United States
Environmental Protection
Agency

DEVELOPMENT DOCUMENT FOR PROPOSED EFFLUENT GUIDELINES AND STANDARDS FOR THE CONSTRUCTION & DEVELOPMENT CATEGORY

NOVEMBER 21, 2008

U.S. Environmental Protection Agency
Office of Water (4303T)
1200 Pennsylvania Avenue, NW
Washington, DC 20460

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1. OVERVIEW

1.1. INTRODUCTION

This document presents technical information to support the U.S. Environmental Protection Agency's (EPA's) decision and compliments the Agency's *Economic Analysis for Proposed Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-R-08-008), and the *Environmental Impact and Benefits Assessment for Proposed Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-R-08-009).

A summary of the information contained in the sections of this document is as follows:

- Section 2 presents a summary of the legal authority for effluent guidelines and the existing EPA stormwater program.
- Section 3 summarizes the data collection activities and the analytical tools and processes followed to support the final action.
- Section 4 summarizes the characteristics of the construction and development industry, including major indicators of industry size and annual construction activity.
- Section 5 presents a description of pollutants in stormwater runoff known to be the most prevalent and of greatest concern to the environment. It also presents the selection of pollutants for the proposed regulation.
- Section 6 presents the method and data used to establish limitations and standards.
- Section 7 presents information and data on erosion and sediment control (ESC) strategies used by the construction and development industry, including applicability, costs, and efficiencies of various technologies.
- Section 8 presents a description of the regulatory options EPA considered for developing the proposal.
- Section 9 presents a description of the approach EPA used for developing model construction sites and selecting indicator cities used in analyzing stormwater BMP costs and pollutant loading reductions under baseline conditions as well as under the regulatory options proposed.
- Section 10 summarizes the approach EPA used to estimate the pollutant loads and load reductions for the regulatory options EPA considered.
- Section 11 summarizes the non-water quality environmental impacts, including the energy requirements, air emissions impacts, and solid waste generation of each proposed regulatory option.

1.2. SUMMARY AND SCOPE OF PROPOSAL

EPA is proposing to establish effluent limitations guidelines (ELGs) and new source performance standards (NSPS) for stormwater discharges from the construction and development industry. These guidelines and standards would require discharges from certain construction sites to meet a numeric turbidity limit. The guidelines and standards would also require all construction sites currently required to obtain a National Pollutant Discharge Elimination System (NPDES) permit to implement a variety of best management practices (BMPs) designed to limit erosion and control sediment discharges from construction sites. EPA evaluated three options in developing the proposed rule. These options are described below:

- Option 1 would establish minimum sizing criteria for sediment basins used at construction sites with 10 or more disturbed acres draining to one location. Under this option, permittees would be required to install sediment basins that provide either 3,600 cubic feet per acre of runoff storage, or be designed to store runoff from the local 2-year, 24-hour storm event. This option also includes requirement for implementing a variety of ESCs on all construction sites that are required to obtain a permit.

- Option 2 contains the same requirements as Option 1. In addition, construction sites of 30 or more acres would be required to meet a numeric turbidity limit in stormwater discharges from the site. The numeric turbidity standard would be applicable to stormwater discharges for all storm events up to the local 2-year, 24-hour event. The turbidity standard would apply only to construction sites in areas where the rainfall runoff erosivity factor (R-factor) as defined in the Revised Universal Soil Loss Equation (RUSLE) is greater than or equal to 50 and if the soils on the site contain 10 percent or more by mass of soil particles smaller than 2 microns in diameter.

- Option 3 contains the same requirements as Option 1. Option 3 also requires all sites with 10 or more acres of disturbed land to meet a numeric turbidity standard. The turbidity standard would apply to all sites, regardless of soil types or R-factor. The turbidity standard would apply to all stormwater discharges for all storm events up to the local 2-year, 24-hour event.

EPA estimates that Option 1 would cost approximately $132 million dollars per year, reduce sediment discharges from construction sites by approximately 670 million pounds per year, and result in benefits of $11 million per year. EPA estimates that Option 2 would cost approximately $1.9 billion dollars per year, reduce sediment discharges from construction sites by approximately 26 billion pounds per year, and result in benefits of $196 million per year. EPA estimates that Option 3 would cost approximately $3.8 billion dollars per year, reduce sediment discharges from construction sites by approximately 50 billion pounds per year, and result in benefits of $322 million per year.

2. BACKGROUND

2.1. LEGAL AUTHORITY

The U.S. Environmental Protection Agency (EPA) is proposing Effluent Limitation Guidelines for discharges associated with construction and development activities under the authority of Parts 301, 304, 306, 308, 402, and 501 of the Clean Water Act (CWA) (the Federal Water Pollution Control Act), 33 United States Code (U.S.C.) 1311, 1314, 1316, 1318, 1342, and 1361. This section describes EPA's legal authority for issuing the regulation, existing state regulations, and other federal regulations associated with construction and development activities.

2.2. CLEAN WATER ACT

Congress adopted the CWA to "restore and maintain the chemical, physical, and biological integrity of the nation's waters" (section 101(a), 33 U.S.C. 1251(a)). To achieve this goal, the CWA prohibits the discharge of pollutants into navigable waters except in compliance with the statute. CWA Part 402 requires *point source* discharges to obtain a permit under the National Pollutant Discharge Elimination System (NPDES). These permits are issued by EPA regional offices or authorized state agencies.

Following enactment of the Federal Water Pollution Control Amendments of 1972 (Pub.L. 92-500, October 18, 1972), EPA and the states issued NPDES permits to thousands of dischargers, both industrial (e.g. manufacturing, energy and mining facilities) and municipal (sewage treatment plants). As required under Title III of the Act, EPA promulgated effluent limitation guidelines and standards for many industrial categories, and these requirements are incorporated into the permits.

The Water Quality Act of 1987 (Pub.L. 100-4, February 4, 1987) amended the CWA. The NPDES program was expanded by defining municipal and industrial stormwater discharges as point sources. Industrial stormwater dischargers, municipal separate storm sewer systems (MS4s) and other stormwater dischargers designated by EPA must obtain NPDES permits pursuant to section 402(p) (33 U.S.C. 1342(p)).

2.2.1. BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

In guidelines for a point source category, EPA may define Best Practicable Control Technology (BPT) effluent limits for conventional, toxic, and nonconventional pollutants. In specifying BPT, EPA looks at a number of factors. EPA first considers the cost of achieving effluent reductions in relation to the effluent reduction benefits. The Agency also considers the age of the equipment and facilities, the processes employed and any required process changes, engineering aspects of the control technologies, non-water quality environmental impacts (including energy requirements), and such other factors as the Agency deems appropriate (CWA section 304(b)(1)(B)). Traditionally, EPA establishes BPT effluent limitations on the basis of the average of the best performance of facilities within the category of various ages, sizes, processes or other common characteristics. Where existing performance is uniformly inadequate, EPA may require higher levels of control than currently in place in a category if the Agency determines

that the technology can be practically applied. See *A Legislative History of the Federal Water Pollution Control Act Amendments of 1972*, U.S. Senate Committee of Public Works, Serial No. 93-1, January 1973, p. 1468.

In addition, the Act requires a cost-reasonableness assessment for BPT limitations. In determining the BPT limits, EPA considers the total cost of treatment technologies in relation to the effluent reduction benefits achieved. This inquiry does not limit EPA's broad discretion to adopt BPT limitations that are achievable with available technology unless the required additional reductions are "wholly out of proportion to the costs of achieving such marginal level of reduction." See Legislative History, op. cit., p. 170. Moreover, the inquiry does not require the Agency to quantify benefits in monetary terms. See, for example, *American Iron and Steel Institute v. EPA*, 526 F. 2d 1027 (3rd Cir., 1975).

In balancing costs against the benefits of effluent reduction, EPA considers the volume and nature of expected discharges after application of BPT, the general environmental effects of pollutants, and the cost and economic impacts of the required level of pollution control. In past effluent limitation guidelines and standards, BPT cost-reasonableness removal figures have ranged from $0.21 to $33.71 per pound removed in year 2000 dollars. In developing guidelines, the Act does not require consideration of water quality problems attributable to particular point sources, or water quality improvements in particular bodies of water. See *Weyerhaeuser Company v. Costle*, 590 F. 2d 1011 (D.C. Cir. 1978).

2.2.2. BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY

The 1977 amendments to the CWA required EPA to identify effluent reduction levels for conventional pollutants associated with Best Conventional Pollutant Control Technology (BCT) for discharges from existing point sources. BCT is not an additional limitation but replaces Best Available Technology Economically Achievable (BAT) for control of conventional pollutants. In addition to other factors specified in section 304(b)(4)(B), the CWA requires that EPA establish BCT limitations after consideration of a two-part *cost-reasonableness* test. EPA explained its methodology for developing BCT limitations in July 1986 (51 *Federal Register* [FR] 24974).

Section 304(a)(4) designates the following as conventional pollutants: biochemical oxygen demand (BOD_5), total suspended solids (TSS), fecal coliform, pH, and any additional pollutants defined by the Administrator as conventional. The Administrator designated oil and grease as an additional conventional pollutant on July 30, 1979 (44 FR 44501). A primary pollutant of concern at construction sites, sediment, is commonly measured as TSS.

2.2.3. BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

In general, BAT effluent guidelines (CWA section 304(b)(2)) represent the best existing economically achievable performance of direct discharging plants in the subcategory or category. The factors considered in assessing BAT include the cost of achieving BAT effluent reductions, the age of equipment and facilities involved, the processes employed, engineering aspects of the control technology, potential process changes, non-water quality environmental impacts (including energy requirements), and such factors as the Administrator deems appropriate. The Agency retains considerable discretion in assigning the weight to be accorded to these factors.

An additional statutory factor considered in setting BAT is *economic achievability*. Generally, EPA determines the economic achievability on the basis of the total cost to the subcategory and the overall effect of the rule on the industry's financial health. The Agency may base BAT limitations on effluent reductions attainable through changes in a facility's processes and operations. As with BPT, where existing performance is uniformly inadequate, EPA may base BAT on technology transferred from a different subcategory or from another category. In addition, the Agency may base BAT on manufacturing process changes or internal controls, even when such technologies are not common industry practice.

2.2.4. NEW SOURCE PERFORMANCE STANDARDS

New Source Performance Standards (NSPS) reflect effluent reductions that are achievable on the basis of the best available demonstrated control technology. New facilities have the opportunity to install the best and most efficient production processes and wastewater treatment technologies. As a result, NSPS should represent the greatest degree of effluent reduction attainable through the application of the best available demonstrated control technology for all pollutants (i.e., conventional, nonconventional, and priority pollutants). In establishing NSPS, CWA Part 306 directs EPA to take into consideration the cost of achieving the effluent reduction and any non-water quality environmental impacts and energy requirements.

2.2.5. PRETREATMENT STANDARDS FOR EXISTING SOURCES AND PRETREATMENT STANDARDS FOR NEW SOURCES

The CWA also defines standards for indirect discharges, i.e., discharges into publicly owned treatment works (POTWs). Such standards are Pretreatment Standards for Existing Sources (PSES) and Pretreatment Standards for New Sources (PSNS) under section 307(b).

2.2.6. EFFLUENT GUIDELINES SCHEDULE AND PREVIOUS ACTIONS RELATED TO CONSTRUCTION AND DEVELOPMENT

CWA section 304(m) requires EPA to publish a plan every 2 years that consists of three elements. First, under section 304(m)(1)(A), EPA is required to establish a schedule for the annual review and revision of existing effluent guidelines in accordance with section 304(b). Section 304(b) applies to ELGs for direct dischargers and requires EPA to revise such regulations as appropriate. Second, under section 304(m)(1)(B), EPA must identify categories of sources discharging toxic or nonconventional pollutants for which EPA has not published BAT ELGs under section 304(b)(2) or NSPS under Part 306. Finally, under section 304(m)(1)(C), EPA must establish a schedule for the promulgation of BAT and NSPS for the categories identified under subparagraph (B) not later than 3 years after being identified in the 304(m) plan. Section 304(m) does not apply to pretreatment standards for indirect dischargers, which EPA promulgates pursuant to CWA sections 307(b) and 307(c).

On October 30, 1989, Natural Resources Defense Council, Inc. (NRDC), and Public Citizen, Inc., filed an action against EPA in which they alleged, among other things, that EPA had failed to comply with section 304(m). Plaintiffs and EPA agreed to a settlement of that action in a consent decree entered on January 31, 1992 (*Natural Resources Defense Council et al v. Whitman, D.D.C.* Civil Action No. 89-2980). The consent decree, which has been modified

several times, established a schedule by which EPA is to propose and take final action for 11 point source categories identified by name in the decree and for eight other point source categories identified only as new or revised rules, numbered 5 through 12. EPA selected the Construction and Development (C&D) category as the subject for new or revised rule #10. The decree, as modified, calls for the Administrator to sign a proposed ELG for the C&D category no later than May 15, 2002, and to take final action on that proposal no later than March 31, 2004. A settlement agreement between the parties, signed on June 28, 2000, requires that EPA develop regulatory options applicable to discharges from construction, development, and redevelopment covering site sizes included in the Phase I and Phase II NPDES stormwater rules (i.e., 1 acre or greater). EPA is required to develop options including numeric effluent limitations for sedimentation and turbidity; control of construction site pollutants other than sedimentation and turbidity (e.g., discarded building materials, concrete truck washout, trash); best management practices (BMPs) for controlling post-construction runoff; BMPs for construction sites; and requirements to design stormwater controls to maintain pre-development runoff conditions where practicable.

On June 24, 2002, EPA published a proposed rule for the C&D category that contained several options for the control of stormwater discharges from construction sites, including effluent limitations guidelines (ELGs) and NSPS. (67 FR 42644; June 24, 2002). In a final action on April 26, 2004, EPA determined that national ELGs would not be the most effective way to control discharges from construction sites, and instead chose to rely on the range of existing programs, regulations, and initiatives that already existed at the federal, state, and local level. (69 FR 22472).

