United States
Environmental Protection
Agency

Office of Water
(WH-553)
Washington, D.C. 20460

May 1991

EPA

Proposed Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters

Proposed Under the Authority of
Section 6217(g) of the Coastal Zone Act
Reauthorization Amendments of 1990

FOREWORD

This document contains proposed guidance specifying management measures for sources of nonpoint pollution in coastal waters. Nonpoint pollution is the pollution of our Nation's waters by runoff from the land surface. In the Coastal Zone Act Reauthorization Amendments of 1990, Congress recognized that nonpoint pollution is a key factor in the continuing degradation of many coastal waters, and established a new program to address this pollution.

The new program established by Congress recognizes that the solution to nonpoint pollution lies in State and local action. It calls for the development and implementation of State coastal nonpoint pollution programs. These State programs are to be developed in conformity with technical guidance developed by EPA on the best, economically achievable measures available to protect coastal waters from nonpoint pollution. This document proposes that "management measures guidance."

The proposed management measures guidance addresses five source categories of nonpoint pollution: agriculture, silviculture, urban, marinas, and hydromodification. A suite of management measures is provided for each source category. The number and type of systems identified per source category are based upon the range and diversity of substantively different subcategories, activities, and pollutants. In addition, the guidance contains a chapter that provides information on other tools available to address many source categories of nonpoint pollution; these include vegetated filter strips, forested buffer strips, and wetlands. EPA regards this proposed guidance as a significant beginning to a year-long process of refinement, ending with publication of the final guidance in May 1992. We welcome public comments, information and data relevant to this continuing effort.

EPA will also soon be publishing, jointly with the National Oceanic and Atmospheric Administration, proposed guidance for the approval of State programs that implement management measures. That guidance will explain more fully how the management measures guidance proposed today would be implemented in State programs. EPA encourages reviewers of this document to review and comment upon that forthcoming guidance as well.

Robert H. Wayland, III, Director,
Office of Wetlands, Oceans, and Watersheds

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CHAPTER 1

INTRODUCTION

I. BACKGROUND

This proposed guidance on management measures is required under section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990. It provides guidance to States and Territories on the types of management measures that should be included in State and Territorial coastal nonpoint pollution control programs. *This Chapter explains in detail the statutory requirements,* the approach used to develop management measures, and the process for developing final management measures guidance, and discusses issues related to State program development and approval. While the program development and approval issues discussed in this Chapter provide a framework for understanding the management measures guidance, the issues will be more fully developed in draft program guidance scheduled to be published for public comment in July 1991.

A. Nonpoint Source Pollution

1. What Is Nonpoint Source Pollution?

Nonpoint source pollution is the pollution of our nation's waters from diffuse sources. It is caused by rainfall or snowmelt moving over and through the ground and carrying natural and manmade pollutants into lakes, rivers, streams, wetlands, estuaries, other coastal waters, and ground water. (As discussed below, some diffuse sources are regulated under the NPDES program as point source discharges.)

A more detailed discussion of the range of nonpoint sources and their effects on water quality and riparian habitats is provided in subsequent chapters of this guidance.

2. National Efforts to Control Nonpoint Pollution

a. Nonpoint source program

During the first fifteen years of the national program to abate and control water pollution, EPA and the States have focused most of their water pollution control activities upon traditional "point sources", such as discharges through pipes from sewage treatment plants and industrial facilities. These point sources have been regulated by EPA and the States through the National Pollutant Discharge Elimination System (NPDES) permit program established by Section 402 of the Clean Water Act. Discharges of dredged and fill materials into wetlands have also been regulated by the U.S. Army Corps of Engineers and EPA under Section 404 of the Clean Water Act.

As a result of the above activities, the Nation has greatly reduced pollutant loads from point source discharges and has made considerable progress in restoring and maintaining water quality.

However, the gains in controlling point sources have not solved all of the nation's water quality problems. Recent studies and surveys by EPA and by State water quality agencies indicate that the majority of the remaining water quality impairments in our nation's rivers, streams, lakes, estuaries, coastal waters, and wetlands result from nonpoint source pollution and other nontraditional sources, such as urban stormwater discharges and combined sewer overflows.

In 1987, given the progress achieved in controlling point sources, coupled with the growing national awareness of the increasingly dominant influence of nonpoint source pollution on water quality, Congress amended the Clean Water Act to focus greater national efforts on nonpoint sources.

In the Water Quality Act of 1987, Congress amended 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.

More importantly, Congress enacted Section 319 of the Clean Water Act, which established a national program to control nonpoint sources of water pollution. Under Section 319, States address nonpoint pollution by assessing nonpoint source pollution problems and causes within the State; adopting management programs to control the nonpoint source pollution; and implementing the management programs. Section 319 provides for the issuance by EPA of grants to States to assist them in implementing those management programs or portions of management programs that have been approved by EPA.

b. National estuary program

EPA also administers the National Estuary Program under Section 320 of the Clean Water Act. This program focuses upon point and nonpoint pollution in geographically targeted, high-priority estuarine waters. In this program, EPA assists State, regional and local governments to develop comprehensive conservation and management plans that recommend priority corrective actions to restore estuarine water quality, fish populations, and other designated uses of the waters.

c. Pesticides program

Another program administered by EPA that controls some forms of nonpoint pollution is the pesticides program under the Federal Insecticide, Fungicide, and Rodenticide Act. Among other things, this program authorizes EPA to control pesticides that may threaten ground and surface water. This approach entails determining the pesticide's potential for leaching into ground and surface waters; if there is such potential, determining whether national-label restrictions will adequately address leaching concerns; if not, determining whether additional training required by restricted use classification for the pesticide will provide adequate protection; and if not, determining whether providing States with the opportunity to develop State Management Plans for the chemical will effectively address the contamination risk. In the event EPA cannot determine that State plans would sufficiently reduce the risks to human health and the environment (i.e., an unreasonable risk remains), then EPA would resort to national cancellation.

EPA's approach to State management is described in a proposed Pesticides and Ground-Water Strategy currently undergoing review by the Office of Management and Budget. The strategy describes the policies and regulatory approaches that the Agency will use to protect the Nation's ground-water resources from risks of contamination by pesticides. Linkage to and integration with other evolving EPA/State programs is critical in order to avoid duplication of effort while promoting related activities.

B. Coastal Zone Management

The Coastal Zone Management Act of 1972 established a program for States and Territories to voluntarily develop comprehensive programs to protect and manage coastal resources (including the Great Lakes). In order to receive federal approval and implementation funding, States and Territories had to demonstrate that they had programs, including enforceable policies, that were sufficiently comprehensive and specific to regulate land uses, water uses, and coastal development; and to resolve conflicts among competing uses. In addition, they had to have the authorities to implement the enforceable policies.

There are 29 federally approved State and Territorial programs. Despite institutional differences, each program must protect and manage important coastal resources, including: wetlands, estuaries, beaches, dunes, barrier islands, coral reefs, and fish and wildlife and their habitats. Resource management and protection is accomplished in a number of ways through State laws, regulations, permits, and local plans and zoning ordinances.

While water quality protection is integral to the management of many of these coastal resources, it was not specifically cited as a purpose or policy of the original statute. The Coastal Zone Act Reauthorization Amendments of 1990 described below specifically charged State coastal programs, as well as State nonpoint source programs, with addressing nonpoint source pollution affecting coastal water quality.

C. Coastal Zone Act Reauthorization Amendments of 1990

1. Background and Purpose of the Amendments

On November 5, 1990, Congress enacted the Coastal Zone Act Reauthorization Amendments of 1990. These Amendments were intended to address several concerns, a major one of which is the impact of nonpoint source pollution on coastal waters. In Section 6202(a) of the Amendments, Congress made a set of findings; the following findings are pertinent here:

"1. Our oceans, coastal waters, and estuaries constitute a unique resource. The condition of the water quality in and around the coastal area is significantly declining. Growing human pressures on the coastal ecosystem will continue to degrade this resource until adequate actions and policies are implemented.

"2. Almost one-half of our total population now lives in coastal areas. By 2010, the coastal population will have grown from 80,000,000 in 1960 to 127,000,000 people, an increase of approximately 60 percent, and population density in coastal counties will be among the highest in the Nation.

"3. Marine resources contribute to the Nation's economic stability. Commercial and recreational fishery activities support an industry with an estimated value of $12,000,000,000 a year.

"4. Wetlands play a vital role in sustaining the coastal economy and environment. Wetlands support and nourish fishery and marine resources. They also protect the Nation's shores from storm and wave damage. Coastal wetlands contribute an estimated $5,000,000,000 to the production of fish and shellfish in the United States coastal waters. Yet, 50 percent of the Nation's coastal wetlands have been destroyed, and more are likely to decline in the near future.

"5. Nonpoint source pollution is increasingly recognized as a significant factor in coastal water degradation. In urban areas, storm water and combined sewer overflow are linked to major coastal problems, and in rural areas, runoff from agricultural activities may add to coastal pollution.

"6. Coastal planning and development control measures are essential to protect coastal water quality, which is subject to continued ongoing stresses. Currently, not enough is being done to manage and protect coastal resources.

. . . .

"8. There is a clear link between coastal water quality and land use activities along the shore. State management programs under the Coastal Zone Management Act of 1972 (16 U.S.C. 1451 et seq.) are among the best tools for protecting coastal resources and must play a larger role, particularly in improving coastal zone water quality. . . ."

Based upon these findings, Congress declared that:

"It is the purpose of Congress in this subtitle [the Coastal Zone Act Reauthorization Amendments of 1990] to enhance the effectiveness of the Coastal Zone Management Act of 1972 by increasing our understanding of the coastal environment and expanding the ability of State coastal zone management programs to address coastal environmental problems." (Section 6202(b))

2. State Coastal Nonpoint Pollution Control Programs

To address more specifically the impacts of nonpoint source pollution on coastal water quality, Congress enacted Section 6217, "Protecting Coastal Waters". This section provides that each State with an approved coastal zone management program must develop and submit to EPA and NOAA for approval a Coastal Nonpoint Pollution Control Program. The purpose of the program "shall be to develop and implement management measures for nonpoint source pollution to restore and protect coastal waters, working in close conjunction with other State and local authorities."

Coastal nonpoint pollution control programs are not intended to supplant existing coastal zone management programs and nonpoint source management programs. Rather, they are to serve as an update and expansion of existing nonpoint source management programs and are to be coordinated closely with the existing coastal zone management programs. The legislative history indicates that the central purpose of section 6217 is to strengthen the links between Federal and State coastal zone management and water quality programs and to enhance State and local efforts to manage land use activities which degrade coastal waters and coastal habitats. The legislative history further indicates that State coastal zone and water quality agencies are to have co-equal roles, analogous to the sharing of responsibility between NOAA and EPA at the Federal level.

Section 6217(b) states that each State program must "provide for the implementation, at a minimum, of management measures in conformity with the guidance published under subsection (g) to protect coastal waters generally," and also to:

(1) Identify land uses which, individually or cumulatively, may cause or contribute significantly to a degradation of (a) coastal waters where there is a failure to attain or maintain applicable water quality standards or protect designated uses, or (b) coastal waters that are threatened by reasonably foreseeable increases in pollution loadings from new or expanding sources;

(2) Identify critical coastal areas adjacent to coastal waters identified under the preceding paragraph;

(3) Implement additional management measures applicable to land uses and areas identified under paragraphs (1) and (2) above that are necessary to achieve and maintain applicable water quality standards and protect designated uses;

(4) Provide technical assistance to local governments and the public to implement management measures;

(5) Provide opportunities for public participation in all aspects of the program;

(6) Establish mechanisms to improve coordination among State and local agencies and officials responsible for land use programs and permitting, water quality permitting and enforcement, habitat protection, and public health and safety; and

(7) Propose to modify State coastal zone boundaries as necessary to implement NOAA recommendations under Section 6217(e), which are based on findings that inland boundaries must be modified to more effectively manage land and water uses to protect coastal waters.

EPA is required to publish proposed management measures guidance under section 6217(g) by May 1991 and final guidance by May 1992. Within 30 months of EPA's publication of final guidance, States must develop and obtain EPA and NOAA approval of their coastal nonpoint pollution control programs. Failure to submit an approvable program (i.e., one that meets the requirements of section 6217(b)) results in a reduction of Federal grant dollars under the nonpoint source and coastal zone management programs. The reductions begin in Fiscal Year 1996 as a 10% cut, increasing to 15% in FY 1997, 20% in FY 1998, and 30% in FY 1999 and thereafter.

3. Management Measures Guidance

Section 6217(g) of the Coastal Zone Act Reauthorization Amendments of 1990 requires EPA to publish (and periodically revise thereafter), in consultation with NOAA, the Fish and Wildlife Service, and other Federal agencies, "guidance for specifying management measures for sources of nonpoint pollution in coastal waters." "Management measures" are defined in section 6217(g)(5) as:

> economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives.

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The management measures guidance is to include at a minimum six elements set forth in section 6217(g)(2):

"(A) a description of a range of methods, measures, or practices, including structural and nonstructural controls and operation and maintenance procedures, that constitute each measure;

"(B) a description of the categories and subcategories of activities and locations for which each measure may be suitable;

"(C) an identification of the individual pollutants or categories or classes of pollutants that may be controlled by the measures and the water quality effects of the measures;

"(D) quantitative estimates of the pollution reduction effects and costs of the measures;

"(E) a description of the factors which should be taken into account in adapting the measures to specific sites or locations; and

"(F) any necessary monitoring techniques to accompany the measures to assess over time the success of the measures in reducing pollution loads and improving water quality."

State coastal nonpoint pollution control programs must implement management measures that are in conformity with this management measures guidance.

The legislative history (Floor statement of Rep. Gerry Studds, House Sponsor of Section 6217, as part of debate on Omnibus Reconciliation Bill, October 26, 1990) confirms that, as indicated by the statutory language, the "management measures" approach is technology-based rather than water-quality based. That is, the management measures, in a manner analogous to the technology-based requirements previously established for point sources, are to be based upon technical and economic achievability, rather than on establishing cause and effect linkages between particular land use activities and particular water quality problems. Congress' rationale is that, with few exceptions, neither States nor EPA have the money or the time to create the complex monitoring programs that would be required to document a causal link between specific land use activities and specific water quality problems. Under the approach adopted by Congress, States will be able to concentrate their resources on developing and implementing measures that experts agree will reduce pollution significantly.

The legislative history indicates that the range of management measures anticipated by Congress is broad and may include, among other measures, use of buffer strips, setbacks, techniques for identifying and protecting critical coastal areas and habitats, soil erosion and sedimentation controls, and siting and design criteria for water-related uses such as marinas. However, Congress has cautioned that the management measures should not unduly intrude upon the more intimate land use authorities properly exercised at the local level.

The legislative history also indicates that the management measures guidance, while patterned to a degree after the point source effluent guidelines technology-based approach (see 40 CFR Parts 400-471 for examples of this approach), is not expected to have the same level of specificity as effluent guidelines. Congress has recognized that the effectiveness of a particular management measure at a particular site is subject to a variety of factors too complex to address in a single set of simple, mechanical prescriptions developed at the federal level. Thus, the legislative history indicates that EPA's guidance should offer State officials a number of options and permit them considerable flexibility in selecting management measures that are appropriate for their State.

An additional major distinction drawn in the legislative history between effluent guidelines for point sources and management measures guidance is that the management measures will not be directly or automatically applied to categories of nonpoint sources as a matter of Federal law.

Instead, the measures must be established under State law, or under local authorities as described through the State coastal nonpoint pollution control program. The State program must provide for the implementation of management measures in conformity with the management measures guidance. Under section 306(d)(16) of the CZMA, coastal zone programs must provide for enforceable policies and mechanisms to implement the applicable requirements of the State coastal nonpoint pollution control program, including management measures.

II. DEVELOPMENT OF PROPOSED MANAGEMENT MEASURES GUIDANCE

A. Schedule and Process Used to Develop Proposed Guidance

1. Schedule

Congress established a six-month deadline (May 5, 1991) for publication of this proposed guidance, and an eighteen-month deadline (May 5, 1992) for publication of the final guidance.

Given the extremely tight statutory deadline for publishing proposed guidance, EPA has worked to make this proposed guidance as broad and comprehensive as possible. To assist the public in commenting on the proposal, we have included below a discussion of our plans for completing the guidance by May 1992. While significant revisions are likely over the course of the nest twelve months, we hope that this proposed guidance clearly outlines EPA's direction and technical approach being considered for the final guidance, thereby providing for fair opportunity for review and comment by interested persons, organizations, and agencies.

2. Work Groups

To meet the tight statutory deadline and draw upon existing sources of technical nonpoint source expertise, EPA chose a work group approach to develop the guidance. Since the guidance is to address all significant categories of nonpoint sources that impact or could impact coastal waters (see Background), EPA drew upon expertise covering the very wide range of subject areas addressed in this guidance.

Because nonpoint experts tend to specialize in particular source categories, EPA decided to form work groups on a category basis. Thus, in consultation with NOAA, the U.S. Fish and Wildlife Service, and other Federal and State agencies, EPA established five work groups to develop this proposed guidance:

(1) Urban, Construction, Highways, Airports/Bridges, and Septic Systems
(2) Agriculture
(3) Forestry
(4) Marinas and Recreational Boating
(5) Hydromodification, Dams and Levees, Shoreline Erosion, and Wetlands

A list of the members in each of these Federal-State workgroups is provided in Appendix A of this guidance.

3. Meetings

EPA focused its initial efforts on briefing various governmental and other groups on the scope of the new coastal legislation; obtaining a broad range of input on potential approaches to developing the management measures guidance; scoping out options for writing management measures; and inviting participation by various interested EPA and NOAA offices and other Federal and State agencies in the work groups.

Some of the groups that EPA met with to discuss potential approaches to implementing the new legislation include the Association of State and Interstate Water Pollution Control Administrators (ASIWPCA), the Coastal States Organization (CSO), several Federal agencies, and the Natural Resources Defense Council.

On January 16, 1991, EPA held the first work group meeting, attended by over 30 Federal and State agency staff with expertise in coastal nonpoint pollution issues. That meeting resulted in commitments for assistance and, in some cases, substantial participation in the effort, especially by USDA and NOAA. Each workgroup has held at least one meeting since February, 1991, with the agriculture work group meeting three times and the urban group holding a two-day meeting. Other groups have utilized teleconferencing for additional communication. Both Federal and State work group members have participated in drafting and reviewing this proposed guidance.

B. Scope and Contents of This Proposed Guidance

1. Categories of Nonpoint Sources Addressed

Many categories and subcategories of nonpoint sources could affect coastal waters and thus could potentially be addressed in this management measures guidance. Including all such sources in this proposed guidance would require more time than the tight statutory deadline allows. For this reason, Congressman Studds stated in his floor statement, "The Conferees expect that EPA, in developing its guidance, will concentrate on the large nonpoint sources that are widely recognized as major contributors of water pollution."

This proposed guidance thus focuses on five major categories of nonpoint sources that impair or threaten coastal waters nationally: (1) agricultural runoff; (2) urban runoff (including developing and developed areas); (3) silvicultural (forestry) runoff; (4) marinas and recreational boating; and (5) hydromodification, dams and levees, and shoreline erosion. EPA has also included management measures for wetlands, riparian areas, and filter strips that apply generally to various categories of sources of nonpoint pollution. Some categories that have not been addressed but may be responsible for nonpoint source pollution in some coastal waters include oil and gas operations; mining activities; land disposal of wastes; and in-place contamination (sediments). EPA intends to investigate these activities' impacts on coastal waters as time and resources allow. We welcome comments from the public on these and other categories that might appropriately be addressed in the management measures guidance.

2. Overlaps Between Nonpoint Sources and Point Sources

Historically, there have always been overlaps and ambiguity between programs designed to control nonpoint sources and point sources. The primary overlap occurs between the stormwater permit program (under section 402(p) of the Clean Water Act) and traditional urban runoff programs. Often, runoff may originate as a nonpoint source but ultimately be channelized and become a point source. A further complication arises because the Clean Water Act currently requires a permit for some municipal stormwater sources while postponing regulatory coverage of other (generally smaller) municipalities' storm water.

A second overlap occurs in connection with confined animal feeding operations. Concentrated animal feeding operations that meet particular size or other criteria are defined and regulated as point sources under the section 402 permit program. Other confined animal feeding operations are not currently regulated as point sources. Other overlaps may occur with respect to aspects of mining operations, oil and gas extraction, land disposal, and other activities.

EPA intends that the coastal nonpoint pollution control programs to be developed by the States apply only to sources that are not currently required to apply for and receive an NPDES permit, and that the management measures similarly apply only to sources that are not required to apply for and receive an NPDES permit. In this proposed guidance, EPA has attempted to avoid addressing activities that are clearly regulated point source discharges. However, for pollution sources for which there may be overlap or ambiguity, EPA has chosen to err on the side of inclusiveness in this proposed guidance and to include management measures to address those sources.

For example, the management measures guidance for marinas does not address pollution from vessels, including marine sanitation devices, which are regulated as point sources under sections 312 and 402 of the Clean Water Act. Nor does it address construction sites exceeding five acres in size, which are regulated under section 402 of the Act. On the other hand, the guidance does include urban runoff management measures. These will apply only to stormwater discharges that are not required to apply for and receive stormwater permits; however, they include some of the same measures that may be addressed in such stormwater permits. Readers should also note that a stormwater discharge that is currently exempt from permit requirements may be required to obtain a permit under section 402(p)(2)(E) of the Clean Water Act if EPA or a State determines that it contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States. Additional stormwater discharges may also be regulated as point sources under section 402(p)(6).

EPA will continue to evaluate overlapping areas and welcomes comment on our proposed attempts to deal with these areas.

3. Contents of This Proposed Guidance

This proposed guidance includes, for the five source categories addressed to date, the following:

(1) A specification of management measures;

(2) A description of the categories and subcategories of activities and locations for which each measure may be suitable;

(3) An identification of the individual pollutants or categories or classes of pollutants that may be controlled by the measures;

(4) A description of the water quality effects of the measures;

(5) Information regarding pollution reductions achievable with the management measures;

(6) Information on costs of the measures; and

(7) A description of some factors which should be taken into account in adapting the measures to specific sites or locations.

Due to the extremely tight time constraints imposed by the statute, EPA could not include detailed information on all of the items identified above, most notably pollutant reduction effectiveness and cost data. EPA will endeavor over the next year to obtain additional information for inclusion in the final guidance.

C. Development of Final Guidance: Request for Comments

Much needs to be accomplished between now and May 1992. EPA intends to examine and evaluate various data sources, including those listed in references listed at the end of many of the chapters of this document. In addition, EPA has existing, yet incomplete, data bases regarding the effectiveness of agricultural and urban management practices, and we will use this information to the extent possible. These data bases include information regarding the study conditions, practices applied, and pollutant reductions achieved. Other literature will be accessed through existing libraries of nonpoint source publications, including information maintained by Universities, other agencies, and State government. EPA will rely primarily on those articles published in the peer-reviewed technical literature, but will use other reliable sources as necessary.

EPA solicits comments on the proposed guidance, including additional information and supporting data on the measures specified in this guidance as well as additional management measures that may be as effective in controlling nonpoint source pollution. In particular, EPA requests the following:

(1) Information on the activities and locations for which each measure may be suitable and on factors which should be taken into account in adapting the measures to specific sites or locations.

(2) Information on the pollutants that may or may not be controlled by the measure.

(3) Data regarding the pollutant reduction effectiveness of the measures.

(4) Data regarding the costs of each measure.

EPA also welcomes comments on the general approach used in the proposed guidance, including the level of detail used to describe management measures.

Comments on this guidance should be mailed, within 120 days of publication of the Federal Register notice announcing the availability of this proposed guidance, to Steven Dressing, Assessment and Watershed Protection Division (WH-553), Office of Water, U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, DC 20460.

The review comments received as a result of public notice will be assessed and summarized. EPA will draw upon the information provided through public review and comment, the technical materials referenced throughout this proposed guidance, and other expertise as available to make final determinations as to the scope and content of the guidance.

III. TECHNICAL APPROACH TAKEN IN DEVELOPING THIS GUIDANCE

A. The Nonpoint Source Pollution Process

Nonpoint source pollutants are transported to surface water by a variety of means, including runoff and ground-water infiltration. Ground water and surface water are both considered part of the same hydrologic cycle when designing management measures. Ground-water contributions of pollutant loadings to surface waters in coastal areas are often very significant. The transport of nonpoint source pollutants to coastal waters through ground-water discharge is governed by physical and chemical properties of the water, pollutant, soil, and aquifer. Appendix B of the proposed guidance contains a discussion of the effects of various nonpoint source management practices on ground water.

1. Source Control

Source control is the first opportunity in any nonpoint source control effort. Source control methods very for different types of nonpoint source problems. Examples of source control include:

(1) Reducing or eliminating the introduction of pollutants to a land area. Examples include reduced nutrient and pesticide application.

(2) Preventing non-introduced pollutants from leaving the site during land-disturbing activities. Examples include conservation tillage; planning forest road construction to minimize erosion; siting marinas adjacent to deep waters to eliminate or minimize the need for dredging; and managing grazing to protect against overgrazing and the resulting increased soil erosion.

(3) Preventing interaction between precipitation and introduced pollutants. Examples include installing gutters and diversions to keep clean rainfall away from barnyards; diverting rainfall runoff from areas of land disturbance at construction sites; and timing chemical applications or logging activities based upon weather forecasts or seasonal weather patterns.

(4) Protecting riparian habitat and other sensitive areas. Examples include protection and preservation of riparian zones, shorelines, wetlands, and highly erosive slopes.

(5) Protecting natural hydrology. Examples include the maintenance of pervious surfaces in developing areas (conditioned based upon ground-water considerations); riparian zone protection; and water management.

2. Delivery Reduction

Pollution prevention often involves delivery reduction (intercepting pollutants prior to delivery to the receiving water) in addition to appropriate source control measures. Management measures include delivery reduction practices to achieve the greatest degree of pollutant reduction economically achievable, as required by the statute.

Delivery reduction practices intercept pollutants leaving the source by capturing the runoff or infiltrate, followed either by treating and releasing the effluent or by permanently keeping the effluent from reaching a surface or ground water resource.

By their nature, delivery reduction practices often bring with them side effects that must be accounted for. For example, management practices that intercept pollutants leaving the source may reduce runoff, but also increase infiltration to ground water. For example, infiltration basins trap runoff and allow for its percolation. These devices, although highly successful at controlling suspended solids, may not, because of their infiltration properties, be suitable for use in areas with high ground-water tables and nitrate or pesticide residue problems.

The performance of delivery reduction practices is to a large extent dependent on suitable designs, operational conditions, and proper maintenance. For example, filter strips may be effective for controlling particulate and soluble pollutants where sedimentation is not excessive, but may be overwhelmed by high sediment input. In many cases, filter strips are used as pretreatment or supplemental treatment for other practices within a management system.

These examples illustrate that the combination of source control and delivery reduction practices, and the application of those practices as components of management measures, are dependent upon site-specific conditions. Technical factors that may affect the suitability of management measures include, but are not limited to, land use, climate, size of drainage area, soil permeability, slopes, depth to water table, space requirements, the type and condition of the water resource to be protected, depth to bedrock, and the pollutants to be addressed. In the proposed management measure guidance below, some of these factors are discussed as they affect the suitability of particular measures. EPA expects to expand this aspect of management measures in the final guidance.

B. Management Measures as Systems

Technical experts who design and implement effective nonpoint source control measures do so from a management systems approach as opposed to an approach that focuses on individual practices. That is, the pollutant control achievable from any given management system is viewed as the sum of the parts, taking into account the range of effectiveness associated with each single practice, the costs of each practice, and the resulting overall cost and effectiveness. Some individual practices may not be very effective alone, but, in combination with others, may provide a key function in highly effective systems. This is analogous to the use of treatment "trains," or series of treatment steps, in most point source wastewater treatment systems.

Therefore, this guidance adopts the approach of specifying management measures (defined by [illegible] as the "best available...") as systems of management practices. This is primarily reflected in two ways: (1) the management measures are usually presented as systems, and (2) for those sources that generate pollutants from a number of somewhat discrete activities or unit areas the guidance includes management measures for each activity or area.

For example, the agriculture category includes separate management measures for sediment control on agricultural land; nutrient management; pesticide management; irrigation management; and livestock management. Taken together, however, these measures constitute comprehensive management measures that can address a wide range of farm operations, several of which are frequently found on the same farm.

C. Distinction Between Management "Measures" and "Practices"

Readers should note that the statute provides that State programs need to be "in conformity" only with "management measures", not with "management practices". The "management measures" contained in this guidance are the heart of the guidance. The "practices" listed in the guidance are provided strictly for informational purposes; they are designed to provide ideas on effective tools to achieve the management measures. However, the selection of these or other practices is within the discretion of the State and managers of the sources of nonpoint pollution, provided that the selected set of practices achieves the management measure.

Since nonpoint source pollutants have a limited number of pathways by which they reach water resources, the practices that constitute management measures for the various source categories may be similar in several cases. For example, filter strips of one sort or another are used to address a variety of sources, including agricultural, forestry, and urban sources. At the same time, the filter strip design specifications, operation and maintenance, and pollutant reductions for each of these sources and specific activities within these source categories may vary considerably, however. In this proposed guidance, filter strips are addressed in the final chapter as a multi-source management measure. Similarly, the water-quality benefits of protecting and restoring coastal wetlands apply across many categories of nonpoint sources and are thus addressed in the final chapter. EPA may identify other management measures in the final guidance that can be applied to more than one source category.

D. Management Measures: Adaptation to Local Conditions

It is generally not possible to prescribe a highly specific management measure that will be uniformly applicable nationally or regionally. For example, when designing erosion and sediment control systems on agricultural lands, one considers soil types, cropping patterns, precipitation patterns, slopes, depth to water table, and other factors to determine the proper system for each parcel of land. Similarly, in determining management measures for developing urban areas, a local community might consider transportation system needs, land use, soils, slopes, precipitation patterns, permeability, rate of growth, and other factors. The multitude of combinations of site-specific factors that arise across the nation, within States, and even within watersheds, makes it impractical to develop a list of specific management measures that is most effective to control all of the existing and potential nonpoint source problems affecting our coastal waters.

Rather than developing an exhaustive list of specific management measures (each of which is a system of practices) tailored to all scenarios (an impossible task), or even a defined subset of possible scenarios, EPA proposes to specify management measures in a manner that can be applied on a broader scale to categories of nonpoint sources. By identifying measures that reflect best achievable pollutant reductions, yet allowing for approaches that achieve equivalent or better pollutant control, EPA's proposal enables adaptation to site-specific conditions. This adaptation would occur through flexible application of management measures contained in State coastal nonpoint pollution control programs approved by NOAA and EPA.

This proposed guidance provides a suite of management measures for each source category. The number and type of systems identified per source category are based upon the range and diversity of substantively different subcategories, activities, and pollutants.

EPA used a consistent approach to determine the number and type of management measure systems needed under each category. We first determined the range of subcategories and activities that fall under each source, and how they related to each other. We then identified the types of nonpoint source pollution and impacts that could be caused by each subcategory and activity, as well as by combinations of subcategories and activities. This step is key to preventing pollution at the source. Management measures were then identified based upon several factors, including the types of pollutants, pollutant fate and transport, and land management patterns and opportunities.

Pollution prevention was always considered as the first component of management measures. Pollutant delivery reduction measures were typically added only after it was determined that additional control was necessary to reach the greatest degree of pollutant reduction economically achievable.

For each management measure, a list of management practices that can be used in designing an equivalent or better system is provided. The list of practices reflects the best available set of practices, or components of best available systems, but is not all-inclusive of those practices that could be used to develop systems that are equivalent to or better than specified management measures.

The pollutant reductions that can be achieved using the specified management measures are also described in this guidance, quantitatively wherever possible. These reductions serve as the benchmarks for equivalent or better management measures. Pollutant reductions achievable with the management practices listed are also given to the extent data are available.

The proposed guidance also describes factors that need to be taken into account in adapting the systems to specific sites or locations. These factors are illustrative of conditions that may lead to (1) selection of equivalent or better management measures for any given application, (2) special design considerations, or (3) special operation and maintenance considerations. As for other aspects of the proposed guidance, EPA intends to expand this information in the final guidance.

E. Pollution Reduction Estimates

Estimates of pollution reduction are provided for the management measures and a subset of the management practices contained in this proposed guidance. All estimates provided are based upon data available to EPA, but EPA has to date performed little or no analysis of these data due to the tight statutory deadline for proposal. Therefore, the estimates provided should be considered only indicative of the types of estimates that will be given in the final guidance, but should not be considered best estimates at this time.

EPA expects during the coming year to assemble and analyze additional pollutant reduction data on the effectiveness of various practices and measures; improve its understanding of the site-specific variability of pollutant reduction estimates by identifying factors that appear to cause differences in reductions; and characterize reduction results more rigorously. EPA will also examine the specific practices to determine if differences in design or application affected the study results. For example, pipe outlet terraces may have a very different impact upon ground water than terraces with no pipe outlets. Further, pipe outlet terraces on soils underlain by carbonate rock may have very different effects than terraces underlain by noncarbonate rocks.

In many cases, EPA was unable to obtain or analyze data that would enable EPA to estimate pollutant reduction effects of proposed management measures. EPA intends to do considerable work in the coming year to develop such quantitative information and welcomes commenters' ideas and data in this regard.

F. Costs, Economic Achievability, and Net Economic Benefits of Proposed Management Measures

A limited amount of cost information is provided in various chapters of this proposed guidance. The cost data, like the pollutant reduction effects estimates provide a preliminary indication of the type and range of estimates likely to appear in the final guidance, but should not be considered final or best estimates at this time. EPA has also prepared a preliminary scoping analysis of the net economic benefits of management measures for coastal waters.

Congress defined "management measures" to mean "economically achievable measures ... which reflect the greatest degree of pollutant reduction achievable through the application of the best available nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives. Thus the management measures must be "economically achievable".

Congress has not defined the term "economically achievable"; nor has it explained the term in legislative history. However, as noted previously, the legislative history indicates that the management measures approach of Section 6217 is "patterned" after the "best available technology economically achievable" (BAT) approach used in the Clean Water Act for point sources. Thus, the meaning of "economically achievable" would seem to be its historical interpretation in the point source program.

It is unclear that "economically achievable" would be interpreted precisely the same way for nonpoint source management measures guidance as it has been for point source BAT regulations. Indeed, there are important distinctions between the "management measures" guidance and BAT regulations that clearly limit the extent to which economic achievability can be assessed and factored into a general analysis of proposed guidance. These distinctions relate to the more extensive flexibility inherent in implementing nonpoint source management measures.

The ability of a particular management measure to deal with nonpoint source pollution from a particular site is subject to a variety of factors (e.g., geography, geology, soils, hydrology, and production methods) too complex to address in a single set of simple, mechanical prescriptions developed at the federal level. Thus, Congress indicated the need to provide in the management measures guidance considerable flexibility for local selection of management measures. Furthermore, unlike BAT regulations, the management measures guidance is not directly applicable to nonpoint sources, but, rather, will be directly implemented only through state programs developed in conformity with the guidance. These considerations make it very difficult to predict the costs and economic impacts of management measures that will ultimately be developed, applied, and implemented on a localized basis.

Many of the proposed management measures are generally regarded as low-cost, yet highly effective. Examples include agricultural measures such as sediment control and nutrient management. Others are more expensive, yet are widely practiced (e.g., animal waste controls and construction of vegetative filter strips). Further, it should be noted that significant cost-share assistance is available to farmers from a variety of federal and state programs to assist in the implementation of the agricultural management measures.

The exceptionally tight six-month statutory deadline, coupled with the analytical limitations outlined above, have precluded a formal economic analysis. To assist readers in evaluating the effect of this guidance, EPA has prepared a preliminary net benefits analysis of nonpoint source management measures for coastal waters. This preliminary analysis indicates that implementation of nonpoint pollution management measures in coastal areas may yield significant net economic benefits. EPA solicits comments on this preliminary benefits analysis.

Commenters are also invited to identify particular management measures that they believe are or are not economically achievable; provide information or analyses to support their comments; and suggest alternative analytical methodologies that they believe would be useful in determining economic achievability. Commenters are also invited to suggest methods for analyzing economic achievability in a manner that overcomes the analytical limitations outlined above and that could be performed rapidly, consistent with the May 1992 deadline for publication of final management measures guidance.

IV. ISSUES TO BE ADDRESSED IN PROGRAM GUIDANCE

A complete understanding of the proposed management measures depends on a consideration of how they will be implemented in State programs. As described in "Background", each State Coastal Nonpoint Pollution Control Program (CNPCP) must "provide for the implementation, at a minimum, of management measures in conformity with the guidance published under subsection (g) to protect coastal waters generally,...." States will implement the CNPCP through amendments to their existing State nonpoint source program under section 319 of the Clean Water Act (as amended in 1987) and their Coastal Zone Management Program.

EPA and NOAA plan to publish draft state program development and approval guidance in August 1991. This guidance will address the key issues of how the management measures are to be implemented in State programs, as well as other program requirements. States and other interested parties will be given the opportunity to review and comment on the guidance at that time. The agencies expect to publish final state program guidance in May 1992.

We recognize that many reviewers of the proposed management measures guidance will wish to understand how these measures will apply programmatically as they evaluate and comment upon the measures. Therefore, to assist readers to consider the proposed measures in the broader implementation context, pending publication of the proposed state program guidance, we identify below some of the key management measures implementation issues that EPA and NOAA expect to address in the proposed program guidance, along with an indication of the range of options being considered.

A. State Conformity with Management Measures Guidance

Section 6217 assigns to the States the responsibility for developing and implementing management measures "in conformity" with the subsection (g) guidance. The interpretation of this requirement is key in that it will prescribe the degree of discretion that States will have in developing alternative management measures and targeting specific sources and areas. NOAA and EPA are currently developing programmatic guidance which will explain how the Agencies will make decisions with respect to whether State programs are "in conformity with" the guidance.

Some options currently under consideration are:

(1) States could be required to implement the specified management measures for all sources that contribute nonpoint source pollution to coastal waters.

(2) States could be required to implement either the specified management measures or tailored management measures that are equivalent in performance to the specified management measures for all sources that contribute nonpoint source pollution to coastal waters.

(3) States could be required to identify significant sources of nonpoint pollution and implement the specified management measures, or equivalent State management measures, as necessary to protect and restore coastal water quality.

(4) States could be required to develop performance requirements to determine where to implement the specified management measures, or equivalent State management measures, to guarantee protection of coastal waters, on a case-by-case basis.

B. Applicability of Management Measures to Individual Sources

A major issue in the implementation of management measures is whether the management measures should be required by State programs for all sources or only for a subset of sources or geographic areas that are determined to be significant sources of nonpoint source pollution. The most stringent approach would require that every land owner or manager should implement a minimum set of management measures to prevent nonpoint source pollution, without first estimating the extent of a coastal water quality problem or threat and the land's relationship to the problem or threat. This approach would parallel the highly effective point source program, in which uniform BAT controls applicable to all sources in a particular category has led to relatively rapid progress in the treatment of point source discharges. The approach also establishes equal requirements for all competing producers.

A potential pitfall of this approach is that costs and pollutant reduction effects cannot readily be taken into account by States in developing management measures appropriate to individual sources or classes of activities. By requiring minimum measures of all land owners or managers, the agencies may thus impose unnecessary costs and requirements upon those that do not contribute to nonpoint source problems or the threat of such. Furthermore, a broadly uniform approach may divert implementing agencies' efforts from focussing on the primary problems that contribute most significantly to coastal water quality problems.

Between the two extreme options (applying management measures to all sources, and applying management measures only to sources demonstrated to have particular well-defined impacts on coastal waters) lie certain intermediate options. For example:

(1) A tiered approach could set different levels of minimum control based upon the extent and type of the problem, and the likelihood that any given land area or class of sources might contribute to the problem. (Readers should note that section 6217(b)(3) already provides for additional management measures to address critical coastal areas and land uses. See the next section below.)

(2) A targeted approach that identifies certain areas or classes of sources for treatment, while leaving others untreated, presents a similar way to achieve effective control at lower cost within each tier.

(3) A tiering or targeting approach could use tiering or targeting not to distinguish among different sources' control requirements, but rather to prioritize and schedule State implementation activities.

C. <u>Land Uses and Critical Coastal Areas</u>

Section 6217(b) requires that states identify land uses which, individually or cumulatively, may cause or contribute significantly to a degradation of (a) coastal waters where there is a failure to attain or maintain applicable water quality standards or protect designated uses, or (b) coastal waters that are threatened by reasonably foreseeable increases in pollution loadings from new or expanding sources. The section also requires states to identify critical coastal areas adjacent to the coastal waters identified above. Finally, the section requires that the state coastal nonpoint pollution control program provide for implementation of additional management measures that are necessary to achieve and maintain applicable water quality standards.

Unlike the management measures specified in this guidance, the implementation of these additional measures is tied directly to water quality standards and designated uses of coastal waters. EPA and NOAA will work with the states to determine the scope and application of these additional management measures and their relationship to the measures developed in accordance with section 6217(g).

D. Conclusion

EPA reminds readers that the above issues, together with other implementation issues, will be addressed in forthcoming State program approval guidance, scheduled for publication in draft form in August 1991. The brief discussion above has been intended to assist the public in understanding related implementation issues as they review and comment upon the proposed management measures guidance. However, we request that commenters on this proposed management measures guidance focus their comments upon the technical soundness of the proposed management measures and reserve implementation-related considerations until the forthcoming State program approval guidance is published for public comment.

V. REQUEST FOR INFORMATION AND COMMENTS

EPA is soliciting comments on the proposed guidance on management measures to control coastal nonpoint pollution. We are seeking additional information and supporting data on the measures specified in this guidance and on additional measures that may be as effective or more effective in controlling nonpoint source pollution. The following information is sought by EPA in preparing the final guidance:

(1) Information on the activities and locations for which each measure may be suitable and information on factors which should be taken into account in adapting the measures to specific sites or locations;

(2) Information on the pollutants that may or may not be controlled by the measures;

(3) Data regarding the pollution reduction effects of the measures;

(4) Data regarding the costs of each measure; and

(5) Appropriate monitoring techniques for each resource.

EPA also welcomes comments on the general approach used in the proposed guidance, including the level of detail used to describe management measures. As mentioned above, EPA requests that commenters focus their comments upon the technical soundness of the proposed management measures guidance and reserve implementation-related considerations until the forthcoming state program approval guidance is published for public comment.

CHAPTER 2. AGRICULTURAL MANAGEMENT MEASURES

CHAPTER 2

AGRICULTURAL MANAGEMENT MEASURES

I. INTRODUCTION

This chapter specifies management measures for agricultural sources of nonpoint pollution. Agriculture is the nation's largest contributor of nonpoint source pollution. In coastal waters, its effect varies regionally. In some coastal waters, agriculture has been identified as the single largest contributor of sediment, nutrients, and other pollutants of concern. For example, agricultural runoff has been identified as the leading source of pollution in the Chesapeake Bay and in other estuaries. Thus, applying management measures to control agricultural nonpoint pollution is an essential component of a State program to protect coastal waters from nonpoint pollution.

II. POLLUTANTS THAT CAUSE AGRICULTURAL NONPOINT SOURCE POLLUTION*

The primary agricultural nonpoint source pollutants are nutrients, sediment, animal wastes, salts, and pesticides. These pollutants' effects on water quality are discussed below.

A. Nutrients

Nitrogen and phosphorus are the two major nutrients from agricultural land that degrade water quality. All plants, whether land based, aerial, or aquatic, require nutrients for growth. In an aquatic environment, nutrient availability usually limits plant growth. Nitrogen and phosphorus generally are present at background or natural levels below 0.3 and 0.05 mg/l, respectively. When these nutrients are introduced into a stream, lake, or estuary at higher rates, aquatic plant productivity may increase dramatically. This process, referred to as cultural eutrophication, may adversely affect the suitability of the water for other uses.

Increased aquatic plant productivity results in additional organic material being added to the system that eventually dies and decays. The decaying organic matter produces unpleasant odors and depletes the oxygen supply required by aquatic organisms. Excess plant growth also may interfere with recreational activities such as swimming and boating. Depleted oxygen levels,

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* This section on Pollutants that Cause Agricultural Nonpoint Source Pollution is adapted from: USDA, Soil Conservation Service. 1983. Water Quality Field Guide. SCS-TP-160, Washington, D.C.

especially in colder bottom waters where dead organic matter tends to accumulate, will reduce the quality of fish habitat and encourage the propagation of fish which are adapted to less oxygen or to warmer surface waters. Highly enriched waters will stimulate algae production, with consequent increased turbidity and color. Algae growth is also believed to be harmful to coral reefs (e.g., Florida coast). Furthermore, the increased turbidity results in less sunlight penetration and availability to submerged aquatic vegetation (SAV). Since SAV provides habitat for small or juvenile fish, the loss of SAV has severe consequences for the food chain. Chesapeake Bay is an example where nutrients are believed to have contributed to SAV loss.

B. Nitrogen

All forms of transported nitrogen are potential contributors to eutrophication in lakes, estuaries, and some coastal waters. In general, though not all cases, nitrogen availability is the limiting factor for plant growth in marine ecosystems. Thus, the addition of nitrogen can have a significant affect on the natural functioning of marine ecosystems.

In addition to eutrophication, excessive nitrogen causes other water quality problems. Dissolved ammonia at concentrations above 0.2 mg/l may be toxic to fish, especially trout. Nitrates in drinking water are potentially dangerous, especially to newborn infants. Nitrate is converted to nitrite in the digestive tract, which reduces the oxygen-carrying capacity of the blood (methemoglobinemia), resulting in brain damage or even death. The U.S. Environmental Protection Agency has set a limit of 10 mg/l nitrate-nitrogen in water used for human consumption (Robillard, et al., 1981).

Nitrogen is naturally present in soils but must be added to increase crop production. Nitrogen is added to the soil primarily by applying commercial fertilizers and manure, but also by growing legumes (biological nitrogen fixation) and incorporating crop residues. Not all nitrogen that is present in or on the soil is available for plant use at any one time. Organic nitrogen normally constitutes the majority of the soil nitrogen. It is slowly converted (2 to 3 percent per year) to the more readily plant available inorganic ammonium or nitrate.

The chemical form of nitrogen affects its impact on water quality. The most biologically important inorganic forms of nitrogen are ammonium (NH_4+), nitrate (NO_3-), and nitrite (NO_2). Organic nitrogen occurs as particulate matter, in living organisms, and as detritus. It occurs in dissolved form in compounds such as amino acid, amines, purines, urea, etc.

Nitrate-nitrogen is highly mobile and can move readily below the crop root zone, especially in sandy soils. It can also be transported with surface runoff, but not generally in large quantities. Ammonium on the other hand, becomes adsorbed by the soil and is lost primarily with eroding sediment. Even if nitrogen is not in a readily available form as it leaves the field, it can convert to an available form later.

C. Phosphorus

The phosphorus content in most soils is low, between 0.01 and 0.2 percent by weight. Most of this is unavailable for plant uptake. Manure and fertilizers are used to increase the level of available phosphorus in the soil to promote plant growth. If runoff and erosion occur, some of the applied phosphorus can reach nearby bodies of water. High-intensity storms increase the loss of particulate inorganic phosphorus from croplands because this form of phosphorus is associated with eroding sediments.

Phosphorus can be found in the soil in dissolved, colloidal, or particulate forms. Dissolved inorganic phosphorus (orthophosphate phosphorus) is probably the only form directly available to algae. Algae consume dissolved inorganic phosphorus and convert it to the organic form. Phosphorous is rarely found in concentrations high enough to be toxic to higher organisms.

Phosphorus unavailable in the soil system may erode with soil particles and later be released when the bottom sediment of a stream becomes anaerobic, creating water quality problems. While phosphorus typically plays the controlling role in freshwater systems, in some estuarine systems, both nitrogen and phosphorus can limit plant growth. Thus, the addition of phosphorus as a nonpoint source pollutant can have an adverse effect in both freshwater and estuarine systems.

D. Sediment

Sediment is the result of erosion. It is the solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site or origin by air, water, gravity, or ice. The types of erosion associated with agriculture that produce sediment are: (1) sheet and rill erosion and (2) gully erosion. Sediments from different sources vary in the kinds and amounts of pollutants that are adsorbed to the particles. For example, sheet and rill erosion mainly move soil particles from the surface or plow layer of the soil. Eroded soil is either redeposited on the same field or transported from the field in runoff.

Sediment which originates from surface soil will have a higher pollution potential than that from subsurface soils. The topsoil of a field is usually richer in nutrients and other chemicals because of past fertilizer and pesticide applications, as well as nutrient cycling and biological activity. Topsoil is also more likely to have a greater percentage of organic matter. Sediment from gullies and streambanks usually carries less adsorbed pollutants than sediment from surface soils.

Sediment from cropland usually contains a higher percentage of finer and less dense particles than the soil from which it originates. Large particles are more readily detached from the soil surface because they are less cohesive. They will also settle out of suspension more quickly because of their size. Organic matter is not easily detached because of its cohesive properties, but once detached it is easily transported because of its low density. Clay particles and organic residues will remain suspended for longer periods and at slower flow velocities. This selective erosion process can increase overall pollutant delivery, because small particles have a much greater adsorption capacity per mass than larger particles. As a result, eroding sediments generally contain higher concentrations of phosphorus, nitrogen, and pesticides than the original soil.

Sediment affects the use of water in many ways. Suspended solids reduce the amount of sunlight available to aquatic plants, cover fish spawning areas and food supplies, smother coral reefs, and clog the filtering capacity of filter feeders and the gills of fish. This reduces fish, shellfish, coral and plant populations, and decreases the overall productivity of lakes, streams, estuaries, and coastal waters. Turbidity interferes with feeding habits of fish. Recreation is limited because of the decreased fish population and the water's unappealing, turbid appearance. Turbid water reduces visibility, thus it is less safe for swimming.

Chemicals such as some pesticides, phosphorus, and ammonium are transported with sediment in an adsorbed state. Changes in the aquatic environment, such as a lower concentration in the overlying waters or the development of anaerobic conditions in the bottom sediments, can cause these chemicals to be released from the sediment. Adsorbed phosphorus transported by the sediment may not be immediately available for aquatic plant growth but does serve as a long-term contributor to eutrophication.

E. Animal Wastes

Animal wastes (manure) includes the fecal and urinary wastes of livestock and poultry, process water (such as from a milking parlor), and the feed, bedding, litter, and soil with which they become intermixed. Animal wastes can contribute nutrients, organic materials, and pathogens to receiving waters.

Manure will be more easily removed in runoff when applied to the soil surface than when incorporated in the soil. Spreading manure on frozen ground or snow can result in high concentrations of nutrients being transported from the field during rainfall or snowmelt. The problems associated with nitrogen and phosphorus, as discussed in the section **Nutrients**, also apply to animal wastes. If sufficient manure is applied to meet the nitrogen needs of a crop, phosphorus will generally be in excess. The soil generally has the capacity to adsorb any phosphorus leached from manure applied on land. However, as previously mentioned, nitrates are easily leached through soil into ground water or to return flows, and phosphorus can be transported by eroded soil.

The demand for oxygen exerted by carbonaceous materials (individually or in combination with nitrogen) can deplete dissolved oxygen supplies in water, resulting in anoxic or anaerobic conditions. When the decomposition process causes water to become anaerobic, methane, amines, and sulfide are produced. The water acquires an unpleasant odor, taste, and appearance and becomes unfit for drinking, and for fishing and other recreational purposes.

Animal diseases can be transmitted to humans through contact with animal feces. Runoff from fields receiving manure will contain extremely high numbers of bacteria if the manure has not been incorporated or the bacteria have not been subject to stress. Pathogen contamination from animal waste has been responsible for shellfish contamination in some coastal waters. However, bacteria levels in receiving waters may be attributed in some cases to either agricultural runoff or septic systems, and determination of actual sources is difficult.

Conditions which cause a rapid dieoff of bacteria are low soil moisture, low pH, high temperatures, and direct solar radiation. Manure storage generally promotes dieoff, although pathogens can remain dormant at certain temperatures. Composting the wastes is quite effective in decreasing the number of pathogens.

F. Salts

Salts are a product of the natural weathering process of soil and geologic material. They are present in varying degrees in all soils and in freshwater, coastal/estuarine waters, and ground waters.

In soils that have poor subsurface drainage, high salt concentrations are created within the root zone where most water extraction occurs. The accumulation of soluble and exchangeable sodium leads to soil dispersion, structure breakdown, decreased infiltration, and possible toxicity; thus, salts often become a serious problem on irrigated land, both for continued agricultural production and for water quality considerations. High salt concentrations in streams can harm freshwater aquatic plants just as excess soil salinity damages agricultural crops. While salts are generally a more significant pollutant for freshwater ecosystems than for saline ecosystems, they may also adversely affect anadromous fish, which while living in coastal and estuarine waters most of their lives, depend on freshwater systems near the coast for crucial portions of their life cycle.

The movement and deposition of salts depend on the amount and distribution of rainfall and irrigation, the soil and underlying strata, evapotranspiration rates, and other environmental factors. In humid areas, dissolved mineral salts have been naturally leached from the soil and substrata by rainfall. In arid and semiarid regions, salts have not been removed by natural leaching and are concentrated in the soil. Soluble salts in saline and sodic soils consist of calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, and chloride ions. They are fairly easily leached from the soil. Sparingly soluble gypsum and lime also occur. The amounts present range from traces to more than 50 percent of the soil mass. The total dissolved solids of ions in ground water and streams include the soluble ions mentioned above. Irrigation water, whether from ground water or surface water sources, has a natural base load of dissolved mineral salts. As the water is consumed by plants or lost to the atmosphere by evaporation, the salts remain and become concentrated in the soil. This is referred to as the "concentrating effect."

The total salt load carried by irrigation return flow is the sum of the original salt in the applied water resulting from the concentrating effect plus salt pick-up. Irrigation return flows provide the means for conveying the salts to the receiving streams or ground-water reservoirs. If the amount of salt in the return flow is low in comparison to the total stream flow, water quality may not be degraded to the extent that use is impaired. However, if the process of water diversion for irrigation and the return of saline drainage water is repeated many times along a stream or river, water quality will be progressively degraded for downstream irrigation use as well as for other uses.

G. Pesticides

Pesticides--insecticides, herbicides, fungicides, miticides, nematicides, etc.--are used extensively in agriculture to control plant pests and enhance production. However, despite the documented benefits, these chemicals may, in some instances, endanger surface and ground water and ultimately human health.

Pesticides may harm the environment by eliminating or reducing populations of desirable organisms, including endangered species. Some types of pesticides or their metabolites are resistant to degradation. These pesticides or their degradation products may persist and accumulate in the aquatic ecosystems. The entire food chain, including man, can be affected. Sublethal effect include the behavioral and structural changes of an organism that jeopardize its survival. For example, certain pesticides have been found to inhibit bone development in young fish or affect reproduction by inducing abortion.

Herbicides in the aquatic environment can destroy the food source for higher organisms, which may then starve. Also, decaying plant matter causes a reduction in dissolved oxygen.

Sometimes a pesticide is not toxic by itself, but is lethal in the presence of other pesticides. This is referred to as a synergistic effect and may be difficult to predict or evaluate. Bioconcentration is a phenomenon that occurs if an organism ingests more a pesticide than it excretes. During its lifetime, the organism will accumulate a higher concentration of that pesticide than is present in the surrounding environment. When the organism is eaten by another animal higher in the food chain, the pesticide will then be passed to that animal and up the food chain.

The amount of field-applied pesticide that leaves a field in the runoff and enters a stream primarily depends on:

(1) The intensity and duration of rainfall; and

(2) The length of time between pesticide application and rainfall occurrence.

Pesticide losses are largest when rainfall is intense and occurs shortly after pesticide application, a condition for which water runoff and erosion losses are also greatest.

The rate of pesticide movement through the soil profile to ground water is inversely proportional to the pesticide "adsorption partition coefficient" or K (defined as a measure of the sorption phenomenon, whereby a pesticide is divided between the soil and water phase). The larger the

K the slower the movement and the greater the quantity of water required to leach the pesticide to a given depth. In general, it appears that only pesticides with K values less than 0.5 ml/g, water solubilities greater than 100 mg/l, and/or long half-lives pose a serious threat to deep ground-water resources.

Pesticides can be transported to receiving waters either in dissolved form or attached to sediment. Dissolved pesticides may be leached to ground-water supplies. Pesticides have varying characteristics as to degradation and the percent to which they will attach to sediment.

III. REQUEST FOR COMMENTS

In Chapter 1 of this guidance (Introduction), EPA has generally requested submission of comments, information and data on relevant management practices, their effectiveness, and their costs. We also request specific comment on the following aspects of the agricultural management measures:

Erosion and Sediment Control. In Section IV.A below, EPA sets forth the management measure for Erosion and Sediment Control. This measure consists in major part of reducing erosion as close to zero as possible, but no greater than the lesser of (1) T or (2) the erosion produced after application of conservation tillage. T is the soil loss tolerance of the Universal Soil Loss Equation, used by soil conservationists to estimate the maximum rate of annual soil erosion that will permit crop productivity to be sustained economically and indefinitely. There are five classes of T factors ranging from 1 ton per acre per year for shallow or otherwise fragile soils to 5 tons per acre per year for deep soils that are least sensitive to damage by erosion.

T does not address the acceptability of a particular rate of erosion from a water quality perspective, nor does it necessarily reflect the reduced rate of erosion that can be accomplished through application of the best available control measures that are economically achievable.. For example, Wisconsin is currently using a T-1 standard (which allows one less ton per acre of soil loss than a T standard allows) in its water quality program to address agricultural erosion. It may be that T-1 more accurately reflects the best available measures for erosion control.

EPA has attempted in this proposed guidance to partially compensate for the shortcomings of T as a management measure to protect water quality by specifying conservation tillage as an alternative management measure where it yields less erosion. However, this measure too may not reflect the best available measure that is economically achievable. Indeed, given the low net costs associated with conservation tillage in many contexts, it may be that additional management measures that would provide substantial incremental pollutant reduction benefits that reduce the delivery of pollutants (e.g., contour farming and/or vegetated filter strips) would be achievable.

EPA requests comment on the above issues and on options available to address them.

Nutrient and Pesticide Management. Two of the agricultural management measures, nutrient and pest management, do not actually specify the measures to be taken "on the ground", but rather define broad goals ("eliminate excess nutrient use"; "eliminate application of excess pesticides") and then describe a process of evaluating certain relevant considerations.

EPA requests comment on whether the nutrient and pesticide management measures are sufficiently specific to assure that compliance with them would achieve the desired water quality objectives. If not, what additional specific practices could be added that are generally achievable and add significant pollutant reduction effectiveness?

IV. SOURCES OF AGRICULTURAL NONPOINT POLLUTION

EPA has identified six major categories of sources of agricultural nonpoint pollution that affect coastal waters. These are: erosion from cropland; confined animal facilities; the application of nutrients to cropland; the application of pesticides to cropland; land used for grazing; and irrigation of cropland.

Each of these source categories are addressed separately in the following section of this chapter. For each source the following items are identified: the pollutants that result from these sources; the management measures representing the best available systems of practices economically achievable to reduce off-site delivery of these pollutants; a performance expectation for the management measures; and some preliminary information on the pollutant reduction effectiveness and cost of the measures and, in some cases, the particular practices that comprise the measure.

V. MANAGEMENT MEASURES

In this section, the management measures that represent systems of practices which reflect the best available, economically achievable, nonpoint pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives are specified for each of the major sources of agricultural nonpoint source pollution. Major sources of agricultural nonpoint source pollution include:

(1) Agricultural land needing treatment for erosion control;

(2) Concentrated animal production facilities;

(3) Land receiving nutrients from sources such as commercial fertilizers, animal wastes, and sludge;

(4) Land receiving pesticide applications;

(5) Land used for grazing; and

(6) Irrigated lands.

Each of these sources is addressed separately in the following section and the following items are discussed for each of the sources:

(1) Where the management measures should be utilized or where they are applicable (for example, the erosion and sediment control management measures are utilized on all agricultural lands and the pesticide management measures are utilized on all agricultural lands that have pesticides applied to them);

(2) Pollutants associated with each source such as nutrients, sediment, salts, etc.;

(3) The management measures which represent the best available systems of practices economically achievable to reduce off-site delivery of the pollutants resulting from each source (in some cases a performance expectation is specified and variety of practices may be used to achieve the performance expectation; in other cases, particular practices are specified);

(4) Information on management practices that are available as tools to achieve the management measures.

(5) Preliminary information on the pollutant reduction effectiveness of the management measures;

(6) Preliminary information on the cost of the management measures; and

(7) Operation and maintenance information.

Several agricultural sources may need to be addressed on a given piece of agricultural land in the coastal zone to protect water quality. For example, in some cases, erosion and sediment control measures, nutrient management measures as well as pesticide management measures will be needed i.e., systems of management measures. In other areas, depending on site-specific conditions, only one source may need to be addressed.

A. Erosion and Sediment Control

1. Management Measure Applicability

This management measure is to be utilized on all agricultural lands, including all land that is converted from other land uses to agricultural land. Agricultural lands include, but are not limited to:

- Cropland, dryland;
- Cropland, irrigated;
- Range and pastureland;
- Orchards;
- Specialty crop production; and
- Nursery crop production.

Those agricultural lands that also meet the applicability definitions of the concentrated animal facility management measure; nutrient management measure; pesticide management measures; grazing management measure; irrigation water management measure; or other management measures are also subject to those management measures.

2. Pollutants Produced by Soil Erosion and Transported by Runoff and Sediment

Runoff water from agricultural land may transport the following types of pollutants:

- Sediment and particulate organic solids;

- Particulate bound nutrients, chemicals and metals, such as phosphorus, organic nitrogen, a portion of applied pesticides, and a portion of the metals applied with some organic wastes and found naturally within the soil;

- Soluble nutrients, such as nitrogen, a portion of the phosphorus, a portion of the applied pesticides, a portion of the soluble metals and many other major and minor nutrients;

- Salts; and

- Bacteria, viruses and other microorganisms.

