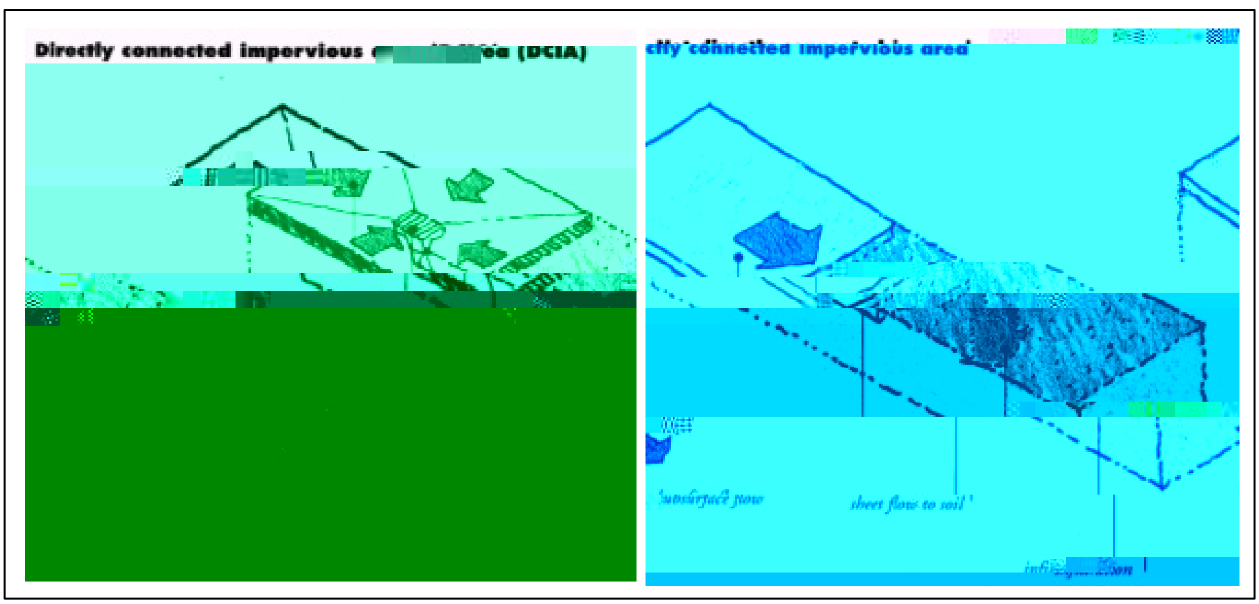


Figure 4.5: Schematic representation of directly connected and not-directly connected impervious areas (BASMAA, 1997).

4.3.2.2 Practice rooftop greening

Rooftop greening has become an increasingly common practice in Europe and other parts of the world. This practice involves growing vegetation on the roofs of businesses and homes to intercept rainfall and promote evaporation rather than runoff (Natural Carpets, 1998). Rooftop mats are typically multilayered and include prevegetated coir fiber mats, a mineral-based substrate, and a synthetic matrix (see Figure 4.6). The coir fiber mat absorbs rainfall; the mineral substrate provides the plants with nutrients; and the synthetic matrix promotes drainage. Mats can be used on roofs with slopes of up to 30 degrees and are capable of reducing runoff by two-thirds (see Figure 4.7). These mats provide benefits other than runoff reduction, including:

- Visual aesthetics
- Protection of roofs from damaging solar radiation, wind, and precipitation
- Insulation
- Noise reduction
- Habitat for wildlife

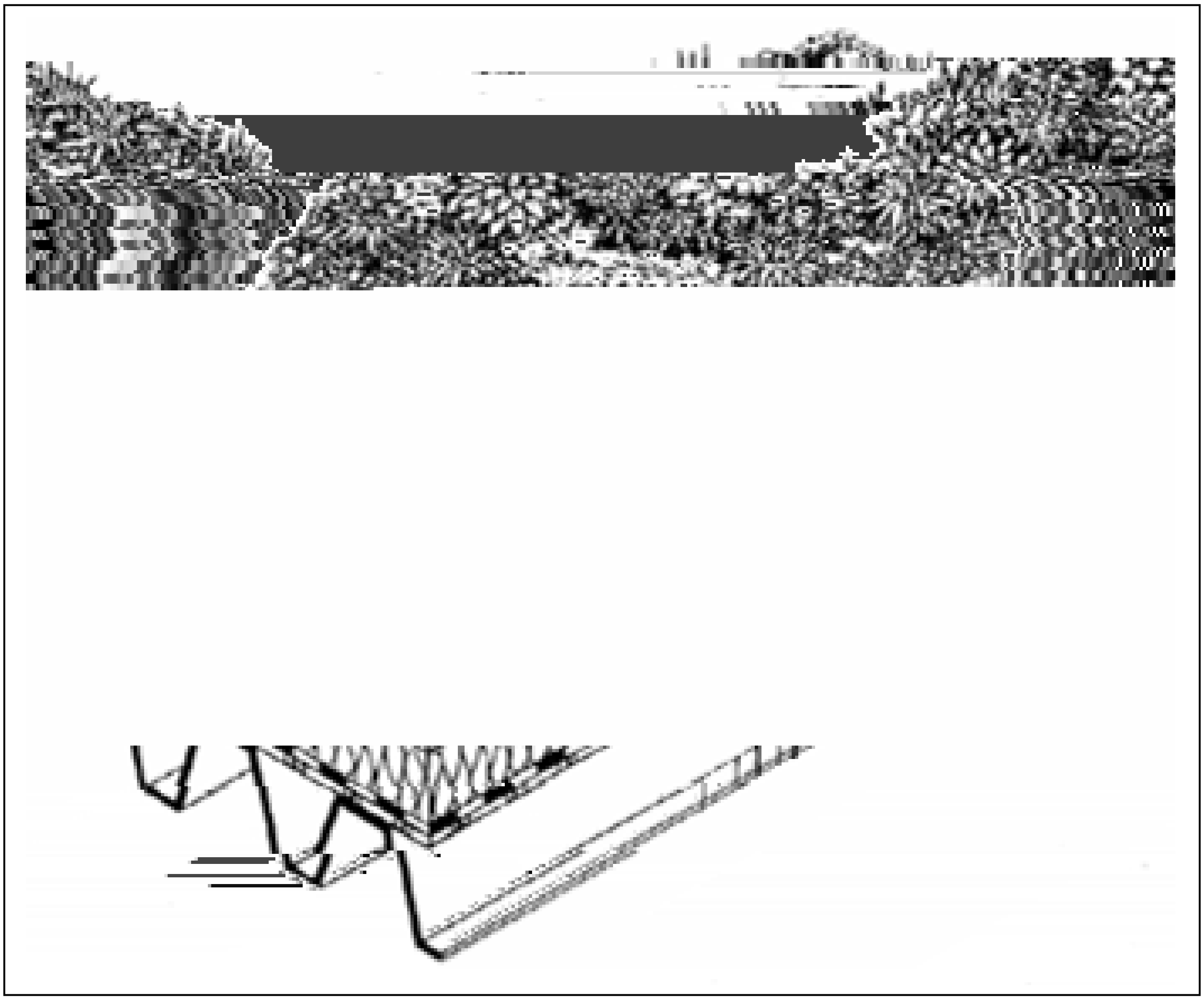


Figure 4.6: Components of the vegetated roof cover (USEPA, 2000).

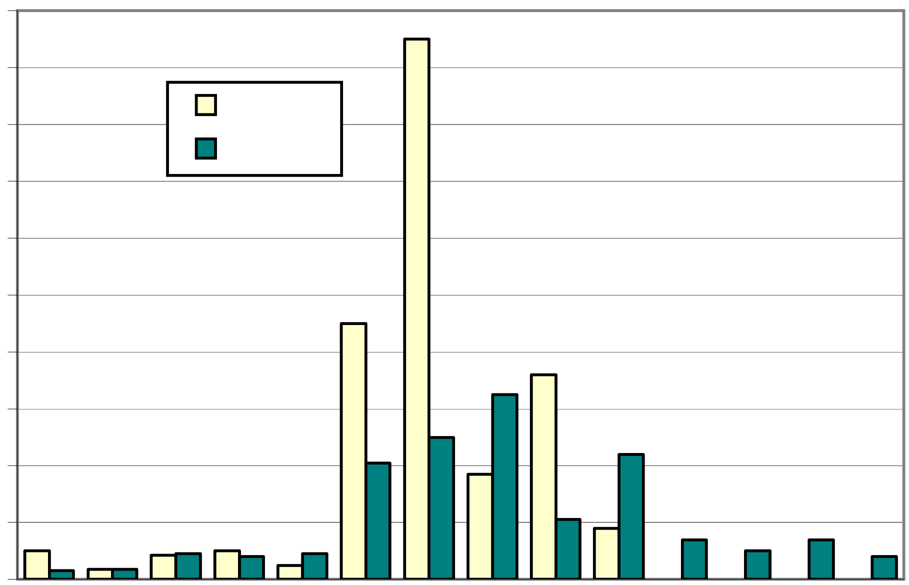


Figure 4.7: Runoff attenuation efficiency for a 0.4-inch rainfall event with saturated media (USEPA, 2000).

- Dust-trapping
- Evaporation and ambient cooling

Vegetation should be well-adapted to the growing conditions of the area where it is installed. Maintenance includes a limited amount of irrigation on steep slopes and periodic fertilization and weeding. Additional roof support might be necessary because the mats, when saturated with water, can add 5 to 17 pounds per square foot.

In response to a court order requiring $3 billion in storm water improvements, Atlanta is targeting commercial buildings for the installation of green roofs, with the anticipation that the resulting decrease in storm water runoff volume will provide water quality benefits. Commercial buildings are being targeted because commercial rooftops cover a huge amount of surface area in the city (Copeland, 2002).

Moran et al. (2004) studied runoff quality from two green roofs installed in North Carolina. They found that each green roof retained approximately 60 percent of the total recorded rainfall during a nine-month observation period. The green roofs reduced average peak flow by approximately 85 percent. Water quality data indicated higher concentrations of total nitrogen and total phosphorus were present in the green roof runoff than in the control roof runoff and in the rainfall at each green roof site. The researchers attribute this to nitrogen and phosphorus leaching from the soil media, which was composed of 15 percent compost. A soil column test of three different green roof soil media indicated that reducing organic matter in the soil media will

4.3.2.5 Modify driveway standards

In a sense, driveways are small-scale parking lots that are designed to accommodate two to four cars. Typical residential driveways and parking pads often total 400 to 800 square feet. Communities that want to reduce driveway impervious cover should consider:

- Shortening driveway length by shortening front yard setback requirements;
- Narrowing driveway widths;
- Encouraging the use of driveways that are shared by two or more homes; and
- Providing incentives for use of alternative driveway surfaces that allow for infiltration, such as porous pavers, gravel, or a two-track surface with grass in between.

4.3.3 Residential Street and Right-of-Way Impervious Surfaces

The largest percentage of impervious cover in residential neighborhoods is typically associated with the streets, driveways, and sidewalks that together aid in the transport of people to and from their various destinations. Management practices associated with residential streets and their rights-of-way typically are focused on minimizing impervious cover or treating runoff. In general, these objectives can be achieved by developing, updating, or revising codes, ordinances, and standards that determine the size, shape, and construction of residential streets and their rights-of-way.

4.3.3.1 Decrease street pavement width and length

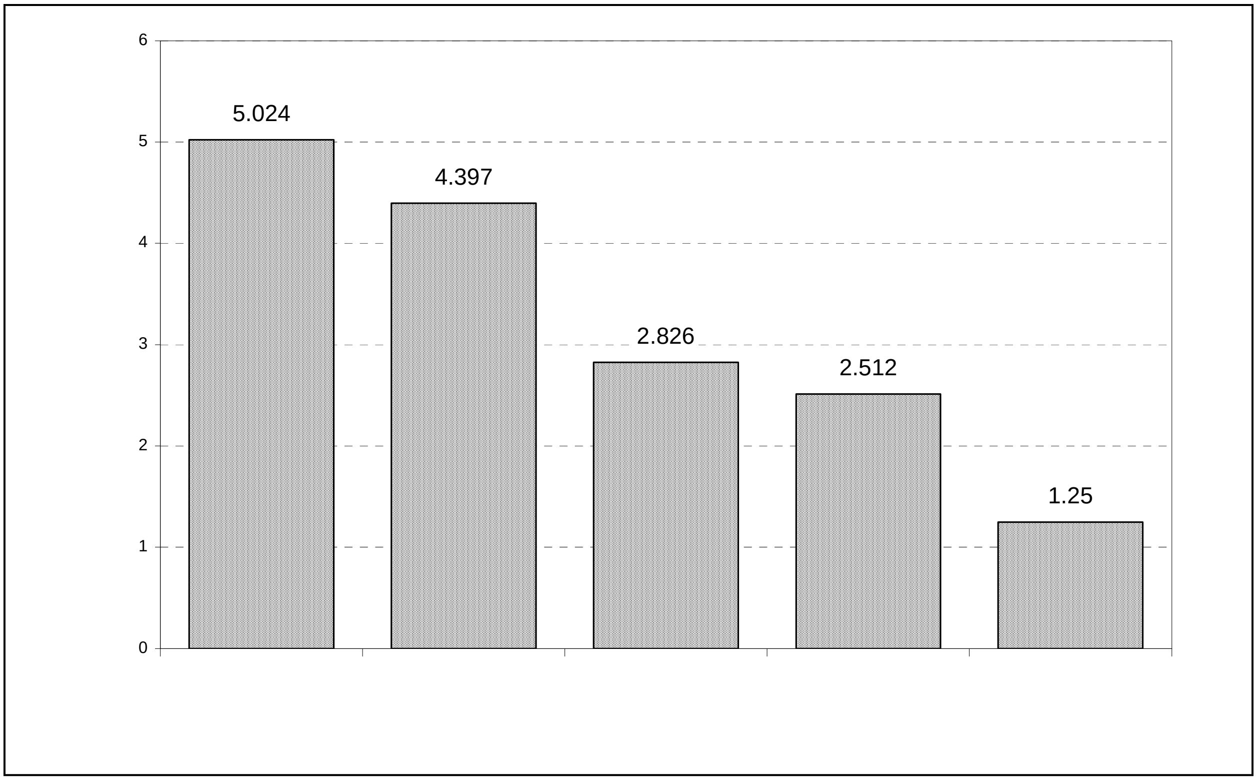
Streets typically make up the largest percentage of transport system impervious cover in residential neighborhoods. Communities can significantly reduce this type of cover in new developments by revising street standards so that street pavement widths are based on traffic volume, on-street parking needs, and other variables rather than requiring all streets to have one universal width. Additionally, communities can encourage developers to design street networks that minimize the total length of pavement. The length of residential streets can be reduced by altering the design and placement of new development. Techniques include:

- Reducing frontage distances and side yard setbacks;
- Allowing narrower lots;
- Clustering smaller lots;
- Reducing the number of non-frontage roads; and
- Eliminating long streets that serve only a small number of homes.

4.3.3.2 Decrease street right-of-way width

A street right-of-way is a public easement corridor through which people, vehicles, runoff, utility services, and other items and materials move in, out, and around the development. A right-of-way usually includes the street itself, its gutters and curbs, and some amount of land on either

- Eliminating cul-de-sac streets altogether;
- Using alternative designs for turnarounds, such as a T-shaped turnaround or a looped road;
- Reducing the radius of the turnaround bulb; or
- Incorporating a pervious cover island in the center of the turnaround bulb that accepts runoff.


6
5
4
3
2
1
0
5.024
4.397
2.826
2.512
1.25

Traditionally, developers have provided an overabundance of parking as a convenience for shoppers, workers, and landowners. A goal of watershed managers should be to reduce the surface area of parking lots and integrate runoff treatment practices to reduce adverse impacts, demand. For instance, mulching can help retain water and humidity and reduce the need for irrigation. Shading and windbreaks can reduce evaporation, particularly from young plants. In contrast to overhead sprinklers, drip irrigation waters plants directly on the roots without wetting plant leaves, helping to reduce evaporation and control disease. Timers are available that allow automatic watering with drip irrigation systems. Watering early in the morning can also reduce evaporation, and prevent the propagation of disease that often results from leaving foliage wet overnight (Relf, 1996). Xeriscaping can reduce the contribution of landscaped areas to nonpoint source pollution, and it can reduce landscape maintenance by as much as 50 percent, primarily as

4.4 Information Resources

In 1991 the Center for Watershed Protection published the *Consensus Agreement on Model Development Principles to Protect Our Streams, Lakes, and Wetlands*, which outlines the series of 22 nationally endorsed principles developed by the Site Planning Roundtable, a national cross-section of diverse planning, environmental, homebuilder, fire, safety, public works, and local government personnel, and details the basic rationale for their implementation. The *Consensus Agreement* can be purchased at http://www.cwp.org/.

The Center for Watershed Protection also published *Better Site Design: A Handbook for Changing Development Rules in Your Community* in 1998. This document outlines 22 guidelines for better developments and provides a detailed rationale for each principle. *Better Site Design* also examines current practices in local communities, details the economic and environmental benefits of better site designs, and presents case studies from across the country. It can be purchased at http://www.cwp.org/.

Wildlife Reserves and Corridors in the Urban Environment: A Guide to Ecological Landscape Planning and Resource Conservation, by Lowell Adams and Louise Dove (1989) reviews the knowledge base regarding wildlife habitat reserves and corridors in urban and urbanizing areas, and it provides guidelines and approaches to ecological landscape planning and wildlife conservation in such areas. It can be purchased from the Urban Wildlife Resources Bookstore at http://users.erols.com/urbanwildlife/bookstor.htm.

In 1997 Randall Arendt of the Natural Lands Trust, Inc., published *Growing Greener: Putting Conservation into Local Codes*. *Growing Greener* is a statewide community planning initiative designed to help communities use the development regulation process to their advantage to protect interconnected networks of greenways and permanent open space. The booklet can be downloaded in PDF format at http://www.dcnr.state.pa.us/growinggreener/growing.pdf.

The Low Impact Development Center was established to develop and provide information to individuals and organizations dedicated to protecting the environment and our water resources through proper site design techniques that replicate preexisting hydrologic site conditions. More information about this organization can be found on the Low Impact Development Center Web site at http://www.lowimpactdevelopment.org/ or by contacting the Center at 301-345-0440.

The Prince George's County, Maryland, Department of Environmental Resources produced two documents, *Low-Impact Development Design Strategies: An Integrated Design Approach* (EPA-841-B-00-003) and *Low-Impact Development Hydrologic Analysis* (EPA-841-B-00-002), that discuss site planning, hydrology, distributed integrated management practice technologies, erosion and sediment control, and public outreach techniques that can reduce storm water runoff from new and existing developments. Both publications can be ordered free of charge through EPA’s National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

Residential Streets, prepared by the American Society of Civil Engineers, the National Association of Home Builders, and the Urban Land Institute (1990), discusses design considerations for residential streets based on their function and their place in the neighborhood.

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- Flow velocity, turbulence, and other conditions that promote the suspension of solids in the water column; and
- The sampling techniques employed.

Generally, individual particles found in a TSS sample are 62 µm (0.062 µm) or less in diameter and classified as either silts or clays (Table 5.1). Solids greater than 62 µm can also be found in the water column if conditions are turbulent enough to keep them in suspension.

Table 5.1: Sediment particle size distribution (shaded classes are found in a typical urban TSS sample).

General Class	Class Name	Diameter (m)
Sand	Very coarse sand	2000–1000
	Coarse sand	1000–500
	Medium sand	500–250
	Fine sand	250–125
	Very fine sand	125–62
Silt	Coarse silt	62–31
	Medium silt	31–16
	Fine silt	16–8
	Very fine silt	8–4
	Coarse clay	4–2
	Medium clay	2–1
	Fine clay	1–0.5

There are alternatives to the TSS method, including turbidity and suspended sediment concentration (SSC). Monitoring turbidity in urban runoff is advantageous because the measurements can be conducted in situ using continuous methods (e.g., Secchi disk). It should be noted, however, that using turbidity as a surrogate for TSS may be appropriate only in instances where a strong statistical correlation has been established, such as in low-energy environments like lakes and estuaries. This correlation should be established on a case-by-case basis if turbidity is to be used as a surrogate.

The SSC method is used by the U.S. Geological Survey (USGS) as the standard for determining concentrations of suspended material in surface water samples (USGS, 2000). Gray et al. (2000) examined the comparability of SSC and TSS measurements. SSC and TSS are the predominant analytical methods used to quantify concentrations of solid-phase material in surface waters. SSC values are obtained by measuring the dry weight of all the sediment from a known volume of a water-sediment mixture. TSS data are produced by several methods, most of which involve measuring the dry weight of sediment from a known volume of a subsample of the original. Analysis of paired SSC and TSS data showed bias in the relationship between SSC and TSS. In samples where sand-size material was greater than nearly a quarter of the dry sediment mass, SSC values tended to be higher than corresponding paired TSS values.

According to Gray, the SSC method produces relatively reliable results for natural water samples, regardless of the amount or percentage of sand-size material in the samples. SSC and TSS are not comparable and should not be used interchangeably. Rather, the authors suggest using the SSC analytical method to enhance the accuracy and comparability of suspended solid-phase concentrations of natural waters (Gray et al., 2000). More information about the SSC analytical method can be found at http://www.astm.org/ by searching for standard number ASTM D 3977-97, *Standard Test Method for Determining Sediment Concentration in Water Samples* (ASTM International, 2002).

5.2.1.2 Runoff

Runoff management programs have traditionally focused on reducing or preventing induced flooding from new development. Performance standards were typically developed to control large storms, e.g., 50- or 100-year storms. Although the control of these large storms is still essential, it has become apparent in the last 20 years that a broad range of storms must be managed to prevent streambed and streambank erosion. Recent research points to the need to control total discharge volumes and rates so that they do not result in stream channel degradation. As a result, some states and local governments have developed performance requirements that are intended to prevent stream channel erosion as well as flooding of downstream properties.

This management measure was written to address the control of both peak runoff rates and average runoff volumes with the intent to maintain postdevelopment runoff characteristics at predevelopment levels. Even though EPA recommends that structural runoff controls be designed to control all storms less than or equal to the two-year, 24 hour storm, state and local governments should determine the locally appropriate storm size threshold to control based on local hydraulics, hydrology, meteorology and other regional and local factors. Watershed managers also should consider the development and implementation of volume and peak discharge performance standards to address problems associated with the frequency and duration of erosive flows (MacRae and Rowney, no date). The use of low-impact development (LID) techniques may be one way to achieve these goals (Prince Georges' County, Maryland, Department of Environmental Resources, 2000a, 2000b).

5.2.2 Management Measure Selection

This management measure was selected because of the following factors:

- Removal of 80 percent of TSS is assumed to control heavy metals, phosphorus, and other pollutants.
- Several states and local governments have implemented a TSS removal treatment standard of at least 80 percent. Table 5.2 presents TSS reduction standards and design criteria for select state and local runoff management programs.
- Analysis has shown that constructed wetlands, wet ponds, and infiltration basins can remove 80 percent of TSS, provided they are designed and maintained properly. Other practices or combinations of practices can also be used to achieveT1 1 Tf0 ar

The Delaware Department of Natural Resources and Environmental Conservation (2005) developed the Delaware Urban Runoff Management Model (DURMM) to quantitatively estimate how “green technology” management practice designs achieve pollutant removal and flow reductions. Green technology includes the following management practices:

Conservation site design
Source area disconnection
Biofiltration swales/grassed swales

– Filters out sediment and other pollutants by various chemical, physical, and biological processes as runoff water moves through the bottom of the infiltration structure and into the underlying soil; and

– Augments ground water reserves by facilitating aquifer recharge. Groundwater recharge is vital to maintain stream and wetland hydrology. During dry weather, ground water recharge helps to assure baseflow necessary for survival of biota in wetlands and streams.