The June 28, 2000, settlement agreement also required EPA to issue guidance to MS4s and other permittees on maintenance of post-construction BMPs identified in the proposed ELGs. Because EPA's proposal or final action did not contain requirements for post-construction BMPs, this guidance was considered no longer necessary and therefore was not fully developed. However, a draft of the maintenance guidance that was prepared while EPA was considering including options for post-construction BMPs is contained in the public docket.

On October 6, 2004, NRDC and Waterkeeper Alliance, as well as the States of New York and Connecticut filed a motion against EPA alleging that EPA failed to promulgate ELGs and NSPS as required by the Clean Water Act. On December 1, 2006, the district court—in *Natural Resources Defense Council, et al. v. U.S. Environmental Protection Agency, et al.*, 437 F.Supp.2d 1137, 1139 (C.D. Cal.2006)—held that CWA section 304(m), read together with CWA section 304(b), imposes on EPA a mandatory duty to promulgate ELGs and NSPS for industrial point source categories named in a CWA section 304(m) plan. EPA argued during this litigation that the Agency is required only by statute to publish a biennial schedule listing potential industries to regulate and that EPA is not compelled to actually promulgate regulations for those industries identified in the plan. The court found that merely publishing a schedule is not reasonable and that EPA has a mandatory duty to promulgate effluent guidelines for categories of industry listed in the biennial effluent guidelines plan. The court also found that the review and comment process serves to elicit response to the content of ELGs, not to the advisability of promulgating them at all. The court ordered EPA to publish proposed regulations in the FR by December 1, 2008, and to promulgate ELGs and NSPS for the C&D category as soon as practicable, but no later than December 1, 2009.

2.2.7. NPDES PHASE I AND II STORMWATER RULES

As authorized by the CWA, the NPDES permit program was established to control water pollution by regulating point sources that discharge pollutants into waters of the United States. Stormwater runoff from construction activities can have a significant impact on water quality. The NPDES stormwater program requires operators of construction sites to apply for either a general permit or an individual permit under the NPDES Phase I and II stormwater rules. Phase I of EPA's stormwater program was promulgated in 1990 under the CWA and addresses, among other discharges, discharges from construction activities disturbing 5 acres or more of land. Phase II of the NPDES stormwater program, promulgated in 1999, expands the Phase I Rule by addressing stormwater discharges from small construction sites disturbing between 1 and 5 acres. In addition, operators of small construction sites are also required to develop and implement a stormwater pollution prevention plan (SWPPP), which includes implementation of the appropriate ESC BMPs. The BMP selection and design are at the discretion of permittees (in conformance with applicable state or local requirements). Moreover, construction activities disturbing less than 1 acre are also included in Phase II of the NPDES stormwater program if they are part of a larger, common plan of development or sale with a planned disturbance of equal to or greater than 1 acre and less than 5 acres, or if they are designated by the NPDES permitting authority.

Most states are authorized to implement the stormwater NPDES permitting program. However, EPA remains the permitting authority in a few states, territories, and on most Indian country lands. For construction (and other land disturbing activities) in areas where EPA is the permitting authority, operators must meet the requirements of the EPA Construction General Permit (CGP).

The current CGP became effective on June 30, 2008 (as modified effective September 29, 2008) and expires on June 30, 2010. This permit contains substantially the same terms and conditions as the 2003 CGP. In response to comments on the proposal, EPA has reorganized the content of the 2003 permit to better clarify existing requirements. The 2008 CGP applies only to new discharges. Construction site operators with permit coverage under the 2003 CGP may continue to operate under the terms of conditions of that permit and need not file a new Notice of Intent for coverage under the 2008 CGP. Permit coverage is now available for eligible construction activities in New Hampshire, Oklahoma, Texas, Puerto Rico, federal facilities, and Indian country lands in Colorado and Montana.

The 2003 permit expanded coverage from the 1998 CGP that provided coverage for large construction sites (i.e., those disturbing greater than 5 acres) to include both small and large construction activities (i.e., any project disturbing greater than 1 acre). Small construction activity was added to the 2003 CGP in response to the promulgation of the NPDES Phase II Rule.

A major provision required by the CGP is preparation of a SWPPP. The SWPPP focuses on two major requirements: (1) Providing a site description that identifies sources of pollution to stormwater discharges associated with industrial activity on site; and (2) identifying and implementing appropriate measures to reduce pollutants in stormwater discharges to ensure compliance with the terms and conditions of the permit. All SWPPPs must be developed in accordance with sound engineering practices and must be developed specific to the site. For

coverage under the permit, the SWPPP must be prepared before commencement of construction and then updated as appropriate. Commencement of construction activities is defined as the initial disturbance of soils associated with clearing, grading, or excavating activities or other construction-related activities (e.g., stockpiling of fill material).

The permit also clarifies that once a definable area of the site has been finally stabilized, no further SWPPP requirements apply to that portion of the site as long as the SWPPP has been updated accordingly to identify that portion of the site as complete. The SWPPP must be implemented as written from commencement of construction activity until final stabilization is complete. Stabilization practices include seeding of temporary vegetation, seeding of permanent vegetation, mulching, geotextiles, sod stabilization, vegetative buffer strips, preservation of trees and mature vegetative buffer strips, and other appropriate measures. For a detailed description of all permit requirements and conditions, see the CGP.

2.3. POLLUTION PREVENTION ACT OF 1990

The Pollution Prevention Act of 1990 (PPA) (42 U.S.C. 13101 et seq., Pub. L. 101-508, November 5, 1990) makes pollution prevention the national policy of the United States. The PPA identifies an environmental management hierarchy in which pollution "should be prevented or reduced whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or release into the environment should be employed only as a last resort..." (42 U.S.C. 13103). In short, preventing pollution before it is created is preferable to trying to manage, treat, or dispose of it after it is created. According to the PPA, source reduction reduces the generation and release of hazardous substances, pollutants, wastes, contaminants, or residuals at the source, usually within a process. The term *source reduction* "...includes equipment or technology modifications, process or procedure modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control. The term 'source reduction' does not include any practice which alters the physical, chemical, or biological characteristics or the volume of a hazardous substance, pollutant, or contaminant through a process or activity which itself is not integral to or necessary for the production of a product or the providing of a service." In effect, source reduction means reducing the amount of a pollutant that enters a waste stream or that is otherwise released into the environment before out-of-process recycling, treatment, or disposal.

Although the PPA does not explicitly address stormwater discharges or discharges from construction sites, the principles of the PPA are implicit in many of the practices used to reduce pollutant discharges from construction sites. These include controls that minimize the potential for erosion such as proper phasing of construction, retention of on-site vegetation and stabilization of disturbed areas as soon as practicable. These controls and practices are described in Section 7 of this document.

2.4. STATE REGULATIONS

States and municipalities have been regulating discharges of runoff from the construction and land development industry to varying degrees for some time. A compilation of state CGPs and regulations was prepared to help establish the baseline for national and regional levels of control. Data were collected by reviewing state CGPs, Web sites, summary references, and state erosion and sediment control and/or stormwater management guidance manuals. The state regulatory data are discussed in Sections 3.4 and 9.2 of this document, and the complete data sheets are included in Appendix A.

3. DATA COLLECTION

3.1. INTRODUCTION

As part of the regulatory efforts to develop the proposed Construction and Development (C&D) regulations in 2002 and the related final action in 2004, the U.S. Environmental Protection Agency (EPA) gathered and evaluated an extensive amount of technical and economic data from various sources. EPA used much of the data collected for the previous rulemaking effort in support of this effort. EPA also collected additional data and information to support the technical analyses used in developing this proposal. This section summarizes EPA's data collection efforts.

3.2. LITERATURE SEARCH

A literature search was performed to obtain additional information on various erosion and sediment control (ESC) technologies that pertain to the C&D industry. Journal articles and professional conference proceedings were reviewed to collect recent data and information related to ESC design and installation criteria, performance, and related costs. Appendix B provides annotated bibliographies for the journal articles and professional conference proceedings that EPA reviewed for possible use in developing this proposal.

3.3. DATA AND INFORMATION PROVIDED IN RESPONSE TO THE 2002 REGULATORY ACTION

In response to the previous rulemaking efforts for the C&D industry, EPA received numerous public comments on most aspects of the 2002 proposed rule. EPA considered these comments in developing this proposal.

3.4. COMPILATION OF STATE CONTROL STRATEGIES, CRITERIA, AND STANDARDS

EPA compiled and evaluated existing state program information for the control of construction site stormwater. The data were collected by reviewing state construction general permits (CGPs), Web sites, summary references, state regulations, and ESC design and guidance manuals. A summary of criteria and standards for construction site stormwater ESC that are implemented by states is presented in Appendix A. More information on this analysis is in Section 9.2, Analysis of State Equivalency. Appendix A also includes updated state information that EPA obtained in early 2007, state-level data sheets and information originally presented in Section 7 and Appendix D of the 2004 *Development Document for Final Action for Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-B-04-001), and information originally presented in Appendix A of the June 2002 *Development Document for Proposed Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-R-02-007).

3.5. OTHER DATA SOURCES

3.5.1. LAND USE DATA

EPA accessed a number of sources of land cover information at a national scale for use in estimating the potential number of acres subject to C&D activities.

3.5.1.1. National Land Cover Dataset

The National Land Cover Database (NLCD) provides a national source of data on land cover change. The Multi-Resolution Land Characteristics Consortium (MRLC) has produced the NLCD data sets that created a 30-meter resolution land cover data layer over the conterminous United States (CONUS) from Landsat Thematic Mapper satellite imagery. NLCD data are publicly available for the years 1992 and 2001 (see http://www.epa.gov/mrlc/ and http://www.mrlc.gov/).

Because of new developments in mapping methodology, new sources of input data, and changes in the mapping legend for the 2001 NLCD confound direct comparison between NLCD 2001 and the 1992 NLCD (MRLC 1992 and 2001), the U.S. Geological Survey (USGS) prepared and released the NLCD 1992/2001 Retrofit Land Cover Change Product. The NLCD 1992/2001 Retrofit Land Cover Change Product was developed to offer more accurate direct change analysis between the two products.

The NLCD 1992/2001 Retrofit Land Cover Change Product uses a specially developed methodology to provide land cover change information at the Anderson Level I classification scale, relying on decision tree classification of Landsat imagery from 1992 and 2001. While NLCD 1992 reported on developed land in the categories of low residential intensity, high residential intensity, commercial/industrial/transportation, and urban/recreational grasses, NLCD 2001 reported categories of developed low, medium, high, and open space. To compare change between the two data sets, the developed categories were merged into one overall urban class. Unchanged pixels between the two dates are coded with the NLCD 2001 Anderson Level I class code, while changed pixels are labeled with a *from-to* land cover change value. Modified Anderson Level 1 Classifications include the following:

- Open water
- Urban
- Barren
- Forest
- Grassland/Shrub
- Agriculture
- Wetlands Ice/Snow

The NLCD 1992/2001 Retrofit Land Cover Change Product was intended to provide a current, consistent, and seamless data set for the United States at medium spatial resolution for Anderson Level 1 classes. This land cover change map and all documents pertaining to it are considered *provisional* until a formal accuracy assessment can be conducted.

EPA used the NLCD to estimate the annual number of acres of land converted to urban land uses in the United States during the period between 1992 and 2001. This estimate serves as a surrogate measure of the acres of construction activities subject to national effluent guidelines regulations, because no national database of the number and size of construction activities exists. Figure 3-1 illustrates an example of the Reach File Version 1.0 (RF1)-level analysis of the NLCD data.

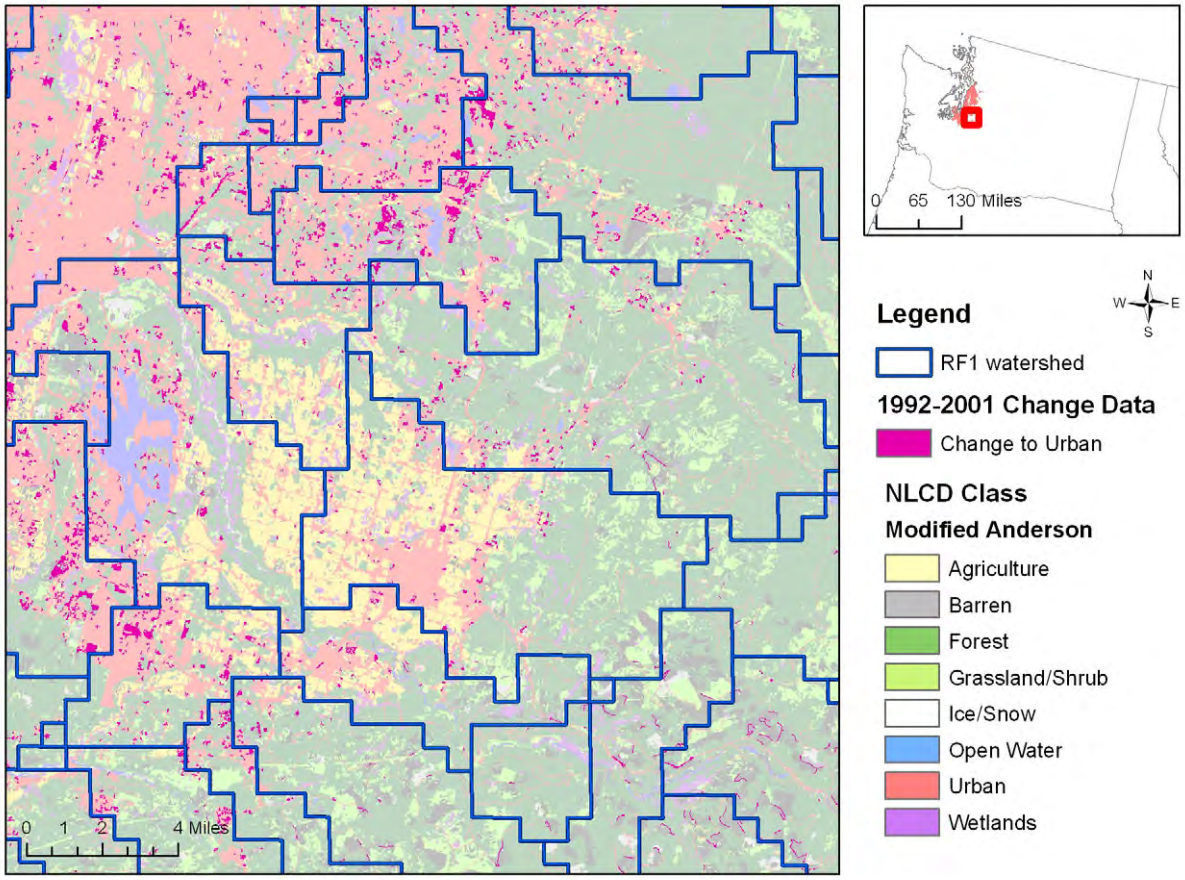

Figure 3-1. NLCD 1992/2001 Land Cover Change Product near Seattle, Washington.