3. Management Measure for Erosion and Sediment Control

The management measure for erosion and sediment control on agricultural lands is a combination of practices that (1) control gully erosion, (2) protect wetlands and riparian zones, and (3) minimize the detachment and transport of soil by water, wind, ice, or gravity such that the average annual erosion rate (expressed as tons per acre per year, or T/Ac/Yr) is as close to zero as feasible (taking cost into account), but is in no case greater than the lesser of (a) "T" (the soil loss tolerance value* for the soil series in the field) or the average annual erosion rate achieved with conservation tillage.

EPA recognizes that USDA is changing from the Universal Soil Loss Equation to the USDA-Water Erosion Prediction Project (WEPP) model (Laflen et. al., 1991) now scheduled for FY 92. The WEPP system will not only estimate the erosion to a tolerable rate for productivity maintenance, but will estimate on-site deposition to prevent excessive adverse effects from deposition, sediment yield from fields to allowable rates that prevent excessive off-site sedimentation, and sediment yield from fields to prevent excessive degradation of off-site water quality. It will also estimate sediment characteristics needed to develop erosion control plans for improvements in downstream water quality. EPA will track developments regarding WEPP, particularly as they apply to this management measure.

4. Erosion and Sediment Control Management Practices

Following is a list of management practices for agricultural erosion and sediment control that are available as tools to achieve the erosion and sediment control management measure. Under each management practice, the U.S. Soil Conservation Service (SCS) practice number and a definition are provided. The list of practices included in this section is not exhaustive and does not preclude States or local agencies from developing special management measures in cooperation with the appropriate technical agency within the State for unique conditions and problems that may be encountered in particular areas, provided that the management measures (the system of individual practices adopted) achieve a level of performance that is as effective as that provided by the management measure specified in this guidance. There may also be State or local standards that would require additional practices.

Conservation cover (327)
Establishing and maintaining perennial vegetative cover to protect soil and water resources on land retired form agricultural production.

The purpose is to reduce soil erosion and sedimentation, improve water quality, and create or enhance wildlife habitat.

Conservation cropping sequence (328)
An adapted sequence of crops designed to provide adequate organic residue for maintenance or improvement of soil tilth.

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*The "T" factor is the soil loss tolerance of the Universal Soil Loss Equation. It is defined as the maximum rate of annual soil erosion that will permit crop productivity to be sustained economically and indefinitely. There are five classes of T factors ranging from 1 ton per acre per year for shallow or otherwise fragile soils to 5 tons per acre per year for deep soils that are least sensitive to damage by erosion.

The purpose of this practice is to improve or maintain good physical, chemical, and biological conditions of the soil; help reduce erosion; improve water use efficiency and water quality; improve wildlife habitat; or break reproduction cycles of plant pests.

Conservation tillage (329)
Any tillage or planting system that maintains at least 30 percent of the soil surface covered by residue after planting to reduce soil erosion by water; or where soil erosion by wind is the primary concern, maintains at least 1,000 pounds of flat, small grain residue equivalent on the surface during the critical erosion period.

The purpose is to reduce soil erosion; help maintain or develop good soil tilth, efficient moisture use, and cover for wildlife.

Contour systems

Contour farming (330)
Farming sloping land in such a way that preparing land, planting, and cultivating are done on the contour. This includes following established grades of terraces or diversions.

The purpose is to reduce erosion and control water.

Contour orchard and other fruit area (331)
Planting orchards, vineyards, or small fruits so that all cultural operations are done on the contour.

The purpose is to reduce soil and water loss, to better control and use water, and to operate farm equipment more easily.

Cover and green manure crop (340)
A crop of close-growing grasses, legumes or small grain grown primarily for seasonal protection and soil improvement. It usually is grown for 1 year or less, except where there is permanent cover as in orchards.

The purpose is to control erosion during periods when the major crops do not furnish adequate cover; add organic material to the soil; and improve infiltration, aeration, and tilth.

Critical area planting (342)
Planting vegetation, such as trees, shrubs, vines, grasses, or legumes, on highly erodible or critically eroding areas (does not include tree planting mainly for wood products).

The purpose is to stabilize the soil, reduce damage from sediment and runoff to downstream areas, and improve wildlife habitat and visual resources.

Crop residue use (344)
Using plant residues to protect cultivated fields during critical erosion periods.

The purpose is to conserve soil moisture, increase soil infiltration, reduce soil loss, and improve soil tilth.

Delayed seed bed preparation (354)
Any cropping system in which all of the crop residue and volunteer vegetation are maintained on the soil surface until approximately 3 weeks before the succeeding crop is planted, thus shortening the bare seedbed period on fields during critical erosion periods.

The purpose is to reduce soil erosion by maintaining soil cover as long as practical to minimize raindrop splash and runoff during the spring erosion period. Other purposes include moisture conservation, improved water quality, increased soil infiltration, improved soil tilth, and food and cover for wildlife.

Diversion (362)
A channel constructed across the slope with a supporting ridge on the lower side.

The purpose is to divert excess water from one area for use or safe disposal in other areas.

Field border (386)
A strip of perennial vegetation established at the edge of a field by planting or by converting it from trees to herbaceous vegetation or shrubs.

The purpose is to control erosion, protect edges of fields that are used as "turnrows" or travel lanes for farm machinery, reduce competition from adjacent woodland, provide wildlife food and cover, or improve the landscape.

Filter strip (393)
A strip or area of vegetation for removing sediment, organic matter, and other pollutants from runoff and wastewater.

The purpose is to remove sediment and other pollutants from runoff or wastewater by filtration, deposition, infiltration, absorption, decomposition, and volatilization, thereby reducing pollution and protecting the environment.

Grade stabilization structure (410)
A structure used to control the grade and head cutting in natural or artificial channels.

The purpose is to stabilize the grade and control erosion in natural or artificial channels, to prevent the formation or advance of gullies, and to enhance environmental quality and reduce pollution hazards.

Grassed waterway (412)
A natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff.

The purpose is to convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding, and to improve water quality.

Grasses and legumes in rotation (411)
Establishing grasses and legumes or a mixture of them and maintaining the stand for a definite number of years as part of a conservation cropping system.

The purpose is to produce forage for hay, silage, seed, or grazing; reduce soil and water loss; maintain a favorable level of organic matter; and improve soil productivity.

Sediment basins (350)
A basin constructed to collect and store debris or sediment.

The purpose is to preserve the capacity of reservoirs, ditches, canals, diversions, waterways, and streams; to prevent undesirable deposition on bottom lands and developed areas; to trap sediment originating from construction sites; and to reduce or abate pollution by providing basins for deposition and storage of silt, sand, gravel, stone, agricultural wastes, and other detritus material.

Stripcropping systems

Contour stripcropping (585)
Growing crops in a systematic arrangement of strips or bands on the contour to reduce water erosion. The crops are arranged so that a strip of grass or close-growing crop is alternated with a strip of clean-tilled crop or fallow or a strip of grass is alternated with a close-growing crop.

The purpose is to reduce erosion and control water.

Field stripcropping (586)
Growing crops in a systematic arrangement of strips or bands across the general slope (not on the contour) to reduce water erosion. The crops are arranged so that a strip of grass or a close-growing crop is alternated with a clean-tilled crop or fallow.

The purpose is to help control erosion and runoff on sloping cropland where contour stripcropping is not practiced.

Terraces (600)
An earthen embankment, a channel, or combination ridge and channel constructed across the slope.

The purpose is to: (1) reduce slope length, (2) reduce erosion, (3) reduce sediment content in the runoff water, (4) improve water quality, (5) intercept and conduct surface runoff at a nonerosive velocity to a stable outlet, (6) retain runoff for moisture conservation, (7) prevent gully development, (8) re-form the land surface, (9) improve farmability, or (10) reduce flooding.

Water and sediment control basin (638)
An earthen embankment or a combination ridge and channel generally constructed across the slope and minor watercourses to form a sediment trap and water detention basin.

The purpose is to: improve farmability of sloping land; reduce watercourse and gully erosion; trap sediment; reduce and manage onsite and downstream runoff; and improve downstream water quality.

Wetland and Riparian Zone Protection
Wetlands and riparian zone protection practices are described in Chapter 7.

5. Effectiveness Information

Following is information to illustrate the pollution reductions that can be achieved from installation of some of the management practices that may be used to implement this management measure. Two tables (Tables 2-1 and 2-2) are presented to show the variability in effectiveness information as reported by different sources. Also, general, qualitative information of the effectiveness of selected management practices is included in Table 2-3.

The information contained herein is primarily practice-oriented, yet EPA seeks data regarding the overall effectiveness of management measures, or systems of practices. To this end, EPA is continuing to collect and analyze more information regarding pollutant reductions, and solicits comments regarding information sources to utilize.

USDA estimates that the level of erosion control provided for by the specified management measure ("T") will result in an average annual savings of 9 Tons/Ac/Yr in the 28 coastal States. This will be achieved by bringing average erosion rate down from 11.4 Tons/Ac/Yr to an of 4.5 Tons/Ac/Yr ("T" values).

6. Cost Information

Cost estimates for control of erosion and sediment transport from agricultural lands are provided in Tables 2-4, 2-5, and 2-6. The costs in Table 2-4 are based upon experiences in the Chesapeake Bay Program, but are illustrative of the costs that could be incurred in coastal areas across the Nation. The costs in Table 2-5 are based on modeling runs for Indiana. The costs in Table 2-6 are national summaries provided by the USDA, and represent costs on a much broader scale. Only the costs in Table 2-5 represent net costs to the landowner or operator. It

Table 2-1. Estimated Pollutant Reductions for Selected Management Practices

Practice	Runoff Volume Reduction (%)	Sediment Load Reduction (%)	Total P Load Reduction (%)	Total N Load Reduction (%)
Conservation tillage	up to 40	up to 50	up to 45	NA
Stripcropping	up to 85	up to 75	NA	NA
Grassed water ways[1]	NA	up to 65	up to 50	up to 30
Diversions[2]	NA	up to 40	up to 45	up to 20
Sediment retention and Water control structures	NA	up to 65	NA	up to 30[3]
Grassed filter strips	NA	85-90	50	NA

SOURCE: New York Department of Environmental Conservation, 1990.
NOTE: All reductions are relative to conventional (moldboard plow) tillage.

[1] This is a transport practice. Reductions are based upon modeling.
[2] Reductions are based upon modeling.
[3] Particulate organic nitrogen.

Table 2-2. Estimated Pollutant Reductions for Selected Management Practices

Practices	Runoff Volume Reduction	Sediment Load Reduction	Total P Load Reduction	Total N Load Reduction
	% unless otherwise noted			
Conservation tillage system	NA	30 to 90	35 to 90	50 to 80
Stripcropping systems	NA	up to 75	up to 50	NA
Contour and across slope tillage	NA	50 to 90	35 to 60	NA
Terrace systems	NA	90	75	NA
Sod waterways	NA	70	50	NA
Cover crops	NA	40 to 60	30 to 50	NA
Permanent Veg. Cover on Critical areas	NA	95	50	NA
Permanent Veg. Cover	NA	less than 1 T/Ac/Yr delivered	very high	NA
Reforestation of Erodible Crop and Pastureland	NA	less than 1 T/Ac/Yr delivered	very high	NA
Buffer/Filter strips	NA	70	50	NA
Water/Sediment control basins	NA	NA	NA	NA
Sediment basin	NA	60	40	NA
Diversions	NA	25	23	NA
Crop residue use	NA	NA	NA	NA
Grade stabilization structure	NA	5	NA	NA
Contour & across slope cropping	NA	up to 50[1]	up to 35	NA

SOURCE: Non-Point Source Task Force, International Joint Commission, 1983.
NOTE: All reductions are relative to conventional (moldboard plow) tillage.
[1] Up to 50% on 2-6% slopes, but less than 10% on 18-24% slopes.

Table 2-3. Water Quality Statement for Selected Management Practices

Practice	Water Quality Statement
Conservation cover (327)	Agricultural chemicals are usually not applied to this cover in large quantities and surface and ground water quality may improve where these material are not used. Ground cover and crop residue will be increased with this practice. Erosion and yields of sediment and sediment related stream pollutants should decrease. Temperatures of the soil surface runoff and receiving water may be reduced. Effects will vary during the establishment period and include increases in runoff, erosion and sediment yield. Due to the reduction of deep percolation, the leaching of soluble material will be reduced, as will be the potential for causing saline seeps. Long-term effects of the practice would reduce agricultural nonpoint sources pollution to all water resources.
Conservation croppping sequence (328)	This practice reduces erosion by increasing organic matter, resulting in a reduction of sediment and associated pollutants to surface waters. Crop rotations that improve soil tilth may also disrupt disease, insect and weed reproduction cycles, reducing the need for pesticides. This removes or reduces the availability of some pollutants in the watershed. Deep percolation may carry soluble nutrients and pesticides to the ground water. Underlying soil layers, rock and unconsolidated parent material may block, delay, or enhance the delivery of these pollutants to ground water. The fate of these pollutants will be site specific, depending on the crop management, the soil and geologic conditions.
Conservation tillage (329)	This practice reduces soil erosion, detachment and sediment transport by providing soil cover during critical times in the cropping cycle. Surface residues reduce soil compaction from raindrops, preventing soil sealing and increasing infiltration. This action may increase the leaching of agricultural chemical into the ground water.

Table 2-3. (Continued)

Practice	Water Quality Statement
	In order to maintain the crop residue on the surface it is difficult to incorporate fertilizers and pesticides. This may increase the amount of these chemicals in the runoff and cause more surface water pollution.
	The additional organic material on the surface may increase the bacterial action on and near the soil surface. This may tie-up and then breakdown many pesticides which are surface applied, resulting in less pesticide leaving the field. This practice is more effective in humid regions.
	With a no-till operation the only soil disturbance is the planter shoe and the compaction form the wheels. The surface applied fertilizers and chemicals are not incorporated and often are not in direct contact with the soil surface. This condition may result in a high surface runoff of pollutants (nutrient and pesticides). Macropores develop under a no-till system. They permit deep percolation and the transmittal of pollutants, both soluble and insoluble to be carried into the deeper soil horizons and into the ground water.
	Reduced tillage systems disrupt or bread down the macropores, incidentally incorporate some of the materials applied to the soil surface, and reduce the effects of wheeltrack compaction. The results are less runoff and less pollutants in the runoff.
Contour farming (330)	This practice reduces erosion and sediment production. Less sediment and related pollutants may be transported to the receiving waters.
	Increased infiltration may increase the transportation potential for soluble substances to the ground water.

Table 2-3. (Continued)

Practice	Water Quality Statement
Contour orchard and other fruit area (331)	Contour orchards and fruit areas may reduce erosion, sediment yield, and pesticide concentration in the water lost. Where inward sloping benches are used, the sediment and chemicals will be trapped against the slope. With annual events, the bench may provide 100 percent trap efficiency. Outward sloping benches may allow greater sediment and chemical loss. The amount of retention depends on the lope of the bench and the amount of cover. In addition, outward sloping benches are subject to erosion form runoff from benched immediately above them. Contouring allows better access to rills, permitting maintenance that reduces additional erosion. Immediately after establishment, contour orchards may be subject to erosion and sedimentation in excess of the now contoured orchard. Contour orchards require more fertilization and pesticide application than did the native grasses that frequently covered the slopes before orchards were started. Sediment leaving the site may carry more adsorbed nutrients and pesticides than did the sediment before the benches were established from uncultivated slopes. If contoured orchards replace other crop or intensive land use, the increase or decrease in chemical transport from the site may be determined by examining the types and amounts of chemical used on the prior land use as compared to the contour orchard condition. Soluble pesticides and nutrients may be delivered to and possibly through the root zone in an amount proportional to the amount of soluble pesticides applied, the increase in infiltration, the chemistry of the pesticides, organic and clay content of the soil, and amounts of surface residues. Percolating water below the root zone may carry excess solutes or may dissolve potential pollutants as they move. In either case, these solutes could reach groundwater supplies and/or surface downslope from the contour orchard area. The amount depends on soil type, surface water quality, and the availability of soluble material (natural or applied).

Table 2-3. (Continued)

Practice	Water Quality Statement
Cover and green manure crop (340)	Erosion, sediment and adsorbed chemical yields green manure could be decreased in conventional tillage systems crop because of the increased period of vegetal cover. Plants will take up available nitrogen and prevent its undesired movement. Organic nutrients may be added to the nutrient budget reducing the need to supply more soluble forms. Overall volume of chemical application may decrease because the vegetation will supply nutrients and there may be allelopathic effects of some of the types of cover vegetation on weeds. Temperatures of ground and surface waters could slightly decrease.
Critical area planting (324)	This practice may reduce soil erosion and sediment delivery to surface waters. Plants may take up more of the nutrients in the soil, reducing the amount that can be washed into surface waters or leached into ground water. During grading, seedbed preparation, seeding, and mulching, large quantities of sediment and associated chemicals may be washed into surface waters prior to plant establishment.
Crop residue use (344)	When this practice is employed, raindrops are intercepted by the residue reducing detachment,use oil dispersion, and soil compaction. Erosion may be reduced and the delivery of sediment and associated pollutants to surface water may be reduced. Reduced soil sealing, crusting and compaction allows more water to infiltrate, resulting in an increased potential for leaching of dissolved pollutants into the ground water.

Table 2-3. (Continued)

Practice	Water Quality Statement
	Crop residues on the surface increases the microbial and bacterial action on or near the surface. Nitrates and surface-applied pesticides may be tied-up and less available to be delivered to surface and ground water. Residues trap sediment and reduce the amount carried to surface water. Crop residues promote soil aggregation and improve soil tilth.
Diversion (362)	This practice will assist in the stabilization of a watershed, resulting in the reduction of sheet and rill erosion by reducing the length of slope. Sediment may be reduced by the elimination of ephemeral and large gullies. This may reduce the amount of sediment and related pollutants delivered to the surface waters.
Field border (386)	This practice reduces erosion by having perennial vegetation on an area of the field. Field borders serve as "anchoring points" for contour rows, terraces, diversions, and contour strip cropping. By elimination of the practice of tilling and planting the ends up and down slopes, erosion from concentrated flow in furrows and long rows may be reduced. This use may reduce the quantity of sediment and related pollutants transported to the surface waters. When the field borders are located such that runoff flows across them in sheet flow, they may cause the deposition of sediment and prevent it from entering the surface water. Where these practice are between cropland and a stream or water body, the practice may reduce the amount of pesticide application drift from entering the surface water.
Filter strip (393)	Filter strips for sediment and related pollutants meeting minimum requirements may trap the coarser grained sediment. They may not filter out soluble or suspended fine-grained materials. When a storm caused runoff in excess of the design runoff, the filter may be flooded and

Table 2-3. (Continued)

Practice	Water Quality Statement
	may cause large loads of pollutants to be released to the surface water. This type of filter requires high maintenance and has a relative short service life and is effective only as long as the flow through the filter is shallow sheet flow. Filter strip for runoff form concentrated livestock areas may trap organic material, solids, materials which become adsorbed to the vegetation or the soil within the filter. Often they will not filter out soluble materials. This type of filter is often wet and is difficult to maintain. Filter strips for controlled overland flow treatment of liquid wastes may effectively filter out pollutants. The filter must be properly managed and maintained, including the proper resting time. Filter strips on forest land may trap coarse sediment, timbering debris, and other deleterious material being transported by runoff. This may improve the quality of surface water and has little effect on soluble material in runoff or on the quality of ground water. All types of filters may reduce erosion on the area on which they are constructed. Filter strips trap solids from the runoff flowing in sheet flow through the filter. Coarse-grained and fibrous materials are filtered more efficiently than fine-grained and soluble substances. Filter strips work for design conditions, but when flooded or overloaded they may release a slug load of pollutants into the surface water.

Table 2-3. (Continued)

Practice	Water Quality Statement
Grade stabilization structure (410)	Where reduced stream velocities occur upstream and downstream from the structure, streambank and streambed erosion will be reduce. This will decrease the yield of sediment and sediment-attached substances. Structures that trap sediment will improve downstream water quality. The sediment yield change will be a function of the sediment yield to the structure, reservoir trap efficiency and of velocities of released water. Ground water recharge may affect aquifer quality depending on the quality of the recharging water. If the stored water contains only sediment and chemical with low water solubility, the ground water quality should not be affected.
Grassed waterway (412)	This practice may reduce the erosion in a concentrated flow area, such as in a gully or in ephemeral gullies. This may result in the reduction of sediment and substances delivered to receiving waters. Vegetation may act as a filter in removing some of the sediment delivered to the waterway, although this is not the primary function of a grassed waterway. Any chemicals applied to the waterway in the course of treatment of the adjacent cropland may wash directly into the surface waters in the case where there is a runoff event shortly after spraying. When used as a stable outlet for another practice, waterways may increase the likelihood of dissolved and suspended pollutants being transported to surface waters when these pollutants are delivered to the waterway.

Table 2-3. (Continued)

Practice	Water Quality Statement
Grasses and legumes in rotation (411)	Reduced runoff and increased vegetation may lower erosion rates and subsequent yields of sediment and sediment-attached substances. Less applied nitrogen may be required to grow crops because grasses and legumes will supply organic nitrogen. During the period of the rotation when the grasses and legumes are growing, they will take up more phosphorus. Less pesticides may similarly be required with this practice. Downstream water temperatures may be lower depending on the season when this practice is applied. There will be a greater opportunity for animal waste management on grasslands because manures and other wastes may be applied for a longer part of the crop year.
Sediment basin (350)	Sediment basins will remove sediment, sediment- associated materials and other debris from the water which is passed on downstream. Due to the detention of the runoff in the basin, there is an increased opportunity for soluble materials to be leached toward the ground water.
Contour stripcropping (585)	This practice may reduce erosion and the amount of sediment and related substances delivered to the surface waters. The practice may increase the amount of water which infiltrates into the root zone, and, at the time there is an overabundance of soil water, this water may percolate and leach soluble substances into the ground water.
Field stripcropping (586)	This practice may reduce erosion and the delivery of sediment and related substances to the surface waters. The practice may increase infiltration

Table 2-3. (Continued)

Practice	Water Quality Statement
	and, when there is sufficient water available, may increase the amount of leachable pollutants moved toward the ground water. Since this practice is not on the contour there will be areas of concentrated flow, from which detached sediment, adsorbed chemicals and dissolved substances will be delivered more rapidly to the receiving waters. The sod strips will not be efficient filter areas in these areas of concentrated flow.
Terraces (600)	This practice reduces the slope length and the amount of surface runoff which passes over the area downslope from an individual terrace. This may reduce the erosion rate and production of sediment within the terrace interval. Terraces trap sediment and reduce the sediment and associated pollutant content in the runoff water which enhance surface water quality.Terraces may intercept and conduct surface runoff at a nonerosive velocity to stable outlets, thus, reducing the occurrence of ephemeral and classic gullies and the resulting sediment. Increases in infiltration can cause a greater amount of soluble nutrients and pesticides to be leached into the soil. Underground outlets may collect highly soluble nutrient and pesticide leachates and convey runoff and conveying it directly to an outlet, terraces may increase the delivery of pollutants to surface waters. Terraces increase the opportunity to leach salts below the root zone in the soil. Terraces may have a detrimental effect on water quality if they concentrate and accelerate delivery of dissolved or suspended nutrient, salt, and pesticide pollutants to surface or ground waters.
Water and sediment control basin (638)	The practice traps and removes sediment and sediment-- attached substances from runoff. Trap control efficiencies for sediment and total phosphorus, that are transported by runoff, may exceed 90 percent in silt loam soils. Dissolved substance, such as nitrates, may be removed

Table 2-3. (Continued)

Practice	Water Quality Statement
	from discharge to downstream areas because of the increased infiltration. Where geologic condition permit, the practice will lead to increased loadings of dissolved substances toward ground water. Water temperatures of surface runoff, released through underground outlets, may increase slightly because of longer exposure to warming during its impoundment.

SOURCE: Soil Conservation Service, 1988.

Table 2-4. Cost Estimates for Selected Management Practices From Chesapeake Bay Installations

Practice	Total Acres Treated[1]	Total Cost (1990 Dollars)	Annual Cost (\$/Ac/Yr)[2]	Practice Life Span
Conservation Tillage	20,627	371,704	18.1[3]	1
Stripcropping	4,754	213,941	11.9	5
Terraces	812	175,925	35.3	10
Grassed Water Ways	4,311	2,488,144	94.0	10
Diversions	615	153,516	40.6	10
Sediment Retention Water control Structures	21,190	3,952,752	30.5	10
Grassed Filter Strips	4,351	44,206	2.7	5
Permanent Veg. Cover on Cr. Areas	18,041	627,368	9.2	5
Reforestation of Crop and Pastureland	4,658	677,069	23.6	10
Cover Crops	1,845	20,022	10.9	1

SOURCE: U.S. Environmental Protection Agency, Chesapeake Bay Program, 1991.

[1] Total acres treated is the actual area upon which the practice is applied. Some practices, such as filter strips and diversions, actually serve or benefit several times more acreage than is treated, so cost per acre served or benefitted can be substantially lower, and cost per ton of sediment "saved" can also be much lower.

[2] Annual cost is calculated as total amortized cost (10%) over life span of practice, divided by (acres treated x life span).

[3] Net costs are often much lower than this, frequently being negative.

Table 2-5. Effects of Three Tillage Systems on Returns in Indiana

Crop/Tillage	Poorly Drained Soils	Somewhat Poorly Drained Soils	Well Drained Soils
	Dollar Values are Returns per Acre[1]		
Continuous Corn			
Moldboard	$34.32	$16.74	$7.69
Ridge	$49.36	$33.16	$30.26
No-Till	$31.11	$25.58	$29.31
Rotation Corn			
Moldboard	$79.20	$54.26	$34.18
Ridge	$94.30	$63.76	$54.41
No-Till	$90.49	$62.81	$53.51
Rotation Soybeans			
Moldboard	$94.10	$65.90	$40.15
Ridge	$104.55	$74.90	$58.85
No-Till	$810.00	$64.95	$57.90

?

SOURCE: Griffith et al., 1986.
[1] Returns (profit) to land, labor, and management.

Table 2-6. Summary of Costs for Selected Practices Applied for Erosion Control as a Primary Purpose

System Number and Name (Systems are combinations of SCS practices - see Appendix 2-A)	Total Cost Per Ton of Soil Saved (1990, amortized $)
SL1 Permanent Vegetative Cover Establishment	0.92
SL2 Permanent Vegetative Cover Improvement	1.05
SL3 Stripcropping System	0.71
SL4 Terrace Systems	0.85
SL5 Diversions	0.84
SL7 Windbreak Restoration or Establishment	0.32
SL8 Cropland Protective Cover	3.48
SL11 Permanent Vegetative Cover on Critical Area	1.41
SL13 Contour Farming	0.30
SL14 Reduced Tillage Systems	1.58
SL15 No-Till System	0.83
WP1 Sediment Retention or Water Control Structure	1.78
WP2 Stream Protection	2.84
WP3 Sod Waterways	1.81
WL1 Permanent Wildlife Habitat	2.09

Source: U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, 1991.

is important to note that for some practices such as conservation tillage the net costs often approach zero and in some cases can be negative due to the savings in labor and energy.

For example, modeling has been used to demonstrate that in Minnesota (Conservation Tillage Information Center, 1986) the return over total cost (i.e., total profit) increases for corn after beans when changing from moldboard plow ($8.52/Ac) to chisel till ($18.09/Ac), ridge till ($28.71), or no-till ($27.80). Similarly, modeling has shown that the relative cost (1982 dollars) for no-till versus conventional tillage in Indiana can vary from losses of $27.87/Ac to savings of $18.13/Ac (Griffith, 1983).

The net cost of conservation tillage depends upon several factors, including crops, soils, and climate. For example, a modeling study for a 750-acre cash grain operation in central Indiana (Griffith et al., 1986) compared projected returns for moldboard plowing, ridge tillage, and no-till planting for poorly drained soils (Group I), somewhat poorly drained soils (Group II), and well-drained soils (Group III). The results are given in Table 2-5 Either no-till or ridge till provides greater returns than moldboard in all nine scenarios, while moldboard provides a greater return than either no-till or ridge till in only three of nine scenarios.

Cost estimates for practices to control erosion and sediment on agricultural lands are also taken from the U.S. Department of Agriculture (USDA, Agricultural Stabilization and Conservation Service, 1991). Cost estimates reported by USDA are given by primary purpose, type of agreement (long term agreement or regular Agricultural Conservation Program (ACP)), and as overall estimates. The costs reported in Table 2-6 are for the primary purpose of erosion control, and long-term agreements and regular ACP agreements are lumped. The components of each practice are given in Appendix 2-A.

The cost to install stripcropping systems (practice SL3) for the primary purpose of erosion control was about $300 per acre treated in 1990. This cost is not amortized. Practice SL3 decreased the average annual erosion rate from 11 to 4.2 T/Ac/Yr, a reduction of 62 percent.

The cost to install permanent vegetative cover on critical areas (practice SL11) for the primary purpose of erosion control was about $152.00 per acre served in 1990. This cost is not amortized. Practice SL11 decreased the average annual erosion rate from 31 to 2.1 T/Ac/Yr, a reduction of 93 percent.

The cost to install contour farming (practice SL13) for the primary purpose of erosion control was about $200 per acre treated in 1990. This cost is not amortized. Practice SL13 decreased the average annual erosion rate from 18 to 6 T/Ac/Yr, a reduction of 67 percent.

The cost to install reduced tillage systems (practice SL14) for the primary purpose of erosion control was about $100 per acre treated in 1990. This cost is not amortized. Practice SL14 decreased the average annual erosion rate from 12 to 3.7 T/Ac/Yr, a reduction of 69 percent.

The cost to install no-till systems (practice SL15) for the primary purpose of erosion control was about $25.00 per acre treated in 1990. This cost is not amortized. Practice SL15 decreased the average annual erosion rate from 12 to 3.7 T/Ac/Yr, a reduction of 69 percent.

7. Operation and Maintenance

Operation:

Most structural practices for erosion and sediment control are designed to operate without human intervention. Water table control structures for example, would require some "operation" to change the water level in the system. Management practices such as conservation tillage, on the other hand, do require "operation" each time they are used. They must be factored into each field operation that takes place to produce the crop, in order to ensure that they are not destroyed. Extreme care must be used to ensure that herbicides are not applied to any practice that uses a permanent vegetative cover, such as waterways and filter strips.

Maintenance:

Structural practices such as diversions, grassed waterways and other practices that require grading and shaping may need to be repaired to maintain the original design; they may also need reseeding to maintain the vegetative cover. Trees and brush should not be allowed to grow on berms, dams or other structural embankments. Sediment retention basins will need to be cleaned to maintain the design volume and efficiency.

Filter strips and field borders need to be maintained to prevent channelization of flow and the resulting short-circuiting of filtering mechanisms. Reseeding of filter strips may be required on a frequent basis.

Cost: The annual cost of operation and maintenance is estimated to range from zero to ten percent of the investment cost (U.S. Department of Agriculture, Soil Conservation Service-Michigan, 1988).

8. Planning Considerations

Site specific resource information should be obtained from the SCS Field Office Technical Guide. Before deciding on the management practices for building a management measure system, there are several planning issues that should be considered. System adaptation to the site conditions, acceptability of the practice(s) in the system to the land user, and the reduction in erosion that will be realized by installation of the practices are key aspects that must be considered.

Local or state laws and regulations may dictate a specific level of erosion reduction or specific conservation practices that must be included. Practices that are chosen for the management measure must also meet objectives of the land user.

There are many conservation practices that can be used in developing a management measure. Standards for these practices can be found in the local Soil Conservation Service Field Office Technical Guide. Other site specific resource information necessary for good system planning can be found in these SCS guides.

Generally, more than one conservation practice will be needed to meet the sediment delivery required of the management measure. Several combinations of practices are likely to exist for meeting the established sediment delivery rate.
Management measure system options should be prepared based on water quality objectives and the land users' objectives. Each alternative should contain erosion and sediment reduction evaluations. The land user can then choose the system that best addresses personal objectives while also meeting the erosion and sediment control guidelines as well as water quality goals.

Other conservation practices, such as wildlife upland habitat management, tree planting, farmstead and feedlot windbreak, pastureland and hayland planting, or other land use conversion practices should be considered when developing a management measure. Adding one or more of these practices may provide additional erosion and sediment control, improve the environment, and add aesthetic values previously not realized.

B. Confined Animal Facility Management

1. Management Measure Applicability

Confined animal facilities are: areas used to grow or house the animals; equipment and supplies for production, processing and storage of product; the land near the buildings that the animals have access to that does not support vegetative cover; manure and runoff storage areas; and silage storage areas. These areas are subject to runoff control. The land upon which the manure, runoff and other wastes are utilized is considered agricultural crop, hay and pasture land and also subject to management measures for: erosion and sediment control, pesticides, nutrients irrigation water and grazing, where applicable.

This management measure is to be applied to all existing confined animal facilities, except those facilities that are required to apply for and receive discharge permits under 40 CFR, Section 122.23 ("Concentrated Animal Feeding Operations"). All new facilities are expected to be built and operated in accordance with this measure.

2. Pollutants Produced by Confined Animal Facilities

The following pollutants may be contained in manure and associated bedding materials and may be transported by runoff water from confined animal facilities and process wastewater:

- Nitrogen, phosphorus and many other major and minor nutrients or other deleterious materials;
- Salts;
- Bacteria, virus and other microorganisms;
- Organic solids;
- Oxygen demanding substances; and
- Sediments.

3. Management Measure to Control Confined Animal Facilities

The management measure for confined animal facilities control is a combination of practices that reduce discharge of pollutants from a confined animal facility by storing the runoff from storms up to and including a 24 hour, 25 year frequency storm and preventing pollutant movement to ground water. Manure and runoff water that is utilized on agricultural land will be applied in accordance with the nutrient management measure. Disposal of dead animals will be accomplished in a manner that will prevent any pollution to surface and ground waters. The management measure for confined animal facilities consists of:

(1) Storing the runoff from an confined animal facility from storms up to and including of 24 hour, 25 year frequency storm, and preventing contamination of ground water.This will require diversion of clean water around the facility and from roofs; control of runoff from lot surfaces and from storage areas for runoff and manure; and control of process wastewater.

(2) Utilizing manure and runoff water on agricultural lands in accordance with the nutrient management measure; utilizing manure for bedding; or processing of manure for commercial marketing.

(3) Disposing of dead animals from the facility by composting, incineration, utilization of an approved burial site or, removal via commercial service.

4. Confined Animal Facilities Management Practices

Following is a list of management practices for confined animal facilities that are available as tools to achieve the management measure as set forth in section B.3. Under each management practice, the U.S. Soil Conservation Service (SCS) practice number and a definition are provided. The list of practices included in this section is not exhaustive and does not preclude States or local agencies from developing special management practices in cooperation with the appropriate technical agency within the State for unique conditions and problems that may be encountered in particular areas, provided that the management measures (the system of individual practices adopted) achieve a level of performance that is as effective as that provided by the management measure specified in this guidance. There may also be State or local standards that would require additional practices.

a. For runoff control at the production facility

Dikes (356)
An embankment constructed of earth or other suitable materials to protect land against overflow or to regulate water.

The purpose is to permit improvement of agricultural land by preventing overflow and better use of drainage facilities, to prevent damage to land and property, and to facilitate water storage and control in connection with wildlife and other developments. Dikes can also be used to protect natural areas, scenic features, and archeological sites from damage.

Diversions (362)
A channel constructed across the slope with a supporting ridge on the lower side.

The purpose is to divert excess water from one area for use or safe disposal in other areas.

Grassed waterway (412)
A natural or constructed channel that is shaped or graded to required dimensions and established in suitable vegetation for the stable conveyance of runoff.

The purpose is to convey runoff from terraces, diversions, or other water concentrations without causing erosion or flooding and to improve water quality.

Heavy use area protection (561)
Protecting heavily used areas by establishing vegetative cover, by surfacing with suitable materials, or by installing needed structures.

The purpose is to stabilize urban, recreation, or facility areas frequently and intensely used by people, animals, or vehicles.

Lined waterway or outlet (468)
A waterway or outlet having an erosion-resistant lining of concrete, stone, or other permanent material. The lined section extends up the side slopes to a designed depth. The earth above the permanent lining may be vegetated or otherwise protected.

The purpose is to provide for safe disposal of runoff from other conservation structures or from natural concentrations of flow, without damage by erosion or flooding, where unlined or grassed waterways would be inadequate. Properly designed linings may also control seepage, piping, and sloughing or slides.

Roof runoff management (558)
A facility for controlling, and disposing of runoff water from roofs.

The purpose is to prevent roof runoff water from flowing across concentrated waste areas, barnyards, roads and alleys, and to reduce pollution and erosion, improve water quality, prevent flooding, improve drainage, and protect the environment.

Terrace (600)
An earthen embankment, a channel, or combination ridge and channel constructed across the slope.

The purpose is to: (1) reduce slope length, (2) reduce erosion, (3) reduce sediment content in the runoff water, (4) improve water quality, (5) intercept and conduct surface runoff at a non-erosive velocity to a stable outlet, (6) retain runoff for moisture
conservation, (7) prevent gully development, (8) re-form the land surface, (9) improve farmability, or reduce flooding.

b. Manure and runoff storage

Waste storage pond (425)
An impoundment made by excavation or earthfill for temporary storage of animal or other agricultural wastes.

The purpose is to store liquid and solid wastes, waste water, and polluted runoff to reduce pollution and to protect the environment.

Waste storage structure (313)
A fabricated structure for temporary storage of animal wastes or other organic agricultural wastes.

The purpose is to temporarily store liquid or solid wastes as part of a pollution-control or energy-utilization system to conserve nutrients and energy and to protect the environment.

Waste treatment lagoon (359)
An impoundment made by excavation or earthfill for biological treatment of animal or other agricultural wastes.

The purpose is to biologically treat organic wastes, reduce pollution, and protect the environment.

c. Utilization of manure and runoff water

1. Application of manure and/or runoff water to agricultural land
Manure and/or runoff water will be applied to agricultural lands and incorporated into the soil in accordance with the management measures for nutrients.

Waste Utilization (633)
Using agricultural wastes or other wastes on land in an environmentally acceptable manner while maintaining or improving soil and plant resources.

The purpose is to safely use wastes to provide fertility for crop, forage, or fiber production; to improve or maintain soil structure; to prevent erosion; and to safeguard water resources.

2. Commercial marketing of manure

Composting facility (317)
A facility for the biological stabilization of waste organic material.

The purpose is to treat waste organic material biologically by producing a humus-like material that can be recycled as a soil amendment and fertilizer substitute or otherwise utilized in compliance with all laws, rules, and regulations.

d. Disposal of dead animals

"Dead Bird" composting

Composting facility (317)
A facility for the biological stabilization of waste organic material.

The purpose is to treat waste organic material biologically by producing a humus-like material that can be recycled as a soil amendment and fertilizer substitute or otherwise utilized in compliance with all laws, rules, and regulations.

Commercial Disposal Services

Incineration

Approved Burial Sites

5. **Effectiveness Information**

Pollution reductions that can be expected from installation of the management practices outlined above are as follows:

When runoff from storms up to and including the 24 hour, 25 year storm is stored, there will be no release of pollutants from a confined animal facility via the surface runoff route. Rare storms of a greater magnitude may produce runoff, but the "first flush" from them would be contained by the 24 hour, 25 year storage volume. Table 2-7 reflects the occurrence of such storms by indicating less than 100 percent control for runoff control systems.

Table 2-7. Runoff Control Efficiency

Management Practice	Removal efficiency Solids	Removal efficiency Phosphorus
Runoff Control System	80 to 90	70 to 95

SOURCE: Development Planning and Research Associates, Inc., 1986.

The information contained herein is primarily practice-oriented, yet EPA seeks data regarding the overall effectiveness of management measures, or systems of practices. To this end, EPA is continuing to collect and analyze more information regarding pollutant reductions, and solicits comments regarding information sources to utilize.

6. Cost Information

Cost factors for control of runoff and manure from confined animal facilities.

Table 2-8. Estimated Cost for Runoff Control Systems, by Size Range
Runoff Control Systems Only

Feedlot Capacity (head)	Investment	Cost Ranges Annual Dollars	Annualized
100	5000-12000	300-600	770-1730
500	9000-16000	400-800	1250-2310
1000	11000-20000	500-1000	1540-2900

SOURCE: Development Planning and Research Associates, Inc., 1986.

7. Operation and Maintenance of this Measure

a. Runoff control system

Operation: The holding ponds or lagoons should be drawn down to design storm capacity within 14 days of a runoff event. Solids should be removed from the solids separation system after a runoff event to ensure that solids will not enter the runoff holding facility.

Maintenance: Diversions will need to be reshaped periodically and should be free of trees and brush growth. Gutters and downspouts should be inspected annually and repaired when needed. Established grades for lot surfaces and conveyance channels must be maintained at all times.

Channels must be free of trees and brush growth. Debris basins, holding ponds and lagoons will need to be cleaned to assure that design volumes are maintained. Irrigation equipment, if used to apply runoff water, should be flushed with fresh water after use. This is usually done twice per year. In warm climates this may be done four times per year, while in other colder climates, only once per year. Clean water should be excluded from the storage structure unless it is needed for further dilution in a liquid system.

Table 2-9. Estimated Cost Implications for Selected Management Practices

Practice	Unit	Capital (approximate)	Operating and Maintenance (Approximate)
Terrace systems	$14-39 per ha	$120-330 per ha	est. 5% of capital annually
Sod waterways	$7/ha drained	$100/ha drained	$500/ha/yr
Diversions	$90/ha	$600/ha	est. 5% of capital annually
Manure storage and use of nutrients	$10-20 per ha	$250-500 per ha	pumping, spreading of manure
Feedlot runoff control	$4/ha	$50/ha	5% of capital annually
Exclusion or limited access to water courses	$12/ha	$100/ha	5% of capital annually

SOURCE: Non-Point Source Task Force, International Joint Commission, 1983.
NOTE: All costs are 1982 dollars and amortized at a zero discount rate.

b. Manure storage system

Operation: The storage structure should be emptied when manure can be applied to cropland.Maintenance: Storage structures should be inspected for cracks and leaks after each use cycle. Manure transfer equipment must be inspected and repaired after each use cycle.

c. Cost

The annual cost of maintenance is estimated to be five percent of the investment cost.

C. Nutrient Management Measure

The basic concept of nutrient management is pollution prevention, by using only the nutrients necessary to produce a crop. This measure may result in some reduction in the amount of nutrients being applied to the land, thereby reducing the cost of production as well as protecting water quality.

1. Management Measure Applicability

This management measure is to be utilized on all agricultural lands that have nutrients applied to them. When the source of the nutrients is other than commercial fertilizer, the material must be tested to determine the nutrient value and the rate of availability of the nutrients. Also, for municipal and/or industrial treatment plant sludge and effluent, the concentration of metals and organic toxics must be known before these wastes are considered for application to agricultural lands as nutrient sources.

Those agricultural lands that also meet the applicability definitions of the pesticide management measure, erosion and sediment control management measure, grazing management measure, irrigation water management, or other management measures, are also subject to those management measures.

2. Pollutants Produced by Application of Nutrients Sources

Surface water runoff from agricultural lands that have had nutrients applied to them, may transport the following pollutants:

- Particulate bound nutrients, chemicals and metals, such as phosphorus, organic nitrogen, metals applied with some organic wastes and found naturally within the soil;

- Soluble nutrients and chemicals, such as nitrogen, phosphorus, metals and many other major and minor nutrients;

- Sediment, particulate organic solids, oxygen demanding material;

- Salts; and
- Bacteria, viruses and other microorganisms.

Ground-water infiltration from agricultural lands that have had nutrients applied to them, may transport the following pollutants:

- Soluble nutrients and chemicals, such as nitrogen, phosphorus, metals and many other major and minor nutrients, and salts.

3. Sources of Nutrients That Are Applied to Agricultural Lands

Nutrients are applied to agricultural land in several different forms and come from various sources, including;

- Commercial fertilizer in a dry or fluid form, containing N,P,K, secondary nutrients and micro-nutrients;
- Manure from animal production facilities including bedding and other wastes added to the manure, containing N,P,K, secondary nutrients, micro-nutrients, salts, some metals and organics;
- Municipal and/or industrial treatment plant sludge, containing N,P,K, secondary nutrients, micro-nutrients, salts, metals and organic solids;
- Municipal and/or industrial treatment plant effluent, containing N,P,K, secondary nutrients, micro-nutrients, salts, metals and organics;
- Irrigation water; and
- Atmospheric deposition of nutrients such as nitrogen and sulphur.

4. Management Measure to Control Nutrients

Following are the management measures for controlling excess nutrient use in agriculture. To eliminate application of excess nutrients, to improve timing of application, and to increase the use efficiency of nutrients, a nutrient management plan should be developed and implemented:

(1) Prepare a farm and field map containing soils information, a history of previous crops and current crop rotation.

(2) Assess soil productivity by field to determine expected yields for the target crop.

(3) Calculate the nutrient resources available to the producer for the target crop.

(4) Utilizing the limiting nutrient/element concept, establish nutrient/element requirement for the soil or the target crop and the nutrient sources available.

(5) Identify timing and application methods for nutrients that maximize plant utilization of nutrients and minimize the loss to the environment.

(6) Evaluate using cover crops to scavenge nutrients that might remain in the soil after harvest and water level control to keep nitrogen laden water within the root zone for plant use and to promote denitrification in drainage system.

(7) Evaluate field limitations based on environmental hazards or concerns.

(8) Control phosphorus loss from a field by controlling sediment loss. The primary management measure for control of phosphorus will be the erosion and sediment management measure, Section A., which is hereby included within the measure.

5. Nutrient Management Practices

Following is a list of management practices for nutrient management that are available as tools to achieve the management measure as set forth in section C.4. This list of practices is not exhaustive and does not preclude States and local agencies from developing special management practices, in cooperation with appropriate technical agencies for unique conditions and problems that may be encountered in particular areas, provided that the management measures (the system of individual practices adopted) achieve a level of performance that is as effective as that provided by the management measures specified in the guidance. There may also be State and local standards that would require additional nutrient management practices.

Following are the necessary components of a nutrient management plan:

(1) Soils information, a history of previous crops and current crop rotation for each field.

(2) An assessment by field to determine expected yields for the target crop. The expected yield is determined by using the following:

- University fertility recommendations (based on soil series where available),
- SCS Soils 5 information for the soil series, and
- Average yield history for the field.

(3) A summary of the nutrient resources available to the producer for the target crop. This would include the following steps:

- Testing of the soil in the field for phosphorus, potassium and nitrates;*

- Plant tissue testing for nutrient needs during the growing season (where tissue tests are calibrated with crop nutrient needs);

- Estimate of the nitrogen contribution form soil organic matter mineralization, where important;

- Nutrient analysis of manure and sludge; and

- Calculation of the nitrogen contribution to the soil from legumes grown in rotation.

(4) Use of proper timing and application methods for nutrients that maximize plant utilization of nutrients and minimize the loss to the environment, including split application and banding of the nutrients and incorporation of fertilizers, manures and other organic sources.

(5) Use of cover crops (see practice 340 below) to scavenger nutrients and water level control to keep nitrogen-laden water within the root zone for plant use and to promote denitrification in drainage system.

<u>Cover and Green Manure Crop (340)</u>)
A crop of close-growing grasses, legumes or small grain grown primarily for seasonal protection and soil improvement. It usually is grown for 1 year or less, except where there is permanent cover as in orchards.

The purpose is to control erosion during periods when the major corps do not furnish adequate cover; add organic material to the soil and improve infiltration, aeration and tilth.

(6) Evaluate field limitations based on environmental hazards or concerns such as:

- Sinkholes, wells and other routes of direct access to ground water such as karst topography;
- Proximity to surface water;
- Highly erodible soils;
- Highly permeable soils; and
- Shallow aquifers.

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* Soil testing for nitrates in humid regions has produced inconsistent results and should be used with caution. Consideration should be given to the alternative approach of plant tissue testing early in the growing season to determine the nitrogen needs of the crop.

(7) Provide a narrative explaining the plan and its use.

Nutrient Management (590)
Manage the amount, form, placement, and timing of applications of plant nutrients.

The purpose is to supply plant nutrients for optimum forage and crop yields, minimize entry of nutrients to surface and ground water, and to maintain or improve chemical and biological condition of the soil.

6. Effectiveness Information

Following is a summary of some of the available information regarding pollution reductions that can be expected from installation of nutrient management practices.

The State of Maryland estimates that average reductions of 34 pounds of nitrogen and 41 pounds of phosphorus per acre can be achieved through the implementation of nutrient management plans (Maryland Department of Agriculture, 1990). These average reductions may be high because they are mostly for farms that utilize animal wastes, average reductions for farms that only use commercial fertilizer may be much lower. However, they do represents a significant amount of nutrients that will not be applied to the fields and will not be available for transport from the field in surface water or for movement into the ground-water system. The actual percent reduction in the amount of these nutrients reaching coastal waters is difficult to measure or predict at this time. However, field scale and watershed models can be use to predict the *reduction in nutrients moving to the edge of the field and to the ground water.*

As of July 1990, the Chesapeake Bay drainage basin States of Pennsylvania, Maryland, and Virginia reported that approximately 114,300 acres (1.4 percent of eligible cropland in the basin) had nutrient management plans for in place (USEPA, Chesapeake Bay Program, 1991). The average nutrient reduction of total nitrogen and total phosphorus was 31.5 and 37.5 pounds per acre, respectively. The States initially prioritized nutrient management efforts toward animal waste utilization. Because initial planning was focused on animal wastes (which have a relatively high total nitrogen and phosphorus loading factor), estimates of nutrient reduction (see Table 2-10) attributed to nutrient management may decrease as more cropland using only commercial fertilizer is enrolled in the program.

Table 2-10. Estimated Nutrient Reductions for Selected Management Practices

Management Practice	Total P Load Reduction (%) (approximate)
Proper Rate of Fertilizer Application	3
Optimum Timing of Fertilization	20
Optimum Method of Fertilization	up to 90

SOURCE: Non-Point Source Task Force, International Joint Commission, 1983.

7. Cost Information

Following is available information on the costs of implementing nutrient management practices.

In general, most of the costs are associated with providing additional technical assistance to landowners to develop nutrient management plans. In many instances landowners can actually save money by implementing nutrient management plans. For example, Maryland estimates from the over 750 nutrient management plans that were completed prior to September 30, 1990, that if plan recommendations are followed, the landowners will save an average of $23 per acre per year (Maryland Department of Agriculture, 1990). The average saving may be high because most plans were for farm utilizing animal waste, future saving may be reduced as more farms using commercial fertilizer are included in the program.

Table 2-11. Estimated Cost Implications for Selected Management Practices

Practice	Unit	Capital (approximate)	Operating and Maintenance (approximate)
Proper Rate of Fertilizer Application	0	0	0
Optimum Timing of Fertilization	minimal	0	minimal
Optimum Method of Fertilization	minimal	NA	minimal

SOURCE: Non-Point Source Task Force, International Joint Commission, 1983.

8. Planning Considerations for a Nutrient Management Measure

When developing a nutrient management plan the following items should be given careful consideration.

- A farm and field map

  The land that will be included in the nutrient plans should be located on a map of the farm and detailed on field maps showing the location of crop to be grown. A soils map for each field should be included in this initial information package. The map should be accompanied by the exact acres within the field, a five year average of crop yield for the field and an indication of the soil productivity of the field.

- Nutrient requirements of the target crop

  The most critical element of the plan is the yield goal established for the crop. This is to be based on the yield history and productivity of the soil in the field. The goal must be realistic for the soil, the growing season rainfall and management ability of the producer. Once the yield goal for a target crop is established, the nutrient requirements for the target crop can be calculated.

- Nutrient sources available by field and rotation system used for the field

  A list of all sources of nutrients must be developed for each field. This would include results from soil testing, analysis of animal wastes that will be applied to the field, analysis of any other organic wastes that will be applied to the field, credit for crop residues from previous crops, credit for cover crop if grown prior to the target crop, credit for nitrogen in irrigation water and atmospheric deposition on nitrogen on the field during the growing season.

- Indication of any environmental hazards or concerns

  A list of environmental hazards for each field should be developed at this time. The list should indicate areas of excessive leaching within the field, depth to ground water, distance to surface water, location of sink holes, indication of karst subsurface formations, location of water supply wells and areas of the field that are included in a wellhead protection zone.

- The narrative explaining the plan and its use

  The plan will specify the nutrients needed to reach the yield goal and the sources of these nutrients. It will recommend times of application for the sources and the methods of application. This may include split applications of commercial fertilizer, incorporation of manure and the use of slow release nutrient sources. The plan may require either soil testing or tissue testing after the crop reaches a specified stage as a guide for the application of additional nutrients to complete the requirements for the yield goal. Winter cover crops may also be specified to hold nutrients during this time period.

9. Operation and Maintenance for Nutrient Management

Operation:

The utilization of a nutrient management plan requires periodic soil testing for each field, soil and/or tissue testing during the early growth stages of the crop and testing of manure, sludge and irrigation water if they are used. The plan may call for multiple applications of nutrients requiring more that one field operation to apply the total nutrients required for the crop.

Maintenance:

A nutrient management plan should be updated whenever the crop rotation is changed or the nutrient source is changed. Application equipment must be calibrated and inspected for wear and damage periodically and repaired when necessary. Records of nutrient use and source should be maintained along with other production records for each field. These will be used to update or modify the management plan when necessary. The management plan should be reviewed at least every three years.

D. Pesticide Management

The basic concept of pesticide management is pollution prevention. The most effective approach to reducing pesticide pollution of waters is, first, to release fewer pesticides into the environment and, second, to use practices which minimize the movement of pesticides to surface and ground water. In addition, pesticides should only be applied when an economic benefit to the grower will be achieved. Such an approach emphasizes using pesticides only when, and to the extent, necessary to control the target pest. This usually results in some reduction in the amount of pesticides being applied to the land, thereby enhancing the protection of water quality as well as reducing the cost of production.

1. Management Measure Applicability

The management measures set forth in this section are to be utilized on all agricultural lands that have or are intended to have pesticides applied to them.

Those agricultural lands that also meet the applicability definitions of the erosion and sediment management measure, nutrient management measure, grazing management measure, or other management measures are also subject to those management measures.

2. Pollutants Associated with Agricultural Pesticide Use

Pesticides include any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest or intended use as a plant regulator, defoliant, or desiccant. The principal pesticidal pollutants that may be detected in surface water and in ground water are the active and inert ingredients and any persistent degradation products. Pesticides may enter ground and surface water in dissolved form or bound to eroded soil particles.

3. Sources of Pesticides

A major source of contamination from pesticide use is the result of application of pesticides. Other sources of pesticide contamination are atmospheric deposition, spray drift during the application process, misuse, and spills, leaks, and discharges that may be associated with pesticide storage, handling and waste disposal.

4. Management Measures to Manage Pesticide Use

Following are the management measures for managing agricultural pesticide use. They will reduce surface and ground-water contamination, eliminate application of excess pesticides, improve timing and efficiency of application, increase the use efficiency of pesticides, and reduce the generation of pesticide wastes. Specific pesticide management measures are as follows:

(1) Evaluate the pest problems, previous pest control measures, and cropping history.

(2) Evaluate the physical characteristics of the site for the leaching of soluble pesticides or runoff of soluble or soil-borne pesticides.

(3) Utilize integrated pest management (IPM) systems to reduce the amount of pesticides applied to the maximum extent that is technically and economically achievable. IPM is defined as a pest control strategy based on the determination of an economic threshold that indicates when a pest population is approaching the level at which control measures are necessary to prevent a decline in net returns. In principle, IPM is an ecologically based strategy that relies on natural mortality factors, such as natural enemies, weather, and crop management, and seeks control tactics that disrupt these factors as little as possible (National Research Council, 1989).

(5) If pesticide applications are necessary and a choice of materials exists, consider the persistence and leachability of products along with other factors in making a selection. Users must apply pesticides in accordance with the instructions on the label of each pesticide product, and when required, be trained and certified in the proper use of the pesticide.

(6) Ensure that pesticides are handled safely, and stored and disposed of properly.

5. Pesticide Management Practices

Following is a list of management practices for pesticide management that are available as tools to achieve the management measure as set forth in section D.4. This list of practices is not exhaustive and does not preclude States and local agencies from developing special management practices, in cooperation with the appropriate technical agency within the State for unique conditions and problems that may be encountered in particular areas, provided that the management measures (the system of individual practices adopted) achieve a level of performance that is as effective as the provided by the management measures specified in the guidance. There may also be State and local standards that would require additional pesticide management practices:

(1) Inventory of current and historical pest problems, cropping patterns and use of pesticides for the field.

(2) Consider soil and physical characteristics of the site, including the potential for the leaching or runoff of pesticides. In situations where the potential for loss is high, emphasis should be given to practices and/or management measures that will minimize these potential losses. The physical characteristics to be considered should include limitations based on environmental hazards or concerns such as:

- Sinkholes, wells and other areas of direct access to ground water such as karst topography;

- Proximity to surface water;
- Highly erodible soils;
- Soils with poor adsorptive capacity;
- Highly permeable soils; and
- Shallow aquifers;

(3) Following is a list of the primary practices available to implement IPM systems:

- More efficient application methods e.g. spot spraying;
- Pesticide application based on economic thresholds;
- Use of resistant crop strains;
- Use less environmentally persistent pesticides;
- Use pesticides with reduced mobility in water;
- Use timing of field operations (planning, cultivating, and harvesting) to minimize application of pesticides;
- Conduct scouting (use periodic scouting to determine when pest problems reach the economic threshold on the farm);
- Use of biological controls:
  - (a) introduction and fostering of natural enemies;
  - (b) preservation of predator habitats; and
  - (c) release of sterilized male insects;
- Use of pheromones:
  - (a) for monitoring populations;
  - (b) for mass trapping;
  - (c) for disrupting mating or other behaviors of pests; and
  - (d) to attract predators/parasites;
- Crop rotations
- Use cover crops in the system, as needed, to promote water use and reduce deep percolation of water that contributes to leaching of pesticides into ground water;
- Destruction of pest breeding, refuge and overwintering sites;
- Use of "trap" crops;
- Habitat diversification; and
- Use of botanicals.

(4) Maintain a history of pesticide use for each field. This could include the types of pesticides used, amount, and the method of application.

(5) A strong State role and linkage with other evolving ground and surface water protection programs is critical to protect water resources from contamination from pesticide chemicals. Therefore, States should integrate this aspect of their Coastal program with State and Federal strategies designed to reduce ground and surface water contamination associated with pesticide use. Particular attention should be paid to practices which provide flexibility for decisions to be made on a geographic basis--taking into account use, value and vulnerability of ground-water resources.

6. Implementation of Management Measure

The management measures specified in section D.4 identify the changes in behavior and thought processes that are needed to manage pesticides to reduce excess pesticide use. FIFRA can be used to enforce requirements to follow pesticide label instructions and for applicator training and certification, when necessary. States are using a variety of approaches to encourage change in behavior and thought processes regarding pesticide use, such as State wide and regional strategies and farm-specific plans. EPA believes that farm-specific pesticide management plans may be necessary to document the changes in behavior and the thought processes necessary to implement the management measure.

EPA solicits comment on whether the pesticide management measure should include development of a pesticide management plan so that the behavior and thought process associated with the management measures is documented.

7. Effectiveness Information

Following is a summary of available information regarding pollution reductions that can be expected from using pesticide management practices.

Table 2-12 summarizes estimates of potential pesticide loss reductions from various management practices and systems of practices at a field level as compared with a hypothetical field utilizing cropping practices which were typical until the late 1970's. The uncertainty of the estimates is a function of the rapid transitions in production methods coupled with the variance among regions and seasons. Traditional sediment and erosion control practices are not as effective on cotton as with corn and soybeans because much cotton is grown on relatively flat land with little or no water erosion problem (Heimlich and Bills, 1984).

Table 2-13 summarizes the estimates of pesticide loss reductions from various management practices and combinations of practices for corn (North Carolina State University, 1984). These estimates are made at the field level as compared with a hypothetical field utilizing conventional, traditional or typical cropping practices realizing that these practices may vary considerably between geographic regions.

The Non-Point Source Task Force of the International Joint Commission (1983) for the Great Lakes Basin also estimated pesticide reductions associated with selected management practices and the data are summarized in Table 2-14. The Task Force found that the most effective, although not necessarily the most acceptable method of pesticide Great Lakes loading control, is regulation of the use of volatile and persistent pesticides (see practice no. 2 below). They noted that this has been effective in the Great Lakes Basin.

The Great Lakes Pollution from Land Use Activities Reference Group (PLUARG) agricultural watershed studies found that 66 percent of simazine loadings and 22 percent of atrazine loadings were due to spills in 1976-77 (Frank et al., 1978). Thus, safe handling, storage and disposal practices (see practice no.6 below) alone, can significantly reduce pesticide losses.

Table 2-12. Estimates of Potential Reductions in Field Losses of Pesticides for Cotton Compared to a Conventionally and/or Traditionally Cropped Field[1]

	Transport Route(s)	Range of Pesticide Loss Reduction (Percent)[2]
Terracing	SR and SL #	0-(20*)
Contouring	SR and SL	0-(20*)
Reduced Tillage	SR and SL	-40 - +20 AB
Grassed Waterways	SR and SL	0-10 AB
Sediment Basins	SR	0-10 AB
Filter Strips	SR	0-10 A
Cover Crops	SR and SL	-20 - +10 B
Optimal Application Techniques[3]	All Routes ($)	40-80 A
Nonchemical Methods	All Routes	
Scouting Economic Thresholds	All Routes	40-65 A 0-30 B
Crop Rotations	All Routes	0-20 A 10-30 B
Pest Resistant Varieties	All Routes	0-60 A 0-30 B
Alternative Pesticides	All Routes	60-95 A 0-20 B

SOURCE: North Carolina State University, 1984.