Treatment effectiveness depends on whether the facility is sited on-line or off-line, and on the sizing criteria used to design the facilities. Online systems receive all of the runoff from an area. Off-line practices receive diverted runoff for treatment and isolate it from the remaining fraction of runoff, which must still be controlled to prevent flooding. Off-line infiltration practices prevent all of the TSS and other pollutants contained in the volume of runoff infiltrated from exiting the site. Thus, the total annual load reduction depends on how much of the annual volume of runoff is diverted to the infiltration structure. On-line infiltration practices, on the other hand, have lower treatment effectiveness, averaging approximately 75 percent removal of TSS (WMI, 1997b).

The overall hydrologic benefits of infiltration practices may also vary depending on site characteristics and the frequency and intensity of storms. Holman-Dodds et al. (2003) modeled the potential for infiltration techniques to reduce the adverse hydrologic effects of urbanization. The study indicated that the greatest reductions in flow are achievable when rainfall is limited and relatively frequent, and when soils are relatively porous.

Infiltration facilities require porous soils (i.e., sands and gravels) to function properly. Generally, they are not suitable in soils with 30 percent or greater clay content or 40 percent or greater silt/clay content (WMI, 1997b). They are also not suitable:

– In areas with high water tables;
– In areas with shallow depth to impermeable soil layers;
– On fill sites, which have low permeability, or on steep slopes;
– In areas where infiltration of runoff would likely contaminate ground water;
– In areas where there is a high risk of hazardous material spills; or

– Where additional groundwater could form sinkholes.

Special protection for ground water is needed when runoff is used as a drinking water source in urban areas (see Management Measure 3—Watershed Protection). Certain types of infiltration facilities, called Class V injection wells, may be regulated as part of the federal Underground Injection Control (UIC) Program, authorized by the Safe Drinking Water Act. Class V wells discharge fluids underground. Class V wells include French drains, tile drains, infiltration sumps, and percolation areas with vertical drainage. Dry wells, bored wells, and infiltration galleries are all Class V wells. Class V wells do not include infiltration trenches filled with stone (with no regarding the applicability of the UIC regulations to a storm water facility should be directed to federal or state UIC contacts. This information is available at http://www.epa.gov/safewater/uic.html.

The effect of infiltration practices on ground water quality is unclear, but a few studies exist that indicate potential ground water quality concerns from infiltrating urban runoff (Pitt, et al., 1994; Fischer, no date; Ging et al., 1997, Morrow, 1999). For example, Fischer (no date) studied the effects of infiltration of urban runoff on ground water quality in the New Jersey Coastal Plain. He found that although many pollutants were removed from runoff before reaching the water table, elevated concentrations and occurrences of certain compounds and ions indicated contributions from urban runoff, implying that infiltration practices could have a detrimental effect on ground water quality. Conversely, Fischer hypothesized that infiltrating runoff would have the beneficial effect of diluting other 0.0002 Tc 0.0102 Tw (f23 0(l indicated) late, cate 0.0 rizing each as low, moderate, or high. Of the pollutants, only ounds anfid iofrequnfi aaat
chloride, has a high potential, and only fluoranthe0-7(n)-1(e and pqun1(y)19(ren)-11(e)3(hav)-11(e)3(a mo)-11

5.2.3.2 Filtration practices

Filtration practices are so named because they filter particulate matter from runoff. The most common filtering medium is sand, but other materials, including peat/sand combinations and leaf compost material, have been used. Filtration systems provide only limited flood storage; therefore, they are most often implemented in conjunction with other types of quantity control management practices. Most filtration techniques require a forebay or clarifier to remove larger particles in runoff from clogging the filter media.

Biofiltration refers to practices that use vegetation and amended soils to retain and treat runoff from impervious areas. Treatment is through filtration, infiltration, adsorption, ion exchange, and biological uptake of pollutants.

5.2.3.3 Detention/retention practices

Runoff *detention* facilities provide pollutant removal by temporarily capturing runoff and allowing particulate matter to settle prior to release to surface waters. Dry detention runoff management ponds are one type of detention facility. Peak flows are reduced in drainage systems/receiving waters downstream of detention facilities.

Runoff *retention* facilities are used to capture runoff, which is subsequently withdrawn or evaporated. Therefore, peak flows and total flow volume can be reduced in downstream drainage systems/receiving waters. Wet runoff management ponds are one type of retention facility. These retention facilities can be designed to accept flow from receiving streams/drainage systems offline.

Both detention and retention facilities can use biological uptake as a mechanism for pollutant removal. Runoff management ponds can be designed to control the peak discharge rates, thereby reducing excessive flooding and downstream erosion in reaches of the drainage system/receiving stream immediately downstream. At some point downstream, however, runoff flow that is not retained will increase the volume of total flow, thereby increasing the risk of flooding and erosion if the receiving stream at that point does not have a stable channel and riparian area or floodplain.

Constructed wetlands are engineered systems designed to employ the water quality improvement functions of natural wetlands to treat and contain surface water runoff pollution and decrease pollutant loadings to surface waters. They can be designed with extended detention to control runoff peak flow and volume. Where site-specific conditions allow, constructed wetlands and retention basins should be located to minimize the impact on the surrounding areas (e.g., in upland areas of the watershed). Ponds, constructed wetlands, and other structural management practices degrade the functions of natural buffer areas and natural wetlands, and they may also interrupt surface water and ground water flow when soils are disturbed for installation. Therefore, the placement of structural management practices in natural buffers and natural wetlands should be avoided where possible.

next storm. Infiltration basins ar

Figure 5.3: Photo showing several types of pervious modular pavement installations.

Modular pavement consists of individual blocks made of pervious material such as sand, gravel, or sod interspersed with strong structural material such as concrete. The blocks are typically placed on a sand or gravel base and designed to provide a load-bearing surface that is adequate to support personal vehicles, while allowing infiltration of surface water into the underlying soils. They usually are used in low-volume traffic areas such as overflow parking lots and lightly used access roads. An alternative to pervious and modular pavement for parking areas is a geotextile material installed as a framework to provide structural strength. Filled with sand and sodded, it provides a completely grassed parking area. More information about concrete pavers can be found at http://www.concretenetwork.com/concrete/porous_concrete_pavers/ (Concretenetwork.com, 2003).

Some states no longer promote the use of porous pavement because it tends to easily clog with fine sediments (Washington Department of Ecology, 1991). If this type of pavement is installed, a vacuum-type street sweeper should be used regularly to maintain porosity. Frequent washing with a high-pressure jet of water can also keep pores clear of clogging sediments. Sites where pervious pavement is to be installed must have deep, permeable soils, slopes of less than 5 percent, and no heavy vehicle traffic.

The City of Kinston, North Carolina, installed a permeable pavement parking lot as a demonstration and research project and to meet the daily parking needs of city employees (Hunt and Stevens, 2001). The final parking lot design included 26 stalls; 20 of the stalls were

The Bath Club Concourse Storm Water Rehabilitation Project, Florida

The Bath Club Concourse is located on a small barrier island community in North Redington Beach, Florida. A combination roadway and parking area, which connects Bath Club Circle and Gulf Boulevard, was previously an impervious slab of concrete pavement. The concourse could not absorb falling rain, which caused runoff to flow directly into a single storm sewer. The sewer would then carry pollutants directly to Boca Ciega Bay. In August 1990, the Water Management District and the town agreed to construct a stormwater rehabilitation project using pervious concrete pavement at the Bath Club Concourse (USEPA, 1999).

The main objective of the rehabilitation project was to reduce nonpoint source pollutant loading by reducing the volume of runoff discharging directly into Boca Ciega Bay. A second objective was to demonstrate an innovative way to treat or improve the quality of runoff in highly urbanized areas, where it can sometimes be difficult or expensive to manage runoff because of land constraints.

To maximize infiltration of runoff and reduce the amount of untreated runoff discharged directly into storm sewers, drainage was directed toward two pervious concrete parking areas. These areas were separated by an unpaved island in the center of the concourse, which also provides infiltration. Engineers installed two 150-foot under-drains to maximize infiltration by allowing subsurface soils to drain beneath the parking areas.

The rehabilitation project resulted in a significant reduction of direct discharge of runoff from the site. Estimates indicate that these improvements resulted in a 33 percent reduction in total on-site runoff volume. Additionally, the volume of surface runoff discharging directly to Boca Ciega Bay was reduced by nearly 75 percent. Overall removal efficiencies for the project, which are based on the pollutant removal efficiency of the under-drain/filter system, indicate that the project can remove 73 percent of lead (Bateman et al., no date). Other removal efficiencies and additional information about the project are available at http://www.stormwaterauthority.org/assets/103BFloridaRetrofits.pdf

> Small concrete blocks with approximately 90 percent impervious coverage, with the spaces between blocks filled with gravel.

At the end of the study, none of the systems showed major signs of wear. The pavements infiltrated nearly all rainwater, generating almost no surface runoff. The researchers compared the quality of infiltrated water to surface runoff from an asphalt area and found significantly lower levels of copper and zinc in the infiltrated water. Motor oil was not detected in infiltrated water but was detected in 89 percent of samples of surface runoff from asphalt. Measurements of infiltrated rainwater from five years earlier showed significantly higher concentrations of zinc and lower concentrations of copper and lead.

5.3.2 Vegetated Open Channel Practices

Vegetated open channels are explicitly designed to capture and treat runoff through infiltration, filtration, or temporary storage.

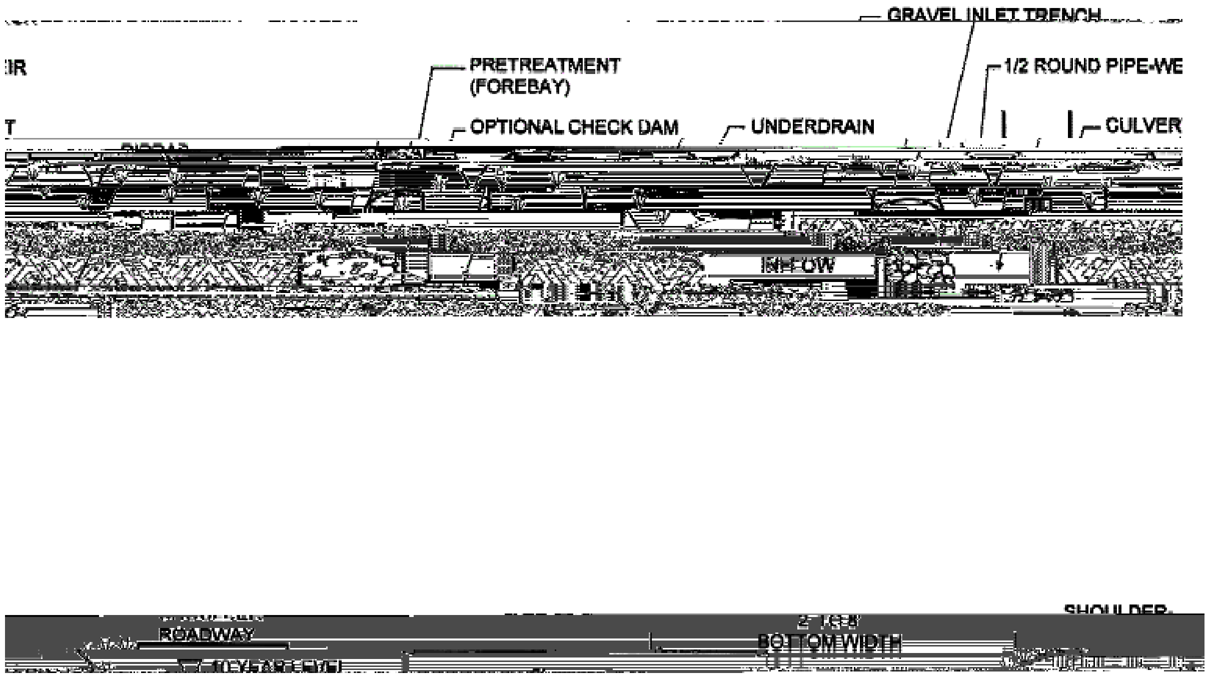


Figure 5.4: Schematic of a grass channel (Claytor and Schueler, 1996).

In a research study conducted by J.F. Sabourin and Associates (1999), two grass swale/perforated pipe systems and one conventional curb-and-gutter system were compared. Flow monitoring results indicate that much less water reached the outlet of the perforated pipe systems than the conventional system. Peak flows and total runoff volumes from the outlet of the perforated pipe/grass swale system were 2 to 6 percent of those of the conventional system, and total runoff volumes were 6 to 30 percent of conventional system volumes. Water quality monitoring results indicate that for most elements, concentrations measured in the perforated pipes were the same or lower than in the conventional system. Chloride concentrations were found to be higher in the perforated pipe system, most likely from the use of road salt. However, a loading analysis indicated that the perforated pipes released significantly fewer pollutants than the conventional system.

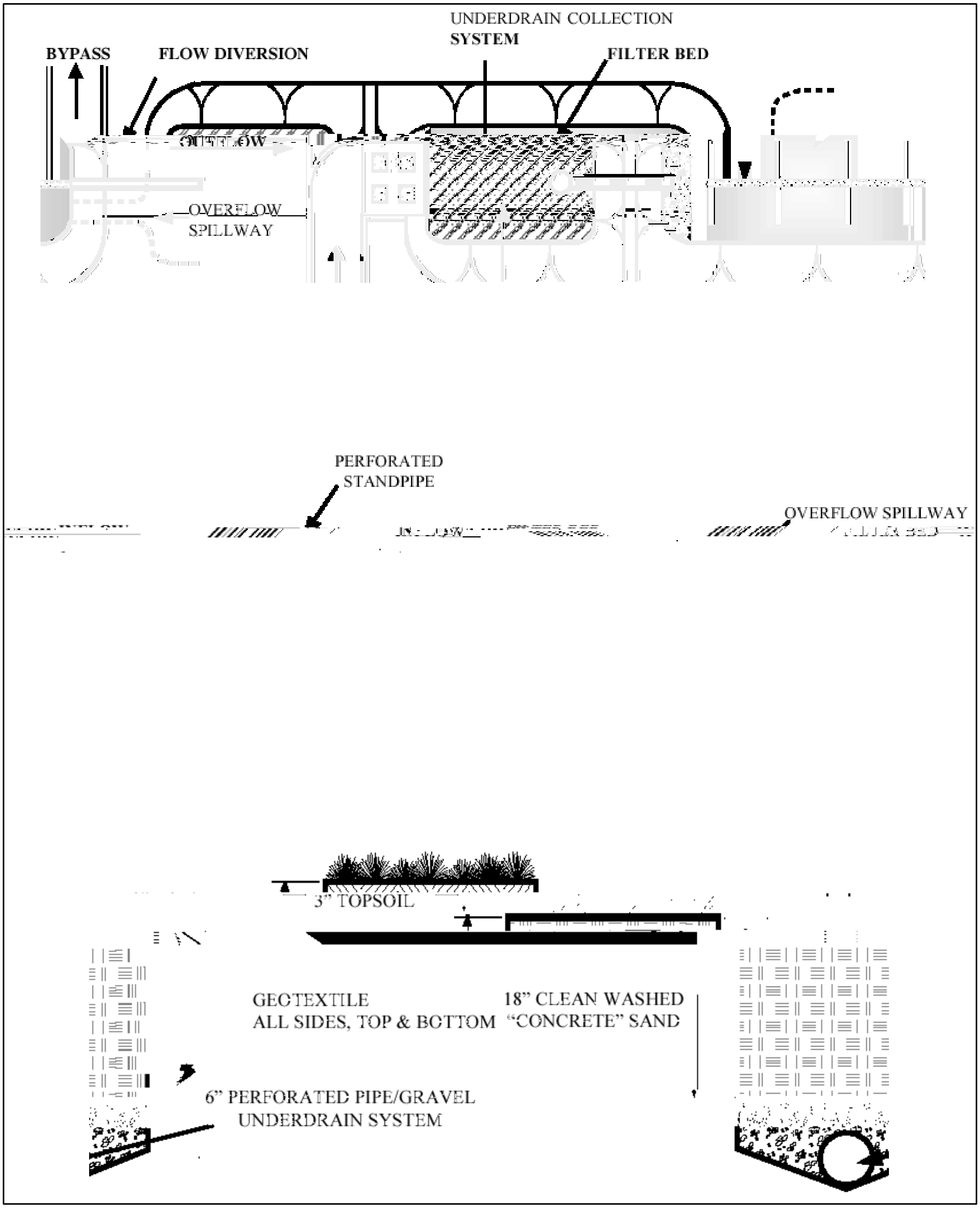


Figure 5.6: Schematic of a surface sand filter (MDE, 2000).

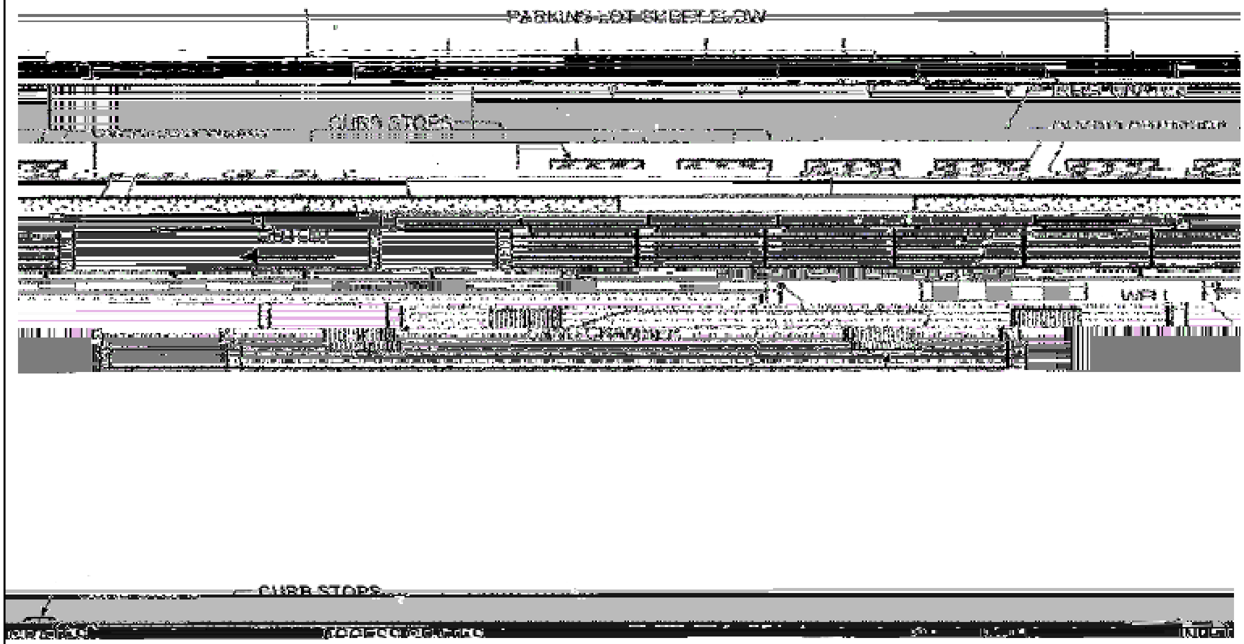


Figure 5.8: Schematic of a perimeter sand filter (MDE, 2000).

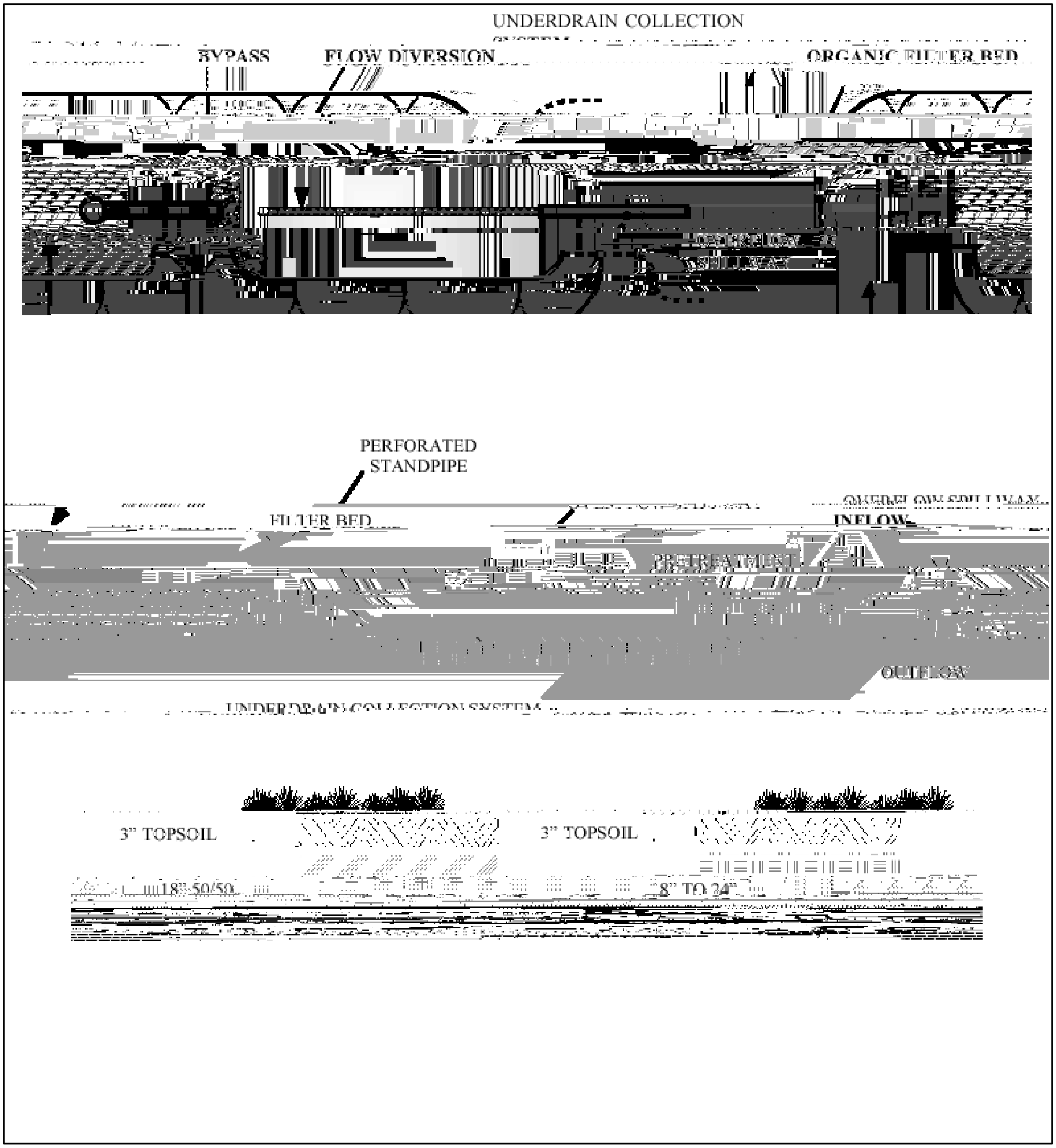


Figure 5.9: Schematic of an organic media filter (MDE, 2000).