Table 3-1 summarizes the national- and state-level estimates obtained from the NLCD analysis. Figures 3-2 through 3-11 graphically present the results of the NLCD land use change analysis at the RF1 level. Results are presented as percent urban change between 1992 and 2001. (See DCN 43097 in the Administrative Record for an index of the NLCD-related analyses conducted for the proposed rule.)

Table 3-1. State and National Estimates of Urban Land from NLCD

	1992 Urban acres	2001 Urban acres	% State that is developed (1992)	% State that is developed (2001)	Annual rate of development, 1992–2001 (acres)
Alabama	2,066,843	2,197,370	6.4%	6.8%	14,503
Alaska	NO DATA				
Arizona	1,285,258	1,407,907	1.8%	2.0%	13,628
Arkansas	1,836,496	1,912,867	5.5%	5.8%	8,486
California	6,278,143	6,524,934	6.2%	6.5%	27,421
Colorado	1,609,387	1,751,860	2.4%	2.6%	15,830
Connecticut	727,078	736,131	23.4%	23.6%	1,006
Delaware	113,052	120,552	9.4%	10.0%	833
Florida	4,526,626	4,869,204	13.0%	14.0%	38,064
Georgia	3,026,921	3,320,243	8.2%	9.0%	32,591
Hawaii	NO DATA				
Idaho	847,520	898,587	1.6%	1.7%	5,674
Illinois	4,014,480	4,198,994	11.3%	11.8%	20,502
Indiana	2,238,170	2,349,522	9.9%	10.4%	12,372
Iowa	2,527,225	2,618,075	7.1%	7.4%	10,094
Kansas	2,463,194	2,666,039	4.7%	5.1%	22,538
Kentucky	1,740,669	1,830,453	6.8%	7.2%	9,976
Louisiana	1,788,423	1,904,013	6.6%	7.0%	12,843
Maine	653,697	694,157	3.3%	3.5%	4,496
Maryland	698,386	757,203	11.3%	12.2%	6,535
Massachusetts	1,174,234	1,204,116	23.9%	24.5%	3,320
Michigan	3,746,569	3,949,025	10.3%	10.9%	22,495
Minnesota	2,648,001	2,731,981	5.2%	5.4%	9,331
Mississippi	1,721,138	1,827,846	5.7%	6.1%	11,856
Missouri	2,845,661	2,967,610	6.5%	6.8%	13,550
Montana	1,187,901	1,246,005	1.3%	1.4%	6,456
Nebraska	1,699,570	1,754,268	3.5%	3.6%	6,078
Nevada	572,706	646,109	0.8%	0.9%	8,156
New Hampshire	426,786	442,861	7.5%	7.7%	1,786
New Jersey	1,124,705	1,163,128	23.7%	24.5%	4,269
New Mexico	799,207	841,237	1.0%	1.1%	4,670
New York	2,682,301	2,751,793	8.9%	9.1%	7,721
North Carolina	2,816,229	2,984,873	9.1%	9.6%	18,738
North Dakota	1,667,029	1,725,866	3.9%	4.0%	6,537
Ohio	3,549,025	3,705,609	13.6%	14.2%	17,398
Oklahoma	2,387,508	2,538,082	5.4%	5.7%	16,730
Oregon	1,552,824	1,618,391	2.5%	2.6%	7,285
Pennsylvania	3,006,384	3,150,410	10.4%	10.9%	16,003
Rhode Island	173,764	177,161	27.0%	27.5%	377
South Carolina	1,487,194	1,632,717	7.7%	8.5%	16,169
South Dakota	1,315,111	1,389,905	2.7%	2.9%	8,310
Tennessee	2,189,700	2,307,498	8.3%	8.8%	13,089
Texas	8,229,892	8,781,625	5.0%	5.3%	61,304

	1992 Urban acres	2001 Urban acres	% State that is developed (1992)	% State that is developed (2001)	Annual rate of development, 1992–2001 (acres)
Utah	758,031	833,531	1.4%	1.6%	8,389
Vermont	304,570	309,695	5.4%	5.5%	569
Virginia	1,818,500	1,954,814	7.2%	7.7%	15,146
Washington	2,286,574	2,401,699	5.4%	5.7%	12,792
West Virginia	1,016,805	1,048,419	6.7%	6.9%	3,513
Wisconsin	2,345,956	2,414,075	6.7%	6.9%	7,569
Wyoming	491,168	516,758	0.8%	0.8%	2,843
District of Columbia	26,381	26,973	82.8%	83.8%	66
Nation	**96,492,992**	**101,802,191**			**589,911**

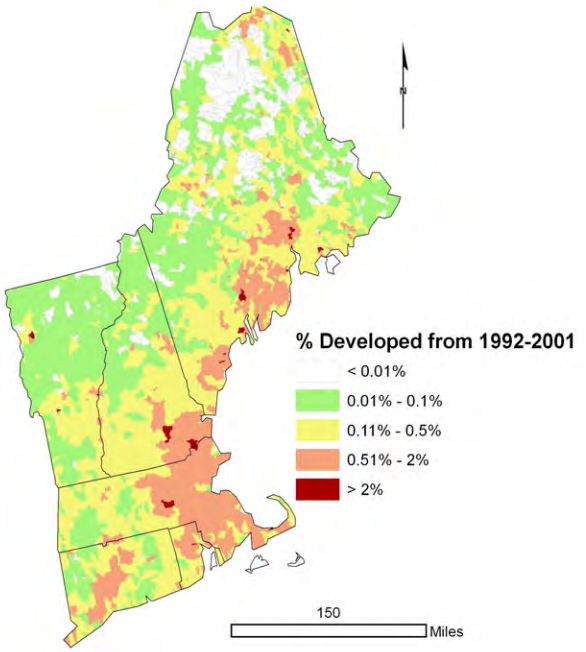

Figure 3-2. EPA Region 1: Percent urban change 1992–2001 by ERF1_2 Watershed.

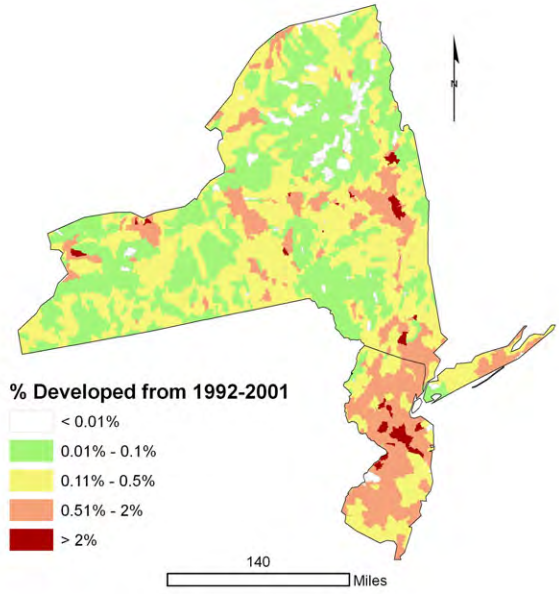

Figure 3-3. EPA Region 2: Percent urban change 1992–2001 by ERF1_2 Watershed.

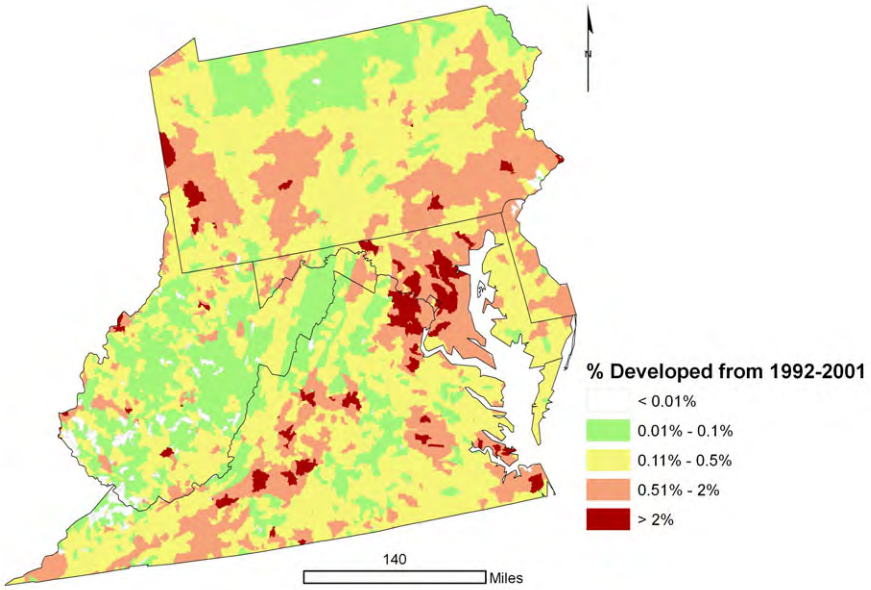

Figure 3-4. EPA Region 3: Percent urban change 1992–2001 by ERF1_2 Watershed.

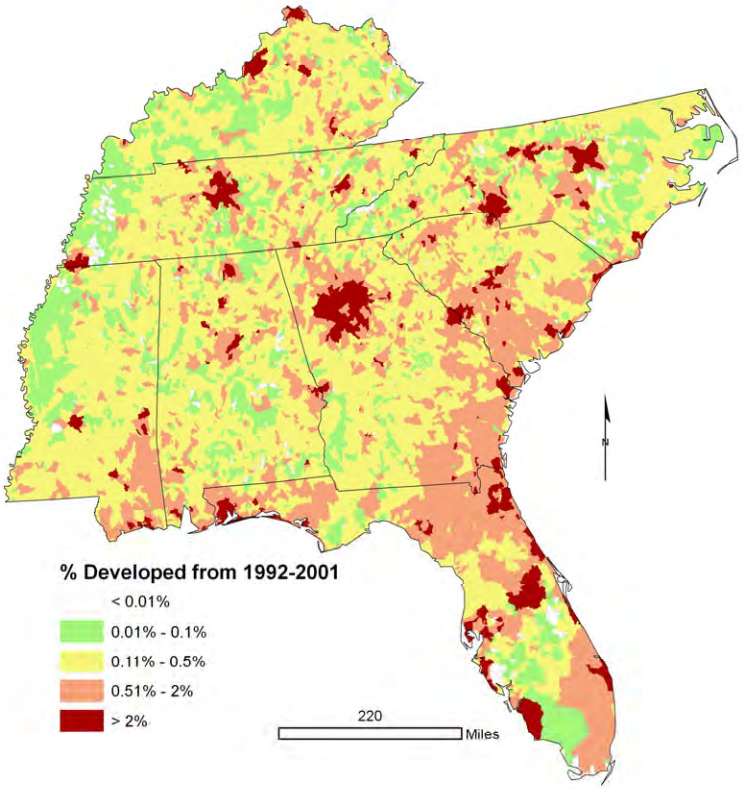

Figure 3-5. EPA Region 4: Percent urban change 1992–2001 by ERF1_2 Watershed.

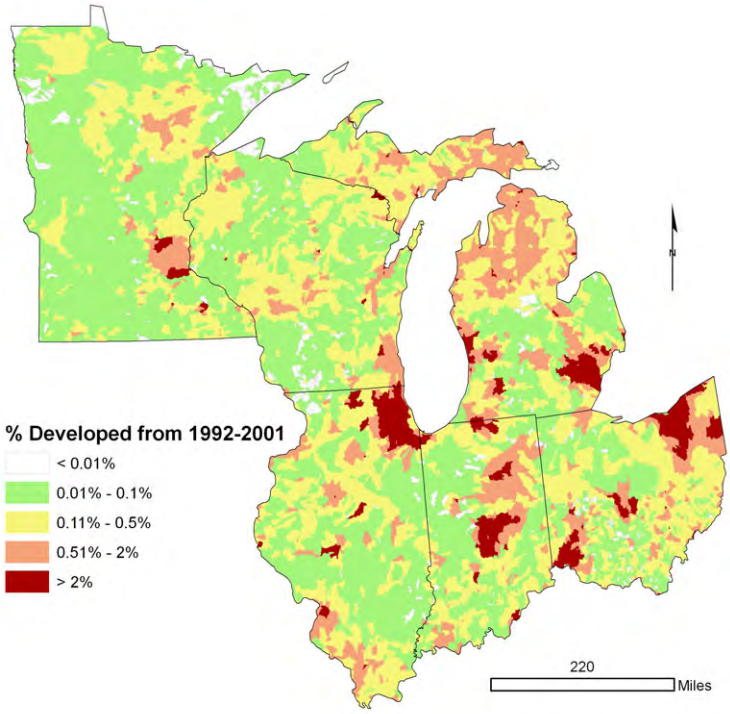

Figure 3-6. EPA Region 5: Percent urban change 1992–2001 by ERF1_2 Watershed.