* Refers to estimated increases in movement through soil profile.
\# SR = Surface Runoff
SL = Soil Leaching
$ Particularly drift and volatilization

[1]The hypothetical traditionally cropped comparison field utilizes the following management system:
a) conventional tillage without other SWCPs,
b) aerial application of all pesticides with timing based only on field operation convenience,
c) ten insecticide treatments annually with a total application of 12 kg/ha based on a prescribed schedule,
d) cotton grown in 3 out of 4 years,
e) long season cotton varieties.

[2]Assumes field loss reductions are proportional to application rate reductions.
A = insecticide (toxaphene, methylparathion, synthetic pyrethroids).
B = herbicides (trifluralin, fluometron).
Ranges allow for variation in production region, climate, slope and soils.
[3]Defined for cotton as ground application using optimal droplet or granular size ranges with spraying restricted to calm periods in late afternoon or at night when precipitation is not imminent.

Table 2-13. Estimates of Potential Reductions in Field Losses of Pesticides for Corn Compared to a Conventionally and/or Traditionally Cropped Field[1]

Management Practice	Transport Route(s) Affected	Range of Pesticide Loss Reduction (Percent)[2]
SWCPs	SR and/or SL(#)	
Terracing	SR and/or SL	40-75AB (25*)
Contouring	SR and/or SL	15-55AB (20*)
No-till	SR and/or SL	-10 - +40B 60 - +10A (10*)
Other Reduced Tillage	SR and/or SL	-10 - +60B -40 - +20A (15*)
Grassed Waterways	SR	-10-20AB
Sediment Basins	SR	0-10AB
Filter Strips	SR	0-10AB
Cover Crops	SR and/or SL	0-20B[3]
Optimal Application Techniques[4]	All Routes $	10-20 20-40B
Nonchemical Methods	All Routes	
Adequate Monitoring	All Routes	40-65A
Crop Rotations	All Routes	40-70A 10-30B

SOURCE: North Carolina State University, 1984
* Refers to estimated increases in movement through soil profile.
# SR = Surface Runoff
SL = Soil Leaching
$ Particularly drift and volatilization

[1]The hypothetical field used as the basis for comparison utilizes the following management system:
a) conventional tillage without other SWCPs,
b) ground application with timing based only on field operation convenience,
c) little or no pest monitoring; spraying on prescribed schedule,
d) corn grown in 3 out of 4 years.
[2]Assumes field loss reductions are proportional to application rate reductions. A = insecticides (carbofuran and O.P.s) B = herbicides (Triazine, Alachlor, Butylate, Parquat) Ranges allow for variation in climate, slope, soils and types of pesticides used. Ranges for no-till and reduced-till are derived from a combination of increased application rates and decreased runoff losses.
[3]Cover crops only will affect runoff and leaching losses for pesticides persistent enough to be available over the non-growing season. In the case of pesticides used on corn only the triazine and anilide herbicides will generally meet this criteria.
[4]Defined here for corn as ground application using optimal droplet or granular size ranges, with spraying restricted to calm periods in late afternoon or evening.

Table 2-14. Estimated Pesticide Reductions for Selected Management Practices

Management Practice	Percent Reduction (Approximate)
1. Proper rate of pesticide application	50 - 75% (in conjunction with No. 3)
2. Use of pesticides with minimum persistence and volatility	100%
3. Optimum method of pesticide application	50 - 75% (in conjunction with No. 1)
4. Optimum timing of pesticide application	50% (if application prior to spring runoff can be avoided)
5. Integrated pest management	Undocumented (but up to 100% is possible)
6. Safe handling, storage and disposal of pesticides	up to 50%

SOURCE: Non-Point Source Task Force, International Joint Commission, 1983.

8. Cost Information

In general, most of the costs of implementing a pesticide management plan are program costs associated with providing additional technical assistance to landowners to develop pesticide management plans and for field scouting during the growing season. Producers can actually save money by implementing pesticide management plans.

The Non-Point Source Task Force of the International Joint Commission for the Great Lakes Basin (1983) estimated the cost implications for selected pesticide management practices and the data are summarized in Table 2-15.

Costs for erosion and sediment control and for irrigation management are in Sections A and F, respectively.

Table 2-15. Estimated Cost Implications for Selected Pesticide Management Practices

Management Practice	Unit	Capital Approximate	Operating
1. Proper rate of pesticide application	minimal	0	minimal
2. Use of pesticides with minimum persistence and volatility	0	0	
3. Optimum method of pesticide application	minimal	minimal	0
4. Optimum timing of pesticide application	minimal	0	minimal
5. Integrated pest management	minimal	0	major inconvenience

SOURCE: Non-Point Source Task Force, International Joint Commission, 1983.

9. Planning Considerations for Implementing Pesticide Management

Following is a more detailed discussion regarding effective pesticide management:

- A farm and field map.

  The land where pesticides will be used should be located on a map of the farm. In addition, the following information should be compiled for each field:

  - Crops to be grown and a history of crop production;
  - Information on soils types;
  - The exact acres within each field; and
  - Record on past pesticide use on each field.

- Pesticide requirements for the target pest(s).

  The most critical element is establishment of the economic yield reductions thresholds for each crop. The reduction thresholds must be realistic for the producer.

- Pesticide sources available by field and rotation system used for the field.
- Indication of any environmental hazards or concerns.

  A list of environmental hazards for each field should be developed at this time. The list should indicate
  areas of excessive leaching within the field, depth to ground water, distance to surface water, location of sink holes, indication of karst subsurface formations, location of water supply wells and areas of the field that are included in a wellhead protection zone.

10. Operation and Maintenance for Pesticide Management

Operation:

Effective pesticide management may require periodic scouting of each field for pests. Also, multiple applications of pesticides may require more that one field operation to apply the pesticides required for the crop.

Maintenance:

Pesticide management measures should be updated whenever the crop rotation is changed or the pesticide source is changed. Application equipment must be calibrated and inspected for wear and damage periodically and repaired when necessary. Records of pesticide application should be maintained along with other production records for each field. These will be used to update or modify the management measure when necessary. The management measure for each field should be reviewed every year.

E. Grazing Management

This management measure is designed to improve water quality from, and protect riparian zones within, range or pasture land. The key elements are grazing management for the proper utilization of the forage component of the vegetation, controlling access to or excluding livestock from sensitive areas such as streambanks and riparian zones, and improving of vegetative cover to reduce erosion.

1. Management Measure Applicability

The management measure is to be utilized on all irrigated and non-irrigated agricultural pasture lands and range lands.

Those range and pasture lands that also meet the applicability definitions of the erosion and sediment control management measure, pesticide management measure, nutrient management measure, irrigation water management, or other management measures are also subject to those management measures.

2. Pollutants Produced by Utilization of Agricultural Range and Pasture Lands

Runoff water from agricultural pasture lands and range lands may transport the following types of pollutants:

- Sediment and particulate organic solids;
- Particulate bound nutrients, chemicals and metals, such as phosphorus, organic nitrogen, a portion of applied pesticides, and a portion of the metals applied with some organic wastes and found naturally within the soil;
- Soluble nutrients, such as nitrogen, a portion of the phosphorus, a portion of the applied pesticides, a portion of the soluble metals and many other major and minor nutrients;
- Salts; and
- Bacteria, viruses and other microorganisms.

3. Management Measure to Control Range and Pasture Land Grazing

The range and pasture land grazing control management measure is a combination of practices to reduce the discharge of sediment, nutrients and chemicals from agricultural pasture land and range lands to receiving waters; to prevent streambank erosion caused by livestock; and to enhance or maintain riparian zones at the good to excellent conditional status. At a minimum, for range land this measure will maintain the range condition at the good condition status* or above; for pasture this measure will maintain a vegetation cover that will reduce erosion to, or maintain soil stability within, the soil loss tolerance value or below. For both range and pastures, areas will be provided for livestock watering, salting and shade that are located away from streambanks and riparian zones. This will be accomplished by managing livestock grazing and providing facilities for water, salt and shade, as needed.

4. Range and Pasture Land Management Practices

Following is a list of management practices for range and pasture grazing control that are available as tools to achieve the range and pasture land management measure as set forth in Section E.3. Under each management practice the U.S. Soil Conservation (SCS) practice number and a definition is provided. The list of practices included in this section is by no means exclusive and does not preclude States or local agencies from developing special management practices in cooperation with the appropriate technical agency within the State for unique conditions and problems that may be encountered in particular areas, provided that the management measures (the system of individual practices adopted) achieve a level of performance that is as effective as that provided by the management measure specified in this guidance. There may also be state or local standards that would require additional practices.

(1) Implementation of a grazing management scheme that assures proper grazing use by grazing at an intensity that balances the number of livestock with the available forage and feed and describes the animal movement through the operating unit of range or pasture lands. Proper grazing use will maintain enough live vegetation and litter cover to protect the soil from erosion, and will maintain or improve the quality and quantity of desirable vegetation. Practices that accomplish this are:

Deferred Grazing (352)
Postponing grazing or resting grazing land for prescribed period.

The purpose is to: (1) promote natural re-vegetation by increasing the vigor of the forage stand and permitting desirable plants to produce seed, (2) provide a feed reserve for fall and winter grazing or emergency use, (3) improve the appearance of range having inadequate cover, and (4) reduce soil loss and improve water quality.

Planned Grazing System (556)
A practice in which two or more grazing units are alternately rested and grazed in a planned sequence for a period of years, and rest periods may be throughout the year or during the growing season of key plants.

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* Range land condition rating (percent climax vegetation): Excellent = 76-100%, Good = 51-75%, Fair = 26-50%, and
Poor = 0-25%.

The purpose is to: (1) maintain existing plant cover or hasten its improvement while properly using the forage of all grazing units, (2) reduce erosion and improve water quality, (3) increase efficiency of grazing by uniformly using all parts of each grazing unit, (4) insure a supply of forage throughout the grazing season, (5) increase production and improve quality of forage, (6) enhance wildlife habitat, (7) promote flexibility in the grazing program and buffer the adverse effects of drought, and (8) promote energy conservation through reduced use of fossil fuel.

Proper Grazing Use (528)
Grazing at an intensity that will maintain enough cover to protect the soil and maintain or improve the quantity and quality of desirable vegetation.

The purpose is to: (1) increase the vigor and reproduction of key plants; (2) accumulate litter and mulch necessary to reduce erosion and sedimentation and improve water quality; (3) improve or maintain the condition of the vegetation; (4) increase forage production; (5) maintain natural beauty; and (6) reduce the hazard of wildfire.

(2) Providing water and salt supplement facilities away from streams will help keep livestock away from streambanks and riparian zones. The establishment of alternate water supplies for livestock is an essential component of this measure when distribution problems of livestock occurs in a grazing unit. In some locations, artificial shade may be constructed to encourage use of upland sites for shading and loafing. This will be accomplished through the following:

Pipeline (516)
Pipeline installed for conveying water for livestock or for recreation.

The purpose is to convey water from a source of supply to a point of use.

Pond (378)
A water impoundment made by constructing a dam or an embankment or by excavation a pit or dugout.

The purpose is to provide water for livestock, fish and wildlife, recreation, fire control, and other related uses, and to maintain or improve water quality.

Trough or Tank (614)
A trough or tank, with needed devices for water control and waste water disposal, installed to provide drinking water for livestock.

The purpose is to provide watering facilities for livestock at selected locations that will protect vegetative cover through proper distribution of grazing or through better grassland management for erosion control. Another purpose on some sites is to reduce or eliminate the need for livestock to be in streams, which reduces livestock waste there.

Well (642)
A well constructed or improved to provide water for irrigation, livestock, wildlife, or recreation.

The purpose is to facilitate proper use of vegetation on rangeland, pastures, and wildlife areas; and to supply the water requirements of livestock and wildlife.

(3) Minimizing access to or excluding livestock from streambanks and riparian zones is essential to the implementation of this management measure. This could be accomplished by fencing of areas where animals tend to congregate, including stream corridors and riparian zones.

Fencing (516)
Enclosing or dividing an area of land with a suitable permanent structure that acts as a barrier to livestock, big game, or people (does not include temporary fences).

The purpose is to: (1) exclude livestock or big game from areas that should be protected from grazing, (2) confine livestock or big game on an area, (3) control domestic livestock while permitting wildlife movement, (4) subdivide grazing land to permit use of grazing systems, (5) protect new seedings and plantings from grazing, and (6) regulate access to areas by people or prevent trespassing.

Livestock exclusion (472)
Excluding livestock from an area not intended for grazing.
The purpose is to protect, maintain, or improve the quantity and quality of the plant and animal resources; to maintain enough cover to protect the soil; to maintain moisture resources; and to increase natural beauty.

(4) Where existing conditions result in excessive erosion, it will be necessary to improve or re-establish the vegetative cover on range and pasture lands. When re-establishment of vegetation is required, it may be accomplished using the following practices:

Pasture and Hayland Planting (512)
Establishing and reestablishing long-term stands of adapted species of perennial, biannual, or reseeding forage plants. (Includes pasture and hayland renovation. Does not include grassed waterways or outlets or cropland.)

The purpose is to reduce erosion,or maintain soil stability and to produce high quality forage.

Range Seeding (550)
Establishing adapted plants by seeding on native grazing land (does not include pasture and hayland planting).

The purpose is to: (1) prevent excessive soil and water loss and improve water quality; (2) produce more forage for grazing of browsing animals on rangeland or land converted to range from other uses; and (3) improve the visual quality of grazing land.

Critical area planting (342)
Planting vegetation, such as trees,shrubs, vines grasses, or legumes, on highly erodible or critically eroding areas (does not include tree planting mainly for wood products).

The purpose is to stabilize the soil, reduce damage from sediment and runoff to downstream areas, and improve wildlife habitat and visual resources.

5. Effectiveness Information

Table 2-16 presents information on pollution reductions that can be expected from installation of the management practices outlined within this management measure.

Table 2-16. Estimated Pollutant Reductions for Selected Management Practices

Practice	Sediment Load Reduction	Total P Load Reduction
Permanent Veg. Cover	less than 1 T/Ac/Yr delivered	very high
Reforestation of Erodible Crop and Pastureland	less then 1 T/Ac/Yr delivered	very high

SOURCE: Non-Point Source Task Force, International Joint Commission, 1983.
NOTE: All reductions are relative to conventional (moldboard plow) tillage.

The information contained herein is primarily practice-oriented, yet EPA seeks data regarding the overall effectiveness of management measures, or systems of practices. To this end, EPA is continuing to collect and analyze more information regarding pollutant reductions, and solicits comments regarding information sources to utilize.

The Soil Conservation Service has developed a set of water quality statements for each practice that provide some insight into the use of the practice for water quality improvement. They also include warnings of negative water quality impacts that might occur by using the practice. Water quality statements for the practices listed in this management measure are contained in Table 2-17.

6. Cost Information

Cost factors for control of erosion and sediment transport from agricultural lands.

The cost to install the Grazing Land Protection system (SL6) for the 42 states which used the practice, was $5.68 per acre in 1990 (USDA, ASCS, 1991).

The system reduced erosion by an average of 2.2 tons per acre at an amortized cost of $0.50 per ton (USDA, ASCS, 1991).

The SL6 Grazing Land Protection contain many of the practices recommended in this management measure (see Appendix 2-A).

7. Planning Considerations

The selection of management practices for this measure will be based on an evaluation of current conditions, problems identified, quality criteria, and management goals.

Successful resource management on range and pasture land is the correct application of a combination of practices that will meet the needs of the range and pasture land ecosystem - the soil, water, air, plant and animal resources and the objectives of the land user.

For a sound grazing land management system to function properly and to provide for a sustained level of productivity, the following should be considered.

(1) Know the key management plant species and their response to different seasons and degrees of use by various kinds and classes of livestock.

(2) Know the demand for, and seasons of use, of forage and browse by wildlife species.

Table 2-17. Water Quality Statement for Selected Management Practices

Practice	Water Quality Statement
Deferred Grazing (352)	In areas with bare ground or low percent ground cover, deferred grazing will reduce sediment yield because of increased ground cover, less ground surface disturbance, improved soil bulk density characteristics, and greater infiltration rates. Areas mechanically treated will have less sediment yield when deferred to encourage re-vegetation. Animal waste would not be available to the area during the time of deferred grazing and there would be less opportunity for adverse runoff effects on surface or aquifer water quality. As vegetative cover increases, the filtering processes are enhanced, thus trapping more silt and nutrients as well as snow if climatic conditions for snow exist. Increased plant cover results in a greater uptake and utilization of plant nutrients.
Fencing (382)	Fencing is a practice that can be on the contour or up and down slope. Often a fence line has grass and some shrubs in it. When a fence is built across the slope it will slow down runoff, and cause deposition of coarser grained materials reducing the amount of sediment delivered downslope. Fencing may protect riparian areas which act as sediment traps and filters along water channels and impoundments. Livestock have a tendency to walk along fences. The paths become bare channels which concentrate and accelerate runoff causing a greater amount of erosion within the path and where the path/channel outlets into another channel. This can deliver more sediment and associated pollutants to surface waters. Fencing can have the effect of concentrating livestock in small areas, causing a concentration of manure which may wash off into the stream, thus causing surface water pollution.

Table 2-17. (Continued)

Practice	Water Quality Statement
Pasture and Hayland Planting (556)	The long-term effect will be an increase in the quality of the surface water due to reduced erosion and sediment delivery. Increased infiltration and subsequent percolation may cause more soluble substances to be carried to ground water.
Planned grazing system (556)	Planned grazing systems normally reduce the system time livestock spend in each pasture. This increases quality and quantity of vegetation. As vegetation quality increases, fiber content in manure decreases which speeds manure decomposition and reduces pollution potential. Compacted layers of the soil tend to diminish because of the opportunity for freeze-thaw, shrink-swell, and other natural soil mechanisms to occur that reduce compacted layers during the absence of the grazing animals. This increases infiltration, increases vegetative growth, slows runoff, and improves the nutrient and moisture filtering and trapping ability of the area. Decreased runoff will reduce the rate of erosion and movement of sediment and dissolved and sediment-attached substances to downstream water courses. No increase in ground water pollution hazard would be anticipated from the use of this practice.
Range seeding (550)	Increased erosion and sediment yield may occur during the establishment of this practice. This is a temporary situation and sediment yields decrease when reseeded area becomes established. If chemicals are used in reestablishment process, chances of chemical runoff into downstream water courses are reduced if application is applied according to label instructions. After establishment of the grass cover, grass sod slows runoff, acts as a filter to trap sediment, sediment attached substances,

Table 2-17. (Continued)

Practice	Water Quality Statement
	increase infiltration, and decreases sediment yields.
Pipeline (516)	Pipelines may decrease sediment, nutrient, organic, and bacteria pollution from livestock. Pipelines may afford the opportunity for alternative water sources other than streams and lakes, possibly keeping the animals away from the stream or impoundment. This will prevent bank destruction with resulting sedimentation, and will reduce animal waste deposition directly in the water. The reduction of concentrated livestock areas will reduce manure solids, nutrients, and bacteria that accompany surface runoff.
Trough or tank (614)	By the installation of a trough or tank, livestock may be better distributed over the pasture, grazing can be better controlled, and surface runoff reduced, thus reducing erosion. By itself this practice will have only a minor effect on water quality; however when coupled with other conservation practices, the beneficial effects of the combined practices may be large. Each site and application should be evaluated on their own merits.
Pond (378)	Ponds may trap nutrients and sediment which wash into the basin. This removes these substances from downstream. Chemical concentrations in the pond may be higher during the summer months. By reducing the amount of water that flows in the channel downstream, the frequency of flushing of the stream is reduced and there is a temporary collection of substances held temporarily within the channel. A pond may cause more leachable substance to be carried into the ground water.

Table 2-17. (Continued)

Well (642)	When water is obtained it has poor quality because of dissolved substances, its use in the surface environment or its discharge to downstream water courses the surface water will be degraded. The location of the well must consider the natural water quality and the hazards of its use in the potential contamination of the environment. Hazard exists during well development and its operation and maintenance to prevent aquifer quality damage from the pollutants through the well itself by back flushing, or accident, or flow down the annual spacing between the well casing and the bore hole.

SOURCE: USDA, Soil Conservation Service, 1988.

(3) Know the amount of plant residue or grazing height that should be left to protect grazing land soils from wind and water erosion and to provide for plant regrowth.

(4) Know the range site production capabilities and the pasture land suitability group capabilities so an initial stocking rate can be established.

(5) Know how to use livestock as a tool in the management of the range ecosystems and pasture lands to insure the health and vigor of the plants, soil tilth, proper nutrient cycling, erosion control, and riparian area management, while at the same time meeting livestock nutritional requirements.

(6) Establish grazing unit sizes, watering, shade and salt locations, etc. to secure optimum livestock distribution and utilization.

(7) Provide for livestock herding, as needed, to protect sensitive areas from excessive use at critical times.

(8) Encourage proper wildlife harvesting to ensure proper population densities and forage balances.

(9) Know the livestock diet requirements in terms of quantity and quality to ensure that there are enough grazing units to provide adequate livestock nutrition for the season, kind and classes of animals on the farm/ranch.

(10) Maintain a flexible grazing system to adjust for unexpected environmentally and economically generated problems.

F. Irrigation Water Management

1. Management Measure Applicability

This management measure is to be utilized on all irrigated agricultural lands, including but not limited to the following: cropland, pastureland, orchards, specialty crop production, and nursery crop production.

Those irrigated agricultural lands that also meet the applicability definitions of the erosion and sediment management measure, nutrient management measure, pesticide management measure, grazing management measure, or other management measures are also subject to those management measures.

2. Pollutants Produced by Irrigation

Runoff water and leachate from irrigated land may transport the following types of pollutants:

- Sediment and particulate organic solids;
- Particulate bound nutrients, chemicals and metals, such as phosphorus, organic nitrogen, a portion of applied pesticides, and a portion of the metals applied with some organic wastes and also found naturally within the soil;
- Soluble nutrients, such as nitrogen, soluble phosphorus, a portion of the applied pesticides, soluble metals, salts and many other major and minor nutrients; and
- Bacteria, viruses and other microorganisms.

3. Management Measure to Control Irrigation Water

The management measure for irrigation water on agricultural lands is a combination of practices that maximizes the water use efficiency of the irrigation system, minimizes the amount of water that is wasted or discharged from the system, and improves the water quality of both surface and subsurface return flows from the system by: (1) scheduling and managing the application of irrigation water; (2) minimizing to the extent possible irrigation water runoff from all irrigation systems except for surface irrigation, which will be recovered and reused with a tailwater recovery system*; and (3) eliminating unnecessary deep percolation, thereby reducing the amount of pollutants entering nearby surface waters and groundwater. When chemigation is used, the management measure includes backflow preventers.

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* In some locations, tailwater or runoff of applied irrigation water are subject to other water rights or are required to be released to maintain stream flow. In these special cases, reuse on-site may not be allowed and would not be considered part of the management measure for such locations.

(1) Proper irrigation scheduling is a key element in irrigation water management. Irrigation scheduling should be based on knowing the daily water use of the crop, the water holding capacity of the soil, the lower limit of soil moisture for each crop and soil and measuring the amount of water applied to the field. Also natural precipitation should be considered and proper adjustment made in the scheduled irrigations.

(2) Irrigation water should be applied properly in a manner that assures efficient use and uniform distribution of irrigation water and minimizes runoff or deep percolation.

(3) Irrigation water transportation systems that move water from the source of supply to the irrigation system should be designed and managed in a manner that minimizes evaporation, seepage flow-through water losses from canals and ditches.

(4) The utilization of runoff water for additional irrigation or to reduce the amount of water diverted increases the efficiency of use of irrigation water. For surface irrigation systems that require runoff or tailwater as part of the design and operation, a tailwater management practice be installed and used.

(5) Drainage water from an irrigation system should be managed to reduce deep percolation, move tailwater to the reuse system, reduce erosion at the end of the irrigated field and help control adverse impacts on surface and ground water. A total drainage system should be an integral part of the planning and design of an efficient irrigation system.

4. <u>Irrigation Water Management Practices</u>

Following is a list of management practices for irrigation water management that are available as tools to achieve the irrigation water management measure as set forth in Section F.3. Under each management practice the U.S. Soil Conservation Service (SCS) practice number and a definition are provided. The list of practices included in this section is not exhaustive and does not preclude States or local agencies from developing special management practices in cooperation with the appropriate technical agency within the State for unique conditions and problems that may be encountered in particular areas, provided that the management measures (the system of individual practices adopted) achieve a level of performance that is as effective as that provided by the management measures specified in this guidance. There may also be state or local standards that would require additional practices.

(1) Proper irrigation scheduling

Practices that may be used to accomplish proper irrigation scheduling are:

Irrigation water management (449)
Determining and controlling the rate, amount, and timing of irrigation water in a planned and efficient manner.

The purpose is to effectively use available irrigation water supply in managing and controlling the moisture environment of crops to promote the desired crop response, to minimize soil erosion and loss of plant nutrients, to control undesirable water loss, and to protect water quality.

To achieve this purpose the irrigator must have knowledge of: (1) how to determine when irrigation water should be applied, based on the rate of water used by crops and on the stages of plant growth, (2) how to measure or estimate the amount of water required for each irrigation, including the leaching needs, (3) the normal time needed for the soil to absorb the required amount of water and how to detect changes in intake rate, (4) how to adjust water stream size, application rate, or irrigation time to compensate for changes in such factors as intake rate or the amount of irrigation runoff from an area, (5) how to recognize erosion caused by irrigation, (6) how to estimate the amount of irrigation runoff from an area, and (7) how to evaluate the uniformity of water application.

Water measuring device
An irrigation water meter, flume or other water measuring device installed in a pipeline or ditch. The measuring device must be installed between the point of diversion and water distribution system used on the field. The device should be a recording meter that will indicate both the rate of flow and the total water used.

The purpose is to provide the irrigator the rate of flow and/or application of water, and the total amount of water applied to the field with each irrigation.

Soil and crop water use data
From soils information the water holding capacity of the soil can be determined along with the amount of water that the plant can extract from the soil before additional irrigation is needed. Water use information for various crops can be obtained from various USDA publications.

The purpose is to allow the irrigator to estimate the amount of available water remaining in the root zone at any time, thereby indicating when the next irrigation should be scheduled and the amount of water needed. There are methods to measure the soil moisture and these should be employed for high value crops or where the water holding capacity of the soil is very low.

(2) Proper application of irrigation water

The type of irrigation system employed will vary with the type of crop grown, the topography, and soils. There are several systems that, when properly designed and operated, can be used as follows:

Irrigation system, drip or trickle (441)
A planned irrigation system in which all necessary facilities are installed for efficiently applying water directly to the root zone of plants by means of applicators (orifices, emitters, porous tubing, or perforated pipe) operated under low pressure. The applicators can be placed on or below the surface of the ground.

The purpose is to efficiently apply irrigation water directly to the plant root zone to minimize water loss, erosion, impacts to water quality, and salt accumulation while maintaining soil moisture within the range for good plant growth.

Irrigation system, sprinkler (442)
A planned irrigation system in which all necessary facilities are installed for efficiently applying water by means of perforated pipes or nozzles operated under pressure.

The purpose is to efficiently and uniformly apply irrigation water to minimize water loss, erosion, and impacts to water quality while maintaining soil moisture for optimum plant growth.

Irrigation system, surface and subsurface (443)
A planned irrigation system in which all necessary water control structures have been installed for efficient distribution of irrigation water by surface means, such as furrows, borders, contour levees, or contour ditches, or by subsurface means.

The purpose is to efficiently convey and distribute irrigation water to the point of application to minimize water loss, erosion, and impacts to water quality while maintaining soil moisture for optimum plant growth.

Irrigation field ditch (388)
A permanent irrigation ditch constructed to convey water from the source of supply to a field or fields in a farm distribution system.

The standard for this practice applies to open channels and elevated ditches of 25 ft^3/second or less capacity formed in and with earth materials.

The purpose is to prevent erosion or loss of water quality or damage to the land, to make possible proper irrigation water use, and to efficiently convey water to minimize conveyance losses.

Irrigation land leveling (464)
Reshaping the surface of land to be irrigated to planned grades.

The purpose is to permit uniform and efficient application of irrigation water without causing erosion, loss of water quality, or damage to land by waterlogging and at the same time to provide for adequate surface drainage.

(3) Irrigation water transportation systems

Transporting irrigation water from the source of supply to the irrigation system can be a significant source of water loss and cause of degradation of both surface water and ground water. Losses during transmission include seepage from canals and ditches, evaporation from canals and ditches, and flow-through water (water that is never applied to the land but is needed to maintain hydraulic head in the ditch). The primary water quality concern is the development of saline seeps below the canals and ditches and the discharge of saline waters. Another water quality concern is the potential for erosion caused by the discharge of flow-through water. Practices that are used to assure proper transportation of irrigation water from the source of supply to the irrigation system are:

Irrigation water conveyance, ditch and canal lining (428)
A fixed lining of impervious material installed in an existing or newly constructed irrigation field ditch or irrigation canal or lateral.

The purpose is to prevent waterlogging of land, to maintain water quality, to prevent erosion, and to reduce water loss.

Irrigation water conveyance, pipeline (430)

A pipeline and appurtenances installed in an irrigation system.

The purpose is to prevent erosion or loss of water quality and damage to land, to make possible proper water use, and to reduce water conveyance losses.

Structure for water control (587)
A structure in an irrigation, drainage, or other water management systems that conveys water, controls the direction or rate of flow, or maintains a desired water surface elevation.

The purpose is to control the stage, discharge, distribution, delivery, or direction of flow of water in open channels or water use areas. Also used for water quality control, such as sediment reduction or temperature regulation. These structures are also used to protect fish and wildlife and other natural resources.

(4) Utilization of runoff water for additional irrigation or to reduce the amount of water diverted. The practice is described as follows:

Irrigation system, tailwater recovery (447)
A facility to collect, store, and transport irrigation tailwater for reuse in the farm irrigation distribution system.

The purpose is to conserve farm irrigation water supplies and water quality by collecting the water that runs off the field surface for reuse on the farm.

(5) Management of drainage water

There are several practices to accomplish this:

Filter strip (393)
A strip or area of vegetation for removing sediment, organic matter, and other pollutants from runoff and waste water.

The primary purpose is to remove sediment and other pollutants from runoff or waste water by filtration, deposition, infiltration, absorption, decomposition, and volatilization, thereby reducing pollution and protecting the environment. An additional purpose is to prevent erosion at the upland edge of fields by dissipating the energy of irrigation water applied as concentrated flow.

Surface drainage field ditch (607)
A graded ditch for collecting excess water in a field.

The purpose is to drain surface depressions for recovery and reuse of excess water or for the controlled delivery of excess water to a filter strip for treatment; collect or intercept excess surface water, such as sheet flow, from natural and graded land surfaces or channel flow from furrows and carry it to an outlet for recovery and reuse or for the controlled delivery of excess water to a filter strip for treatment; and collect or intercept excess subsurface water and carry it to an outlet for recovery and reuse or for the controlled delivery of excess water to a filter strip for treatment.

5. Effectiveness Information

Following is information on pollution reductions that can be expected from installation of the management practices outlined within this management measure.

The Rock Creek Rural Clean Water Program (RCWP) project in Idaho is the source of much information regarding the benefits of irrigation water management (Idaho Department of Health and Welfare, 1990). All crops in the Rock Creek watershed are irrigated with water diverted from the Snake River and delivered through a network of canals and laterals. The combined implementation of irrigation management practices, sediment control practices, and conservation tillage has resulted in high reductions (from 61 percent to 95 percent reduction for all six stations) in suspended sediment loadings in Rock Creek from 1981 to 1988. Similarly, eight of ten sub-basins showed reductions in suspended sediment loadings over the same time period.

The Soil Conservation Service has developed a set of water quality statements for each practice that provide some insight into the use of particular irrigation water management practices for water quality improvement (USDA, SCS, 1988). They also include warnings of negative water quality impacts that might occur by using the practices. Water quality statements for the practices listed in this management measure are contained in Table 2-18.

6. Cost Information

Cost estimates for practices to control irrigation water on agricultural lands are taken from the U.S. Department of Agriculture (USDA ASCS, 1991). Cost estimates reported in this document are given by primary purpose, type of agreement (long-term agreement or regular ACP), and as overall estimates. The costs reported here lump long term agreements and regular ACP agreements. The components of each practice are given in Appendix 2-A.

The cost to install the irrigation water conservation system (practice WC4) for the primary purpose of water conservation in the 28 states which used the practice, was about $77.00 per acre served in 1990. Practice WC4 increased the average irrigation system efficiency from 47 percent to 63 percent at an amortized cost of $9.74 per acre foot of water conserved.

The cost to install water management systems for pollution control (practice SP35) with the primary purpose being water quality was about $103 per acre served. Overall, the cost of practice SP35 was about $50 per acre served.

Table 2-19 shows the cost (per ton of soil saved) of implementing practices WC4 and SP35 for the primary purpose of erosion control.

Table 2-18. Water Quality Statement for Selected Management Practices

Practice	Water Quality Statement
Irrigation water management (449)	Management of the irrigation system should management provide the control needed to minimize losses of water, and yields of sediment and sediment attached and dissolved substances, such as plant nutrients and herbicides, from the system. Poor management may allow the loss of dissolved substances from the irrigation system to surface or ground water. Good management may reduce saline percolation from geologic origins. Returns to the surface water system would increase downstream water temperature.
Irrigation system, drip or trickle (441)	Surface water quality may not be significantly affected by transported substances because runoff is largely controlled by the practice. Chemical applications may be applied through the system. Reduction of runoff will result in less sediment and chemical losses from the field during irrigation. If excessive, local, deep percolation should occur, a chemical hazard may exist to shallow ground water or to areas where geologic materials provide easy access to the aquifer.
Irrigation system, sprinkler (442)	Proper irrigation management controls runoff and prevents downstream surface water deterioration from sediment and sediment attached substances. Over irrigation through poor management can produce impaired water quality in runoff as well as ground water through increased percolation. Chemigation with this system allows the operator the opportunity to mange nutrients, waste water and pesticides. For example, nutrients applied in several incremental applications based on the plant needs may reduce ground water

Table 2-18 (Continued)

Practice	Water Quality Statement
	contamination considerably, compared to one application during planting. Poor management may cause pollution of surface and ground water. Pesticide drift from chemigation may also be hazardous to vegetation, animals, and surface water resources. Appropriate safety equipment, operation and maintenance of the system is needed with chemigation to prevent accidental environmental pollution or backflows to water sources.
Irrigation system, surface and subsurface (443)	Operation and management of the irrigation system in a manner which allows little or no runoff may allow small yields of sediment or sediment-attached substances to downstream waters. Pollutants may increase if irrigation water management is not adequate. Ground water quality from mobil dissolved chemicals may also be a hazard if irrigation water management does not prevent deep percolation. Subsurface irrigation that requires the drainage and removal of excess water from the field may discharge increased amounts of dissolved substances such as nutrients or other salts to surface water. Temperatures of downstream water courses that receive runoff waters may be increased. Temperatures of downstream waters might be decreased with subsurface systems when excess water is being pumped from the field to lower the water table. Downstream temperatures should not be affected by subsurface irrigation during summer months if lowering the water table is not required. Improved aquatic habitat may occur if runoff or seepage occurs from surface systems of from pumping to lower the water table in subsurface systems.

Table 2-18 (Continued)

Practice	Water Quality Statement
Irrigation field ditch (388)	Salinity changes may occur in the soil and water. This will depend on the irrigation water quality, the level of water management, and the geologic materials of the area. The quality of ground and surface water may be altered depending on environmental conditions. Water lost from the irrigation system to downstream runoff may contain dissolved substances, sediment, and sediment-attached substances that may degrade water quality and increase water temperature. This practice may make water available for wildlife, but may not significantly increase habitat.
Irrigation land leveling (464)	The effects of this practice depend on the level of irrigation water management. If root zone water is properly managed, then quality decreases of surface and ground water may be avoided. Under poor management, ground and surface water quality may deteriorate. Deep percolation and recharge with poor quality water may lower aquifer quality. Land leveling may minimize erosion and when runoff occurs concurrent sediment yield reduction. Poor management may cause an increase in salinity of soil, ground and surface waters.
Irrigation water conveyance, ditch and canal lining (428)	Potentials for ground water effects from infiltration of poor quality water with and canal lining dissolved substances would be reduced. Potential for ground water effects from infiltration of high quality water would be reduced. Increased stability of the conveyance will also reduce bank or bed erosion which would provide sediment yield reduction within the system and to downstream waters.

Table 2-18 (Continued)

Practice	Water Quality Statement
Irrigation water conveyance, pipeline (430)	Potentials for ground water effects from infiltration of poor quality water would be eliminated by this practice. No streambank or bed erosion would occur which may provide sediment or sediment attached substances to downstream water courses. Deep percolation of saline water may be avoided. Temperature increases that occur from flow in an open conveyance may be eliminated by the pipeline. Wildlife or aquatic habitat that had depended on seepage from the irrigation water conveyance will be decreased.
Structure for water control (587)	Use of the practice to conduct water one elevation to a lower elevation within, to or from a ditch, channel, or canal may not have any effect on the quality of surface or ground water. Use of the practice to control the elevation of water in drainage or irrigation ditches may reduce bank erosion and scouring in the channel; this results in the reduction of sediment and related pollutants delivered to the surface water. When used to control, the division or measurement of irrigation water may have an insignificant effect on the quality of surface and ground water. Use of the practice to keep trash, debris, or weed seeds from entering pipelines has little effect on the quality of surface and ground water. Use of the practice to control the direction of channel flow resulting from tides and high water or backflow from flooding has little effect on the quality of surface and ground water.

Table 2-18 (Continued)

Practice	Water Quality Statement
	Use of the practice to control the level of water table or to remove surface subsurface water from adjoining land, to flood land for frost protection, or to manage water levels for wildlife or recreation may increase infiltration and percolation of water by supplying a surplus of water to the surface when used for flooding. This will enable soluble pollutants to be carried into the ground water. When used to remove drainage water from the surface or subsurface, substances may be "straight-lined" into the surface waters. When the function is to impound water, the pH of the surface water may be lowered with a consecutive increase in tannic acid and iron content. Water temperature may be increased in the summer months.
	Use of the practice to convey water over, under, or along a ditch, canal, road, railroad, or other barriers will have little effect on the quality of surface or ground water.
	Use of the practice to modify water flow to provide habitat for fish, wildlife, and other aquatic animals may increase the dissolved oxygen content of the stream, and may lower the water temperature.
Irrigation system, trailwater recovery (447)	The reservoir will trap sediment and sediment attached substances from runoff waters. Sediment and chemical will accumulate in the collection facility entrapping would decrease downstream yields of these substances.
	Salts, soluble nutrients, and soluble pesticides will be collected with the runoff and will not be released to surface waters. Recovered irrigation water with high salt and/or metal content will ultimately

Table 2-18 (Continued)

Practice	Water Quality Statement
	have to be disposed in an environmentally safe manner and location. Disposal of these waters should be part of the overall management plan. Although some ground water recharge may occur, little if any pollution hazard is expected.
Filter strip (393)	Filter strips for sediment and related pollutants meeting minimum requirements may trap the coarser grained sediment. They may not filter out soluble or suspended fine-grained materials. When a storm caused runoff in excess of the design runoff, the filter may be flooded and may cause large loads of pollutants to be released to the surface water. This type of filter requires high maintenance and has a relative short service life and is effective only as long as the flow through the filter is shallow sheet flow. Filter strip for runoff form concentrated livestock areas may trap organic material, solids, materials which become adsorbed to the vegetation or the soil within the filter. Often they will not filter out soluble materials. This type of filter is often wet and is difficult to maintain. Filter strips for controlled overland flow treatment of liquid wastes may effectively filter out pollutants. The filter must be properly managed and maintained, including the proper resting time. Filter strips on forest land may trap coarse sediment, timbering debris, and other deleterious material being transported by runoff. This may improve the quality of surface water and has little effect on soluble material in runoff or on the quality of ground water. All types of filters may reduce erosion on the area on which they are constructed.

Table 2-18 (Continued)

Practice	Water Quality Statement
	Filter strips trap solids from the runoff flowing in sheet flow through the filter. Coarse-grained and fibrous materials are filtered more efficiently than fine-grained and soluble substances. Filter strips work for design conditions, but when flooded or overloaded they may release a slug load of pollutants into the surface water.
Well (642)	When water is obtained it has poor quality because of dissolved substances, its use in the surface environment or its discharge to downstream water courses the surface water will be degraded. The location of the well must consider the natural water quality and the hazards of its use in the potential contamination of the environment. Hazard exists during well development and its operation and maintenance to prevent aquifer quality damage from the pollutants through the well itself by back flushing, or accident, or flow down the annual spacing between the well casing and the bore hole.

SOURCE: USDA, SCS, 1988.

Table 2-19. Summary of Costs for Selected Irrigation Management Practices

System Number and Name (Systems are combinations of SCS practices - see Appendix 2-A)		Total Cost Per Ton of Soil Saved (1990, amortized $)
WC4	Irrigation Water Conservation	3.65
SP35	Water Management systems for Pollution Control	0.46

SOURCE: USDA, Agricultural Stabilization and Conservation Service, 1991.

7. Planning Considerations for Irrigation Water Management

During the development and implementation of this management measure for irrigation, the following water quality effects and impacts should be considered.

(1) Effects on erosion and the movement of sediment and soluble and sediment-attached substances carried by runoff.

(2) Effects on the movement of dissolved substances below the root zone or to ground water.

(3) Short-term and construction related effects on the quality of downstream water courses.

(4) Potential of uncovering or redistributing toxic materials such as saline soil.

(5) Effects of water management on the salinity of soils, soil water, or aquifers.

(6) Potential for development of saline seeps or other salinity problems resulting from increased infiltration near restrictive layers.

(7) Effects of soil water levels on such nutrient processes as nitrification and denitrification.

(8) Effects on the temperatures of downstream waters that could prevent undesirable effects on aquatic and wildlife communities.

(9) Effects of installing the lining on the erosion of the earth conveyance and the movement of sediment and soluble and sediment-attached substances carried by water.

(10) Effects of installing the pipeline (replacing other types of conveyances) on channel erosion or the movement of sediment and soluble and sediment-attached substances carried by water.

(11) Effects on the nutrient budget within the filter strip as related to removal, residence, or accumulation of nutrients. Nutrient budgets should account for effects of growing and decaying vegetation.

(12) Filtering effects of vegetation on movement of sediment, pathogens, organic loads, and dissolved and sediment-attached substances.

(13) Effects of the filter strip vegetation's uptake of nutrients on surface and ground water.

(14) Effects of the timing of the vegetation's management, including clipping, harvesting, removal and re-establishment on the nutrient balance within the filter strip.

(15) Effects on the visual quality of on-site and downstream water resources.

(16) Effects on wetlands or water-related wildlife habitats.

VI. MANAGEMENT PRACTICE TRACKING

Tracking of the installation of agricultural management measures and systems of management measures is critical to knowing how well a program is working. It is also important to know where and by whom a management measure is installed, when it was certified, and how long it should stay in place. This will allow program managers to go back to a farm or field and re-certify that the management measure or practice is still there and operating according to design.

Such tracking systems may be used and/or developed to track initial installation of management measures and to provide a system to check on them at specific time intervals in the future. The funding agency for a particular management practice should know when and where a management measure or practice is installed and should certify it for payment, as appropriate. This should be the first check needed. For later re-certification, field evaluations will be needed to re-certify a practice. The funding agency may decide that it is most practical for county conservation districts to fulfill the role of checking and re-certifying management measures and practices.

VII. SOURCES OF ASSISTANCE TO IMPLEMENT MANAGEMENT MEASURES

This section is to be developed in a later draft. Following is a preliminary draft outline for this section:

A. Federal

1. USDA

- SCS, ES, ASCS, etc.
- Agricultural Conservation Program
- Hydrologic Unit Projects
- Demonstration Projects
- PL 566 Projects
- Conservation Reserve Program
- New Farm Bill programs (Water Quality Incentive Program, etc.)

2. EPA

- Section 319, Nonpoint Source Program
- Section 320, National Esturary Program
  Section 117, Chesapeake Bay Program
- Section 314, Clean Lakes Program
- Wellhead Protection Program
- Nitrogen Action Plan

B. State/Local

- State/Local NPS Programs
- State Revolving Funds
- State/Local Land Use Control Programs
- Conservation Districts

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APPENDIX 2-A
Practice Names and Codes Used by USDA-ASCS
(USDA, Agricultural Stabilization and Conservation Service, 1989)

ASCS PRACTICE CODE	DESCRIPTION TITLE	TECHNICAL PRACTICE CODE
SL 1	Permanent vegetative cover establishment	
	Conservation tillage	329
	Pasture and hayland Planting	512
	Range seeding	550
	Cover and green manure crop (orchard and vineyards only)	340
	Field borders	386
	Filter strips	393
SL 2	Permanent vegetative cover improvement	
	Conservation tillage	329
	Pasture and hayland management	510
	Pasture and hayland Planting	512
	Fencing	382
	Range seeding	550
	Deferred grazing	352
	Firebreak	394
	Brush management	314
SL 3	Stripcropping System	
	Divided slopes	363
	Obstruction removal	500
	Stripcropping, contour	585
	Stripcropping, field	586
	Stripcropping, wind	589
	Subsurface drain	606
SL 4	Terrace system	
	Critical area planting	342
	Grade stabilization structure	410

ASCS PRACTICE CODE	DESCRIPTION TITLE	TECHNICAL PRACTICE CODE
	Grassed waterway	412
	Lined waterway outlet	468
	Obstruction removal	500
	Terrace	600
	Subsurface drain	606
	Underground outlet	620
	Vertical drain	630
	Water and sediment crt. basin	638
SL 5	Diversions	
	Critical area planting	342
	Dike	356
	Diversion	362
	Grassed waterway	412
	Lined waterway outlet	468
	Obstruction removal	500
	Pipeline	516
	Subsurface drain	606
	Underground outlet	620
	Vertical drain	630
SL 7	Windbreak restoration or establishment	
	Fencing	382
	Field windbreak	392
	Well	642
	Windbreak renovation	650
	Irrigation system	
	Trickle (drip)	441
	Sprinkler	442
	Surface or subsurface	443
SL 8	Cropland protection cover	
	Cover and green manure crop	340

Appendix 2-A (Continued)

ASCS PRACTICE CODE	DESCRIPTION TITLE	TECHNICAL PRACTICE CODE
SL 11	Permanent vegetative cover on critical areas	
	Cover and green manure crop	340
	Critical area planting	342
	Fencing	382
	Field borders	386
	Filter strip	393
	Forest land erosion control system	408
	Mulching	484
	Streambank and shoreline protection	580
	Tree planting	612
SL 13	Contour farming	
	Contour farming	330
	Obstruction removal	500
	Subsurface drain	606
SL 14	Reduced tillage system	
	Conservation tillage	329
	Stubble mulching	588
SL 15	No-till system	
	Conservation tillage	329
	Stubble mulching	588
SP 35	Water management system for pollution control	

ASCS PRACTICE CODE	DESCRIPTION TITLE	TECHNICAL PRACTICE CODE
	Grass and legumes in rotation	411
	Underground outlets	620
	Land smoothing	466
	Structure for water control	587
	Subsurface drain	606
	Surface drainage-field ditch	607
	Surface drainage-main or lateral	608
	Toxic salt reduction	610
WC 4	Irrigation water conservation	
	Critical area planting	342
	Irrigation canal or lateral	320
	Structure for water control	587
	Irrigation field ditch	388
	Sediment basin	350
	Grassed waterway or outlet	412
	Irrigation land leveling	464
	Irrigation water conveyance ditch and canal lining	428
	Irrigation water conveyance pipeline	430
	Irrigation system, trickle (drip)	441
	Irrigation system, sprinkler	442
	Irrigation system, surface or subsurface	443
	Irrigation system, tailwater recovery	447
	Land smoothing	466
	Irrigation pit or regulation reservoir	552
	Subsurface drainage (for salinity only)	607
	Toxic salt reduction	610

Appendix 2-A (Continued)

ASCS PRACTICE CODE	DESCRIPTION TITLE	TECHNICAL PRACTICE CODE
WL 1	Permanent wildlife habitat	
	Fencing	382
	Wildlife upland habitat management	645
WP 1	Sediment retention, erosion or water control structures	
	Critical area planting	342
	Dam, diversion	348
	Dam, multiple purpose	349
	Sediment basin	350
	Diversion	362
	Fencing	382
	Dam, floodwater retention	402
	Grade stabilization structure	410
	Grassed waterway	412
	Lined waterway outlet	468
	Mulching	484
	Pond sealing or lining	521
	Structure for water control	587
	Subsurface drain	606
	Underground outlet	620
	Vertical drain	630
	Water and sediment control basin	638
WP 2	Stream protection	
	Filter strip	393
	Channel vegetation	322
	Fencing	382
	Pipeline	516
	Streambank and shoreline protection	580

Appendix 2-A (Continued)

ASCS PRACTICE CODE	DESCRIPTION TITLE	TECHNICAL PRACTICE CODE
	Field border	386
	Tree planting	612
	Trough or tank	614
	Stock trails or walkways	575
WP 3	Sod waterways	
	Critical area planting	342
	Grassed waterway	412
	Lined waterway outlet	468
	Mulching	484
	Structure for water control	587
	Subsurface drain	606
	Underground outlet	620
	Vertical drain	630

CHAPTER 3. FORESTRY MANAGEMENT MEASURES

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FORESTRY MANAGEMENT MEASURES

I. TYPES OF NPS PROBLEMS FROM FORESTRY ACTIVITIES

The potential for forestry related activities to cause water pollution has long been recognized. Water quality concerns for forestry were addressed in the 1972 Clean Water Act and later more comprehensively under Sections 208 and 319 as nonpoint sources. The types of problems related to Forestry activities include generation of sediment from roads and landslides, loss of shade from stream canopy removal, woody debris jams from poorly managed logging slash, increased channel erosion and increased stream bedload sediments. In some areas this has resulted in:

- Suspended and bedload sediments
- Turbidity
- Woody material accumulations on bottoms
- Temperature increases, including potential temperature induced effects to the development of salmonid smolts and changes in aquatic communities
- Loss of important stream structural habitat provided by large woody debris from fallen trees, especially conifers. In smaller streams these obstructions perform many important functions including: pool formation, cover, habitat complexity, nutrient and energy retention, stream bank and bed stability, and bed sediment storage.
- Concentration and channelization of flows entering wetlands from road drainage systems and drainage of wetlands due to mechanical site preparation.
- Loss of chum, humpback, pink, chinook, atlantic, and coho salmon, steelhead and sea-run cutthroat trout (salmonids), smelt, and other anadromous fish species.
- Nutrient accumulations from forest fertilizer mis-applications or spills.
- Toxic pollutant accumulations from mis-applications of pesticides or spills.

II. APPROACHES TO THE USE OF MANAGEMENT MEASURES

If management measures are needed to prevent or correct the problems listed, then they should be comprehensively designed to prevent or address the causes of the problems. Often this means a site specific design to best achieve effectiveness. In some cases it may mean a prohibition of activity in certain especially sensitive areas to ensure prevention of impairment. For example, some harvesting practices may need to be avoided on steep slopes or the amounts of pesticide or herbicide applied may be reduced in order to prevent pollution. It should focus on the pathways and causes of the NPS pollution to be an effective control.

There may be a number of Management Measures approaches to a certain problem. States should remain flexible to work with operators and other agencies to find feasible solutions to water quality and habitat problems which achieve equivalent NPS control levels specified in this guidance.

III. PRESENT STATE FORESTRY NPS PROGRAMS

All states with important forestry activities have identified Best Management Practices (BMP's) to control silviculturally (forestry activities) related nonpoint source (NPS) water quality problems. Often the water quality problems which are presently occurring are not due to the ineffectiveness of the practices themselves, but of the failure to implement them appropriately.

There are two basic types of state forestry NPS programs. One is a voluntary program relying upon a set of Best Management Practices as guidelines to operators. Sometimes BMP's can be applied in the normal course of forest harvest operations with few significant added costs. Operator education and technology transfer is a primary activity of the state departments of forestry. Workshops, brochures, field tours are continually held to educate and demonstrate to operators the latest water quality management techniques. Landowners hiring operators are often encouraged to require operators who have attended state sponsored workshops or to stipulate in contracts that the state forestry BMP's must be applied.

The other type of state forestry program is a set of Forest Practice Rules and Regulations based on a State Forest Practices Act or local government regulations. These Rules and Regulations may closely resemble the sets of BMP guidelines described previously, but have requirements which are enforceable. Often streams are classified based upon importance for municipal water supply or propagation of aquatic life as the most sensitive designated use. Protective requirements of various kinds for shade, large woody debris recruitment, bank stability, and others are often stipulated for streamside zones, riparian areas, filter, or buffer strips. Harvest plans of operations or applications to perform a timber harvest are frequently required for review by the State Department of Forestry and other state agencies.

Present state Coastal Zone Management (CZM) programs may already include specific regulations or BMP guidelines for forestry activities. In some states, CZM programs have adopted by reference, or as part of a networked program, the state forestry regulations or BMPs.

IV. FEDERAL LAND MANAGEMENT AGENCIES

Federal land management agencies engaged in forestry activities such as the USDA Forest Service and the USDI Bureau of Land Management are to meet all federal, state, interstate, and local requirements to the same extent as any nongovernmental entity. Similarly, the revised CZMA Act requires federal agencies to comply with state Coastal Zone NPS Management Plans to protect coastal water quality and habitat.

The USFS and BLM in nearly all of the states where agency lands are situated have developed Memoranda of Understanding (MOU) with the water quality agencies to develop and use BMP's which meet or exceed the state BMP'S and Forest Practice Rules. Many of these MOU's have been recently updated to become a part of states' 319 NPS Management Programs. In most cases these agencies have become a Designated Management Agency (DMA) under authority in Section 208 of the Clean Water Act. The DMA authority requires the agency to develop its own Water Quality Program which must be approved by the State. The agency then is delegated responsibility to manage the waters under its jurisdictions according to state law meeting water quality standards and other state requirements. Often there is an action plan required by the state, and agency progress is evaluated on an annual basis. State enforcement of the MOU and DMA programs varies among states. A few states require the agencies to provide annual monitoring reports and annual monitoring plans.

V. LOCAL GOVERNMENTS

Counties, municipalities, and local soil and water conservation management districts may also impose additional requirements on landowners and operators conducting forestry activities. In urban settings this often relates to the conversion of forested lands to urban uses, primarily for residential and business developments. Developers are not always familiar with forestry activity BMP'S or state forest practice rules and regulations. In some cases, the potential for speculative investing leads to major land development which may overwhelm a small government agencies ability to monitor and manage these types of forestry activities.

In rural areas additional requirements for forestry activities may be made by soil and water conservation districts. These requirements primarily apply to small non-industrial forest owners who manage small woodlots. Collectively, non-industrial forest owners control a majority of the productive timber lands in the eastern U.S. and sizeable acreages in some western states. The major industrial privately owned timber lands are located in the Southeast and Northwest parts of the U.S.

VI. MANAGEMENT MEASURES

A. MM No. 1 Identification and Designation of Streamside Special Management Areas

1. Components and Specifications

The objective of this MM is to protect water quality and aquatic habitat and prevent the occurrence of adverse impacts from logging, roadbuilding, and other land disturbing management activities. Streamside Special Management Areas are the areas immediately neighboring streams or waterbodies, which greatly influence water quality and aquatic habitats. These areas function in the following ways:

(1) Filters sediments from waters flowing across the surface toward waterbodies,

(2) Provides a renewable source of large woody debris for cover for fishes and other aquatic organisms, hydraulic control features to dissipate flow energy and develop pools, and bed and bank structure to improve stream channel stability. This large woody debris also provides hydraulic control features to dissipate flow energy and develop pools, and bed and bank structure to improve stream channel stability,

(3) Provide important water surface shading to moderate stream temperature during extreme weather conditions in the summer and winter,

(4) Provide hydraulic roughness on banks and within stream channels to attenuate flood flows, thereby reducing the extreme nature of high flow events

(5) Provide a source of energy and nutrients (litter and leaves) for small tributary streams supporting efficiently functioning aquatic communities.

The identification and designation of streamside areas is needed to determine the extent and distribution of highly valued and sensitive riparian resources. The boundaries of these areas are determined by the minimum distance needed to provide protection to the water quality and habitat functions. Distances needed may vary depending on soil type, slope and riparian cover. Some States and forest management agencies and companies have set minimum distances to protect water quality and ecosystem function. Additional distance is required if there is reasonable risk of pollution or loss of the functions described above.

Use of existing resource inventories, water quality data, stream classifications, state water quality designations, topographic maps, aerial photos, and best professional judgment of the harvest sale planner and resource specialists are needed to define the boundaries of the streamside special management area. Any activities planned within the area must not degrade water quality or habitat value. Most states have identified streamside management zone widths in BMP guidelines or State regulations.

Boundaries of this area must be clearly identified to avoid any misunderstanding by the forestry operator. This will prevent the inadvertent continuation of forestry activities which are occurring outside of the streamside special management area which would impair the water quality and habitat values if conducted in the SSMA. The designation of this area must accomplish the following:

(1) Reduce delivery of forestry activity created sediments from upland or adjacent areas to the waterbody being protected except during storm events with

recurrence intervals greater than 10 years estimated using standard procedures and appropriate storm durations for the local climatic conditions.

(2) Provide a source of large woody debris within the Streamside Special Management Area to the stream at a rate that is equivalent to natural rates of supply over a time period that is the average lifespan of the tree species in the stand.

(3) Provides shading to the stream water surface which is equivalent to natural levels for the potential natural vegetation present. If the existing shading condition prior to activity is less than the natural levels for the potential natural vegetation present, then there should be no reductions of shading caused by proposed activities.

(4) Provide sufficient width to withstand wind damage or blowdown.

2. Effectiveness

The effectiveness of SSMA identification to prevent impacts to streamside areas is 75-85%. This rate of effectiveness is limited by runoff from roads which drains directly to the stream network. Errors in marking and identification of the appropriate boundary occur. Temporary boundary markers occasionally are removed or become lost permitting accidental incursions into the special management with higher disturbance levels. In the west landslides may deliver large quantities of sediments from upslope roads or harvest units across the SSMA.

3. Costs

The net cost for the establishment of streamside management zones may include the costs of layout and marking of the zone. It may also include any additional costs from special harvesting techniques which are used to extract merchantable timber from the streamside management zone. However, these extra harvesting costs are generally offset by the value of the harvested stumpage. It is possible that merchantable timber which is not harvested from the streamside zone due to percent removal restrictions or other management considerations, may be considered an indirect cost of the SMZ. If there is existing vegetation on the site direct cost of implementing this management measure will be limited.

For situations where existing vegetation is not present, cost estimates for control of erosion and sediment transport from forestry activities in streamside areas have been summarized by the USDA Agricultural Stabilization and Conservation Service (ASCS). For streamside management zones the ASCS Stream Protection Practice (WP2) the average cost to install was about $130.00 per mile.

In the State of Virginia Best Management Practices Handbook for forestry, forest filter strips were estimated to have no direct costs if preserving existing vegetation. If the management measure requires the planting of a filter strip on a disturbed area the costs estimated to be the same as for revegetation.

The following example costs for activities related to the establishment of streamside special management zones are USDA Forest Service estimates from the Pacific Northwest:

Activities	Costs
Streamside prescription	$250/mile
Boundary marking	$200/mile
Indirect or Foregone Opportunity Cost of Merchantable stumpage not harvested	
	10 MBF/ac @ $100/MBF = $1000/acre
	20 MBF/ac @ $150/MBF = $3000/acre
	50 MBF/ac @ $200/MBF = $10000/acre

B. MM No. 2 Identification and Designation of Wetland Special Management Areas

1. Components and Specifications

The objective in designating boundaries for Wetland Special Management Areas (WSMA) is to maintain wetland functions and values and to prevent adverse impacts to water quality and habitat in wetland areas from logging.

Wetlands are important in providing moderating influences for water quality and habitats in coastal areas. Wetland ecosystems are commonly key components to a healthy coastal environment. The CWA protects the chemical, physical and biological integrity of wetlands as waters of the United States. Management activities in these areas must not degrade or adversely affect the functions and values of these ecosystems. Effects to the hydrologic conditions in wetlands are commonly the most permanently destructive to the ecosystems. Vegetation communities may also be adversely affected by the introduction of exotic plants or selective removal of key component species.

The boundaries of these WSMAs are determined by the minimum distance needed to provide protection to the water quality and habitat. Additional distance is required if there is reasonable risk of impairment or loss of the functions described above.

Information from resource inventories, topographic maps, aerial photos, and soil surveys and the Federal Manual for Identifying and Delineating Jurisdictional Wetlands will be useful to identify areas needing protection as WSMAs. Planning must identify the areas where operation of heavy equipment may not be appropriate. Flowing wetlands connected to riverine systems should be distinguished from isolated wetlands, because these ecosystems function differently.

Forestry access must be designed to avoid wetland areas and minimize road construction across wetlands. Where roads must be constructed across wetlands flow passages should be planned to prevent disturbances and hydrologic differences between the two sides of the road. Driest seasons should be used to access and harvest these areas.

Boundaries of Wetland Special Management Areas must be clearly identified to prevent misunderstanding by the forestry operator about the location and extent of the WSMA. In many cases this will require on site boundary marking with flagging, paint, or signs where the WSMA adjoins an area with planned forestry activities. The designation and planning of activities in the WSMA'S must provide a level of protection that:

(1) Prevents ground disturbing activities which would cause wetland areas to drain during wet periods or clearly cause a disruption of the hydrologic conditions of the wetland.

(2) Prevents delivery of human activity created sediments from the areas outside of the area to the wetland being protected except during storm events with recurrence intervals estimated using standard procedures to be greater than 10 years.

(3) Prevents loss of sensitive aquatic habitat conditions which otherwise would occur without the designation of the Wetland Special Management Area.

2. <u>Effectiveness</u>

The effectiveness of wetland boundary identification to prevent impacts to wetlands is 75-85%. This rate of effectiveness is limited by runoff from roads which drains directly to wetlands or to the stream network upstream. Errors in marking and identification of the appropriate boundary occur. Boundary markers occasionally are removed or become lost permitting accidental incursions into the special management area with higher disturbance levels.