Performance of a Compost Storm Water Treatment System in Hillsboro, Oregon

Bioretention system designs are very flexible, can be adapted to a wide range of commercial, industrial, and residential settings, and can be linked in series or combined with structural devices to provide the necessary level of treatment depending on expected runoff volumes and pollutant loading. A common technique is to use bioretention areas to pre-treat sheet flow before it is channelized or collected in an inlet structure.

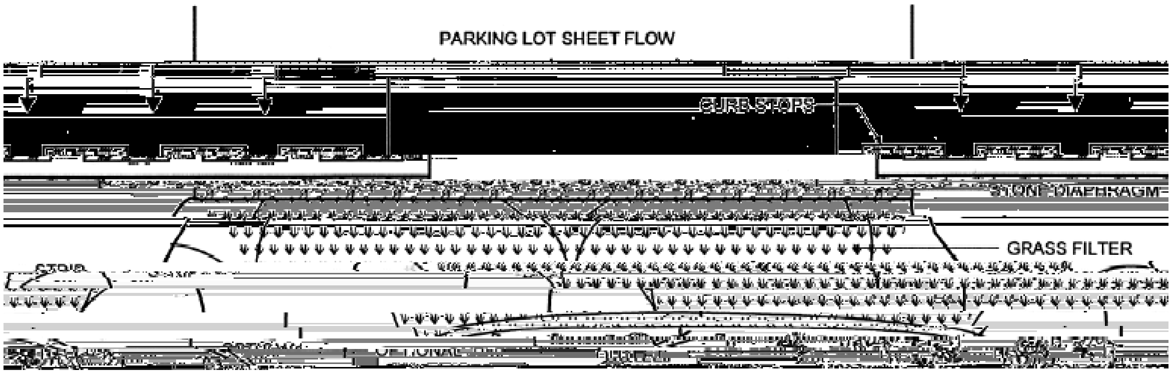


Figure 5.11: Schematic of a bioretention system (MDE, 2000).

Using Landscaped Rain Gardens to Control Runoff

The city of Maplewood, Minnesota is seeking to improve drainage in its older neighborhoods through the use of rain gardens. A successful pilot project, which was implemented in 1995, was the starting point for the current citywide rain garden initiative. Rain gardens from the pilot project have prevented runoff from flowing out of the area, containing 100 percent of the flow. City officials decided to expand the project when they recognized the aesthetic and environmental benefits resulting from the pilot project rain gardens.

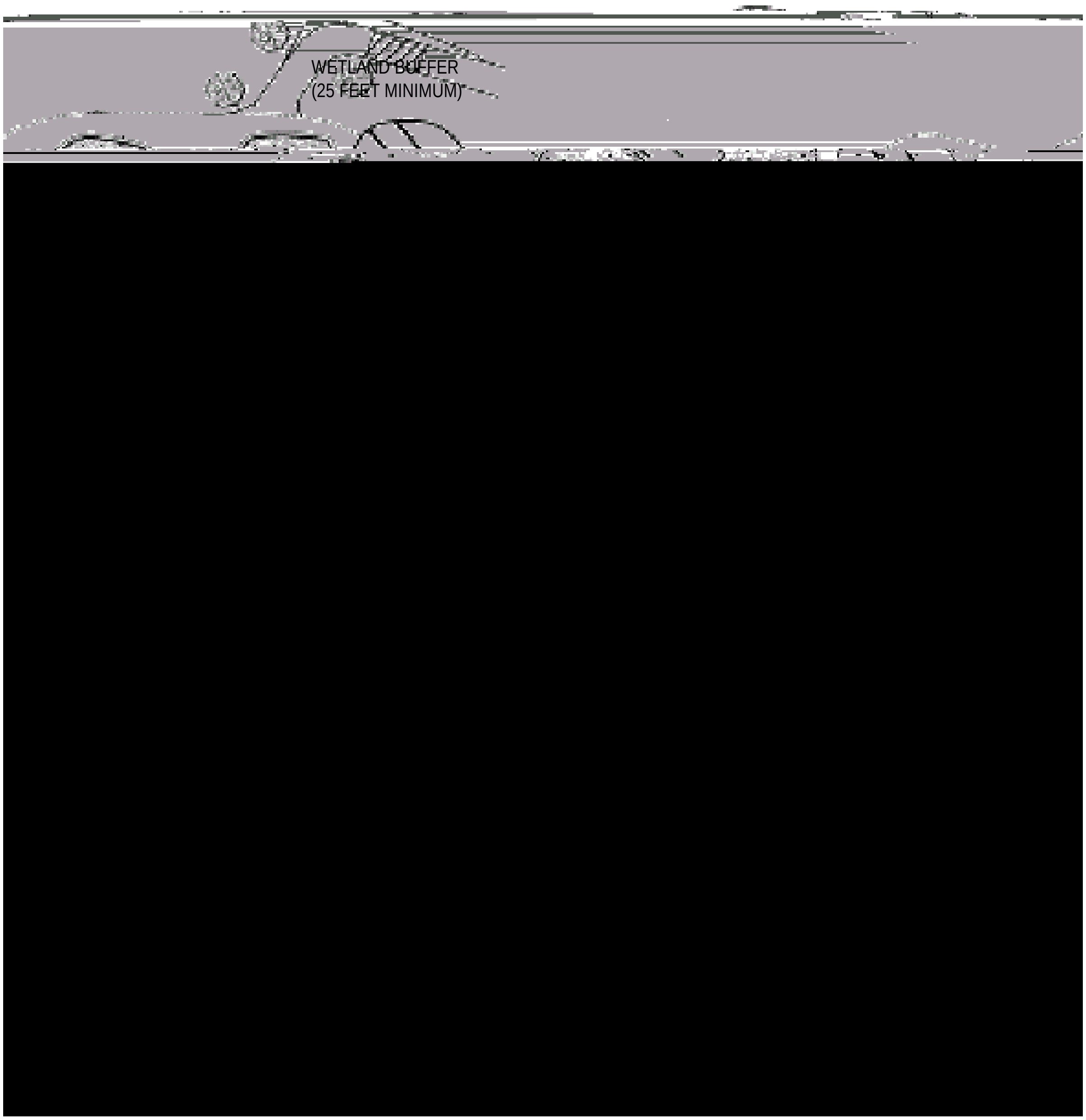
The city is focusing on demonstration, education, and outreach to convey the benefits of using rain gardens for runoff management, rather than requiring homeowners to participate. Although rain gardens can be a solution for people who are opposed to adding curbs and gutters to their streets, some are concerned that rain gardens may attract and breed mosquitoes. Before beginning a street improvement project for a specific neighborhood, the city holds neighborhood meetings and distributes a comprehensive educational mailing and questionnaire to homeowners. These materials contain a fact sheet that explains the purpose of rain gardens, how they are designed, how they work, their benefits, and the plants best suited for a variety of hydrologic conditions. A questionnaire is also included to ascertain existing drainage problems and to determine whether the homeowner would be willing to agree to use a rain garden.

Once a homeowner has decided that they want a rain garden, they choose the location and size. The city works with homeowners to make these types of decisions and to help them comply with restrictions on garden placement caused by existing trees, natural drainage, or the presence of gas and water mains and other utilities. Homeowners may choose from three standard rain garden sizes (12-foot by 24-foot, 10-foot by 20-foot, and 8-foot by 16-foot) and from one of six different garden themes, including an easy shrub garden, easy daylily garden, sunny garden, sunny border garden, butterflies and friends garden, Minnesota prairie garden, and shady garden.

To begin construction, the city's contractor excavates a gently sloping depression to collect the water. Rain garden depths vary depending on garden size and topography. The contractor digs a sump 42 inches wide and 3 feet deep at the deepest part of the garden to accommodate a geotextile filter fabric bag, which is filled with clean crushed rock. The sump promotes rapid infiltration to reduce the standing time of water in the rain garden. After the infiltration sump is in place, the contractor adds at least 8 inches of bedding material (typically a mixture of salvaged topsoil and clean organic compost) and covers the area with 3 to 4 inches of shredded wood mulch. Residents are provided with all necessary plants and a landscape plan at no additional cost. However, many Minnesota municipalities charge residents a street assessment to cover a percentage of the project cost.

Table 5.5: Design considerations for ponds and wetlands (MDE, 2000).

Design Consideration	Ponds	Wetlands
Watershed Design Requirements		
Streams in intensely developed areas	Drainage area may limit the applicability of ponds except for pocket ponds.	Drainage area may limit the applicability of ponds except for pocket wetlands.
Cold-water streams	An offline design is recommended. Maximize shading of open pool areas.	An off-line design is recommended. Maximize shading of open pool areas.
Streams in sparsely developed areas	Require additional storage to ensure adequate downstream channel protection.	Require additional storage to ensure adequate downstream channel protection.
Aquifer protection	May require a liner depending on soil type.	May require a liner depending on soil type.


WETLAND BUFFER
(25 FEET MINIMUM)

The Use of Wetlands to Reduce Fecal Coliform

Unusually high levels of fecal coliform have been found in an area of Laguna Niguel, California. Runoff from a neighborhood is washing into Aliso Creek and then to the Pacific Ocean. In response to a cleanup order issued by state water regulators, city officials built a series of wetlands to filter fecal inspection and cleaning, should be budgeted as a long-term operating expense if this practice is selected.

(2) *Diversion weir*. Diversion weirs may be needed for designs where the entire runoff volume is not directed to the constructed wetland. This diverted fraction of the runoff is often routed to collection systems or inlets. The amount of rainfall that may be diverted will vary according to local requirements and design objectives.

(3) *Outlet*. As is the case with all ponds having a normal pool of water, algae can clog outlets with small orifices that are needed for extended detention. A below-surface withdrawal

rather than pollutants, and therefore it is most applicable in coastal areas and areas that receive heavy trash loads such as leaf litter, plastics, and cans. Prefabricated units are currently available with capacities up to 300 cubic feet per second (cfs). The devices are constructed so that a vacuum truck can regularly remove the floatable and settleable debris collected in the treatment chamber.

Limited data are available on the performance of these devices, and independently conducted studies suggest marginal fine particle and soluble pollutant removal. Therefore, swirl separators should not be used as a stand-alone practice for new development. Also, these devices require regular maintenance. Communities may reduce maintenance costs by sharing a vactor truck. Swirl separators are best installed on highly impervious sites. These products have application as pretreatment to another runoff treatment practice and in a retrofit situation where space is limited.

5.3.5.3 Baffle boxes

Sediment control devices called "baffle boxes" have been used in Brevard County, Florida, as an "end of pipe" treatment method (England, 1996). They are concrete or fiberglass boxes, typically 10 to 15 feet long and 6 to 8 feet high, which are placed at the end of existing storm drain pipes. The box is divided into multiple chambers by weirs set at the same level as the pipe invert to minimize hydraulic losses. Trash screens are incorporated in the design to remove floating debris. Baffle boxes have been shown to have a removal efficiency of up to 90 percent for sand or sandy clay at entrance velocities of up to 6 feet per second, and 28 percent removal efficiency for fly ash at the same velocity. Baffle box designs can be modified to serve as a retrofit installation at curb or manhole inlets or beneath grates. Regular maintenance, especially removal of sediment and debris, is essential to maintain the effectiveness of this practice.

5.3.5.4 Catch basin inserts

Catch basin inserts consist of a fra
min-25.to 15n The(r)18(evardh)-8um flsissd0231 Tw 18.38 0 Td[(feet3.1(t)5(c)6(
debri19 Td[(ins1)-3(o)-1(15Tc (h,0.ig)4c p2.ig)3-3t17(E)(.)00(/oce

5.3.5.5 Alum

Alum, which is an aluminum sulfate salt, can be added to storm water to cause fine particles to flocculate and settle out (USEP to

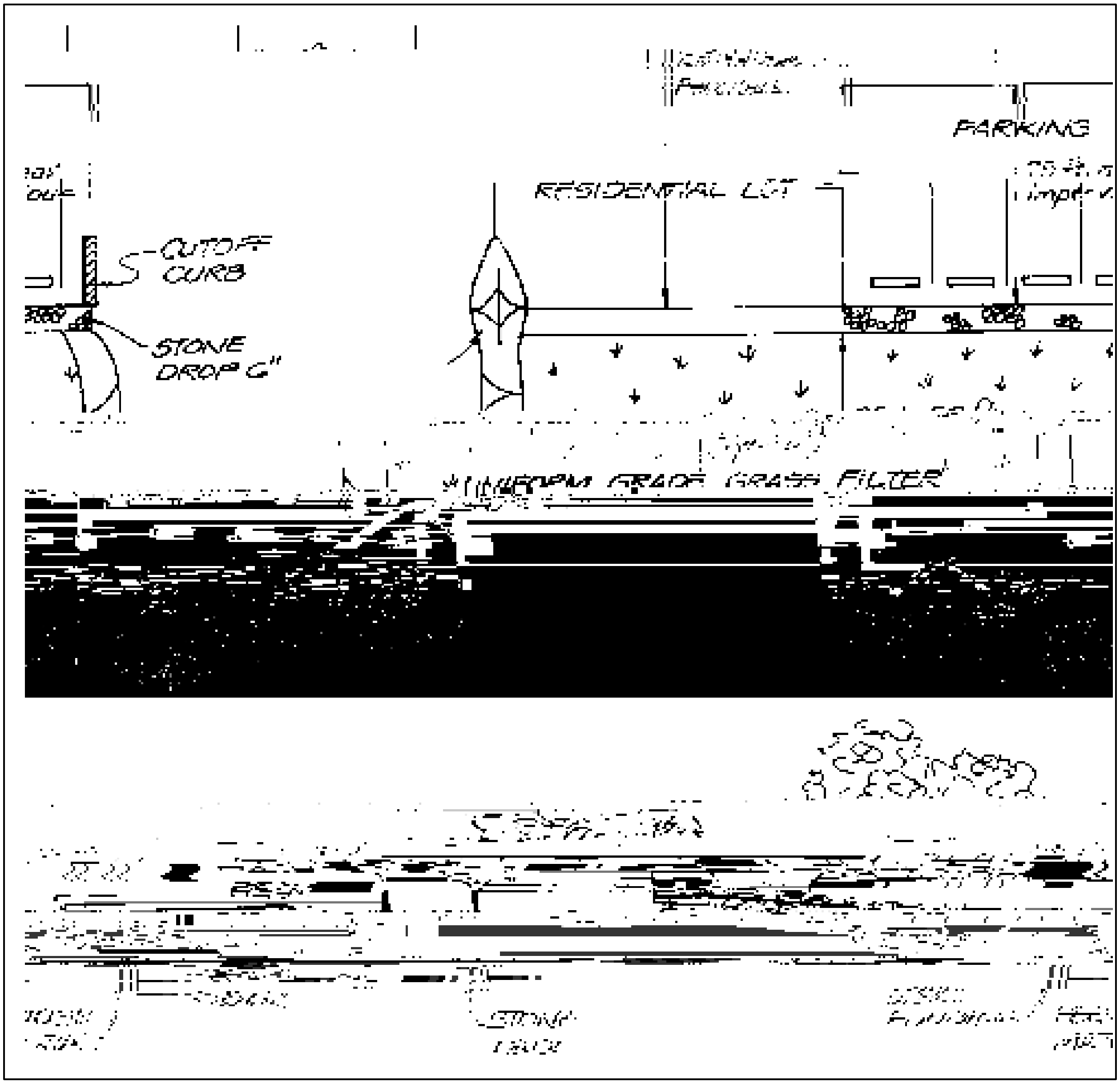


Figure 5.16: Schematic of a vegetated filter strip (Claytor and Schueler, 1996).

– The filter strip should be designed with a pervious berm of sand and gravel at the toe of the slope. This feature provides an area for shallow ponding at the bottom of the filter strip. Runoff ponds behind the berm and gradually flows through outlet pipes in the berm. The volume ponded behind the berm should be equal to the water quality volume. The water quality volume is the amount of runoff that will be treated for pollutant removal in the practice. Typical water quality volumes are the runoff from a 1-inch storm or ½-inch of runoff over the entire drainage area to the practice.

– The filter strip should have a length of at least 25 feet to provide water quality treatment.

–

homeowners want to save money, they can build their own rain barrel, which cou-6([nf-0.0093 Tc 0.0092 Tw 0-91.5

5.4 Performance and Cost Information for Management Practices

Some advantages, disadvantages, and costs of specific runoff control practices described above are listed in Table 5.6. Site-specific information, regional limitations, operation and maintenance burdens, and longevity for these practices are listed in Table 5.7.

Table 5.6: Advantages and disadvantages of management practices (MDE, 2000).

Practice	Advantages	Disadvantages	Comparative Cost[a]
Runoff control ponds			
Wet pond	– Can provide peak flow control – Can serve large developments; most cost-effective for larger, more intensively developed sites – Enhances aesthetics and provides recreational benefits – Little ground water discharge – Permanent pool in wet ponds helps to prevent scour and re-suspension of sediments – Provides moderate to high removal of both particulate and soluble urban runoff pollutants	– Not economical for drainage area less than 10 acres – Potential safety hazards if not properly maintained – If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors – Requires considerable space, which limits use in densely urbanized areas with expensive land and high property values – Not suitable for hydrologic soil groups “A” and “B” (USDA-NRCS classification) unless a liner is used – With possible thermal discharge and oxygen depletion, may severely impact downstream aquatic life – Hydrologic damage to stream channels and aquatic habitat is possible due to flow volume.	Moderate to high compared to conventional runoff detention
Infiltration practices			

Table 5.7: Regional, site-specific, and maintenance considerations for management practices (USEPA, 1993; Caraco and Cl

Table 5.8: Effectiveness of management practices for runoff control (adapted from Caraco and Winer, 2000).

Runoff Treatment or Control Practice Category or Type	Median Pollutant Removal (Percent)							
	No. of studies	TSS	TP	OP	TN	NOx	Cu	Zn
Quality Control Pond	3	3	19	N/A	5	9	10	5
Dry Extended Detention Pond	6	61	20	N/A	31	-2	29	29
Dry Ponds	9	47	19	N/A	25	3.5	26	26
Wet Extended Detention Pond	14							

concentrations because if enough samples are collected, total loads into and out of the management practice can be used reliably.

Strecker et al. (2000) also analyzed the use of effluent data to measure the influence of certain design criteria on management practice efficiency. Some studies suggest that management practices can only treat runoff to a specified pollutant concentration. However, if relatively clean water enters a practice, performance data based on removal efficiency might not fully characterize whether the practice is well designed and effective. Therefore, pollutant removal efficiency, when it is expressed as percent removal, might not be an accurate representation of

Verifying the Performance of Environmental Technologies

EPA's Environmental Technology Verification (ETV) Program, which began in October 1995, was instituted to verify the performance of innovative technical solutions to problems that threaten human health and the environment. ETV was created to significantly accelerate the entrance of new environmental technologies into the domestic and international marketplaces. The program operates through public and private testing partnerships to evaluate the performance of environmental technology in all media, including air, water, soil, ecosystems, waste, pollution prevention, and monitoring. More information about the ETV Program is available at http://www.epa.gov/etv (USEPA, 2001b).

Another method for evaluating technology is the Environmental Technology Evaluation Center (EvTEC), which was established by the Civil Engineering Research Foundation (CERF) through EPA's ETV Program. EvTEC is an independent, market-based approach to technology verification and was established to accelerate the adoption of environmental technologies into practice. More information about EvTEC is available at http://www.cerf.org/evtec (CERF, 2001).

EPA and NSF International, an independent, nonprofit testing organization, have developed a testing how well a management practice is performing. Although more research is necessary to accurately determine the effectiveness of management practices, Strecker et al. recommend that standard methods and detailed guidance on data collection be used to improve data transferability.

Table 5.9 presents information concerning the costs

between storm water management and mosquito breeding exists because the presence of standing and sometimes stagnant water facilitates the two aquatic stages of a mosquito's life cycle—the egg and larval stages.

Not all mosquito species are vectors for disease, but control is still warranted because, even if not a health risk, mosquitoes are considered a nuisance. Mosquito species have different habitat preferences, and two basic groups can breed in the urban environment: permanent water species and floodwater species (Metzger et al., 2002). Permanent water species would be likely to propagate in storm water management facilities that always contain water, such as wet detention ponds and constructed wetlands. Floodwater species would likely inhabit "dry" systems such as extended detention dry ponds that have fluctuating water levels.

This issue has caused a fair amount of controversy because mosquito-breeding habitats are prevalent in urban and suburban environments. Metzger et al. (2002) identified a few of the numerous manmade mosquito-breeding habitats in urban and suburban environments:

> Urban environments provide mosquitoes with a vast array of new habitats: humid and arid, above and below ground, small water-holding containers and large ponds, polluted and clean water. Aquatic habitats are found around people's homes (birdbaths, jars, flower pots, neglected pools and Jacuzzis and clogged rain gutters), in unregulated waste dumps (used tires, barrels, bottles, and cans), in parks (ponds, lakes, and streams), and in the city's own infrastructure (storm drains, sewer systems, catch basins, and culverts). Many of these sources are replenished frequently by stormwater and urban runoff (e.g., irrigation, washing cars). Adding to this, increasingly stringent urban stormwater runoff regulations have recently mandated the construction of structural practices for both volume reduction and pollution management, many of which have created additional sources of standing water. This abundance of habitats has favored mosquitoes and

mosquito-producing areas in marshes are connected by shallow ditches to deep-water habitats to allow drainage or fish access, and minimally flooding the marsh during the summer but flap-gating impounded areas to reintegrate them to the estuary for the rest of the year.

Biological control can be achieved using various predators such as dragonfly nymphs and predacious mosquitoes (Rose, 2001). Mosquito fish are the most commonly used agents for biological control because they are easily reared, although they also feed on non-target species. Other types of organisms that might be used for mosquito control include several fish types other than *Gambusia*, as well as fungi, protozoans, nematodes, and predacious copepods.

It is essential that storm water managers and public works crews who maintain storm water management facilities be educated in integrated pest management. They should be trained to identify design flaws or maintenance needs that might create mosquito-breeding habitat, and they should know the procedures for reporting and remedying the problem. Pesticide handlers should have the required training under the Federal Insecticide, Fungicide, and Rodenticide Act and all chemicals should be applied at rates recommended on the packaging. Treated areas should be monitored after application to determine the efficacy of the applications and identify where pesticide resistance might be occurring.

There are steps that a storm water manager can take to reduce the likelihood that mosquitoes will breed in storm water management facilities. From a design standpoint, most management practices other than wet retention ponds are intended to drain within 72 hours. This is a safe drainage time because mosquitoes need at least that long for their aquatic life stages. Additionally, Metzger et al. (2002) found that several design features of storm water management practices contributed to vector production, including the use of sumps, catch basins, or spreader troughs that did not drain completely; the use of loose riprap that could hold small amounts of water; pumps or motors designed to “automatically” drain water from structures; and effluent pipes with discharge orifices prone to clogging because of their small diameter.

Livingston (no date) recommends the following design considerations to minimize mosquitoes:

– Designs must be based on site characteristics to ensure that the most appropriate type of storm water management facility is selected. Vegetated dry retention systems should be designed as off-line systems. They should

5.6 Information Resources

The *Technology Review: Ultra-Urban Stormwater Treatment Technologies* (Brueske, 2000) was compiled to provide a review of “ultra-urban” storm water treatment technologies. These types of technologies are designed to comply with Maryland's 14 storm water performance standards. A unique feature is the use of storm water credits for rewarding innovative storm water management designs. The second volume contains detailed technical information on runoff control practices, including step-by-step design examples. Both volumes are available for download at http://www.mde.state.md.us/environment/wma/stormwatermanual.