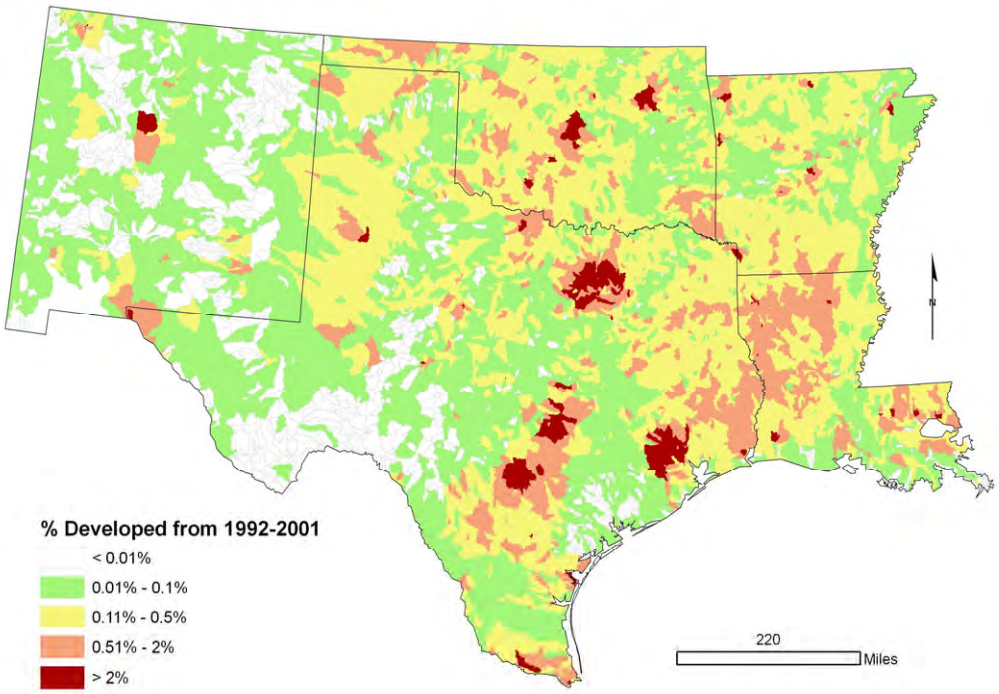

Figure 3-7. EPA Region 6: Percent urban change 1992–2001 by ERF1_2 Watershed.

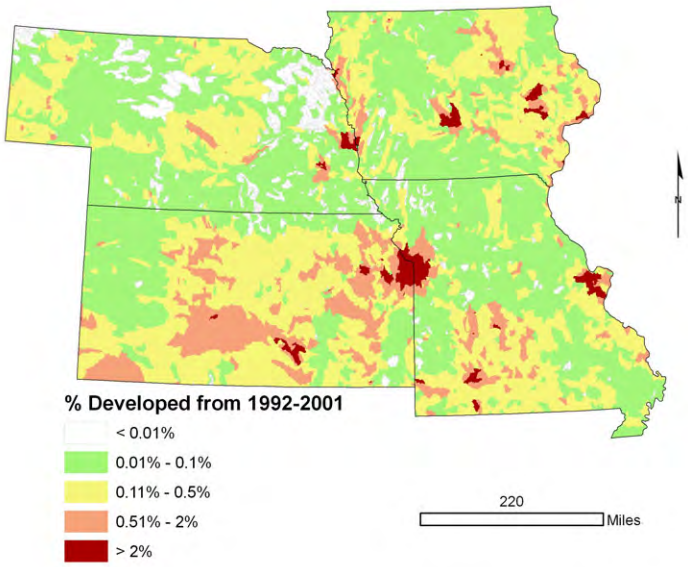

Figure 3-8. EPA Region 7: Percent urban change 1992–2001 by ERF1_2 Watershed.

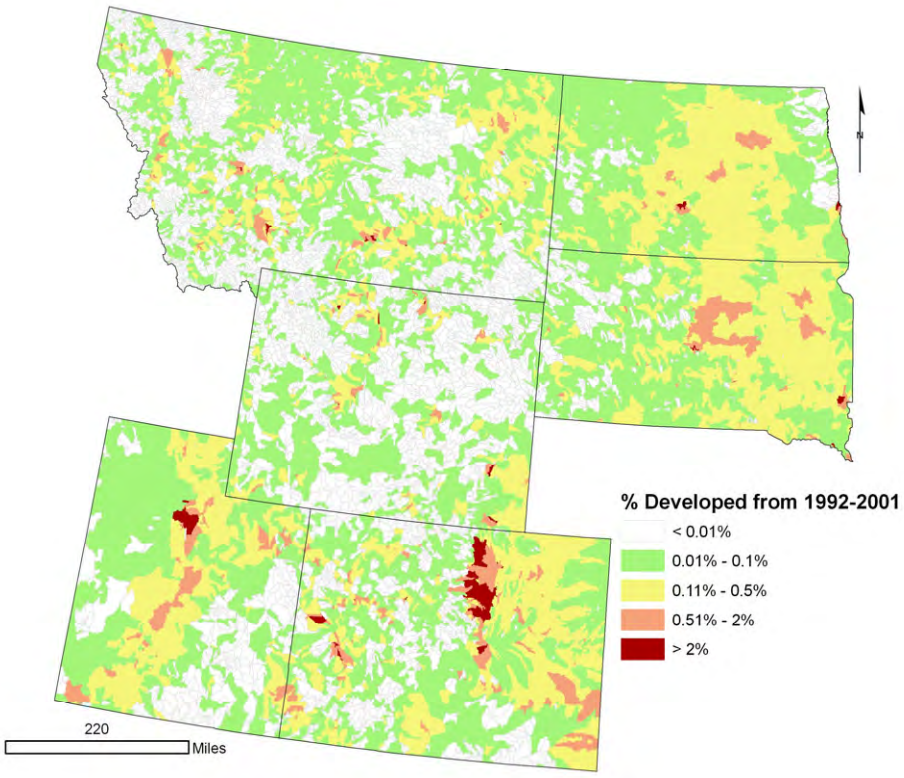

Figure 3-9. EPA Region 8: Percent urban change 1992–2001 by ERF1_2 Watershed.

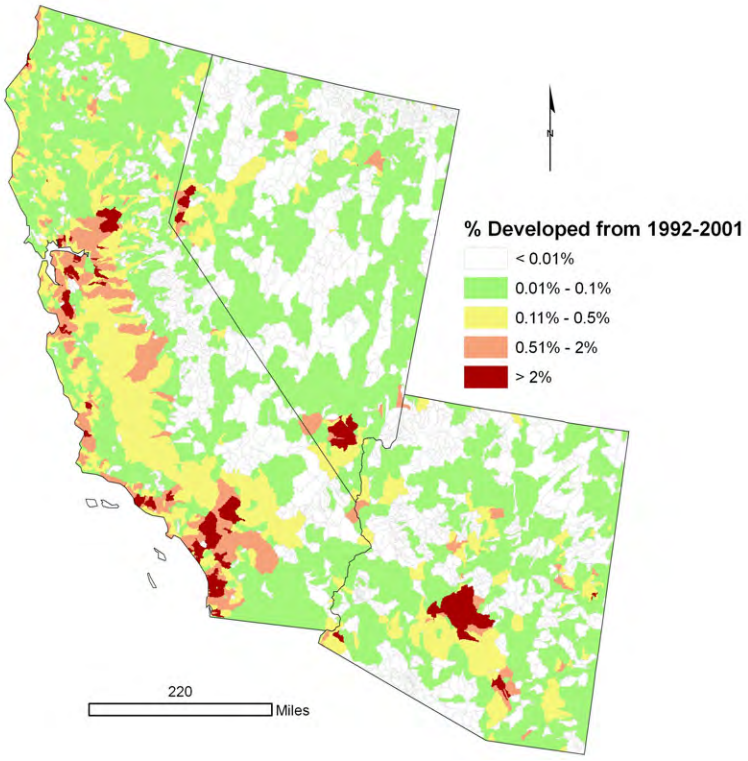

Figure 3-10. EPA Region 9: Percent urban change 1992–2001 by ERF1_2 Watershed.

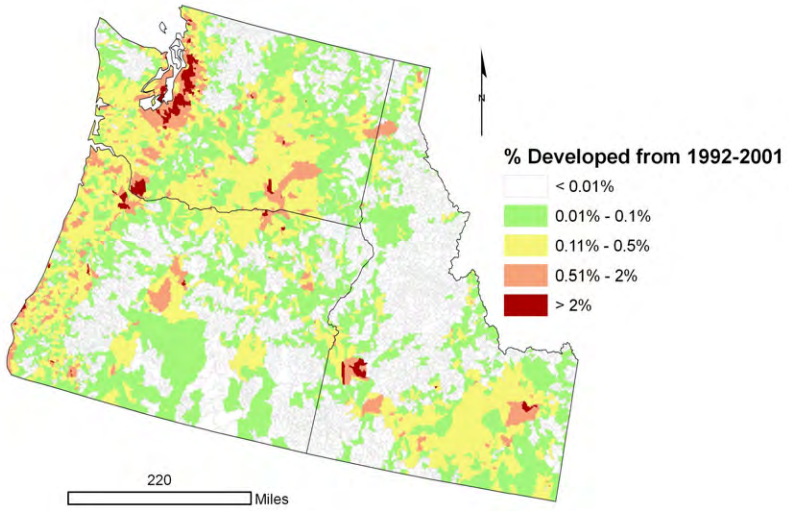

Figure 3-11. EPA Region 10: Percent urban change 1992–2001 by ERF1_2 Watershed.

Estimates of the amount of construction activity occurring in each state based on NLCD data were used as a basis for calculating state-level compliance costs. NLCD data was also used to estimate the amount of construction activity occurring in each of the watersheds in the United States on the basis of the EPA RF1 cataloging system (discussed below). RF1-level data (along with other data sources) were used to estimate the quantity of construction activities and the associated pollutant loads occurring in each RF1 and to link these loads to stream reaches for

modeling of water quality improvements and benefits estimates. Because NLCD data does not exist for Alaska, Hawaii, or the U.S. territories, EPA's analysis does not consider costs or pollutant loading reductions for these areas. Detailed definitions and discussion of the NLCD 1992/2001 Retrofit Product is presented in Appendix E. DCN 43097 in the Administrative Record provides an index to the NLCD-related analyses conducted for the proposed rule.

3.5.1.2. River Reach File Data

An option for summarizing national land cover change in drainage area units is to use EPA's RF1 for the CONUS. RF1 is a vector database of approximately 700,000 miles of streams and open waters in the CONUS. EPA and states use it extensively, and the U.S. Fish and Wildlife Service and the National Weather Service (NWS) have used it for many years. EPA prepared RF1 in 1982 from National Oceanic and Atmospheric Administration (NOAA) aeronautical charts having a scale of 1:500,000. These charts provided the best nationwide hydrographic coverage available on a single scale at that time. They include all hydrography shown on USGS maps having a scale of 1:250,000 with extensive additions, corrections, and improvements in detail made by NOAA from aerial photography and satellite imagery. In the 1980s, EPA used RF1 for performing water quality modeling on whole river basins for all the hydrologic regions in the CONUS. In this role, it was used to provide national assessments and overviews of water quality and to provide the foundation for a nationwide, stratified, sampling frame for performing statistical summaries of modeled and measured water quality on all surface waters of the CONUS.

A consistent, national scale watershed data set was prepared to enhance the RF1 hydrology data set. This watershed data set, the Enhanced River Reach File 1.2 (ERF1), was designed to be a digital database of river reaches capable of supporting regional and national water-quality and river-flow modeling and transport investigations in the water-resources community. ERF1 has been used at the USGS to support interpretations of stream water-quality monitoring network data. In these analyses, the reach network has been used to determine flow pathways between the sources of point and nonpoint pollutants and downstream water-quality monitoring locations in support of predictive water-quality models of stream nutrient transport.

The Enhanced River Reach File 2.0 (ERF1_2) expands on ERF1 and includes the incremental and total drainage area founded on the 1-kilometer (km) elevation data for North America (Nolan 2002). Previous estimates of the water time-of-travel were recomputed for reaches with water quality monitoring sites that included two reaches. The mean flow and velocity estimates for these split reaches are based on previous estimation methods (Alexander et al. 1999) and are unchanged in ERF1_2. Drainage area calculations provide data used to estimate the contribution of a given nutrient to the outflow. ERF1_2 contains 67,171 watersheds with a minimum size of 247 acres (1 square km [km^2]) and an average size of 30,182 acres (122 km^2).

EPA used the ERF1_2 as the foundation for summarizing land cover change and in drainage area units (or watersheds) and for SPARROW (Spatially Referenced Regressions [of nutrient transport] on Watershed) modeling. Within the context of a geographic information system (GIS), SPARROW estimates the proportion of watersheds in the CONUS with outflow concentrations of several nutrients, including total nitrogen and total phosphorus, (Smith et al.

1997). EPA modified SPARROW to model changes in sediment flux in the RF1 network to evaluate potential benefits of regulatory options.

3.5.2. NPDES PERMIT NOTICE OF INTENT DATA

EPA used CGP Notice of Intent (NOI) records to characterize construction activity by project type and project size for subsequent analysis of costs and pollutant loading reductions. Using NOI data, EPA broadly characterized the construction industry into three land use types (residential construction, nonresidential construction, and road/highway construction). EPA has NOI data for approximately 138,000 permit applications, containing data from 38 states for construction activities occurring primarily between the mid-1990s and 2006. Depending on the state, the number of NOI records available ranged from fewer than 10 to more than 10,000. The data are available either from a database of permits processed directly by EPA (referred to as the EPA_NOI database) or per-state databases obtained independently. In general, the NOI records are sufficiently similar to allow pooling of all sources regardless of whether EPA or an individual state is the permit processing entity. While the NOI data are useful for characterizing construction activities into different project types and different project sizes, EPA did not find the NOI data useful as a national data set to estimate the amount of construction occurring. This is because the NOI data obtained by EPA is not national in coverage. EPA's analysis of the NOI data can be found in Appendix C, Analysis of Construction Industry Trends using Notice of Intent Records. The NOI permit characterization data is DCN 43093 and the NOI Model Site Assessment is DCN 43094 in the Administrative Record.