3. <u>Costs</u>

The net cost for the establishment of wetland special management zones may include the costs of layout and marking of the zone. The following example costs for activities related to the establishment of streamside special management zones are USDA Forest Service estimates from the Pacific Northwest:

Activities	Costs
Wetland prescription	$250/mile
Boundary marking	$200/mile

C. MM No. 3 Transportation System Planning and Design

1. Components and Specifications

The objective of this MM is to locate and design roads with minimal sediment delivery potential to streams and coastal areas. Roads have been shown consistently to be the largest cause of sedimentation resulting from forestry activities. Good location and design of roads can greatly reduce sources and transport of sediment materials.

Important sediment sources are associated with stream crossings, fills on slopes greater than 60 percent, poorly designed road drainage structures, and road locations close to streams. In the west the largest sources of sediment are often associated with landslides. Certain rock types and geomorphic conditions are conducive to the risk of landslides. Such areas can be identified and avoided. In other areas inadequate cross drainage and poor location are the greatest sources of sediment to waterbodies.

a. Location

Location of roads on ridges versus natural drainages is an important way to distance, and thereby prevent, the effects of surface erosion of road surfaces, cut, and fills from streams. Roads must not be located along stream channels where the road fill extends within 25 horizontal feet of the average annual high water level, except for crossings. Existing roads in poor locations must be relocated when the road is to be reconstructed. Roads on gentle slopes drain more freely than roads on flat areas. Roads on steep terrain should avoid use of switchbacks through more favorable locations. "Stacking" of roads above one another should be avoided by the use of longer span cable harvest techniques.

b. Drainage crossings

Sizing of bridges and large culverts for major drainage crossings must be designed based upon reliably tested regionalized methods for permanent well trafficked roads. Appropriate equipment and materials must be planned for installation of the drainage crossing structures. Crossings should be designed to cross drainages at 90° to the flow to minimize effects to the channel and flow capacity through the structure. Designs must provide suitable measures to facilitate fish passage when fish-bearing streams are crossed. This is especially important in the west for streams with anadromous fish.

Structures for permanent road crossings should be adequately designed to avoid failure as follows:

(1) Small culverts should be designed to pass the 25 year recurrence interval discharge without entrance head above the top of the structure

(2) Major culverts and small bridges should pass the 50 year recurrence interval discharge without head above the top of the structure and

(3) Major bridges should pass the 100 year recurrence interval discharge without head above the structure.

(4) Additional capacity must be provided when debris loading above the structure would potentially become lodged in the structure opening and reduce its capacity.

Use of fords should be limited to extreme situations where use of bridges and culverts is not feasible. Fords should be located where streambeds are stable having bedrock or a concrete apron carefully installed. Springs flowing continuously for more than 1 month must have drainage structures, rather than allowing use of road ditches to carry the flow to a drainage culvert.

c. Road prism

Design of the road prism must be appropriate to the terrain where the road is located. Alignments that roll with the terrain cause less slope disturbance than strongly controlled sections with sustained grades and alignments. Balanced construction of the road cross-section must be limited to reasonable sideslopes. Sideslopes greater than 60 percent requires full-bench construction and removal of the excavated road cut material to a suitable disposal area. Surface design as crowned, insloped, or outsloped must be consistent with the road drainage structures.

d. Road drainage

Careful design of the surface drainage to match natural sideslope drainage swales and appropriate spacings must occur. Inlet and outlet structures for culverts must be planned to avoid sedimentation where erosion of ditches and fills occurs. Road dips must be designed to drain freely without eroding the road surface. Roads in flat areas should have elevated roadbeds to avoid development of mudholes (this practice may not be appropriate in flat areas with periodic surface flows.

e. Surfacing

Roads planned for all-weather use must be surfaced with suitable materials unless native surfaces support truck traffic without becoming rutted or eroding. Planning for rock quarry locations must include a quarry development and rehabilitation plan.

f. Landslides

Use of available geologic information, soil maps, topographic maps, aerial photos, local experience, and technical consultation with a geologist, a geotechnical engineer or a qualified specialist must be made when landslide prone areas are known to exist in the planned area to be accessed. Landslide prone areas should be avoided even if alternative routes are longer or more costly to construct. If there are no alternative routes and landslide prone areas must be crossed, specialized construction techniques will be planned to prevent landsliding. Sufficient testing of the bearing materials, piezometric surface of shallow groundwater during storm events, and other site specific investigative techniques must be used to appropriately design slope drains, locations of bin walls, use of geotextile materials, riprap, and other specialized techniques to prevent landslides.

g. Water sources

Locations of water sources used to wet and compact road beds and surfacing must be pre-planned. The water source development and water tank-truck access must be planned to minimize sedimentation and protect the natural water source. Road fills at drainage crossings must not be used as water impoundments unless they have been suitably designed as an earthfill dam. Such earthfill embankments must have outlet controls to allow draining prior to runoff periods.

h. Muskegs

Roads crossing muskegs (high water table areas in northern climates typified by humus and acid waters) must use overlay construction techniques with suitable non-hazardous materials. Cross drains must be provided to allow free drainage especially in sloping areas.

The following are specifications for this MM:

(1) Location: The locations of new roads must not encroach on streams, fills must not be located within 25 horizontal feet of the annual high water level. Construction of new switchback roads must not occur near streams. There must not be planned construction of a streamside road when there is an existing road on the opposite side of the drainage, unless the existing road is being replaced and will be obliterated.

(2) Drainage crossings: Must meet the design levels described above. Must be designed to allow fish passage in fish-bearing streams. Fish passage specifications should be designed for the fish species present.

(3) Road prism: Sideslopes greater than 60 percent for new construction require full bench construction and removal of fill material to a suitable location. Planning of the road surface prism must match the road surface drainage system.

(4) Road drainage: Spacing of drainage structures must match terrain and be appropriate to endure the 25 year precipitation recurrence interval for a storm duration appropriate to the area without rilling, gullying or loss of drainage structures.

(5) Surfacing: Appropriate sized aggregate, percent fines, and suitable particle hardness must protect the surface from rutting and eroding under heavy truck traffic during wet periods of operation. Ditch runoff should not be visibly turbid during these conditions. Aggregate must not contain high sulfide ores that would produce acid drainage or be contaminated with hazardous materials.

(6) Landslides: Designs must prevent the occurrence of landslides for storms with a precipitation recurrence interval of 100 years or less for an appropriate design storm duration typically causing flooding in the area being considered.

(7) Water sources: Planned water source developments to be used to wet and compact roadbeds and surfaces should not impact channel banks and streambeds of the watercourses being used for this purpose. Access roads to water sources should not provide sediment to the water source.

(8) Muskeg roads: Roads must not pond water on the upslope side of the road. Overlay materials cannot include hazardous materials.

2. Effectiveness

The effectiveness of this MM to prevent sedimentation is 85-90 percent. Careful planning is the most effective aspect of road management. The variation in effectiveness is due to the differing complexity of terrain. Landslide prone areas present a difficult challenge for road planners. Vertical relief, slope steepness are other factors influencing design effectiveness. Available funding to allow certain expensive structural designs may be lacking. Design tools and techniques are continually improving. Models for predicting unstable slope conditions are presently available, if data can be collected.

3. Costs

Activities	Costs
Planning	Add 25%

D. MM No. 4 Transportation System Construction/Re-construction

1. Components and Specifications

The objective of this MM is to minimize erosion and sedimentation during road construction/reconstruction projects. The disturbance of soil and rock during road construction/reconstruction creates a significant potential for erosion and sedimentation of nearby streams and coastal waters. Road construction includes: (1) the clearing phase to remove trees and woody vegetation from the road right-of-way, (2) the pioneering phase, where the slope is excavated and filled to establish the road centerline and approximate grade, (3) the construction phase, where final grade and road prism design specifications are made, bridges, culverts and road drainage structures are installed, and (4) the surfacing phase when the road bed is placed, compacted; road fills are compacted, and the lifts of gravel surfacing and pavement (if planned) is placed and compacted.

Slash materials from right-of-way clearing should not be left in streams. This material is often useful if placed as windrows along the base of the fill slope. This operation is efficiently handled by an excavator or "big hoe". This same piece of equipment is often used in the pioneering and road construction phases. Right of way material that is merchantable is often utilized by the operator.

Pioneering earthwork activities should not be allowed to proceed more than .5 miles from the finished road surface. During rainy seasons this distance should be reduced due to the necessity for shutdown if wet conditions develop. Crossing of flowing streams during the pioneering operation should be minimized. Operation within streams during seasons when spawning and where salmonid eggs are incubating must not occur. Careful planning of equipment operation is necessary to minimize the movement of excavated material downslope as unintentional sidecast. Disposal sites identified in the planning phase must be used.

Construction of bridges and culverts must be conducted carefully. The construction should occur during low flow conditions. Equipment operation within the streambed must be minimized. Construction of piers, footing, abutments, wingwalls, and other structures within the normally wetted portion of the stream will require measures to redirect flows within the channel area and contain turbid waters in settling basins. Care must be taken to minimize sedimentation.

Construction of cuts, fills, and the roadway must be done according to planning and design specifications. Care must be used to contain materials and minimize loss of excavated material downslope. Culverts and ditches must be properly bedded, and placed according to appropriate procedures. Inlet and outlet structures must be installed properly.

Compaction of the road base at the proper moisture content, surfacing, and grading is accomplished to give the designed road surface drainage shaping. Surface drainage waterbars, open-top culverts, or slit-troughs are installed to prevent rilling and intercept rut drainage which may develop.

Use of straw bales, straw mulch, grass-seeding, hydromulch, and other erosion control and re-vegetation techniques complete the construction project. Freshly disturbed soils will need protection until vegetation is established. Construction and Reconstruction activities must be managed to minimize impacts to streams and coastal areas as follows:

(1) Slash material must not be left in watercourses. It must be removed before the appropriate equipment to retrieve it leaves the area.

(2) Excess fill material must be carefully managed and not permitted to slough downslope beyond reach of construction equipment.

(3) Bridges, culverts, and other stream crossing structure installations must be conducted to minimize production of sediment. Turbid waters must be contained and diverted to settling basins or flat areas before discharge to the stream. Equipment should not operate within the streambed, but should be limited to making the minimum number of crossings for access to the site.

(4) Installation of road drainage culverts and structures must be made according to planned and designed specifications. Road surfacing and shaping must follow designs.

(5) Mulching and revegetation must be done as quickly as possible to protect disturbed soils from excessive erosion such as rilling and gullying.

2. <u>Effectiveness</u>

This MM has an effectiveness range of 65-80 percent to prevent entry of sediment into area waterbodies. The reason that complete prevention of sedimentation does not occur is the fine particles that are eroded from freshly exposed soils. Studies show that 80 percent of erosion on studied roads occurred during the first 3 years following construction. A certain amount of fillslope material sloughs downslope and finally, the road drainage systems acts as a new stream network on the landscape which must establish an equilibrium with its bed. The variation in effectiveness is due to slope steepness, rock type and soils, climate, landslide sensitivity, runoff events during the first 3-year period, execution error, and unanticipated springs, supplying additional runoff and erosion.

3. <u>Costs</u>

The cost of implementing erosion control practices for forest land management access roads has been estimated to be $11.00 per mile based on national summaries provided by the USDA Agricultural Stabilization and Conservation Service (ASCS). In the State of Virginia Best Management Practices Handbook for forestry, the following costs were estimated[1] for the construction of woodland access roads and skid trails:

Activities	Costs
Construction of Access Roads:	$160.00/100 feet
Land clearing and earthwork	
Culverts	
Bridges	
Drainage Dips	
Water Bars	$4.75 each

Surface Materials	
Seed	$4.75/100 feet
Mulching	$160.00/acre
Construction of Skid Trails (Water Bars) (Drainage Dips)	$40.00/100 feet

The following example percentages for activities related to the construction of forest roads are based on USDA Forest Service estimates from the Pacific Northwest:

Activities	Costs
Clearing phase	Add 5%
Pioneering phase	Add 30%
Construction phase	Add 30%
Surfacing phase	Add 50%

E. MM No. 5 Road Management

1. Components and Specifications

Landowners with roads must manage those roads to prevent sedimentation and pollution from transported materials. Roads that are actively eroding and providing sediment to waterbodies, whether in use or not, must be treated to prevent erosion. Major sources such as landslides must be prevented by maintenance or removal of drainage crossings such as bridges, culverts, and fords as well as road surface drainage structures such as ditches, culverts, dips, waterbars, etc. Large deposits of sediment due to sloughing or road related landsliding must be stabilized to the greatest degree practicable to reduce sedimentation.

If roads are no longer needed, an effective treatment is to remove drainage crossings and culverts if there is a risk of plugging or failure from lack of maintenance. In other cases it is economically more viable to periodically maintain the crossing and drainage structures. Roads subject to rutting must either be maintained to properly drain without excess sediment or be blocked from traffic. While road maintenance is an expensive proposition, it is far cheaper than repair after failure or decades of fish population losses. For some unstable sections, the only effective treatment is excavation and haul of the road section or expensive geotechnical solutions such as groundwater drainage, grouting, or support by pilings.

2. Effectiveness

The effectiveness of this MM is 75-90% due to the periodic nature of road maintenance activities, especially for older roads not in use. The effectiveness varies with the landslide sensitivity, slope steepness, rock type and soils, runoff events, and overall condition of the road system.

3. Costs

In the State of Virginia Best Management Practices Handbook for forestry, the following costs were estimated[1] for the management and maintenance of forest roads and skid trails:

Activities	Costs
Road Maintenance	$3.25/100 feet
Cleaning Culverts	
Filling Ruts and Grading	$3.25/100 feet
Retirement of Roads	$8.00/100 feet
Filling Ruts and Grading	$3.25/100 feet
Bedding with Brush	$2.00/100 feet
Water Bars	$4.75/each
Seeding	$4.75/100 feet
Retirement of Skid Trails	$ .80/100 feet
Bedding with Brush	$2.00/100 feet
Water Bars	$4.75/each
Seeding	$4.75/100 feet
Mulching	$160.00/acre

The following example costs for activities related to the construction of forest roads are based on USDA Forest Service estimates from the Pacific Northwest:

Activities	Costs
Routine maintenance of drainage	$200-600/mile structures
Routine maintenance of the road surface	
native surface	$200-$1200/mile
gravel	$200-$600/mile
Road barriers	$300-5,000 each
Replacement of drainage culverts	$30-50,000/mile
Replacement of drainage crossings	
culverts	$5-500,000 each
bridges	$.1-5.0 million
Excavation of unstable road section	$.1-1.0 million
Underground drainage, piles	$.2-1.0 million

F. MM No. 6 Timber Harvest Planning

1. Components and Specifications

Timber harvest is usually selected for areas with merchantible stands of timber that economically are viable. Selection of stands for harvest also is made based on silvicultural considerations for the regeneration or future condition of the stand. Such planning must also include provisions to identify unsuitable areas which may have merchantible trees, but pose risks for landslides. These concerns are greatest for steeply sloping areas in areas of high rainfall or snowpack in sensitive rock types. Decomposed granite, highly weathered sedimentary, fault zones in metamorphic rocks are potential rock-types of concern. Deep soils derived from these rocks, colluvial hollows, and fine textured clay soils often referred to as "blue goo" are soil conditions causing potential problems. Such areas usually have a history of landslides either naturally or related to earlier land disturbing activities. When risks of landslides are present, a technical specialist such as a geologist, soil scientist, hydrologist or geotechnical engineer should be consulted.

Studies have identified cumulative sedimentation effects from the incremental additions of small sediment volumes added together within a drainage basin. In some climatic zones often related to elevation and orientation to the prevailing winds, streamflow peaks may be increased from timber harvest at certain points in the drainage network. These peaks may cause adjustments in channel beds and banks with net sediment increases. In areas where the cumulative effects of timber harvest activities are affecting water quality and habitats, adjustments in planned harvest are necessary. This includes selection of harvest units with low risks of sedimentation, such as flat ridges or broad valleys, postponement of harvesting until erosion sources are stablilized, and selection of limited areas of harvest using existing roads.

Planning of the silvicultural system of harvest as even-aged (eg. clearcut, seedtree, shelterwood,) or un-evenaged (eg. group selection, or individual tree selection) and the type of yarding system must consider potential water quality and habitat impacts. At first, it may appear more beneficial to water quality to use un-even aged silvicultural stand management, because less ground disturbance and loss of canopy cover occurs. This may be misleading, because more acres must be treated to yield equivalent timber volumes which require more miles of road construction and/or re-construction. Roads have been shown repeatedly to produce the greatest volumes of sediment in forestry activities.

Additionally for moderately sloping areas, yarding of uneven-aged silvicultural systems is most often accomplished by ground-skidding equipment which disturbs soils several times more in total area than cable yarding systems. Cable yarding systems may be used in sloping areas for even-aged silvicultural systems. Whichever silvicultural system is selected will require planning to minimize erosion and sediment delivery to waterbodies. Harvested areas should be immediately replanted or regenerated to prevent further erosion and potential impact to waterbodies. The following are specifications for this MM:

(1) Planned harvest units will not add to problems of cumulative sedimentation effects.

(2) Selection of the silvicultural system will include consideration of potential water quality impacts from needed roads and skidding operations.

(3) Areas with identified risks of landslides by a qualified specialist, eg. geologist, soil scientist, geotechnical engineer, or hydrologist will not be harvested.

2. Effectiveness

This MM will provide a 85-100% effectiveness in preventing the entry of sediments into waterbodies. This variation is due to uncertainties in identifying landslide prone areas, the slope steepness, the uncertainty of assessing cumulative effects, and the runoff events.

3. Costs

Provide an additional 15 percent of planning time for water quality considerations in timber harvest planning.

G. MM No. 7 Landings and Groundskidding of Logs

1. Components and Specifications

Landings and skidtrails will be pre-planned to control erosion and delivery of sediments to watercourses. Locations are primarily determined in the field based upon the distribution of timber volumes designated for harvest. Generally, this pre-planning will take place when the harvesting unit is layed out as described in MM No. 6. The most economically efficient locations for landings and skidtrails will be adjusted to protect waterbodies from the delivery of sediments. Landings must be located outside of the Streamside or Wetland Special Management Areas.

Landings will be no larger than necessary to safely and efficiently store and load trucks. *Drainage structures such as waterbars, culverts, and ditches will be constructed. Slope of the* landing surface should be less than 5 percent and will be shaped to promote efficient drainage of runoff. Landing fills must not exceed 40 percent slope and must not have incorporated woody or organic materials. If landings are to be used during wet periods a suitable depth of gravel surfacing will be necessary to prevent rutting.

Groundskidding of logs will be limited to slopes less than 40 percent. For sensitive soils further limitation of activities on slopes is needed. During wet periods, groundskidding should be stopped when rutting and churning of the soil begins and when runoff from skidtrails is turbid and no longer infiltrates within a short distance from the skidtrail. Groundskidding on frozen soils or frozen snowpack should be conducted as a method to avoid disturbance of sensitive soils during winter logging. Winter logging may still lead to sedimentation if provisions for drainage during the spring thaw or break up are not made.

Skidtrails should also be pre-planned (again, this should be done prior to harvest - MM No. 6) to minimize disturbance and compaction of soils. In SSMAs felling of trees should be carried out with the large ends toward the skidtrails (felling to the lead) to minimize disturbance and yarding costs. Skidtrails will not be located within Streamside or Wetland Special Management Areas. Yarding of trees within these areas must be accomplished by endlining, use of winch and cable to each log turn. Unimproved skidtrails should not be located across flowing drainages. Improved crossings may be constructed as long as earth material does not enter waters and woody materials are removed immediately following skidding operations in the area. Skidtrails must not exceed 1200 feet in length. The pattern of skidtrails will disperse rather than concentrate runoff. Drainage waterbars will be constructed with appropriate spacing and locations to prevent rilling and gullying of the skidtrail and for areas receiving the drainage.

2. Effectiveness

Depending upon the sensitivity of the area considering factors such as percent slope, amount of area in skidtrails, volume of timber yarded, soils, climate, runoff events, proximity to streams, proper location and pre-planning of landings and skidtrails should provide 85-100 percent effectiveness in preventing sediment entry to watercourses immediately after harvest.

3. Costs

	Cost
Landings	
Pre-planning and drainage design	\$80-100/landing
Construction drainage structures	\$30-50/landing
Skidtrails	
Pre-planning	\$20/mile
Construction, drainage structures	\$40/mile

H. MM No. 8 Landings and Cable Yarding

1. Components and Specifications

Landings for cable yarding equipment will be carefully located and designed. Locations with risk of landslides identified by a qualified specialist (geologist, geotechnical engineer, soil scientist, or hydrologist) will not be used. Landings will not be located within Streamside or Wetland Special Management Areas or located over drainages.

Landings will be no larger than necessary to operate yarding and loading equipment safely and efficiently. Drainage structures such as waterbars, culverts, and ditches will be constructed to efficiently control runoff. Slope of the landing surface will be less than 5 percent and will be carefully shaped for efficient drainage. Landing fills must not exceed 40 percent slope and must not incorporate woody and organic materials. Landing fills will not slough or fail into watercourses. If landings are to be used during wet periods, a suitable depth of gravel surfacing will be necessary to prevent rutting.

Landings will be located where slope profile data indicate favorable deflection conditions for the yarding equipment planned for use. Profiles must allow only minimal area of yarding corridor gouge or soil plowing. Such disturbed areas will be hand water-barred and covered with straw mulch if the continuous disturbance area is greater than 450 square feet.

High lead cable systems should be used on an average profile slope of less than 15 percent to avoid soil disturbance from side wash. Skyline cable systems are suitable for average profile slopes greater than 15 percent. Yarding corridors for Special Streamside Management Areas will meet Components and Specifications for these areas. Yarded logs will not make surface contact within the major channel banks of the watercourse of the SSMA. Yarding generated slash materials will be removed from watercourses by the end of the workday.

2. <u>Effectiveness</u>

Preplanning of landings and yarding corridors for cable yarding should provide a range of effectiveness of 70-100 percent effectiveness depending upon the sensitivity of the site to landsliding, based on such factors as percent slope, proximity to streams, rock type, soils, climate, runoff events, and the volume of timber harvested.

3. <u>Costs</u>

	Cost
Landings	
Pre-planning and drainage design	\$80-100/landing
Construction drainage structures	\$30-50/landing
Cable Corridors	
Pre-planning	0
Hand water-barring	\$5-30/corridor
Straw mulching	\$30-50/corridor

I. MM No. 9 Mechanical Site Preparation

1. Components and Specifications

Mechanical site preparation will not be applied to slopes greater than 30 percent. On sloping terrain greater than 10 percent, ground disturbing activities will be conducted on the contour leaving slash windrows also on the contour. The objective is to provide a seedbed or remove competing vegetation species from seedlings while minimizing the potential for erosion. Mechanical site preparation will not be conducted within Streamside Special Management Areas. Filter strips of suitable width will protect all drainages to prevent sedimentation by the 10 year precipitation event for storms of common duration for the climate of the area. All slash material must be removed from drainages by the end of the workday. Operation is prohibited during wet periods when equipment begins to cause rutting or churning of the soil. Windrows will be located a safe distance from drainages to prevent movement of the material during high runoff conditions. Breaks in the windrows will occur at regular intervals to equalize water levels on both sides of the windrow.

Bedding operations in high water table areas will be conducted during dry periods of the year. Bedding areas will be located on the contour or at right angles to the direction of flow when flooded. Openings in the beds will occur at sufficient intervals to avoid ponding and allow water levels to equalize on both sides of the bed. Disturbed soil area between beds will be minimized. Special care will be used to prevent changes in the natural hydrologic conditions of these forested wetlands.

2. Effectiveness

The use of this MM should provide 80-100% effectiveness in preventing sedimentation to streams and in protecting the hydrologic conditions in wetlands.

3. Costs

The cost to conduct erosion control practices during site preparation for forest regeneration averaged about $62.00 per acre treated in 1990 based on national summaries provided by the ASCS. In the State of Virginia Best Management Practices Handbook for forestry, the following costs were estimated[1] for the site preparation:

Activities	Costs
Prescribed Burning	$16.00/acre
Bulldozing or Shear Blading	$105.00/acre
Chemical	
Ground	$41.00/acre
Aerial	$38.00/acre
Chopping	$70.00/acre

Discing	$40.00/acre
Bedding	$24.00/acre

The following example costs for activities related to site preparation are USDA Forest Service estimates from the Pacific Northwest:

Add 5 percent to the cost of mechanical site preparation for achieving these MM's.

J. MM No. 10 Prescribed Fire

1. Components and Specifications

No prescribed fire for site preparation or forestry slash removal purposes will be conducted in SSMAs. Prescribed fire in wetland areas should be carefully designed to protect wetland values and prevent erosion. Intense prescibed fire will not occur in streamside vegetation for small drainages where there is risk of sedimentation due to the loss of canopy and the soil binding ability of vegetation roots. Firelines will be constructed outside of the streamside zones protected from prescribed fire. Intense prescribed fire on steeply sloping areas must not increase the risk of sedimentation to nearby drainages. Prescriptions for prescribed fire will avoid conditions requiring extensive blading of fire lines by heavy equipment. Where possible, prescriptions should rely on hand lines, firebreaks, and hose lays to minimize soil disturbance, especially on sloping areas where firelines must be parallel to the slope. All firelines must be water-barred at appropriate intervals to prevent rills and gullies on the fireline and in the area receiving the runoff. Waterbars should be constructed to drain runoff outside of the burned area.

2. Effectiveness

Use of this MM to reduce erosion related to prescribed fire should provide 90-100% effectiveness in preventing sedimentation to waterbodies in the area. Variation in effectiveness is due to slope, soils, intensity of the burn, runoff events, and climate.

3. Cost

In the State of Virginia Best Management Practices Handbook for forestry, the following costs were estimated[1] for the use of prescribed fire for site preparation:

Activities	Costs
Prescribed Burning	$16.00/acre

The following example cost percentages for prescribed fire are USDA Forest Service estimates from the Pacific Northwest:

Firelines	Cost
Additional to protect drainages, fall	Add 30-50%
Reductions due to wetter conditions	Minus 30-50%

K. MM No. 11 Mechanical Tree Planting

1. Components and Specifications

Equipment will be operated on the contour to prevent erosion. Mechanical planting will not be conducted within Streamside Special Management Areas. When crossing small ephemeral drainages (drainages which only flow during storms or snowmelt), the plow will be raised until the equipment passes well beyond the zone of flow. Slits should be turned upslope before crossing the drainage to prevent entry of slit runoff.

2. Costs

The cost to install forest tree plantations for the primary purpose of erosion control was about $137.00 per acre in 1990 based on national summaries provided by the ASCS. In the State of Virginia Best Management Practices Handbook for forestry, the following costs were estimated[1] for tree planting:

Activities	Costs
Tree Planting	
Hand	
Loblolly Pine	$47.00/acre
White Pine	$70.00/acre
Hardwoods	$141.00/acre
Machine	
Loblolly Pine	$50.00/acre
White Pine	$71.00/acre

The following are example cost percentage for mechanical tree planting based on USDA Forest Service contracts from the Pacific Northwest:

Add 5 percent to the cost of mechanical site preparation for achieving these MM's.

L. MM No. 12 Revegetation of Disturbed Areas

1. Components and Specifications

The objective of this MM is to reduce erosion by the fastest revegetation possible. Revegetation efforts will be conducted in the most efficient and effective manner economically feasible appropriate to the area. In humid areas during the growing season, grass and legume seeding will be done immediately following the completion of the earth disturbing activity, preferably within days after the activity has ended. Use of straw as mulch, hydromulch, lime and fertilizer, wetting agents, jute netting, woven fabrics, etc. will depend on the most successful mixes of species and treatments for the area.

In dry areas during the growing season, it is most often successful to postpone seeding and related treatments to just prior to the normal beginning of the wet period, often fall and spring. Seeding done earlier would commonly fail due to the lack of sufficient moisture. Late fall or winter seeding often fails due to cold soil temperatures inhibiting germination, and being conducive to seed-killing mold and fungi.

Revegetation efforts should be concentrated on the largest areas of disturbance near waterbodies. On steep slopes use of native woody plants planted in rows, cordones, or wattles may be more effective than grass in becoming established and binding the soil with roots.
Seed mixtures will contain plants with soil binding properties. Cattle grazing must be prevented on newly re-established vegetation plantings. Seed selection should include natives where possible, and should consist primarily of annuals to allow natural revegetation of native understory plants in time. Exotic species which may spread to other areas must not be used.

2. Effectiveness

The effectiveness of revegetation to prevent sedimentation of area waterbodies varies from 40% to 60% This variation and limited effectiveness is due to the period of time that soils are exposed to rain and snowmelt before vegetation is established. The period of exposure is strongly related to the weather, climate, antecedant soil moisture, soils, slope steepness, runoff events, and grazing by animals.

3. Costs

The cost to establish permanent vegetative cover on critical areas for the primary purpose of erosion control was about $140.00 per acre in 1990 based on national summaries provided by the ASCS. In the State of Virginia Best Management Practices Handbook for forestry, the following costs were estimated[1] for the use of prescribed fire for site preparation:

Activities	Costs
Seedbed Preparation	
Lime	$19.00/ton
Fertilizer	Variable- depending on sowing rate
Seed	$4.75/100 feet
Mulching	$158.00/acre

The following example costs for revegetation methods are based on USDA Forest Service contracts from the Pacific Northwest:

Method	Cost
Grass-seeding (hand)	$50/acre
Grass-seeding (helicopter)	$100/acre
Hydromulching seed and fertilizer	$150/acre
Straw mulch	$500/acre
Jute netting	$1,000/acre
Woven fabric	$5,000/acre
Woody plant rows, cordon, wattles	$1/foot

M. MM No. 13 Stream Protection for Pesticide and Fertilizer Projects

1. Components and Specifications

Pesticides: Pesticides are used for many different purposes. Since they are toxic materials, they must be mixed, transported, loaded, applied, and their containers disposed of with great care. Their use must be prescribed for the appropriate pest after consideration of integrated pest management (IPM) approaches. Application must be conducted according to label instructions for the certified use. Applicators must be licensed by the appropriate state agency.

Spray programs must meet state requirements. For aerial applications this commonly involves inspection of the mixing and loading process, nozzle calibration, and approval of appropriate weather conditions, and spray area and buffer area monitoring. Buffer areas for identifiable flowing waters must be established and made identifiable for applicators. Accidental spills of toxic materials into waterbodies must be immediately reported to the state water quality agency. Spill contingency plans must be in place and include effective means to control spills to the maximum extent practicable.

Streams must be sampled adjacent to or below application areas at time intervals to measure the expected peak concentration based upon time of application, travel time, and nature of the material. Sampling results must be reported to the state water quality agency and licensing agency.

Fertilizers: Fertilizers may also be toxic materials depending upon the concentration. Similar planning, care in use, sampling, and reporting are necessary. Serious consideration of the costs and benefits of fertilizer use in forest applications will be made. Spill contingencies apply as well. Appropriate buffers for flowing waters and aerial weather conditions will be properly managed to prevent the entry of fertilizers into waterbodies.

2. Effectiveness

This MM varies between 95-100% effective in preventing entry of pesticides and fertilizers in waterbodies. While the consequences of entry of pesticides and fertilizers is high, the risk of entry is low when this MM is applied.

3. Costs

In the State of Virginia Best Management Practices Handbook for forestry, the following costs were estimated[1] for control of the use of pesticides to protect water quality:

Activities	Costs
Chemical application for Pine Release	
Ground	$32.00/acre
Aerial	$32.00/acre

The following cost estimate is based on USDA Forest Service information from the Pacific Northwest:

Activities	Costs
Planning and coordination	Equal to Application Costs

N. MM No. 14 Petroleum Products Pollution Prevention

1. Components and Specifications

Planning to designate appropriate areas for petroleum storage, procedures and equipment for dispensing, and procedures for spill containment and contingencies will be done. Sites for storage and transfer must meet state and federal regulations. Spills of fuels must be contained and treated. Fuel trucks and pickup mounted fuel tanks must not have leaks. Fuel storage and transfer sites must be located sufficiently distant from waterbodies to prevent entry of petroleum products should the storage tank lose its entire capacity of storage.

A specified area must be designated for draining lubicants from equipment during routine maintenance. The area should allow all waste lubricants to be collected and stored until transported off-site for recycling, re-use, or disposal at an approved site. Waste oil, filters, grease cartridges, and other petroleum contaminated materials will not be left as refuse in the forest, but must be transported to an approved disposal site.

2. Effectiveness

This MM is 95% effective in preventing the entry of petroleum products into streams. The small percentage of failure occurs as fuel spills from leaking tanks or traffic accidents. Leaking of petroleum from moving vehicles cannot be completely eliminated nor can traffic accidents.

3. Costs

Activities	Costs
Preventive measures	$0 These measures are already required by state and federal rules and regulations

NOTE: Comments are solicited on all aspects of this section, and particularly on the amount and the level of detail in this discussion. In addition, comments on the cost and effectiveness information which is provided or additional information which may be available elsewhere are requested. Additional or alternative management measures required to address a given practice or pollutant source, or which are more applicable to a specific region of the United States, are also requested. EPA will be collecting additional information on management measures, and their costs and effectiveness, during the revision of this draft guidance. The contributions and suggestions of commenters on these subjects will be welcome.

FOOTNOTES

[1]Costs are in converted from 1979 to 1990 dollars using an aggregate cost index from the Engineering News Report, March 25, 1991.

REFERENCES

Commonwealth of Virginia. 1979. Best Management Practices Handbook - Forestry. Virginia State Water Control Board, Planning Bulletin 317.

USDA. 1991. Agricultural Conservation Program - 1990 Fiscal Year Statistical Summary. ASCS, Washington, DC.

CHAPTER 4. MANAGEMENT MEASURES FOR URBAN SOURCES OF NONPOINT POLLUTION

CHAPTER 4

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MANAGEMENT MEASURES FOR URBAN SOURCES OF NONPOINT POLLUTION

I. INTRODUCTION

This chapter specifies management measures to abate and control water quality problems in coastal areas resulting from urban runoff. Urbanizing and urbanized areas, construction, onsite sewage disposal systems (septic systems), highways, and bridges will be covered under this heading.

It has been well documented that urban sources of pollution contribute significantly to the degradation of coastal and estuarine water resources. The National Urban Runoff Program (NURP), State 305(b) reports, and the Section 319 Assessment reports all indicate that urban loadings of sediments, nutrients and toxic substances to surface waters are significant and may cause impairment or denial of beneficial uses.

Curtailment of recreational and commercial uses of coastal waters due to contamination from urban runoff has been well publicized. Land conversion associated with the urbanization of undeveloped lands has resulted in the loss of vegetation and sensitive wetlands, alteration of natural drainage patterns and the creation of expanded areas of imperviousness. This loss of infiltrative capacity has been correlated with increases in the velocity, volume and frequency of stormwater runoff. Mitigation and prevention of this process is inherently difficult in that sources are diverse, changes in water quality may be gradual and cumulative, existing institutional frameworks often fail to address NPS pollution in a comprehensive manner, and political constraints tend to limit the number of viable options for meaningful change.

Management measures appropriate to control urban runoff must address an array of pollutants. As urbanization occurs, strategies must comprehensively address pollutants generated during all phases of this process. Management practices or systems need to be developed for urban sources of NPS which anticipate and adjust to these ongoing changes. In such an environment, a phased approach is often necessary to prevent and control each type of pollutant generated. Planning and site design can be effective means to prevent and control nonpoint source pollution. Both watershed and site planning can be used to (1) locate development away from sensitive land forms which may be highly erodible or serve as natural filters for stormwater runoff and (2) design developments to allow more effective or efficient control of nonpoint source runoff. This subject will be addressed in more detail within the body of this section. To further illustrate this point, where development or construction are planned, site suitability evaluations are appropriate prior to the planning and design phase. As planning and design occur, best management strategies should assess the environmental effects of the project and identify practices or controls needed to prevent or mitigate runoff during and after construction. During construction, management practices should schedule activities to minimize site disturbance and include the use of sediment control measures and practices. Finally, post construction measures should ensure that proper operation and maintenance of control devices such as buffer strips and detention basins occur on a long term basis.

The management measures presented in the following sections represent the EPA's preliminary effort to specify the best practices or management systems to control urban sources of nonpoint pollution. Where possible, data on effectiveness, cost of implementation and operation and maintenance has been provided. In the absence of readily available data, the guidance contains examples or cites existing State practices which are under consideration as best management practices. The Agency is soliciting information both on additional management measures that apply to urban problems and any cost or effectiveness data which is applicable to these or previously identified measures. The Agency will consider these and additional information regarding costs and pollution reduction effects prior to publishing the final guidance.

Listed below are some of the major sources of urban nonpoint pollution:

(1) Construction on sites less than five acres in size
(2) Onsite Sewage Disposal Systems - septic tanks
(3) Households
(4) Roads, Highways and Bridges
(5) Golf Courses/Parks
(6) Service stations

As pointed out in the introduction, some of these activities may be required to apply for and receive point source permits. In such cases, they are not subject to this guidance. (See the National Pollutant Discharge Elimination System Permit Application Regulations for Storm Water Discharges published in 55 Fed. Reg. 47990 (November 16, 1990) for more information concerning point source discharges.)

A. Urban Nonpoint Pollutants and Water Quality Effects

Most pollutants enter coastal waters either as soluble forms or bound to sediments. Additional pollutants result from atmospheric deposition. Data from both the National Urban Runoff Program (NURP) and the §319 Report documents that sediments, nutrients and pathogens are the most likely pollutants to impair water quality and designated uses. Heavy metals, oils and grease, toxic organic chemicals and oxygen-demanding materials may also contribute to water quality problems.

Volume and pollutant concentration in urban runoff affect the extent receiving coastal waters are impaired. Daniel (1978) found high concentrations of pollutants are generally associated with the following conditions: (1) densely populated and/or industrial areas; (2) intensive storms; (3) beginning stages of storms; (4) prolonged dry periods prior to a runoff event; and (5) drainage areas with significant construction activity.

Some generic water quality impacts associated with urban runoff include: (1) rapid short-term changes in water quality during and shortly after storm events which result from the discharge of pollutants at relatively high concentrations; (2) longer-term water quality impacts on biological communities and health associated with the discharge of toxic pollutants at lower concentrations; (3) long-term effects associated with the discharge of nutrients and other pollutants into estuaries and wetlands; (4) physical changes related to the erosion of stream banks and/or the creation of sediment deposits in near coastal areas; and (5) water quality changes associated with the scouring and resuspension of in place pollutants.

B. Urban Nonpoint Source Pollutants

Listed below are the principal types of NPS pollutants found in urban runoff with brief descriptions of their potential to adversely affect surface and coastal waters (Schueler, 1987). Table 4-1 further illustrates types and sources of hazardous urban pollutants (EPA, Urban Targeting and BMP Selection, 1990)

Sediment: Suspended sediments comprise the bulk of urban nonpoint source pollutants. Sediment has both short and long term impacts on receiving waters. Some immediate detrimental impacts of high sediment loadings include: increased turbidity, impaired respiration of fish and aquatic invertebrates, reduced fecundity and impairment of commercial and recreational fishing. High sediment concentrations may also cause long term effects. Heavy sediment deposition in low velocity receiving waters may result in smothered benthic communities, increased sedimentation of watercourses, changes in bottom substrate composition and alteration of the water's aesthetic value. Additional chronic effects may occur where sediments rich in organic matter or clay are present. Such sediments tend to bind and transport nutrients, toxic substances and trace metals. These enriched depositional sediments may present a continued risk to aquatic and benthic life especially where the sediments are disturbed and resuspended.

Oxygen Demanding Substances: Dissolved oxygen levels are critical to healthy waters. Decomposition of organic matter by microorganisms depletes dissolved oxygen (DO) levels in receiving waters, especially estuaries. Data has shown that urban runoff with high concentrations of decaying organic matter can severely depress DO levels after storms (EPA, 1983). The NURP study found that oxygen demanding substances are present in urban runoff at concentrations approximately equal to those in secondary treatment discharges. The Chesapeake Bay Office is currently recommending that DO levels not fall below specified thresholds for selected habitats (see Table 4-2: Note, however, that Table 4-2 only applies to the Chesapeake Bay and should not be applied elsewhere without adjustment).

Nutrients: The problems created by excess phosphorus and nitrogen loading to water bodies are well known and discussed in detail in Chapter 2 (agriculture). Accelerated eutrophication, decreases of submerged aquatic vegetation (SAV) and toxicity to humans or wildlife may occur when the concentration of certain forms of nutrients exceed a critical level. Surface algal scum,

Table 4-1. Potential Sources of Toxic and Hazardous Substances in Urban Runoff

	Automobile Use	Pesticide Use	Industrial/Other Use
Heavy Metals			
Copper	metal corrosion	algicide	paint, wood preservative electroplating
Lead	gasoline, batteries		paint
Zinc	metal corrosion tires, road salt	wood preservative	paint, metal corrosion
Chromium	metal corrosion		paint, metal corrosion, electroplating
Halogenated Aliphatics			
Methylene chloride		fumigant	plastics, paint remover solvent
Methyl chloride	gasoline	fumigant	refrigerant, solvent
Phthalate Esters			
Bis (2-ethylhexyl) phthalate			plasticizer
Butylbenzyl phthalate			plasticizer
Di-N-butyl phthalate		insecticide	plasticizer, printing inks, paper, stain, adhesive
Polycyclic Aromatic Hydrocarbons			
Chrysene	gasoline, oil, grease		
Phenanthrene	gasoline		wood/coal combustion
Pyrene	gasoline, oil, asphalt	wood preservative	wood/coal combustion
Other Volatiles			
Benzene	gasoline		solvent
Chloroform	formed from salt, gasoline & asphalt	insecticide	solvent, formed from chlorination
Toluene	gasoline, asphalt		solvent
Pesticides and Phenols			
Lindane (gamma-BHC)		mosquito control seed pretreatment	
Chlordane		termite control	
Dieldin		insecticide	wood processing
Pentachlorophenol		wood preservative	paint
PCBs			electrical, insulation

Table 4-2. Recommended DO Habitat Requirements

Category	DO Value (mg/L)	Specific Requirements
Spawning Reaches: Instantaneous DO	5.0	DO should not fall below 5.0 mg/L at any time within anadromous fish spawning reaches and nursery areas during late winter through late spring (February 1 - June 15).
All Tidal Waters of the Chesapeake Bay for All Seasons Except the Spawning Areas and Times Defined Above:		
Category I - Instantaneous DO	0.5	DO should not be below 0.5 mg/L at any location, at any season, or for any duration.
Category II - One-hour DO	1.0	DO should not fall below 1.0 mg/L for more than one hour at any location or at any time. Excursions below 1.0 mg/L should not occur more frequently than every 12 hours.
Category III - Twelve-hour DO	3.0	DO should not fall below 3.0 mg/L for more than 12 hours at any location or time. Twelve-hour excursions below 3.0 mg/L should not occur more frequently than every 48 hours.
Category IV - Monthly Average DO	5.0	Monthly mean DO should not be below 5.0 mg/L at any location or season.

water discoloration, strong odors, depressed oxygen levels, and release of toxins are also common problems.

Heavy Metals: Heavy levels of copper, lead and zinc are the most prevalent priority pollutant constituents found in urban runoff. The presence and concentrations of these metal is in some cases high enough to impact beneficial uses and cause detrimental effects to aquatic life. Groundwater sources of drinking water supplies may also be degraded or endangered by the presence of heavy metals and nitrates.

Oil and Grease: Oil and grease contain a wide variety of hydrocarbon compounds. Some polynuclear aromatic hydrocarbons (PAH's) are known to be toxic to aquatic life at low concentrations. The precise impacts of hydrocarbons on the aquatic environment are not well understood.

Pathogens: The presence of pathogens in surface water may cause public health standards for water contact to be exceeded and restrict shell fish harvesting. Although high fecal coliform counts have documented in urban runoff, the health implications are unclear where contamination is not from improper sanitary connections or septic systems.

Other Pollutants: Other toxic chemicals are rarely found in urban runoff from residential and commercial land use areas in concentrations that exceed current water quality criteria. Pesticide concentrations in urban runoff generally are near detection limits. PAHs commonly detected organic compounds found in urban runoff have not been correlated with known problems. There is currently a lack of data on industrial runoff to draw conclusions about the fate and effects of related pollutants.

II. CONSTRUCTION MANAGEMENT MEASURE

A. Management Measure Applicability

This management measure is applicable to all construction activities which result in land development or disturbance and are not subject to a requirement to apply for and receive an NPDES permit [Note: All construction activities, including clearing, grading and excavation which result in the disturbance of areas greater or equal to 5 acres or are part of a larger development plan are covered by the NPDES regulations]. Activities subject to this management measure include, but are not limited to, commercial or residential development, road, highway, airport and bridge construction, landscaping and installation of underground storage tanks or sewer/stormwater conveyances.

B. Pollutants Generated by Construction Activities

Construction related pollutants transported in urban runoff, listed in decreasing order of importance include:

- Sediment and particulate organic solids;
- Toxic metals and hydrocarbons
  (deposited from onsite equipment);
- Nutrients
  (applied to promote revegetation and site stabilization).

The major pollutant generated from construction activities is sediment. Sediment loadings from construction sites may be as much as 100 times greater per acre than those from agricultural lands and perhaps 2,000 times per acre greater than from undisturbed forestland (IEN p. 64, Bergquist, 1986). Exposed, disturbed and stockpiled soils are extremely susceptible to erosion and transport off site. In general, downstream suspended sediment levels are greatest during the advanced stages of construction when sediment delivery conditions are optimal (Schueler, 1990).

C. Construction Management Measures

Management measures for construction consist of the following sets of measures.

(1) Reduce site disturbance and the detachment and transport of soil on construction sites by disturbing the smallest area for activities, stabilizing disturbed areas within a reasonable time, reducing runoff velocities, and protecting disturbed areas from stormwater runoff.

(2) Control eroded sediment on site such that off-site sediment and particulate organic solids delivery is reduced to or below the lower of either pre-development sediment loadings (to the extent practicable) or the acceptable soil loss tolerance for agricultural lands.

(3) Reduce toxic and nutrient loadings to pre-development levels (to the extent practicable) by reducing the generation and migration of toxic substances and avoiding excess applications of nutrients.

D. Available Management Practices to Achieve Management Measures

Listed below is a selection of state-of-the-art erosion and sediment control practices ideal for coastal regions. These practices are available as tools to achieve the construction management measure specified in section II.C.

1. Practices Available to Achieve Management Measures 1 and 2

Practices for general use:

- Plan development to fit the topography, soils, drainage patterns and natural vegetation of the site.
- Avoid mass clearing and grading of the entire site (e.g., use phased construction sequencing to limit the amount of disturbed area at any given time).
- Establish vegetative cover on all disturbed sites where construction activity has been interrupted for an unreasonable time.
- Configure site plans to retain the maximum area of open vegetated space.
- Divert and convey off-site runoff around disturbed soils and steep slopes to stable areas in order to retain sediment onsite and prevent transport of pollutants offsite.
- Utilize grading methods which impede vertical runoff and provide maximum runoff infiltration capacity.
- Implement a maintenance and follow-up program for control practices including post storm event inspections of all control practices.
- Restrict the clearing and grading of all areas that will later function as post development buffer zones.
- Locate large graded areas on the most level portion of the site and avoid the development of steep vegetated slopes.
- Reestablish vegetative areas that have been filled or damaged by construction equipment or activities.
- Conduct temporary construction and fill activities outside of floodplains.

- Prepare an erosion and sediment control plan which specifies location, installation, and maintenance of practices to prevent and control erosion and sediment loss at the site. The efficacy of this practice can be further enhanced by communicating the provisions of the control plan to all employees associated with the project and by designating responsibility for implemention of the plan to an individual certified in erosion and sediment control practices by the local authority.

- Use surface roughening (horizontal depressions) to control erosion and aid the establishment of vegetative cover.

- Avoid the placement of entrances on steep grades or curves.

- Protect inlets to storm sewers by suitable filtering devices during construction.

- Construct access roads with grades less than 10%.

- Stockpile topsoil and reapply it to revegetate the site.

- Use practices such as benching, terracing, or diversional structures where development occurs on steep vegetated slopes.

- Physically mark off limits of land disturbance on the site with tape, signs or barriers to ensure preservation of offsite areas.

- Evaluate the need for extraordinary controls and, if necessary, implement such controls.

Vegetative Stabilization Practices - Rapid establishment of a grass or mulch cover on a cleared or graded area at construction sites is the single most important factor in reducing downstream sediment and can reduce suspended sediment levels to receiving waters by up to six fold (Schueler, 1990).

- Temporary seeding - Temporary seeding may be the single most important factor in reducing construction related erosion ("New York Guidelines for Urban Erosion and Sediment Control:, USDA - Soil Conservation Service, March 1988). Temporary seeding practices have been found to be up to 95% effective in reducing erosion ("Guides for Erosion and Sediment Control in California"- Soil Conservation Service, Davis, CA, Revised 1985). For critical areas, vegetation should cover 90% of each square yard of disturbed area to adequately stabilize soils. Moderately sloped areas with fertile soils require at least 75% of each square yard of exposed area to be vegetated. (Pennsylvania Soil and Erosion Control Manual, 1983)

- Permanent Seeding
- Mulching - wood Fiber hydroseeder slurries are well suited to establish vegetation on steep slopes, in critical areas, and areas with severe climates
- Sod stabilization - good sod cover may be up to 98% effective in controlling erosion (PA S & E,1983)
- Vegetative buffer strips
- Tree and shrub protection: fencing, tree armoring, retaining walls or tree wells

(See Chapter 7 for additional data on vegetative stabilization/filtration practices.)

Perimeter Control practices - Perimeter controls are devices placed at the edge or boundary of construction site disturbance to: (1) prevent sediments from washing off site and; (2) direct surface runoff into a sediment trap or basin.

- Temporary and permanent diversions - "among the most effective and least costly practices for controlling erosion and sediment" (North Carolina Erosion and Sediment Control Planning and Design Manual, 1988).
- Grass covered earthen berms
- Silt fences or curtains
- Infiltration trenches
- Straw bales - When installed properly straw bales can remove up to 67% of the sediment provided rotten or broken bales are replaced (VA Erosion and Sediment Control Handbook, 1980).

Trap & Basin Practices - Sediment traps and basins are used at construction sites to capture surface runoff of sediment during storm events. The sediment-laden water is retained for a period or time to allow sediment particulates to settle to the bottom of the trap. Current designs of sediment traps and basins have been found to be only moderately effective. Sattherwaithe, found that for 2/3 of storms in the Northeast, sediment controls were less than 50% effective. In Maryland, current recommendations have been proposed to require traps and basins with 1800 cubic feet/acre of permanent pool and 1800 cf/acre of "dry de-watering storage". This design with a total volume of 3600 cf/acre will effectively treat 90% of the storms each year assuming (1) a runoff coefficient of .5 during the most active stage of construction and (2) 90% of annual runoff results from storms of 1.5 inches or less (Performance of Current Sediment Control Measures at Maryland Construction Sites, Schueler and Lugbill, 1990).

Super Basin Practices - Super basins have wet and dry storage equivalent to one-inch of sediment per acre of upland watershed area. Properly designed and maintained super basins can provide reliable high rates of sediment removal for most annual storm events.

Extraordinary and Redundant Control Practices - Extraordinary controls apply to both stormwater management and sediment and erosion control.

- Oversized devices such as sediment basins or traps
- Immediate stabilization of disturbed areas
- Inspections of erosion and sediment control practices following every storm event

(Note: For additional extraordinary practices, refer to section E.)

2. Additional Practices Available to Achieve Management Measures 1 and 2

Listed below are other practices which have varying degrees of effectiveness and can be utilized in combination with the preceding practices to achieve the level of reduction specified in management measures 1 and 2. This list is not all inclusive.

- Riprap - use on or for:
    - Steep cut and fill slopes subject to severe weathering or seepage;
    - Channel liners;
    - Inlet and outlet protection at culverts;
    - Streambank protection;
    - Shorelines subject to wave action.
- Temporary construction entrance/exit - gravel buffer to collect mud and sediment and prevent tracking of soils offsite
- Vehicle washing in area with drainage and sediment trap
- Dune stabilization - vegetative planting
- Diversion dikes (Perimeter protection) - require immediate vegetation after construction and stabilization of the channelized area according to flow conditions
- Grass-lined channels
- Riprap lined and paved channels
- Temporary slope drains
- Level spreaders
- Temporary stream crossings (fords, culverts, bridges)
- Streambank stabilization practices - vegetative and structural including gabions, deflectors, log cribbing, reinforced concrete and grid pavers. (Stream channel velocities for 10 year storm must be less than 6 ft/sec for vegetative stabilization to be effective)
- Subsurface drains
- Check dams
- Paved flumes
- Nets and mats
- Dust control measures - vegetative, sprinkling, wind barriers

3. Practices Available as Tools to Achieve Management Measure 3

Toxic substances and nutrients tend to bind to fines. In most cases where proper erosion and sediment controls have been utilized, heavy metals, hydrocarbons and nutrients will be immobilized. There is, however, an additional set of practices which can be utilized to reduce the volume and concentration of floatable and soluble pollutants such as oil and grease and nitrates.

- Provide sanitary facilities for construction workers.
- Maintain highway equipment and machinery only in confined areas specifically designed to control runoff (BMP Handbook, VA State Water Control Board Planning Bulletin 321, 1979).
- Use absorbent materials such as hay bales, cat litter and absorbent pads to collect and prevent migration of pollutants.
- Store, cover and isolate construction materials, including topsoil and chemicals to prevent runoff of pollutants and contamination of groundwater.
- Spill Prevention and Control Plan - Spill prevention and control is an important element of a runoff control strategy. Agencies, contractors and other commercial entities that store, handle, or transport fuel, oil or hazardous materials should develop a spill response counter measures plan.
- Maintain and wash highway equipment and machinery in confined areas specifically designed to control runoff (BMP Handbook, VA State Water Control Board Planning Bulletin 321, 1979).

E. Erosion and Sediment Practices for Particularly Sensitive Watersheds

Sensitive watersheds may need additional protection above the level required for most construction activities. Consistent with other measures in this guidance, the watershed affected and the type of resources needing protection will dictate the combination of practices which are necessary. Comments are solicited on the following set of practices and their suitability for inclusion in the final guidance as a management measure for particularly sensitive watersheds. (Note: The Maryland Chesapeake Bay Critical Area Program regulations define sensitive areas as having the following features: hydric soils or soils with hydric properties, highly erodible soils with high K values, steep slopes greater than 15%)

(1) 72-hour stabilization requirement;
(2) Installation of double rows of silt fencing;
(3) Oversizing of sediment traps and basins;

(4) Immediate installation of infiltration practices with provisions to maintain these devices until vegetation is established;
(5) Innovative scheduling for paving vs. vegetative stabilization and implementation of infiltration practices to reduce thermal impacts;
(6) Minimization of cleared forest lands;
(7) Establishment or protection of forested buffers along streams;
(8) Phased clearing operations;
(9) Installation of traps and basins prior to grading;
(10) Installation of turbidity curtains;
(11) Maintenance of controls following every storm-event; and
(12) Increased inspection intervals (once a week minimum; the 1983 Maryland Standards and Specifications for Erosion and Sediment Control suggest daily inspections).

(Maryland State Highway Administration Chesapeake Bay Initiatives Action Plan, August 15, 1990)

F. Effectiveness and Cost

Table 4-3 provides information on effectiveness, cost and applicability of some of the erosion and sediment control practices discussed above.

Table 4-3. Erosion and Sediment Control Practices

	Extraordinary Controls	Super Basins	Traps & Basins	Perimeter Controls	Vegetative Stabilization	Time/Area Disturbance	EROSION & SEDIMENT CONTROL
	S	S	G	G	G	G	General
● 0-40% High Level of Control ◑ 30-40% Moderate Level of Control ○ 0-20% Low Level of Control ⊗ Ineffective	●	●	◒	○	◒	◒	Nutrient Control
● Highly Effective ◑ Moderately Effective ○ Low Effectiveness ⊗ Ineffective	◒	●	◒	○	○	○	Shellfish
● Directly Protects ◑ Indirectly Protects ○ No Protection ⊗ Not Related	●	●	◒	◒	◒	●	Estuarine Habitat Protection
● 60%+ High ◑ 30-60% Mod ○ 0-30% Low ⊗ Ineffective * *Performance of BMP Affected by High Sediment Inputs*	●	●	◒	◒	●	◒	Sedimentation
● Highly Effective ◑ Moderately Effective ○ Low Effectiveness ⊗ Ineffective	◒	◒	◒	⊗	⊗	⊗	Sediment Toxics
● Highly Effective ◑ Moderately Effective ○ Low Effectiveness ⊗ Ineffective	◒	●	◒	⊗	○	○	Stormwater Control
● Widely Applicable ◑ Applicable Depending on Site ○ Seldom Applicable ⊗ Not Applicable	◒	◒	●	●	●	●	Feasibility in Coastal Areas
● Low Burden ◑ Moderate Burden ○ High Burden ⊗ Not Applicable	○	●	◒	○	◒	●	Maintenance Burdens
● Long Lived ◑ Long Lived w/Maintenance ○ Shortlived ⊗ Not Applicable	●	●	◒	◒	○	●	Longevity
● Positive ◑ Neutral ○ Negative ⊗ Mixed	◒	◒	●	●	●	●	Community Acceptance
● None or Positive ◑ Slight Negative Impacts ○ Strong Negative Impacts at Some Sites ⊗ Prohibited	◒	◒	◒	●	●	●	Secondary Environmental Impacts
● Low ◑ Moderate ○ High ⊗ Very High	○	○	◒	●	●	●	Cost to Developers
● Low ◑ Moderate ○ High ⊗ Very High	○	◒	◒	◒	◒	◒	Cost to Local Governments
● Easy ◑ Moderate ○ tough ⊗ Very Tough	○	◒	◒	●	●	●	Difficulty in Local Implementation
● Simple ◑ Moderate ○ Complex ⊗ None	○	◒	◒	●	●	◒	Site Data Required
● Can Be Used Moderately in These Areas ◑ Sometimes Can Be Used ○ Seldom Used ⊗ Not Used	●	⊗	◒	●	●	●	Water Dependent Use

Source: Metropolitan Washington Council of Governments, Draft, 1991

III. URBAN STORMWATER RUNOFF MANAGEMENT

A. Applicability of This Management Measure

This management measure applies to all urban areas other than those which are required to apply for and receive NPDES stormwater permits.

B. Problem Description

Urbanized areas, or those in which development has altered the natural infiltration characteristics of the land, experience increased surface runoff. Land development alters the natural balance between stormwater runoff and natural absorption areas by replacing them with greater amounts of impervious surface. This results in increased surface runoff at greater velocity.

As a result of increased quantity and velocity of runoff, greater amounts of pollutants are carried in the increased runoff flow, streambanks are eroded, greater amounts of pollutants are carried in the increased runoff flow, and the likelihood of flooding, erosion and water quality degradation increases. Moreover, streambank erosion results in degraded aquatic habitat.

Urbanized areas experience pollutant runoff loadings many times that of land in its pre-development state. The principal pollutants found in urban runoff include sediment, oxygen-demanding substances, nutrients, heavy metals, bacteria & pathogens, oil & grease, and toxics & pesticides.

C. Management Measures for Urban Stormwater Management

(1) Limit the creation of impervious surface and retain the appropriate amount of pervious surface in order to achieve optimal infiltration of runoff into soil. Protect natural vegetation and drainageways.

(2) Limit disturbance of areas such as steep slopes and unstable areas.

(3) Control the first flush of runoff to reduce loadings of sediment and toxic pollutants, taking into account cost and pollutant reduction effects.

(4) Protect against streambank erosion by reducing post-development stormwater runoff peak flows.

(5) Implement source controls where appropriate to reduce the availability of pollutants to be entrained in stormwater runoff.

(6) Control the application of nutrients and pesticides to golf courses and parks.

D. Principal Management Practices

Following is a list of management practices for urban stormwater runoff management that are available as tools to achieve the urban stormwater runoff management measure:

(1) Pond Systems (Detention/Retention)

(a) Detention devices: Runoff is temporarily stored, then subsequently discharged to a surface water. Pollution abatement results from the settling of pollutants during the detention period.

(b) Retention devices: Runoff is permanently captured so that it is never discharged directly to surface waters. Wetlands may often be constructed in such devices to promote nutrient uptake.

(2) Biofiltration

These methods accomplish pollutant removal by filtration, biological uptake, or trapping sediment. These controls comprise an infiltration system which not only allows pollutant removal but also recharges the groundwater through infiltration. These methods may also be incorporated as components of pond systems. (See Chapter 7 for further discussion of biofiltration)

(3) Infiltration Devices

Infiltration devices utilize various methods for removing the soluble and fine particulate pollutants found in stormwater runoff.

The devices or practices described above are the primary means by which to control the bulk of pollutants in urban stormwater runoff after they leave the site.

E. Effectiveness of Stormwater Runoff Controls

The best available procedures for urban stormwater management include both structural and non-structural components and involve a combination of detention, infiltration and filtering devices. Treatment systems, rather than individual practices, will tend to achieve the greatest pollutant reduction goal. Systems should include source control, stormwater management and riparian protection to achieve the highest level of effectiveness.

Stormwater treatment systems are site-specific; their effectiveness is highly variable and dependent on many factors, including the following: contributing drainage area; the infiltration characteristics of soils on site; site topography; and available space for a treatment structure on site.

In addition, practices or combinations of practices which are considered to be "best available" in some or in many situations, may nevertheless not be the most effective or economically achieveable for a particular site, and may even be entirely ineffective for the site. A system of practices should be tailored to a particular site to avoid selection of unsuitable practices, maintenance problems, or failure to achieved desired pollutant reduction.

Table 4-4 provides a matrix that shows the relative suitability, effectiveness, and costs of a variety of stormwater runoff treatment or control practices. A brief discussion of these practices follows immediately below.

1. Pond Systems (Detention/Retention)

The ponds described below (and referred to in D(1) above) range from completely dry structures to permanently wet structures with various combinations included. In addition, wetland components are discussed for their ability to enhance pollutant removal, create habitat diversity, and provide visual interest.