In 1995 the Metropolitan Washington Council of Governments (MWCOG) published *Site Planning for Urban Stream Protection*, which presents a watershed approach to site planning and examines new ways to reduce pollutant loads and protect aquatic resources through nonstructural practices and improved construction site planning. The book also provides insight into the importance of imperviousness, watershed-based zoning, concentration of development, headwater streets, stream buffers, green parking lots, and other land planning topics. The document is available for purchase from MWCOG at http://www.mwcog.org/ic/95708.html.

The *Texas Nonpoint SourceBOOK* is an interactive Web tool that was designed to provide runoff management information to public works professionals and other interested parties in Texas and elsewhere. This site, which can be accessed at http://www.txnpsbook.org/, includes a beginner's guide to urban nonpoint source management issues, a discussion of water quality issues in Texas, elements of a storm water management program, information on storm water utilities, tips for assessing and selecting management practices, a comprehensive listing of links to other sites, frequently asked questions, and nonpoint source news.

In 1999 the Denver Urban Drainage and Flood Control District published the *Urban Storm Drainage Criteria Manual*. The manual was designed to provide guidance for local jurisdictions, developers, contractors, and industrial and commercial operators in selecting, designing, implementing, and maintaining management practices to improve runoff quality. The third volume of this manual is primarily targeted at developing and redeveloping residential and commercial areas. The manual is available for purchase at http://www.udfcd.org/.

In 1995 EPA published *Economic Benefits of Runoff Controls* (EPA-841-S-95-002), which contains a description of studies that document increases in property values and rental prices when properly designed runoff controls are used as visual amenities. The document is available for download from EPA's National Environmental Publications Internet Site (NEPIS) at http://www.epa.gov/ncepihom/nepishom.

EPA published the *Preliminary Data Summary of Urban Storm Water Best Management Practices* in 1999. The document summarizes existing information and data on the effectiveness of management practices to control and reduce pollutants in storm water. The report also provides a synopsis of what is currently known about the expected costs and environmental benefits of management practices, and identifies information gaps. The document is available for download in PDF format at http://www.epa.gov/ost/stormwater/usw_a.pdf.

In 1992 the Washington State Department of Ecology published its *Stormwater Management Manual for the Puget Sound Basin*. The manual is divided into five documents: Volume I: Minimum Technical Requirements; Volume II: Construction Stormwater Pollution Prevention; Volume III: Hydrologic Analysis and Flow Control Design; Volume IV: Source Control BMPs;

and Volume V: Runoff Treatment BMPs. All five volumes are available for download at http://www.ecy.wa.gov/biblio/9911.html.

The Washington State Department of Ecology's Water Quality Program has developed a Nonpoint Source Pollution home page. This Web site, accessible at http://www.ecy.wa.gov/programs/wq/nonpoint, contains nonpoint source program information, posters, resources, and references. The Department of Ecolog

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MANAGEMENT MEASURE 6
NEW AND EXISTING ON-SITE WASTEWATER TREATMENT SYSTEMS

6.1 Management Measure

Develop or ma/nta/n on-site wastewaOC2ter treaOC2tment system (OWTS) permitting aOC2nd installaOC2tion programs that adequately protect surface water and ground water quality. Programs should include:

- A process to ideny aOC2n protecOC2t sensitive aOC2reOC2as (e.g., wellheOC2adotecOC2tion zones, nitrogen/phosphorus limited waters, shellfish habitat) and ensure that cumultive hydraulic discharges and mass pollutant loads from on-site systems do not impair surfaceO4( )]TJ-0.0005

- InspecOC2tions of new on-site systems during aOC2nd immediaOC2tely following cOC2urrons ofllaOC2tion 13(1(se)5(nnewy)21( )-10(f)5(cOC2titting)11aOC2t(imme)5aOC2xe)5(s1(a

6.2 Management Measure Description and Selection

6.2.1 Description

Table 6.2: Pollutants of concern for OWTSs (adapted from Tchobanoglous and Burton, 1991).

Pollutant	Reason for concern
Pathogens	Microorganisms such as parasites, bacteria, and viruses can cause communicable diseases through direct/indirect body contact or ingestion of contaminated water or

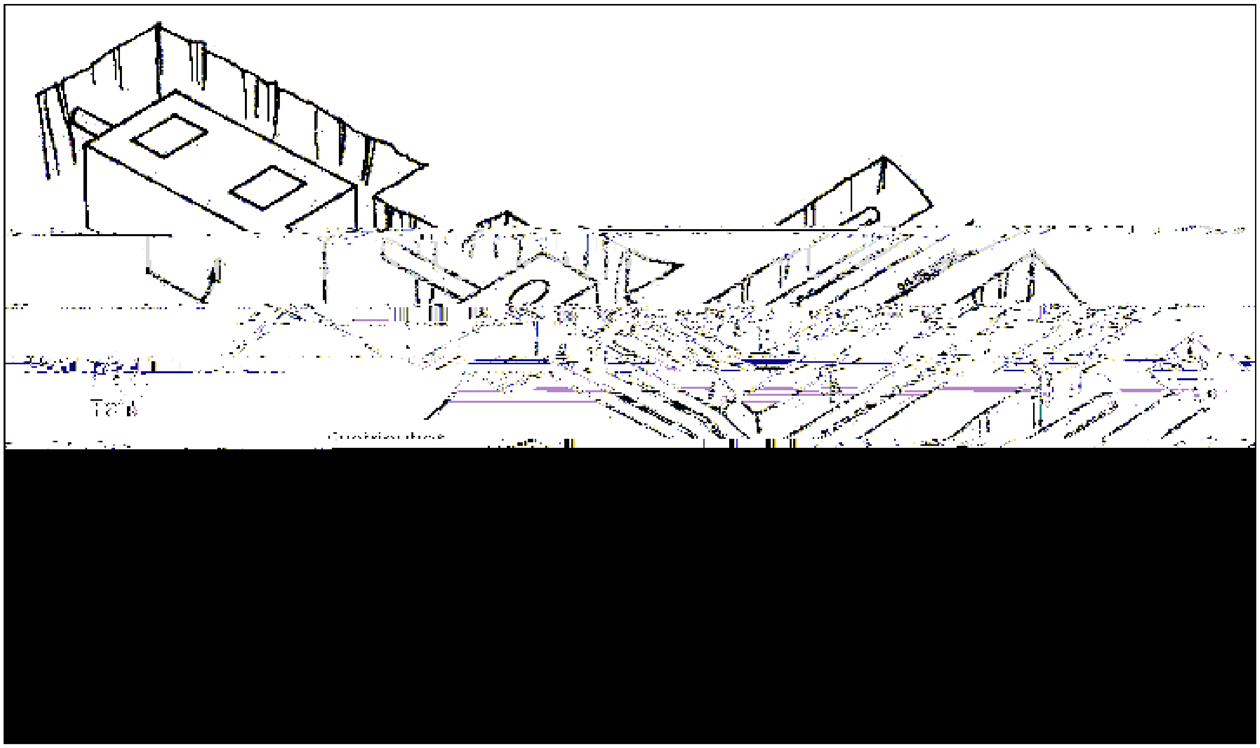

Figure 6.1: Conventional on-site wastewater treatment system.

OWTSs can generally be divided into two categories: conventional systems and alternative or innovative systems.

Conventional systems (see Figure 6.1) consist of a septic tank and a subsurface soil absorption field, commonly called a subsurface wastewater infiltration system (SWIS). Buried in the ground, septic tanks are essentially watertight, single- or multiple-chamber sedimentation and anaerobic digestion tanks. They are designed to receive and pretreat domestic wastewater, mediate peak flows, and keep settleable solids, oils, scum, and other floatable material out of the SWIS. Wastewater effluent is discharged from the tank and passes through pipes to a series of underground perforated pipes that can be wrapped in a permeable synthetic material. From there, the partially treated effluent flows onto and through the soil infiltrative surface, and finally into the SWIS infiltration medium (i.e., soil). Treatment occurs in the septic tank, on and within the biomat that forms at the soil infiltrative surface, and in the soil (or other medium); it then continues as the effluent moves through the underlying soil (biomats are discussed further in Section 6.3.1.5.2, which describes subsurface wastewater infiltration systems). Treated effluent that is not drawn into plant roots, incorporated into microbial biomass, or evaporated ultimately reaches ground waters and possibly nearby surface waters.

Alternative or innovative systems such as mound systems, fixed-film contact units, wetlands, aerobic treatment units ("package plants"), low-pressure drip applications, and cluster systems, are used in areas where conventional soil-based systems cannot provide adequate treatment of wastewater effluent. Areas that might not be suitable for conventional systems are those with nearby nutrient-sensitive waters, high densities of existing conventional systems, highly permeable or shallow soils, shallow water tables, large rocks or confining layers, and poorly drained soils. Alternative or innovative systems feature components and processes designed to promote degradation and/or treatment of wastes through biological processes, oxidation/ reduction reactions, filtration, evapotranspiration, and other processes. Cluster systems can be used to collect and treat wastewater from multiple facilities at a common site (e.g., lagoon, wetland, infiltration field). Alternative, innovative, and cluster systems often require individual septic tanks for each facility served to provide primary treatment and minimize fat, oil, grease, and solids loadings to secondary treatment units. (Note: Cluster systems that serve 20 or more people may be regulated by a federal, state, and/or local Underground Injection Control Program for Class V facilities. For more information, visit EPA's Underground Injection Control Program Web site at http://www.epa.gov/safewater/uic.html.)

Many states, tribes, and municipalities use a prescriptive approach to on-site system management. Such an approach assumes that a prescribed system design will adequately protect public health and water resources when installed at sites meeting established minimum requirements. Site evaluations are usually based on empirical approaches such as percolation tests and setback/separation dist-004 Tc 0.0004 Tw -18.04 -1.15 1]TJ Td[lE tees aleat abl.yTJm04 Tuaents. do n

Therefore, alternative approaches, which include

- Specify prescriptive or performance requirements for individual or clustered systems installed in unsewered areas, preferably by watershed, subwatershed, or ground water recharge area;

- Limit, manage, or prevent development on sensitive natural resource lands or in designated critical areas (e.g., in wellhead protection zones or shellfish habitat runoff catchments, or near nutrient-sensitive waters and wetlands);

- Encourage development within urban growth areas serviced by sewer systems, if adequate capacity exists; and

- Consider factors such as system densities, hydraulic and pollutant output, proximity to water bodies, soil and hydrogeological conditions, water quality, and cumulative loadings from all systems, including future systems, in planning and zoning decisions. Large numbers of soil-based on-site systems discharging to a confined area (e.g., high-density subdivisions) can overwhelm the capacity of soils to assimilate and treat wastewater pollutants of concern, such as nutrients and pathogens.

It should be noted, however, that it is not necessary for the on-site regulatory agency or management entity to oversee or administer the planning program. In many areas, local or regional planning offices collect and store the types of information needed for on-site system management. Some of these offices have the ability to generate geographic information system (GIS) maps that can incorporate water resource, soil, topographic, and other information that provides screening-level site criteria for proposed installation of on-site systems. Coordination with planning offices to designate ecologically sensitive areas and those approved for future on-site system installations can significantly improve the management capabilities of the on-site regulatory agency or management program and improve watershed protection.

6.3.1.1.2 *Wastewater treatment continuum concept*

Decision-makers responsible for approving wastewater collection and treatment services for existing or new facilities often require information and guidance on the various options available. Protection of public health and valued water resources and cost are the primary decision-making criteria in most cases. Both centralized sewer service and decentralized/on-site systems protect public health and water resources, though treatment levels and cost may vary depending on technology, operational factors, system maintenance, and site-specific conditions (e.g., combined sewer overflows, bypasses, and nutrient removal requirements for centralized systems; and geology, soils, climate, and other factors for decentralized/on-site systems).

A number of wastewater treatment and collection options exist along the continuum between individual on-site systems and centralized sewer service. The following options are suggested for decision-makers seeking to improve collection and treatment in existing areas or to provide these services to new development (Venhuizen, 2000):

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- Alternative on-site systems for each lot. Examples include sand filters, aerobic treatment units, vegetated submerged wetlands, and dispersal in shallow, pressure-dosed subsurface wastewater infiltration systems;

- Small-diameter collection/treatment facilities using septic tank effluent drains (STEDs) or other shallow, low-cost collection systems to pump or route the flow from each lot to a common site for final treatment and dispersal or discharge; or

- Centralized sewage collection and treatment with the option of either conventional or alternative treatment facilities at one centralized plant.

Each of these strategies should include oversight and management programs to ensure that collection and treatment equipment and processes continually meet performance requirements. The responsible management entity (RME) should be charged with keeping collection and treatment systems working. The RME should have sufficient authority to enforce programmatic and other requirements, pay for operational and other costs, and take necessary actions in the event of performance failure or emergencies.

Developing operation, maintenance, and management strategies for decentralized/on-site systems in a manner similar to those in existence for centralized systems—or incorporating on-site treatment options into the centralized system strategy—can help to ensure that public health and water resources are protected effectively and efficiently.

6.3.1.1.3 *Centralized sewage treatment*

As development activity increases the density of OWTS-served housing, commercial establishments, and other facilities in a region, it is sometimes cost-effective to extend service lines from centralized sewage treatment facilities (i.e., publicly owned treatment works or POTW) for wastewater collection and treatment at a central plant. Small towns in the past have typically only considered connections to a regional POTW or the construction of a treatment facility. Factors to consider other than costs when deciding whether it is beneficial to use decentralized/onsite systems, construct a new treatment plant, or extend service lines of a nearby

6.3.1.2 System selection, site evaluation, design, and installation

On-site systems often fail because of improper design and inadequate site evaluation and/or installation. Some states require higher levels of treatment near wellhead recharge zones, nutrient-sensitive waters, shellfish habitat, or other areas of special concern. On-site wastewater treatment systems discharging pathogens that can reach wells or shellfish habitat areas, and those that discharge significant inputs of nitrogen or phosphorus to nutrient-sensitive waters, should be

(d) *Performance monitoring*. Performance monitoring tracks progress in achieving performance requirements. Typical approaches involve measuring or assessing performance criteria at some specified point of compliance (e.g., a designated performance boundary). For example, if waters of a commercial shellfish habitat in a coastal bay are experiencing elevated bacterial contamination, a fecal coliform bacteria performance requirement for on-site systems in the area might be established at the property line or shoreline of the lot. A variety of monitoring programs have been developed to assess the performance of on-site systems. Approaches include measurement of chemical pnce (e.13(eatiphosphot fo)-us, B(n OD)9f mat regulations (Florida HRS, 1993). The model incorporated features of the state's varied surficial hydrology and soil regimes and provided estimations of the transport and fate of nitrogen compounds. The Florida model uses a steady-state, one-dimensional flow field with three-dimensional dispersion and assumes retardation and first-order decay rates to be zero. Nitrate contaminant plumes generated by the model show a variety of dispersion and07 mfnpordrieos

Hydrogeologic characterization can also include testing for hydraulic conductivity, porosity, and permeability, usually requiring multiple extended

Three American Society for Testing and Materials (ASTM) practices covering surface

experience. They must also pass a written examination and a field practices test (Maine Department of Health Services, 1996).

Requirements for site evaluators, system designers, installers, inspectors, and maintenance service providers vary widely among the states. Some states have few, if any, requirements for service personnel, whereas other states require professional certification and ongoing training for most service providers (see Table 6.6). In addition, some states issue permits or grant exemptions that allow homeowners to design a

Table 6.6 (continued).

State	Contractors	Installers	Inspectors	Pumpers	Designers	Engineers	Geologists	Operators
SC	Y	Y	NA	Y	NA	NA	NA	NA
SD	N	Y	N	N	N	N	N	N
TN	N	Y	N	Y	N	Y	Y	Y
TY	N	Y	Y	Y	N	N	N	Y
UT	N	N	N	N	N	N	N	N
VT	N	N	N	N	Y	N	N	Y
VA	N	N	N	N	N	Y	Y	Y
WA	N	N	Y	N	Y	N	N	N
WV	N	N	N	Y	N	N	N	N
WI	N	Y	Y	Y	Y	Y	Y	N
WY	N	N	N	N	Y	Y	Y	N

Y = yes; N = no; NA = not available.

NSF Onsite Wastewater Inspector Accreditation Program

NSF International has developed an accreditation program to verify the proficiency of persons performing inspections on existing on-site wastewater treatment systems (NSF International, 2000). The accreditation program includes written and field tests and provides credit for continuing education.

license and taking the certification examination are either a degree in engineering, soils, geology, or a similar field plus one year of experience, or a high school diploma or equivalent and four years of experience (Maine Department of Human Services, 1996).

Some jurisdictions opt to secure planning, operation, maintenance, and inspection services by partnering with other agencies or contracting with private entities to perform these functions. For example, the Massachusetts communities of Yarmouth and Dennis contract with an engineering firm to conduct system inspections (Shephard, 1996). Many management agencies in highly developed areas depend on regional planning or environmental agencies for guidance on the hydraulic and pollutant assimilation capacity of water resources in areas proposed for development. When on-site management functions are s rni(t. rvic9capa1 othe)5(e)339(g)1(tions 5(e)uype uth a

3. Partial anaerobic digestion (liquefaction) of settled organic matter; and
4. Flow attenuation.

Table 6.7: Treatment technologies for OWTSs.

Treatment objective	Treatment process	Treatment methods

sinks, and laundry) and blackwater (wastewater from toilets). Depending on climate, diet, and other factors, the tank will need to be pumped every 3 to 5 years, since the pumping interval depends on the rate of accumulation of sludge, oils, and grease. Periodic visual inspection or remote sensing of the depth of those accumulations is possibly the most efficient way to determine pumping intervals.

A gravity-flow SWIS is the most commonly used treatment and discharge method for OWTS septic tank effluent. Soil absorption systems usually consist of covered excavations filled with porous media and perforated pipes or plastic leaching chambers with a distribution system for introducing and dispersing wastewater throughout. SWISs work well at sites with moderately permeable soils and sufficient vertical depth to ground water (i.e., the seasonally high water table), bedrock, or other limiting layer. The most common types of hydraulic failure of these

Table 6.8: Wastewater constituents of concern and representative estimates of concentrations in the effluent of various treatment units (adapted from Siegrist et al., 2000).

		Tank-based treatment unit effluent concentrations		
Constituents of concern	Direct or indirect measures	Domestic STE[a]	Domestic STE with N-removal recycle[b]	

Septic tanks should be fitted with a regularly serviced effluent screen, commonly called a filter, at the outlet pipe. Several states and localities (e.g., Connecticut, Georgia, Florida, Alabama, North Carolina, Contra Costa County, California) now require septic tank screens to help protect the integrity of the SWIS for long-term performance (Schaub, 2000; Stuart, 2000). Screens not only prevent the discha-18.0kcodge of neut0kcosolids and reduce TSS during tank upsets, but also provide an early warning sign that an inspection is needed, since they will clog and cause plumbing fixtures to drain poorly as they screen solids attempting to exit the tank through the outlet pipe.

Bec-18.ause septic tanks need to be serviced, the top of a septic tank riser should extend above the ground surfa-18.ce. Older installations can be difficult to locate when these features are not provided. Both septic tanks and SWISs are usully required to be at least 50 to 100 feet from any surface water body, but this setback might not be adequate in some cases (e.g., high-porosity soils, high water tables). Septic tank of one or more leaching systems while others rest for six months to a year to restore their effectiveness.

Most SWISs are designed to oxidize carbonaceous organics and convert the ammonium in septic tank effluent to nitrate by providing an aerobic environment. Nitrogen removal capabilities of SWISs are minimal and depend in part on temperature. Nitrate is water-soluble and travels freely to ground water. Elevated nitrate concentrations in ground water used as drinking water can cause the childhood illness methemoglobinemia (blue baby syndrome), can cause problems during pregnancy, and can present a risk to poultry livestock. In soils with no denitrifying capability, nitrate can travel with the ground water to nearby surface waters. Nitrogen loadings in coastal areas can cause eutrophication and related problems (e.g., low dissolved oxygen) that impair the life functions of desirable aquatic biota.

Some clogging of infiltrative surface pores from biomass and slimes produced by natural wastewater decomposition processes occurs under normal conditions. In coarser soils, this "biomat" improves treatment performance. Research conducted in Marion County, Florida, found that the predominant cause of hydraulic failure in systems less than five years old was hydraulic overload. After 15 years of service, root clogging was the cause of hydraulic failure in most cases. In general, SWISs located high in the soil profile provide access to both carbon (from organic matter) and oxygen (diffusion from ground surface), two elements needed for biochemical wastewater decomposition processes. Shallow placement also maximizes vertical separation between the infiltrative surface and ground water.

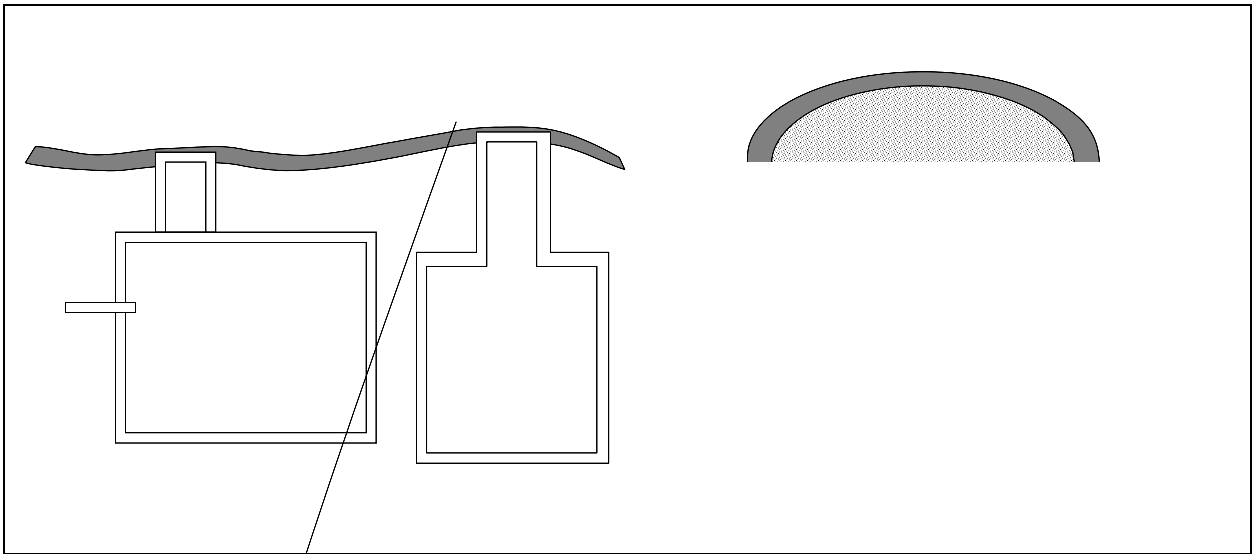
The vertical distance between the soil infiltration system and ground water is an important consideration. If seepage from the SWIS reaches the ground water in an area where unsaturated soil depth is inadequate, it could contaminate drinking water supplies. Furthermore, during wet seasons, ground water might rise into the SWIS, causing sewage to move upward toward the ground surface. This is especially important to consider in areas with a high water table (Lockwood, 1997) or in areas with poor permeability. Dickey et al. (1996) recommend that SWISs be placed at least 4 feet above the ground water table during the wettest season. The type of soil also influences the potential for ground water contamination. If sewage is applied to coarse soils, for example, the potential for contamination may be higher (Dickey et al., 1996). Clays that crack when dry or contain other types of macropores can also have a high contamination potential.