3.5.3. CLIMATIC/RAINFALL DATA

3.5.3.1. NOAA National Weather Service Precipitation Frequency Data Server

Variations in rainfall depth and intensity are important factors in determining erosion rates, sediment discharges, pollutant load reductions, and control technology costs for construction sites. For the pollutant loading analysis, EPA used a case study approach based on 11 indicator cities. EPA selected representative areas in each of the 10 EPA Regions to be used as a point estimate for the entire region. EPA generally selected the urban area within each region with the greatest rate of development, on the basis of EPA's analysis of land use change from the NLCD analysis. EPA selected one metropolitan area in each of the 10 EPA Regions, with the exception of Region 10. In Region 10, EPA selected two indicator cities because the two areas with the greatest rate of development (Boise City, Idaho, and Seattle, Washington) have very different rainfall patterns. For each of these 11 indicator cities, EPA obtained detailed rainfall data and rainfall summaries. EPA also obtained detailed soils data for each of these 11 areas. The 11 indicator cities are identified in Table 3-2.

EPA's costing analysis used state-specific rainfall estimates for determining stormwater runoff rates and volumes and for determining sediment basins and treatment system sizing. EPA identified one major city within each state to serve as an indicator for the entire state. EPA obtained rainfall summary data for each of these cities for using as a basis for determining expected runoff rates and rainfall volumes for costing of technologies.

Table 3-2. EPA Region Indicator Cities

EPA Region	Indicator city
1	Manchester, NH
2	Albany, NY
3	Washington, DC, VA, and MD
4	Atlanta, GA
5	Chicago, IL—IN
6	Dallas, Fort Worth, and Arlington, TX
7	Kansas City, MO and KS
8	Denver and Aurora, CO
9	Las Vegas, NV
10	Boise City, ID, and Seattle, WA

Precipitation data was gathered and analyzed using the NOAA NWS Precipitation Frequency Data Server (PFDS). The Hydrometeorological Design Studies Center (HDSC) within the Office of Hydrologic Development of the NWS is in an ongoing process of updating its precipitation frequency estimates, which are available in NOAA Atlas 14 format. At the time of this writing, only a portion of the United States had been updated into this format (NWS 2008). Atlas 14 supercedes precipitation frequency estimates contained in previous NWS publications. The updates are based on more recent and extended data sets, currently accepted statistical approaches, and improved spatial interpolation and mapping techniques. A complete list of NWS publications is at http://www.nws.noaa.gov/ohd/hdsc/currentpf.htm.

NOAA Atlas 14 contains precipitation frequency estimates with associated confidence limits for the United States for 5-minute through 60-day durations at average recurrence intervals of 1-year through 1,000-year. The estimates are based on the analysis of annual maximum series and then converted to partial duration series results. The Atlas 14 rainfall data results used in this study are shown in Attachment D to Appendix D.

For the states not currently updated by NOAA Atlas 14, the rainfall-frequency values for selected durations were estimated using a series of maps presented in the older NWS publications. The data for the remainder of the Western United States were estimated by using NOAA Atlas 2, Precipitation Frequency Atlas of the Western United States (NOAA 1973), which are generalized maps presented for 6- and 24-hour point precipitation for the return periods of 2, 5, 10, 25, 50, and 100 years. Atlas 2 is published in separate volumes for each of the states. Similarly, the maps presented in the corresponding Technical Paper were used for the remainder of the Eastern United States and Hawaii. (Alaska was not included in this study because EPA lacked sufficient data on the annual amount of construction activities in Alaska).

Precipitation frequency results not generated by Atlas 2 or Technical Paper maps are presented in Attachment E to Appendix D. The rainfall depths were estimated by identifying the target city on the Atlas 2 or Technical Paper map and linearly approximating the rainfall value. For example, if a city fell between a depth of 4.5 and 5 inches and the city was approximately 20 percent of the map distance from the 5-inch line, a rainfall depth of 4.9 inches was estimated. Note that the maps provided data for depth only. Intensity estimates were calculated by dividing the duration

(e.g., 6- or 24-hour) by the depth. Additionally, Atlas 2 depths were converted from tenths of an inch to inches.

To analyze the percent of total construction site runoff captured and treated for various regulatory options, EPA obtained hourly precipitation data for each indicator city. EPA obtained 30 years of hourly rainfall data from EarthInfo Version 2.31 (www.earthinfo.com). EarthInfo provides National Climatic Data Center (NCDC) meteorological data in an easy-to-use format from which precipitation data can be extracted. From the 7,000 NCDC gages available, EPA generally used data collected at an airport in or adjacent to each indicator city. In general, EPA analyzed data for the period between the mid-1970s and mid-2000s.

Table 3-3 summarizes the state-specific rainfall data EPA used in its analyses. It is important to note that EPA's analysis does not distinguish between precipitation that falls as rain from precipitation that falls as snow or ice.

3.5.3.2. Parameter Elevation Regressions on Independent Slopes Model (PRISM)

Although EPA is not proposing an option that contains an annual precipitation cutoff, EPA did evaluate several scenarios that included annual precipitation as applicability criteria for the turbidity option. EPA's analyses of rainfall-based scenarios required an estimate of the total annual precipitation for each RF1 watershed. PRISM is a climate mapping system that was used to estimate the annual acres that would be exempt from the regulatory scenarios given various rainfall cut-offs. For each RF1 watershed, the average annual rainfall amount was obtained from the 1-km resolution United States Average Monthly or Annual Precipitation (1971–2000) PRISM Group raster data coverage (PRISM Group 2006). RF1 watershed boundaries were used to summarize the PRISM Group average annual rainfall values, and each RF1 was assigned a value by spatially averaging contributing raster data. Using PRISM GIS layers of average annual precipitation along with RF1-level estimates of annual acres of new construction, EPA was able to estimate acres that would be in-scope for regulations given various average annual precipitation cutoffs. Figure 3-12 shows average annual precipitation for the CONUS from the PRISM data. Table 3-4 summarizes percent of new development that would be subject to regulation for various annual precipitation cutoffs. Table 3-5 summarizes these results as acres of new development Additional information on the PRISM data is in Appendix D.

Table 3-3. Rainfall Summary Data for Indicator Cities

State	City	Average annual precipitation (inches)	2-year, 24-hour storm depth (inches)	10-year, 24-hour storm depth (inches)	25-year, 24-hour storm depth (inches)	10-year, 6 hour storm depth (inches)
Alabama	Montgomery	49	4.50	6.5	7.6	4.60
Arizona	Phoenix	8	1.40	2.14	2.59	1.57
Arkansas	Little Rock	48	4.10	6.05	7	4.35
California	Sacramento	18	2.00	3	3.5	1.70
Colorado	Denver	13	2.00	3	3.8	2.30
Connecticut	Hartford	44	3.10	4.8	5.5	3.25
Delaware	Dover	43	3.26	5.08	6.36	3.44
Florida	Tallahassee	62	4.75	7.4	8.5	5.25
Georgia	Atlanta	51	3.70	5.5	6.5	4.20
Hawaii	Honolulu	18	4.25	7.8	8.9	4.80
Idaho	Boise	11	1.20	1.8	2.2	1.20
Illinois	Chicago	33	2.85	4.29	5.25	3.30
Indiana	Indianapolis	40	2.95	4.13	4.83	3.12
Iowa	Des Moines	32	3.25	4.7	5.5	3.54
Kansas	Kansas City	37	3.50	5.2	6.1	3.90
Kentucky	Frankfort	45	3.00	4.34	5.23	3.09
Louisiana	Baton Rouge	59	5.25	8.2	9.1	5.75
Maine	Augusta	42	2.80	4.25	4.9	2.90
Maryland	Baltimore	42	3.16	4.85	6.08	3.32
Massachusetts	Boston	42	3.10	4.5	5.5	3.30
Michigan	Lansing	30	2.40	3.6	4.2	2.70
Minnesota	St. Paul	29	2.75	4.2	4.7	3.10
Mississippi	Jackson	52	4.45	6.7	7.8	4.70
Missouri	Kansas City	37	3.45	5.3	6	3.85
Montana	Helena	12	1.30	2.1	2.4	1.10
Nebraska	Lincoln	28	3.00	4.8	5.4	3.52
Nevada	Las Vegas	4	1.00	1.62	1.96	1.29
New Hampshire	Manchester	40	2.80	4.3	5	3.20
New Jersey	Hightstown	47	3.31	5.07	6.3	3.55

State	City	Average annual precipitation (inches)	2-year, 24-hour storm depth (inches)	10-year, 24-hour storm depth (inches)	25-year, 24-hour storm depth (inches)	10-year, 6 hour storm depth (inches)
New Mexico	Santa Fe	15	1.54	2.22	2.62	1.77
New York	Albany	37	2.90	4	5.9	3.10
North Carolina	Charlotte	43	3.34	4.86	5.76	3.54
North Dakota	Bismarck	16	1.90	3.25	3.75	2.50
Ohio	Columbus	38	2.62	3.73	4.44	2.80
Oklahoma	Oklahoma City	33	3.70	5.8	6.9	4.25
Oregon	Salem	41	2.50	3.5	4	2.90
Pennsylvania	Philadelphia	42	3.23	4.8	5.85	3.38
Rhode Island	Providence	45	3.20	4.8	5.7	3.40
South Carolina	Columbia	45	3.62	5.28	6.39	3.85
South Dakota	Pierre	16	2.25	3.5	4.1	2.75
Tennessee	Nashville	46	3.37	4.7	5.53	3.31
Texas	Fort Worth	33	3.90	6.3	7.4	4.55
Utah	Salt Lake City	15	1.40	1.9	2.21	1.27
Vermont	Montpelier	34	2.40	3.7	4.25	2.70
Virginia	Arlington	40	3.11	4.78	5.98	3.29
Washington	Seattle	35	2.00	3	3.4	1.40
West Virginia	Charleston	43	2.56	3.55	4.16	2.56
Wisconsin	Madison	31	2.80	4.1	4.75	3.15
Wyoming	Cheyenne	15	1.60	2.4	2.8	1.90
Puerto Rico	San Juan	51	4.26	6.76	8.29	4.42
District of Columbia	Washington	42	3.16	4.85	6.07	3.32

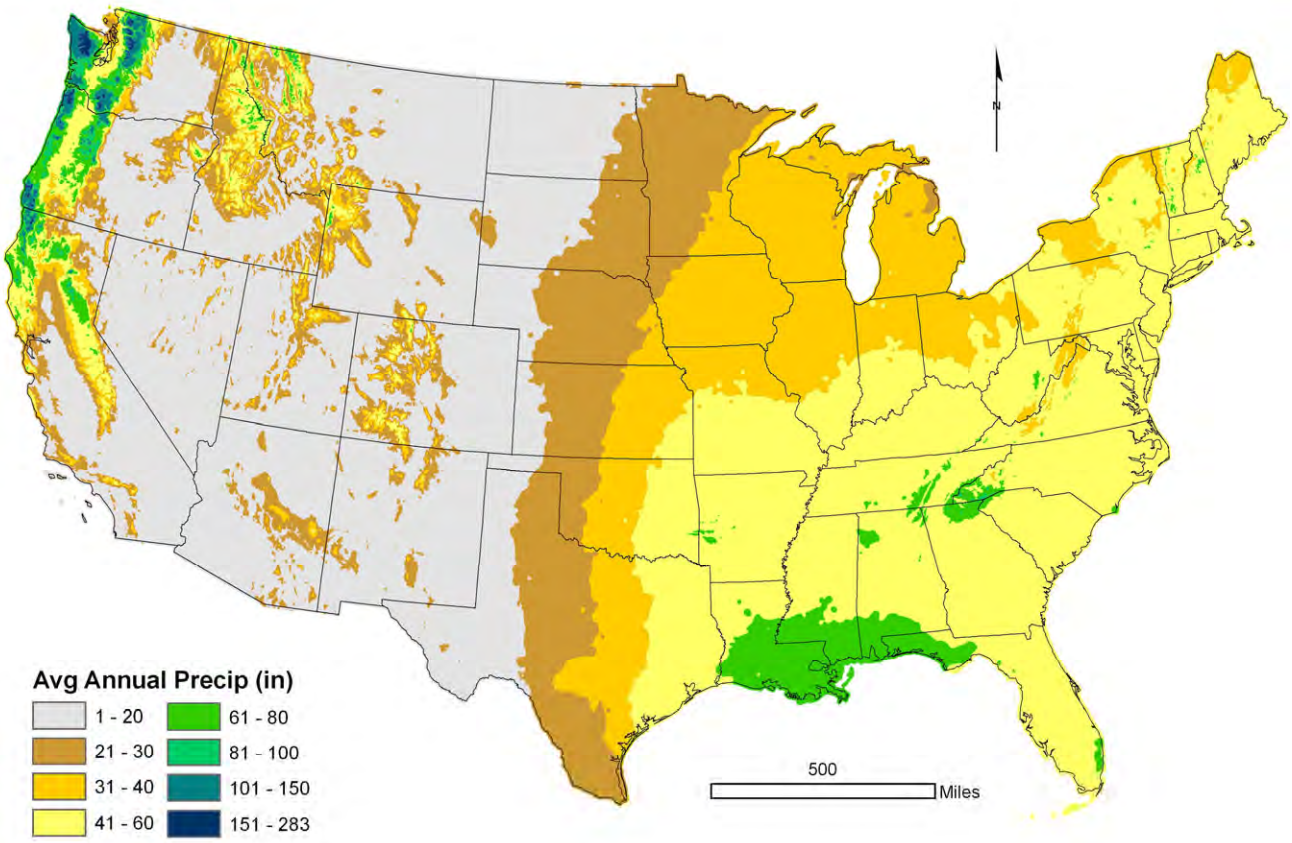

Figure 3-12. Average Annual Precipitation in the CONUS from PRISM.