Wet Extended Detention Pond - A permanent pool system containing a forebay near the inlet to trap sediments and a deeper pool near the riser. This pond system provides an optimal combination of downstream channel protection and urban pollutant removal. Extended detention wet ponds are generally the most cost effective urban/coastal practices available for pollutant removal and stormwater control.

Wet Pond - A pond system with all of its storage utilized as a permanent pool. This system provides high levels of urban pollutant removal through biological uptake from aquatic wetland plant species. In addition, a wet pond can be an attractive community feature.

ED Micró-Pool - A dry ED system containing one or two small permanent pools for pollutant removal. One micro-pool located near the riser protects the ED pipe from clogging. A second micro-pool located near the inlet acts as a sediment forebay. The micro-pool system has a much lower maintenance burden than conventional dry ED pond systems and is a particularly useful design for fingerprinting a pond into a sensitive woodland or wetland area.

ED Shallow Marsh - A system utilizing emergent aquatic wetland plant species as its principal pollutant removal mechanism. The ED shallow marsh typically consists of a 0-3 foot deep irregularly shaped permanent pool, creating diverse wetland habitats in a relatively small space, while providing moderate levels of soluble pollutant removal.

Shallow Marsh - A system with much of its storage devoted to a shallow marsh, this pond design can consume a great deal of land area. However with proper grading, design and propagation techniques, this system can result in the creation of extensive, high quality emergent wetland habitat. The shallow marsh can achieve high removal rates of soluble and particulate pollutants through the biological uptake mechanism of emergent aquatic plants.

Table 4-4. Stormwater Runoff Treatment/Control BMPs

		Peat/Sand Filters	Sand Filters	Bio-Filters	Grassed Swale	Forest Filter Strip	Grass Filter Strip	Porous pavement	Dry Well	Infiltration Basin	Infiltration Trench #2	Infiltration Trench	In-filter Dry	Shallow Marsh	Wet Pond	Wet ED Pond	ED Shallow Marsh	ED Micro-Pool	Dry ED Pond
		FILTER SYSTEMS						*INFILTRATION SYSTEMS*					*POND SYSTEMS*						
General		*All Can Be Used in Stormwater Projects*																	
Nutrient Control	● 0-40% High Level of Control ◑ 30-40% Moderate Level of Control ○ 0-20% Low Level of Control ⊗ Ineffective	●	◑	●	◑	●	◑	●	◑	●	●	◑	●	●	●	●	●	◑	◑
Shellfish	● Highly Effective ◑ Moderately Effective ○ Low Effectiveness ⊗ Ineffective	●	◑	●	◑	●	◑	◑	◑	◑	◑	◑	●	●	●	●	●	●	●
Estuarine Habitat Protection	● Directly Protects ◑ Indirectly Protects ○ No Protection ⊗ Not Related	◑	◑	◑	◑	●	◑	◑	○	◑	◑	◑	◑	●	◑	◑	●	◑	◑
Sedimentation	● 60%+ High ◑ 30-60% Mod ○ 0-30% Low ⊗ Ineffective ■ *Performance of BMP Affected by High Sediment Inputs*	● ■	●	●	◑	● ■	●	● ■	● ■	● ■	● ■	● ■	● ■	●	●	●	●	●	●
Sediment Toxics	● Highly Effective ◑ Moderately Effective ○ Low Effectiveness ⊗ Ineffective	●	◑	●	◑	●	●	●	●	●	●	●	◑	●	●	●	●	◑	◑
Stormwater Control	● Highly Effective ◑ Moderately Effective ○ Low Effectiveness ⊗ Ineffective	⊗	◑	◑	○	⊗	⊗	●	◑	●	◑	⊗	●	●	●	●	●	●	●
Feasibility in Coastal Areas	● Widely Applicable ◑ Applicable Depending on Site ○ Seldom Applicable ⊗ Not Applicable	◑	◑	◑	◑	●	◑	○	◑	◑	◑	◑	◑	●	●	●	●	●	●
Maintenance Burdens	● Low Burden ◑ Moderate Burden ○ High Burden ⊗ Not Applicable	○	◑	●	●	●	◑	○	◑	○	○	◑	○	◑	●	●	◑	◑	○
Longevity	● Long Lived ◑ Long Lived w/Maintenance ○ Shortlived ⊗ Not Applicable	◑	◑	◑	●	●	●	○	◑	○	◑	◑	◑	◑	●	●	◑	◑	◑
Community Acceptance	● Positive ◑ Neutral ○ Negative ⊗ Mixed	◑	◑	⊗	●	●	●	◑	◑	◑	◑	◑	◑	⊗	●	●	⊗	⊗	○
Secondary Environmental Impacts	● None or Positive ◑ Slight Negative Impacts ○ Strong Negative Impacts at Some Sites ⊗ Prohibited	●	●	●	●	●	●	●	●	◑	◑	◑	●	◑	◑	◑	◑	●	◑
Cost to Developers	● Low ◑ Moderate ○ High ⊗ Very High	⊗	○	●	●	●	●	⊗	●	◑	◑	◑	○	○	○	○	○	◑	◑
Cost to Local Governments	● Low ◑ Moderate ○ High ⊗ Very High	○	○	◑	●	●	●	⊗	◑	◑	◑	◑	○	⊗	○	○	○	○	○
Difficulty in Local Implementation	● Easy ◑ Moderate ○ tough ⊗ Very Tough	○	○	◑	●	●	●	○	●	◑	◑	◑	○	◑	◑	◑	◑	◑	◑
Site Data Required	● Simple ◑ Moderate ○ Complex ⊗ None	◑	◑	◑	●	●	●	○	●	○	◑	◑	○	⊗	◑	◑	◑	◑	◑
Water Dependent Use	● Can Be Used Moderately In These Areas ◑ Sometimes Can Be Used ○ Seldom Used ⊗ Not Used	◑	◑	●	●	●	●	○	●	⊗	◑	◑	⊗	◑	⊗	⊗	⊗	⊗	⊗

Source: Metropolitan Washington Council of Governments, Draft, 1991

In-Filter Dry Pond - An innovative dry pond system for sites having permeable soils that promote infiltration. Design includes stormwater detention, pretreatment via plunge pools and grassed swales, and a series of infiltration trenches and basins.

Dry ED Pond - A pond system typically comprised of two stages: The upper stage is graded to remain dry except for infrequent storms; whereas the lower stage is designed for regular inundation. Runoff pretreatment is difficult to achieve with this pond system, and it is equally difficult to prevent clogging of the ED control device.

Evaluation

Wet Ponds and Wet Extended Detention Ponds are extremely effective water quality practices. When properly sized and maintained, Wet Ponds and Wet Extended Detention Ponds can achieve a high removal rate for sediment, BOD, nutrients, and trace metals. Biological processes within the pond also remove the soluble nutrients (nitrate and ortho-phosphorous) that contribute to nutrient enrichment (eutrophication). Soluble nutrient removal is achieved through a process known as biological uptake where aquatic plants convert the soluble nutrients into biomass which then settles into pond sediments and is later consumed by bacteria and thus removed from the pond system.

Wet Extended Detention Ponds are most cost effective in larger, more intensely developed sites. Pond practices normally require a significant contributing watershed area (greater than 10 acres) to ensure proper operation. Positive impacts associated with wet pond systems can include: creation of local wild life habitat, increased property values, recreation, and landscape amenities.

Extended Detention Ponds are effective in controlling post-development peak stormwater discharge rates to a desired pre-development level for the design storm(s) specified. If stormwater is detained for 24 hours or more, as much as 90% removal of particulate-form or suspended solid pollutants is possible.

However, it should be noted that extended detention ponds have the disadvantage of elevating water temperatures. Thus their use may be inappropriate in some locations, such as trout habitat. In addition, care should be taken not to reduce base flows below levels necessary to sustain the aquatic habitat.

2. Infiltration Systems

The infiltration systems described below (and described in D(3) above) range in design from stone-filled trenches and basins to permeable asphalt pavement. All utilize differing methods for removing soluble and fine particulate pollutants found in stormwater runoff. To prevent infiltration systems from becoming clogged with fine sediment, it is essential to pretreat the incoming runoff. Methods of pretreatment range from filter cloth to vegetated filter strips. With pretreatment, infiltration systems can be an effective component of an urban water quality practices.

It is important to recognize that infiltration systems create a risk of transferring pollutants from surface water to ground water. Therefore, infiltration systems should not be used near wells or in wellhead protection areas or in settings in which drinking water supplies may become contaminated.

Infiltration Trench - An Infiltration Trench works by diverting stormwater runoff into a shallow (3 - 8 feet) excavated trench which has been back-filled with stone to form an underground reservoir. Runoff is then either exfiltrated into the sub-soil or collected in under-drain pipes and conveyed to an outflow facility. Infiltration Trenches are an adaptable practice that adequately remove both soluble and particulate pollutants. Infiltration Trenches are primarily an on-site control and are seldom practical or economical for drainage areas larger than 5 to 10 acres. Infiltration Trenches are one of the few practices that adequately provide pollutant removal on small sites or infill development. Infiltration Trenches preserve the natural groundwater recharge capabilities of a site and can often fit into margins, perimeters, and other unutilized areas of the site. A disadvantage is that Infiltration Trenches require careful construction, pretreatment, and regular maintenance to prevent premature clogging.

Infiltration Trench #2 - Similar to the trench system described above, this design accepts sheet flow from the lower end of a parking lot or paved surface. Runoff is diverted off the paved parking lot through slotted curbs. The slotted curbs function as a level spreader for stormwater. A grass filter strip separates the trench from the paved surface for capture of sediments. This trench includes a perforated PVC-type pipe for passage of large design storm events. At the end of the trench is a grassed berms to ensure that runoff does not escape.

Infiltration Basin - Infiltration Basins are an effective means for removal of soluble and fine particulate pollutants. Unlike other infiltration systems, basins are easily adaptable to provide full control for peak storm events. Basins can also serve large drainage areas (up to 50 acres). Basins are a feasible option where soils are permeable. Basins are advantageous in that they can preserve the natural water table of a site, serve larger developments, can be used as a construction sediment basin, and are reasonable cost effective in comparison to other practices. One disadvantage is the need for frequent maintenance. In addition, infiltration basins have sometimes failed because they were installed in unsuitable locations or soils.

Dry Well - A small infiltration system designed to accept stormwater from a roof-drain down-spout. Rather than dispersing its stormwater across a paved surface or grassed area, the down spout pipe connects directly into the dry well which filters roof top runoff into soils.

Porous Pavement - Porous Pavement is a permeable pavement having the capability to remove both soluble and fine particulate pollutants in urban runoff and provide groundwater recharge. Use is restricted to low traffic volume parking areas. Porous Pavement systems can receive runoff from adjacent roof tops. This reasonably cost-effective practice is only feasible on sites with gentle slopes, permeable soils, deep water tables and bedrock levels. Requires careful design, installation, and maintenance. Although Porous Pavement has the high capability to remove both soluble and fine particulate pollutants from urban runoff, it can become easily clogged and is difficult and costly to rehabilitate.

Evaluation

From a pollutant removal standpoint, Infiltration Trenches, Basins, and Porous Pavement have a moderate to high removal capability for both particulate and soluble urban pollutants, depending upon how much of the annual runoff volume is effectively exfiltrated through the soil layer. It should be noted that infiltration practices should not be entirely relied upon to achieve high levels of particulate pollutant removal (particularly sediments), since these particles can rapidly clog the device. For these systems to be effective, particulate pollutants must be removed before they enter the structure by means of a filter strip, sediment trap or other pre-treatment devices, and these devices must be regularly maintained.

In summary, infiltration systems can adequately remove soluble urban pollutants on smaller sites (10 acres or less). As a practice for controlling coastal non-point source pollution, infiltration systems should only be considered as part of an integrated system of management measures.

3. Filter Systems

The filter systems described below (and described in D(2) above) rely on various forms of erosion resistant vegetation to amplify particulate pollutant removal, improve terrestrial habitat, and enhance the appearance of a development site. In addition, filter systems can improve both the performance and amenity value of pond and infiltration practices via stormwater pretreatment, and can be used in such areas as golf courses and parks to intercept runoff and prevent its entry into surface waters and coastal shorelines.

Grass Filter Strip - Similar to a grassed swale, but can only accept overland sheet flow. Filter strips are effective when used to protect surface infiltration trenches from clogging by sediment. Effective in removal of sediment, organic material, and trace metals. Should be used as a component in an integrated stormwater management system. Filter strips are inexpensive to establish and cost almost nothing if preserved prior to site development. As with all filter systems, long-term maintenance (mowing, inspection for short circuiting, etc.), should be included in overall costs. Grass filter strips are discussed in detail in chapter 7 of this guidance.

Riparian Buffer Strip - Riparian buffer strips improve water quality by removing nutrients, sediment and suspended solids, and pesticides and other toxics from surface runoff, as well as subsurface and groundwater flows. The pollutant removal mechanism associated with riparian vegetation combines the physical process of filtering and the biological processes of nutrient uptake and denitrification. Riparian buffer strips are discussed in detail in chapter 7 of this guidance.

Grassed Swale - A grassed, low gradient conveyance channel that provides some water quality improvements for stormwater via natural filtration, settling, and nutrient uptake of the grass cover. Often used as an alternative to curb and gutter drainage conveyance. Grassed swales affect peak discharges by lengthening time of concentration. Can be fitted with low check dams to increase removal efficiency via temporary ponding.

Sand Filters - A water quality control filtration system used to remove large particulates from runoff and protect filter media from excessive sediment loading at stormwater quality control basins. Sand filters can be used independently or with a dry pond/basin element.

Peat/Sand Filters - A man-made soil filter system utilizing the natural absorptive features of peat. The system features a grass cover crop and alternating sub-layers of peat, sand, and a perforated pipe underdrain system. Systems are presently used for municipal waste effluent treatment and are being adapted for use in stormwater management.

Evaluation

Filter strips have a low to moderate capability of removing pollutants in urban runoff, and exhibit higher removal rates for particulate rather than soluble pollutants. Pollutant removal techniques include filtering through vegetation and/or soil, settling/deposition, and uptake by vegetation. Riparian buffer strips appear to have a higher pollutant removal capability than grass filter strips. However, length, slope, and soil permeability are critical factors which influence the effectiveness of any strip. Another practical design problem is prevention of stormwater from concentrating and thereby "short-circuiting" the strip.

Filter Systems are an essential component of a comprehensive nonpoint source control strategy, but should generally be used in conjunction with infiltration systems and/or pond systems, as a pre-treatment for runoff.

4. Source Control Systems

Source control systems reduce the availability of pollutants that can become entrained in stormwater runoff.

Street Maintenance - Implementation of street-cleaning programs, scheduled on a regular basis, can be effective at removing pollutants attached to fine sediment. Street-cleaning should occur on a more frequent basis during periods of more frequent storm events. Street maintenance can be effective in reducing the total amount of pollutant load which is carried off-site by runoff. Implementation of catch-basin maintenance and cleaning programs to remove sediment and debris from storm drains is an additional practice.

Leaf & Lawn Vegetation Collection - Implementation of leaf and lawn vegetation collection programs to reduce the amount of nutrient load in stormwater runoff can be an effective, yet inexpensive management practice. Collection frequency should be increased during autumn and spring periods of increased leaf fall.

Toxic and Hazardous Pollutants Recycling - Sources of toxic and hazardous pollutants can be identified and programs to educate and inform citizens about how to control and recycle them can be implemented. Used motor oil recycling programs are one example of this management practice.

REQUEST FOR COMMENTS

In Chapter 1 of this guidance (Introduction), EPA has generally requested submission of comments, information and data on relevant management practices, their effectiveness, and their costs. We also request specific comment on the following aspects of the urban stormwater management measures:

1. One of the stormwater management measures for control of the first flush of runoff, does not specify the amount of runoff to be treated or the length of time it should be treated. EPA requests comment and information on the costs and pollution reduction effects of specifying the treatment of the first flush of stormwater runoff by detaining at least 1/2 inch of runoff from the drainage area for 12-48 hours, depending on particle size and settling velocity. If this is not feasible or appropriate, what management measure should be established for controlling the first flush of urban stormwater runoff?

2. Another of the stormwater management measures calls for implementing source controls to reduce the availability of pollutants to be entrained in stormwater runoff, but does not specify source controls for runoff from service stations. Other, specific controls are listed in the section on recommended practices. EPA requests comment on the costs and pollutant reduction effects of specifying, in the management measure, service station runoff controls and collection systems, including the control of oil and grease through appropriate disposal methods utilized off-site.

REFERENCES

Florida Department of Environmental Regulation, The Florida Development Manual: Storm Water Management Practices (June 1988)

Metropolitan Washington Council of Governments, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs (Washington, DC, 1987)

North Carolina Department of Natural Resources and Community Development, Erosion and Sediment Control Planning and Design Manual (September 1988)

USEPA, Urban Runoff and Stormwater Management Handbook (Chicago, 1990)

USEPA, Urban Targeting and BMP Selection (Chicago, 1990)

IV. ROADS AND HIGHWAYS

A. Management Measure Applicability

This management measure applies to new and existing roads and highways located in coastal areas.

B. Pollutants of Concern

The primary pollutants associated with roads and highways are:

- Deicing chemicals
- Vehicular deposits
- Erosion and sediment
- Herbicides
- Dust, dirt, and debris

In areas where deicing agents are used, deicing chemicals and abrasives are the largest source of pollutants during winter months. The major source of pollutants are from vehicular deposits and runoff. (FHWA, US DOT, Technical Summary, Sources and Migration of Highway Runoff Pollutants, Reports No. FHWA/RD-84/057-060-XX, June 1987.)

Table 4-5 lists the pollutants found in stormwater runoff from roads and highways and their sources. The disposition and subsequent magnitude of pollutants found in highway runoff are site-specific and affected by traffic volume, highway design, surrounding land use, climate, and accidental spills. The major impacts of these pollutants can cause impairment to coastal area surface and ground waters.

C. Management Measures

The management measures for roads and highways are devised to (1) prevent direct discharge of stormwater runoff from impervious road surfaces into coastal receiving waters, and (2) to minimize the flow of runoff to coastal waters.

1. Location and Design

Locate roads and highways away from wetlands, critical habitat areas, and drainage channels in the coastal zone, and to minimize cut and fill. Design drainage systems to avoid direct discharge into surface waters. Additional management measures set forth in Section VIII of this chapter should be used where applicable.

Table 4-5. Highway Runoff Constituents and Their Primary Sources

Constituents	Primary Sources
Particulates	Pavement wear, vehicles, atmosphere, maintenance
Nitrogen, Phosphorus	Atmosphere, roadside fertilizer application
Lead	Leaded gasoline (auto exhaust), tire wear (lead oxide filler material, lubricating oil and grease, bearing wear)
Zinc	Tire wear (filler material), motor oil (stabilizing additive), grease
Iron	Auto body rust, steel highway structures (guard rails, etc.), moving engine parts
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides
Cadmium	Tire wear (filler material), insecticide application
Chromium	Metal plating, moving engine parts, break lining wear
Nickel	Diesel fuel and gasoline (exhaust), lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
Manganese	Moving engine parts
Cyanide	Anticake compound (ferric ferrocyanide, sodium ferrocyanide, yellow prussiate of soda) used to keep deicing salt granular
Sodium, Calcium, Chloride	Deicing salts
Sulphate	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate
PCB	Spraying of highway rights-of-way, background atmospheric deposition, PCB catalyst in synthetic tires

Source: U.S. DOT, FHWA, Report No. FHWA/RD-84/057-060, June 1987.

2. Construction

Minimize construction debris and deposits. Cut and fill areas are to be stabilized to prevent sink holes and erosion. Additional management measures set forth in Section II of this Chapter should be used where applicable.

3. Operation and Maintenance

Establish inspection and compliance programs. Stabilize slopes in accordance with Section II. Prevent herbicides from entering drainage systems. Maximize overland flow for runoff containing deicing salts and abrasives to prevent direct discharge to surface and coastal waters. Additional management measures for erosion and sediment control in Section III of this chapter also apply.

D. Management Practices

Following is a list of management practices for roads and highways that are available as tools to achieve the management measures specified above. These practices can be used separately or as combined systems and are applicable for new roads and highways, and are also suitable for retrofitting to existing roads and highways. See Sections II, III, and VIII for detailed information on extended detention ponds, wet ponds, infiltration practices, filter strips, and grassed swales.

In addition, the following practices can be effective:

(1) Washing and Cleaning- Wash construction vehicles to remove mud and other deposits prior to leaving the construction site. Construction vehicles entering or leaving the site with debris or other loose material should be covered with protective tarps. Construction materials and stockpiles on-site should be covered to prevent transport of dust, dirt, and debris. Install and maintain mud and silt traps.

Sweeping and vacuuming road surfaces is a practical means of removing accumulated dust, dirt, and debris. Road cleaning programs need to be effective at removing pollutants attached to fine sediment. Cleaning should occur on a scheduled basis with more frequent cleaning during periods of frequent storm events. This reduces the total amount of pollutant load which is carried away by runoff.

(2) Restabilize Slopes - Eroded slopes and washed-out areas should be stabilized with newly applied vegetative cover, rocks or gabions. Vegetative cover is preferred to reduce runoff and to filter/absorb pollutants. Vegetative materials that require minimal maintenance should be used.

(3) Herbicide Controls - Ensure proper handling, application, and disposal of herbicides used to control weeds and other unwanted vegetative material.

(4) Education Programs - Encourage public participation through programs such as " Adopt A Highway" to alert action to remove animal debris and wastes, and call attention to abuses affecting the disposal of toxic wastes such as waste crankcase oil into drainage systems.

(5) Water Quality Inlets - Current designs of water quality inlets appear to have low to moderate removal rates for particulate pollutants, and low to zero rates for soluble pollutants. Water quality inlets rely primarily on settling for removal, and given their small storage capacity and brief residence times, it is likely that only coarse grit, sand, and some silts will be trapped. Inlets do show some promise in removing hydrocarbons, such as oil, gas and grease, from runoff. Due to resuspension problems, however, pollutant removal can only be attained in water quality inlets if they are cleaned regularly.

E. Effectiveness and Cost

Effectiveness of each of the management practices identified, with approximate costs where available, are discussed in the appropriate sections referenced above. EPA intends to collect additional information on effectiveness and costs of these and the additional practices identified.

V. BRIDGES

A. Applicability

This management measure is applicable to new and existing bridges with solid roadways that cross coastal waters or their tributaries.

This management measure does not apply to U.S. Coast Guard-approved bridges that are covered by Nationwide Permit No. 15 issued by the U.S. Army Corps of Engineers under Section 404 of the Clean Water Act.

B. Problem Description

Bridge construction in coastal areas may cause significant erosion and sedimentation resulting in the loss of wetlands and riparian vegetation. Runoff from bridges may deliver considerable loadings of heavy metals, hydrocarbons and toxic substances from cars and de-icing of roads as a result of direct delivery through scupper drains into coastal waters with no overland buffering or treatment. Maintenance of structures can result in runoff and direct discharge of lead, rust, paint, particulates, solvents, and cleaners.

C. Management Measures for Bridges

The management measures for bridges are devised to control direct delivery of pollutants to coastal waters and reduce the pollutants which reach coastal waters in stormwater runoff.

(1) Site new bridges so that significant adverse impacts to wetlands and riparian vegetation are minimized.

Implement applicable measures identified in Development Section VIII.

(2) Design new bridges to reduce the amount of pollutants transported to surface water, where appropriate.

Route runoff to land for treatment in accordance with management measures for stormwater runoff identified in Section III.

(3) Control sedimentation activities during bridge construction (especially on steep slopes at crossing).

Implement applicable measures identified in Construction Section II.

(4) Control sediment from dredging.

(5) Reduce the delivery of any pollutants used or generated during maintenance

operations (paint, rust and paint removal agents) to coastal waters by capturing, containing storing and properly disposing of work or waste materials. (COMAR)

D. Management Practices

(1) Site bridges as far as possible from wetlands, sensitive areas such as shellfish beds, and critical habitat areas.

(2) Limit the use of scupper drains (which drain runoff directly into coastal waters) on bridges. Scupper drains allow runoff in the bridge gutters to drain directly into coastal waters (South Carolina Coastal Council Policy).

(3) Capture, contain and collect scrapings, paint, and sand blast material that could fall into coastal waters using suspended tarps, vacuums, or booms in water.

(4) Require proper disposal of wastes; prohibit the disposal of any waste material into coastal waters.

VI. HOUSEHOLD MANAGEMENT MEASURES

A. Applicability

The following management measures apply to households and workplaces.

B. Pollutants Generated

Pollutants generated from households include:

(1) Household toxics - used oil, paint, solvents and pesticides
(2) Nutrients - nitrogen and phosphorus
(3) Pathogens - bacteria, fecal coliform and other pathogens

Municipal housekeeping and homeowner participation have been shown to have an effect on water quality especially in areas of high population density (The Jones Falls Watershed Urban Stormwater Runoff Project, 1986). Public education and outreach are crucial to the effectiveness of these measures.

The main sources of household pollution are:

- Landscaping activities - erosion (see construction section)
- Lawn/garden care - over-fertilization, unnecessary herbicide or pesticide use, improper leaf management
- Household toxics - improper disposal of oil/grease, antifreeze, paint, household cleaners and solvents
- Pets - improper disposal of fecal matter
- Car/boat care - poor maintenance, washing

C. Management Measure

Communities should establish and implement programs to educate, assist, and where appropriate, require households and workplaces to minimize the introduction of pollutants and pollutant sources into surface water or terrestrial areas in a manner that may result in runoff to surface or ground waters.

D. Management Practices Available as Tools to Achieve the Management Measure

The management practices listed below are principles and tools that local communities may use to build household management programs to achieve the management measure in section VI.C. These practices are arranged by source and implementable on an individual basis. These practices, based on the principle of source reduction, are self-implementing, reduce use of materials and in general lower operating and maintenance costs to existing pollution reduction systems:

(1) Lawn Management and Landscaping

- Reduce herbicide application and watering by mulching to retain moisture and inhibit weeds
- Do not apply pesticides or fertilizers before rainstorms or pesticides on windy days; reduce chemical lawn additives to bare minimum or use organic methods; test soils for nitrogen and phosphorous content before fertilizing; leave grass clippings on lawn to provide nutrients; compost leaf matter and other yard waste; avoid late spring fertilization; use manual or mechanical weed control methods where possible
- Prevent soil erosion - do not mow within 5 feet of water body; plant ground cover in bare areas; reduce disturbed areas as much as possible
- contour lawns to avoid erosion, impede runoff and facilitate infiltration
- limit amount of water applied to lawns and gardens; water only when necessary preferably in the morning

(2) Household Toxics

- Dispose of used paints, pesticides, toxic household cleaners and solvents at hazardous waste collection centers
- Recycle used oil at designated service stations or collection centers
- Soak up oil spills and other automobile fluid leaks with absorbent materials; place used material in municipal trash
- Minimize use of toxic cleaners, encourage use of biodegradable cleaners.

(3) General

- Refrain from placing materials down the storm drains; keep drains clear of foreign matter
- Retain as much permeable area as possible; consider alternatives to concrete such as permeable pavement or flagstones
- Use phosphate free detergents

(4) Pet Wastes

- Manage pet waste to minimize runoff into surface waters

(5) Car/boat Care

- Dispose of antifreeze down household drain while running tap water (this practice is not applicable for septic systems)
- Minimize use of antifouling paint; dispose paint and paint scrapings at hazardous waste collection center
- Use biodegradable cleaners

- Use absorbent materials (e.g., cat litter) to soak up household chemical spills or engine leaks

E. Effectiveness

Pet waste control has been shown to remove greater than 50% of nutrients and pathogens (Maryland Regional Planning Council, 1986). The Agencies solicit information on cost and effectiveness of the above practices.

VII. ONSITE SEWAGE DISPOSAL SYSTEMS

A. Applicability

This management measure applies to any residential sewage that is not treated or planned for treatment in a centralized public sewer system. Onsite sewage disposal systems (OSDS) include conventional septic systems, large scale conventional systems, alternative and innovative designs, and private sewage treatment facilities.

B. Coastal Water Pollution Caused by Onsite Sewage Disposal Systems

Proper treatment of wastewater effluent with onsite disposal systems is an essential component of coastal water quality protection. When properly sited, designed, installed, and maintained, individual sewage disposal systems can be used to treat most pollutants found in household waste simply and effectively. Treated wastewater usually reaches coastal waters by groundwater recharge or by groundwater/surface water interfaces.

1. Nutrients Cause Eutrophication

Nitrogen is generally not removed by conventional onsite systems, and can therefore cause eutrophication in coastal areas. For example, Nixon (1982) found OSDS effluent to contribute an estimated 12 to 44 percent of the annual nitrogen load to eight south shore coastal lagoons in Rhode Island.

Under most conditions, phosphorus tends to be attenuated quickly and effectively by soil processes. Except in sensitive waterbodies (including fresh waters and some fresher inshore sectors of estuaries), phosphorus presents less hazard as a transportable nutrient than does nitrogen. In sensitive phosphorus limited waterbodies, however, extremely low phosphorus concentrations can induce eutrophication, and concern is warranted. For example, Sikora and Corey concluded that phosphorus contamination of groundwater could be anticipated primarily in sandy soils with low organic matter content, soil having high water table, and shallow soils over creviced bedrock. Systems in sandy soil near surface water bodies, therefore, are most likely to contribute phosphorus loading to receiving waters.

2. Nitrogen/Pathogens Cause Drinking, Swimming, and Shellfish Contamination

Many coastal areas depend on groundwater sources for water supplies, and are vulnerable to loss of supplies to OSDS-related contamination. EPA has established a drinking water standard of 10 mg/L nitrate nitrogen to reduce the risk of infant cyanosis or methemoglobinemia caused by elevated nitrate levels in drinking water. Improperly treated OSDS effluent can also create significant health hazards if pathogens (bacteria & viruses), which may be present in effluent, contaminate groundwaters, saturated surface soils, or coastal waters. Research indicates that bacteria and viruses are capable of traveling considerable distances, and that transport may be particularly rapid in highly permeable soils. Heufelder (1988) prepared an extensive review of many pertinent issues relating to entrainment of nonpoint source pathogens in groundwater, transport of groundwater entrained organisms in estuarine areas, and survival of viruses in marine systems. In many coastal states, closure of shellfish areas and swimming areas, and restriction of other beneficial uses, have been attributed to pollutant concentrations traceable to improperly functioning septic systems within the contributing watershed or recharge area.

3. Poorly Operating Systems Worsen Problems

The degree of the problems can increase significantly in poorly operating systems. In overt system failure, soils can no longer accept effluent and sewage may break out onto the ground surface where it is transported by drainage systems or overland runoff to surface runoff. Overland pipes and subsurface drainage pipes, designed to prevent system flooding, may intercept contaminated groundwater and discharge contaminants directly to surface waters. Hydraulic overloading(too much wastewater for the system to handle) can cause bacteria, viruses, and nutrients to enter coastal waters via groundwater. Often, both groundwater and surface waters are vulnerable to contamination, due to coastal areas' susceptibility to flooding and sea level rise, high water tables, and groundwater recharge of coastal embayments.

C. Management Measures

Five management measures apply to OSDS in coastal areas. The goals of the management measures are to: (1) minimize pollutants discharges to OSDS; (2) minimize the flow of water to OSDS through conservation, thereby prolonging OSDS life and improving operation, and (3) minimize or eliminate the discharge of nutrients, pathogens (viruses & bacteria), and other pollutants from the OSDS into ground and surface waters.

1. Phosphate Limits in Detergents

a. Management measure

Detergents should contain low amounts of phosphates. Phosphate restrictions are already in place in many coastal States, including the District of Columbia, Indiana, Maryland, Michigan, Minnesota, New York, Virginia, Wisconsin (see Table 4-6).

This measure is especially protective of systems located near where groundwater discharges to the surface or that are failing/overloaded, enabling phosphorus to reach sensitive, phosphorus limited embayments.

b. Effectiveness/Costs

The use of these detergents in place of high phosphate detergents is expected to reduce the loadings of phosphates to OSDS by 50 percent (EPA, 1980). Cost should be negligible.

Table 4-6. Phosphate Limits in Detergents

State	Phosphorus (P) Laundry Detergents	Phosphorus (P) Dishwashing Detergents	Phosphorus (P) Levels Industry
District of Columbia	≤ 0.5% by weight as elemental P		
Indiana [1,2]	≤ 0.5% by weight as elemental P		1mg/L total P effluent conc. at discharges ≥ 3,785m^3/d (1MGD) within Great Lake Basin
Maryland	≤ 0.5% by weight as elemental P	≤ 8.7% by weight as elemental P	
Michigan[1]	≤ 0.5% by weight as elemental P	≤ 8.7% by weight as elemental P	1mg/L total P effluent conc. at discharges ≥ 3,785m^3/d (1MGD) within Great Lake Basin
Minnesota[1]	≤ 0.5% by weight as elemental P		1 mg/L total P effluent conc. at discharges ≥ 3,785m^3/d (1MGD) within Great Lake Basin
New York[1]	≤ 0.5% by weight as elemental P		1mg/L total P effluent conc. at discharges ≥ 3,785m^3/d (1MGD) within Great Lake Basin
Wisconsin[1]	≤ 0.5% by weight as elemental P		1mg/L total P effluent conc. at discharges ≥ 3,785m^3/d (1MGD) within Great Lake Basin

1 Sonzogni, William, and Thomas Heidtke. 1986. "Effect of Influent Phosphorus Reductions on Great Lakes Sewage Treatment Costs." Water Resources Bulletin AWRA 22:4 (623-627).

2 Indiana Administrative Code. 1991. Cumulative Supplement. Title 327 IAD 2-5-1.

2. High Efficiency Plumbing Fixtures

a. Management measure

New or replacement plumbing fixtures should be high-efficiency. Plumbing fixtures in failing systems should be replaced as soon as possible.

b. Effectiveness/Costs

Water conservation will help solve hydraulic overloading problems and reduce the cost of retrofit management measures for system improvement and nitrogen removal. Modern, high efficiency fixtures include: 1.5 gallon or less per flush toilets, 2.0 gallon per minute (gpm) or less shower heads, faucets of 1.5 gpm or less, and front loading washing machines of up to 27 gallons per 10 to 12 pound load. These can result in a 30 to 70 percent reduction of total in-house water use (Consumer Reports July 1990 and Feb. 1991 and Krause, et al, 1990). When used in connection with management practices for new and replacement construction, the reduced flows save costs by reducing the size of new and retrofit treatment facilities, extending the life of OSDSs, increasing performance of existing facilities, and lowering costs of operation for holding tanks. Cost savings have also been documented due to reduced demands for potable water (Logsdon, 1987). The cost is minimal, especially for replacement when a fixture breaks.

3. Garbage Disposals

a. Management measure

Garbage disposal use should not be allowed when an on-site system is failing. Garbage disposals should generally be avoided to: (1) reduce loadings of nitrogen to OSDS, and (2) reduce solids/BOD and decrease pumping frequency for septic/holding tanks.

b. Effectiveness/Costs

The use of a garbage disposal contributes substantial quantities of biochemical oxygen demand (BOD), suspended solids, and nutrients to the wastewater load (Table 4-7). As a result, it has been shown that the use of a garbage disposal may increase sludge and scum, and also produce a higher failure rate for conventional OSDS under otherwise comparable situations (EPA, 1980). Also, most waste handled by a garbage disposal could be handled as solid wastes, either for compost piles or trash pick up to public landfills. The cost is minimal as other disposal options are available, such as home composting and solid waste removal to municipal disposal sites. The effectiveness would be to remove from the total household loadings to the OSDS about 28 percent of the BOD, 37 percent of suspended solids, 5 percent of total nitrogen, and 2 percent of total phosphorus from entry into OSDS's (Table 4-7).

Table 4-7. Pollutant Contributions of Major Residential Wastewater Fractions (gm/cap/day)

Parameter	Garbage Disposal	Toilet	Basins, Sinks, Appliances	Approximate Total
BOD_5	18.0 (10.9 - 30.9)	16.7 (6.9 - 23.6)	28.5 (24.5 - 38.8)	63.2
Suspended Solids	26.5 (15.8 - 43.6)	27.0 (12.5 - 36.5)	17.2 (10.8 - 22.6)	70.7
Nitrogen	0.6 (0.2 - 0.9)	8.7 (4.1 - 16.8)	1.9 (1.1 - 2.0)	11.2
Phosphorus	0.1	1.2 (0.6 - 1.6)	2.8 (2.2 - 3.4)	4.0

Means and ranges of results reported by EPA, 1980.

4. Onsite Sewage Disposal Systems for Removal of Pathogens, Phosphorus, BOD

a. Management measure

A properly designed and maintained septic system, with appropriate set-backs from coastlines based on soil types, should be used to achieve almost complete removal of pathogens, phosphorus, and BOD within the property line of an individual residence.

b. Effectiveness/Costs

Modern conventionally designed septic systems are composed of a building sewer, a septic tank, a distribution box, and a drainfield or leachfield. Most solids entering the septic tank settle to the bottom and are partially decomposed by anaerobic bacteria. Some treatment of the wastewater occurs in the septic tank, which is primarily designed to remove 30-40% of the biochemical oxygen demand (BOD) and most solids to prevent their entering the drainfield. Periodic septic tank pumping is essential to preserve the capacity of the tank and prevent clogging of the drainfield and premature system failure. Periodic inspections should be required. The liquid effluent from the tank is discharged to a distribution box, which separates effluent flow into approximately equal flow, for discharge to a drainfield perforated pipe network, usually crushed stone surrounded by native soil. Once in the drainfield, effluent leaving the perforated pipe network percolates through the crushed stone and moves downward into the underlying soil material where treatment takes place. Nutrients and pathogens may be mechanically filtered out, microbially decomposed, or chemically attached to soil particles. The rate and efficiency of this treatment depends upon the characteristics of the soil, depth to water table, and the nature of the wastestream.

There are a number of alternative designs which apply to areas of high water tables, sandy soils, and other site specific factors. Some of these are discussed below and in the EPA Onsite Wastewater Treatment and Disposal Systems Design Manual, 1980 - which is being updated. Costs of a Septic System usually range from $4,000 to $10,000.

5. Onsite Sewage Disposal Systems for the Removal of Nitrogen

a. Management measure for OSDS in existing development

Install Denitrifying Treatment Systems where appropriate to reduce nitrogen from existing onsite sewage disposal systems.

b. Practices available to achieve this management measure

A number of treatment systems, two of which are identified below, are known to remove nitrogen using denitrification, which is carried out under anoxic conditions by microorganisms which convert nitrate to nitrogen gasses. Most are in early stages of development and require nitrification of septic tank effluents as an intitial part of the treatment process, because between

65%-75% of the total nitrogen in septic tank effluents is in ammonia form. Operation and maintenance of denitrification systems are complex. EPA solicits cost and effectiveness information on these and other systems to remove nitrogen onsite from sewage.

(1) Intermittent Sand Filters - The intermittent sand filter consists of a pretreatment unit such as a septic tank, a dosing unit, and a sand filter with underdrains. A sand filter is an open bed of 2 to 3 feet of sand underlain by graded gravel with collector drains. Dose recycling between sand filter and septic tank can reportedly remove 50 to 70 percent of the total nitrogen. These systems can also treat BOD and suspended solids to less than 10 mg/l and pathogens to 100 to 900 colonies/100 ml. To meet the management measure for BOD, suspended solids, and pathogens a leaching field, either existing or new, must be included. Costs from $5,000 - $10,000.

(2) Upflow Anaerobic Filter (UAF) and Sand Filter - The UAF and sand filter are an emerging technology which could provide nitrogen removal from existing onsite disposal systems. The UAF is a tank resembling a septic tank filled with 3/8 inch gravel with a deep inlet tee and a shallow outlet tee. Dosed recycling between the sand filter and UAF has been shown in research to result in 60-75 percent overall nitrogen removal. This technology would have to be used between existing septic tanks and leaching fields to provide equivalent removal of other pollutants. Costs from $3,000 - $8,000.

c. Management measures for OSDS in new development

Use either a wastewater separation or siting approach to minimize nitrogen discharges from OSDS in areas of new development.

d. Practices available to implement this management measure

(1) Wastewater Separation with Holding Tank (Blackwater) and Conventional System (Greywater) - Wastewater separation consists of separating toilet wastes (blackwater) from other residential wastes (greywater) using watertight holding tanks, hauling the blackwater offsite, and treating of greywater in a conventional septic tank and absorption field.

Coupled with elimination of garbage disposals, the waste separation with holding tanks for blackwater and conventional treatment for greywater is expected to result in a reduction of 55 percent of the BOD, 75 percent of the suspended solids, 83 percent of the nitrogen, and 32 percent of phosphorus. The remaining pollutant loadings in greywater, except for nitrogen, will be removed by conventional treatment. The effectiveness of this measure is dependent on periodic inspections of the holding tank, routine pumping and hauling, and effective treatment of the hauled waste. The incremental cost increase in new construction will be for the additional plumbing, for which EPA, soliciting cost information, and a water-tight holding tank, which should cost about $1,000. The costs to haul and treat the blackwater will be about $200/yr to haul it a reasonable distance plus treatment costs.

(2) Site Density Controls to Limit Loadings of Nitrogen to Coastal Waters - The total loadings of nitrogen from combined OSDS can be controlled to the equivalent treatment level of the nitrogen management measures using low density zoning or other site restrictions to limit the number of sources in a discrete area under the control of one or more jurisdictions.

D. Other Practices That May Be Used as Tools to Achieve OSDS Management Measures

Many practices are available or being developed which could treat pollutants from OSDS to levels equivalent to those obtained using the Management Measures above. These include:

(1) Wastewater Separation and Hauling for Existing Systems - Low volume toilets would result in pumping/hauling costs of 200 dollars per year (at $50 every 3 months), but the high cost and inconvenience for replumbing residences to separate sewer lines is expected to make this option less preferable than some practices discussed above. Estimated removals due to separation and hauling of blackwater (including elimination of garbage disposals) will be the same as in 5.d.i. above. Existing conventional treatment for greywater would likely remove pathogens and the remaining BOD and suspended solids unless the system is failing.

(2) Wastewater Separation and RUCK Systems - This system may be used in lieu of hauling separated wastes. A RUCK system is designed to nitrify blackwater in a buried sand filter and then mix the nitrified blackwater with greywater in an anaerobic tank. The greywater provides the carbon source for denitrification within the anaerobic tank. Final disposal of the effluent is in a conventional soil absorption system. The RUCK system requires blackwater/greywater separation, tanks and a buried sand filter. Supposedly, effectively treats BOD, suspended solids, and as much as 50 percent of the nitrogen. The Agency is soliciting for actual application and cost-effectiveness data.

(3) Holding Tanks for All Wastewater from Existing Systems - Holding tanks are most effective as controls for all pollutants but are usually too costly an option for existing housing due to the high cost of pumping and hauling. A watertight holding tank of a 1000 gallon capacity would have to be pumped out every 5-10 days at 50 gallons/capita/day and a family of four, even with flow reduction from high efficiency fixtures. At 50 dollars per load the operating cost is 150-300 dollars per month.

(4) Elevated Sand Mounds - A mound system is a pressure dosed, absorption system that is elevated above the natural soil surface in a sand fill. The general design configuration overcomes certain site restrictions such as slowly permeable soils, shallow permeable soils over porous bedrock, and permeable soils with water tables somewhat higher than otherwise allowable by local codes. This system consists of a septic tank, dosing chamber, and the elevated mound, and can treat septic tank waste effluent to approach Primary Drinking Water Standards for BOD, suspended solids, and pathogens. Nitrogen is not usually removed. Costs are $7,000 with a septic tank.

(5) Evapotranspiration Systems - Evapotranspiration (ET) Systems combine the process of evapotranspiration from the surface of a bed and transpiration (water used by plants) to dispose of wastewater. Wastewater is given pretreatment by some mechanism, such as a septic tank or aerobic unit. It then flows into the ET system for final treatment and disposal. An ET bed usually consists of a liner, drainfield tile, and gravel and sand layers. ET systems can be a viable means of on-site disposal where evapotranspiration rates consistently exceed rainfall. A majority of the systems in use in the United States are combinations of evapotranspiration and soil absorption systems. Properly designed, sited, and maintained, this system should provide no discharge of wastewater. Construction costs are expected to be high. Careful inspection of the linerbed and periodic checks of the ground water are required to insure integrity of the liner.

(6) Wetlands and Greenhouses - These are new, innovative approaches which are climate specific, delicate, and expensive to operate and maintain. The Agency solicits data on design, effectiveness and cost.

E. Implementation

Effective implementation of the OSDS measure generally depends on formation of specific wastewater management entities. With adjoining communities, local governments should consider adoption of joint wastewater management districts to complement inter-local facilities planning and community education for sewage and septage disposal. Public education and outreach can effectively address the ineffectiveness and dangers associated with use of septic tank cleaners/additives, and disposal of paint/thinners in OSDSs. Density zoning and similar practices also become valid alternatives to these management measures when developed jointly by districts that represent large coastal areas.

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VIII. URBAN RUNOFF IN DEVELOPING AREAS

A. Applicability

This management measure is applicable to areas which currently contain significant undeveloped areas which are or will be experiencing development. This measure is in addition to other applicable management measures contained in this chapter that may apply to such areas.

B. Urban Runoff Problems in Developing Areas

The problems caused by urban runoff in developing areas are the same as those discussed generally for urban runoff elsewhere in this chapter.

C. Management Measures for Urban Runoff in Developing Areas

Undeveloped areas provide the opportunity for local communities to implement solutions that are either unavailable or costly to implement in areas that are already heavily developed. These opportunities include the ability to apply siting criteria and processes, as specified in section 6217(g)(5), to encourage development to take place in a manner that is compatible with maintaining water quality. This section contains management measures that focus on those opportunities:

(1) Maintain natural hydrology at both the watershed and site levels. In practice, this often is achieved by: 1) minimizing impervious surface area 2) protecting natural vegetation and 3) retaining natural drainageways to the maximum extent possible;

(2) Minimize disturbance of unstable areas: locate development on the most suitable areas within the watershed and within individual sites; direct development away from critical areas within the watershed such as steep slopes and highly erodible soils;

(3) Protect natural forms which contribute to beneficial water quality impacts within the watershed, i.e., wetlands, forest areas and riparian areas; where possible, contiguous buffer areas within the watershed should be retained.

D. Practices Available as Tools to Implement the Management Measures

This section discusses practices that available as tools to achieve the management measures set forth in section VIII.C. The key opportunity to protect water from urban nonpoint pollution occurs prior to development. Local communities and state and regional agencies have found that pre-development protection can best be provided through the adoption of environmentally-based decisions to govern the development process. The greatest level of coastal protection is afforded where a single development ordinance is adopted by a community, and administered by a single authority within that community. Practices available to the regional and local authorities include:

1. District Classification System

District classification systems can be used to direct heavy development away from sensitive areas and assure any development in sensitive areas is limited in a manner that protects and sustains water quality. The use of districting controls allows local authorities to address preservation of critical areas necessary for coastal water quality protection and retain flexibility in planning development.

2. Environmental Reserves

Environmental reserves include, but are not limited to, establishing a comprehensive buffer system for protection of environmentally sensitive coastal areas. The preservation of these areas can greatly reduce the detrimental impacts commonly associated with coastal NPS pollution. The following buffers and development restrictions are useful tools to help coastal communities maintain the integrity of coastal environmental resources.

(1) Stream Buffers - A stream buffer is a variable width strip of vegetated land for protection of water quality, aquatic and terrestrial habitats. Development should not be allowed within a variable width buffer strip on each side of an ephemeral and perennial stream channel. Minimum widths for buffer strips of 50 feet for low-order headwater streams and 200 feet or more for larger streams, are recommended. Stream buffers should be expanded to include floodplains, wetlands, steep slope areas, and open space to form a contiguous system.

(2) Wetland Buffers - No habitat disturbing activities should occur within tidal or non-tidal wetlands and a perimeter buffer area (a 25 - 50 foot buffer is recommended).

(3) Coastal Buffers - A coastal buffer is a variable width strip of vegetated land preserved from development activity to protect water quality, aquatic and terrestrial habitats. A 100 foot minimum buffer of natural vegetation landward from the mean high tide line is recommended to remove or reduce sediment, nutrients, and toxic substances from entering coastal waters.

(4) Expanded Buffers - Buffers should be expanded to include contiguous sensitive coastal areas which, if developed or disturbed, may impact streams, wetlands, or other aquatic environments. Expansion of buffers is a good practice whenever new land development or other disruptive activities occur.

3. Site Design

Site design can be used to identify the best site-specific practices to minimize site imperviousness, attenuate runoff from development and also improve the effectiveness of the conveyance and treatment components of a runoff control system. Two highly effective tools are clustering and fingerprinting.

(1) Cluster - Clustering concentrates development and construction activity to a limited portion of the site while leaving the remaining portion undisturbed. Concentrating developed areas allows stormwater to be more effectively treated by a system of runoff management practices.

(2) Site Fingerprinting - The total amount of disturbed area within a site can be minimized by fingerprinting development. Fingerprinting can reduce impacts to surface waters by locating development outside of environmentally sensitive areas which buffer runoff or which may be more prone to erosion (steep slopes). Further erosion and sediment control is achieved by disturbing areas only where structures, roads, and rights of way will exist after construction is complete.

E. Additional Practices Available as Tools to Control Urban Runoff

(1) Floodplain Limits - Limiting development to areas outside of the boundaries of the recommended post development 100 year floodplain will preserve streamside buffers necessary for biofiltration and generally eliminate any needed future flood protection.

(2) Steep Soils Limits - Slope restrictions help reduce erosion and sediment loading. Clearing or grading should generally not occur on slopes in excess of 25%.

(3) Watershed plans - Watershed plans identify existing or potential water quality problems within the watershed, define goals to address water quality problems, and specify measures or practices to prevent or mitigate degradation of water quality.

(4) Environmental Impact Statements (EIS) - An EIS identifies significant environmental impacts from potential development, including water quality impacts, and provides alternatives to minimize short and long term impacts of the proposed development.

(5) Offsets - Structures or actions that compensate for undesirable impacts. Offsets can be a tool to help communities minimize the construction of impervious surfaces and provide other forms of water quality protection. Methods used to meet this goal include reduced side walk widths, the use of porous or gritted pavement and the design of narrow-width roadways in low density residential development.

(6) Capital Improvement Plans (CIP) - Localities may use the development of capital facilities, roads, and sewage lines and POTWs, to guide development in coastal areas away from sensitive areas which protect coastal water quality. Localities can adopt CIPs which describe the location and timing for capital improvements, etc. By establishing development schedules, the locality finalizes those improvements it will implement within a given period (usually 5 years). This type of development may provide incentives to developers to cluster around these improvements and reduce development of critical areas.

(7) Wetland Protection - Tidal and Non-tidal wetlands are vital to the maintenance of water quality in addition to providing flood control benefits. In many cases, the establishment of a stream or coastal buffer will have already protected these important areas. (See the Biofiltration section of this guidance.)

(8) Forest Protection - Forests filter runoff and are a protective land use which provides significant water quality and wildlife habitat benefits. Where possible, tree-save areas should be large blocks and linked to the buffer system rather than small isolated stands. Studies have indicated that linked areas provide more effective sediment filtration and erosion control. (See Chapter 7 of this guidance.)

F. Examples of State and Local Implementation of Management Measures for Development

Maryland Chesapeake Bay Critical Areas Program
Oregon State Land Use Program
Austin, TX Comprehensive Watershed Protection Act
North Carolina Coastal Area Management Act

G. Effectiveness and Cost

Table VIII.1 provides information on effectiveness and cost for various environmental reserve and site design practices.

Table 4-8. Zoning/Land Use Effectiveness

Key	Criterion	SITE PLANNING						ENVIRONMENTAL RESERVES											COASTAL DENSITY SYSTEMS				
		Minimize Imperviousness	Flexible Road Layout	Soft Infiltration	Site Fingerprinting	Performance Criteria	Cluster	Open Space Protection	Habitat Protection	Forest Protection	Wetland Protection	Septic Limits	Steep Soils Limits	Floodplain Limits	Expanded Buffers	Coastal Buffers	Wetland Buffers	Stream Buffers	Performance Zoning	Overlay Zone	Protection Zones	Rural Zones	Intense Zones
	General	S	S	S	G	S	G	G	G	G	G	G	G	G	G	G	G	G	S	S	G	G	G
● 0-40% High Level of Control ◑ 30-40% Moderate Level of Control ○ 0-20% Low Level of Control ⊗ Ineffective	Nutrient Control	○▪	○▪	◑	○▪	●	○▪	○	○	○	●	◑	○	◑	●	◑	◑	◑	◑	◑	◑	○	○
● Highly Effective ◑ Moderately Effective ○ Low Effectiveness ⊗ Ineffective	Shellfish	○▪	○▪	○▪	◑	●	◑	○	○	◑	◑	●	○	○	●	●	○	◑	◑	●	●	◑	○
● Directly Protects ◑ Indirectly Protects ○ No Protection ⊗ Not Related	Estuarine Habitat Protection	○	○	○	◑	●	○	◑	●	◑	●	○	◑	●	●	●	●	●	◑	●	●	◑	○
● 60%+ High ◑ 30-60% Mod ○ 0-30% Low ⊗ Ineffective	Sedimentation	○	○	○	●	●	○	○	○	◑	◑	○	●	○	●	◑	◑	◑	◑	◑	●	◑	○
● Highly Effective ◑ Moderately Effective ○ Low Effectiveness ⊗ Ineffective	Sediment Toxics	○	○	○	○	●	○	○	○	○	○	○	○	○	○	○	○	○	◑	◑	●	◑	○
● Highly Effective ◑ Moderately Effective ○ Low Effectiveness ⊗ Ineffective	Stormwater Control	◑	○▪	◑	◑	●	○▪	○▪	○▪	○▪	◑	⊗	◑	◑	○▪	○▪	○▪	○▪	●	◑	●	◑	○
● Widely Applicable ◑ Applicable Depending on Site ○ Seldom Applicable ⊗ Not Applicable	Feasibility in Coastal Areas	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
● Low Burden ◑ Moderate Burden ○ High Burden ⊗ Not Applicable	Maintenance Burdens		●	◑	◑	○	●	●	●	●	●	●	●	●	●	●	●	●	⊗	⊗	⊗	⊗	⊗
● Long Lived ◑ Long Lived w/Maintenance ○ Shortlived ⊗ Not Applicable	Longevity		●	◑	◑	○	●	●	●	●	●	●	●	●	●	●	●	●	⊗	⊗	⊗	⊗	⊗
● Positive ◑ Neutral ○ Negative ⊗ Mixed	Community Acceptance		◑	◑	●	○	◑	●	●	●	●	◑	◑	◑	◑	●	●	●	○	○	○	○	○
● None or Positive ◑ Slight Negative Impacts ○ Strong Negative Impacts at Some Sites ⊗ Prohibited	Secondary Environmental Impacts		●	◑	●	○	●	●	●	●	●	●	●	●	●	●	●	●	◑	◑	●	◑	○
● Low ◑ Moderate ○ High ⊗ Very High	Cost to Developers		●	○	◑	○	●	○	◑	○	◑	○	◑	◑	◑	○	○	◑	◑	◑	●	◑	○
● Low ◑ Moderate ○ High ⊗ Very High	Cost to Local Governments		●	●	●	○	●	●	●	●	●	◑	●	●	●	◑	●	●	◑	◑	◑	◑	◑
● Easy ◑ Moderate ○ tough ⊗ Very Tough	Difficulty in Local Implementation		◑	◑	◑	○	○	◑	◑	◑	●	○	●	◑	○	○	●	◑	◑	◑	◑	○	○
● Simple ◑ Moderate ○ Complex ⊗ None	Site Data Required		◑	◑	◑	○	◑	◑	○	◑	○	◑	●	◑	○	●	●	●	○	○	◑	◑	◑
● Can Be Used Moderately in These Areas ◑ Sometimes Can Be Used ○ Seldom Used ⊗ Not Used	Water Dependent Use		○	●	●	●	●	●	●	●	●	◑	◑	○	●	●	●	○					

▪ Minimize Site Paving

Source: Metropolitan Washington Council of Governments, Draft, 1991

CHAPTER 5. MANAGEMENT MEASURES FOR MARINAS AND RECREATIONAL BOATING

CHAPTER 5. MANAGEMENT MEASURES FOR MARINAS AND RECREATIONAL BOATING

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MANAGEMENT MEASURES FOR MARINAS AND RECREATIONAL BOATING

I. INTRODUCTION

Properly designed and operated marinas can reduce impacts to the marine environment, as well as benefit the boating public. Many NPS impacts of boats can more easily be prevented and contained at the centralized site a marina provides, than at individual docks and moorings. Denying opportunities for marina development does not necessarily prevent NPS impacts. Ensuring the best possible siting for marinas, as well as best available design and construction practices and ensuring appropriate marina and boating operations and maintenance procedures can greatly reduce NPS pollution from marinas.

The management measures or systems of best management practices described in this chapter are designed to reduce NPS pollution from marinas and recreational boating. Effective implementation will:

- Prevent the introduction of nonpoint source pollutants (or impacts) at the source and/or,

- Reduce the delivery of pollutants from the source to water resources.

This chapter specifies the management measures (in Sections III.B., IV.B., and V.B.) that represent the best systems of practices available to prevent NPS pollution from marinas and recreational boating or reduce NPS pollutant delivery from these sources to coastal waters. The management measures are grouped in three categories: siting (III.B.), design (IV.B.), and operation and maintenance (V.B.). For each of these three categories, following the management measures, the guidance provides information on a variety of practices that may be used as tools to accomplish the management measures. An attempt is also made to identify effectiveness of these measures, or performance goals that can be achieved by these measures. Comments are welcome on the composition, effectiveness and cost of these management measures.

It is expected that each coastal State's decision on implementation of these management measures will be based on the management strategy developed as part of its vision for the future. Pollution prevention should be at the fore of any such strategy. Hence, while flexibility is a keystone we expect that all States will need a process for State or local-level review/ management of environmental impacts from marinas and recreational boating.

A site selection process based upon a clear understanding of potential water quality impacts is the most important factor for avoidance of NPS pollution from marina development and operation. Determination of potential water quality impacts as part of the marina siting process can avoid NPS pollution impacts and degradation of the water body, also protecting designated uses.

A. Nonpoint Source Pollution Impacts from Marinas and Associated Boating Activities

Nonpoint pollution from marinas and recreational boating activities may result in detectable adverse environmental effects to nearby water column and benthic resources. These impacts can be caused by physical and chemical disturbances. A few important examples of these impacts include:

- Toxicity in the water column, both lethal and sublethal, related to decreased levels of dissolved oxygen and elevated levels of metals and petroleum hydrocarbons,
- Increased levels of metals and organic chemicals in the tissues of organisms such as algae, oysters, mussels or other filter feeders,
- Increased levels of pollutants in sediments resulting in toxicity or avoidance of the area by benthic organisms,
- Levels of pathogen indicators that result in shellfish bed or swimming area closure,
- Disruption of the bottom during dredging and positioning of pilings may destroy habitat, resuspend bottom sediment (resulting in the re-introduction of toxic substances into the water column), and increase turbidity which affects the photosynthetic activity of algae and estuarine vegetation, and
- Shoaling, and shoreline and shallow area erosion due to bulkheading, motorboat wake, or changes in circulation.

Degradation of the nearby biological community and sediment should also be considered during the process of assessing NPS pollution impacts from marina development and operation. (EPA is developing methods for assessing risks associated with toxic substances in sediments and standardized bioassays to assess chronic effects and bioaccumulation resulting from sediment contamination. Guidance for the development of biological and wildlife criteria are also being developed by EPA.) Following is a list of specific pollutants and measures of pollution, as well as affected communities that should be considered in siting a marina:

(1) Chemical
- (a) dissolved oxygen (DO)
- (b) nutrients (nitrogen and phosphorus)
- (c) pathogens (coliform as indicator)
- (d) metals (copper, lead, tin)
- (e) petroleum hydrocarbons
- (f) total suspended solids

(g) biochemical oxygen demand (BOD)

(2) Biological
 (a) endangered species
 (b) bird rookeries
 (c) benthos
 (d) fish, shellfish and corals
 (e) submerged aquatic vegetation
 (f) wetlands

(3) Sediments
 (a) contaminated sediments (criteria under development)
 (b) turbidity

B. Sources of NPS Impacts

Some sources at marinas are point sources. These include sewage discharges, both from marinas and from boats, and stormwater discharges. In addition, an entire marina may be potentially be required to apply for and receive permits under the NPDES stormwater permit program. to the extent they are required to do so, they are not covered by the coastal nonpoint source pollution control program. However, many marinas are not currently required to apply for and receive NPDES permits. The nonpoint source pollution control program and these management measures guidelines are applicable to these marinas. Similarly, some aspects of marina dredging may be subject to the section 404 permits for the discharge of dredge and fill material. This guidance is not applicable to dredging subject to section 404 permit requirements. There are essentially three source categories of marina and boating operations that may cause nonpoint pollution:

(1) Marina Construction

(2) Marina and boat operation, repair, and maintenance

(3) Dredging and dredge disposal

The most important step in controlling the impacts of these source categories is appropriate marina siting. Marinas should be sited adjacent to deep waters, in locations where flushing is adequate to avoid shoaling and contamination problems, and where effects on important habitat are minimized.

Runoff from marina construction activities is similar to that of any type of urban development. (See discussion under appropriate chapter for management measures.) Installment of pilings can cause considerable turbidity (as well as possible contaminant resuspension), impairing photosynthesis and harming benthos. Dredging during construction has essentially the same effects as dredging for maintenance, as discussed below.

Day-to-day marina operation can be a source of stormwater runoff from impervious surfaces, including car parking lots and buildings and sanitary and greywater disposal on land (e.g., poorly functioning or overloaded septic systems in sandy coastal soils). Contaminants from land-side boat maintenance projects, including hull scraping, sanding, welding, painting and varnishing can be carried in stormwater runoff or by air.