Installation of a conventional septic tank with a SWIS typically costs between $3,000 and $5,000 per home**,** but costs vary widely based on site-specific physical and regulatory limitations.

6.3.1.5.4 *Leaching chambers*

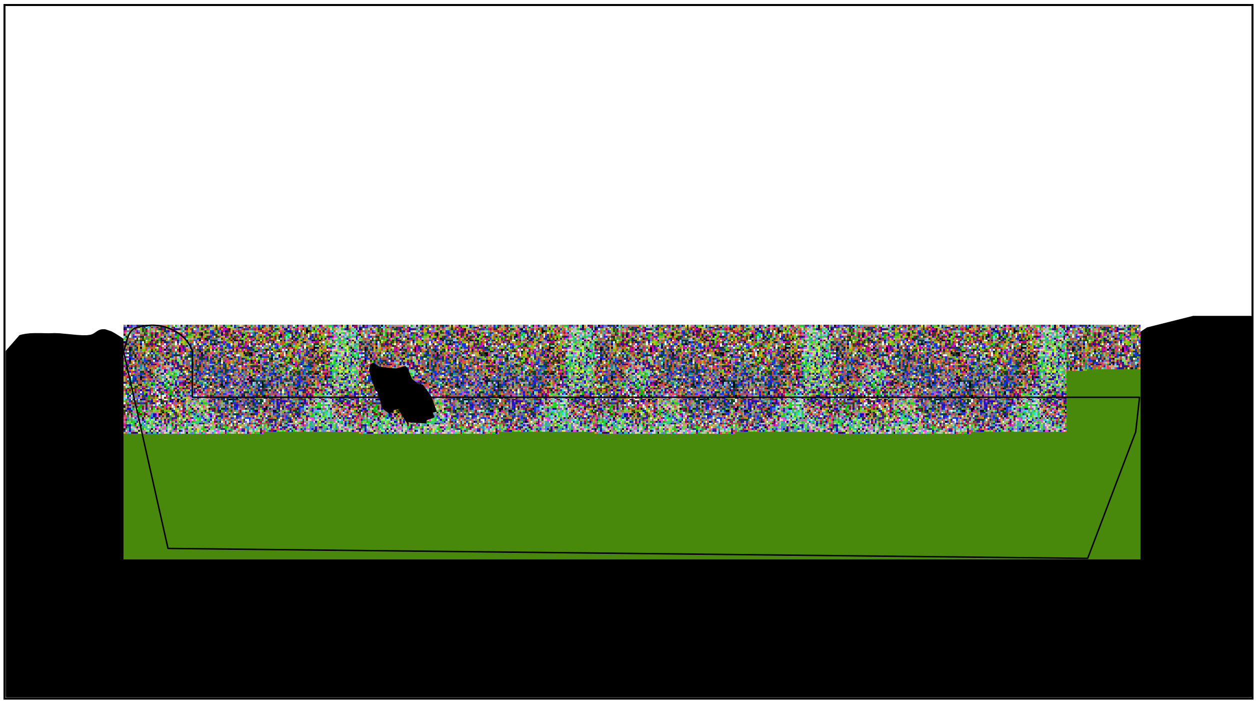
Molded plastic leaching chambers (see Figure 6.3) have been used in lieu of trench-based

Table 6.9 (continued).



MoundAggregatePlow

Washington Island, Wisconsin, covers a 36-square-mile area. Its geology consists of shallow soils and fissured, cavernous carbonate bedrock. Sinkholes are not uncommon and the threat of ground water contamination is real. Conventional systems serve older developments on the island, but the potential for ground water contamination from pathogens and nitrate spurred interest in alternative technologies. As part of a demonstration project, recirculating sand filters were installed and evaluated



Fixed film systems include trickling filters (where the wastewater flows down through a bed of gravel, carbon-based, or composite media such as tire pellets, fabric strips, foam pellets, etc.) and rotating biological contactors (rotating plastic discs colonized by wastewater flora/fauna partially submerged in the wastewater). These systems require pretreatment of sewage in a septic tank. Final effluent can be discharged to a SWIS or reused. Disinfection is necessary if effluent may come into contact with humans or disease vectors. Both systems can achieve TSS concentrations of 60 to 80 mg/L and BOD levels of 80 to 90 mg/L. Maintenance includes periodic inspection of wastewater levels in the septic tank; inspection of pump switches and discharge orifices; and cleaning or replacement of the growth medium at regular intervals, or more frequently if clogging develops.

6.3.1.5.15 *Pressure distribution systems*

Low-pressure effluent distribution into the soil using technologies developed by the drip irrigation industry offers significant treatment performance improvements. Pumping effluent to the dispersal field typically creates a large flow surge that distributes effluent uniformly throughout the dispersal field. This minimizes localized overloading and the consequent potential for eventual failure (Venhuizen, 1995). Pressure systems are placed very high in the soil profile and use periodic dosing to distribute effluent to the soil matrix. Pressure distribution trenches are typically shallow and narrow, providing ease of installation and maximum carbon availability for treatment processes. Reaeration of the infiltrative surface and drying of the biomat between doses reduce potential clogging threats and help to ensure nitrification of ammonia in the septic tank effluent. Drip irrigation distribution lines are typically installed with a vibratory plow at shallower depths (i.e., 8-12 inches below surfd max-12 fuse 9(fo)-11disperslubtion of pump switpO Tw 14 Tw 2

utilities (drinking water, electricity, and septage pumpers and haulers) to develop a database of system owners and contact information.

A variety of commercially available software exists for managing system inventory and other information. Electronic databases can make collecting, retrieving

Table 6.10: Guidelines for OWTS management programs under a tiered approach (adapted from USEPA, 2002a).

Program type	Program objectives	Basic management program elements
System inventory and awareness of operation and maintenance needs	– Owner awareness of permitting program, installation, and operation and maintenance needs – Compliance with codes and regulations	– Only conventional systems allowed – Prescriptive design and site requirements – Owner education to promote operation and maintenance – Complaint inspections and investigations – Point-of-sale inspections
Management through maintenance contracts	– Maintain prescriptive program for sites that meet siting criteria – Permit proven alternative systems on sites not meeting criteria	– Prescriptive design/site requirements – Measurable operation and maintenance requirements – Allowances for approved alternatives – Operation and maintenance contracts for alternative systems – Inspections, owner education
Operating permits	– System design based on site conditions and performance requirements – System performance verified through permit renewal inspections	– Wide variety of designs allowed – Performance governs acceptability – [illegible]9(n)8(s)5(p)-4(r)-1n)46056.9 – Property sale or change of use triggers Operation

1 andliab17(v[(Opeapprov(llo)-16(w)14lrin)-6(TT4

Table 6.11: Program elements and functional responsibilities example matrix.

Program Element	Responsible Party							Comments
Planning								
Stakeholder involvement process								
Watershed assessments								
Sensitive area and critical area designations								
Performance Requirements								
Health and environmental goals								
General requirements								
Requirements for sensitive and critical areas								

6.3.2.2.1 *Voluntary Management*

An effective voluntary program develops recommended guidelines and educational materials and distributes this information to the homeowner or system operator. Voluntary management programs are highly dependent on comprehensive, easy-to-understand educational materials and an aggressive outreach program that includes distribution of the materials, training workshops, and site visits to provide individual assistance.

In 1997 the University of Minnesota Cooperative Extension Service published a guide for homeowners that incorporates important elements of an on-site training program. The guide is available online at http://www.extension.umn.edu/distribution/naturalresources/DD6583.html. Another equally useful guide can be found on the North Carolina Cooperative Extension Web site at http://ces.soil.ncsu.edu/soilscience/publications/Soilfacts/AG-439-22.

6.3.2.2.2 *Regulatory Management*

Under this approach, the regulatory authority—typically a district or local health department—oversees and enforces an on-site program of system design, permitting, installation, operation, and maintenance authorized under state and local codes. The codes may require routine inspections by the health officer either on an annual basis or at the time of property transfer, as is

St. Louis County, located in the northeastern region of Minnesota, extends from the southwestern tip of Lake Superior north to the Canadian border. The physical characteristics of the reequir the Sy-12( )Tj-0.0021 Tc 0.0014 T

– System (technology) description.
– Description of environmental conditions.
– Site evaluation documentation.
– Performance requirements.
– System design, construction plan, specifications, and construction drawings.
– Maintenance requirements.
– Monitoring requirements (frequency, protocol, and reporting).
– Contingency plan to be implemented if the system fails to perform to requirements.
– Enforcement and penalty provisions.

The permit is issued for a limited term, typically 5 years. Renewal requires that the owner document that the permit requirements have been met. If documentation is not provided, a temporary permit is issued with a compliance schedule. If the compliance schedule is not met, the county has the option of reissuing the temporary permit and/or assessing penalties. The permit program is self-supporting through permit fees.

the case in Washtenaw County, Michigan (Washtenaw County, 1999), the Code of Massachusetts Regulations, and other state and local statutes. Financial incentives and disincentives usually aid compliance; these can vary from small fines for poor system maintenance to mandatory repairs if the wastewater treatment system is not functioning properly. Inspection fees can cover program costs. Some jurisdictions (e.g., Florida) issue renewable operating permits and/or ground water discharge permits to

Administrative Code, 1997). Procedures that can be used to apply the wastewater management district concept to a specific problem area include:

- Researching relevant legal and regulatory issues;
- Conducting a thorough site investigation;
-

Comprehensive Monitoring and Inspection Program in Nags Head

The town of Nags Head has implemented a program to identify and address on-site system impacts in that North Carolina Outer Banks community. The town's Septic Health Initiative Program secured competitive bids for tank pumping and inspection and will reimburse full inspection costs (about $65) and provide a $30 rebate on the next water bill if the system owner has the tank pumped. Monitoring consists of a series of ground water well and surface sites that are tested for fecal coliform, ammonia, dissolved oxygen, nitrate, pH, salinity, phosphorus, specific conductance, and turbidity. An education program complements the effort by circulating information on treatment processes, operation, and maintenance (Krafft, 2001).

Management of Onsite/Decentralized Wastewater Treatment Systems (http://cfpub.epa.gov/owm/septic/home.cfm).

Inspection programs operated by OWTS management agencies, special districts, and utilities can be the most effective in terms of cost and results. The State of Arizona requires routine operation and maintenance inspections for alternative on-site systems and pre-sale inspections (NSFC, 1995). Massachusetts requires inspections by a certified individual at the time of property transfer. Minnesota requires property transfers to be accompanied by certification that the on-site system is performing in a satisfactory manner. More than half of all Minnesota counties and most lending entities require inspections because of market-driven desires to ensure that on-site systems are operating properly at the time of property sale (Prager, 2000). Massachusetts also requires that systems with a design flow of 10,000 gal/day or more be inspected every three years, and shared facilities must be inspected annually (Massachusetts Department of Environmental Protection, 1996). Some counties (e.g., Washtenaw County, Michigan) with mandatory property transfer inspection programs require inspectors to be certified. New Hampshire requires an assessment and an on-site system inspection by a permitted designer prior to the sale of any developed waterfront property (New Hampshire Code of Administrative Rules, 2001).

States and localities can also indirectly assess whether on-site systems are failing through surface water and ground water monitoring. If indicator pollutants (e.g., fecal coliform as an indicator of potential pathogen contamination) are found, nearby on-site systems should be inspected to determine if they are a contributing or primary source of the contaminants. For example, residents living along the shore of Ten Mile Lake in Minnesota support a lake association that conducts regular fecal coliform monitoring below lakefront homes. High coliform concentrations prompt system inspections and involvement of property owners in remediation discussions. Owners who repair their system or install a new one are added to the OWTS "honor roll," which is published in the association's monthly newsletter.

Health department personnel and/or system inspectors often use tracer dye to observe effluent movement (USEPA, 1991). Many local agencies use non-toxic tracer dye to determine wastewater migration into nearby wells or surface waters. Tracer dye, which is typically flushed down the toilet, is often used to demonstrate to system owners that effluent is migrating rapidly into nearby surface waters or ground water. Rapid movement of effluent, that is, 20 to 30 feet in less than 30 minutes, may indicate that subsurface infiltration and treatment of wastewater have been short-circuited. Other confirmatory tests should be employed to verify this fact.

decrease the required septic tank size. The use of smaller septic tanks could negate the advantages of using low-flow plumbing fixtures by increasing organic loading rates to the soil infiltrative surface.

Table 6.12: Comparison of current and federally mandated flow rates and flush volumes (USEPA, 1998b).

Fixture	Current Practice	Energy Policy Act of October 1992	Potential reduction in water used (%)
Kitchen Sink	3.0 gpm	2.5 gpm	17
Lavatory	3.0 gpm	2.5 gpm	17
Shower	3.5 gpm	2.5 gpm	29
Tub	6.0 gpm	4.0 gpm	33

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tank volume available for storing settleable solids and raw wastewater results in less contact time. When sludge or scum levels get too near the outlet entrance level, solids can move directly to the soil absorption system and cause clogging (Mancl and Magette, 1991). Septic tank effluent screens can provide some protection from neutrally buoyant solids and during tank upsets, but periodic removal of solids from the tank is necessary to protect the soil absorption system. Most tanks should be pumped out every three to five years in lieu of a regular inspection program. If a septic system is not pumped out regularly, failure will not occur immediately; however, continued neglect will cause the SWIS to fail because it is no longer protected from greases, oils, and solids. Failure may require replacement, often at considerable expense.

Responsibility for ensuring proper operation and maintenance is most often left to homeowners. Homeowners generally are not properly trained or informed on how to take care of their systems, and many do not care to do so. On-site system regulatory authorities and management entities have recognized the need for more comprehensive management programs and have developed educational and other programs to help owners understand their responsibility for system management. Some regulatory authorities have opted for a more proactive approach and have developed inspection programs, renewable permits, and financial incentives (e.g., low-interest loans, grants) for installing, upgrading, or repairing underperforming systems. More than 100 OWTS management programs that provide operational oversight beyond initial permitting are now operating across the country (Knowles, G., Coordinator, National Onsite Demonstration Program (NODP) Phase IV, personal communication, 2000; see also

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MANAGEMENT MEASURE 7
BRIDGES AND HIGHWAYS

7.1 Management Measure

Plan, design, operate, and maintain highways and bridges to:

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downslope of the highway than along the upslope and that particle size distributions (PSDs) along the downslope were consistently coarser across the entire size gradation than the upslope and pavement PSDs (Sansalone and Tribouillard, 1999). Solids in the 2 to 8 µm range generated the largest counts and were rapidly washed from the pavement in a "first flush" effect (Sansalone et al., 1998). Lateral pavement sheet flow rate and duration controlled the yield and size of transported solids; particle transport was mass-limited during extended, high-intensity events, but was flow-limited during intermittent, low-intensity events with high traffic (Sansalone et al., 1998).

These particles, when transported in runoff to receiving waters, contribute to high levels of total suspended solids and turbidity and act as carriers for pollutants that adhere to their surfaces. Because of this adsorption phenomenon, surface area can be an important determinant in pollutant loading from highways. A relationship exists between particle size and surface area. Sansalone et al. (1998) found that particles 425 µm to 850 µm in size contributed the greatest total surface area. Sansalone and Tribouillard (1999) found that total surface area decreased with decreasing particle size. Particle-specific surface area, however, increased with decreasing particle size (Sansalone and Tribouillard, 1999; Sansalone et al., 1998), but measured values deviated from the monotonic pattern expected for spherical particles (Sansalone et al., 1998).

Because total surface area is predominantly associated with the coarser fraction, heavy metal mass (adhered to particle surfaces) is also strongly associated with this fraction (Cristina et al., 2000). Cumulative analyses for lead, copper, cadmium, and zinc in snow residuals indicated that more than 50 percent of these heavy metals (by mass) was associated with particles greater than 250 µm, and more than 80 percent was associated with particles greater than 50 µm (Sansalone and Glenn, unpublished).

Heavy metals such as lead, iron, and aluminum are typically particulate-bound in urban runoff (Sansalone and Buchberger, 1997). Sansalone and Glenn (2000), however, found that lead was predominantly dissolved in highway runoff, a phenomenon they attributed to low urban rainfall pH and alkalinity and relatively short pavement residence times. Other metals predominantly found in the dissolved phase in highway runoff were zinc, cadmium, and copper (Sansalone and Buchberger, 1997; Sansalone and Glenn, 2000).

The California Department of Transportation (Caltrans) conducted a study of highway runoff quality from 1999 to 2000 at 100 locations throughout the state. Caltrans found a positive correlation between the concentration of most pollutants and traffic volume. In addition, more than 30 percent of the total arsenic, cadmium, chromium, copper, nickel, silver, and zinc were found in the dissolved state (Kayhanian et al., 2001).

The partitioning of heavy metals between the pa-(e)i.0000 13ne-bnd a p a e5pfo coc200

Other pollutants found in highway runoff, along with their likely sources, are shown in Table 7.1. Although runoff characteristics tend to be site-specific, a number of studies have been performed to compile typical concentrations of

- *Heavy metals* are toxic to many aquatic organisms and can bioaccumulate in fish tissues, thus posing potential health risks to humans.

- *Nutrients* degrade water quality by stimulating the growth of algae and aquatic weeds. Rapid increases in these populations can then deplete oxygen levels to the extent that fish and other aerobic organisms die off.

- *Biochemical oxygen demand (BOD)* reduces dissolved oxygen levels as a result of the biological processes that break down organic constituents in runoff.

- *PAHs* include compounds such as benzo(a)pyrene that are found in petroleum products and are carcinogenic. These compounds can pose risks to human health if drinking water or fish become contaminated with them. PAHs in streams and lakes usually do not pose a health risk for people because they tend to adhere to sediment particles rather than dissolve in water. As a result, the risk of drinking water degradation is low (Van Metre et al., 2000). Aquatic invertebrates were impacted in the previously identified study from Austin, Texas (Hayward et al., 2002).

Paved roadways often generate higher loads of metals and toxicants than other nonpoint source pollutants[1]. Nutrient loadings from highways tend to be of concern when they are located upstream of a reservoir or estuary.

Winter maintenance activities to prevent ice and snow buildup on highways can also be significant contributors to loadings of particulates, salts, and various other chemicals. Salts in particular can harm both vegetation and aquatic ecosystems. Other highway maintenance activities, including roadside vegetation management, can also contribute herbicides, pesticides, and nutrients to runoff pollutant loads.

In several studies, Sansalone and Glenn (2002a, 2002b, and unpublished) examined the characteristics of snowbanks and snowmelt. Table 7.3 summarizes their findings for several pollutants and physical characteristics. From their research, they concluded the following:

- Traffic and winter maintenance practices generate significant levels of inorganic and organic constituents, many of which become predominantly particulate-bound in the snowbank with increasing residence time.

- The accretion of.77redThey (:)Ț0000410 011(a 1 Tf0 Td[T12 Tw 0.51 T9(: / u-c 0.00mariz is)TJl, c)5(

materials tested were conventional, recycled, and waste materials; and excluded constituents originating from construction processes, vehicle operation, maintenance operations, and atmospheric deposition. The research team esta

7.3 Management Practices

The use of structural and nonstructural runoff control practices during the planning, design, operation, and maintenance of highways and bridges can significantly mitigate the adverse effects of runoff. Specifically, by using environmentally sensitive highway and bridge designs and implementing proper operation and maintenance practices, highway authorities can reduce both the volume and concentration of contaminants generated by motor vehicle traffic and maintenance and repair operations. In addition, controls can be used to store and treat contaminants so that pollutant loadings can be further reduced or prevented from entering sensitive ecosystems.

7.3.1 Site Planning and Design Practices

A wide range of environmental planning and design management practices, especially those presented in Management Measures 3 and 4, can be used to reduce the environmental impacts of highways and bridges and can be initiated long before a road is completed. In general, highways and bridges should be planned so that mileage through sensitive environments, such as wetlands and estuaries, is minimized. River crossings should be avoided if possible, and sufficient setbacks should be established during construction to minimize disturbance of the surrounding environment. During the siting process, consideration should also be given to maintaining sufficient setbacks for the protection of drinking water sources. Efforts should be taken to avoid channelization and floodplain alteration to allow natu Tc 0.00e9d to se continues after roads are in place.

Highway development is most disruptive adjacent to water bodies, riparian areas, and wetland areas because it increases sediment loss, alters surface drainage patterns, changes th01 Tw 1.15 Tqerh01 Tw 1.15

7.3.2 Soil Bioengineering and Other Runoff Controls for Highways

Soil bioengineering techniques can be used to augment or replace structural slope stabilization practices such as retaining walls. They are appropriate for relatively moderate slopes where vegetation can be established easily. Soil bioengineering techniques can create wildlife habitats and promote infiltration of rainfall and runoff in addition to stabilizing slopes. Installation of bioengineering practices can be labor-intensive, and periodic inspection and maintenance, especially after large storms, is necessary to repair slumps and replace dead vegetation. Soil engineers or scientists should confirm that the stability and structural integrity of the site are appropriate for soil bioengineering practices. Several kinds of soil bioengineering practices are described by the U.S. Department of Agriculture (USDA, 1992):

7.3.2.1 Live stakes

The use of live stakes involves inserting and tamping live, rootable vegetative cuttings into the ground to create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and extracting excess soil moisture. Live stakes are appropriate for repairing small earth slips and slumps caused by excessively wet soil and should be used only at sites with relatively uncomplicated conditions. They are especially useful when construction time is limited and an inexpensive method is desired. They can be used to secure erosion control measures and can be used in combination with other bioengineering techniques. Finally, they facilitate plant colonization by providing a favorable microclimate for plant growth. Native species that are appropriate for the soil conditions onsite should be used wherever possible.

7.3.2.2 Fascines

Fascines are long bundles of branch cuttings bound together into sausage-like structures. They are installed in contoured or angled trenches and are secured to the slope with both live and dead stakes. They reduce surface erosion and rilling, protect slopes from shallow slides, and reduce long slopes into a series of shorter slopes that trap and hold soil. They also enhance vegetative growth by creating a microclimate conducive to plant hey atolonizar Tdclimate erosion and scouring and provides immediate soil reinforcement. Branchpacking is not effective in slump areas more than 4 feet deep or 5 feet wide.

7.3.2.5 Live gully repair

Live gully repair is a technique that is similar to branchpacking but is used to repair rills and gullies. Live gully repairs offer immediate reinfor

operation practices, such as line painting, to major structural repairs. Bridge scraping and painting, which are required to prevent corrosion, can be significant sources of pollutant loads if proper management practices are not used.

Of the most common bridge maintenance activities, bridge painting has the greatest potential for environmental impact. A 1996 study found that up to 80 percent of steel bridges repainted each year had been painted with lead paint, and this material along with cleaners and abrasives, can directly enter the surrounding environment (Young et al., 1996). Paint overspray and solvents can be toxic to aquatic life (Dalton et al., 1985), and metal bridge cleaning has been found to pose a serious water quality problem (TRB, 2002b). The cost of implementing measures to mitigate the impacts of bridge painting are estimated to be an additional 10 to 20 percent for containment and 10 to 15 percent for waste disposal (Young et al, 1996).