Table 3-4. Percent of Developed Acres In-Scope for Various Annual Precipitation Amounts

Annual precipitation (in inches) =>>	5	10	15	20	25	30	35	40	45	50
Alaska	NOT ANALYZED									
Alabama	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.4%
Arizona	96.8%	43.7%	13.1%	5.2%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Arkansas	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.4%	64.6%
California	98.9%	83.9%	56.9%	32.0%	11.0%	8.0%	6.8%	5.8%	4.1%	3.0%
Colorado	100.0%	93.9%	62.4%	8.0%	1.7%	0.9%	0.5%	0.2%	0.0%	0.0%
Connecticut	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	60.3%
Delaware	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	45.5%	0.0%
Florida	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.5%
Georgia	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	71.3%
Hawaii										NOT ANALYZED
Idaho	100.0%	93.7%	29.5%	17.3%	9.7%	6.0%	1.8%	0.6%	0.3%	0.0%
Illinois	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.8%	12.2%	4.0%	0.0%
Indiana	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	51.4%	13.2%	0.0%
Iowa	100.0%	100.0%	100.0%	100.0%	100.0%	91.0%	41.0%	0.0%	0.0%	0.0%
Kansas	100.0%	100.0%	100.0%	90.4%	72.7%	58.9%	39.2%	10.4%	0.3%	0.0%
Kentucky	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	85.3%	29.5%
Louisiana	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Maine	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	85.7%	42.0%	2.4%
Maryland	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.8%	25.0%	0.3%
Massachusetts	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	96.9%	1.2%
Michigan	100.0%	100.0%	100.0%	100.0%	100.0%	96.3%	15.6%	0.0%	0.0%	0.0%
Minnesota	100.0%	100.0%	100.0%	99.9%	88.3%	46.6%	0.0%	0.0%	0.0%	0.0%
Mississippi	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Missouri	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	71.2%	11.9%	0.1%
Montana	100.0%	99.8%	38.9%	13.7%	5.6%	2.4%	1.3%	0.9%	0.5%	0.0%

Annual precipitation (in inches) =>>	5	10	15	20	25	30	35	40	45	50
Nebraska	100.0%	100.0%	99.7%	71.9%	47.1%	23.1%	0.0%	0.0%	0.0%	0.0%
Nevada	97.1%	25.8%	9.5%	2.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%
New Hampshire	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.6%	66.1%	3.7%
New Jersey	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	86.5%	13.9%
New Mexico	100.0%	87.2%	28.3%	3.4%	0.6%	0.1%	0.0%	0.0%	0.0%	0.0%
New York	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	93.0%	67.1%	28.2%	7.9%
North Carolina	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%	97.6%	20.4%
North Dakota	100.0%	100.0%	96.9%	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Ohio	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	98.0%	34.5%	0.1%	0.0%
Oklahoma	100.0%	100.0%	100.0%	90.8%	87.1%	72.6%	55.6%	31.6%	11.5%	7.1%
Oregon	100.0%	96.9%	71.3%	63.9%	57.2%	55.7%	51.3%	50.0%	41.5%	35.1%
Pennsylvania	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	85.9%	36.8%	3.7%
Rhode Island	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	10.0%
South Carolina	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	37.0%
South Dakota	100.0%	100.0%	100.0%	55.1%	7.8%	0.0%	0.0%	0.0%	0.0%	0.0%
Tennessee	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.8%	91.6%
Texas	100.0%	99.3%	97.4%	88.8%	79.0%	70.8%	55.8%	32.4%	25.1%	12.6%
Utah	100.0%	94.7%	63.4%	38.4%	12.3%	2.9%	0.4%	0.1%	0.0%	0.0%
Vermont	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.6%	77.4%	45.2%	24.4%
Virginia	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	93.3%	41.4%	4.0%
Washington	100.0%	80.0%	72.2%	68.6%	66.1%	65.1%	62.5%	57.1%	43.3%	32.4%
West Virginia	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	78.5%	37.6%	9.5%
Wisconsin	100.0%	100.0%	100.0%	100.0%	100.0%	99.2%	3.0%	0.0%	0.0%	0.0%
Wyoming	100.0%	75.9%	34.7%	7.8%	3.1%	1.7%	1.0%	0.2%	0.1%	0.0%
District of Columbia	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%
Nation	**99.8%**	**95.9%**	**89.7%**	**82.2%**	**77.2%**	**73.6%**	**64.2%**	**50.7%**	**39.7%**	**25.5%**

Table 3-5. Developed Acres In-Scope for Various Annual Precipitation Amounts

Annual precipitation (in inches) =>>	5	10	15	20	25	30	35	40	45	50
Alaska	NOT ANALYZED									
Alabama	14,503	14,503	14,503	14,503	14,503	14,503	14,503	14,503	14,503	14,420
Arizona	13,191	5,960	1,783	713	59	6	2	--	--	--
Arkansas	8,486	8,486	8,486	8,486	8,486	8,486	8,486	8,486	8,262	5,481
California	27,125	22,998	15,595	8,777	3,013	2,196	1,870	1,596	1,133	826
Colorado	15,830	14,858	9,879	1,267	271	141	80	37	4	--
Connecticut	1,006	1,006	1,006	1,006	1,006	1,006	1,006	1,006	1,006	606
Delaware	833	833	833	833	833	833	833	833	379	--
Florida	38,064	38,064	38,064	38,064	38,064	38,064	38,064	38,064	38,064	37,860
Georgia	32,591	32,591	32,591	32,591	32,591	32,591	32,591	32,591	32,591	23,232
Hawaii	NOT ANALYZED									
Idaho	5,674	5,315	1,675	983	549	339	105	34	19	2
Illinois	20,502	20,502	20,502	20,502	20,502	20,502	20,060	2,505	823	--
Indiana	12,372	12,372	12,372	12,372	12,372	12,372	12,372	6,355	1,634	--
Iowa	10,094	10,094	10,094	10,094	10,094	9,183	4,142	--	--	--
Kansas	22,538	22,538	22,538	20,378	16,388	13,271	8,832	2,354	56	--
Kentucky	9,976	9,976	9,976	9,976	9,976	9,976	9,976	9,976	8,513	2,943
Louisiana	12,843	12,843	12,843	12,843	12,843	12,843	12,843	12,843	12,843	12,843
Maine	4,496	4,496	4,496	4,496	4,496	4,496	4,496	3,854	1,888	108
Maryland	6,535	6,535	6,535	6,535	6,535	6,535	6,535	6,389	1,631	18
Massachusetts	3,320	3,320	3,320	3,320	3,320	3,320	3,320	3,320	3,219	41
Michigan	22,495	22,495	22,495	22,495	22,495	21,652	3,511	--	--	--
Minnesota	9,331	9,331	9,331	9,325	8,241	4,353	--	--	--	--
Mississippi	11,856	11,856	11,856	11,856	11,856	11,856	11,856	11,856	11,856	11,856
Missouri	13,550	13,550	13,550	13,550	13,550	13,550	13,533	9,643	1,613	12
Montana	6,456	6,441	2,514	884	362	154	83	58	35	3

Annual precipitation (in inches) =>>	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Nebraska	6,078	6,078	6,060	4,371	2,861	1,405	1	--	--	--
Nevada	7,916	2,100	779	168	16	3	2	--	--	--
New Hampshire	1,786	1,786	1,786	1,786	1,786	1,786	1,786	1,744	1,180	66
New Jersey	4,269	4,269	4,269	4,269	4,269	4,269	4,269	4,269	3,691	592
New Mexico	4,670	4,072	1,321	158	30	4	--	--	--	--
New York	7,721	7,721	7,721	7,721	7,721	7,721	7,180	5,179	2,174	612
North Carolina	18,738	18,738	18,738	18,738	18,738	18,738	18,738	18,687	18,283	3,828
North Dakota	6,537	6,537	6,333	654	--	--	--	--	--	--
Ohio	17,398	17,398	17,398	17,398	17,398	17,398	17,059	5,997	21	--
Oklahoma	16,730	16,730	16,730	15,190	14,580	12,146	9,309	5,282	1,916	1,191
Oregon	7,285	7,059	5,191	4,656	4,164	4,060	3,738	3,645	3,021	2,558
Pennsylvania	16,003	16,003	16,003	16,003	16,003	16,003	15,994	13,745	5,888	589
Rhode Island	377	377	377	377	377	377	377	377	377	38
South Carolina	16,169	16,169	16,169	16,169	16,169	16,169	16,169	16,169	16,169	5,980
South Dakota	8,310	8,310	8,308	4,577	650	--	--	--	--	--
Tennessee	13,089	13,089	13,089	13,089	13,089	13,089	13,089	13,089	12,799	11,995
Texas	61,304	60,865	59,721	54,455	48,440	43,421	34,231	19,850	15,409	7,717
Utah	8,389	7,943	5,317	3,219	1,034	244	31	9	--	--
Vermont	569	569	569	569	569	569	567	440	257	139
Virginia	15,146	15,146	15,146	15,146	15,146	15,146	15,146	14,133	6,268	599
Washington	12,792	10,239	9,234	8,778	8,453	8,327	7,994	7,301	5,533	4,146
West Virginia	3,513	3,513	3,513	3,513	3,513	3,513	3,513	2,758	1,321	335
Wisconsin	7,569	7,569	7,569	7,569	7,569	7,510	231	--	--	--
Wyoming	2,843	2,158	988	221	88	48	29	5	3	-
District of Columbia	66	66	66	66	66	66	66	66	--	--
Nation	**588,934**	**565,469**	**529,230**	**484,709**	**455,135**	**434,241**	**378,617**	**299,046**	**234,379**	**150,635**

3.5.4. SOILS DATA

The variation in soil types found in the United States is a significant factor in estimating sediment discharges, pollutant load reductions, and stormwater pollution prevention costs for construction sites. EPA used two discrete soils data sets in support of its analysis. For the loading analysis, EPA used a case study approach using the 11 indicator cities described above. For this analysis, EPA used soil coverage data provided in the State Soil Geographic Database (STATSGO) (Wolock 1997 and USDA 2007). STATSGO component and layer tables were accessed through the Pennsylvania State University's active archive (http://www.soilinfo.psu.edu/index.cgi?soil_data&index.html).

The data available in STATSGO are valuable to EPA because they provide enough detail to evaluate broad trends in soil distribution but are still generalized sufficiently to permit analysis of many acres. It is EPA's expectation that evaluating soil over large geographic areas (the sum of which is much larger than the approximate 600,000 acres developed annually) will produce a representative sample sufficient for analyzing loads expected to occur for the C&D industry.

The geographic limits of the STATSGO soil coverage evaluated were determined by superimposing indicator city urban area boundaries—from the U.S. Census Bureau's 2000 Urbanized Areas Cartographic Boundary Files (U.S. Census Bureau 2000)—on intersecting RF1 watersheds. The resulting list of RF1 watersheds intersecting the rapidly developing indicator city urban areas was used to spatially identify underlying STATSGO soil coverage Map Unit Identifiers (MUIDs). Last, soil data associated with the surface soil layer within the selected MUIDs were extracted from STATSGO to produce the suite of data evaluated for each indicator city.

The soil data extracted from STATSGO and used in the loading analysis included the highest and lowest reported land slopes, the erosivity ("K") factor used in the Revised Universal Soil Loss Equation (RUSLE), the soil hydrologic group, and soil texture characteristics (i.e., the percent of soil passing through various sieve sizes). Additional information on this analysis is in Section 10.2.

For the costing analysis and for determining acres within each state that would be subject to the proposed regulation for various soil percent clay contents, EPA used a national GIS data layer on soil characteristics (see http://www.soilinfo.psu.edu/index.cgi?soil_data&conus). Using this data set, along with RF1-level estimates of the amount of construction activity occurring, EPA determined the amount of developed acres annually that would be subject to the turbidity standard for various soil clay contents (where clay is defined as being particles smaller than 2 microns in diameter) at the RF1 and state level. EPA used only the surface soil layer as a basis for this analysis. Figure 3-13 illustrates surface soil percent clay content for each RF1 within the CONUS and presents the geographic basis for determining areas in-scope for the regulatory options evaluated. Additional information on soils data used for the costing analysis is in Section 9.

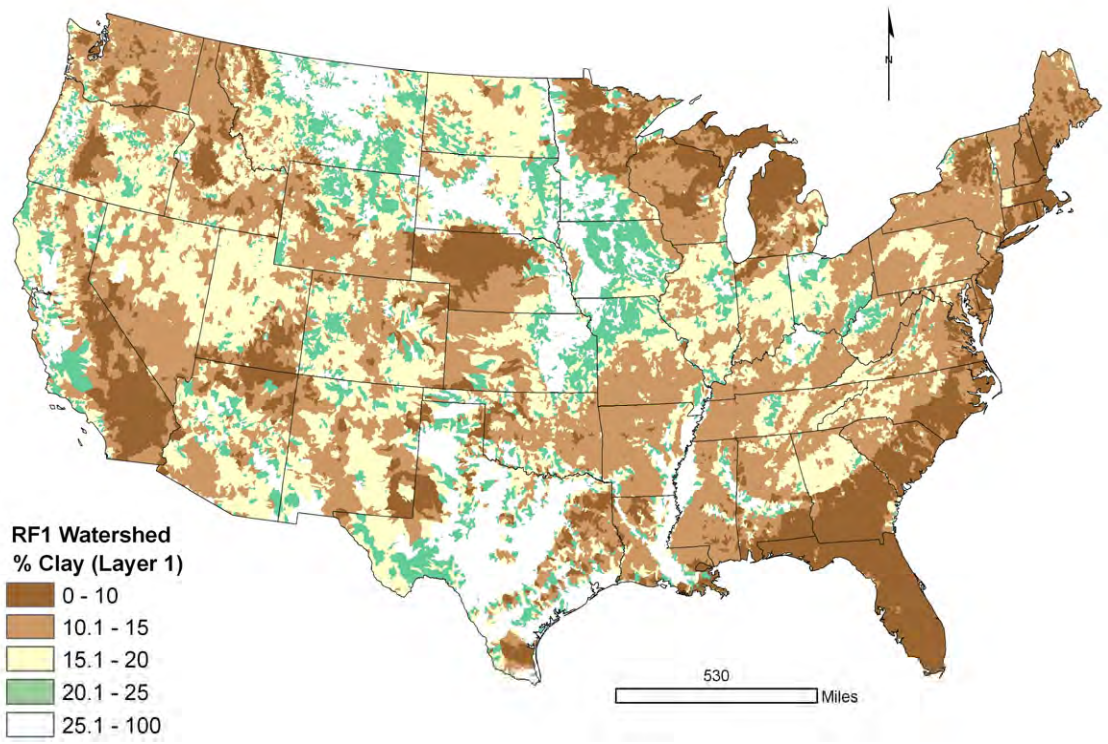

Figure 3-13. Surface Soil Layer Percent Clay Content.