Boat maintenance that occurs in the water will be a direct source of contaminants (as described above). Chemicals, such as chromated copper arsenic-, copper- and tributyltin-based antifouling paints used to protect boats and wooden docks from destruction and fouling, may leach heavy metals directly into surrounding waters. Debris lost or thrown overboard is another problem area.

Concerns related to boat operation include fueling operations, bilge water discharge, accidental fuel or oil spills, propwash within channels (causing turbidity and resuspension of possible contaminated sediments) and shoreline erosion due to motorboat wake. Disposal of sanitary wastes, both legal and illegal (both from boats fitted with marine sanitation devices (MSDs) and those without), and discharge of greywater are other sources.

Another category of NPS pollution from marinas is dredging. For the purposes of this chapter, only the dredging within the marina itself and dredging to ensure access from the marina to the channel is discussed.

Dredging disturbs bottom habitat communities temporarily, increases turbidity (possibly disrupting photosynthetic activity), and may resuspend contaminated sediments. Disposal of dredged material in shallow water or in wetlands may smother habitat, contaminate sites and increase turbidity.

Some of the most visible controversy associated with recreational boating deals with the disposal of sanitary wastes. As a source of fresh pathogen pollution, untreated sewage discharges from boats have a greater potential for the presence and survival of disease-causing organisms than do discharges from treated municipal sewage sources. However, boats are considered point sources under the CWA, and sewage discharges from boats are regulated under section 312 of the CWA.

C. Federal Programs that Apply to Marinas and Recreational Boating

The siting and permitting process which marinas are subject to varies from State to State. State and Federal agencies both play a role in this process. Boats are not required to be equipped with a MSD. However, if a boat does have a MSD, the MSD has to meet certain standards. Section 312 of the CWA required EPA to develop standards for MSD discharges to prevent the discharge of untreated or inadequately treated sewage into or upon the navigable waters of the

U.S. from new and existing vessels. To meet those standards, the CWA required the Coast Guard to promulgate regulations governing design, construction, installation, and use of MSDs. Management measures to address regulated MSDs will not be a part of this chapter, since they are already regulated under the CWA. However, sanitary wastes will be included in regard to siting and design of marinas. In addition to EPA standards for MSDs, EPA may allow a State to prohibit all discharges (treated or untreated) from marine toilets, thus declaring the area a "No Discharge Zone." Any State may petition the EPA Administrator for a "No Discharge Zone" to be designated in some or all of the waters of the state. However, EPA must ensure these waters meet certain tests before considering granting the petition.

Under Section 10 of the Rivers and Harbors Act of 1899, the Army Corps of Engineers (COE) regulates all work and structures in navigable waters of the United States. Under Section 404 of the CWA, COE permits are issued or denied to regulate discharges of dredged or fill materials in navigable waters of the United States including wetlands. Guidelines which the COE applies in evaluating disposal sites for dredged or fill material are developed by EPA. The expressed goal of the 404 program is to protect water quality, aquatic resources and wetlands.

The Food and Drug Administration has established fecal coliform standards for certified shellfish growing waters. Shellfish cannot be harvested in waters with fecal coliform counts of 14/100 ml or higher. Each coastal State regulates its own shellfish sanitation program under the voluntary National Shellfish Sanitation Program. States must participate if they wish to export shellfish across State lines. Various approaches are used to comply.

D. State Programs

Some States issue separate dredge and fill, marshlands or wetlands permits for marina developments, while other States review Federal permit applications and do not issue State permits. All States with Federally approved coastal programs have the authority to object to Section 10/Section 404 permits if the proposed action is inconsistent with the State's Coastal Zone Management Program. Some States require permits for the use of State water bottomlands. All States have authority under the Clean Water Act to issue Section 401 water quality certifications for Federally permitted actions as part of their water quality standards program.

Some States also have a State coastal zone management permit providing them authority over development activities in areas located within their defined coastal zone. Alternatively, or in addition to this permitting authority, some States have regulatory planning authority in given areas of the coast, allowing them to affect the siting of marinas, if not their actual design and construction.

E. Management Measures

Control of NPS pollution from marinas and recreational boating requires the combination and coordination of many management measures: siting and design considerations, implementation of operation and maintenance plans, and public education. Management measures for marinas and recreational boating are organized under the following activities:

- Siting,
- Design, and
- Operation and maintenance.

As with all other management measures in this guidance, there may be more than one way to achieve the same or better pollutant reduction than achieved with the specified management measure. Approaches that equal or exceed the performance of the specified management measures, without resulting in harmful side effects, are for purposes of this guidance considered as alternative management measures.

F. Applicability of Management Measures

These management measures are applicable to:

- Any commercial facility which contains five or more slips, or any facility where a boat for hire is docked, or a boat maintenance/repair yard that is on or adjacent to the water.
- Any residential or planned community marina with ten or more slips.
- Public or commercial boat ramps.
- Any mooring field where 10 or more boats are anchored on a regular basis.
- Any Federal, State, or local facility that involves docking of five or more boats or involves boat maintenance/repair that is on or adjacent to the water.

States may wish to apply these measures to other situations as well.

II. MANAGEMENT MEASURES FOR MARINA SITING

A. Environmental Concerns

The marina siting Management Measures, listed in Section B below, are designed to address the following water quality concerns.

Maintaining water quality within a marina basin depends primarily on how readily the marina renews its waters, a process aptly known as "flushing." If a marina is not properly flushed, pollutants will concentrate to unacceptable levels resulting in impacts to biological resources.

Methods approved for analyzing the flushing potential of a marina are discussed under the Water Quality Assessment section of this chapter.

As discussed in more detail in another chapter of this guidance, wetlands perform many vital functions, such as serving as highly productive nursery areas for aquatic and terrestrial organisms, providing nutrients, reducing flood damages, and maintaining water quality by trapping sediment and filtering pollutants. There is a significant possibility that NPS pollution from marinas could result in loss of are values.

Marinas are commonly located in biologically productive areas that are sensitive to disturbances. The popularity of shellfish make them significant commercial and recreational resources. Submerged aquatic vegetation (SAV) are important because of the shelter which they provide to aquatic organisms, the food source which they provide to waterfowl, and their natural filtering capability to remove suspended solids and disperse wave energy. Benthic resources should be protected because they are important in the food chain, they are also valuable as commercial and recreational food sources. Critical habitats are areas which are essential for maintaining wildlife, particularly for winter survival and breeding, and as nesting areas for migrating species. Highly productive primary nursery areas for aquatic organisms (e.g., fish or crustaceans) should also be considered critical habitats. Marina-related dredging may impact shellfish beds, SAVs, or other benthic resources and habitats directly through construction activities or indirectly through increased turbidity and sediment deposition. Resuspension of sediments by boats also may affect biological resources adversely.

B. Management Measures

This section contains the management measures to be applied in the siting of marinas:

(1) Site marinas such that tides and currents are adequate to flush the site, or renew its water regularly. Marina construction should only be allowed in areas where a water quality assessment reveals that standards will not be violated and biological resources dependent upon clean water will not be degraded.

(2) Site marinas adjacent to deep water to avoid or minimize dredging needed. The area to be dredged should be the minimum needed for the marina itself, including the docking areas, fairways, and channels, and for other maneuvering areas that are needed. In no case should the bottom of the marina be deeper than the adjacent open water. During dredging operations, turbidity should be minimized through the proper placement of silt screens or turbidity curtains.

(3) Site marinas near currently permitted public areas for disposal of dredged materials.

(4) Site marinas away from wetlands, shellfish resources, submerged aquatic vegetation, and critical habitat areas.

(5) Locate piers such that shading of submerged aquatic vegetation is minimized.

(6) Site marinas such that they have easy access to roads, utilities, public sewers (where available), and water lines, to avoid NPS impacts associated with developing these services.

(7) Site marinas away from surface or ground water that is used for water supply.

C. Marina Siting Practices

This section provides technical guidance on practices that may be used as tools to assist in the implementation of the management measures set forth in Section III.B. above.

1. Water Quality

To aid in the determination as to whether a site is appropriate for marina construction, a water quality assessment of the proposed project is recommended. Also, the cumulative impacts of proposed new and existing development projects should be considered. For instance, if a group of small marinas were proposed in one area, whether by design or by chance, the impact of the marinas taken together should be examined. Therefore, even if any one of the projects would cause negligible impacts on water quality, one or more projects may be precluded based on the cumulative impacts. Alternately, each marina developer may be required to modify their project so that the cumulative impacts of all the projects can be made acceptable. In any event, based on the ecological sensitivity of the proposed site, a water quality monitoring plan may be required for the periods of time prior to, during, and after construction.

A water quality assessment should include appropriate modeling, monitoring, and data analysis to determine the proposed marina's impact on:

(1) Fecal coliform concentrations (to indicate potential impacts due to microbial pathogens),

(2) Dissolved oxygen concentrations, and

(3) Other parameters, if there is a concern that the water quality standards for those parameters may be violated.

Examples of other types of parameters which could be of concern include:

- Various polycyclic aromatic hydrocarbons (derived from petroleum products) - Other toxic organics (i.e. PCB's, benzene, various solvents, etc.)

- Heavy metals such as chromium, copper, cadmium, mercury, lead, nickel, and zinc, and

- Nutrients (i.e. nitrogen and phosphorus).

The discussion below provides guidance in assuring adequate flushing, compliance with water quality standards, and protection of shellfish harvest areas. The water quality assessment may be divided into a two tiers, as follows:

Tier 1 - If screening methods are determined to be appropriate for the system being investigated, the initial screening methods described in this guidance can be used. Screening methods are acceptable provided that they are appropriate for the system and they do not predict water quality problems.

Tier 2 - If screening-level analysis predicts water quality problems, then additional, more detailed, investigations of water quality impacts should be performed.

A valid water quality assessment should include, at a minimum, appropriate modeling, monitoring, and data analysis to determine:

- The flushing characteristics of the proposed marina.

- The spatial extent of the shellfish harvest closure zone resulting from presumed or actual pathogen contamination.

- If the 24-hour average dissolved oxygen concentration and the one-hour (or instantaneous) minimum dissolved oxygen concentration **both** inside the marina and in adjacent ambient waters would violate state water quality standards. (The national recommended water quality criteria are dependent upon water temperature.)

For each of the items described above, the analyses should be conducted based on the following conditions:

(1) Average ambient water temperature and salinity for the critical season of marina operation. The critical season is defined as the season which has the highest potential for adverse water quality impacts.

(2) For tidally influenced sites, the average tidal conditions (high and low tide elevations, tide range, and current velocities) for the critical season of marina operation.

(3) Sediment Oxygen Demand (SOD) rates of at least 2.0 gm/sq m/d at 20 degrees C. SOD varies from area to area. The default value should be used unless it can be demonstrated that another value is more appropriate. This base rate should be adjusted to the temperature of the analysis based on the following formula:

$$SOD_T = SOD_{20}\ (1.065)^{(T-20)}$$

Where,

SOD_{20} = SOD at 20° Celsius
SOD_T = SOD at temperature of analysis
T = Temperature in degrees Celsius

(4) Seasonal average background BOD_5 and BOD_{20} concentrations of the adjacent ambient waters.

(5) Seasonal 24-hour average background dissolved oxygen concentrations of the adjacent ambient water.

(6) A typical instantaneous minimum and maximum dissolved oxygen concentration determined by continuous dissolved oxygen, temperature, and possibly salinity monitoring of the adjacent waters at the site. The monitoring should be conducted during the season of interest. Temperatures should approximate the average critical season temperature identified in 1) above.

(7) Additional or alternative conditions may be required or approved if there is documented evidence that the additions or alternatives are appropriate.

a. Flushing of marina sites

The method chosen to estimate expected flushing from a marina site depends upon the hydrographic characteristics of the location. Marinas anticipated to be located within a confined area with one or two relatively narrow openings would have flushing characteristics considerably different from marinas located directly on larger bays or estuaries or along river shorelines. Two openings may improve flushing in semi-enclosed marina basins.

Flushing time within a semi-enclosed area can be estimated using simplified dilution calculations. The parameters required for the estimation are:

- Average marina depth at low and high tide following completion of dredging, based upon the representative tidal range of the area,
- Volume of non-tidal freshwater inflow into the marina,
- Surface area of the marina, and
- The percentage of discharged water returning to the basin on the following tidal cycle.

The flushing time of a semi-enclosed marina can be approximated by the following equation:

$$T_f = \frac{T_c \text{Log} D}{\text{Log} \dfrac{AL + BAR - IT_c}{AH}}$$

where:

T_f = Time of flushing (hours)
T_c = Tidal cycle, high tide to high tide (hours)
A = Surface area of marina (m^2)
D = Desired dilution factor
R = Range of tide (m)
b = Return flow factor (dimensionless)
I = Non-tidal freshwater inflow (m^3/hour)
L = Average depth at low tide (m)
H = Average depth at high tide (m)

The parameter "b" represents the percentage of the tidal prism ("AR" in Equation 1) that was previously flushed from the marina on the outgoing tide; has returned on the subsequent incoming tide; and is expressed as a decimal fraction. For example, if a river had a relatively low flow rate, water discharged from a marina at the completion of one tidal cycle may still exist in proximity to the marina inlet and portions may flow back into the marina on the incoming tide. This water mass portion would not be considered as aiding flushing for water quality considerations.

Non-tidal freshwater inflow from runoff or stream discharge into the marina basin can be estimated using hydrologic techniques. If "IT_c" is much less than "AL + BAR," this component of the equation can be ignored. Estimating the flushing time of a marina may be dependent upon several factors. Additional information on estimating flushing time can be found in the Coastal Marinas Assessment Handbook (EPA, 1985) or Draft Final Report on Marina Water Quality Models (Morton, M. and Moustafa, Z., 1991). Many characteristics of the marina site, including location relative to other water bodies, ambient water quality, biological activity, total volume and expected marina activity, and type and volume of discharge, would all affect flushing time. For most cases a two to four day flushing time is satisfactory while longer flushing times could result in unacceptable buildup of toxic pollutants or decrease in dissolved oxygen.

b. Shellfish harvest closure zones

Federal regulations administered by the Food and Drug Administration require that States establish closure zones around marinas to protect the food supply from contaminated shellfish. Good water quality is an absolute necessity in order to provide this protection. This is because shellfish are filter feeding organisms and are therefore able to concentrate pollutants. Even if overlying waters contain low levels of pollutants, shellfish can assimilate and magnify both biological and chemical contaminants.

Construction of a marina or docking facility may result in short term localized water quality problems due to alteration of existing upland vegetation and changes in the area's watershed. However, the long term effects of marina maintenance and operations cause the greatest concern. Marina operation may contribute pathogenic organisms as well as petroleum hydrocarbons and heavy metals. The concentration of human activity in the area of a marina also poses a particular water quality concern because of the potential problem of sewage disposal.

Fecal coliform bacteria are used as an indicator of the pathogenic organisms (viruses, bacteria, and parasites) that may be present in sewage. Therefore, all water quality assessments for water-based marina designs should identify and document potential fecal coliform loadings and the shellfish closure zones that would result from those estimated loadings (see Figure 5-1).

The shellfish harvest closure zone for the proposed project should be determined based upon a water quality standard for fecal coliform of 14 organisms MPN (most probable number) per 100 milliliters of water. Once the closure zone has been determined, it should be determined if the shellfish closure zone would result in any impact to existing shellfish harvest areas. If the closure zone intersects productive shellfish areas that are approved for shellfish harvesting, development of the marina should not be allowed as planned.

c. Dissolved oxygen concentrations

All water quality assessments should address the potential for violations of water quality standards for dissolved oxygen concentrations. In most States' waters, a standard exists for the 24-hour average concentration and an instantaneous minimum concentration. The assessment must present reasonable estimates of these concentrations for the planned marina and adjacent waters. The estimates should be based on monitoring or modeling, depending on the nature of the marina.

The water quality assessment should be based on marina location and configuration. The first and most basic distinction made is that of open versus semi-enclosed marinas (marinas located within an embayment which effectively partitions the marina from the open ambient waters). Within the semi-enclosed marina category, further distinctions are made for existing versus proposed embayments, and whether the waters at the site are completely mixed or vertically stratified due to temperature and salinity gradients.

i. Tier 1 assessments: open marinas

Marinas are considered to be open if they are located along an existing shoreline and have no man-made or natural barriers which tend to restrict the exchange of water between ambient water and water within the marina area. These marinas generally consist of a number of piers or docks which extend from the shoreline (Figure 5-2). The water quality assessment for dissolved

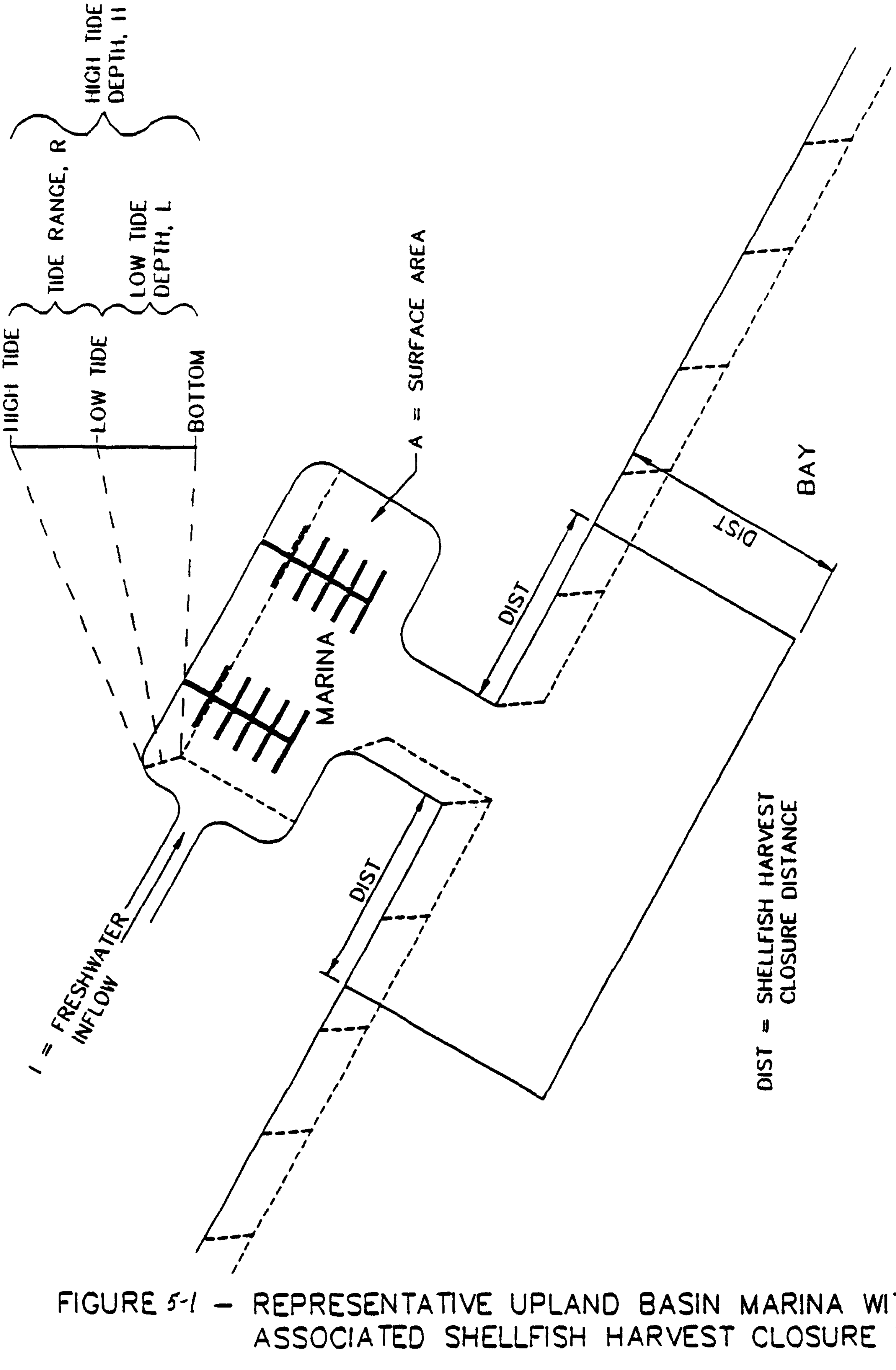

FIGURE 5-1 — REPRESENTATIVE UPLAND BASIN MARINA WITH ASSOCIATED SHELLFISH HARVEST CLOSURE ZONE

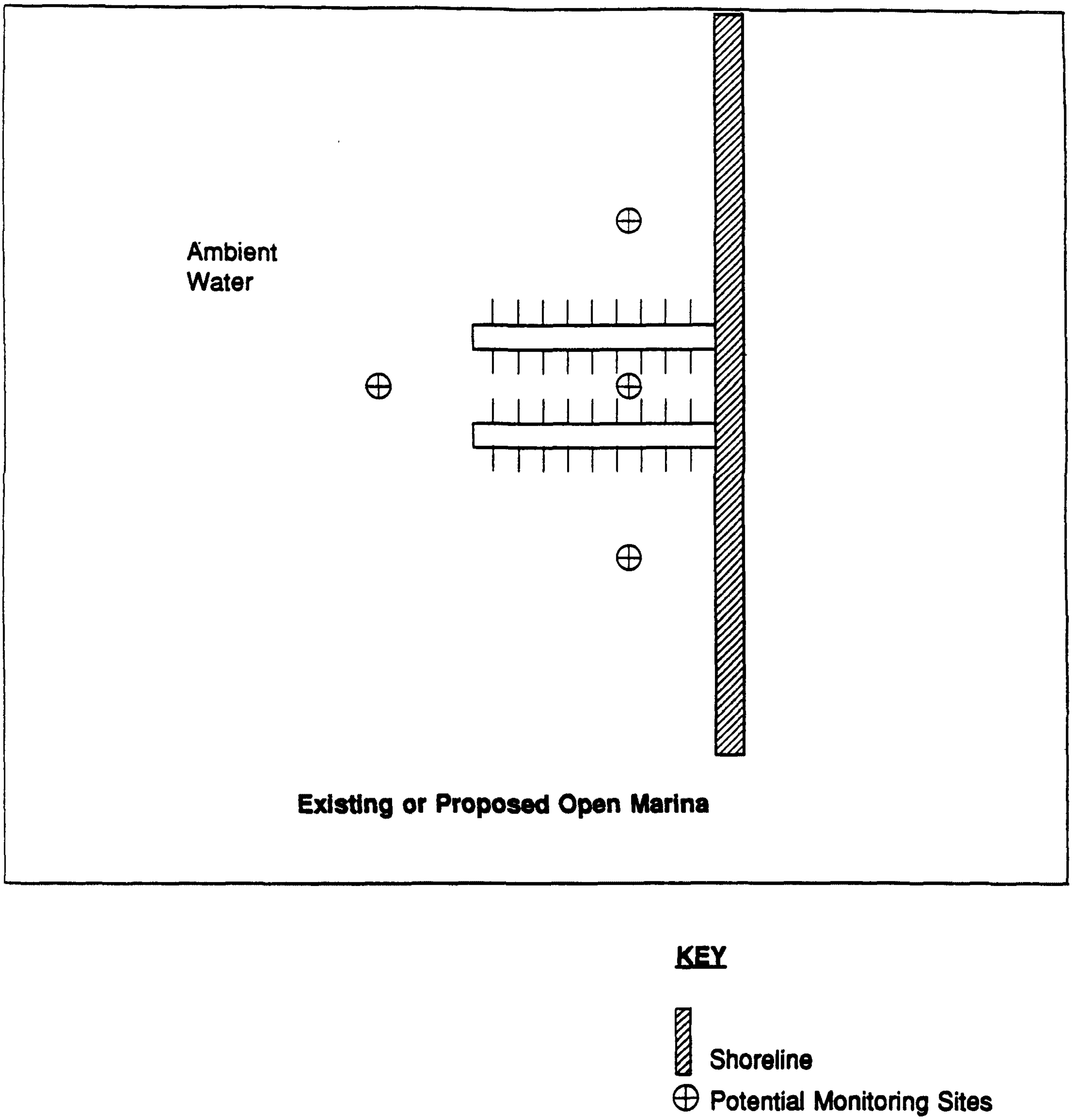

Figure 5-2. Illustration of Open Marinas and Potential Monitoring Sites

oxygen should rely on actual monitoring of dissolved oxygen concentrations within the proposed marina area. The monitoring should be representative of conditions which will be most critical in terms of meeting dissolved oxygen standards. These conditions generally occur during periods of high water temperature and low freshwater flow. In tidal areas, the monitoring should occur during average or neap tide conditions since mixing will be restricted during these periods. Occurrences of algal blooms or other conditions may influence when the critical condition occurs for a particular site.

A minimum of two days of dissolved oxygen monitoring should be collected. The monitoring should be conducted at no less than two-hour intervals and should include dissolved oxygen concentration, temperature, and salinity (if in estuarine or marine waters). The site or sites selected should be representative of the range of conditions found within the marina area. If the water column is stratified at the site, samples should be collected near the bottom, middle and surface of the water column. From the data collected, the twenty-four hour average, maximum, and minimum dissolved oxygen concentrations should be reported and compared to water quality standards to assess the potential for violations.

ii. Tier 1 assessments: semi-enclosed marinas

Marinas are considered to be semi-enclosed if they are located in a natural or man-made embayment which limits the mixing of waters in the marina area with ambient waters (Figure 5-3). The water quality within the embayments may differ significantly from the water quality of adjacent ambient waters. In cases like these, a combination of monitoring and modeling may be needed to estimate dissolved oxygen concentrations. If the embayment for the marina exists, the analysis may rely primarily on monitoring similar to that discussed for open marinas. If the embayment does not exist, a combination of monitoring and modeling may be necessary.

iii. Tier 1 assessments: existing embayments

For semi-enclosed marinas in which the embayment currently exists and no changes are proposed that would change the hydrodynamics of the embayment, the analysis may be limited to diel monitoring of dissolved oxygen concentrations during the critical period. The monitoring guidance provided for the open marinas applies. Modeling may be required if additional loadings of oxygen demanding substances are likely to be introduced during the operation or construction of the marina. The models discussed below in the Proposed Embayments section would be applicable.

iv. Tier 1 assessments: proposed embayments

For semi-enclosed marinas which have not yet been excavated, or for which changes have been proposed that would affect the hydrodynamics of the embayment, the water quality assessment should rely on monitoring and the application of appropriate models to predict dissolved oxygen concentrations. The dissolved oxygen screening procedures will serve as an initial assessment to determine if dissolved oxygen water quality standards are likely to be violated. If problems

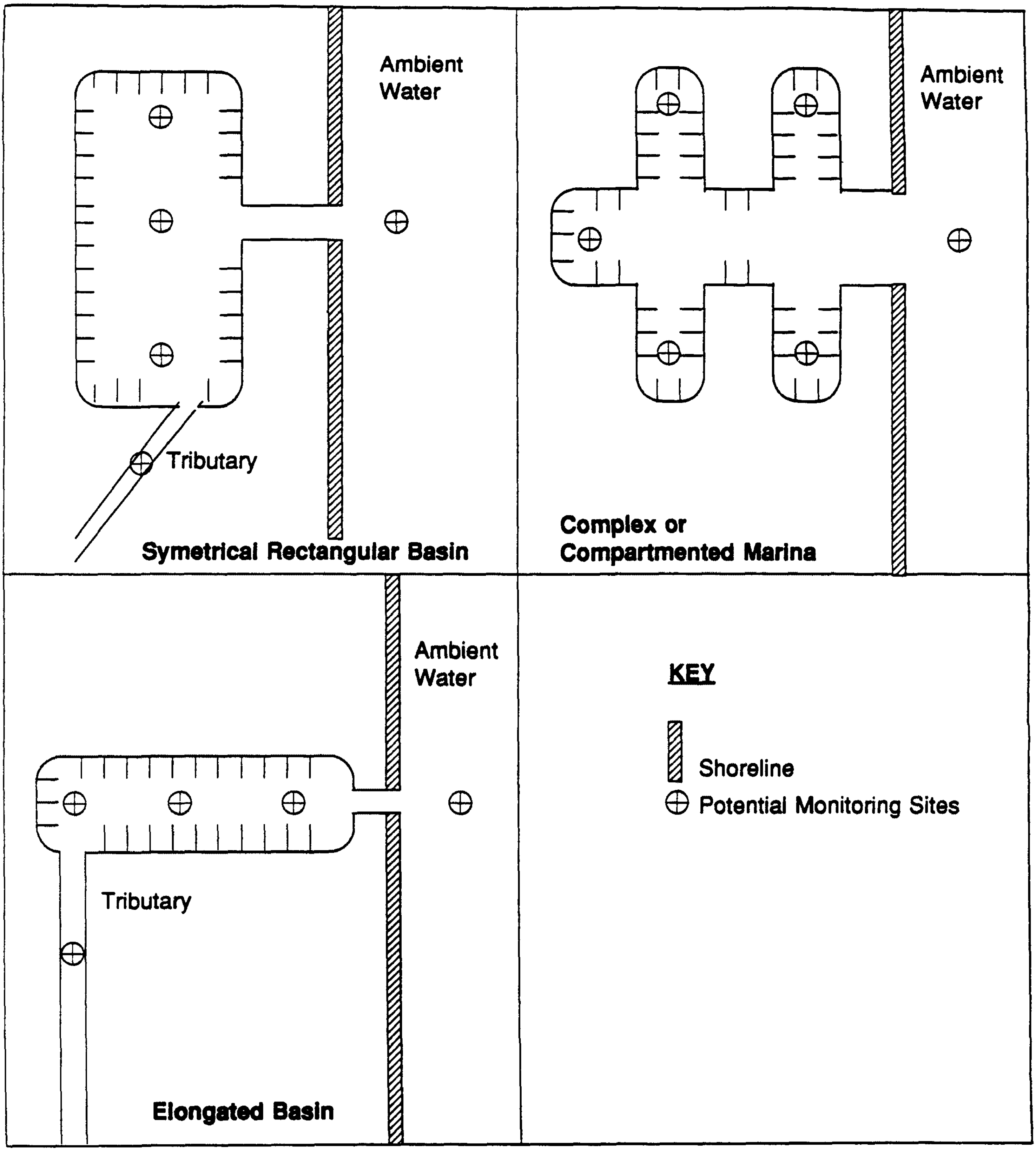

Figure 5-3 -Illustration of Enclosed Marinas and Potential Monitoring Sites

are indicated at the screening level, more detailed procedures may be applied to examine dissolved oxygen concentrations (see Figure 5-4).

The presence of salinity, dissolved oxygen or temperature gradients that result in stratification (as discussed in the open marina monitoring section) will require detailed procedures. The screening procedures for dissolved oxygen concentrations for proposed marinas located in semi-enclosed embayments should be based on a combination of dissolved oxygen monitoring coupled with the application of a steady state, tidally averaged water quality model and a flushing model. The monitoring guidance provided in the Open Marina section, above, should serve as the basis for the screening procedure. In addition, the average tide range and high and low water depths of the adjacent ambient waters, as well as the proposed marina, should be required to implement the screening models. Flow rates (seven day, ten year low), BOD, and dissolved oxygen concentrations of tributaries that will enter the proposed basin should also be provided or monitored. Additional monitoring may be necessary in areas where there is significant algal productivity, or in cases where detailed models are applied. Typical sampling sites for enclosed marinas are illustrated in Figure 5-3.

The screening level assessment of the minimum dissolved oxygen concentration should be based on the average dissolved oxygen concentration for the proposed basin as calculated above, and on the deviation between the average and minimum dissolved oxygen concentration measured in the ambient waters.

v. Tier 2 assessments: detailed procedures

Detailed procedures for dissolved oxygen analyses are recommended for proposed marinas that are not expected to be completely mixed due to stratification within the water column or due to the configuration of the marina basin. For example, proposed marina basins that are significantly elongated or segmented will prevent thorough mixing and will require detailed modeling. Detailed procedures may also be necessary to evaluate potential problems indicated by the screening level analysis. The detailed procedures used will be dependent on the specific site and model being considered.

As with the screening-level analysis, the detailed analysis should include a combination of monitoring and modeling. The model selected for the detailed analysis should have demonstrated applications in predicting average and minimum dissolved oxygen concentrations for systems that are similar to the marina basin configuration being proposed. The most available and accepted model with these abilities is the WASP model, which was developed and is supported by EPA. In most situations it will be the model of choice. The monitoring required to support a detailed model will vary with the model and the specific site. Sufficient data should be collected to calibrate the hydrodynamic and water quality components of each model for the specific site.

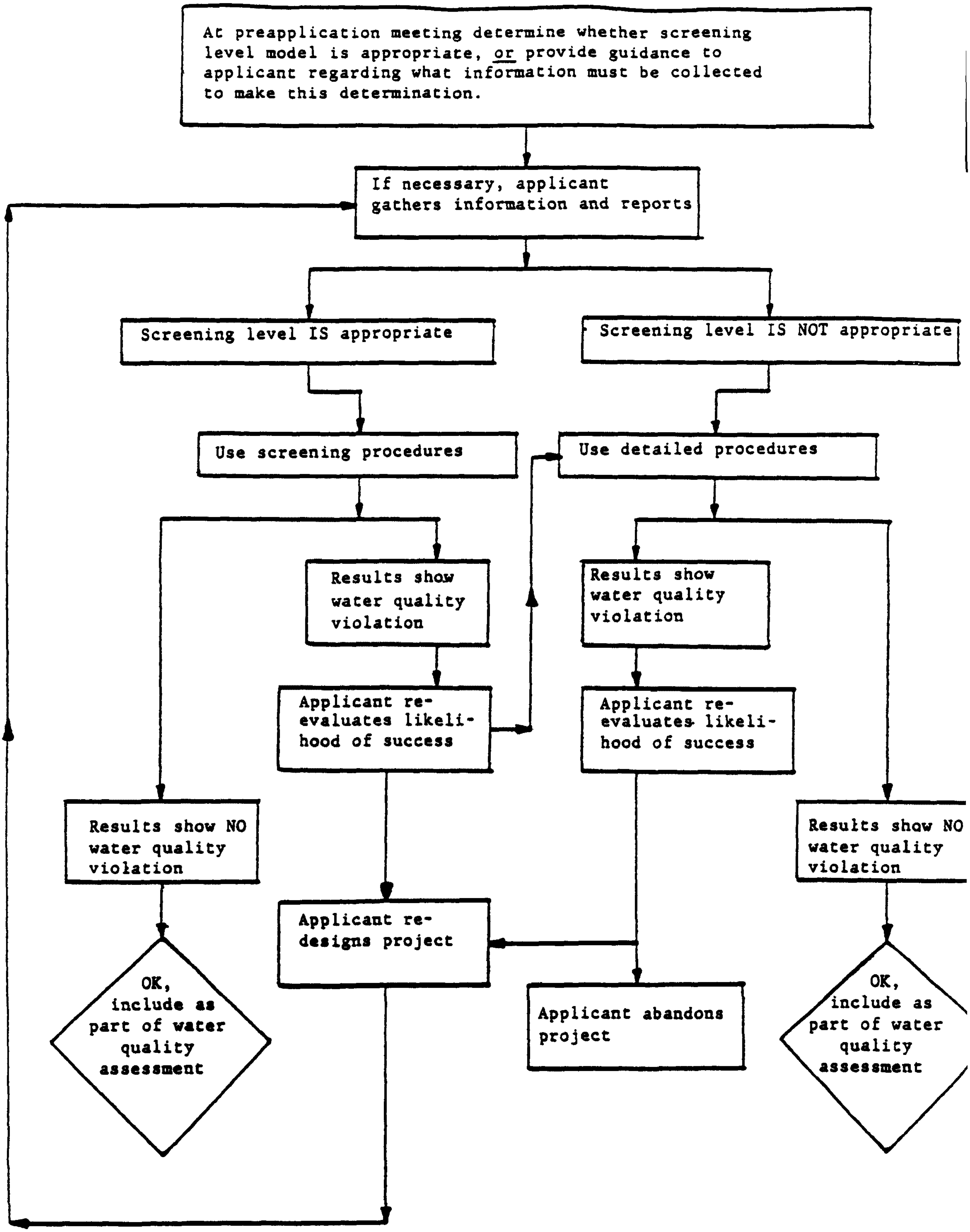

Figure 5-4. Flow Chart for Water Quality Assessments Requiring Modeling Analysis

d. Other parameters

Other parameters need only be investigated if there is a concern about the potential for violation of water quality standards.

2. Wetlands

The despoliation and destruction of public and private wetlands during marina construction and operation should be avoided. Further discussion on wetlands can be found in another chapter of this guidance.

3. Submerged Aquatic Vegetation

The net loss of submerged aquatic vegetation (SAV) should not be allowed. In no case should highly productive SAV be adversely impacted. If a marina is sited in the proximity of SAV, any related disturbance of these SAV areas should require compensation measures. Before such measures are approved it should be determined that substantial, prudent, and reasonable measures have been taken to avoid the impacts. Since this kind of vegetation cannot survive when heavily shaded, shading of SAV by piers crossing over them should be avoided.

4. Benthic Resources

The benthic community at the marina site should be evaluated using rapid bioassessment techniques (EPA, 1989; Luckenbach, Diaz and Schaffner, 1989). Benthic areas that are found to have degraded benthic communities should be considered for marina siting over those areas that are found to be healthy and productive. It is recommended that each state should develop rapid bioassessment techniques and criteria appropriate to their bioregions.

5. Critical Habitats

Marinas should not be sited in proximity to such areas if the project would adversely affect natural populations. A buffer zone should be established around critical habitats located near the project. The size of this zone should be decided on a case-and species-basis. No general or specific guidance regarding the extent of these buffer zones can be given because of the wide variation in requirements between species.

6. Dredging and Dredged Material Disposal

Ideally, marinas should be located where dredging will not be necessary to allow safe navigation. In many locations, unfortunately, this is not possible. Therefore, marinas should be sited at locations that require the least amount of dredging for the draft of the boats that will use that marina. In some cases, the draft may have to be limited to avoid or to minimize the amount of dredging. The area to be dredged should be the minimum needed for the marina itself, including the docking areas, fairways, and canals, and for other maneuvering areas that are needed. In no case should the bottom of the marina be deeper than the adjacent open water. Marinas should not be built in sites that will require maintenance dredging more frequently than once every four years.

Previous sections of this guidebook have described natural resources which may be impacted by the construction and operation of a marina. Dredging to construct or maintain a marina can result in losses of these resources and/or adverse impacts to nearby resources because of the turbidity associated with dredging. In addition, because certain times of the year are more critical than others due to migration, spawning and early development of important species, dredging should not occur at all at such times.

During dredging operations, any project-related turbidity should be contained, thus minimizing adverse impacts to the surrounding habitat and avoiding possible violations of water quality standards. Proper placement of silt screens or turbidity curtains is a common and relatively effective method of containment. Marinas should not be built in sites that will require maintenance dredging more frequently than once every four years.

Whenever dredged material may be contaminated, disposal in an upland diked containment area is the preferred disposal method. Wherever feasible, applicants should use existing diked disposal areas. Diked disposal areas must be sized and designed to prevent resuspension or erosion of the dredged material and subsequent transport back into adjacent waters. They must also be sited to avoid ground water contamination.

Another disposal option, available only for clean, uncontaminated fill, is placement on or near shore, where it is desirable to enhance beach profiles, stabilize shorelines, and/or build or enhance wetlands.

Dredging in waters of the United States is regulated by the Army Corp of Engineers, as discussed earlier in the introduction. This guidance on dredging and dredge disposal is provided so that prospective marina owners have an indication as to what they may expect from efforts to site a marina.

7. Water Supply

Marinas should be sited and designed to preclude any contamination of surface water or groundwater that is used for water supply. Runoff from potential areas of contamination, such as maintenance areas should be treated, as described under the Stormwater Management Section of this section.

Upland basins should not be excavated in areas upgradient or within 1000 feet of public or private well fields, nor should excavation occur within water supply protection areas, or where an increased threat of saline water encroachment is likely. A danger exists that dredging may improve the hydrologic "connection" between brackish water and the fresh water aquifer, which, when coupled with a head loss from pumpage within the aquifer, may result in contamination of the aquifer. A buffer of less than 1000 feet may be used if it can be demonstrated that a lesser distance will result in no adverse impact on groundwater.

It should be demonstrated that there is an adequate water supply to serve all of their project needs. As a rule of thumb, 30 gallons/slip/day will be needed during peak usage periods.

D. Pollutant Reductions and Costs

Proper siting of marinas can completely avoid some of the NPS pollution impacts associated this type of development. Direct impacts to shellfish areas, wetlands, SAVs, and other benthic resources and habitats can be averted. Water quality problems can be greatly reduced or eliminated entirely through proper siting. The costs of identifying a good site for a marina and preparing a water quality assessment will be dependent upon regional and local conditions. Past efforts have varied from $2,000 to $16,000.

III. MANAGEMENT MEASURES FOR THE DESIGN OF MARINAS

A. Environmental Concerns

The management measures, listed in Section B below, are designed to address the following water quality concerns.

Design considerations for the minimization of NPS pollution associated with marinas should include: shoreline stabilization, location of navigation channels, stormwater, dryboat storage, boat maintenance areas, fueling areas, and control of spills. Improper shoreline design can result in erosion or degradation of habitat. Placement and design of navigation channels is a major factor in flushing and resulting water quality. Boat maintenance activities that can result in NPS pollution include:

- Painting and paint removal,
- Welding, brazing, soldering, and metal cutting,
- Woodworking,
- Engine repair and service,
- Servicing LPG and CNG systems, and
- Boat washing and hull cleaning.

Rainfall runoff from areas where these activities occur becomes polluted with oils, greases, organic and inorganic wastes, and other potentially harmful substances. Introduction of these substances into adjacent waters can have significant adverse water quality impacts.

Marina fueling systems typically consist of storage tanks (usually underground) and pumps on shore, with fuel meters and dispensers mounted on a fuel pier or dock. Areas where boats are fueled are subject to contamination from petroleum hydrocarbons from leaks and spills.

B. Management Measures

This section contains the management measures to be applied in the design of marinas:

(1) Use natural vegetation to stabilize shorelines wherever possible.

(2) Navigation and access channels should be located in areas with safe and convenient access to waters of navigable depth, based on the kind of vessel expected to use the marina, but in no case exceeding the depth of adjoining channels and waters.

(3) The first one-half inch of runoff from the entire marina property for a 10-year 24-hour storm should be detained and released over a 24-hour period.

(4) All stormwater management systems should be provided with a bypass or overflow system so that the peak discharge from a 10-year 24-hour storm will be safely conveyed to an erosion and scour-protected storm water outfall.

(5) Dry boat storage should be utilized over wet slips wherever feasible.

(6) Boat maintenance areas should be designed so that all maintenance activities that are significant potential sources of pollution can be accomplished over dry land and under roofs (where practical), allowing for proper control of by-products, debris, residues, solvents, spills, and stormwater runoff. All drains from maintenance areas should lead to a sump, holding tank, or pumpout facility from which the wastes can later be extracted for treatment and/or disposal. Drainage of maintenance areas directly into surface or ground water or wetlands should not be allowed.

(7) Fueling stations generally should be located such that they are accessible by boat without entering or passing through the main berthing areas in order to avoid collisions.

(8) Marina operators should have a spill contingency plan and the proper equipment and training to implement the plan.

C. Marina Design Practices

This section provides technical guidance on practices that may be used as tools to assist in the implementation of the management measures set forth in Section IV.B. above.

1. Shoreline Protection and Basin Design

Natural vegetation should be used wherever feasible to stabilize shorelines. However, when additional stabilization becomes necessary, sloping riprap revetments are preferred over vertical bulkheads, since they generally provide greater habitat and reduce wave reflections. Shoreline intertidal areas should be preserved to the greatest extent possible.

In instances where bulkheads are to be installed, they should be constructed in such a manner that they are effective against erosion and provide adequate bank stabilization. The potential for erosion and scour at the mudline should be evaluated. Bulkheads should be constructed to prevent losses of fine material through joints or cracks from the land side to the water side, which could ultimately lead to failure of the wall. Bulkheads should be stabilized by providing adequate anchorage (such as batter piles or tie backs) or adequate embedment, depending on the type of bulkhead. Where public walkways, steps, or ramps run adjacent to bulkheads, handrails or other safety provisions should be provided along the top of the wall where the vertical drop to the current mean low water line or mud line exceeds three feet, unless local or State building codes stipulate otherwise. Any interference with public access should be avoided.

Basins that are constructed with square corners or other stagnant water areas will tend to trap sediment and debris. If this debris is allowed to collect and settle to the bottom, an oxygen demand will be imposed on the water and water quality will suffer. Therefore, square corners should be avoided in critical down-wind or similar areas where this is most likely to be a problem. If square corners are unavoidable because of other considerations, then points of access should be provided in those corners to allow for easy clean out of accumulated debris.

Riprap revetments are considered to be flexible since they can accommodate minor consolidation and settlement of their foundations. Still, adequate provisions should be made to prevent migration and loss of fine materials through the riprap, such as placement of a filter fabric beneath the armor layer. The slope of the revetment should be sufficiently flat to maintain stability, but in no case should the slope be steeper than one vertical to 1.5 horizontal. In addition, adequate toe protection should be provided to compensate for known or anticipated scour.

Considerations for new construction are addressed in the urban section of this document. Control measures such as turbidity curtains, vegetative barriers, etc. should be used to contain erosion.

2. Navigation and Access Channels

Channels should be located in areas with safe and convenient access to waters of navigable depth, based on the kind of vessels expected to use the marina, but in no case exceeding the depths of adjoining channels and waters. "Safe and convenient" access should be determined on a case-by-case basis, taking into account such factors as existing water depths, distance to existing canals and their depths, and tidal and wave actions. Before considering dredging, should attempt to gain access to deeper water by extending docks and piers farther from shore. The maximum extent to which a pier should extend into the waterway should be determined by each state and applied in a consistent manner (10% of the width of the channel has been set in some cases). In some cases, rather than dredging (and possibly having to develop a compensation plan), it may make more sense to simply limit the maximum boat drafts in the marina or utilize dingy access to moorings. Where channels are narrow, dry stacking of boats should be considered.

Where dredging is unavoidable, natural or existing channels should be used to minimize the amount of dredging. Also, naturally existing channels are less likely than surrounding shallow areas to contain shellfish beds, submerged aquatic vegetation, or other resources which may complicate permitting and require mitigation or compensation measures.

3. Wastewater Facilities

Three types of onshore collection systems are available: marina-wide systems, portable/mobile systems, and dedicated slipside systems. Marina-wide collection systems include one or more centrally located sewage pumpout stations. These stations are generally located at the end of a pier, often on a fueling pier so that fueling and pumpout operations can be combined. Boats requiring pumpout services dock at the pump-out station, a flexible hose is connected to the wastewater fitting in the full of the boat, and pumps or a vacuum system move the wastewater to an on-shore holding tank, a public sewer system, a private treatment facility, or other approved disposal facility. In cases where the boats in the marina use only small portable (removable) toilets, a satisfactory disposal facility could be a toilet into which the portable (removable) toilets can be dumped. Portable/mobile systems are similar to marina-wide systems except that the pumpout stations are mobile. The mobile unit includes a pump and a small storage tank. The unit is connected to the deck fitting on the vessel, and wastewater is pumped from the vessel's holding tank to the pumping unit's storage tank. When the storage tank is full, its contents are discharged into one of the previously listed approved disposal facilities. Dedicated slipside systems provide continuous wastewater collection at a slip. Slipside pumpout should be provided to live-aboard vessels. The remainder of the marina can still be served by either marina-wide or mobile pumpout systems.

Note that chemicals from holding tanks may retard the normal functioning of septic systems. Neither the chemicals nor the concentration of wastes has proven to be a significant problem for properly operating public treatment plants provided there is adequate dilution between the marina and the treatment plant. In some cases, the effluent from the marina may have to be diluted before introducing it to the sewer system.

Shoreside restroom facilities for the use of marina patrons should be required at all marinas. Adequate restroom facilities for any given marina are dependent upon the nature (recreational or public, or residential or planned community) and size of the marina and its ancillary features. Restroom facilities should be conveniently located and well-maintained to encourage their use by boaters at the marina. At residential or planned community marinas public restrooms may not be required unless there are non-residents who routinely use the marina who do not have access to a private bathroom, or unless the convenient travel time from the slips to the residences is longer than five minutes.

Marina operators should post ample signs prohibiting the discharge of sanitary wastewater, dishwater, or greywater from boats into the waters of the State, including the marina basin, and also explaining the availability of pumpout services and public restroom facilities. Signs should also fully explain the procedures and rules governing the use of the pumpout facilities.

4. Stormwater Management

All stormwater management systems should be provided with a bypass or overflow system so that the peak discharge from a 10-year 24-hour storm will be safely conveyed to an erosion and scour-protected storm water outfall. All discharges shall be calculated using methods developed by the U.S. Soil Conservation Service and described in either their Technical Release 20 or 55.

For new construction:

(1) The first one-half inch of runoff from the entire marina property for a 10-year 24-hour storm should be detained and released over a 24-hour period. Runoff to should be controlled with a weir that will direct the first one-half inch of runoff to the are and bypass the rest to the receiving water body. This is known as control of the first flush and is important because this first one-half inch of runoff has high concentrations of pollutants compared with the bulk of the remaining runoff.

(2) Use of infiltration practices may also be an acceptable alternative. Paving materials which allow for increased infiltration include permeable asphalt paving, paving blocks, and, in lighter use areas, coquina, gravel, oyster shells, or similar surfaces. Such infiltration practices are acceptable only in areas with appropriate soils, slopes, and depths to ground water. A strict maintenance schedule should be prepared and adhered to by the marinas operator. Porous asphalt should be used only as a last resort and only after a regular vacuuming schedule has been approved. This is needed because porous pavements can quickly become impermeable when clogged with small quantities of fines. Once they have become impermeable, their storm runoff benefits are nullified.

(3) Other treatment practices for storm runoff may be considered on a case-by- case basis if they can achieve an equivalent removal efficiency of 80% of suspended solids in addition to removal of other pollutants as needed.

5. Dry Boat Storage

Dry boat storage is the storage of boats on dry land (inside or outside) when they are not in use, often in multi-level vertical racks using a forklift truck or crane system. Dry storage of boats drastically reduces the in-water requirements for structures, typically requiring only a few wet staging slips for short term berthing of vessels after being taken from storage for subsequent boarding, and then upon their return before being placed back into storage. Dry storage should be utilized over wet slips wherever feasible due to the reduced potential for adverse environmental impacts from NPS pollution.

Construction of dry storage buildings must conform to all applicable requirements of municipal, county, or State housing, electrical, plumbing, fire protection, and building codes. In the absence of any such fire protection codes, fire protection procedures for dry storage areas are covered in the National Fire Protection Association (NFPA) 303, Fire Protection Standard for Marinas and Boatyards.

6. Boat Maintenance Areas

Boat scraping, sanding, washing, etc. should only be done in areas designed to handle runoff in a manner that prevents it from reaching adjacent waters and wetlands (see sections on stormwater and operations and maintenance).

7. Fuel Storage and Delivery Facilities

In the event of a spill of fuel, oil, or other toxic or hazardous substance, it is the responsibility of the marina operator to properly contain and clean up the spill in a timely and diligent manner. This is true even if the spill has been caused by some negligent or inadvertent action of a patron of the marina. Coast Guard regulations require that all spills that cause a visible sheen on the water must be reported. All spills should also be reported immediately to the proper state authority. A spill contingency plan should be posted and include:

(1) Posting of notification procedures in the event of a spill.

(2) Immediate on-site availability (less than 1/4 hour) of containment equipment such as booms, absorbent materials, or skimmers. This equipment should be conveniently stored on site. Responsible marina personnel should be trained in the proper use of this equipment. Marina personnel should be required to participate in annual drills to demonstrate their readiness in the event of a spill and to assure that containment equipment is in working order.

(3) Disposal of the collected fuel or other material contaminated by the pollutant in accordance with applicable State and Federal regulations.

8. Piers and Dock Systems

All timber used for construction above the water line should be pressure treated with a preservative such as chromated copper arsenate (CCA) or creosote to avoid damage by wood borers. Underwater, or periodically submerged portions of timber structures should not be constructed with CCA or creosote-treated timber. Treated piles that project above deck level should be protected with battens or some protective sheathing.

The use of concrete pilings should be seriously considered both in planned marinas and those undergoing expansion or repair/replacement of piers. Use of concrete pilings eliminates leaching of preservatives and decreases pier maintenance costs.

D. Pollutant Reductions and Costs

Actual numbers on pollutant reductions and costs are not currently available. The following discussion is on the relative pollution reduction of the management measures.

The proper design of marina channels and basins will result in avoidance of impacts to important habitat and protection of water quality. Properly flushed channels and basins will prevent build-up of natural and man induced substances that degrade the environment. Pollutant reductions and cost for the control of stormwater are discussed in the chapter of this guidance on urban management measures.

With dryboat storage, dredging is minimized since there is no large basin, only a small staging area. This will minimize water quality and flushing concerns, as well as flow disruptions caused by structures built to protect boats from wind and wave action. Large amounts of treated timber for docks and bulkheads are not needed, thus minimizing the leaching of wood preservatives into the water and the shading effects of docks, piers, pilings, and boats. The amount of contact time between pesticide-containing bottom paints and the water is minimized, perhaps even eliminating the need for the use of bottom paints. The use of construction material that does not contain CAA or creosote may not add to initial construction costs (unless concrete is used), but may add maintenance costs due to upkeep (unless concrete is used).

Proper design of fueling facilities and prepositioning of spill containment and cleanup equipment (100 feet of boom and absorbent material) will add approximately $2000 to $10,000 in cost to a marina project. Pollutant reduction is difficult to quantify because of the episodic nature of fuel spillage.

IV. MANAGEMENT MEASURES FOR OPERATIONS AND MAINTENANCE OF MARINAS AND BOATS

A. Environmental Concerns

The Management Measures, listed in Section B below, are designed to address the following water quality concerns.

The operation and maintenance of a marina and associated boating produces the same concerns as those addressed in the design of marinas as well as day-to-day activities such as disposal of fish wastes and the repair, maintenance, and operation of boats.

During the summer months, dissolved oxygen depressions, odor complaints and aesthetic problems may result from disposal of fish wastes into the water in concentrations that overload the natural ecosystem.

Small boat yards and marinas are confronted with handling a significant number of hazardous waste sources due to the variety of maintenance and repair operations that result from boat operations. Owners of marinas have a responsibility to see that no hazardous materials enter the body of water on which they are located.

Many of the wastes generated by boat yards and marinas must not be discharged into either sanitary sewers, storms or deck drains. Although there are some exceptions, most inside drains go to sanitary sewers and most outside drains go to natural waters. Wastes improperly, disposed down drains may cause water pollution, damage or impair sewage treatment plants and can be harmful to workers. Contaminants of concern include, antifreeze, oils, detergents, wash water from cleaning floors and decks and paint dust.

B. Management Measures

This section contains the management measures to be applied in the operation and maintenance of marinas and boats:

(1) Encourage the recycling of fish wastes back into the natural ecosystem in a manner that will not degrade water quality or cause other adverse environmental impacts.

(2) Tarps and vacuums should be used to collect solid wastes produced by cleaning and repair of boats. Such wastes should be prevented from entering adjacent water.

(3) Vacuum or sweep up and catch debris, sandings, and trash from boat maintenance areas on a regular basis so that runoff will not carry it into the water.

(4) An oil water separator should be used on outside drains and maintained to ensure performance.

(5) Curbs, berms or other barriers should be built or placed around areas used for the storage of liquid hazardous materials to contain spills.

(6) Tarps should be used to catch spills of paints, solvents, or other liquid materials used in the repair or maintenance of boats.

(7) Used antifreeze should be stored in a barrel labeled "Waste Antifreeze Only" and should be recycled.

(8) Valves should be used on the air vents of fuel tanks that prevent fuel from overflowing and spilling.

(9) All boats with inboard engines should have oil absorption pads in bilge areas and they be changed when they are no longer useful or at least once a year.

(10) Only phosphate-free and biodegradable detergents should be used for boat washing.

C. Marina Operation and Maintenance Practices

This section provides technical guidance on practices that may be used as tools to assist in the implementation of the Management Measures set forth in Section V.B. above.

1. Fish Wastes

A fish waste policy may need to be developed. In order to implement the policy in a consistent manner, guidelines could be established that meet the following requirements:

(1) Fish wastes should not be discharged into surface waters in any dead end lagoons, other poorly flushed locations, or other areas where such discharge could result in a water quality or public nuisance problem.

(2) Where fish waste disposal will not result in water quality or public nuisance problems, fish wastes could be recycled back into the ecosystem from which the organisms were originally harvested.

(3) Fish waste recycling within marina basins should only be allowed if in accordance with approved Operations and Maintenance Plans. Marinas should not provide fish cleaning stations unless the activity has been included in the Operations and Maintenance Plans. Marinas which are not approved for fish waste recycling

should post signs warning fishermen that fish wastes should not be disposed of in the water at that location.

(4) Fish wastes should not be recycled into surface waters in such a way that they will wash up onto any shoreline, or cause odors or other nuisances.

2. Boat Maintenance Areas

Small boat yards and marinas are confronted with handling a significant number of hazardous waste sources due to the variety of maintenance and repair operations that result from boat operations.

a. Hydroblast containment

This practice entails the containment of hydroblast (pressure washing) wastewater to prevent paint chips and oil from being discharged into natural waters and storm drains. In most states, permission must be obtained to discharge these wastes to the local sanitary sewer. The local utilities should be consulted for pretreatment possibilities. Cleaning processes that use chemical additives such as solvents or degreasers must be done in a self-contained system that prevents discharge to storm drains or sanitary sewer. Wastewater without such additives should be directed into wetpond detention basins as described in another section of this guidance. Where feasible, wastewater from this operation can be collected and reused.

b. Abrasive blasting containment

Grit from abrasive blasting contains paint chips and other materials should be prevented from entering natural waters or storms. 'Dockside' blasting, outside a drydock or containment area should not be done. Workshops and yards must be kept clean of debris and grit from sand blasting operations so that runoff and wind will not carry any waste into the water. During blasting operations, outdoor areas should be enclosed in plastic tarps and no blasting should be done on windy days. The bottom edge of tarpaulins and plastic sheeting must be weighted so that it will remain in place during light breezes. A spray booth should be used whenever possible to capture the blast grit and should be used if sand is being used.

c. Spray booths

Spray Booths concentrate paints and as such represent a hazard to both employees and the environment. Booths must meet local building and fire code requirements and must ensure adequate ventilation for people working in them. Paint guns used in spray booths should be either High Velocity Low Pressure (HVLP) or High Efficiency Low Pressure (HELP) which are rated at 65% efficient paint transfer, or electrostatic paint spraying methods. In replacing existing spray guns, convert to HVLP or HELP types. Cleaning paint guns can also be hazardous since spent solvent must be treated as a hazardous waste and not discharged directly into drains. Cleaning should be done in an enclosed gun cleaner/recycler machine.

d. Waste storage

Waste oil, fuels stored above ground and hazardous material must be protected by a berm (a built-in curb or barrier) in an area that is sufficiently large to contain a spill. Its purpose is to catch anything that spills or leaks, in case a container is tipped, overfilled or ruptured. No drains should be inside the secondary containment. If for some reason there is a drain, it should lead to a blind sump. Secondary containment should have a concrete floor and, if outdoors, be roofed. Other measures that count as secondary containment that may be used instead are;

(1) A sump, with no drain, near the tank to catch an accidental spill,

(2) Build a 2 to 4 inch sill across the doorway, high enough to contain a spill yet low enough to allow machinery to access the building,

(3) Buy or build double-containment tanks, and

(4) Or build high drip pans installed under existing tanks.

Outdoor storage of hazardous materials (drums, smaller container, batteries) must be covered and have secondary containment. Containers of hazardous materials should be placed under cover and on impervious pads (concrete is not impervious unless the surface is properly coated). Secondary containment may be a berm or a pallet with a tray. All drums must be labelled with the date, the words "Hazardous Waste", the associated hazards (ie, flammable) and the contents of the container.

e. Waste oil storage

Waste oil should not be contaminated with any other hazardous substances and if it does become contaminated, it should be labelled as a hazardous waste which entails expensive disposal procedures. Drums should be labelled "Waste Oil Only" to prevent mixing in other wastes, especially solvents. The labelling also aids fire fighters who, in case of fire, must treat an unlabeled drum as the worst case. Waste oil should be disposed of according to appropriate statutes and regulations. Recycling is strongly encouraged.

f. Drainage systems

Most local sewer utilities, via pretreatment ordinances and discharge permits, restrict what can be poured into inside drains since some contaminants are not removed by the treatment process. Drains connected to sanitary sewers may need sand traps and oil water separators. Lack of an oil-water separator for steam cleaning and pressure washing of engines and other oily parts may result in a violation of discharge limits. However, an oil-water separator is designed for the specific purpose of removing oil from water and will not remove all hazardous waste. Oil-water separators should be regularly maintained and cleaned whenever three inches of oil has accumulated. Local sewer utilities should be contacted for help in determining the best way to dispose of liquid wastes since discharge limits vary. Great care must be taken not to allow any contaminants to enter outside drains since most drain directly in streams or rivers without any type of treatment. Oil water separators should be installed on outdoor drains in areas where engine maintenance occurs.

g. Liquid waste management

Paints and solvents must be prevented from entering waterways by the use of drip pans, drop cloths or tarpaulins. Whenever possible, paints and solvents should be mixed in bermed areas away from storm drains, surface waters, shorelines and piers. Only one gallon (or less) of paint and solvent should be opened at a time when working on floats and should be contained within drip pans or tarpaulins. Paint and solvent spills should be prevented from reaching storm or deck drains, cleaned up and disposed of appropriately. Cleanup materials soaked with solvent must be handled as hazardous waste.

h. Solid waste management

Cleaning must be done in such a way that no debris falls into the water and is done to prevent the accumulation of waste material that may get blown onto surface waters. Cleaning with a vacuum is the preferred method for collecting sandings and trash. Sandblasting debris should be collected and stored with the spent grit and removed frequently. Hosing of decks and docks should not be done when it might cause debris to be washed into the drains. After the contents of a drum or a container is used they should be flattened and made unusable. If possible, reuse or recycle empty drums rather than dispose as solid waste.