Although most construction activities take place away from water bodies, bridge operation and maintenance activities occur within close proximity to a water body. Therefore, management practices to minimize potential adverse effects on the surrounding environment are recommended. It should be noted that, in some cases, federal regulations, including Section 404 of the Clean Water Act and Section 9 of the Rivers and Harbors Act (

with rainfall or runoff. Washout should not be di

The ultimate success of anti-icing operations depends on the timing of application. Central to this approach is the use of Roadway Weather Information Systems (RWIS), which report road conditions through pavement sensors that monitor pavement temperatures and the amount of anti-icing materials present on the pavement. When this information is combined with meteorological data and fed into a central database, various modeling techniques can be applied to accurately predict the start of ice formation on pavements and the appropriate times to start anti-icing operations. The cost of implementing and maintaining an RWIS must be compared to the cost of labor and materials for deicing and snow removal. For example, the West Virginia Parkway Authority installed four RWIS units along a 95-mile stretch of highway and calculated that the agency was able to save sufficient outlays for materials and labor to pay for the system within a year. In a state with fewer snowstorms, however, the

7.4 Information Resources

The U.S. Geological Survey (USGS) and the Federal Highway Administration (FHWA) developed an online searchable bibliography of more than 2,600 pertinent references to be published in the catalog of available information that is being collected to characterize pollutant loadings and impacts attributable to highway storm water runoff. The catalog includes reports on highway-runoff water quality, urban/storm water issues, atmospheric deposition, and highway/urban runoff management practices from the USGS, FHWA, EPA, and state transportation agencies. The database can be accessed at http://ma.water.usgs.gov/fhwa/biblio/default.htm.

The Local Technical Assistance Program Web site hosts a "Rural Roads Resources" page that includes a compendium of Web sites, manuals, videos, and other media pertaining to road design and maintenance. The site also hosts an email listserver pertaining to rural roads issue isf12(at3he si)-10-0.0011

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MANAGEMENT MEASURE 8
CONSTRUCTION SITE EROSION, SEDIMENT, AND CHEMICAL CONTROL

8.1 Management Measure

Plan, design, and operate construction site land disturbance activities such that:

- An approved erosion and sediment control plan or similar administrative document that contains erosion and sediment control provisions is prepared and implemented prior to land disturbance.
- Erosion is reduced and, to the extent practicable, sediment is retained on-site during and after construction.
- Good housekeeping practices are used to prevent off-site transport of waste material and chemicals.
- The application and generation of pollutants, including chemicals are minimized.

8.2 Management Measure Description and Selection T2 1 Tf0 Tc 0 Tw 00Td[p7Et9

Table 8.1: Erosion and sediment associated with construction (USEPA, 1993).

Location	Problem	Reference
Franklin County, Florida	Sediment yield (ton/ac/yr): Forest < 0.5 Rangeland < 0.5 Tilled 1.4 Construction site 30 Established urban < 0.5	Franklin County, Florida, 1987
Wisconsin	Erosion rates range from 30 to 200 ton/ac/yr (10 to 20 times those of cropland).	Wisconsin Legislative Council, 1991
Washington, DC	Erosion rates range from 35 to 45 ton/ac/yr (10 to 100 times greater than agriculture and stabilized urban land uses).	MWCOG, 1987
Anacostia River Basin, Maryland and Washington, DC	Sediment yields from portions of the Anacostia Basin have been estimated at 75,000 to 132,000 ton/yr. Total basin acreage = 112,640 acres.	U.S. Army Corps of Engineers, 1990
Anacostia River Basin, Maryland and Washington, DC	Erosion rates range from 7.2 to 100.8 ton/ac/yr. Total basin acreage = 112,640 acres.	USGS, 1978
Washington	Erosion rates range from 50 to 500 ton/ac/yr. Natural erosion rates from forests or well-sodded prairies are 0.01 to 1.0 ton/ac/yr.	Washington State Department of Ecology, 1989
Alabama North Carolina Louisiana Oklahoma Georgia Texas Tennessee Pennsylvania Ohio Kentucky	1.4 million tons eroded per year. 6.7 million tons eroded per year. 5.1 million tons eroded per year. 4.2 million tons eroded per year. 3.8 million tons eroded per year. 3.5 million tons eroded per year. 3.3 million tons eroded per year. 3.1 million tons eroded per year. 3.0 million tons eroded per year. 3.0 million tons eroded per year.	Woodward Clyde, 1991

8.2.1.2 Pesticides

Insecticides, rodenticides, and herbicides are used on construction sites to improve human health conditions, reduce maintenance and fire hazards, and curb the growth of weeds and woody plants. Common pesticides employed include synthetic, relatively water-insoluble chlorinated hydrocarbons, organophosphates, carbamates, and pyrethrins. Over-application of pesticides on

Soil Erosion from Two Small Construction Sites in Dane County, Wisconsin

Most construction regulations require sites with more than 5 acres disturbed to have some type of erosion control plan. Sites that are less than 5 acres typically require minimal erosion control measures. To evaluate the significance of erosion on sites less than 5 acres as a source of sediment to surface waters, two small construction sites (less than 5 acres each) in Dane County, Wisconsin, were studied (USGS, 2000).

Results indicate that small construction sites are potential sources of high amounts of erosion and that sediment loads from the active construction phase are significantly higher than those during the preconstruction and postconstruction periods. These sediment loads were dramatically reduced when mulching and seeding were used to control erosion. The results of this study support the need for erosion control plans for small construction sites.

revegetated areas can lead to contamination of soils and subsequent contamination of surface water and ground water. The use of pesticides is controlled by federal or state regulations, such as the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1996.

8.2.1.3 Petroleum products

Petroleum products used during construction include fuels and lubricants for vehicles, power tools, and general equipment main

In addition to spill prevention, one of the best methods to control petroleum pollutants is to retain the sediments that have come into contact with these chemicals through use of erosion and sediment control practices. Improved maintenance and storage facilities reduce the chance of contaminating a construction site. One of the greatest concerns related to the use of petroleum products is the method for waste disposal. Dumping petroleum product wastes into sewers and other drainage channels is illegal and could result in fines or site closure.

8.2.1.7 Contaminated soils

Contaminated soils can be encountered during excavation activities that uncover previously known or unknown site contamination. New contamination also can result from a spill or leak of a hazardous material used at the construction site (e.g., a release from a material or waste storage area). If previously unknown contamination is encountered, its nature should be determined. Sampling and analysis will be required to determine what types of contaminants are present and, therefore, how the contaminated soil needs to be handled.

8.2.2 Management Measure Selection

This management measure was selected to reduce sediment mobilization and transport off of the construction site area. This management measure was selected because construction activities have the potential to increased loadings of toxic substances and nutrients in water bodies. Various states and local governments regulate the control of sediment and chemicals on construction sites through spill prevention plans, erosion and sediment control plans, or other administrative devices. The practices provided herein are commonly used and well-described in handbooks and guidance manuals, and they have been shown to be both economical and effective.

The measures were selected for the following reasons:

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Eugene, Oregon's goals for erosion and sediment control on construction sites

The City of Eugene, Oregon, requires that, to the maximum extent feasible, management practices that meet a specified set of outcomes be employed at cqP <<>>Bqee em,-12(uino)-12(-24(u.735 0 (c)-8(o-8(an)-12(i)3(c

– No deposit or discharge of sediment onto adjacent properties or into waterbodies.

– No degradation of waterbodies due to the removal of vegetation.

– No discharge or runoff containing construction-related contaminants into the city's runoff conveyance system or related natural resources.

– No deposit of construction-related material exceeding 0.5 cubic foot for every 1,000 square feet of lot size onto public rights-of-way and private streets and into the city's runoff conveyance system and related natural resources.

– *Phase construction to limit soil exposure*. Construction phasing is a process by which

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The California Department of Transportation's Storm Water Management Plan

The California Department of Transportation (Caltrans) operates one of the most comprehensive storm water drainage systems in the United States. It has recently undertaken a multifaceted program to investigate and address pollutant load reduction in California's storm water runoff. To improve storm

- Inspecting projects and facilities for compliance with erosion, sediment control, and waste management requirements.
- Providing classroom and on-the job training and consulting.
- Publishing a monthly storm water bulletin for employees and state and local regulatory agencies.
- Reviewing storm water pollution prevention plans for construction sites.
- Providing feedback on how well methods work and what improvements could be made to improve performance.
- Preparing specialized training materials, such as videos and model pollution prevention plans.
- Providing input for storm water guidance manuals and water pollution control specifications for highway design and construction.

repair, reinforcement, or replacement with a more appropriate practice. Inspecting after storms is the best way to ensure that ESC practices remain in place and effective at all times during construction activities.

8.3.1.5 Ensure ESC plan implementation

Because funding for ESC programs is not always dedicated, budgetary and staffing constraints may thwart effective program implementation. Brown and Caraco (1997) recommend several management techniques to ensure that ESC programs are properly administered:

- Local leadership committed to the ESC program;
- Redeployment of existing staff from the office to the field or training room;
- Cross-training of local review and inspection staff;
- Submission of erosion prevention elements for early planning review;
- Prioritization of inspections based on erosion risk;
- Requirement of designers to certify the initial installation of ESC practices;
- Investment in contractor certification and private inspector programs;
- Use of public-sector construction projects to demonstrate effective ESC controls;
- Enlistment of the talents of developers and engineering consultants in the ESC program; and
- Revision and update of the local ESC manual.

To facilitate public participation, a hotline can be established to allow for citizen “monitoring” and reporting of any illicit discharges. Materials should be distributed or public service announcements made to advertise the hotline.

An allowance item that acts as an additional "insurance policy" for complying with the erosion and sediment control plan also can be added to bid or contract documents (Deering, 2000a). This allowance covers costs to repair storm damage to erosion and sediment control measures as specified in the erosion and sediment control plan. This allowance does not cover storm damage to property that is not related to the erosion and sediment control plan, because this would be covered under traditional liability insurance. Damage caused by severe and continuous rain, windblown objects, fallen trees or limbs, or high-velocity, short-term rain on steep slopes and existing grades would be covered by the allowance, as would deterioration from exposure to the elements or excessive maintenance for silt removal. The contractor is responsible for complying with the erosion and sediment control plan by properly implementing and maintaining all specified measures and structures. The allowance does not cover damage to practices caused by improper installation or maintenance.

A study by University of North Carolina researchers measured the effects of erosion and sediment control regulations, inspections, and enforcement on stream biological condition at 17 construction sites in central North Carolina (Reice and Andrews, 2000). At each site, upstream, downstream, and at-site samples were taken before construction began, during the peak land

- Virtually all at-site samples showed some degradation relative to upstream controls.
- Impacts at sites downstream from construction sites were highly variable.
- Degree of degradation was significantly affected by enforcement activities; stronger enforcement resulted in less environmental impact on the streams.
- The stringency of the erosion and sediment control regulations proved unimportant compared to enforcement.

They concluded that staffing, workload, attitudes, and enforcement activities strongly influenced downstream conditions.

8.3.2 Erosion Control Practices

Erosion controls are used to reduce the amount of sediment removed during construction and to prevent sediment from entering runoff. Erosion control is based on two main concepts: (1) disturb the smallest area of land possible for the shortest period of time, and (2) stabilize disturbed soils to prevent erosion from occurring. Table 8.3 shows cost and effectiveness information for several erosion control practices.

8.3.2.1 Schedule projects so clearing and grading are done during the time of minimum erosion potential

Often a project can be scheduled when the erosion potential of the site is relatively low. In many parts of the country, there is a certain period of the year when erosion potential is relatively low

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– Managing runoff separately in each phase;

– Determining whether water and sewer connections and extensions can be included in the disturbed area and installed during the initial phases of disturbance; and

– Providing separate construction and residential accesses to prevent conflicts between residents living in completed stages of the site and construction equipment working on later stages.

Table 8.3: Cost and effectiveness of selected erosion control practices.

Practice	Percent TSS Removal	Effectiveness References	Cost (2001 Dollars[a])	Cost References
Earth dike	NA	NA	Small dikes: \$2.50–\$6.50/linear ft Large dikes: \$2.50/yd^3	NAHB, 1995; SWRPC, 1991
Pipe slope drain	NA	NA	\$5/linear ft for flexible PVC pipe; inlet and outlet	

[a]Costs adjusted for inflation using the Consumer Pricing Index (BLS, 2001).

Phasing can also provide protection from complete enforcement and shutdown of the entire project. If a contractor is in noncompliance in one phase or zone of a site only, that will be the area affected by enforcement activities. This approach can help to minimize liability exposure and protect the contractor financially (Deering, 2000b).

8.3.2.3 Practice site fingerprinting

Areas of a construction site are often unnecessarily cleared. Site fingerpri wetlands. Even with the purchase cost of the new equipment, NCDOT estimates a savings of more than $3 million.

8.3.2.8 Stockpile topsoil and reapply as a soil amendment to reestablish vegetation

Topsoil is essential to establish new vegetation, and it should be stockpiled and then reapplied to the site for revegetation. Reestablishment of vegetation is one of the most common and least expensive means to stabilize disturbed soils.

Reduced infiltration capacity, resulting in increased runoff, erosion, scouring, and sediment and other pollutant loads to receiving waters.

Decreased ground water recharge rates.

Reduced availability of subsurface water to plants, requiring homeowners to water more frequently.

Soil amendments minimize development impacts on native soils by restoring infiltration capacity and the chemical characteristics of healthy soils. Amended soils provide greater infiltration and subsurface storage, which helps to maintain predevelopment conditions. Soil amendments provide the following water quality benefits (Low Impact Development Center, 2003):

8.3.2.9 Cover or stabilize soil stockpiles

Unprotected stockpiles are very prone to erosion and therefore must be protected. Small stockpiles can be covered with a tarp to prevent erosion. Large stockpiles should be stabilized by erosion blankets, seeding, and/or mulching.

8.3.2.10 Use wind erosion controls

Wind erosion controls limit the movement of dust from disturbed soil surfaces and encompass many different practices. Wind barriers block air currents and are effective in controlling soil movement due to wind. Many different materials can be used as wind barriers, including solid board fences, snow fences, and bales of hay. Sprinkling moistens the soil surface with water and must be repeated as needed to be effective for preventing wind erosion (Delaware DNREC, 1989); however, applications must be monitored to prevent excessive runoff and erosion.

8.3.2.11 Intercept runoff above disturbed slopes and convey it to a permanent channel or storm drain

Earth dikes, perimeter dikes/swales, or diversions can be used to intercept and convey runoff from above disturbed areas to undisturbed areas or drainage systems. An earth dike is a temporary berm or ridge of compacted soil that channels water to a desired location. A perimeter dike/swale or diversion is a swale with a supporting ridge on the lower side that is constructed from the soil excavated from the adjoining swale (Delaware DNREC, 1989). These practices should be used to intercept flow from denuded areas or newly seeded areas and to keep clean runoff away from disturbed areas. The structures should be stabilized within 14 days of installation. A pipe slope drain, also known as a pipe drop structure, is a temporary pipe placed from the top to the bottom of a slope to convey concentrated runoff down the slope without causing erosion (Delaware DNREC, 1989).

8.3.2.12 On long or steep, disturbed, or man-made slopes, construct benches, terraces, or ditches at regular intervals to intercept runoff

Benches, terraces, or ditches break up a slope by providing areas of low slope in the reverse direction. These structures keep water from proceeding down the slope at increased volume and velocity. Instead, the flow is directed to a suitable outlet or protected drainage system. The frequency of benches, terraces, or ditches will depend on the erodibility of the soils, steepness and length of the slope, and rock outcrops. This pr conveyance channels. If the runoff during or after construction will cause erosion in a channel, the channel should be lined or flow control practices should be installed. The first choice of lining is grass or sod because they reduce runoff velocities and provide water quality benefits through filtration and infiltration. If the velocity in the channel would erode the grass or sod, turf reinforcement mats, riprap, concrete, or gabions can be used.

8.3.2.15 Use check dams

Check dams are small, temporary dams constructed across a swale or channel. They can be constructed using gravel, rock, gabions, or straw bales. They are used to reduce the velocity of concentrated flow and, therefore, to reduce erosion in a swale or channel. Proper design and

8.3.2.17 Use mulches

Newly established vegetation does not have as extensive a root system as existing vegetation, and therefore it is more prone to erosion, especially on steep slopes. Additional stabilization should be considered during the early stages of seeding. This extra stabilization can be accomplished using mulches or mulch mats, which can protect the disturbed area while vegetation becomes established.

Mulching involves applying plant residues, compost material, or other suitable materials on disturbed soil surfaces. Mulch and mulch mat materials include tacked straw, wood chips, jute netting, coir/coconut fiber, and compost mix, and are sometimes covered by blankets or netting. Mulching alone should be used only for temporary protection of the soil surface or when permanent seeding is not feasible. The useful life of mulch varies with the material used and the amount of precipitation, but is approximately two to six months. Mulching and/or sodding may be necessary as slopes become moderate to steep, as soils become more erodible, and as areas become more sensitive.

During the times of the year when vegetation cannot be established, mulch should be applied to moderate slopes and soils that are not highly erodible. On steep slopes or highly erodible soils, multiple mulching treatments should be used.

The Texas Transportation Institute (2004) undertook a study to measure the performance of the use of compost and shredded wood mulches on highway rights-of-way. The institute found that compost applied to sand produced 92 percent vegetation cover, compost on clay produced 99 percent vegetation cover, and wood chips treated with a tackifier on clay produced 95 percent vegetation cover. Other treatments, including wood chips/tackifier on sand and wood chips with tackifier and germination stimulant on sand and clay did not produce adequate vegetation cover for erosion control (only 48 to 57 percent cover). They concluded that mulch could be advantageous as an erosion control method because it did not need to be removed after construction and it acted as a soil amendment to encourage vegetation establishment. Additionally, use of natural mulches such as compost and wood chips promotes recycling of waste materials and reduces the amount of wastes disposed of in landfills.

Hydromulches containing biosolids or other fertilizers are often useful on soils with poor nutrient organic content and in situations where there are steep slopes or other erosive forces that affect revegetation (e.g., wind).

8.3.2.18 Use sodding for permanent stabilization

Sodding permanently stabilizes an area with a thick vegetative cover. Sodding provides immediate stabilization and should be used in critical areas or where establishing permanent vegetation by seeding and mulching would be difficult. Sodding is also a preferred option when there is high erosion potential during the period of vegetative establishment from seeding. According to the Soil Quality Institute (SQI, 2000), soils that have been compacted by grading should be broken up or tilled before placing sod.

8.3.2.19 Install erosion control blankets

Turf reinforcement mats (TRMs) combine vegetative growth and synthetic materials to form a high-strength mat that helps prevent soil erosion in drainage areas and on steep slopes (USEPA, 1999). TRMs enhance the natural ability of vegetation to permanently protect soil from erosion. They are composed of interwoven layers of non-degradable geosynthetic materials, such as polypropylene, nylon, and polyvinyl chloride netting, stitched together to form a three-dimensional matrix. They are thick and porous enough to allow filling and retention of soil.

In addition to providing scour protection, the mesh netting of TRMs is designed to enhance vegetative root and stem development. By protecting the soil from scouring forces and enhancing vegetative growth, TRMs can raise the threshold of natural vegetation to withstand higher hydraulic forces on stabilization slopes, streambanks, and channels. In addition to reducing flow velocities, the use of natural vegetation provides removal of particulates through sedimentation and soil infiltration and improves the aesthetics of a site.

In general, TRMs should not be used:

- To prevent deep-seated slope failure due to causes other than surficial erosion;
- When anticipated hydraulic conditions are beyond the limits of TRMs and natural vegetation;
- Directly beneath drop outlets to dissipate impact force (although they can be used beyond the impact zone); or
- Where wave height might exceed 1 foot (although they may be used to protect areas up-slope of the wave impact zone).

The performance of a TRM-lined conveyance system depends on the duration of the runoff event to which it is subjected. For short-term events, TRMs are typically effective at flow velocities of up to 15 ft/sec and shear stresses of up to 8 lb/ft^2 (USEPA, 1999), however, specific high-performance TRMs may be effective under more severe hydraulic conditions. Practitioners should check with manufacturers for the specifications and performance limits of different products.

In general, the installed cost of TRMs ranges from \$5/yd^2 to \$15/yd^2 (USEPA, 1999). Factors influencing the cost of TRMs include: (1) the type of TRM material required; (2) site conditions, such as the underlying soils, the steepness of the slope, and other grading requirements; and (3) installation-specific factors such as local construction costs.

In most cases, TRMs cost considerably less than

8.3.2.21 Use wildflower cover

Because of the hardy drought-resistant nature of wildflowers, in some cases they may be more beneficial as an erosion control practice than turf grass. Though not as dense as turf grass, wildflower thatches and associated grasses are expected to be as effective in erosion control and contaminant absorption. An additional benefit of wildflower thatches is providing habitat for wildlife, including insects and small mammals. Because thatches of wildflowers do not need fertilizers, pesticides, or herbicides, and watering is minimal, implementation of this practice may result in cost savings. A wildflower thatch requires several years to become established, but maintenance requirements are minimal once established. Native seeds should be used because they will be better adapted to local conditions. If possible, the seed source should be within 250 miles of the proposed project for promotion of native species.

8.3.3 Sediment Control Practices

Sediment controls capture sediment that is transported in runoff. Filtration and gravitational settling during detention are the main processes used to remove sediment from urban runoff. Table 8.5 shows cost and effectiveness information for several sediment control practices.

8.3.3.1 Install sediment basins

Sediment basins, also known as silt basins, are engineered impoundment structures that allow sediment to settle out of the urban runoff. They are installed prior to full-scale grading and remain in place until the disturbed portions of the drainage area are fully stabilized. They are generally located at the low point of sites, away from construction traffic, where they can be used to trap sediment-laden runoff. Basin dewatering is achieved either through a single riser and drainage hole leading to a suitable outlet on the downstream side of the embankment or through the gravel of the rock dam. In both cases, water is released at a substantially slower rate than would be possible without the control structure.

The following are general specifications for sediment basin design criteria as presented in Schueler (1997):

- Provide 1,800 to 3,600 cubic feet of storage per contributing acre (a number of states, including Maryland, Pennsylvania, Georgia, and Delaware, recently increased the storage requirement to 3,600 ft^3 or more [CWP, 1997b]).
- Surface area equivalent to 1 percent of drainage area (optional, seldom required).
- Riser with spillway capacity of 0.2 ft^3/s/ac of drainage area (peak discharge for 2-year storm with 1-foot freeboard).
- Length-to-width ratio of 2 or greater.
- Basin side slopes no steeper than 2:1 (horizontal to vertical).
- Safety fencing, perforated riser, dewatering (optional, seldom required).

efficiency in sediment basins can be improved through the use of advanced sediment-settling controls.

8.3.3.2 Use modified risers and skimmers

Because traditional riser designs provide little treatment to remove sediments, efforts have been made to improve the design of sediment basins to facilitate greater pollutant removal. Modifications to traditional designs that improve sediment removal efficiency include using perforated risers or perforated risers wrapped in a gravel jacket or filter fabric. An alternative to the riser is a skimmer device that floats on the

Table 8.6: Sediment retention efficiency[a]

level spreader can be used upslope of the fence. Many types of fabrics are available commercially. The characteristics that determine a fence's effectiveness include filtration efficiency, permeability, tensile strength, tear strength, ultraviolet resistance, pH effects, and creep resistance.