3.5.5. VENDOR DATA FOR ACTIVE TREATMENT SYSTEMS

EPA compiled and evaluated information from vendors on treatment technologies that could be used in setting numeric standard discharge limits for stormwater runoff from construction sites. EPA conducted an Internet-based search and placed telephone calls to several vendors to gather data on available treatment technologies, costs, and performance (see Document Control Numbers 43000 through 43011 and Document Control Number 43081 in the administrative record for vendor-specific information and fact sheets). EPA also received unsolicited e-mails with data from vendors.

3.5.6. RAINFALL AND RUNOFF EROSIVITY FACTOR

EPA used a GIS data layer for the RUSLE R-factor to determine acres in-scope for various annual R-factor values. The R-factor (USDA 1997) is an indicator of rainfall energy and intensity and varies seasonally across the United States. EPA uses this data for determining whether small construction sites can qualify for the Low Erosivity Waiver (LEW) contained in the NPDES Phase II stormwater regulations. EPA has an online tool that can be used to determine if sites qualify for the LEW (see http://cfpub.epa.gov/npdes/stormwater/lew/lewcalculator.cfm). By combining the R-factor data with the RF1 data on acres of new development, EPA was able to determine acres in-scope for various annual R-factor values. Figure 3-14 shows annual R-factor values for the CONUS and

Tables 3-6 and 3-7 show percent and quantity of developed acres that would be in-scope for various annual R-factor values.

3.5.7. HYDROLOGIC SOIL GROUPS

EPA used the STATSGO GIS data layer to determine the percent of each hydrologic soil group by state. Hydrologic soil groups were used to estimate runoff coefficients for an indicator city within each state. Table 3-8 shows the percent of each hydrologic soil group by state.

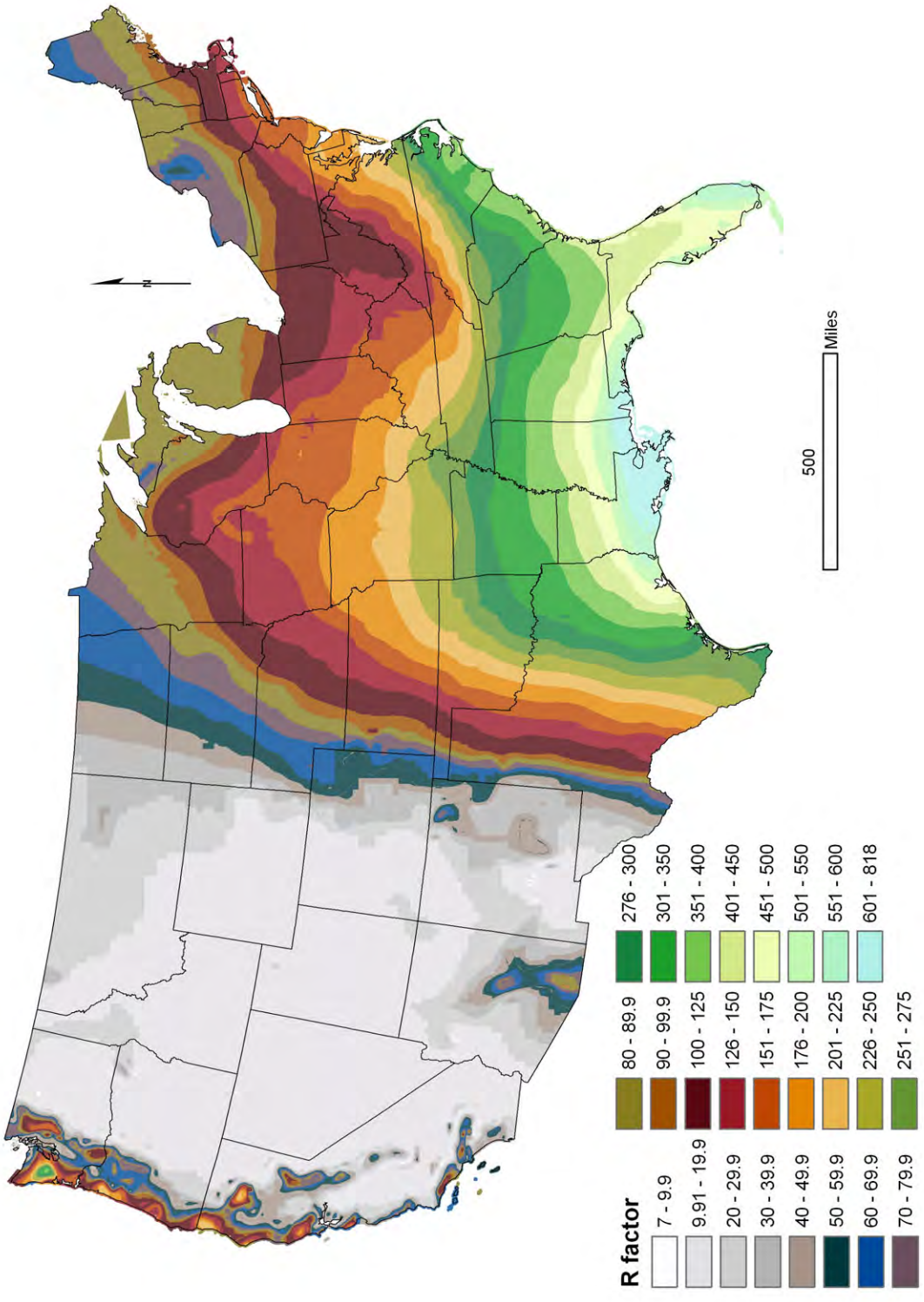

Figure 3-14. Annual R-Factor Values for CONUS.

Table 3-6. Percent Developed Acres In-Scope for Various Annual R-Factor Values

R-Factor =>>	< 10	< 20	< 30	< 40	< 50	< 60	< 70	< 80	< 90	< 100
Alaska	NOT ANALYZED									
Alabama	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Arizona	98.7%	77.6%	44.6%	14.4%	10.8%	4.9%	3.8%	0.5%	0.1%	0.1%
Arkansas	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
California	97.6%	70.8%	58.3%	40.7%	15.9%	11.2%	8.9%	5.9%	4.4%	3.4%
Colorado	82.5%	76.0%	62.7%	24.0%	18.9%	4.8%	0.0%	0.0%	0.0%	0.0%
Connecticut	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Delaware	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Florida	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Georgia	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Hawaii	NOT ANALYZED									
Idaho	8.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Illinois	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Indiana	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Iowa	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Kansas	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	97.7%	96.2%	94.2%	89.4%
Kentucky	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Louisiana	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Maine	100.0%	100.0%	100.0%	100.0%	100.0%	94.7%	85.8%	63.4%	29.9%	0.9%
Maryland	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Massachusetts	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Michigan	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.6%	71.5%	40.9%	13.3%
Minnesota	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	93.2%	80.4%	54.9%	49.0%
Mississippi	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Missouri	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Montana	76.7%	28.9%	7.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Nebraska	100.0%	100.0%	99.9%	98.8%	88.7%	79.3%	74.2%	70.9%	64.8%	56.6%
Nevada	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

R-Factor =>>	< 10	< 20	< 30	< 40	< 50	< 60	< 70	< 80	< 90	< 100
New Hampshire	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.7%	88.1%	37.3%
New Jersey	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
New Mexico	78.2%	63.4%	29.6%	9.0%	3.2%	0.1%	0.0%	0.0%	0.0%	0.0%
New York	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%	92.3%	53.4%	37.2%	26.1%
North Carolina	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
North Dakota	100.0%	100.0%	95.6%	90.9%	68.9%	25.7%	7.3%	0.0%	0.0%	0.0%
Ohio	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	91.8%
Oklahoma	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	98.9%	97.1%	96.7%	92.0%
Oregon	82.9%	54.5%	52.0%	50.8%	48.4%	42.5%	31.6%	25.5%	22.9%	20.1%
Pennsylvania	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	97.7%	90.7%
Rhode Island	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
South Carolina	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
South Dakota	100.0%	100.0%	99.1%	96.8%	93.2%	85.3%	57.9%	32.2%	16.9%	10.5%
Tennessee	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Texas	98.8%	98.5%	98.5%	98.0%	97.8%	96.6%	95.3%	94.2%	91.9%	89.7%
Utah	37.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Vermont	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	55.5%	28.6%	6.7%
Virginia	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Washington	70.7%	62.3%	61.6%	60.0%	43.0%	34.3%	27.6%	20.6%	13.2%	10.8%
West Virginia	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Wisconsin	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	84.7%	76.2%
Wyoming	42.9%	33.7%	5.9%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
District of Columbia	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
National Total	**94.6%**	**90.8%**	**88.3%**	**85.3%**	**83.0%**	**81.1%**	**79.4%**	**76.2%**	**73.0%**	**69.9%**

Table 3-7. Developed Acres In-Scope for Various Annual R-Factor Values

R-Factor =>>	< 10	< 20	< 30	< 40	< 50	< 60	< 70	< 80	< 90	< 100	> 100
Alabama	14,503	14,503	14,503	14,503	14,503	14,503	14,503	14,503	14,503	14,503	0
Arizona	13,456	10,571	6,078	1,962	1,475	672	515	72	15	15	13,613
Arkansas	8,486	8,486	8,486	8,486	8,486	8,486	8,486	8,486	8,486	8,486	0
California	26,771	19,406	15,981	11,155	4,368	3,071	2,427	1,612	1,215	943	26,478
Colorado	13,055	12,036	9,926	3,796	2,984	761	8	0	0	0	15,830
Connecticut	1,006	1,006	1,006	1,006	1,006	1,006	1,006	1,006	1,006	1,006	0
Delaware	833	833	833	833	833	833	833	833	833	833	0
Florida	38,064	38,064	38,064	38,064	38,064	38,064	38,064	38,064	38,064	38,064	0
Georgia	32,591	32,591	32,591	32,591	32,591	32,591	32,591	32,591	32,591	32,591	0
Hawaii	0	0	0	0	0	0	0	0	0	0	0
Idaho	474	0	0	0	0	0	0	0	0	0	5,674
Illinois	20,502	20,502	20,502	20,502	20,502	20,502	20,502	20,502	20,502	20,502	0
Indiana	12,372	12,372	12,372	12,372	12,372	12,372	12,372	12,372	12,372	12,372	0
Iowa	10,094	10,094	10,094	10,094	10,094	10,094	10,094	10,094	10,094	10,094	0
Kansas	22,538	22,538	22,538	22,538	22,538	22,520	22,013	21,673	21,227	20,147	2,391
Kentucky	9,976	9,976	9,976	9,976	9,976	9,976	9,976	9,976	9,976	9,976	0
Louisiana	12,843	12,843	12,843	12,843	12,843	12,843	12,843	12,843	12,843	12,843	0
Maine	4,496	4,496	4,496	4,496	4,496	4,255	3,855	2,852	1,345	40	4,456
Maryland	6,535	6,535	6,535	6,535	6,535	6,535	6,535	6,535	6,535	6,535	0
Massachusetts	3,320	3,320	3,320	3,320	3,320	3,320	3,320	3,320	3,320	3,319	1
Michigan	22,495	22,495	22,495	22,495	22,495	22,495	22,403	16,091	9,189	2,999	19,496
Minnesota	9,331	9,331	9,331	9,331	9,331	9,331	8,697	7,498	5,123	4,569	4,762
Mississippi	11,856	11,856	11,856	11,856	11,856	11,856	11,856	11,856	11,856	11,856	0
Missouri	13,550	13,550	13,550	13,550	13,550	13,550	13,550	13,550	13,550	13,550	0
Montana	4,952	1,864	459	0	0	0	0	0	0	0	6,456
Nebraska	6,078	6,078	6,070	6,006	5,390	4,821	4,508	4,310	3,937	3,439	2,639
Nevada	81	0	0	0	0	0	0	0	0	0	8,156
New Hampshire	1,786	1,786	1,786	1,786	1,786	1,786	1,786	1,744	1,573	667	1,119