Marina operators are responsible for the contents of their dumpsters and hazardous waste should never be placed in them. Dumpsters should be locked within an enclosure to prevent "midnight dumping". Liquid wastes should not be placed in dumpsters but disposed of properly by other methods. Recycling of non-hazardous solid waste such as scrap metal, aluminum, glass wood pallets, papers and cardboard is recommended wherever feasible. Dumpsters, that store items such as used oil filters should, while awaiting transfer to a landfill, be covered to prevent rain from leaching material from the dumpster onto the ground.

i. Antifreeze

Antifreeze from boat engines may be recycled if it is not mixed with other wastes. Some facilities elect to purchase on-site recycling equipment. However, filters from the recycling units must be handled as hazardous waste and may not be disposed of in solid waste. Runoff that contains antifreeze should be prevented from entering storm drains or natural waters.

j. Boating

Discharges from boats are subject to regulation under the Clean Water Act. However, many activities associated with the use of boats result in impact to coastal waters. Activities that may mitigate some of the impacts associated with boating include:

(1) Prohibitions on the use of environmentally damaging materials and encouragement of environmentally sensitive substitutes,

(2) Speed zones where erosion or other detrimental results could occur,

(3) No boating and/or anchorage zones where sensitive or critical habitats could be damaged by "prop-wash",

(4) No discharge zones where water quality standards could be violated by such a discharge,

(5) Limitations on in-the-water boat hull cleaning if it can be demonstrated that this is a significant local problem,

(6) If in-the-water boat hull cleaning can be an acceptable practice if it is done with a soft cloth (instead of scraping) several times a year, and

(7) Prohibitions of disposal of wastes from boats into State waters.

D. Pollutant Reduction and Costs

Pollutant reduction and costs have not been determined for the Management Measures related to the operation and maintenance of marinas and boats. NPS pollution resulting from some of the activities identified above can be eliminated entirely and others can be greatly reduced through implementation of the prescribed Management Measures.

V. RECOMMENDATIONS FOR STATE PROGRAMS TO IMPLEMENT MANAGEMENT MEASURES FOR MARINAS AND RECREATIONAL BOATING

The information in the remainder of this chapter does not represent management measures but are recommendations for States to consider in their overall approach to marina and recreational boating NPS pollution management. The draft program guidance to be published by EPA and NOAA in the summer of 1991 will contain information on State Coastal Nonpoint Pollution Control Program development and approval.

A. Management Process

It is recommended that a process be developed by every State to permit and regulate recreational boating and marina development and operation. This process should be the foundation on which the actual management measures identified in the rest of this chapter can be designated and implemented. Most States already have programs designed to accomplish many of the actions suggested in this guidance and States are not encouraged or discouraged from reorganizing their programs as described in this chapter. However, it is recommended that States review and, if needed, revise their programs to meet the performance goals identified. Marina and boating programs should consist of the following:

(1) Marina regulations,

(2) Marina development application form,

(3) Technical guidance for locating, planning, design and construction of marinas,

(4) Boating regulations,

(5) Chemical bans/controls of certain boat washing or stripping chemicals,

(6) Enforcement/ monitoring plans, and

(7) Public education.

Marina regulations should deal with potential pollution sources that may originate due to the physical presence or operation of marinas. The intent of the regulations should be three-fold. First, to apply strict environmental controls over the siting, design, construction, and operation of new marinas. The controls should be most comprehensive for new marinas because new construction offers the greatest opportunity for proper environmental planning and management. Second, to allow upgrading of existing facilities in ways which can benefit the environment by imposing reasonable restrictions which would effectively discourage or prevent environmentally detrimental impacts. In this case, it is recognized that physical constraints at existing sites may present insurmountable limitations over the scope of feasible improvements that can occur. Third, to provide for safe and environmentally sound operation of existing and future marinas through prevention of pollution by good housekeeping procedures.

B. Public Education

To improve success in reducing NPS pollution from marinas and recreational boating, a public education program is vital. The public should be educated about causes of NPS pollution and practices that will reduce NPS pollution. Specific areas in which boaters should be educated include:

(1) The types and sources of NPS pollution impacts associated with marinas and boats,

(2) Locations and types of sensitive coastal resources and wildlife habitat areas in local waters, and methods of minimizing boater impacts,

(3) New environmental protection initiatives and new operational measures implemented to respond to these initiatives,

(4) Marina operation and maintenance plans,

(5) Encourage limited use of detergents or use of detergents with 0.5% phosphates by weight,

(6) Proper collection and disposal of hazardous material (bottom paint scrapings and sanding dust, fiberglass resins, epoxy, MSD pumpout waste, dump station wastes, acid-type cleaners, wood bleaches, varnishes, etc.),

(7) Environmentally sensitive boat maintenance and upkeep procedures,

(8) Inform the public as to EPA and Coast Guard regulations prohibiting the discharge or oil or oily waste that causes a visible film or sheen,

(9) Proper use of sewage pumpout facilities, and

(10) Other boating regulations.

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CHAPTER 6. HYDROMODIFICATION, DAMS AND LEVEES, AND SHORELINE EROSION MANAGEMENT MEASURES

CHAPTER 6

HYDROMODIFICATION, DAMS AND LEVEES, AND SHORELINE EROSION

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HYDROMODIFICATION, DAMS AND LEVEES, AND SHORELINE EROSION MANAGEMENT MEASURES

This chapter addresses nonpoint pollution caused by hydromodification and shoreline erosion. Hydromodification covers a wide range of different activities, each presenting varying degrees of a range of nonpoint source (NPS) problems. Identified below are a range of hydraulic activities that may cause NPS pollution. A subset of these activities is addressed through the management measures identified in the section. EPA is seeking suggestions on which activities to focus on most extensively over the next year as it develops the final guidance. Hydraulic modifications vary significantly depending on the geographic region of the country. Therefore, we are also soliciting suggestions on geographic-specific activities and accompanying management measures.

In addition, this chapter addresses shoreline erosion which, unlike the previous chapters, is a symptom or result of other activities, rather than an independent activity that causes a problem. Nonetheless, it is a source of nonpoint pollution that significantly affects many coastal waters.

I. HYDROMODIFICATION

A. Overview of Sources

The following is a list of major activities that can cause alterations of the hydrologic characteristics of coastal and non-coastal waters which, in turn, could cause degradation of water resources.

(1) Dredging (e.g., marina basin, channels, borrow pits, underwater mining activities) - These activities alter the depth, width, and/or location of waterways or embayments and potentially reduce flushing characteristics. The reductions in flushing may reduce dissolved oxygen and change bottom sediments. Specifically, there is a tendency for finer textured sediments to accumulate in these areas impacting the benthic biota. Such areas may attract organic material and concentrate pollutants. In addition, dredging for channelization may increase salt water intrusion from the ocean during low river flow periods but decrease salinities during high flow periods by hastening passage of flood flows.

(2) Dams and Impoundments - Dams and impoundments may alter the distribution 'of sediments in the estuary and may cause migration of the turbidity maximum zone (i.e., the zone of greatest sediment concentration) thereby increasing sedimentation rates in some areas and decreasing them in others. Also, by reducing the discharge volumes, downstream current velocities and total flows may be reduced which in turn may promote the accumulation of fine textured sediments with high organic matter content and the reduction of aquatic habitat

dependent upon higher flows. Aquatic habitat may also be lost through inundation. These issues are addressed more extensively in the dams and impoundments section (section II below).

(3) Tidal Flow Restrictors (undersized culverts, transportation embankments, undersized bridges, tide gates, sluice gates, weirs) - These structures may reduce tidal flushing and decrease exchange volumes thereby creating or exacerbating water quality problems. Tidal flow restrictors also cause ponding and may cause a loss of vegetation. There may also be a concurrent change in the sediment quality. Such changes may also restrict movement and migration of fish and crustaceans and affect shellfish populations.

(4) Flow Regime Alterations (e.g. diversions, withdrawals, fixing banklines to accelerate flows or to prevent migration of waterway) - Removing freshwater that otherwise enters the estuary or increasing freshwater flows into an estuary can alter hydraulic characteristics and water chemistry, thus impacting shellfish, fisheries, and habitat. Changes to the distribution, amount, or timing of flows affects living resources. Hardening banks along waterways eliminates habitat, decreases organic matter entering aquatic system, and may improve the efficiency of NPS pollutant movement from upper reaches of watershed into coastal waters.

(5) Breakwaters and Wave Barriers - These activities may, through the dissipation of wave energy, cause sediment quality to degrade especially if accumulated sediment contain contaminants and organic material. These devices may also reduce the flushing characteristics of coastal and inland waters and may cause or exacerbate existing water quality problems.

(6) Excavation of Uplands to Increase Water Area (e.g., excavation of marinas from upland; artificial lagoonal systems) - This activity frequently results in poorly flushed areas. Depending upon the location along a tidal waterbody, there may be a reduction in the height of tides downstream. Such changes may create or exacerbate water and sediment quality.

B. Nonpoint Source Problems Caused by Hydromodification

Nonpoint source constituents/parameters of interest that may be influenced by hydromodification include: sediment, turbidity, salinity, temperature, nutrients, dissolved oxygen and oxygen demand, and contaminants. Hydraulic modifications alter the physical environment which may have either harmful or beneficial nonpoint source effects. The nonpoint source parameters can cause problems if they occur outside of normal or desired ranges. For example, salinity fluctuations within range of about 5 to 20 parts per thousand are needed for optimal production of oysters. Periods of lower salinity within this range enable the oysters to thrive and periods of higher salinity are needed to reduce population of predators that destroy oysters. However, extremes of either prolonged low salinity or prolonged high salinity can reduce oyster populations.

The significance of hydromodification lies not only in how such modifications alter the physical environment but, perhaps more importantly, how they ultimately affect freshwater and marine biota and habitat. In many cases, aquatic life is impacted due to disruption of flow, circulation patterns, and other changes in the characteristics of the waters on which these organisms depend. Hydromodifications have deprived wetlands and estuarine shorelines of enriching sediments, prevented natural systems from absorbing energy and filtering pollutants from other sources, and impacted fish and shellfish landings. Nonpoint source problems associated with hydromodification are characterized in this chapter into the following six areas:

(1) Changes in sediment supply. Erosion of bed sediments may increase turbidity, release nutrients, expose contaminants, or expose organic materials that increased oxygen demand. New or eroded sediments may deposit elsewhere, covering benthic communities, or altering habitat. Insufficient sediment supply may not keep up with subsidence and sea level rise, leading to marsh subsidence and loss, as in Louisiana. Erosion or deposition may lead to loss of habitat, migration pathways, or conditions unsuitable for reproduction and growth of biota.

(2) Loss of water contact with wetlands and non-wetland overbank areas during floods or other high water events. The loss of contact may result in reduced filtering of nonpoint source materials by vegetation and soils. (See Wetlands and Riparian Areas chapter.)

(3) Loss of ecosystem benefits such as habitat, pathways for migration, and conditions suitable for reproduction and growth. For example, in California, flow modifications have resulted in reversal of river/stream flow regimes resulting in disorientation of anadromous fish that rely on flow to direct them downstream to spawn.

(4) Reduced freshwater availability for municipal, industrial, or agricultural purposes. Salinity above threshold levels constitutes pollution of freshwater supplies or alteration of salinity regime such that vegetation die-off occurs. (Some cooling and process water uses are unaffected by salinity.)

(5) Increased delivery or rate of delivery of pollutants from upstream.

(6) Secondary effects such as movement of the estuarine turbidity maximum (zone of higher sediment concentrations caused by salinity and tide-induced circulation) with salinity changes, eutrophication caused by inadequate flushing, and trapping large quantities of sediments.

C. Management Measures

Nonstructural measures are one category of management measures that can be used to prevent or minimize water pollution due to hydrologic modifications. While consideration should be given to both nonstructural and structural measures during the early planning stages, nonstructural measures should be given preference in the planning stage given their potential to protect or restore habitat. Certain environmental conditions such as might exist in wetlands or other sensitive aquatic sites, for example, may rule out structural considerations. A nonstructural program will be easiest to implement if it can be developed and adopted for areas not yet experiencing rapid, urban, commercial or industrial expansion. Where circumstances and costs rule against a complete nonstructural program, an appropriate use of both structural and nonstructural modifications may be satisfactory.

Management Measures for the NPS problems listed above are given below.

1. Management Measures for Changed Sediment Supply

(1) Proper project design. Sediment erosion from (and deposition to) the bed of a coastal waterway can be managed by proper project design. Proper design is site and flow condition specific and cannot be generalized, but appropriate models should be used to design waterway modifications. The best available technology includes 2-dimensional numerical and hybrid (numerical plus physical) models. (McAnally, 1986, "Modeling Estuarine Sedimentation Processes," Proceedings, Symposium to Reduce Maintenance Dredging in Estuaries, National Academy of Sciences, Washington, DC.)

(2) Vegetative cover. Sediment erosion from overbank areas that flood during high water events can best be controlled by vegetative cover.

(a) In salt and brackish water areas, the best available technique is planting marsh grasses suitable to the salinity level. Grasses anchor the soil with roots and detritus and reduce flow stresses on the bed by sheltering it. (Allen, H. H., Webb, J. W. & Shirley, S.O., 1983, Proceedings, 3rd Symposium on Coastal Ocean Management, American Society of Civil Engineers, pp 735-748; Fredette, et al., 1985, "Seagrass Transplanting, 10 Years of CE Research, Wetlands Research Conference.)

(b) In fresh water areas, the best technique is planting of tree breaks, which function much as grasses do plus diminish downstream water flow energy. Tree breaks diminish the flow capacity of the overbank area, so evaluation of the tradeoff between upstream flood control and overbank erosion must be made. (Lower Mississippi Valley Division, U.S. Army Corps of Engineers).

(3) Using noneroding roadways. Noneroding roadways, such as board roads, should be used to access sites within and near wetlands.

(4) Effectiveness. Benefits of these measures consist of significant reduction (but not elimination) of sediment bed erosion during high flow events. Use of models to design projects can result in diminished amounts of sediment deposition away from the modification site.

2. Management Measures for Loss of Water Contact with Overbank Areas During Flood Events

(1) Setback levees and compound-channel designs. Contact between flood waters and overbank soil and vegetation can best be increased by a combination of setback levees (see section on Levees, Dams, and Impoundments) and use of compound-channel designs. Compound-channel designs consist of an incised, narrow channel to carry water during low (base) flow periods, a staged overbank area for the flow to expand into during design flow events, and an extended overbank area, sometimes with meanders for high flow events. Planting of the extended overbank as described above completes the design. (W.M. Linder. 1976. "Designing for Sediment Transport", Water Spectrum. Spring-Summer).

(2) Effectiveness. Benefits of this design practice include (a) improved conveyance with less sediment deposition during low and moderate flows, (b) improved habitat, (c) open migration pathways for fish, and (d) improved filtering with minimal erosion during high flow events.

(3) "Wing wall" impoundment for overbank flow in frequent storm events. Construct a notched impoundment within the stream channel immediately upstream of small stream culvert crossings. Designed to back up flows during frequent storm events and expand flow over streambanks into vegetated floodplain. Flow from larger storm events (typically two-year or greater) will overtop the wall and continue through stream culvert.

(4) Effectiveness. Benefits are directly associated with reduction of sediment loadings. Reduction of nitrogen and phosphorous estimated at 5-15%. Restores or maintains habitat of overbank areas and provides a pathway for fish migration.

3. Management Measures for Loss of Ecosystem Benefits

(1) Site specific design. Preserving ecosystem benefits is best achieved by site specific design to obtain pre-defined optimum/existing ranges of physical environmental conditions. The use of models is one way to achieve this. The process consists of these steps:

(a) Define which ecosystem benefits may be placed at a risk by a project.

(b) Define the range of acceptable values for the system-significant parameters listed in part 1 and the range of flow and net transport values that will maximize/maintain ecosystem benefits. Note that specifying zero change in the parameters may not optimize ecosystem benefits.

(c) Use appropriate models to evaluate system behavior under project alternative plans and appropriate conditions of flow and climate. Verify that the models are capable of reproducing significant processes in the area of interest, then use the sequence of modeling hydrodynamic response, transports, and then water quality.

(d) Refine the project design so as to obtain an acceptable range of significant parameters.

Appropriate models may be 1-dimensional, 2-dimensional, or 3-dimensional, depending on system behavior and economics, and may be physical, numerical or hybrid models, depending on system characteristics and parameters/processes of interest. (Hudson, et al., Coastal Hydraulic Models, SR-5, Sept. 1979. U.S.A.E. Coastal Engineering Research Center, Vicksburg, MS).

4. <u>Management Measures for Reduced Freshwater Availability</u>

(1) For most cases, reduction in freshwater availability is best managed by the same techniques described in item 3 above. In this case, the salinity threshold levels should be selected using defensible criteria, not arbitrary specifications of "zero change" or "zero salinity," neither of which occur in nature.

(2) Salinity increases in fresh or brackish marshes that are caused by canal construction are best managed by the same techniques described in item 3 above.

(3) Artificial nourishment. Salinity increases caused by land subsidence, which lowers marsh levels faster than reduced sediment supply can maintain them are best managed by artificial nourishment with diverted sediment.

5. <u>Management Measures for Increased or Accelerated Delivery of Pollutants</u>

Increased or accelerated delivery of pollutants from upstream are best managed by the techniques described in item 3 above. (For example, the Chesapeake Bay Program's numerical modeling effort provides effective consideration of pollutant delivery. However, it may not adequately consider effects on habitat.)

6. Management Measures for Secondary Effects

(see problem description p. 6-3)

Secondary effects are best managed by techniques described in Section I.C.3 above.

D. Costs of Management Measures

Appropriate model studies described in the preceding best management practices have highly variable costs, but common cost ranges are:

(1) 1-dimensional hydrodynamics and water quality - $5,000 - $50,000.

(2) 2-dimensional hydrodynamics and water quality
   (a) Creeks, small river sections - $10,000 - $100,000
   (b) Sections of rivers to large estuaries - $25,000 - $500,000

(3) 3-dimensional hydrodynamics and water quality
   $100,000 - $5,000,000

Planting overbank and marsh grasses cost between $2,000 and $9,000 per hectare.

Planting overbank tree strips costs between $10,000 and $25,000 per acre.

Channel design and construction to incorporate compound channel design may increase initial and maintenance costs.

Costs of construction of concrete, notched wing wall are in the $10,000-$15,000 range.

E. Overview of Federal, State, and Local Programs and Processes

1. Existing Regulations

a. Administration and background for nonpoint sources

(1) Clean Water Act (Section 404)--permit program for the discharge of dredged and fill material
(2) National Environmental Policy Act--sets the policy requiring all Federal agencies to write an Environmental Impact Statement (EIS) for any major Federal action "significantly" affecting the environment. An EIS must include consideration of environmental factors which tend to help minimize nonpoint source pollution when it has been found abandonment of the proposed action is impractical.

(3) US Army Corps of Engineers permit process for dredging and filling.

(4) Section 73 of Public Law 93-251 on nonstructural flood damage reduction measures.

b. Examples of present State guidelines

(1) Best Management Practices Guidelines for Virginia
(2) Better Quality Management Plan for the State of Louisiana
(3) Puget Sound Water Quality Management Plan, 1989
(4) San Francisco Bay Conservation and Development Commission (BCDC) policies on fill in tidal areas.

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II. DAMS AND LEVEES

A. Coastal Problems Caused by Dams and Levees

1. Overview

Dams and levees can adversely impact coastal and near coastal water quality, as well as the hydrologic regime of stream systems. Direct impacts associated with the siting, construction, and operation of dams and levees are due primarily to the disturbance of soil and ground cover, changes in stream hydraulics, and modification of existing ecosystems (i.e., loss or reduction of ecosystem filtering and uptake functions).

There are two large classes of impoundments (Virginia Department of Conservation and Recreation, 1979). First, there is the run-of-the-river impoundment, which is an impoundment that usually has a small hydraulic head (low dam), limited storage area (thus, a short detention time), and no positive control over lake storage. The amount of water released from this class of impoundments is dependent upon the amount of water entering the impoundment form upstream sources.

The second class is the storage impoundment, in which there is a large hydraulic head (high dam), large storage capacity (long detention time), and a positive control on the amount of water released from the dam. Flood control dams and hydro-power dams are usually of the storage class. Run-of-the-river impoundments generally have a much less pronounced overall effect on water quality than do storage impoundments.

There are several possible intended uses for impoundments:

(1) Flood control
(2) Power generation
(3) Navigation
(4) Water supply - domestic, industrial, irrigation
(5) Other - recreation, fish and wildlife propagation, low flow augmentation, etc.

These various uses often require differing design and management practices and, in cases of multiple-use objectives, present conflicting operational requirements. For example, flood control impoundments have large storage capacities to contain flood waters. As the wet or rainy season approaches, water is released to insure that adequate storage capacity is available for the periods of high flow. The dam is operated to trap excess flow during the wet season, and to later release this flow during periods of low stream flow.

In contrast, the operation of dams for power generation has traditionally been focused on meeting peak electricity demands. The dams, therefore, usually must impound and store large quantities of water, providing control over downstream releases to meet peak needs.

As a further contrast, dams for navigation purposes must be operated to maintain a minimum depth in the impoundment. These dams usually have locks to facilitate the movement of commercial traffic, and control over downstream releases. Water supply dams impound large quantities of water to meet user needs.

Multi-purpose impoundments can have conflicting operational requirements that must be balanced in order to meet all specified uses. For example, the Shasta Dam in northern California (U.S. Fish and Wildlife Service, 1976) is operated for flood control, irrigation, navigation, fish and wildlife conservation, hydroelectric power, recreation, and salinity control in the Sacramento-San Joaquin River Delta.

2. Siting and Construction

The siting of dams and diversions can result in the inundation of wetlands and special aquatic and terrestrial sites above the structures, and the drainage of aquatic and wetland habitats downstream. They can also impede or block migration routes of important sport and commercial fishes. For example, 95 percent of the historic spawning habitat for salmon and steelhead trout in California has been either destroyed or made unavailable by dams.

Construction activities can cause increased sedimentation of coastal and near-coastal waters due to vegetation removal, soil disturbance, and soil rutting. Fuel and chemical spills, and the cleaning of equipment (e.g., concrete washout) are also potential nonpoint source problems associated with construction. The proximity of most dams and levees to streambeds and floodplains heightens the need for on-site pollutant prevention.

Dam construction can have other effects on the local hydraulics (Virginia Department of Conservation and Recreation, 1979). In order to guard against dam failure, the flow of water under and around the sides of the dam site must be impeded. This is done by embedding an impervious core into the ground to prevent the flow of groundwater under or around the dam (piping). While this construction technique is necessary to ensure the safety of the dam, it can impede the flow of groundwater in the vicinity of the dam. This interference might not become apparent until the dam is fully constructed and the impoundment filled. These effects on the groundwater flow can cause drops in the water table below the dam site, and increases upstream. A rise in the water table can lead to the formation of marshes in areas that had been dry. Other effects include the possible accumulation of pollutants in the groundwater because the flow of the groundwater is disrupted.

3. Operation

The operation of dams and levees can also cause a variety of nonpoint source pollution impacts to coastal and near-coastal waters. For example, dams can severely reduce downstream movement of sediment, causing a change in stream hydraulics. This change in stream hydraulics can cause increased downstream scouring and streambank erosion, resulting in increased sediment and nutrient delivery to coastal waters. As another example, lower instream flows and flattening of peak flows associated with controlled releases from dams can result in aggradation of near-coastal stream beds and estuaries, degrading valuable spawning and rearing habitats. Dams can also limit recruitment of favorably sized substrate needed by aquatic fauna, and lower nutrient inflows to estuaries and near-coastal waters. In addition, dams can cause elevated downstream water temperatures and lower downstream dissolved oxygen levels.

Levees can cause increased transport of suspended sediments to coastal and near-coastal waters during high-flow events. Levees can also prevent the lateral movement of sediment-laden waters into adjacent wetland and riparian areas which would otherwise serve as depositories for sediments, nutrients, and other pollutants. This has been a big factor, for example, in the rapid loss of coastal wetlands in Louisiana. Levees also interrupt natural drainage from upland slopes and can cause concentrated, erosive flow of surface water.

B. Management Measures for Dams and Levees

Management Measure Applicability:

These management measures are to be utilized on all dams, and the erosion and sediment control for construction, erosion and sedimentation control for operation, habitat protection, and chemical and other pollutant control for construction apply to all levees.

These management measures do not apply to the extent that their implementation under State law is precluded under California v. Federal Energy Regulatory Commission, 110 S.Ct. 2024 (1990) (addressing the supercedence of State in-stream flow requirements by Federal flow requirements set forth in FERC licenses for hydroelectic power plants under the Federal Power Act).

1. Erosion and Sedimentation Control for Construction

a. Problems to be addressed

Erosion and sedimentation control techniques can be used to address the erosion problems resulting from dam or levee construction.

b. Erosion and sedimentation management measure for construction

The management measure for control of erosion and sedimentation during the construction of dams and levees is a combination of practices that minimizes the detachment and transport of soil by human-induced disturbance, water, wind, ice, or gravity such that the delivery of sediment caused by the construction activities, either directly or indirectly, to natural waterways is not significantly greater than the delivery of sediment from the construction area prior to construction activities.

c. Management practices

Following is a list of management practices for erosion and sedimentation control that are available as tools to achieve the erosion and sedimentation management measure for construction of dams and levees.

Soil Bioengineering - These techniques can be used to address the resulting erosion from dam and levee construction. Grading or terracing a problem streambank or eroding area and using interwoven vegetation mats installed alone or in combination with structural measures will facilitate infiltration stability.

Environmental Design of Waterways (ENDOW) - This problem-solving computer program is a practice that consolidates information on environmental features and facilitates their selection for use in the planning and design of streambank protection and flood control projects (Shields and Schaefer, 1990). The type of project, dominant mechanisms(s) of erosion, and environmental goals are entered into the ENDOW program. The program then lists and determines the relative feasibility of the environmental goals and features (e.g., pool/riffle complexes, preservation and creation of wetlands, low flow channels) within the program.

Other applicable practices are listed in the "Construction Management Measure" section of the urban chapter in this guidance.

2. Erosion and Sedimentation Control for Operation

a. Problems to be addressed

Erosion and sedimentation control techniques can be used to address the erosion problems resulting from dam or levee operation.

b. Erosion and sedimentation management measure for operation

The management measure for control of erosion and sedimentation during the operation of dams and levees is a combination of practices that minimizes the detachment and transport of soil by human-induced disturbance, water, wind, ice, or gravity such that the delivery of sediment caused by dam or levee operation, either directly or indirectly, to natural waterways is not significantly greater than the delivery of sediment from the area influenced by the dam or levee prior to establishment of the dam or levee.

c. Management practices

Following is a list of management practices for erosion and sedimentation control that are available as tools to achieve the erosion and sedimentation management measure for operation of dams and levees.

Downstream Erosion Controls - The release waters from an impoundment can cause problems downstream by eroding the stream channels and by scouring the stream bed (Virginia Department of Conservation and Recreation, 1979). The amount of erosion potential is determined by the erodibility of the stream channel and banks, and by the amount of "excess" energy the water possesses.

The usual method of controlling erosion is to place energy dissipators downstream of the water release to consume the excess energy, lowering the erosion potential. Energy dissipators can take many forms, including:

Riprap or quarried stone can be used to line the streambed, and is resistant to dislodgment because of its jagged shape. Riprap "liner" will not fail due to settling and shifting.

River Rock is frequently used to line the streambed and channels because it is usually available at the site. Advantage is that the rock "liner" is flexible and can withstand settling and shifting without failure. Problem is that river rocks are generally rounded, and, therefore, dislodged easily by flows.

Gabions are wire mesh baskets filled with rock, and can be placed in the stream to form a "liner." Gabions can be anchored into the stream banks or streambed for stability. Gabions are flexible and seldom fail because of settling or shifting. However, gabions require periodic maintenance to insure that none of the wire is broken or corroded.

Concrete Blocks and Liners can usually be made on-site since dam construction typically requires some concrete. Because concrete is less dense than either river rock or riprap, it is necessary to make concrete blocks larger to provide the same resistance to dislodgment. Concrete structures are inflexible, and therefore more likely to fail due to settling and shifting.

Soil Bioengineering techniques can be used to address the resulting erosion from dam and levee operation. Grading or terracing a problem streambank or eroding area and using interwoven vegetation mats installed alone or in combination with structural measures will facilitate infiltration stability.

Environmental Design of Waterways (ENDOW). This practice is described under the management practice for erosion and sediment control for construction.

d. Cost information

River rock is obtained at essentially no cost because it is obtained on site in most cases (Virginia Department of Conservation and Recreation, 1979).

Riprap is more expensive than river rock because of quarrying and transportation costs. In Tennessee, riprap is estimated to cost $2,000 per 100 feet, assuming 1 cubic yard of riprap per linear foot (Tennessee Department of Health and Environment, ca. 1990).

Gabions are usually filled with rock found at the site; however, they require additional hand labor to place the rock and ensure that the containers are not damaged.

3. Habitat Protection

a. Problems to be addressed

The loss of aquatic and terrestrial habitat or habitat function associated with the construction or operation of dams and levees is addressed by this management measure. This includes the preservation and protection of wetlands, riparian zones, and adjacent terrestrial habitat.

The control of natural fluctuations in stream flow can cause an increase in the occurrence of rooted aquatic vegetation and an increase in the deposition of fine particles (U.S. Fish and Wildlife Service, 1976). Fine particles can compact spawning gravels, thus affecting spawning success.

b. Management measure

The management measure for habitat protection is a combination of practices that minimizes the loss of aquatic and terrestrial habitat and habitat function such that habitat function in the area affected by the dam or levee is not significantly degraded. Habitat function includes both the range of environmental benefits provided by habitat (e.g., spawning, food supply, protection), as well as the capacity to support the numbers and diversity of species dependent upon the habitat.

c. Management practices

Following is a list of management practices for habitat protection that are available as tools to achieve the habitat protection management measure.

Setback Levees - Setback levees avoid habitats which serve flood control functions and act as filters for sediment and other pollutants. They allow a given level of high flow to maintain existing floodplain habitats. They also allow the transport of lesser amounts of pollutants than rapid transmission structural systems, lowering the delivery of pollutants to coastal waters.

Low flow gates, channels, and weirs - Allow flow maintenance of fishery and other habitats with the same resultant benefits as cited for setback levees.

Flushing and Scouring Flows for Habitat Maintenance - This practice is intended to maintain habitats and substrates by periodically flushing away sandbars and excessive deposits of fine particles and rooted vegetation in areas downstream from the structure. It is essential to establish an actual ecological need for a flushing or scouring flow before proceeding to predict or prescribe the requirements (U.S. EPA, 1988). Predictive and evaluative methods should be selected which are compatible with site-specific conditions, such as the watershed characteristics, instream flow regime, bed material composition, and channel morphology. It is wise to compare results of several methodologies, which could vary by one or even two orders of magnitude, when predicting flushing or scouring flow requirements, and, if possible, provide field verification. An awareness of the assumptions and limitations inherent in any predictive methodology is important because sediment transport mechanics and channel maintenance theory are still in an early stage of development.

Environmental Design of Waterways (ENDOW) - This practice is described under the management practice for erosion and sediment control for construction.

4. Fisheries Protection for Dams

a. Problems to be addressed

This management measure addresses impacts to fisheries caused by the amount and scheduling of flow releases, downstream sedimentation of spawning areas, changes to water temperature, and fish passage. The generation of power at hydroelectric dams results from the movement of reservoir water through penstocks and turbines to downstream areas. Migrating young fish may suffer significant losses when passing through the turbines unless these facilities have been designed for fish passage.

b. Management measure

The management measure for fisheries protection is a combination of practices that minimizes the loss of desirable fish species by: (1) maintaining minimum instream flows for the protection of desirable aquatic species, (2) controlling flow fluctuations within seasonal bounds to protect against damage to aquatic life, (3) providing for flushing or scouring flows as needed for aquatic habitat maintenance, and (4) providing for adequate fish passage for spawning and migratory (both upstream and downstream) purposes.

c. Management practices

Following is a list of management practices for fisheries protection that are available as tools to achieve the fisheries protection management measure.

Maintaining Minimum Flows - In the design, construction, and operation of structures, the minimum flow requirements to support aquatic and other water-dependent wildlife in downstream areas are addressed. Instream flows are usually maintained to protect or enhance one or a few harvestable species of fish (U.S. Fish and Wildlife Service, 1976). Other fish, aquatic organisms, and riparian wildlife are assumed to also be adequately protected by these flows.

Reduction of Flow Fluctuations - Seasonal discharge limits are established to prevent excessive, damaging rates of flow release. Limits are also placed on the rate of change of flow and river stage (as measured at a point downstream of the release) to further protect against damage to aquatic communities (U.S. Fish and Wildlife Service, 1976).

Fish Ladders - Fish ladders or similar types of structures should be provided to enable upstream and downstream passage of mature fish. Safe downstream passage of mature fish and fry should also be provided (see screens and barriers to intakes). Some fish, such as steelhead and cutthroat trout, migrate to the ocean more than one time during a lifetime, making necessary the provision for safe downstream passage of mature fish.

Screens and Barriers to Intakes - Fish can be prevented from moving into intakes for water pumps and turbines through the use of various types of screens or barriers (U.S. EPA, 1979). The survival chances of the downstream migrating fish can be increased by providing facilities that bypass them into a gatewall before they enter the turbines and direct them into a channel where they can move safely downstream. Fish can be diverted into holding tanks, collected, and transported away from the area of influence of the pumps, and then released back into the water.

Created Spawning Beds - When the effects of a dam on the habitat of anadromous fish are severe, constructed spawning beds may be designed into the project (Virginia Department of Conservation and Recreation, 1979). Additional facilities are then required to channel the fish to these spawning beds. These can include electric barriers, fish ladders, and bypass channels.

Fish Hatcheries - Only use in existing dams where adequate fish passage not possible or as compensation for loss of fish passage (e.g., fish population supplementation). Native stocks should be used wherever practicable.

When reservoirs flood spawning beds for anadromous fish, hatcheries are established to collect, kill, and obtain the roe from migrating fish (U.S. EPA, 1979). The roe is fertilized and then placed in the hatchery under controlled conditions until the fish are hatched. After having reached an appropriate stage in their development, the fish are released into the river downstream (or above dam to enhance reproduction in the upper watershed) of the dam to migrate back to the ocean.

Transference of Anadromous Fish Runs - This practice involves the inducement of anadromous fish to utilize different spawning grounds in the vicinity of the impounded waters. The extent of the spawning grounds to be lost by blockage of the river is assessed, and the feasibility of transferring existing anadromous fish runs affected by the structure to alternative tributaries is determined.

Environmental Design of Waterways (ENDOW) - This practice is described under the management practice for erosion and sediment control for construction.

5. Temperature Control and Aeration of Resorvoir Releases and Tailwaters

a. Problems to be addressed

This management measure is intended to increase dissolved oxygen levels from reservoir releases and tailwaters such that aquatic communities are maintained at levels of abundance, diversity, and function that existed prior to the construction of the dam. Changes in temperature are also addressed to prevent damage to fisheries.

One drawback associated with aeration of release water is the increased possibility of nitrogen supersaturation (Virginia Department of Conservation and Recreation, 1979). Water that discharges over the spillway of a dam and plunges into the spillway basin or plunge pool immediately downstream can become saturated with nitrogen, oxygen, and other gases. As the water plunges rapidly to depths, hydrostatic pressures increase. Entrained air is forced into solution by the pressure before it can rise to the surface and escape. Since air is approximately 80 percent nitrogen, the water becomes supersaturated with nitrogen. Nitrogen levels of 115 percent saturation have been documented to cause mortalities in fish.

b. Temperature and aeration management measure

The management measure for temperature control and aeration of reservoir releases and tailwaters is a combination of practices that restores dissolved oxygen levels to the levels existing prior to the construction of the dam, and maintains temperatures within ranges appropriate for desirable fishes.

c. Temperature control and aeration practices

Following is a list of management practices for temperature control and aeration of reservoir releases and tailwaters that are available as tools to achieve the temperature and aeration management measure.

The following information is taken from Tennessee's Section 319 (Clean Water Act) nonpoint source management program (Tennessee Department of Health and Environment, ca. 1990) unless otherwise noted.

Turbine Venting - Includes Hub baffle, draft tube wall baffle, compressed air through hub or wall. Modify air supply system to increase airflow.

Surface Water Pumps - Pumps surface water with higher dissolved oxygen downward to mix with deeper water as the two strata are entering the turbine.

High Purity Oxygen Injection - Used in combination with turbine venting or surface water pumps to add more oxygen.

Diffused Aeration or Oxygenation of the Reservoir - Used to lower concentrations of dissolved iron, manganese, and hydrogen sulfide.

Surface Water Intake - It may be feasible when constructing a new dam to provide upper elevation outlets to withdraw oxygenated surface water.

Multi-Level Discharge Systems - Multi-level discharge systems have been used successfully to mix waters from all levels of an impoundment to provide some control over the temperature and dissolved oxygen concentrations of the release waters (Virginia Department of Conservation and Recreation, 1979). This consists of providing a release structure with several intake structures at various depths, thus allowing controlled withdrawals from the different levels in the lake. Although this is normally provided during construction, such a structure can be added to an established impoundment. The use of such a system must be carefully considered and designed before implementation because multi-level discharge systems change the thermal structure of the impoundment as a function of withdrawal patterns.

Watershed Management - Control of all point and nonpoint sources of pollutants to achieve improved reservoir inflow quality.

Reregulation Weir - Used to capture hydropower release a short distance downstream and regulate flows to the desired level in reach below the weir.

Small Turbine - Provides continuous generation of power using small flow as opposed to peaking with large turbine units and high flow.

Pulsing - Provides pulse flow on a frequent basis to minimize draining or drying out of tailwater area. This technique requires off-peak operation and decreases the ability to produce peaking power where pulses are needed on a daily basis during certain parts of the year.

Sluice - Modification is made to existing sluice outlet to maintain continuous minimum flow.

Spillway Modification to Prevent Supersaturation of Gases - Spillways are designed or modified to cause the flows to be flipped as they are discharged. Upturned deflectors, cantilevered extension, "flip buckets," or "flip lips" can be designed for spillway terminal structures to deflect the water in a downstream direction and prevent the discharge from plunging straight down. Flows can even be caused to fan out into a thin sheet through the use of a flaring device.

Alternative measures to prevent nitrogen and other gases from reaching supersaturation levels include (1) decreasing spillway flows by providing additional reservoir storage, and (2) decreasing spillway flows by passing water through any available outlet conduit where turbulence will not entrain air.

d. Effectiveness information

The following information is taken from Tennessee's Section 319 (Clean Water Act) nonpoint source management program (Tennessee Department of Health and Environment, ca. 1990) unless otherwise noted.

Turbine Venting - Expect a 2 mg/L to 4 mg/L increase in dissolved oxygen. This is a proven method, but there is a question regarding cavitation resulting from venting.

While the actual design of the turbines is dependent upon many factors, the use of wedge-shaped deflector plates in the draft tubes, slightly below the turbine wheel will create a negative pressure in the flow and thus induce aeration (Virginia Department of Conservation and Recreation, 1979). Howell-Burger valves produce a spray discharge or release that reportedly (TVA) had reaeration efficiencies of 80 percent when the exit velocities exceeded nine meters per second.

Surface Water Pumps - Expect a 2 mg/L to 4 mg/L increase in dissolved oxygen.

High Purity Oxygen Injection - Used in combination with turbine venting or surface water pumps, dissolved oxygen levels can be increased beyond a 2 mg/L to 4 mg/L increase.

Watershed Management - Not expected to correct all dissolved oxygen depletion problems, but is used in combination with other techniques to provide better overall dissolved oxygen levels.

e. Cost information

The cost information provided in Table 6-1 is based upon data provided by the Tennessee Valley Authority (Tennessee Department of Health and Environment, ca. 1990).

6. Chemical and Other Pollutant Control for Construction

a. Problems to be addressed

This management measure addresses fuel and chemical spills associated with dam and levee construction, as well as concrete washout and related construction activities.

b. Management measure

The management measure for control of chemicals and other pollutants during the construction of dams and levees is a combination of practices that minimizes the risk of delivery to natural waterways of chemicals and other pollutants associated with the construction activities.

Table 6-1. Approximate Costs for Reservoir Release and Tailwater Practices (ca. 1990 dollars)

Practice	Cost Description
Turbine Venting	Capital cost can range from $15,000 to $1,000,000 per turbine unit. Annual operation and maintenance cost can range from $50,000 to $100,000 at a project like Norris Dam, and $10,000 to $20,000 at a project like Tims Ford Dam.
Surface Water Pumps	Capital costs about $200,000 per turbine unit. Annual operating cost about $25,000/unit. Operating cost consists primarily of power costs to run the pumps.
High Purity Oxygen Injection	Cost for an experimental system on one turbine unit is as much as $300,000, with an annual operating cost of about $50,000/unit.
Diffused Aeration the Reareation	Capital cost for a small non-power lake is $50,000 to $100,000 with an annual cost of $5,000 to $10,000.
Reregulation Weir	Capital cost of $500,000 to $750,000.
Small Turbine	Capital cost of $500,000 to $750,000, with operating costs at about the break-even point.
Pulsing	Annual cost can be as low as $5,000 to $10,000 where few pulses are needed. This technique requires off-peak operation, and may be subject to additional demand charge because it decreases ability to produce peaking power. Additional charge could range from $100,000 to $700,000 where pulses are needed on a daily basis during part of the year.
Sluice	Capital cost of $150,000, with annual operating cost of about $200,000 to $300,000.

Tennessee Valley Authority water use cost is based on the assumption of lost power-generating potential.

c. Management practices

Following is a list of management practices for chemical and other pollutant control that are available as tools to achieve the management measure for chemical and other pollutant control for construction.

Nutrient Management - The nutrient management measure for agriculture should be applied for all use of nutrients associated with construction (e.g., revegetation).

Pest Management - The pest management measure for agriculture should be applied for all use of pesticides associated with construction.

Spills - Spill containment and cleanup procedures should be in place to address fuels and chemical spills.

Equipment Washout - Treatment or detention of concrete washout and related washout should be provided such that direct entry of washout contaminants to surface waters is prevented.

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III. SHORELINE EROSION

A. Introduction

This section addresses NPS problems related to shoreline erosion in bays, estuaries, tidal streams, and watersheds within the coastal zone. It does not address open coastal shorelines as erosion into open ocean is not likely to cause NPS problems.

Numerous factors affect the processes along the shore zone (see section D on planning and design considerations). Eroding shorelines and streambanks contribute NPS sediment loads and nutrients to the neighboring waterway. The sediment may have beneficial or harmful impacts. Beneficial impacts include beach nourishment, sandbar creation or nourishment of wetlands that combat erosion. Adverse water quality impacts (turbidity, BOD, sediment), burial of shellfish beds, smothering of submerged aquatic vegetation (SAV), impacts to spawning areas and property loss are several detrimental impacts of erosion. Eroding shorelines also contribute nitrogen, phosphorus and other pollutants to the waterbody.

[EPA requests additional information addressing more arid areas and shoreline measures further upstream in coastal watersheds.]

B. Specific NPS Problems

This section focuses on controls for erosion caused or exacerbated by human land use or water activities. Erosion rates ranging from 1 to 20 feet per year are typical in many coastal areas where the fastland along the shore is itself composed of older deposits of interbedded sand, silt, and clay. This type of eroded shoreline sediment may often contain adsorbed nutrients. It has been demonstrated that nutrient loadings from eroded shoreline sediments are significant. High nitrogen concentrations have been found in upper bank sediments, especially on eroding farm fields. For 14 sites in the Virginia portion of the Chesapeake Bay, for example, average loading rates were 0.51 lbs/ton for nitrogen and 0.35 lbs/ton for phosphorous of eroded sediments from the estuarine shorelines. Shoreline erosion can also adversely affect living bay resources by increasing sedimentation rates and turbidity.

C. Management Measures

To address the NPS problems identified in Section B above, shoreline management measures in the coastal bay/estuarine system should incorporate the upland, shore zone and nearshore regimes in order to accomplish the following objectives:

(1) Avoid the generation of NPS pollution from shoreline erosion during a "25-year" event. For fluvial environments (upstream), this event is the "25-year" flood. For estuaries or coastal bays, this event includes tidal storm surge and wind induced wave action.

(2) Achieve no significant sedimentation from the shoreline source and minimal visible loss of shoreline.

(3) Do not transfer erosion energy to or negatively impact other shoreline areas due to management actions. Minimize impacts of controllable erosion potential (form wave energy and overland storm runoff) such as boat wakes or channelized runoff.

(4) Protect natural shoreline vegetation and aquatic habitats such as wetlands, submerged aquatic beds, riffle pool complexes, and riparian habitat. Restore damaged habitat as a shoreline stabilization practice when conditions allow.

Nonstructural management practices are preferred. Structural shoreline erosion practices should be used only in areas where nonstructural practices are ineffective (i.e., areas with high wave energy). Satisfaction of all of the measures for any reach may be difficult. For example, management practices that are effective for certain water quality objectives may be ineffective or even counter productive in achieving other water quality objectives. For instance, even though bulkheads effectively reduce sediment input, they provide little benefit for restoration of habitat, and in some cases, they have caused other NPS problems due to leaching of chemical wood preservatives from the structure.

D. Planning and Design Considerations to Select Management Practices

The following process outlines an approach for selecting the appropriate management practices to achieve the management measures described in Section C above.

(1) Identify extent of erosion problem. The rates of shoreline erosion can be estimated by comparing present and historic shoreline locations through use of maps, photographs, or pre-existing surveys. Additional site-specific information on the bank height of the fastland can be considered with the historic recession rate, to identify areas contributing the greatest volumes of sediment and related pollutants (i.e., agricultural lands).

(2) Evaluate the effects of the adjacent land use. It is important to consider both the adjacent land use activities and water use activities (such as boat wake) that may cause or exacerbate shoreline erosion problems. Therefore, the shoreline management practice should be implemented in conjunction with the management measures prescribed in the earlier chapters of this guidance. (See Chapters on Agriculture, Forestry, Urban, and Marinas.)

(3) Evaluate the natural causes of shoreline erosion. Shorelines along rivers, bays, and estuaries may degrade gradually due to the daily action of tides, waves, and currents. Alternatively, only the most severe storm conditions may cause loss of fastland or wetlands along the shore. Shoreline erosion in coastal areas is

strongly related to an area's wave climate. A relatively simple measure of potential wave climate is the measure of fetch (the distance over open water that winds can generate waves). In coastal bays and estuaries, the fetch is limited to the distance to the opposite shore. For instance, a low energy shore may have a short fetch across a creek but a very long fetch toward the northeast (i.e., storm exposure). Further upstream, the driving factor may be overland runoff and velocities generated by storm events. The Great Lakes shorelines, on the other hand, may have an almost unlimited fetch due to their great widths and deep water. Selection of the appropriate erosion control measure should be directly related to the extent of the problem and an understanding of the underlying causes.

(4) Determine limits of the reach. A reach is a segment of shoreline wherein the erosion processes and responses are mutually interactive. For example, appreciable littoral sand supply would not pass the boundaries of the reach. A reach may also be defined as a shoreline segment wherein manipulation of the shoreline within that segment would not directly influence adjacent segments. That is, measures implemented on an individual property should minimize impacts to neighboring properties in the reach.

(5) Identify wetlands, riparian, submerged aquatic beds, and other nearshore habitats in the shoreline area of concern. Allow adequate flow and circulation to protect the functional value of adjacent wetlands or other aquatic habitat. If wave climate and other erosive conditions allow, consider nonstructural measures such as restoring pre-existing habitat or using a combination of low profile structures with re-establishing aquatic habitats.

E. Management Practices

This section discusses management practices that are available as tools to achieve the shoreline erosion management measures. There are various practices available to achieve the management measures. These practices range from biological and physical engineering processes to zoning/restrictions. The planning process described above is essential in selecting the appropriate management practice. Eroding areas may be influenced by wind-driven wave action, tidal fluxes, storm discharges from land, operation of water craft, or various land use activities. Selection of the appropriate management practice depends upon a comprehensive understanding of the driving forces behind shoreline erosion. The three basic categories of shoreline erosion control measures are:

(1) Nonstructural: includes bank grading and beach nourishment. Also include restoration and re-vegetation of wetlands (emergent marsh, shrub-scrub, or forested) and other vegetation re-establishment (see chapter on wetlands/riparian restoration for additional information).

(2) Combinations and Bioengineering: includes mixed use of structural and nonstructural approaches such as biological engineering practices, including live staking, live fascine, brushlayer, branchpacking, brushmatresses; also headland breakwaters and beach nourishment with vegetation re-establishment, bank grading and beach fill, groins with vegetation re-establishment.

(3) Structural: includes bulkheads, stone revetments, seawalls, groins and breakwaters.

There are various methods and combinations of methods available from which to choose once a decision has been made to stabilize a shoreline. The method or methods selected must be compatible with other methods (if combinations are selected) and with the objectives of the management strategy. Some methods, with price estimations, are as follows:

1. Nonstructural

a. Bank grading

Bank grading is basically the reshaping of the upper shoreface of a sediment bank to enhance upland vegetative growth. This method is typically used in combination with other methods described below. The cost for bank grading ranges from $2.50 to $5.00 per cubic yard of material moved.

b. Marsh vegetation

The use of marsh vegetation to abate shoreline erosion can be attractive in terms of cost. The initial cost of creating a substantial marsh grass fringe ranges from $30.00 to $60.00 per linear foot, depending on the desired width. Yearly maintenance of a marsh fringe generally involves fertilization and debris removal as well as additional planting. Not all estuarine shorelines are suitable for treatment with marsh grass plantings. Shorelines exposed to high energy categories would be excluded from the vegetative alternative due to more frequent damaging wave action (Knutson, 1977). However, it may be possible to establish a marsh fringe under these conditions in conjunction with some type of offshore breakwaters or other wave damping device.

c. Other re-vegetation

(See Wetlands and Riparian area chapter on restoration for additional information beyond emergent marshes like restoring vegetation in areas further upstream such as bottomland forest or scrub-shrub.)

d. Beach nourishment

There are a variety of techniques available to artificially re-nourish beach systems, however the source, quality, and grain size of material used for re-nourishment needs to be economically evaluated in order to determine its suitability for placement. Truck hauling, cutterhead pipeline dredging, hopper dredging, and combinations of these techniques can be used to effectively re-nourish a beach. In evaluating the quantity of material needed to construct the required beach width, the volume of the material needed to fill the offshore zone where the profile is not in dynamic equilibrium must be considered. If this subaqueous portion of the shore is not filled, the erosion rate of the new material might accelerate until the profile adjusts to the dynamic equilibrium condition. In this case the visible portion of the beach may be displaced offshore with little chance of returning.

The location of the optimum placement of material is another important aspect of beach re-nourishment. This location is mostly dependent on the physical characteristics of the shoreline and the desired result of the project. Placement on the visible portion of the beach can occur in the form of a dune and/or berm construction. The benefits of this type of erosion control measure are readily observed due to the increased beach width for recreation and as a storm protection method. However the berm life might be of short duration due to the previously mentioned processes. Other placement options exist in the foreshore zone and in an offshore zone in the form of a bar.

The cost for beach nourishment varies widely based on the distance to the sand source, the type of equipment used, and the method of placement.

2. Combinations and Bioengineering

Soil bioengineering provides an array of practices that are effective for both prevention or mitigation of NPS problems. This applied technology combines mechanical, biological and ecological principles to construct protective systems that prevent slope failure and erosion. Adapted types of woody vegetation (shrubs and trees) are initially installed as key structural components, in specified configurations, to offer immediate soil protection and reinforcement. Soil bioengineering systems normally utilize cut, unrooted plant parts in the form of branches or rooted plants. As the systems establish themselves and develop roots (fibrous inclusions), they provide an additional resistance to sliding or shear displacement in streambanks or upland slopes.

Specific soil bioengineering practices contributing to these systems include live staking, live fascine, brushlayer, branchpacking, brushmatresses, joint planting, live cribwall and live gully repair. Environmental benefits include diverse and productive riparian habitats, shade and organic additions to streams or small water bodies, cover for fish, aesthetic values and water quality.

Soil bioengineering systems contribute to the following partial list of desired effects:

- Protection of soil surface against wind, rain and frost erosion
- Improved water quality through higher interception of rainfall, and stabilization of soil against erosion.
- Increased shade and reduced temperatures in soil, water, and air layers near ground surface.
- Improved soil permeability.
- Improved riparian and aquatic habitat.
- Improved soil enrichment (decaying organics and symbiosis) and improved water retentive capacity of soil.
- Improved subsurface drainage.
- Reduced wave action.
- Stabilization of slopes prone to shallow failure.
- Control of rills and gullies.
- Filtration of runoff sediment.
- Restoration of aesthetically degraded areas of protection of existing aesthetic attributes.
- Minimum disturbance of existing desired site conditions.
- Reduced operation and maintenance costs.

3. Structural

a. Revetments

The primary purpose of a revetment is to protect the land and upland areas behind the structure from erosion by waves and currents. The stability of a revetment depends on the underlying soil conditions and should therefore be constructed on a stabilized slope. Erosion may continue or accelerate on an adjacent shore if it was formerly supplied with material eroded from the now protected area. The three basic components of a revetment are the armor layer which absorbs the wave energy, the underlying filter layer supporting the armor layer, and the toe protection to prevent displacement of the armor units.

Revetments are commonly constructed of graded quarrystone, precast interlocking blocks, gabions, stacked bags, or special mats. The size and quantity of the construction material and therefore the price of a structure varies with the energy category of the shoreline. Important design considerations include use and overall shape of the structure, location with respect to the existing shoreline, structure length and height, soil stability, normal and storm surge water elevations, availability of construction materials, economics, environmental concerns, institutional constraints, and aesthetics. Average costs for revetments constructed from Class II riprap range from $175 to $225 per linear foot.

b. Seawalls and bulkheads

A seawall is a structure that is built to protect the landward side of the wall from damaging tidal elevations and wave attack. Seawalls may be constructed with concrete, steel sheet piles or wood. Bulkheads have two functions. The first is to retain or prevent sliding of material seaward, and the second, to protect the upland against damage from wave action. Seawalls or bulkheads may be used in all three energy categories; however, the effects of these types of structures on the entire reach of shoreline must be evaluated. The costs of bulkheads varies with the energy category and the locality of the project. Typical costs (for timber bulkheads) are $200.00 to $275.00 per linear foot. These costs may vary $25% to 40% depending on the location of the project.

c. Groins

A groin is a shore protection device, usually oriented perpendicular to the shore, that may consist of one or more structures. The purpose of these structures is to trap littoral drift, thus creating a beach on the updrift side of the groin. Careful planning and design of a single groin or groin field is necessary to avoid adverse erosional effects on the downdrift side of a project. Groin fields usually require maintenance in the form of beach nourishment if the volume of longshore drift is insufficient to bypass around the groin tip. The cost per linear foot varies from $35 to $180 depending on the wave energy category and the locality of the project.

d. Breakwaters

The functions of breakwaters is to intercept incoming waves, dissipate their energy, and thus form a low-energy shadow zone on the landward side. This reduction in wave energy reduces the ability of sediment transport. Sand moving along the shore is therefore trapped behind the structures and accumulated. Breakwaters are often placed as segmented structures that allow for the protection of longer reaches of shoreline for less cost.

The headland control concept is to take advantage of the shoreline's natural movement toward equilibrium. Less resistant shorelines between stable headlands continue to erode until the equilibrium point is reached. As the shoreline reaches a stable configuration, a shallow embayment is formed between the headlands. This equilibrium state will depend on the wave climate and the sediment transport mechanisms acting on the shoreline. By maintaining natural headlands as focal points for stabilization or by inducing artificial ones, the shoreline should stabilize between these headlands. An extensive eroding shoreline reach may be controlled by structurally protecting only about 30 percent of the total reach. Breakwaters and headland breakwaters average $90.00 to $350.00 per linear foot.

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CHAPTER 7. MANAGEMENT MEASURE FOR WETLANDS PROTECTION AND BIOFILTRATION

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I. INTRODUCTION

A. Overview

The preceding five chapters of this guidance have specified management measures that represent the most effective systems of practices to prevent or reduce coastal nonpoint pollution from five specific categories of sources. Below, we specify a management measure that, in contrast, applies to a broad variety of sources. This measure addresses wetlands protection, riparian zone protection, and vegetative filter strips.

The loss of wetland and riparian areas as buffers between uplands and the parent waterbody allows for more direct contribution of NPS pollutants to the aquatic ecosystem. Often, loss of these systems is concomitant with other alteration of land features which increase drainage efficiency. As a result, excessive fresh water, nutrients, sediments, pesticides, oils, greases, and heavy metals from nearby land use activities may be discharged through storm events and seepage to the water column and downstream to the coastal waters without the benefits of filtration and attenuation that would normally occur in the wetland (riparian area), if present.

A study performed in the southeastern United States Coastal Plain illustrates, dramatically, the prevention role that wetlands and riparian areas play. The study examined the water quality role played by mixed hardwood forests along stream channels adjacent to agricultural lands. Based on the input/output budgets, these streamside forests were shown to be effective in retaining N, P, Ca, and Mg. It was projected that total conversion of the riparian forest to a mix of crops typically grown on uplands would result in a twenty-fold increase in NO_3-N loadings. (Lowrance, et al 1983).

Land use activities that alter the structure or hydrologic regime of wetlands and riparian areas may contribute significantly to NPS problems. When riparian vegetation is removed or degraded, the banks of streams, bays, or estuaries are destabilized and become more vulnerable to erosion from storm events, wave action, or concentrated runoff. Floodplain wetlands are very efficient in retaining sediments when the wetlands come in contact with flood waters. However, when the hydrology of these same wetlands is modified, such as by channelization, they may become exporters of sediments instead. Tidal wetlands perform many water purification functions. However, when they are severely degraded such as when drained by tide gates, they have been shown to be a source of nonpoint pollution. When such tidal wetlands underlain by a layer of organic peats are drained, the rapidly decomposing soils may release sulfuric acid that may significantly reduce pH in surrounding waters.

Wetlands and riparian zones also offer important advantages in habitat protection. Protection and protective use of wetlands and riparian zones should allow for both nonpoint source control and other corollary benefits of these natural aquatic systems. Land managers should, therefore, utilize proper management techniques to protect and restore the multiple benefits of these systems. For these reasons, EPA recommends that land managers should factor both protection and restoration of wetlands and riparian areas into their NPS and coastal management programs.

Vegetative filter strips can also provide important benefits in protecting coastal waters from nonpoint source pollution. As discussed below, properly designed and maintained vegetative filter strips can substantially reduce the delivery of sediment and some nutrients to coastal waters from nonpoint sources.

B. Definitions

EPA provides definitions for wetlands, riparian areas, and vegetative filter strips below. These definitions are provided for clarification purposes only. Identifying the exact boundaries of wetland or riparian areas is less critical than identifying ecological systems of concern. In fact, in many cases, the area of concern may include an upland buffer adjacent to sensitive wetland areas to protect them from excessive nonpoint source impacts.

1. Wetlands Definition

Below is the regulatory definition used by EPA and the U.S. Army Corps of Engineers.

> "Those areas that are inundated or saturated by surface or groundwater at a frequency and duration to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally includes swamps, marshes, bogs, and similar areas."

Wetlands are generally waters of U.S. and as such afforded protection under the Clean Water Act. Although we are focusing on the function of wetlands in reducing nonpoint source pollutants, it is important to keep in mind that they are ecological systems that perform a range of hydrologic and habitat functions as well as transforming or trapping pollutants.

2. Riparian Area Definition

Simply stated, a "riparian area" is the vegetated area along a waterbody. There is no one well-established definition; however, these areas are typically part of a "riparian system", a complex assemblage of organisms and their environment existing adjacent to and near waterbodies. Riparian areas are zones that are strongly influenced by an adjacent aquatic environment, have linear characteristics, and experience hydrological fluxes at least once within the growing season. These areas are associated with bays, estuaries, rivers, lakes, reservoirs, springs, seeps, and ephemeral, intermittent, or perennial streams. They occur as complete ecosystems or as an ecotone between aquatic and terrestrial ecosystems, but have distinct vegetation and soil characteristics because of high soil moisture. Topographic relief and presence of depositional soils most strongly influence the extent of water regimes and associated riparian zones. Riparian ecosystems may be classified as uplands, wetlands, or some mixture of the two. Generally, riparian wetland soils are high in clay content, organic matter, water-holding capacity, and natural fertility. The term "riparian ecosystem" does not convey definitive boundaries.

Riparian zones differ functionally from vegetative filter strips in that riparian zones have the ability to filter subsurface as well as surface flows, while filter strips are primarily involved in the filtration of surface flows.

3. Vegetative Filter Strips Definition

Vegetative filter (or buffer) strips (VFS) are permanent, maintained strips of planted or indigenous vegetation located between nonpoint sources of pollution and receiving water bodies for the purpose of removing or mitigating the effects of nonpoint source pollutants such as nutrients, pesticides, sediment and suspended solids. VFS employ strips of perennial grasses, legumes, and/or hay crops to act as a filter to remove sediment and suspended solids, to reduce runoff velocity, and to facilitate rain absorption into the soil.

The pollutant-removal mechanism of the filter strip results from a combination of functions, including a change in flow hydraulics and the process of neutralizing or assimilating pollutants. The physical process of removing pollutants involves filtering particulates and sediment through vegetation, its settling and deposition, and, in some cases, uptake by vegetation.

[EPA REQUESTS COMMENT: Should this chapter also address other aquatic resources that are important to maintaining water quality? A proposal to include two other categories of aquatic resources follows:

> Intertidal Flats: trap sediments and reduce the amount of suspended sediments in adjacent coastal waters; flats also influence the chemistry of adjacent coastal waters.
>
> Submerged Aquatic Vegetation: tend to dampen wave energy thereby promoting sedimentation. This in turn reduces amount of suspended sediments in the water.]