The longevity of silt fences depends heavily on proper installation and maintenance. CWP (1997d) identified several conditions that limit the effectiveness of silt fences:

- The length of the slope exceeds 50 feet for slopes of 5 to 10 percent, 25 feet for slopes of 10 to 20 percent, or 15 feet for slopes greater than 20 percent.
- The silt fence is not aligned parallel to the slope contours.
- The edges of the silt fence are not curved uphill, allowing flow to bypass the fence.
- The length of disturbed area draining to the fence is greater than 100 feet.
- The fence receives concentrated flow without reinforcement.
- The fence was installed below an outlet pipe or weir.
- The silt fence is upslope of the exposed area.
- The silt fence alignment does not consider construction traffic.
- Sediment deposits behind the silt fence reduce capacity and increase breach potential.
- The alignment of the silt fence mirrors the property line or limits of disturbance but does not reflect ESC needs.

EvTEC found that the slicer performed as well as or better than the best trenching method and was superior to less stringent methods of trenching. Slicing took less time (1.75 to 4 times faster) and was therefore cost-effective because of man-hour savings. The slicing method prevented runoff seepage and blowout better than most trenching methods and performed as well as the best trenching method. Overall, the static slicing method offers several advantages over traditional trenching methods, These conditions can be avoided with proper siting, installation, and maintenance. Silt fences typically have a useful life of approximately 6 to 12 months.

8.3.3.5 Install compost filter berms

Compost berms can be installed by spraying compost mixture along the perimeter of a denuded area to form a mound. The berms are designed to filter runoff by absorbing flows into the compost mixture's void space and gradually releasing them into the ground or offsite. They are usually installed at the bottom of a slope, but they also can be installed at the top of the denuded area to prevent clean runoff from entering exposed areas. Berms are typically installed in lieu of silt fence and are sized at 1 foot high and 2 feet wide (Tyler, 2001).

Compost berms can be used in conjunction with compost blankets (a sprayed layer of compost mix that functions as a mulch, see section 8.3.2.17); a berm at the top of the slope protects the compost blankets from erosion by preventing water from flowing underneath the protective layer, and a berm at the bottom of the slope provides filtration (Tyler, 2001).

Caine (2001) installed a triangular

practices will help minimize exposure and risk. Erodible or potentially hazardous materials should be stored in such a manner as to prevent contact with rainfall or runoff6r

requirements regarding storage of specified chemicals above certain volume thresholds). Site

- Locate containers in a covered area when possible.

- Arrange for waste collection before containers overflow.

- Explore recycling options for specific wastes generated at the site. Wastes such as used oil, used solvents, and construction debris can often be reclaimed or recycled, thereby reducing the amount of waste actually requiring permanent disposal. Numerous companies can provide recycling services, including the provision and maintenance of on-site recycling containers.

- Implement es ai3(rsec)7(ovosanspr)-ocuci11(r)2(ov)8(J-0.0005 Tc 0.0005 Tw 17.1551 Td[(I) imm)7(ovd to a storm sewer or sanitary sewer, where it can cause soil or water contamination. Instead, it should be evaluated to determine whether it constitutes a hazardous waste. If determined to be a hazardous waste, it should be properly handled and disposed of; if not a hazardous waste, it should be properly managed and disposed of as a solid waste. Dumping wastes into sewers and other drainage channels is illegal and can result in fines or job shutdown (USEPA, 1993).

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http://tti.tamu.edu/enviro_mgmt/facilities/hec/. The St. Anthony Falls Laboratory has an "applied research" Web page (http://www.safl.umn.edu/research/applied/index.html) with links to studies gauging the effectiveness of erosion control products.

Storm Water Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices (USEPA, 1992), published by EPA's Office of Wastewater Management, provides summary guidance on the development of storm water pollution prevention plans and helps users select appropriate management practices to control erosion and sediment loss resulting from construction activities. It was designed to provide technical support for construction activities that are subject to pollution prevention requirements under NPDES permits for storm water point source discharges. This document can be viewed in PDF format at http://www.epa.gov/npdes/pubs/owm0307.pdf or it can be ordered control measures. Information for purchasing

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Getting in Step: A Guide to Effective Outreach in Your Watershed

Getting in Step is a guide published by EPA to provide a summary of useful tools for developing and implementing an effective watershed outreach plan. The manual uses a step-by-step approach to help watershed practitioners address public perceptions, promote management activities, and inform or motivate stakeholders. Getting in Step is divided into three parts, as follows:

- Part I presents the overall framework for developing and implementing an outreach plan. It provides specific information about defining goals and objectives; identifying the target audience; creating, packaging, and distributing the message; and evaluating the outreach plan.

- Part II provides tips and examples for developing and enhancing outreach materials, with emphasis on elements of composition and layout, using artwork and photos, establishing a watershed identity, packaging the watershed message, and estimating costs.

- Part III provides specific tips on working with the news media to gain improved media coverage of water quality issues.

Getting in Step also includes worksheets, graphics for use without permission, and information on

(2) *Improper use*. Failure to follow label instructions properly may result in over-application of

large areas of impervious surface on which automotive-related pollutants concentrate (refer to Management Measure 7, Bridges and Highways, for a discussion of automobile-related pollutants). Other commercial uses, visual pollution and detracts from the aesthetic qualities of the landscape. Boaters have complained that trash and debris clog engine intake valves and propellers, resulting in expensive repairs. Finally, municipalities must incur the cost of clean-up efforts to restore water quality.

9.2.2 Management Measure Selection

This management measure was selected to identify ways in which communities can implement practices that bring about behavioral changes to reduce nonpoint source pollutant loading from the sources listed in the management measure. Such activities include public education, proper management of maintained landscapes, source reduction, training and runoff control plans for commercial sources, pet waste management activities, and trash control. Communities can select practices that best fit local priorities and funding. It is important for the watershed manager to note that community acceptance is often the major determinant of whether education and outreach activities and administrative mechanismes (e)5(wa)5ue24.0 To tihe-10()3(ptament4(mes th)-11(atrequi

detergents, dirt, and automotive fluids can wash into the storm drain system or directly into receiving waters in urban areas.

It is preferable for citizens to patronize commercial car washing facilities because they are mandated under the regulatory authority of the NPDES program (see the Introduction for a description of the NPDES program) to treat and/or reuse wash water, whereas residential car washing activities are exempt from requirements under Phase I MS4 permits and Phase II general permits (USEPA, 2003b). If commercial facilities are not available or if residents prefer to wash their cars themselves, they should be encouraged to wash their cars less often, especially

While all of the above practices are applicable to both citizens and lawn care professionals, they will differ when implemented due to differences in scale. For example, lawn care services may have multiple employees, carry large quantities of fertilizers and pesticides, and manage vast expanses of turf. Therefore, in addition to the above practices, good housekeeping is particularly vegetation that is best suited to local conditions should be chosen to replace turf. Recommendations for drought-tolerant plants are available from a local extension office. State-specific cooperative extension service information is available from the Cooperative State Research, Education, and Extension Service (CSREES) at http://www.csrees.usda.gov.

9.3.2.2 Soil building

Lawn owners should analyze their soil every one to three years to determine its suitability for supporting a lawn and to identify whether additives are needed or adjustments should be made to optimize growing conditions. Soil characteristics that should be measured include pH, fertility, compaction, texture, and earthworm content. Soil test kits (for pH and fertility) can be purchased inexpensively at a garden center, or samples can be analyzed for free by a local cooperative extension service. Soil tests reveal whether fertilizer or lime is needed, helping to avoid over-fertilization and loss of nutrients. Surveys have indicated that only 10 to 20 percent of citizens test their soil to determine fertilization needs (Schueler and Swann, 2000c).

Prior to planting, sandy and heavy clay soils may be amended by adding organic compost to improve aeration and nutrient-holding capacity. Compacted soil under an established lawn should be aerated to improve the flow of water, fresh air, and nutrients to the system. Aeration is a non-chemical technique that relieves compaction, increases rooting, helps prevent thatch accumulation, incorporates organic matter into the soil surface, and helps prevent damage by insects and disease (Trouthge b have been selected to be slow growing, which requires less mowing, fertilizer, and water. Care should be taken to select the species and cultivated variety that are best adapted to the site conditions. Selecting the correct variety will result in a healthier lawn that is better able to compete with weeds and resist insects and disease (Bruneau, 2001; USEPA, 1992).

9.3.2.4 Mowing and thatch management

Each turf grass variety has an ideal mowing height range. Turf grasses use water more efficiently and out-compete weeds better when kept at the higher end of the ideal mowing height range. Mowing grass too short decreases rooting and increases the need for frequent watering. Tall turf competes more vigorously against weeds and can usually tolerate more insect and disease pressure (Troutman, 2003). Property owners might need to mow grass more frequently to maintain a minimum healthy height, depending on the type of grass planted and the local climate. Property owners should understand that grass grows at different rates throughout the

Yard Waste Ban

losses from soils that are prone to leaching (Bureau, 2001). Organic products offer the additional benefits of increasing soil condition and promoting the growth of desirable soil organisms.

Timing of fertilization is very

Targeted Herbicide Application

Targeted herbicide application, which uses infrared and other technologies, can help locate and control roadside weeds at lower costs than conventional weed control methods (Stidger, 2001).

when harmful organisms are present, citizens should determine the level of damage the plant is able to tolerate. No action should be taken if the plant can maintain growth and fertility in the presence of these pest organisms. If controls are needed, there is an arsenal of low-impact pest

Bio Integral Resource Center IPM Partnership Program

The Bio Integral Resource Center (BIRC) in the San Francisco Bay Area has developed a partnership between water pollution prevention agencies, nurseries, hardware stores, and the local cooperative extension to educate the public on less-toxic pest management. The program focuses on educating consumers about pest control products at the point of purchase from nurseries and hardware stores. BIRC encourages stores to carry less-toxic products and trains employees on the use of these products.

BIRC also conducts a Healthy Garden Workshop, which is a four-hour public seminar to introduce home gardeners to various aspects of IPM such as monitoring, physical controls, horticultural controls, and biological controls. Additional topics include water conservation and the use of native plants. An illustrated Healthy Garden Handbook accompanies the workshop, and an instructor's guide is available to assist others who are interested in giving the class (http://www.pesp.org/2000/birc00-final.htm).

Alliance for Chesapeake Bay IPM Partnership Program

The Alliance for Chesapeake Bay IPM Partnership Program promotes IPM by citizens through a partnership with retailers in which less-toxic pest control options are labeled with the slogan, "From your home to our streams…Choose less toxic products." The program includes employee training workshops, IPM informational displays and fact sheets available at participating retail stores. Partnerships with garden clubs and Master Gardeners provide training on minimizing environmental impacts and less-toxic pest management techniques.

watering will reduce soil erosion, runoff, and fertilizer and pesticide movement. An irrigation system should be designed to have an average application rate that is less than the infiltration capacity of the soil to avoid surface ponding and to maximize water percolation. Trickle and drip tracking analysis to determine the origins of elevated bacteria levels (see Section 2.3.5 for more information about water quality indicators and bacterial source tracking).

Instituting building and plumbing codes to prevent connections of potentially hazardous pollutant sources to storm drains.

Organizing structures to be inspected for illicit connections by building age, with older buildings identified as priorities. Businesses whose activities have the greatest potential notify the public that the smoke is nontoxic, though it should be avoided as it can cause irritation of the nose and throat in some people.)

Flow monitoring. Monitoring increases in storm sewer flows during dry weather can

reduce waste and pollution using signage or pamphlets so they will be less likely to contribute to pollution problems that are ultimately the responsibility of the business.

9.3.3.4 Devise spill prevention, control, and clean-up plans

The best way to avoid runoff contamination from spilled materials is to prevent the spill from occurring. Careful storage of materials in sound, clearly labeled containers, and regular inspection and maintenance of equipment, are key practices to prevent spills. Materials stored outdoors should be covered and kept on a paved area to protect them from being mobilized by

oexec6nerls.3fudmd(vedre09.ebilit), thvolumered and ke most cases. When cleaning greasy equipment or trucks, a special cleaning area should be designated and equipment installed to capture, pre-treat, and discharge the wash water to the sanitary sewer. In addition, instructional signs that prohibit changing vehicle oil, washing with solvents, and other activities should be posted in non-wash areas. Finally, sumps or drain lines should be installed to collect wash water for treatment and discharge to the sanitary sewer.

Waste materials from vehicle maintenance activities also deserve special attention. Proper storage of materials and proper disposal of waste products are imperative. For example, waste oil, antifreeze, spent solvents, and some other liquids can be recycled. Spent batteries, however, should not be discarded with trash, but must either be disposed of as a hazardous waste or returned to the dealer from whom they were purchased. In addition vehicle maintenance should be performed in an indoor garage, not in an outdoor parking area. If performing work outdoors, all oil and grease should be captured unless precautions are taken to prevent them from being carried in runoff, such as with the use of absorbent pads in inlets or grates.

9.3.3.7 Use care when performing construction, repairs, or remodeling

When repairing, remodeling, or constructing buildings there are several key techniques that can prevent adverse effects on natural systems. Paints should be mixed where spills can be recovered or cleaned easily, and an impermeable ground cloth should be used while painting. Paint chips and scrapings might contain lead and should be managed properly to prevent contamination of water or soil. Paint buckets and barrels of materials should be stored away from contact with runoff. During painting clean-up, if a water-based paint was used, brushes and equipment should be cleaned in a sink connected to the sanitary sewer; if oil-based paints were used, they should be stored or recycled and not be disposed of in the sink or storm drain. Spray painting requires a few extra precautions. Temporary scaffolding should be used to hang drop cloths or draperies to shield the user from the wind, to collect overspray, and to minimize the spreading of windblown materials. Users should be aware of air quality restrictions on spray paints that use volatile chemicals and should consider water-based spray paints instead to minimize adverse effects on air quality.

Sand blasting can be controlled to keep particles off of paved surfaces and out of storm drains by placing a tarp or ground cloth beneath the work to capture the blasting medium, protect the work area from wind, and capture airborne particles.

9.3.3.8 Proper disposal of pet waste

Pet owners have several options for properly managing pet waste. Collecting the waste and flushing it down the toilet, where it can be treated by a sewage treatment facility or septic tank, is the preferred method. Small quantities can also be buried in the yard (when ground water is not

Los Angeles County Pet Waste Program

The Los Angeles County Department of Public Works Environmental Programs Division developed a program to control pet waste (Lehner et al., 1999). By profiling various groups of pet owners, the division identified the best targets for reducing coastal pollution. The program included a multimedia campaign to educate new and existing pet owners about the water quality impacts of pet waste. The

earning activities about water science, history, geography, and drama. The Albuquerque-based Ciudad Soil and Water Conservation District used its “Rolling River” educational model to show how all the components of a watershed are connected and how changes in one part affect others. Students created a mini-river, purified water from the Rio Grande, and built aquifers from edible ingredients. They also used a computer model to make projections of water use in the future and a ground water model to see how water moves underground. Students analyzed water samples and played the roles of algae, fish, and raptors to understand how toxins can travel through the food chain. They created wetlands, simulated flood and drought situations, changed the

9.4 Information Resources

9.4.1 General

The Center for Watershed Protection published *Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments*. This publication provides information on cost-effective methods to detect and eliminate illicit discharges from municipal storm drains. The document is available for download at http://www.cwp.org/PublicationStore/TechResearch.htm.

EPA's GreenScapes program provides cost-efficient and environmentally friendly solutions for large-scale landscaping. GreenScapes encourages companies, government agencies, and other entities to make more holistic decisions regarding waste generation and disposal. The GreenScapes program emphasizes four elements: reduce, reuse, recycle, enm companies, gre3.4gram Devl b(re3

education pieces. A list of agencies and organizations that have water-related environmental education programs and projects is provided in an appendix. The publication is available from EPA's National Service Center for Environmental Publications Web site at http://www.epa.gov/ncepihom. It can also be ordered by phone, fax, or ma8mc3rro military bases, but the information is applicable to any pollution prevention initiative. It includes guidance on proper management of household chemicals, as well as descriptions of applicable state and federal laws, regulations and reporting requirements, and state resources. It describes various types of collection programs, lists resources for disposal and recycling by material type, and includes examples of outreach and education materials. The resource guide is available in PDF format at http://www.p2pays.org/ref/13/12935.pdf.

9.4.2 Yards: General Resources

The Bay Area Water Pollution Prevention Agency's "Our Water, Our World" program published *Less-Toxic Pest Management: Problem Pesticides*, a fact sheet describing the current state of chlorpyrifos and diazinon regulation, as well as some additional pesticides of concern. It provides information on alternative pest management techniques and sources of additional information. The site can be accessed at http://www.ci.livermore.ca.us/wrd/pdf_files/pesticides.pdf.

The *National Foundation for IPM Education* (NFIPME) is a non-profit organization that promotes education, provides information, and encourages research on integrated pest management. The Web site, http://www.ipm-education.org/, contains links to sponsored programs and information on grants for pesticide environmental stewardship.

Robert Mugaas at The University of Minnesota Cooperative Extension published *Responsible Fertilizer Practices for Lawns.* The paper provides soil-specific information on fertilizer application practices to protect water quality. It can be accessed at http://www.extension.umn.edu/distribution/horticulture/DG6551.html.

9.4.3 Yard Resources for Homeowners

Water Quality and Home Lawn Care, by the North Carolina State University Cooperative Extension, takes citizens through the process of establishing a healthy lawn and maintaining it using practices that protect water quality. It provides specific instructions on watering, mowing, and fertilization. This fact sheet can be downloaded in PDF format from http://www.turffiles.ncsu.edu/PUBS/MANAGEMENT/HOMELAWN.PDF.

The U.S. EPA publication *Healthy Lawn, Healthy Environment* is a user-friendly brochure that describes lawn care practices for citizens. It covers the basic principles of soil building, mowing techniques, appropriate thatch buildup, and IPM. The brochure also discusses important considerations for citizens in selecting a professional lawn care service. The brochure can be downloaded in PDF format from http://www.epa.gov/oppfead1/Publications/lawncare.pdf.

9.4.4 Yard Resources for Lawn Care Professionals

The University of Florida Cooperative Extension maintains a database of fact sheets for lawn care professionals, *Professional Lawn and Landscape Fact Sheets*. The fact sheets cover athletic fields, golf courses, roadsides, interiorscapes and non-residential lawns. The fact sheets can be downloaded from http://edis.ifas.ufl.edu/TOPIC_Professional_Lawn_and_Landscape.

The North Carolina State University Cooperative Extension's fact sheet, *Water Quality & Commercial Lawn Care*, is a resource for lawn care professionals on fertilizer, mowing, and

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Protecting water quality in urbanized areas is difficult because of many factors, including diverse pollutant loadings, large runoff volumes, limited areas suitable for surface water runoff treatment systems, the high implementation costs associated with structural controls, and the destruction or absence of buffer zones that can filter pollutants and prevent the destabilization of streambanks and shorelines.

An important nonstructural component of many watershed management plans is the establishment and preservation of buffers and natural systems (e.g., by policy, code, or ordinance). These areas help to maintain and improve surface water quality by filtering and infiltrating urban runoff. In areas of existing development, natural buffers and conveyance systems may have been altered as urbanization occurred. Where possible and appropriate, additional impacts on these areas should be minimized, and if the areas are degraded, their functions should be restored. Establishing and protecting buffers is most appropriate along surface water bodies and their tributaries where water quality and the biological integrity of the water body are dependent on the presence of an adequate buffer or riparian area. Buffers may be necessary where the buffer or riparian area:

- Reduces significant nonpoint source pollutant loadings;
- Provides habitat necessary to maintain the biological integrity of the receiving water;
- Reduces undesirable thermal impacts on the water body; or
- Reduces erosion.

Structural practices may be a suitable option to decrease the nonpoint source pollution loads

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quality inlets with oil/grit separators might be appropriate for retrofits because they do not limit use of the land.

10.2.2 Management Measure Selection

The first and second components of this management measure were selected to encourage communities to develop and implement watershed management programs. Local conditions, availability of funding, and problem pollutants vary widely among communities. Watershed management programs allow communities to select and implement the practices that best address local needs. Prioritizing local and/or regional pollutant reduction opportunities and setting schedules for implementing appropr

- Applies the Davis Bacon Act, which maintains local wage and labor standards for federal construction work, on the same terms as the authority for the current program; and
- Makes funds available for technical assistance, training, and research.

More information about the Small Business Liability Relief and Brownfields Revitalization Act can be found at http://www.epa.gov/brownfields/sblrbra.htm.

Cost was a major factor in the selection of this management measure. EPA acknowledges the following constraints to implementing nonpoint source controls for existing development:

- High costs and other limitations inherent in treating existing sources to levels consistent with the standards set for developing areas;
- Frequent lack of suitable areas for structural treatment systems that can adequately protect receiving waters;
- Lack of universal cost-effective treatment options;
- Frequent lack of funding for mandatory retrofitting; and
- Extraordinarily high costs associated with implementing retention ponds and exfiltration systems in developed areas.

10.3 Management Practices

10.3.1 Identify, Prioritize, and Schedule Retrofit Opportunities

In the watershed assessment phase of the urban runoff management cycle, watershed managers should identify water bodies that have been degraded by urban runoff and prioritize them for restoration based on the costs and benefits for watershed stakeholders. One method to halt further degradation and initiate water body recovery is to retrofit existing runoff management practices or conveyance structures. It is important for watershed managers to have clear goals and realistic expectations for retrofitting existing structures. Each retrofit project should be planned in the context of a comprehensive watershed plan, and managers should have a clear set of objectives to ensure that the project results in measurable improvements in hydrologic, habitat, and/or water quality indicators.

10.3.1.1 Evaluate existing data

The first step in identifying candidate sites for storm water retrofitting is to examine existing data. These data can include results from a watershed assessment, topographic maps, land use or zoning maps, property ownership maps, aerial photos, and maps of the existing drainage network. For example, results from a watershed assessment can be used to identify areas with good habitat and water quality that should be protected, as well as areas with poor habitat and water quality that need to be improved. Topographical maps can be used to delineate drainage units within the watershed at the subwatershed zon9g aerial photographs can be used to identify open spaces that can be more easily developed into runoff management facilities. According to the Center for Watershed Protection (CWP, 1995a), the best retrofit sites:

- Are located adjacent to existing channels or at the outfall of storm drainage pipes;
- Are located within an existing open area;
- Have sufficient runoff storage capacity;
- Are feasible for diverting runoff to a potential treatment area (forested or vegetated area) or structural management practice; and
- Have a sufficient drainage area to contribute meaningfully to catchment water quality.

Specific areas well-suited for new runoff controls include undeveloped parkland and open space, golf courses, wide floodplains, highway rights-of-way, and edges of parking lots.

Information for potential retrofit sites, such as location, ownership, approximate drainage area, utility locations, and other pertinent details, can be compiled in a retrofit inventory sheet (CWP, 1995a). A site visit can provide information on site constraints, topography, adjacent sensitive land uses, receiving water conditions, utility crossings, and other considerations that would affect the feasibility of implementing the management practice. At this point, a conceptual sketch for rerouting drainage and siting management practices should be drawn and preliminary cost estimates made for each site.