II. MANAGEMENT MEASURE FOR WETLANDS, RIPARIAN AREAS, AND VEGETATIVE FILTER STRIPS

Wetlands, riparian areas, and vegetative filter strips are important components of systems to control nonpoint sources of pollution. A principle of protection involves minimizing impacts to wetlands and riparian areas serving to control nonpoint source pollution, by maintaining existing functions of the wetlands and riparian areas, including: vegetative composition and cover; flow characteristics of surface and ground water; hydrology and geochemical characteristics of substrate; and species composition. In addition, vegetated filter strips have wide applicability and should be broadly employed to protect coastal waters from sediments and nutrients.

III. MANAGEMENT PRACTICES FOR WETLANDS

A. Benefits of Wetlands in NPS Control

Wetlands provide many beneficial uses including habitat, flood attenuation, water quality improvement, shoreline stabilization, and groundwater recharge and discharge. Wetlands can play a critical role in reducing nonpoint source pollution problems in open bodies of water by trapping and/or transforming pollutants before releasing them to adjacent waters. Their role in water quality includes processing, removing, transforming and storage of such pollutants as sediment, nitrogen, phosphorus, pesticides, and certain heavy metals in exchanges with adjacent waters or with waters that pass through the wetland. Wetlands are also major exporters of carbon and nutrients.

A wetland's position in the landscape, both in relation to the pollutant source and the wetland's position in the watershed, affects its water quality functions. Wetlands in the upper reaches of the watershed are believed to have the greatest overall impact on water quality because a larger percentage of water in the river has contact with adjacent wetland environments. It has been estimated that the first 20 meters of a wetland (both riparian and salt marshes) immediately below the source of nonpoint source pollution may be the most effective filter.

In its June 18, 1990, "National Guidance: Wetlands and Nonpoint Source Control Programs", EPA formally recognized and advised EPA Regional and State program managers of the importance of linking NPS and wetland program activities to enhance the effectiveness of both. That linkage can be extended to include the State coastal zone programs to address the new NPS requirements in the Coastal Nonpoint Pollution Control Program. This linkage between wetlands and nonpoint source programs is particularly appropriate given the special emphasis placed on wetlands within the enhancement grants provisions of the CZMA.

B. Management Practices to Protect and Restore Wetlands

There are two overall management practices for wetlands: 1) Establish a preference for protection of existing wetland systems adjacent to parent waterbodies (impact avoidance), 2) Identify wetland areas in a watershed to target for restoration for their NPS reduction and other benefits.

1. Management Practice - Protection

Establish a preference in NPS programs for protecting wetlands (impact avoidance). Avoiding impact to wetlands is fundamental to pollution prevention. A principle emphasizing protection advocates avoiding impact to wetland areas when practicable to maintain existing beneficial uses (functions) and to meet existing water quality standards.

(1) **Consider wetlands and riparian areas on a watershed or landscape scale so that they form a continuum of filters before waters enter an estuary.** This practice includes basin wetlands, riparian buffers and wetlands adjacent to streams and rivers that together serve important NPS functions to buffer the estuary from the sources of NPS pollution.

(2) **Identify wetlands with significant nonpoint source control potential within coastal watersheds.**

(3) **Existing wetlands should not be altered to maximize their water quality function at the expense of their other functions as waters of the U.S.** For example, the following practices should be avoided: location of stormwater ponds or sediment retention basins within a wetland; or extensive dredging and plant material harvest as part of nutrient or metals management in natural wetlands.

(4) **Conduct permitting, licensing, certification, and nonregulatory NPS activities in a manner that protects existing beneficial uses (functions) and meets applicable water quality standards for wetlands.** Because almost all wetlands are "waters of the U.S." they are provided the same protection under water quality standards as other waters. EPA has issued guidance for States to develop or improve standards for their wetlands no later than 1993 (U.S. EPA. 1990). These standards include not only chemical numeric criteria, but biological and physical narrative or numeric criteria designed to protect the designated uses (functions) of the wetland.

(5) **Use upland buffers around existing wetlands when necessary to prevent NPS impairment to wetlands.** For example, if sediment runoff is a problem in an area, consider the assimilative capacity of a wetland area to determine what other measures such as upland buffers are needed to handle the volume of sediment.

a. <u>Effectiveness of protection practices</u>

<u>Inorganic solids (sediments)</u> - The role of wetlands in trapping suspended sediments is well documented. Due to their relatively low slope, wetlands positioned between sediment sources and open bodies of water, such as a bottomland hardwood forested wetland, can remove moderate amounts of sediment from turbid runoff without ecological damage to the wetland. In addition, vegetated wetlands along streams or rivers stabilize soils and help to minimize sediments transported downstream to the estuary. Sediment removal rates of 80 to 90% are common in floodplain wetland and riparian areas.

<u>Fecal coliform</u> - Bacteria are generally associated with particulates in the water column. When sediments settle out in wetland areas, a long retention time of the particulates promotes die off of the bacteria.

Nutrients - The vegetation in a wetland is important both for uptake of nutrients and as a carbon and litter source for the soil. The carbon, in turn, fuels the immobilization of phosphorus and nitrogen by microorganisms in the soil and the transformation of nitrogen into a gaseous form through denitrification. The layer of litter along the riparian area surface also serves to trap sediments which in turn also captures the particulate phosphorus.

Nitrogen - The effectiveness of wetlands in removing and transforming nitrates varies with retention time of the water in the wetland and the wetland type. Nitrogen is removed primarily from ground water flowing near the surface and is transformed and released as a gas. The net effect of wetlands is to reduce nitrate concentrations. However, nitrate may be flushed from wetlands during periods of high flow (Brown, 1985) (Johnston, Detenbeck, Niemi, 1990).

Riparian vegetation that borders first order streams appears to most efficiently remove nitrate due to contact of a large percentage of the water with the wetland or riparian area. In higher order streams, the primary contact with wetlands occurs during flooding periods (e.g., palustrine wetlands) or when water is impounded (Whigham and Chitterling, 1988). Some examples of effectiveness of nitrogen removal are (Whigham and Chitterling, 1988; Johnston, 1990):

Vegetation Type	Removal
Cypress swamp in Louisiana:	49%
Riparian zone in Piedmont of Georgia:	68%
Cypress dome in Florida:	74%
Riparian forest of North Carolina coastal plain:	86%
Riparian forest of Maryland inner coastal plain	89%

Phosphorus - The role of wetlands in retaining phosphorus has shown mixed results, depending on the wetlands location. Because total phosphorus is sorbed to fine silts and clays, the sediment retention functions of wetlands tend to trap phosphorus as well. In contrast, studies have shown that phosphorus is not efficiently trapped in upland riparian areas because the fine sediments with attached phosphorus either move through the riparian zone, or particulate phosphorus is trapped and released as dissolved phosphorus (Cooper, 1986; Whigham and Chitterling, 1988).

The most important wetlands for phosphorus removal appear to be palustrine wetlands further down the watershed from first order streams. In addition, phosphorus removal appears to be greatest where the surface water comes in contact with the wetland vegetation and litter zone.

Riverine wetlands have also been shown to reduce both nitrogen and phosphorus, but it depends on contact time with the wetland usually associated with flooding events. For example, one study shows a 10-17 percent retention of phosphorus when 50% of the wetland is inundated, and a 46-69 percent retention when more than 50% is inundated. When surface flow is diffuse rather than channelized, fine silts and clays along with attached phosphorus are deposited in wetlands along rivers.

b. Programs to protect wetlands

In highly developed urban areas, the riparian area may virtually be destroyed by construction, filling in wetlands, channelization or other significant alteration. In agricultural areas, the wetland and riparian systems may either involve no management, use of the area for grazing, or removal of native vegetation and replacement by annual crops or perennial cover. Significant hydrologic alterations may have occurred to expedite drainage of farmland. Agricultural impacts to riparian systems may involve clear cutting, filling for stream crossings, and other activities that may significantly affect hydrology and sediment deposition in the riparian zone and the neighboring stream, lake, or estuary. Similar destruction or significant impact may occur as a result of various other activities such as highway construction, silviculture, surface mining, deposition of dredged material, and excavation of ports and marinas. All of these activities have the potential to degrade or destroy the water quality functions of wetlands and riparian areas and may generate additional nonpoint source problems as well.

General approaches - There are many programs, both regulatory and nonregulatory, to protect wetland functions. The list includes elements such as:

Acquisition - Obtain easements or full acquisition rights for wetland and riparian areas along impaired streams, bays, and estuaries. There are numerous federal programs such as Soil Conservation Service Wetlands Reserve and Fish and Wildlife Service National Waterfowl Management Plan funding that can provide assistance for acquiring easements or full purchase.

Zoning - Control activities negatively impacting these targeted areas through special area zoning and transferable development rights.

Water Quality Standards - Put water quality standards in place for wetlands. Factor natural water quality functions into designated uses for wetlands, and include biological and hydrologic criteria to protect the full range of wetland functions.

Regulation and Enforcement - Establish, maintain, strengthen regulatory and enforcement programs. Include nonpoint source conditions in permits and licenses under CWA §401 and §404, state regulations, etc.

Restoration - Maximize opportunities to set aside and restore wetland and riparian areas using USDA's Conservation Reserve and Wetlands Reserve Programs and other federal assistance.

Education and Training - Educate farmers and urban dwellers and other agencies on the role of wetland and riparian areas in protecting water quality and BMP's for restoring stream edges. Teach courses in simple restoration techniques for landowners.

Comprehensive watershed planning - Establishes a framework for multi-agency program linkage and presents opportunities to link implementation efforts aimed at protection or restoration of wetlands or riparian areas. A number of State and Federal agencies carry out programs with compatible mechanisms and objectives to NPS implementation goals in the coastal zone. For example, the Corps of Engineers administers the CWA Section 404 program; USDA implements Swampbuster, Conservation Reserve and Wetlands Reserve Programs; EPA, the COE and States work together to perform Advance Identification of wetlands for special consideration (Section 404); and States administer the CZM program which provides opportunity for consistency determinations and the CWA 401 certification program which allows for consideration of wetland protection and water quality objectives.

As an example of a linkage to protect nonpoint source and other benefits of wetlands, a State could determine under CWA Section 401 or a State regulatory program that a proposed activity in wetlands is inconsistent with State water quality standards or the objectives of the established watershed strategy. Or, if a proposed permit is allowed contingent upon mitigation by creation of wetlands, such mitigation might be targeted in areas defined in the watershed assessment as needing restoration. Watershed or site specific permit conditions may be appropriate (i.e., specific buffer widths/structure based on adjacent land use activities). Similarly, USDA's Conservation or Wetlands Reserve Programs could provide landowner assistance in areas identified by the NPS program as needing particular protection or riparian zone re-establishment.

c. Examples from State and local programs

Baltimore County, Maryland, adopted a bill to protect the water quality of streams, wetlands, and floodplains that requires forest buffers for any activity that is causing or contributing to pollution including: nonpoint pollution of the waters of the State in that county; erosion and sedimentation of stream channels; or degradation of aquatic and riparian habitat.

The county has management requirements for the forest buffers including wetlands and floodplains tha specify limitations on alteration of the natural conditions of these resources. The provisions also call for public and private improvements to the forest buffer to abate and correct water pollution, erosion and sedimentation of stream channels, and degradation of aquatic and riparian habitat.

Washington has developed draft wetland water quality standards to protect wetlands that include enforceable provisions to address stormwater and nonpoint discharges into wetlands. The primary means for requiring compliance with standards will be through waste discharge permits, rules, orders, and directives issued by the Department of Ecology. In cases where BMPs are not being implemented, the Department may pursue voluntary corrective action, orders, directives, permits, or civil or criminal sanctions to gain compliance with standards.

2. Management Practice - Restoration

When conditions are appropriate, restoration of wetlands and riparian areas should be preferred over structural management measures to gain NPS and additional benefits for waters of the U.S. Restoration of wetlands refers to re-establishing a wetland and its range of functions where one existed previously by re-establishing the hydrology, vegetation, and other habitat characteristics.

Restoration of wetlands and riparian areas in the watershed have been shown to result in NPS benefits.

A restoration management practice should be used in conjunction with other measures addressing the adjacent land use activities and in some cases water activities as well.

A preference should be established for restoring multiple ecological functions of waters of the U.S. When conditions are appropriate, restoration of the aquatic ecosystem is a wholistic approach to water quality that addresses NPS problems while meeting the goals of the Clean Water Act to protect and restore the chemical, physical, and biological integrity of the nation's waters. Full restoration of complex wetland and riparian functions may be difficult or expensive, based on site conditions, complexity of system to be restored, availability of native plants, etc. The following are general approaches to factor into wetland and riparian restoration projects for NPS benefits. Specific practices under these approaches must be tailored to specific ecosystem type and site conditions. The preceding chapter's section on shoreline erosion also discusses restoration in the context of mitigating shoreline erosion in wetland or riparian areas.

(1) **Restoration of hydrology is a critical factor to gain NPS benefits and increase probability of successful restoration.**

(2) **Restore native plant species when possible either allowing natural succession or through selected planting.** When consistent with pre-existing wetland type, plant a diversity of plant types, or manage natural succession of diverse plant types rather than planting monocultures. Deep rooted plants may work better than grasses for transforming nitrogen because they reach the water moving under the surface. For forested systems, a simple approach to successional restoration would be to plant one native tree species, one shrub species, and one ground cover species and allow natural succession to add diversity of native species over time.

(3) **When possible plan restoration as part of naturally occurring aquatic ecosystems. Factor in ecological principles when selecting sites and designing restoration such as:** seek high habitat diversity and high productivity in the river/wetland systems; look for opportunities to maximize habitat connectedness (between different habitat types); and restore to provide refuge or migration corridors along rivers between larger patches of upland habitat -- animals are most likely to colonize new areas if they can move upstream and downstream under cover.

(4) **Seek a range of pre-existing functions:** Maximize the wetland functions restored to replicate pre-existing functions. In addition to pollutant transformation, functions to restore may include flood control, food chain support, and habitat. Additional measures (such as adjacent land use BMPs) and

monitoring should be used to ensure that there are no detrimental impacts to wildlife if loadings include pollutants toxic to wildlife. See chapters on Agriculture, Silviculture, and Urban Activities for specifications of applicable management measures.

a. Effectiveness of restoration practices

The ultimate goal of wetland and riparian restoration is to restore ecosystems as opposed to buffer strips, but this may evolve over time through managed succession.

- An ecosystem should be self-sustaining, whereas buffer strips are generally not.
- Restore targeted water quality functions.
- Restore a range of wetland or riparian functions that used to exist at that site.
- Do not degrade value of surrounding natural habitats through uncontrolled expansion of exotic species.

See section II.B.1.b. for typical removal effectiveness of NPS pollutants by these systems.

b. Planning and siting considerations

A relatively high degree of success has been achieved with revegetation of coastal, estuarine, and freshwater marshes because hydrology is relatively easy to restore, native seed stocks are often present, and natural revegetation often occurs. Marsh vegetation also quickly reaches maturity in comparison with shrub or forest vegetation. Success rates for marshes seem to be correlated to proper elevation. Spartina patens has been difficult to restore due to sensitivity to elevation requirements. Spartina alterniflora restoration has succeeded where the elevation and soils are within a given range (depending on the site) and the wave conditions are not extreme (Walker, 1988). Since many of the factors vary with site conditions and wetland type, a careful review of existing literature and case-studies (both successful and unsuccessful) is needed.

Planning:

- Identify sources of NPS problems. Consider the role of restoring sites within a broader landscape context.

- Set goals for the restoration project based on location and type of NPS problem; when practical, replicate multiple functions while still gaining NPS benefits.

- Locate historic accounts (i.e., maps, descriptions, photographs) to identify sites that were previously wetland or riparian. These sites are likely more suitable for restoration if the original hydrology has not been permanently altered.

Site considerations:

It is difficult to establish any single methodology for identifying potential restoration sites on a national scale. Project goals, NPS problems, and site specific parameters all must be considered in restoration design. The following list identifies some important information or considerations for siting a restoration project. This should not be regarded as the final word on considerations, but should be adapted as appropriate for a given project or proposal.

- Site history. Past uses of site including past functioning as wetland.
- Topography. Surface topography including elevations of levees, drainage channels, ponds, islands.
- Slope and tidal range.
- Existing water control structures. Location of culverts tide gates, pumps, and outlets.
- Hydrology. Hydrologic conditions affecting the site. Wave climate, currents, overland flows and flood events.
- Sediment budgets. Sediment inflow, outflow, and retention.
- Soil. Description of existing soils with analysis of suitability for supporting wetland plants.
- Existing (or native) vegetation.
- Salinity.
- Timing of restoration project.
- Potential impact to site from adjacent human activities.

c. Cost considerations for restoration

The cost of wetland and riparian restoration projects will vary significantly depending on the degree of grading, hydrologic changes required, the availability and cost of native vegetation, and whether any physical structures are needed to help ensure success.

An example of restoration costs for an east coast coastal marsh includes the following:

- If substrate is already sufficient and minimal site preparation is required, costs average less than $30.00 per linear foot to plant a single marsh species (Spartina).
- If more extensive bank grading, preparation, or fill is required, the same marsh restoration costs may range from $60.00 to $100.00 per linear foot.
- If a protective structure, typically a low-crested sill, is necessary to reduce erosional forces, the costs can range from $120.00 to 150.00 per linear foot.

EPA requests additional cost data for other wetland and riparian types such as mangrove swamp, scrub-shrub swamp, forested wetland or riparian zone, or grassland riparian zone.

IV. MANAGEMENT PRACTICES FOR RIPARIAN AREAS

A. Benefits of Riparian Areas in NPS Control

Riparian areas are able to intercept surface runoff, wastewater, subsurface flow, and certain groundwater flows from sources upland of the area, removing or buffering the receiving water body from the effects of the pollutants, or preventing the entry of pollutants into the receiving water body. A riparian buffer strip should be used to protect a stream from land use activities adjacent to the stream, and normally consists of grasses, shrubs and trees in the streambank area (New York DEC, 1986). Riparian buffers perform much like wetlands by filtering, storing and even transforming nonpoint source pollutants (Stuart and Greis, 1991).

Like planted vegetation in riparian zones, naturally-occurring vegetation has been shown to be effective in removing sediment, nutrients, pesticides and other nonpoint source contaminants from upland runoff as well as in the abatement of streambank erosion (U.S. EPA, 1988). The pollutant removal mechanisms associated with riparian vegetation combines the physical process of filtering (much like the vegetative filter strip), and the biological processes of nutrient uptake and denitrification (Peterjohn and Correll, 1984). In addition to these two functions, the preservation of vegetation along the streambank shades the stream and helps to maintain lower water temperatures, which preserves fish habitat. The presence of riparian vegetation also helps to prevent streambank erosion.

B. Management Practices to Protect Riparian Areas

1. Management Practice - Protection

As for wetlands, the best way to ensure riparian areas provide NPS benefits in the watershed is to establish a preference for protection of existing riparian areas adjacent to parent waterbodies (impact avoidance). The nonpoint source goal in protecting riparian areas is to improve water quality (1) by removing nutrients, sediment and suspended solids, and pesticides and other toxics from surface runoff, wastewater, subsurface and groundwater flows from sources upland of the riparian area, and (2) by buffering the effects of upland nonpoint source pollution before its entry into waters of the riparian zone.

(1) **Consider wetlands and riparian areas on a watershed or landscape scale so that they form a continuum of filters before waters enter an estuary.** This practice includes basin wetlands, riparian buffers and wetlands adjacent to streams and rivers that together serve important NPS functions to buffer the estuary from the sources of NPS pollution.

(2) **Identify riparian areas with significant nonpoint source control potential within coastal watersheds.**

The identification and designation of streamside areas is needed to determine the extent and distribution of highly valued and sensitive riparian resources. The boundaries of these areas are determined by the minimum distance needed to provide protection to the water quality and habitat functions. Distances needed may vary depending on soil type, slope, and riparian cover. Some States and forest management agencies have set minimum distances to protect water quality and ecosystem function. Additional distance is required if there is reasonable risk of pollution or loss of riparian functions.

This practice applies to the following water bodies where they are located downslope of croplands, pastures, etc.:

(1) Adjacent to streams (streambanks)

(2) Around lakes or ponds

(3) Adjacent to wetlands

(4) Near groundwater recharge areas

(5) In areas where soil erosion and sediment deposition is a significant problem

2. Effectiveness of Protection Practices

One study suggests that good water quality for streams and water bodies in agricultural watersheds is directly related to nutrient removal and uptake in the riparian ecosystem. It concludes that the absence of riparian vegetation will result in higher nutrient loadings and stresses that maintenance of the riparian ecosystem is vital to the preservation of high water quality (Peterjohn and Correll, 1984).

Research indicates that nonpoint source pollutant mitigation can also be achieved through the process of denitrification in the riparian zone. Bacterial denitrification in anaerobic sites has been shown to remove large quantities of nitrates from riparian zone groundwater (Schipper, et al., 1989).

A riparian buffer is most effective as a component of an integrated land management system which combines nutrient, sediment and soil erosion control management. The riparian ecosystem consists of a complex organization of biotic and abiotic elements. Like planted vegetative filter strips or grassed swales, riparian buffer strips have been shown to be effective in removing sediment, suspended solids, nutrients, pesticides and other contaminants from upland runoff. In addition, some studies suggest that riparian vegetation acts as a nutrient sink, taking up and storing nutrients, and that this function may be related to age (Lowrance, et al.).

It is clear that the long-term maintenance of natural riparian vegetation zones in areas subject to inputs from upland areas can be an effective management practice for reducing certain types of nonpoint source pollution and that efforts to improve watershed water quality should emphasize maintenance of riparian vegetation (Fail, et al.). Other studies confirm the important role of riparian ecosystems as nutrient sinks and buffers against runoff from surrounding lands.

Studies done in agricultural watersheds suggest that good water quality is directly related to nutrient removal and nutrient uptake in the riparian ecosystem (Lowrance, et al.). While some data supports the hypothesis that bottomland riparian ecosystems act as short- and long-term nutrient filters and sinks through vegetative uptake of upland-applied nutrients, these studies are not conclusive (Fail, et al.).

While the exact nature of the process by which pollutant reduction is achieved may be open to debate, numerous research studies have documented the effectiveness riparian buffer areas in removing nutrient loadings from runoff from upland agricultural areas. Three major studies from Maryland, North Carolina, and Georgia are summarized below Stuart and Greis, 1991):

Study	Total P	Total N
Peterjohn/Correll (MD)	76%	88%
Jacobs/Gilliam (NC)	50%	93%
Lowrance (GA)	50%	83%

Additional data regarding the effectiveness of riparian areas can be found under section II.B.1.b.

3. Cost Considerations

The following costs are provided to give some indication of the cost of restoring riparian zones.

$100/acre (conifer seedling)
$200/acre (deciduous seedling)
$1000-5000/acre (nursery stock)

There is no direct cost involved in preserving existing vegetation in the riparian zone.

C. Maintenance

The maintenance of riparian buffer areas is especially important in preventing sediment from entering streams where its effect on fish and spawning can be a serious problem.

V. MANAGEMENT PRACTICES FOR VEGETATIVE FILTER STRIPS

A. General Role

Runoff water quality management methods generically referred to as biofiltration methods have been shown to provide significant reductions in pollutant delivery. These include vegetative filter strips, grassed swales or vegetated channels, and created wetlands. These methods have been applied in a wide range of settings, including cropland, pastureland, forests, and developed as well as developing urban areas, where biofiltration methods can perform a complementary function in terms of sediment control and stormwater management. When properly installed and maintained, biofiltration methods have been shown to effectively prevent the entry of sediment and sediment-bound pollutants, nutrients, and oxygen-consuming substances into water bodies.

Vegetative filter strips are discussed and described in particular source category-specific chapters of this guidance, but it is clear that they should be considered to have wide-ranging applicability to various nonpoint source categories. Vegetative filter strips *SHOULD* be widely adopted as components of management systems to address nonpoint source pollutants in runoff from a wide variety of sources.

B. Management Practices for Vegetative Filter Strips

The purpose of vegetative filter strips is to remove sediment and other pollutants from runoff and wastewater by filtration, deposition, infiltration, absorption, adsorption, decomposition and volatilization and thereby reduce the amount of pollution entering adjacent water bodies (U.S.D.A., 1988). Vegetative filter strips are used in areas adjacent to water bodies which may be subject to sediment, suspended solid, and/or nutrient runoff. They improve water quality by removing nutrients, sediment, suspended solids, pesticides, etc., from surface runoff and waste water.

1. Effectiveness

A substantial body of research suggests that vegetative filter strips improve water quality and are an effective management practice for the control of silvicultural, urban, construction and agricultural nonpoint sources of sediment, phosphorus, bacteria, and some pesticides. There are also studies which suggest that the results are inconclusive and variable. However, the following are sources for which filter strips may provide some removal capability (Lanier, 1990):

(1) Forestry - Forest filter strips are used to prevent entry of sediment into riparian water bodies.

(2) Cropland - The primary function of grass filter strips is to filter sediment from soil erosion and sediment-borne nutrients. However, filter strips should not be relied upon as the sole or primary means of preventing nutrient movement from cropland.

(3) Urban - Filtering and removal of sediment, organic material and trace metals. According to the Washington Council of Governments, filter strips have a low to moderate capability of removing pollutants in **urban runoff**, and have higher removal rates for particulate than for soluble pollutants (Schueler, 1987).

Filter strips are designed to be used under conditions in which runoff passes over the vegetation in a uniform sheet flow. The distribution of runoff across the filter in such a manner is critical to the success of the filter strip. If runoff is allowed to concentrate or channelize, the filter strip is easily inundated and its purpose defeated.

Filter strips need the following elements to work properly: 1.) a device such as a level spreader which ensures that runoff reaches the filter strip as a sheet flow (berms can be used for this purpose if they are placed at a perpendicular angle to the filter strip area to prevent concentrated flows); 2.) a dense vegetative cover of erosion-resistant plant species; 3.) a gentle slope of no more than 5%; 4.) length at least as long as the adjacent contributing area (Schueler, 1987). If these requirements are met, the VFS has been shown to remove a high degree of particulate pollutants. Its effectiveness at removing soluble pollutants, however, is not well-documented (Schueler, 1987).

The effectiveness of vegetative filter strips varies with topography, vegetative cover, implementation and use with other management practices, as well as the following key variables:

(1) Slope - Filter strips function optimally at slopes of less than 5%; slopes greater than 15% render them ineffective because surface runoff flow will not be sheet-like and uniform. Their effectiveness is strongly site-dependent, i.e., VFS have been demonstrated to be ineffective on hilly plots or in terrain which allows concentrated flows.

(2) Site Considerations - Filter strips are most effectively employed at sites which generate suspended solids, sediment and sediment-bound pollutants. As sediment increases in the filter, effectiveness decreases; if the filter strip becomes inundated, it becomes ineffective. Without maintenance, the effectiveness of filter strips will decline over time, as more runoff events occur (Magette, et al., 1989).

(3) Pollutant Type - Sediment and sediment-bound nitrates, phosphorus, and toxics are efficiently removed by filter strips. However, removal rates are much lower for soluble nutrients and toxics. Soluble nutrients are more effectively removed by riparian vegetation.

(4) Vegetated Area - Criteria for choosing the best vegetation type include dense growths of grasses and legumes which are resistant to overland flow. Effectiveness increases as the ratio of vegetated filter area to unvegetated area increases. A filter strip should be at least as long as the runoff-contributing area. "Contact time" between runoff and the vegetation is a critical variable.

Different filter strip characteristics such as size and type of vegetation can result in different pollutant loading characteristics as well as loading reductions. Following are some reduction rates based on strip size and vegetation:

Study/Source	Size	Vegetation	Reduction[1]
Barker/Young	21x91m	Fescue/rye	89.9% TSS 97.3% TN 98.4% TP
Dillaha et al	6x5m	Orchard grass	95% TSS 77% TN 80% TP
Overman/Schanze	5 ha	Bermuda grass	81.3% TSS 67.2% TN 38.8% TP

Dillaha, et al., (1988) found vegetative filter strips to be very effective at removing sediment and sediment-bound pollutants from feedlot runoff, but much less effective at removing pathogens, fine sediment and soluble nutrients such as nitrate (NO_3) and orthophosphorus (PO_4).

Filter width	Percent reduction/Pollutant
9.1 m	95% TSS 69% NH_4 4% NO_3 30% PO_4 80% P_t
4.6 m	87% TSS 34% NH_4 -36% NO_3 -20% PO_4 63% P_t

As the data above shows, the study found that the filter strips were not very effective at removing nitrate (NO_3) and orthophosphate (PO_4). Effluent nitrate loadings exceeded influent loadings, indicating that the filter strips not only did not trap nitrate, but through mineralization actually released previously trapped nitrogen as nitrate. Although sediment-bound phosphorus

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[1]Reductions in concentration.

was fairly effectively removed, soluble phosphorus (PO_4) also produced greater effluent loadings than influent ones (Dillaha, et al., 1988).

The universality of these results should not be assumed. The same researcher determined that VFS were frequently ineffective for water quality improvement because of the difficulty in assuring sheet flow of runoff. This study found that filter strips are most appropriate in small fields where runoff cannot concentrate before reaching the strip (Dillaha, et al., 1989).

Furthermore, the long-term effectiveness of vegetative filter strips is unclear. In addition, trials conducted under controlled experimemtal conditions may differ from on-site effectiveness in "real world" conditions.

2. Design Criteria

Whereas a grassed swale or waterway is used to control or reduce the pollutant load from concentrated stormwater runoff, **preventing concentrated flows** is the key element of filter strip design. Filter strips are designed to accept overland sheet flow of runoff only.

The primary factors in determining filter strip effectiveness are filter length; uniformity of runoff flow through the filter, field slope, type and density of vegetation, and sediment size. The following critical factors should be observed:

(1) The contour of the filter strip should be identical (in terms of elevation) to the adjacent area.

(2) A device, such as a berm placed at a perpendicular angle to the filter strip area, should be used to distribute runoff over the filter strip in an even manner.

(3) The filter strip should be directly adjacent to the impervious area to avoid runoff bypassing or short-circuiting the device.

(4) Minimum filter strip width for flat terrain should be 20 feet if a grass or turf strip. Studies suggest that a minimum 50-75 feet width is preferable, while others suggest attempting to achieve a one-to-one vegetated to unvegetated area ratio.

(5) Generally speaking, increasing slope steepness requires increased filter strip width to maintain effectiveness. Grass filter strips function best on slopes of 5% or less. They will not function effectively on slopes greater than 15%.

(6) Grasses with a high runoff retardance value, such as Bahia and Bermuda grass, are recommended for use in the filter strip.

(7) Contact time between runoff and the filter strip should be maximized to permit infiltration and sedimentation to occur.

C. Cost

Vegetative filter strips can be an inexpensive component of an overall pollutant reduction system. If they are preserved before development occurs, they are virtually free (Schueler, 1987). There is, however, an opportunity cost for leaving land undeveloped.

Establishment of filter strips of grass, trees, or permanent wildlife plantings on cropland adjoining a stream, creek, river or other water body may be eligible for enrollment in the Conservation Reserve Program of the U.S. Department of Agriculture.

The following table briefly describes representative costs for establishing filter strip vegetation (Schueler, 1987):

Comparative Costs for Establishing Vegetative Control Practices

Method	Avg. Cost per Acre
Conventional Seeding	$1633
Hydroseeding	$1725
Sodding	$10,900
Riparian buffer	$100 (conifer seedling) $200 (deciduous seedling) $1000-5000 (nursery stock)

D. Maintenance

The design, placement and maintenance of filter strips are all very critical to their effectiveness and serious attention should be directed to prevent concentrated flows from occurring. Although intentional planting and naturalization of the vegetation will enhance the effectiveness of the larger filter strip, it should be inspected periodically to determine if concentrated flows are bypassing or overwhelming the device, particularly at the perimeter.

For shorter filter strips, where natural vegetative succession is not intended, the vegetation should be managed like a lawn. It should be mowed 2-3 times a year, fertilized, and weeded in an attempt to achieve dense, hearty vegetation. The goal is to increase vegetation density for maximum filtration.

Accumulated sediment and particulate matter in the filter strip should be removed at regular intervals to prevent inundation of the device. Frequency of this type of service will depend on the frequency and volume of runoff flows.

Development of channels and erosion rills within the filter strip area must be avoided. To ensure effectiveness, sheet flow must be maintained at all times.

VI. MONITORING CONSIDERATIONS

The effectiveness of practices to protect and restore wetland and riparian systems as management measures should be monitored. Establish specific objectives and milestones to aid in assessing effectiveness. Following are examples of ways to monitor results. Additional monitoring tools which are more appropriate for specific projects and conditions may be needed. Establish a feedback mechanism to provide opportunity for management considerations during the implementation and maintenance period.

Assess effectiveness of protection/restoration through some or all of the following:

- Assess maintenance/restoration of beneficial uses
- Conduct baseline mapping (quantification and spatial distribution)
- Monitor water quality changes
- Track restoration and losses (acreage and type)
- Track structural changes (i.e., forest removal, restoration of pasture/cropland to wetland/forest)
- Monitor institutional progress in avoidance/protection such as: (1) State or local tax incentives (2) multi-agency participation in protection/restoration efforts, (3) watershed initiatives, (4) acreage protected through long-term protection/restoration through acquisition or easements, (6) number of zoning restrictions, local adoption of restriction ordinances, (7) citizen participation, (8) emphasis on wetlands/riparian protection/restoration across NPS activity areas (not limited to agriculture, but also urban, construction, silviculture, etc.), (9) number of Wetlands Reserve or Conservation Reserve sign-ups.

Success often depends upon the long-term ability to manage, protect, and manipulate wetlands and adjacent buffer areas. Restored wetland and riparian systems often require "mid-course corrections" and management over time. Careful monitoring of systems after their original establishment and, in some cases, active management of the systems, are often critical to long term success. To increase chances of success, restored wetlands should be designed as self sustaining or self managing systems. This is more likely if the project is re-establishing a wetland area where one existed previously.

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Diane Davis	U.S. EPA, Office of Marine and Estuarine Protection
Roger Dean	U.S. EPA, Region VIII
Charles DesJardins	Federal Highway Administration
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David Engel	NOAA/NMF, F/PR3
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APPENDIX B. EFFECT OF COASTAL ZONE MANAGEMENT BMPS ON NONPOINT SOURCE CONTAMINANT LOADING IN GROUND WATER

Effect of Coastal Zone Management BMPs on Nonpoint Source Contaminant Loading in Ground Water

INTRODUCTION

Coastal Zone Management (CZM) best management practices (BMPs) are designed to reduce or eliminate the degradation of coastal waters by controlling contaminant migration from agricultural, forest, and urban lands. In doing so, these BMPs can alter the quality and quantity of water discharging into coastal waters that either runs off the land surface or percolates through the soil. For example, BMPs that are designed to reduce surface water discharge of stormwater may substantially increase infiltration into ground water (Mannering et al., 1987; Baker, 1987). In addition, selection of BMPs should be coordinated with State ground-water protection priorities based on ground-water use value and vulnerability. Otherwise, certain BMPs that increase infiltration of water could contribute to contamination of private and public drinking water wells. As a result, BMPs should be assessed in terms of their impact on both surface-water and ground-water resources.

The transport of contaminants in subsurface waters is governed by the physical and chemical principles associated with soil-water flow and contaminant transport. An understanding of these principles will facilitate assessments of the potential effects that BMPs may have on contaminant loading in ground water and the subsequent pollution of coastal waters. Section I will discuss basic principles of contaminant transport associated with the flow of water through soil and aquifers. Section II will compare the effects of general BMP types on the quantity and quality of water movement to ground and surface waters.

I. PRINCIPLES OF CONTAMINANT LOADING IN GROUND WATER

Transport of nonpoint source pollutants to coastal waters through ground-water discharge is governed by physical and chemical properties of the water, pollutant, soil, and aquifer (Cheng and Koskinen, 1986). This section will discuss general influences of soil water flux, contaminant properties, soil properties and aquifer properties on the migration of contaminants through soil and ground waters.

A. Water Flux

Water is the transport mechanism most responsible for pollutant movement in the subsurface environment (Nielsen et al., 1989). Saturated and unsaturated water flow through the soil provide mass and diffuse transport of soluble pollutant constituents, as well as displacement of non-soluble constituents. This discussion influencing water flux through the soil addresses the following factors:

- infiltration;
- infiltration from impoundments; and
- water balance.

i. Infiltration

Transport of pollutants to ground water is a function of the amount of water that enters the soil (infiltration) over a specified area. Infiltration can be characterized by the following equation (Hanks and Ashcroft, 1980):

$$\text{Infiltration} = \text{Precipitation} + \text{Irrigation} - \text{Run-off} \quad (1)$$

Precipitation and irrigation (influx) intensities and duration that exceed the water intake ability of the soil surface will result in run-off. Soils may accept brief periods of high intensity influx or prolonged periods of low intensity influx before run-off occurs (Taylor and Ashcroft, 1972). This is because infiltration is driven by soil hydraulic conductivity and hydraulic gradients that change rapidly during an infiltration event (Kirkham and Powers, 1972). These hydraulic properties are governed by soil physical properties. Infiltration rates will also generally decrease after tillage, in relation to run-off, with progressive infiltration events due to changing soil physical properties (Baker and Laflen, 1983; Onstad and Voorhees, 1987). Soil physical properties related to water intake ability are the soil texture, antecedent (previous) soil water content, and soil structure (compaction or bulk density). In general, coarser soil textures (larger soil particle size), lower antecedent water contents, and better soil structure (lower bulk densities) will provide increased infiltration. Time-related factors such as antecedent soil moisture contents, soil compaction, and the occurrence of frozen soil conditions significantly affect infiltration rates (Schepers, 1987).

The presence of vegetation and organic matter on the soil surface also may substantially increase the water intake ability of the soil (Baker and Laflen, 1983). Vegetation will provide interception and limited storage of stormwater by the plant canopy (Banerjee, 1973). Interception of rainfall by vegetation will also reduce displacement of soil particles and degradation of surface soil structure due to direct impact of raindrops (Onstad and Voorhees, 1987; Brady, 1974). The presence of vegetation also has the effect of increasing soil moisture holding capacities, increasing surface storage of water, and slowing the rate of run-off (Baker et. at., 1987). These plant-related properties will change with season and site activities due to decomposition of organic matter and the seasonal nature of plant growth.

ii. Induced Infiltration from Impoundments

Rainfall in excess of soil infiltration capabilities can be collected in impoundments designed to control run-off (as cited in Nightingale et. al., 1985). This provides increased localized opportunity for water to infiltrate and carry pollutants through the soil by extending infiltration times over a limited area (Hannam and Leece, 1986). Infiltration amounts and rates will depend on the design and construction of the impoundment and the properties of the underlying soil. Impoundments built over soils with low hydraulic conductivities, lined with clay or other artificial liners, or that experienced substantial compaction of the soil during construction will reduce infiltration rates and prolong surface storage of the run-off.

Such prolonged surface storage in impoundments may reduce the total amount of stormwater infiltrating and discharging into surface streams by increasing the amount of run-off water evaporated into the atmosphere. This may be due to direct evaporation from the impoundment or from subsequent use of the stored water such as for irrigation or artificial wetlands (Edwards et al., 1985).

iii. Water Balance

The amount of pollutant that migrates to ground water is dependent upon the site-specific water balance. Drainage is calculated from the water balance as the amount of water entering the soil minus the amount of water leaving the soil surface. This is dependent upon site-specific rainfall, irrigation, vegetation, soil properties, and climatic energy. This relationship is characterized by the soil water balance equation (Hanks and Ashcroft, 1980):

$$Dr = Inf + Ds\,(\theta_{v\,act} - \theta_{v\,fc}) - Es - Tp \qquad (2)$$

where:

- Dr = drainage in equivalent depth
- Inf = infiltration in equivalent depth
- Ds = maximum depth of soil subject to Es or Tp
- $\theta_{v\,act}$ = volumetric water content of the soil
- $\theta_{v\,fc}$ = volumetric water content of the soil at field capacity
- Es = soil evaporation in equivalent depth
- Tp = plant transpiration in equivalent depth

Gravitational force will remove water from soils as drainage when their water contents are above a soil moisture level commonly referred to as field capacity (soil water holding capacity). This term is associated with a condition of equilibrium between gravitational forces and the attractive forces exerted on water by the soil particles (Brady, 1974).

Soil water can also be removed from the soil at soil water contents below field capacity by soil evaporation and plant transpiration. Soil evaporation and plant transpiration are inter-dependent and are often considered collectively as evapotranspiration (Hanks and Ashcroft, 1980). For areas where plants are not present or not actively transpiring, it may be inappropriate to include the plant transpiration or evapotranspiration component. Similarly, when plants completely cover the ground surface, the soil evaporation component may also be negligible (Kidman, 1990). Soil water loss due to evaporation is limited to a relatively shallow surface layer of the soil (Hanks, 1985). Transpiration, however, may remove soil water from depths corresponding to the depth of root penetration. Once water has infiltrated below the surface layer of bare soils, or below the root zone of vegetated soils, a discharge of water into the ground water (drainage) will be induced.

As infiltration induces drainage when soil moisture content in the root zone and/or surface soil layer exceeds field capacity, drainage can be minimized by reducing the soil water content. This can be accomplished on irrigated land by regulating irrigation amount and timing to maintain soil water contents at or below field capacity. This rigorous control of irrigation water may necessitate improved irrigation and water delivery systems. Drainage in non-irrigated areas can also be minimized through the establishment of appropriate plant species that will enhance extraction of soil water and provide increased capacity in the soil to store infiltrating stormwater.

B. Contaminant Migration

The amount of pollutant reaching coastal waters will depend on the physical and chemical properties of the pollutant. These properties will define, in conjunction with soil and water properties, the persistence, mobility, and migration pathway of the pollutant (Cheng and Koskinen, 1986). This discussion on contaminant migration through the soil includes an examination of the following factors:

- persistence; and
- mobility.

i. Persistence

Pollutant persistence is the relative measurement of the portion remaining after a period of time. The two major processes affecting persistence are, in general, volatilization and degradation (Helling, 1987). Volatilization is a potentially major movement pathway for contaminants with high vapor pressures, especially when exposed to the atmosphere at or near the soil surface (Glotfelty, 1987). Degradation of organic pollutants in the soil to non-toxic end products is the result of chemical reactions and soil microbial activities (Cheng and Koskinen, 1986). The rate at which this degradation proceeds is related to the concentration of the pollutant. Organic chemical degradation rates are commonly assumed to be described by the exponential decay function (Strenge and Peterson, 1989):

$$C(t) = C_o \cdot 0.5^{\left(\frac{t}{T_o}\right)} \tag{3}$$

where:
C(t) = amount of pollutant present at time t

C_o = amount of pollutant initially present
t = time in days from initial time
T_e = time in days for ½ the initial pollutant concentration to degrade

ii. Mobility

The rate of pollutant migration through the unsaturated zone, relative to soil water velocity, is dependent upon complex geochemical interactions such as precipitation/dissolution and adsorption/desorption (Strenge and Peterson, 1989). Pollutant properties affecting these interactions include water solubility, viscosity, density, volatility, and adsorptivity (Camp Dresser and McKee, 1986). Mobility of the contaminant is strongly related to its degree of water solubility (Wagenet, 1987).

For insoluble contaminants, viscosity and density determine its mobility through the soil and aquifer. Insoluble contaminants with a solution density greater than water tend to sink to the bottom of an aquifer and move slowly in relation to ground-water flow. In contrast, contaminants with a solution density less than water tend to remain at the top or float to the top as they move through an aquifer and upon discharge into coastal surface waters (Camp Dresser and McKee, 1986). The rate of migration for liquid contaminants that do not mix with water will depend, in large measure, on the viscosity of the contaminant. The physical and chemical nature of the soil provides charged surface area that can attract and immobilize contaminants in soil water (Jurinak, 1988). The adsorptivity of a pollutant is its relative attraction to these charged soil surfaces (Strenge and Peterson, 1989).

The complex physical and chemical interactions that dictate the mobility of the contaminant are not completely understood. However, their effects on contaminant mobility can be simplified by the use of distribution coefficients. This is a "bulk" chemical parameter that estimates the relative amount of the contaminant immobilized in the soil (Strenge and Peterson, 1989):

$$\text{Distribution Coefficient } (K_d) = \frac{\text{Concentration of Contaminant Immobilized}}{\text{Concentration of Contaminant in Solution}} \quad (4)$$

For example, nitrate has a K_d of zero which means that its movement is not retarded in the soil and will move as fast as the soil water (Bouwer, 1989). Other contaminants, with higher retardation factors, such as chlorinated aromatics move as much as 40 times slower than the water (Bouwer, 1987). These less mobile chemicals will pose less immediate risk to ground water contamination but may concentrate at the soil surface and have a higher risk to surface water contamination due to migration with sediments in run-off (Baker and Laflen, 1983; Dick and Daniel, 1987).

These characterizations of contaminant degradation rate and mobility are generalizations based largely on laboratory studies and their application to field conditions should be viewed with some skepticism (Jury et. al., 1983). Application of these relationships should be limited to surface soils where organic carbon contents and microbial activities are high (Bouwer, 1987) as they may be of little value in predicting transport of pesticides in the ground water.

C. Soil Properties

The soil provides resistance to the movement of the pollutant by limiting the flow of water and providing surface area for adsorption of the pollutant. The amount of this resistance will vary with different soil materials, configurations of different soil materials, and the thickness of the unsaturated portion of the soil. Layering of differing soil materials or densities will affect the rate and direction of water flow (Taylor and Ashcroft, 1972). Palmer (1986) indicates that unsaturated flow might travel laterally as much as several kilometers before reaching the water table. This discussion on soil properties includes examination of factors governing:

- preferential soil water flow; and
- soil chemical properties.

i. Preferential Soil Water Flow

Preferential soil water flow is the principal factor responsible for underestimation of chemical movement in the soil by chemical transport models (Jury et. al., 1983). The amount of soil disturbance and the occurrence and frequency of preferential flow paths may differ significantly among forest, agricultural, and urban soils. Forest soils, and other undisturbed soils, have a higher potential for preferential water flow due to increased occurrence of animal burrows, root and worm holes, and cracks. Van Wesenbeeck and Kachanoski (1991) indicate that tillage of agricultural soils reduces bypass or channel flow by reducing the lateral variability of soil properties. Certain configurations of soil material, such as karst formations may also induce preferential soil water flow allowing very minimal resistance to percolating water (Palmer, 1986). Preferential flow conditions (enhanced contaminant migration rates) occur in relatively uniform soils and will be intensified by intermittent applications of non-uniform irrigation (Bouwer, 1987; Bouwer, 1989).

ii. Soil Chemical Properties

Chemical properties of the soil such as cation exchange capacity, pH, and organic matter content will affect the capacity of the soil to store and immobilize the pollutant. Cation exchange capacity (CEC) is a measure of the soil adsorption capacity for positively charged solutes (Brady, 1974). This capacity is related to the amount of surface area which is a function of the size of soil particles and the type of minerals within the soil. Representative surface areas of soils and clay minerals (Jurinak, 1988) include the following:

	Surface Area (m^2/g)
Montmorillonite	600-800
Illite	70-120
Kaolinite	10-20
Clay soil	150-200
Loam soil	50-100
Sandy soil	10-40
Humus	600-850

Effective CEC will generally decrease with lower pH levels, as hydrogen ions will dominate the exchange complex, and increase with higher organic matter contents (Wagenet, 1987; Tisdale et. al., 1985), largely due to increased surface area as shown above.

The pH of the soil solution will also have important effects on pollutant degradation and solubility (mobility) due to hydrolysis (Dick and Daniel, 1987; Glotfelty, 1987). For inorganic contaminants, hydrolysis determines metal species that exist in solution. For organic contaminants, the effects of hydrolysis are indirectly addressed through consideration of degradation rates or rate constants (Strenge and Peterson, 1989).

Cation exchange does not explain the retention by soils of heavy metals and organic anions. This retention is often determined by the formation of complexes between the pollutant and the organic matter or soil surface (EPA, 1983). Organic matter complexes within the soil are complicated and not well understood but do significantly contribute to the retardation or immobilization of pollutants.

D. Aquifer Properties

The release of contaminants into coastal waters from an aquifer is dependent on the discharge rate of ground water and the movement of contaminants in the aquifer. This discussion on aquifer properties includes examination of factors governing:

- ground water flow and
- contaminant movement in aquifers.

i. Ground Water Flow

The discharge of ground water is controlled by the permeability (hydraulic conductivity) of the aquifer, the distribution of hydraulic potential over the aquifer, and the cross sectional area of an aquifer perpendicular to the ground-water flow (Todd, 1960).

Gravitation is the primary force driving water flow in the unsaturated zone causing water flow, in the absence of interfering layers, tends to be mainly vertical. In the saturated zone, however, water flow will be in response to water pressure gradients along the flow path of the aquifer.

The rate of aquifer flow in response to pressure gradients will be determined by the permeability of the material comprising the aquifer. Permeability is a function of the interconnected pore space within the material. For consolidated material (rock formations), permeability will depend on the presence and extent of fractures, joints, or the inherent permeability of the material itself. Configurations of subsurface materials of differing permeabilities will determine the rate and pathway for water flow within the aquifer.

ii. Contaminant Movement in Aquifers

Transport of contaminants in an aquifer is controlled by the processes of advection and dispersion. Advection is the transport of a contaminant at an average ground-water velocity which is dependent on the hydraulic conductivity, hydraulic gradient, and effective porosity of the aquifer (Freeze and Cherry, 1979). Dispersion, on the other hand, refers to the spreading of a contaminant as it flows through the aquifer. Because dispersion causes the mixing of contaminated ground water with uncontaminated ground water, it is a mechanism for dilution. Both advection and dispersion are controlled by the physical properties of the aquifer, the distribution of hydraulic potentials within the aquifer, and chemical processes within the aquifer.

The advection of contaminants in an aquifer is directly associated with the flow of ground water. In aquifers of high hydraulic conductivity (i.e., permeable), rapid movement of contaminants is facilitated by rapid movement of ground water. The movements of ground water and contaminants are also dependent on the steepness of the hydraulic gradient in the direction of ground-water flow. Finally, in aquifer with high porosity (e.g., fine grain material), the movement of ground water is generally slow and the transport of contaminants is dominated by dispersion.

The dispersion of contaminants in an aquifer is controlled by mechanical dispersion and molecular diffusion. Mechanical dispersion is directly related to velocity of ground-water flow, and molecular diffusion can be determined by the contaminant diffusion coefficient and the particle size of the aquifer media. In aquifers with low hydraulic conductivity and small particle size, diffusive transport of contaminants is large when compared to advective transport. In this case, dispersion can cause contaminants to arrive at a discharge point (e.g., coastal water) prior to the arrival time derived from the average ground-water velocity.

The movement of contaminants in an aquifer is also controlled by properties of the contaminants. The properties affecting contaminant persistence and mobility, as previously discussed, generally apply to contaminants in the aquifer with the exception of chemical and microbial degradation processes. Degradation within the aquifer environment may be severely restricted due to limited amounts of oxygen and organic material.

II. ASSESSMENT OF BMPS

The preceding Section I, presented an overview of the factors influencing water and contaminant movement through the soil. The following section addresses the impacts that specific types of BMPs may have on surface water and ground-water supplies. The following describes the general types of agricultural, forestry, and urban BMPs and the rational for these impacts which are summarized in Exhibit 1.

A. Sedimentation Controls

Reduction of run-off velocity: BMPs which provide obstructions to surface water flow. These may include techniques that use soil surface alteration (pitting, primary tillage), slope modification (leveling, terracing), residue management (conservation tillage), and contour agricultural practices to slow run-off velocities. These BMPs affect ground and surface waters through:

- decreased transport of sediments and contaminants adsorbed on sediments to surface waters;
- increased infiltration and evaporation thus decreasing run-off; and
- increased ground water transport of soluble contaminants and/or decreased concentration of contaminants in the ground water.

Surface stabilization: BMPs which physically reduce or prevent displacement of soil particles. These may include techniques such as surfacing of rural and forest roads, use of surface mulches, and establishment of permanent vegetative cover on disturbed roadsides and fields. These BMPs affect ground and surface waters through:

- decreased transport of sediments and contaminants adsorbed on sediments to surface waters.

The effect on run-off, infiltration, and ground water contamination will depend on the permeability of the material used to stabilize the surface.

Filtration of sediments: BMPs which remove sediments from run-off waters by passing run-off water through vegetated areas. These may include techniques such as strip farming, buffer zones around surface waters, and artificial wetlands. These BMPs affect ground and surface waters through:

- decreased transport of sediments and contaminants adsorbed on sediments to surface waters;
- increased infiltration and evaporation thus decreasing run-off; and
- increased ground water transport of soluble contaminants and/or decreased concentration of contaminants in the ground water.

Settling impoundments: BMPs which include diversion of run-off into impermeable surface impoundments thus reducing turbulence and allowing sediments to settle. These BMPs affect ground and surface waters through:

- decreased transport of sediments and contaminants adsorbed on sediments to surface waters and
- increased evaporation.

The effect on run-off, infiltration, and ground water contamination will depend on the use of the stored water and collected sediments.

Infiltration impoundments: BMPs which collect run-off water in permeable surface impoundments such that collected water will recharge ground water or evaporate. These BMPs affect ground and surface waters through:

- decreased transport of sediments and contaminants adsorbed on sediments to surface waters;
- increased infiltration and evaporation thus decreasing run-off;
- increased evaporation; and
- increased ground water transport of soluble contaminants and/or decreased concentration of contaminants in the ground water.

Watercourse stabilization: BMPs which physically reduce or prevent the displacement of soil particles lining watercourses. These may include techniques such as establishment of permanent streambank vegetation or the lining of streambanks with geotextiles, rocks, or concrete. These BMPs affect ground and surface waters through:

- decreased transport of sediments and contaminants adsorbed on sediments to surface waters.

The effect on run-off, infiltration, evaporation, and ground water contamination will depend on the permeability of the materials used to stabilize the watercourse.

Timing of activities: BMPs which reduce the disturbance of soils during periods when the potential for displacement of soil particles is high. These may include management practices that restrict site activities when the soil is excessively wet, dry, devoid of cover, or frozen and during periods when high winds or precipitation occurs or is expected to occur. These BMPs affect ground and surface waters through:

- decreased transport of sediments and contaminants adsorbed on sediments to surface waters; and
- increased capacity for soil to retard migration of adsorbed contaminants to ground water.

Localized use restriction: BMPs which restrict site activity on areas of high sediment producing potential. These may include techniques such as restricting livestock access to susceptible streambanks, restricting cultivation of areas with excessive slope, and restricting timber operations on sensitive watersheds. These BMPs affect ground and surface waters through:

- decreased transport of sediments and contaminants adsorbed on sediments to surface waters;
- decreased run-off;
- increased evaporation; and
- decreased contamination of surface and ground waters due to elimination of activity-related contamination.

The effect on infiltration will depend on the water use of the vegetation at the site.

B. Nutrient Controls

Reducing excess in soil: BMPs which include careful nutrient management techniques to meet but not substantially exceed the nutrient requirements of the managed vegetation (i.e., crops, pasture, turf, or timber). This also includes BMPs which maximize production (therefore nutrient uptake) through cultural management and control of pests and diseases. These BMPs affect ground and surface waters through:

- decreased contamination of surface and ground waters by reducing the quantity of contaminant in the soil.

Application timing: BMPs which alter timing of nutrient applications based on climatic conditions which affect the transport and fate of nutrients. These may include techniques such as multiple fertilizer applications, fertigation, and the avoidance of applications during the fall, early spring or at other times when precipitation is in excess of evapotranspiration. These BMPs affect ground and surface waters through:

- decreased contamination of surface and ground waters by reducing the quantity of contaminant in the soil.

Surface application of nutrients: BMPs which minimize soil disturbances, such as conservation tillage, may impose restrictions on the incorporation of soil-applied nutrients. Surface application of nutrients affect ground and surface waters through:

- increased surface water contamination due to concentration of nutrients at or near the soil surface and
- decreased ground water contamination due to a reduction in contaminant quantity through surface run-off, volatilization, or photodegradation.

The effect on ground water contamination may change if nutrient applications are increased to compensate for these losses.

Shelter of manure sources: BMPs which reduce or exclude precipitation from manure source and storage areas. These BMPs affect ground and surface waters through:

- decreased contamination of surface and ground waters by reducing the quantity of contaminant in run-off water;
- increased run-off; and
- decreased infiltration.

Containment of manure sources: BMPs which prevent surface and subsurface migration of manure at manure source or storage sites. This includes BMPs which specify the use of cement floors or other restrictive liner materials in commercial animal and poultry producing operations. These BMPs affect ground and surface waters through:

- decreased contamination of surface and ground waters by eliminating run-off and infiltration.

This effect may be dependent upon the final use of the manure and effluent.

C. Pesticide Controls

Biological pest control: BMPs which utilize biological competition and predators to control pests and reduce pesticide usage. These include techniques which introduce or enhance biological controls as well as those which minimize the disturbance to natural biological controls. These BMPs affect ground and surface waters through:

- decreased contamination of surface and ground waters by reducing the usage of pesticides.

Mechanical pest control: BMPs which physically limit, remove, or destroy the pest without the use of pesticides. These include techniques such as cultivation, insect traps, timing of operations to afford maximum resistance or competition to managed vegetation from pests, and avoidance of diseased vectors such as the presence of certain plant residues. These BMPs affect ground and surface waters through:

- decreased contamination of surface and ground waters by reducing the usage of pesticides; and
- increased infiltration and decreased run-off due to increased tillage.

Crop selection/rotation: BMPs which prevent buildup of pest populations due to a monoculture environment or the use of a crop or variety which has increased pest resistance. These include techniques such as crop rotation, use of varieties with increased resistance, or the use of a different crop type to facilitate pest control. These BMPs affect ground and surface waters through:

- decreased contamination of surface and ground waters by reducing the usage of pesticides.

On demand pesticide use: BMPs which minimize pesticide usage through correlation of the amount and type of pesticide to actual pest conditions. These include techniques which monitor the presence and population of pests as a basis for pesticide usage instead of predetermined application schedules. These BMPs affect ground and surface waters through:

- decreased contamination of surface and ground waters by reducing the usage of pesticides.

Pesticide application timing: BMPs which minimize pesticide usage through adventitious timing of pesticide applications. These include techniques that correlate applications to the most vulnerable periods of pest life cycles, those that prevent major infestations through monitoring of pest populations, and those that correlate applications with climatic conditions. These BMPs affect ground and surface waters through:

- decreased contamination of surface and ground waters by reducing the amount of pesticide used through control of pest populations and
- decreased contamination of surface and ground waters by restricting pesticide usage when storms are likely to occur.

D. Water Controls

Irrigation scheduling: BMPs which include continual evaluation of soil moisture conditions to determine the optimal irrigation timing and amounts to minimize ground-water recharge. These include techniques which combine soil moisture measurements with computer programs that forecast water demands of the crop so that irrigation applications do not produce excess ground-water recharge. These BMPs affect ground and surface waters through:

- decreased contamination of surface water by increasing infiltration and reducing run-off; and
- decreased contamination of ground water by reducing drainage.

Selective irrigation: BMPs which minimize irrigation quantities by limiting the area irrigated to the root zone of the crop. These include irrigation application techniques that utilize localized point- and line-source drip and seepage irrigation systems. These BMPs affect ground and surface waters through:

- decreased contamination of surface water by reducing run-off; and
- decreased drainage from the root zone.

Selective irrigation may tend to concentrate contaminants at specific locations within the soil. Therefore the effect of this practice on ground-water contamination may depend on site specific conditions.

Irrigation uniformity: BMPs which reduce the amount of ground-water recharge due to irrigation by increasing the ability to uniformly place irrigation water within the root zone. These include the use of higher technology irrigation systems such as center pivot, fixed line, and lateral move sprinklers. These BMPs affect ground and surface waters through:

- decreased contamination of ground water by reducing the amount of drainage from the root zone.

Soil moisture control: BMPs which manipulate soil moisture in non-irrigated areas. These include techniques which establish vegetation or crops for the purpose of extracting water from the soil to limit water table recharge. These BMPs affect ground and surface waters through:

- decreased contamination of surface water by increasing infiltration and reducing run-off; and
- decreased contamination of ground water by reducing drainage.

EXHIBIT 1

COMPARISON OF BMP EFFECTS ON THE QUANTITY AND QUALITY OF GROUND AND SURFACE WATER

	IMPACT OF BMPs ON:			
General BMPs	Ground Water		Surface Water	
SEDIMENTATION CONTROLS	Recharge	Contamination	Recharge	Contamination
reduction of runoff velocity	increase	variable	decrease	decrease
surface stabilization	variable	variable	variable	decrease
filtration of sediments	increase	variable	decrease	decrease
settling impoundments	variable	variable	variable	decrease
infiltration impoundments	increase	increase	decrease	decrease
watercourse stabilization	variable	variable	variable	decrease
timing of activities	no effect	decrease	no effect	decrease
localized use restriction	variable	decrease	decrease	decrease
NUTRIENT CONTROLS				
reducing excess in soil	no effect	decrease	no effect	decrease
application timing	no effect	decrease	no effect	decrease
surface applications	no effect	decrease	no effect	increase
shelter of manure sources	decrease	decrease	increase	decrease
containment of manure sources	decrease	decrease	decrease	decrease
PESTICIDE CONTROLS				
biological pest control	no effect	decrease	no effect	decrease
mechanical pest control	increase	decrease	decrease	decrease
crop selection/rotation	no effect	decrease	no effect	decrease
on demand pesticide use	no effect	decrease	no effect	decrease
pesticide application timing	no effect	decrease	no effect	decrease
WATER CONTROLS				
irrigation scheduling	decrease	decrease	decrease	decrease

selective irrigation	decrease	variable	decrease	decrease
irrigation uniformity	decrease	decrease	decrease	decrease
soil moisture control	decrease	decrease	decrease	decrease

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