10.3.1.2 Choose appropriate management practices based on site conditions

The choice of one potential retrofit site over another for management practice implementation can be based on several different factors in addition to site limitations and cost. For instance, the preliminary goals of a retrofit program may be to preserve streams or reaches known to have high-quality habitat or exceptional water quality. The goal of another program may be to restore poor habitat and degraded water quality. The program may elect to target particular land uses thought to contribute the majority of pollutants to receiving waters. Retrofit facilities also can be installed to treat runoff from large parts of a watershed or subwatershed (regional controls), thereby requiring fewer overall projects. Once retrofit sites are identified and prioritized, a schedule for installing new facilities or updating old facilities should be devised.

10.3.1.3 Incorporate low-impact development practices into existing development

In many cases, sites that are already developed can be retrofitted with low-impact development practices such as biofilters, rain barrels, rooftop greening, and cisterns (see Management Measure 5 for a more detailed discussion of these practices). Soil rehabilitation and tree planting can also contribute to the reduction of runoff. All of these practices can be designed on a small scale to accommodate space constraints that may be present on developed sites. The use of these practices will aid in retaining

The City of Chicago has incorporated low-impact development practices such as rooftop greening and downspout disconnection into its urban runoff management strategy. The City Hall Rooftop Garden is a $1.5 million retrofit project to demonstrate the benefits of green roofs. The city has published *A Guide to Rooftop Gardening* (http://www.cityofchicago.org/Environment/GreenTech/pdf/GuidetoRooftopGardening.pdf) to communicate the lessons learned from this project and provide information to the public on green roof development. The city is also targeting flood-prone areas for its downspout disconnection campaign, distributing door hangers and brochures to residents, and encouraging the use of rain barrels (Murante, 2003).

The *Low-Impact Development Design Strategies: An Integrated Design Approach* (Prince George's County, Maryland, Department of Environmental Resources, 2000) and the Low Impact Development Center Web site (http://www.lowimpactdevelopment.org/) can provide more information about these and other practices appropriate for existing developments. Additionally, a search for "urban forestry" on the USDA Forest Service's Web site (http://www.fs.fed.us/) produces many good references about how trees can be used to reduce runoff volume and improve runoff quality.

10.3.1.4 Identify undeveloped and privately owned land for acquisition

In addition to the installation of conventional storm water management practices, the acquisition and preservation of open space in developed watersheds can protect against the threat of further development, reduce runoff volume, and provide storm water treatment. This practice involves the identification of parcels in a developed watershed that are undeveloped or privately owned and can be protected or restored to provide storm water benefits by attenuating additional runoff volume and peak flow. This watershed-wide planning effort involves mapping open space, cadastral data (e.g., property boundaries, subdivision lines, buildings), drainage systems, urban forests, floodplains, and other land use data. The planning effort also involves selecting sites based on their proximity to receiving waters, the condition of the soil and vegetation, and ease of purchase. Selected parcels are purchased, restored if necessary, and modified to receive and retain more runoff using berms or diversions (O'Leary, 2003). For more information on land acquisition, see Management Measure 3: Watershed Protection.

10.3.1.5

detention ponds can be modified to accommodate a greater variety of species by transforming

Cost-Effectiveness Study of Retrofitting Runoff Treatment Facilities

potentially affect channel design flows and the floodplain, however, careful analysis must be conducted before the instream practice is implemented. In addition, cleanout frequency should be considered before selecting this practice, as regular maintenance will be needed to remove trapped sediments.

10.3.2.5 Install runoff management practices in or adjacent to large parking areas

Retrofit practices can be installed near large parking lots to capture, detain, and/or treat runoff. Infiltration practices such as bioretention areas, porous pavement, sand filters, and underground vaults are good candidates. Two examples of successful use of bioretention areas can be found at http://www.epa.gov/owow/nps/bioretention.pdf (USEPA, 2000a). In addition, a case study illustrating the effectiveness of porous pavement in reducing runoff is provided at http://www.epa.gov/owow/nps/pavements.pdf (USEPA, 2000b).

10.3.2.6 Constrt--1 areas EMC P DC T1 0.014 T-0.0014 w 12 0 49.652 547Es. Two2(k)23(y)2(k)re rk8

runoff, peak flows during storm events, erosion, and pollutant transport. The use of traditional runoff management technology, such as piping, channeling, and curbing, has aggravated these impacts.

Efforts should be made to restore previously developed or redeveloping sites so they more closely mimic predevelopment hydrologic conditions. The predevelopment condition should be estimated based on historical records and existing slopes, soils, and natural drainage features. Consideration should be given to the time of concentration—the time it takes water to travel from the farthest point in a subwatershed to the outlet. (Sites might contain multiple subwatersheds and multiple outlets.) Paving and curbing substantially reduce time of concentration, resulting in high peak flows during storms. Time of concentration can be

More information about the Downspout Disconnection Program can be found at http://www.portlandonline.com/oni/index.cfm?c=28992.

10.3.3.2 Encourage overland sheet flow

Concentrated flow of runoff during storms results in decreased time of concentration, decreased infiltration, and increased erosion due to high runoff velocity. Careful regrading to reduce steep slopes slows runoff, promotes in used. Excess compaction of these areas by heavy equipment should be avoided. To enhance the benefits of vegetated areas, part of a site can be regraded during redevelopment activities to direct runoff to these areas. See Management Measure 3: Watershed Protection (section 3.3.3.8) for a discussion of urban forestry practices that can help in achieving these goals.

10.3.3.6 Reestablish ground water recharge

Traditional development techniques that focus on quickly conveying runoff off-site have resulted in decreased infiltration of rainfall to ground water. This ground water deficit results in a lowered water table and decreased seepage and baseflow in streams during dry periods. Infiltration practices can be installed to promote ground water recharge. Such practices include infiltration trenches, infiltration basins, sand filters, biofiltration systems, and vegetated areas underlain by permeable soils (see Management Measure 5: New Development Runoff Treatment).

A Watershed Restoration Plan for the Norwalk River Watershed

Habitat quality and water quality in the Norwalk River watershed of southeastern Connecticut have been degraded by erosion, sediment, pesticides, excessive algae growth, driftwood and other impoundments, and other types of pollution associated with increased watershed urbanization (NWRI, 1998). In 1997 federal, state, and local government agencies, environmental groups, and concerned citizens formed the Norwalk River Watershed Initiative (NRWI) to halt further degradation and promote cd 81.(ps)-8()4(er

when the tools are applied together; otherwise, the same sources that degraded the stream remain unchanged, causing similar effects.

A resource for information about restoring natural streams is *Stream Corridor Restoration: Principles, Processes, and Practices* (FISRWG, 2000), which is available for purchase or download at http://www.usda.gov/stream_restoration/newgra.html. Another resource is *Urban Stream Restoration: A Video Tour* the height and angle of eroded banks, a series of different tools can be applied to stabilize the

Restoring Atlanta's Watersheds

The International Life Sciences Institute's Risk Science Institute (RSI) was tasked with assessing the

10.3.4.5 Protect critical stream substrates

A stable, heterogeneous streambed is often a critical requirement for fish spawning and secondary production by aquatic insects. The bed of an urban stream, however, is often highly unstable and clogged by deposits of fine sediment. It is often necessary to mechanically restore the quality of stream substrates at points along the stream channel. Often, the energy of urban storm water can be used to create cleaner substrates through the use of flow concentrators and other manufactured devices. (See Management

10.3.6 Redevelop Urban Areas to Decrease Runoff-Related Impacts

10.3.6.1 Encourage infill development

Infill development is a tool planners use to encourage siting of new development on unused lands in existing urban areas. Infill development usually works in tandem with community redevelopment initiatives to foster revitalization of exis

The brownfields initiative has several advantages for communities with underused, potentially contaminated sites. It provides a catalyst for assessment of urban areas for sites in need of clean-up and redevelopment to improve the community's surface water and ground water quality, quality of life, and property values. Redeveloping properties that have already been disturbed helps to prevent development of greenfields—undeveloped suburban areas—and slows the growth of imperviousness in the outskirts of urban areas. It also provides an incentive for communities to alleviate soil and ground water contamination and to convert abandoned, eyesore lands to viable businesses, recreational facilities, or other uses.

In 2002, the brownfields program was expanded a

10.4 Information Resources

The *Anacostia Watershed Restoration Progress and Conditions Report 1990–1997* summarizes accomplishments and ongoing projects of the Anacostia Watershed Resoration Committee as they relate to their six restoration goals. In addition, the report provides recommendations to the committee for future actions to sustain and further promote the restoration effort.

The Federal Interagency Stream Restoration Working Group (2000), which is a collaboration document is a summary of the information available regarding the pollutant removal effectiveness of the most common LID practices. The report is available for download in PDF format at http://www.epa.gov/owow/nps/lidlit.html. This page also contains links to low-impact development fact sheets on bioretention, vegetated roof covers, permeable pavements, and street surface storage of runoff.

EPA's River Corridor and Wetland Restoration Web site contains general information about restoration and its benefits, a list of restoration guiding principles that cover the entire life of a restoration project from early planning to postimplementation monitoring, restoration project descriptions, and links to other restoration resources. The site is located at http://www.epa.gov/owow/wetlands/restore.

The Center for Watershed Protection developed 11 manuals, called the Urban Subwatershed Restoration Manual Series, that present the information needed to restore small urban watersheds in a format that can easily be accessed by watershed groups, municipal staff, environmental consultants, and other users. The manuals are available for a fee in hard copy or as a download at http://www.cwp.org/USRM_verify.htm.

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MANAGEMENT MEASURE 11
OPERATION AND MAINTENANCE

11.1 Management Measure

Develop a program for regular inspection and maintenance of urban runoff management practices.

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Maintenance activities may vary by management practice. For example, vegetation management is necessary for some extended detention wet ponds and constructed wetlands to maintain optimal removal efficiency, to avoid the net export of nutrients during winter, and to maintain design flow patterns. Removal of sediment build-up is essential to maintain properly functioning practices. Infiltration devices must be protected and maintained to prevent pore clogging and loss of infiltration capacity.

Preventative maintenance may also be necessary to protect the performance of management practices. Run-on sedimentation from off-site areas may need to be addressed through stabilization measures to prevent unnecessary maintenance expenditures.

The incorporation of maintenance considerations into management practice designs will often reduce subsequent maintenance costs and repairs and help to avoid failures. For example, the removal of material from sediment traps can be facilitated by designs that allow easy access to accumulated sediments without specialized equipment. Safe and convenient access to inlet and outlet structures can reduce maintenance costs and prevent nuisance flooding. Finally, the use of proper construction techniques and phasing can reduce the potential for initial clogging of infiltration devices during the construction process.

Enforcement of inspection and maintenance programs is crucial to their success. A 1992 study in Maryland evaluated 250 storm water practices to determine whether they were being maintained in compliance with the state's Stormwater Management Act. The researchers found that after a few years, approximately one-third of the practices were not functioning as designed, and most required maintenance. Approximately one-half of the facilities were undergoing sedimentation and many had problems with clogging (Lindsey et al., 1992). Implementing the practices described under this management measure can help develop an effective O&M program for continued effectiveness and longevity of runoff management practices.

11.2.2 Management Measure Selection

This management measure was selected because improper operation and maintenance of runoff control practices can result in poor performance and increased discharge of pollutants to downstream waters. Flooding may occur and downstream channel stability could be jeopardized. Poorly maintained runoff systems also may increase risks to public safety and the potential for property damage.

To prevent these potential impacts, effective maintenance programs should include standards for the inspection and maintenance of runoff controls. The entities responsible for maintaining runoff controls must be clearly identified and adequate resources must be provided to conduct the necessary maintenance activities. Because maintenance issues are critical to successful program implementation, they should be planned for at the outset of the runoff management program and conducted continuously for the lifespan of the practice(s).

The following section contains descriptions of specific O&M requirements for various types of management practices.

11.3.1.3

11.3.1.5 Schedule maintenance, cleaning, and debris removal to avoid sediment accumulation

Sediment and debris can contain hazardous contaminants and can clog filtration and infiltration practices, reducing their effectiveness over time. In addition to major structural controls, maintenance programs should include measures for cleaning catch basins and drainage channels. Establishment of an effective O&M program should include the creation of maintenance logs

Table 11.1: Properties of urban storm water solids/residuals (adapted from USEPA, 1999).

Properties of Residuals	Wet Ponds[1]	Sediment Basin[2]	Swirl and Helical Bend Solids Separators[3]	In-Line Upsized Storm Conduit[4]	Urban Storm Water Runoff Residuals[5]
Solids					
Volatile Suspended Solids	6%	104–155 mg/l	107,310 mg/l	25,800 mg/l	90 mg/l
Total Suspended Solids	43%	233–793 mg/l	344–1,140 mg/l	161,000 mg/l	415 mg/l
Nutrients					
Phosphorus	583 mg/kg	< 5 mg/l	<5 mg/l	0.3–2,250 mg/l	502–1,270 mg/kg
Total Kjeldahl Nitrogen	2,931 mg/kg	<5 mg/l	<5 mg/l	0.3–2,250 mg/l	1,140–3,370 mg/kg
Heavy Metals					
Zinc	6–3,171 mg/kg				302–352 mg/kg
Lead	11–748 mg/kg				251–294 mg/kg
Chromium	4.8–120 mg/kg				168–458 mg/kg
Nickel	3–52 mg/kg				69–143 mg/kg
Copper	2–173 mg/kg				251–294 mg/kg
Cadmium	No detect–15 mg/kg				
Iron		6.1–2,970 mg/l	6.1–2,970 mg/l	6.1–2,970 mg/l	
Hydrocarbons	2,087-12,892 mg/kg				

[1] Scheuler and Yousef, 1994
[2] Marquette University, 1982 (Racine, Wisconsin)
[3] Marquette University, 1982 (Boston, Massachusetts)
[4] Marquette University, 1982 (Lansing, Michigan)
[5] Field and O'Shea, 1992

A system for managing residuals in runoff should address the proper handling and disposal of both liquid and solid residuals. Ponds, infiltration practices, vegetative controls, and catch basin inserts have different removal mechanisms, and the type of residuals generated from these practices will vary. All residuals should be tested for contamination (unless the management entity has determined that residuals from an individual practice or category of practices pose no hazard), and maintenance employees should be trained in properly identifying and handling contaminated waste according to the requirements of the Resource Conservation and Recovery Act (RCRA) and state and local regulations (USEPA, 1999). Removal mechanisms and requirements for specific practices are described below.

Non-hazardous solids in residuals can be recycled, sent to a landfill, or applied to land. Land application involves spreading the material on designated land at approved application rates. The material should not be applied to cropland, but application to a nonagricultural vegetated area may be appropriate (USEPA, 1999). Disposal of the waste in a landfill may be the most expensive option because of travel costs, testing requirements, and disposal fees (Lenhart and Harbaugh, 2000).

Table 11.3 (continued).

Category	Management Practice	Annual Maintenance Cost (% of Construction Cost)	Maintenance Cost for a "Typical" Application	Maintenance Activity	Schedule
				– Cleaning and removal of debris after major storm events (>2" rainfall) – Harvesting of vegetation when a 50% reduction in the original open water surface area occurs – Repair of embankment and side slopes – Repair of control structure	Annual or as needed

Table 11.3 (continued).

11.3.3.3 Ponds and wetlands

Extended dry detention ponds are submerged only during storms and are dry between storms. Depending on the type of vegetative cover used, they may require mowing at least once a month to maintain turf grass cover, or once a year to prevent the establishment of woody vegetation. Sediments should be removed when they are dry and cracked to separate them from vegetation more easily. Pilot or low-flow channels require inspection to prevent undermining of concrete channels and overgrowth of stone channels. Inlets and outlets should be cleared of sediment and debris to prevent clogging.

Wet ponds are susceptible to algae blooms as a result of high nitrogen levels and may need to be cleaned periodically. Sediments that accumulate in the pond inlet or forebay should be removed more frequently than fine sediment, which collects near the pond outlet. Sediment removal requires draining the pond (some water to maintain fish populations should be left), collection of solids, and drying and testing of the residuals before disposal. Pond water should be disposed of in a locally approved manner; it should be tested for pollutants and released to the receiving water, if allowed. s7pond Td 19.44 0 TdD[more emo thepl. P8(W)nd llud 0 Td(oi8(W)n)1(g)9(Tw 19.44)]TJ-044 0es)- (

If clogging results in pooling, sediment can be removed to restore the facility to its original capacity. If the standing water results from high water table conditions, the facility owner should consider converting the site to a permanent pool facility such as a constructed wetland or detention pond. For systems designed with filter fabric to collect sediments, periodic inspections can identify when and where the mesh should be replaced. In cold climates where street sanding occurs in the winter, the filter fabric in infiltration devices adjacent to roads and parking lots should be replaced prior to spring.

Promotion of a vegetative cover will help to maintain percolation rates, slow runoff velocity, and minimize ground water pollution. To maintain aeration and permeability, nonvegetated basins require tilling or disking and leveling after sediment is removed. Vegetated filters adjacent to infiltration trenches should be cleared of sediments periodically to prevent sediment loading to the trench.

Regular monitoring of infiltration rates after storms will indicate when maintenance is required to maintain the system’s treatment design capacity.

11.3.3.5 Filtration practices

Filtration practices include media filters (typically sand) and biofilters. Sand filters contain two phases: a sedimentation chamber and a filtration chamber. The sedimentation chamber can be inspected by measuring to determine if the deposited sediments are becoming deep enough to interfere with the filtration chamber. Different types of sand filters require different levels of maintenance. The Austin sand filter system usually requires maintenance every five to 10 years, depending on the stability of soils in the contributing areas, and can be treated like a dry detention facility. The filter component can be raked of fine sediments or skimmed with a shovel to restore permeability. The Washington and Delaware sand filter sedimentation chambers, which maintain a pool of water, should be vacuumed to remove sediment when inspections identify accumulation greater than 75 percent of capacity. Filtration chambers for these systems may need to be cleaned of fine particles as frequently as twice per year to maintain their efficiency and prevent overflows. A flat-bottomed shovel can be used to remove the sediment-laden filter media and roughen surfaces to improve permeability.

Each system should be inspected for vandalism, leaks, cracks, or damage to concrete at least once per year. These problems should be remedied immediately. Forebays should be pumped or cleaned as necessary. All materials removed from the systems should be tested for contamination and to identify how the material should be disposed of (e.g., as clean fill, in a landfill, or as a hazardous waste).

Biofiltration system vegetation should be mowed periodically to maintain an optimum height (2 to 6 inches) that maximizes infiltration and minimizes runoff velocity. Special effort should be made to promote native species and exclude invasive species, which can grow too vigorously and reduce treatment capacity. Some natural vegetation replacement is desirable, such as wetland plants that colonize a low-lying biofilter. Inspection and maintenance records should reflect these changes.

Biofiltration facilities should be inspected and maintained regularly. Sediment removal is an important and sometimes expensive part of biofilter maintenance. Sediment should be removed when it fills 20 percent of the design depth in

Table 11.4 (continued).

Equipment	Purchase	Rent (per day)
Materials (continued)		

11.4 Information Resources

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MANAGEMENT MEASURE 12
EVALUATE PROGRAM EFFECTIVENESS

12.1 Management Measure

Develop and implement a program to evaluate and improve the effectiveness of the urban runoff management program.

12.2 Management Measure Description and Selection

12.2.1 Description

The purposes of this management measure are to:

- Determine whether implementation of the runoff management program framework is protecting and/or improving water quality by evaluating management practices that are being used to meet Management Measure 1. If these practices aren't effective, improvements to the runoff management program framework should be implemented.

- Periodically reassess the watershed (see Management Measure 2) to determine whether aspect of the program framework will require a different type of measurement. Watershed sediments, and the biological community, Florida measures program success by the number of

12.3.2 Track Management Practice Implementation

Implementation monitoring can be used to determine the extent to which management measures and practices are implemented in accordance with relevant standards and specifications. This

12.3.2.3 Use geographic information systems

Geographic information systems (GISs) are useful tools for inventorying management practice implementation. A GIS can detect and track trends in management practice implementation, land treatment, changes in land use, and virtually any data related to management practices and water quality. Another advantage is the ability of a GIS to update information and integrate it with existing data in a timely manner. GISs allow watershed managers to do more than just manage information in a database—they are powerful analysis tools that can be used to design sampling protocols for tracking studies and help watershed managers analyze program effectiveness by integrating land treatment and water quality information.

12.3.2.4 Develop surveys

Surveys of property managers and developers can be used to collect background information about management practice implementation, such as:

- Type, number, and size of management practices installed
- Management practice location/watershed
- Land use (i.e., residential, commercial, industrial)
- Percent impervious area
- Inspection results
- Operation and maintenance practices

Maryland's GIS-Based Restoration Project Tracking Database

The Maryland Department of Natural Resources has developed a Restoration Project Tracking Database that provides a list of riparian forest buffer and stream restoration projects by watershed and county with details such as waterway; length, width, area, and other quantifiers as appropriate; and details about the project such as owner type, planting reason, year established or completed, and project components. These data can be displayed in tabular format and are linked on the Web site to an interactive GIS for the public and interested partiesecows (MDNR, 2004). The databas can be accessed at

- Dates of management practice installation
- Design specifications
- Type of water body or area protected
- Previous management practices used
- Erosion and sediment control plans (for construction)
- Dates of plan preparation and revisions
- DBDC BT6 0.0004 T06 Tw 0oti5(tio-11(a)-5(eviimpl(nt pra)5(c)]TJETEMC /P BDC BT/TT1 1 Tf0 Tc 0

The review should help determine whether existing data provide sufficient information to address the monitoring goals and what data gaps exist.

The next step should be to identify project constraints such as finances, staffing, and time. Clear and detailed information should be obtained on the time frame for management decisions, the amounts and types of data that must be collected, the level of effort required to collect them, and the equipment and personnel needed to conduct the monitoring. This will determine whether available personnel and budget are sufficient to implement or expand the monitoring program.

As with its design, the program's level of monitoring is largely determined when goals and objectives are set, although there is some flexibility for achieving most monitoring objectives. Watershed managers should determine the appropriate timeframe and geographic scope of the monitoring program based on program goals and objectives. For example, if the objective is to determine the effectiveness of a nutrient management program for reducing nutrient inputs to a downstream lake, monitoring a subwatershed for five years or longer might be necessary.

Watershed managers also need to

Another important aspect of setting up a monitoring and evaluation program is variable selection. Variables should be selected based on the monitoring objectives. For example, if a dissolved oxygen problem is suspected, then dissolved oxygen should be monitored in addition to biochemical oxygen demand, sediment oxygen demand, temperature, and nutrients. Surrogate measures can also be used to satisfy monitoring objectives. For example, if the objective is to monitor the condition of salmon spawning areas, surrogate measures are necessary because the condition of salmon spawning areas is a composite of many factors. Good surrogate variables would be stream bank undercut, embeddedness, and vegetative overhang (Platts et al., 1983). The corresponding surrogate goals could be to reduce cobble embeddedness and to increase vegetative overhang to appropriate

A guidance manual describing protocols for monitoring the effectiveness of storm water management practices, *Urban Stormwater BMP Performance Monitoring*, is available for download in PDF format from the International Stormwater Best Management Practices

12.4 Information Resources

Restoring Life in Running Waters: Better Biological Monitoring (Karr, 1998) describes how and why biological monitoring and multi-metric indices can be used to assess environmental degradation and how this information can be integrated into regulatory and policy decisions. This book can be purchased at bookstores or ordered from Island Press at http://www.islandpress.com/.

Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls, published by EPA's Office of Water in 1997, gives an overview of nonpoint source pollution and covers the development of a monitoring plan, data analysis, quality assurance/quality control, and biological monitoring. It can be ordered through EPA’s R/Span kre

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