R-Factor =>>	< 10	< 20	< 30	< 40	< 50	< 60	< 70	< 80	< 90	< 100	> 100
New Jersey	4,269	4,269	4,269	4,269	4,269	4,269	4,269	4,269	4,269	4,269	0
New Mexico	3,650	2,961	1,383	422	149	3	0	0	0	0	4,670
New York	7,721	7,721	7,721	7,721	7,721	7,700	7,124	4,124	2,873	2,012	5,709
North Carolina	18,738	18,738	18,738	18,738	18,738	18,738	18,738	18,738	18,738	18,738	0
North Dakota	6,537	6,537	6,251	5,944	4,504	1,682	477	0	0	0	6,537
Ohio	17,398	17,398	17,398	17,398	17,398	17,398	17,398	17,398	17,398	15,975	1,423
Oklahoma	16,730	16,730	16,730	16,730	16,730	16,727	16,540	16,242	16,172	15,384	1,346
Oregon	6,041	3,968	3,791	3,700	3,522	3,095	2,299	1,858	1,668	1,465	5,820
Pennsylvania	16,003	16,003	16,003	16,003	16,003	16,003	16,003	16,003	15,638	14,508	1,495
Rhode Island	377	377	377	377	377	377	377	377	377	377	0
South Carolina	16,169	16,169	16,169	16,169	16,169	16,169	16,169	16,169	16,169	16,169	0
South Dakota	8,310	8,310	8,239	8,040	7,742	7,088	4,815	2,678	1,403	872	7,438
Tennessee	13,089	13,089	13,089	13,089	13,089	13,089	13,089	13,089	13,089	13,089	0
Texas	60,550	60,390	60,384	60,102	59,943	59,232	58,416	57,742	56,326	54,971	6,333
Utah	3,176	0	0	0	0	0	0	0	0	0	8,389
Vermont	569	569	569	569	569	569	569	316	163	38	531
Virginia	15,146	15,146	15,146	15,146	15,146	15,146	15,146	15,146	15,146	15,146	0
Washington	9,045	7,967	7,880	7,679	5,494	4,381	3,534	2,634	1,683	1,382	11,410
West Virginia	3,513	3,513	3,513	3,513	3,513	3,513	3,513	3,513	3,513	3,513	0
Wisconsin	7,569	7,569	7,569	7,569	7,569	7,569	7,569	7,560	6,409	5,770	1,799
Wyoming	1,220	959	169	28	1	0	0	0	0	0	2,843
Puerto Rico	0	0	0	0	0	0	0	0	0	0	0
District of Columbia	66	66	66	66	66	66	66	66	66	66	0
National Total	557,879	535,462	520,950	503,076	489,744	478,595	468,389	449,748	430,576	412,348	177,563
% of Total	95%	91%	88%	85%	83%	81%	79%	76%	73%	70%	30%

Table 3-8. Hydrologic Soil Groups by State

	Hydrologic Soil Group					Hydrologic Soil Group			
	A	**B**	**C**	**D**		**A**	**B**	**C**	**D**
Alabama	8.7%	41.2%	28.8%	21.3%	Nebraska	31.9%	53.6%	3.0%	11.5%
Arizona	4.7%	38.6%	17.2%	39.5%	Nevada	5.6%	26.4%	17.7%	50.3%
Arkansas	0.6%	28.3%	35.9%	35.1%	New Hampshire	17.1%	24.8%	41.4%	16.6%
California	10.9%	32.2%	18.4%	38.5%	New Jersey	12.5%	32.8%	25.1%	29.6%
Colorado	7.2%	46.7%	24.6%	21.4%	New Mexico	5.6%	41.9%	16.5%	36.0%
Connecticut	9.1%	41.1%	35.9%	13.9%	New York	9.6%	18.5%	51.1%	20.7%
Delaware	20.8%	30.9%	13.4%	34.9%	North Carolina	7.9%	48.8%	16.5%	26.8%
Florida	18.1%	6.3%	8.6%	67.0%	North Dakota	4.7%	56.1%	16.6%	22.6%
Georgia	6.6%	53.1%	16.9%	23.5%	Ohio	0.6%	16.8%	54.6%	28.0%
Idaho	4.4%	46.8%	23.1%	25.7%	Oklahoma	6.8%	44.5%	22.3%	26.4%
Illinois	1.4%	44.5%	27.0%	27.1%	Oregon	5.2%	32.1%	37.1%	25.6%
Indiana	3.5%	32.6%	41.8%	22.1%	Pennsylvania	6.0%	28.4%	54.2%	11.5%
Iowa	0.9%	66.0%	11.6%	21.5%	Rhode Island	15.3%	35.7%	32.4%	16.5%
Kansas	3.8%	58.0%	19.5%	18.7%	South Carolina	11.9%	41.8%	19.5%	26.8%
Kentucky	0.1%	42.7%	44.9%	12.3%	South Dakota	2.9%	45.2%	11.5%	40.4%
Louisiana	1.7%	14.4%	28.9%	55.1%	Tennessee	0.1%	53.6%	30.4%	15.9%
Maine	7.7%	12.9%	43.9%	35.5%	Texas	5.1%	27.2%	24.5%	43.2%
Maryland	10.0%	38.6%	26.4%	25.0%	Utah	5.3%	36.2%	16.2%	42.3%
Massachusetts	23.9%	16.6%	34.4%	25.2%	Vermont	4.9%	18.0%	54.3%	22.8%
Michigan	29.0%	28.7%	12.9%	29.4%	Virginia	1.7%	53.7%	32.3%	12.3%
Minnesota	8.3%	37.4%	15.4%	38.9%	Washington	6.6%	53.4%	24.2%	15.8%
Mississippi	2.3%	32.3%	38.6%	26.9%	West Virginia	7.3%	21.5%	54.2%	17.0%
Missouri	1.0%	40.1%	39.8%	19.0%	Wisconsin	14.4%	46.8%	18.1%	20.7%
Montana	2.9%	39.5%	27.2%	30.4%	Wyoming	4.5%	40.5%	19.5%	35.5%

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4. INDUSTRY PROFILE

4.1. INTRODUCTION

The construction industry is divided into three major subsectors: general building contractors, heavy construction contractors, and special trade contractors. General contractors build residential, industrial, commercial, and other buildings. Heavy construction contractors build sewers, roads, highways, bridges, and tunnels. Special trade contractors typically provide carpentry, painting, plumbing, and electrical services.

Because the proposed effluent guidelines are being developed to address water quality issues, this document focuses on the construction subsectors most closely associated with land-disturbing activities. General contractors and heavy construction establishments are by definition the most likely to conduct activities that could affect water resources. Note, however, that for individual projects, responsibility for land-disturbing activities and potential effects on water quality might not be obvious because general contractors often subcontract all or some of the actual construction work. Hence, the following subsections describe the subsector categories most likely to be responsible for land-disturbing activities at the national level.

The construction and development (C&D) industry is classified in the *2007 North American Industry Classification System* (NAICS) under Sector 23, Construction (U.S. Census Bureau 2008a). NAICS is the system used for classifying industry establishments by type of economic activity, which replaced the U.S. Standard Industrial Classification (SIC) system.

The construction sector comprises establishments primarily engaged in constructing buildings or engineering projects (e.g., highways and utility systems). Establishments primarily engaged in preparing sites for new construction and establishments primarily engaged in subdividing land for sale as building sites also are included in this sector (U.S. Census Bureau 2008a).

Construction work done may include new work, additions, alterations, or maintenance and repairs. Activities of these establishments generally are managed at a fixed place of business, but they usually perform construction activities at multiple project sites. Establishments identified as construction-management firms are also included in the sector. The construction sector is divided into three types of activities or subsectors as described below (from U.S. Census Bureau 2008a):

- **Subsector 236 – Construction of Buildings**
  This subsector comprises establishments of the general contractor type and operative builders involved in the construction of buildings. The work performed may include new work, additions, alterations, or maintenance and repairs. The on-site assembly of precut, panelized, and prefabricated buildings and construction of temporary buildings are included in this subsector. Part or all of the production work for which the establishments in this subsector have responsibility may be subcontracted to other construction establishments--usually specialty trade contractors. Establishments in this subsector are classified based on the types of buildings they construct. This classification reflects variations in the requirements of the underlying production processes.

- **Subsector 237 – Heavy and Civil Engineering Construction**
  This subsector comprises establishments whose primary activity is the construction of entire engineering projects (e.g., highways and dams), and specialty trade contractors, whose primary activity is the production of a specific component for such projects. Specialty trade contractors in Heavy and Civil Engineering Construction generally are performing activities that are specific to heavy and civil engineering construction projects and are not normally performed on buildings. The work performed may include new work, additions, alterations, or maintenance and repairs.

  Specialty trade activities are classified in this subsector if the skills and equipment present are specific to heavy or civil engineering construction projects. For example, specialized equipment is needed to paint lines on highways. This equipment is not normally used in building applications so the activity is classified in this subsector. Traffic signal installation, while specific to highways, uses much of the same skills and equipment that are needed for electrical work in building projects and is therefore classified in Subsector 238, Specialty Trade Contractors. Establishments in this subsector are classified based on the types of structures that they construct. This classification reflects variations in the requirements of the underlying production processes.

- **Subsector 238 – Special Trade Contractors**
  This subsector comprises establishments whose primary activity is performing specific activities (e.g., pouring concrete, site preparation, plumbing, painting, and electrical work) involved in building construction or other activities that are similar for all types of construction, but that are not responsible for the entire project. The work performed may include new work, additions, alterations, maintenance, and repairs. The production work performed by establishments in this subsector is usually subcontracted from establishments of the general contractor type or operative builders, but especially in remodeling and repair construction, work also may be done directly for the owner of the property. Specialty trade contractors usually perform most of their work at the construction site, although they may have shops where they perform prefabrication and other work. Establishments primarily engaged in preparing sites for new construction are also included in this subsector. There are substantial differences in types of equipment, work force skills, and other inputs required by specialty trade contractors. Establishments in this subsector are classified based on the underlying production function for the specialty trade in which they specialize.

Table 4-1 provides a list of the 3-digit subsectors, 4-digit industry groups and 5-digit NAICS industries in the construction sector.

Table 4-1. 2007 NAICS Subsectors, Industry Groups, and Industries Performing Construction Activities that Might Disturb Land

2007 NAICS Sector 23 - Construction	
236	Construction of Buildings
2361	Residential Building Construction
23611 236115 236116 236117 236118	Residential Building Construction New Single-Family Housing Construction New Multifamily Housing Construction New Housing Operative Builders Residential Remodelers
2362	Nonresidential Building Construction
23621 236210 23622 236220	Industrial Building Construction Industrial Building Construction Commercial and Institutional Building Construction Commercial and Institutional Building Construction
237	Heavy and Civil Engineering Construction
2371	Utility System Construction
23711 237110 23712 237120 23713 237130	Water and Sewer Line and Related Structures Construction Water and Sewer Line and Related Structures Construction Oil and Gas Pipeline and Related Structures Construction Oil and Gas Pipeline and Related Structures Construction Power and Communication Line and Related Structures Construction Power and Communication Line and Related Structures Construction
2372	Land Subdivision
23721 237210	Land Subdivision Land Subdivision
2373	Highway, Street, and Bridge Construction
23731 237310	Highway, Street, and Bridge Construction Highway, Street, and Bridge Construction
2379	Other Heavy and Civil Engineering Construction
23799 237990	Other Heavy and Civil Engineering Construction Other Heavy and Civil Engineering Construction
238	Specialty Trade Contractors
2381	Foundation, Structure, and Building Exterior Contractors
23811 238110 23812 238120 23813 238130 23814 238140 23815 238150	Poured Concrete Foundation and Structure Contractors Poured Concrete Foundation and Structure Contractors Structural Steel and Precast Concrete Contractors Structural Steel and Precast Concrete Contractors Framing Contractors Framing Contractors Masonry Contractors Masonry Contractors Glass and Glazing Contractors Glass and Glazing Contractors

2007 NAICS Sector 23 - Construction	
23816	Roofing Contractors
238160	Roofing Contractors
23817	Siding Contractors
238170	Siding Contractors
23819	Other Foundation, Structure, and Building Exterior Contractors
238190	Other Foundation, Structure, and Building Exterior Contractors
2382	Building Equipment Contractors
23821	Electrical Contractors and Other Wiring Installation Contractors
238210	Electrical Contractors and Other Wiring Installation Contractors
23822	Plumbing, Heating, and Air-Conditioning Contractors
238220	Plumbing, Heating, and Air-Conditioning Contractors
23829	Other Building Equipment Contractors
238290	Other Building Equipment Contractors
2383	Building Finishing Contractors
23831	Drywall and Insulation Contractors
238310	Drywall and Insulation Contractors
23832	Painting and Wall Covering Contractors
238320	Painting and Wall Covering Contractors
23833	Flooring Contractors
238330	Flooring Contractors
23834	Tile and Terrazzo Contractors
238340	Tile and Terrazzo Contractors
23835	Finish Carpentry Contractors
238350	Finish Carpentry Contractors
23839	Other Building Finishing Contractors
238390	Other Building Finishing Contractors
2389	Other Specialty Trade Contractors
23891	Site Preparation Contractors
238910	Site Preparation Contractors
23899	All Other Specialty Trade Contractors
238990	All Other Specialty Trade Contractors

Source: U.S. Census Bureau 2008a

Before NAICS was created, C&D industries were classified using the SIC system. Any data collected before January 1997 might still be classified under that system. SIC classifications are relevant to the effluent guidelines, because certain U.S. Census Bureau data for the construction industry were collected until 1994 and therefore classified under the SIC system rather than the NAICS. Under the SIC system, industries that might perform land-disturbing activities were classified under Division C–Construction, and Division H–Finance, Insurance, and Real Estate. These divisions include the following SIC major groups (from U.S. Census Bureau 2008b):

- **SIC Major Group 15–Building Construction General Contractors and Operative Builders**
  This group includes general contractors and operative builders primarily engaged in the construction of residential, farm, commercial, or other buildings. General building contractors who combine a special trade with their contracting are also included.

- **SIC Major Group 16–Heavy Construction Other Than Building Construction Contractors**
  This group includes general contractors primarily engaged in heavy construction other than building construction, such as highways and streets, bridges, sewers, railroads, irrigation projects, flood control projects, and marine construction, as well as special trade contractors primarily engaged in activities of a type clearly specialized in such heavy construction and not normally performed on buildings or building-related projects.

- **SIC Major Group 17–Construction Special Trade Contractors**
  This group includes special trade contractors who undertake activities of a type that are specialized either in building construction or in both building and non-building projects.

- **SIC Major Group 65–Real Estate**
  This group includes real estate operators and the owners and lessors of real property, as well as buyers, sellers, developers, agents, and brokers.

Major groups 15 and 16 are further defined by the type of construction performed. Table 4-2 provides a list of the more specific industry groups and industries that might perform land-disturbing activities.

The focus of the proposed rule is on construction activities carried out by firms covered by NAICS codes 233 and 234 or SIC codes 15 and 16. (As discussed in Section V in the preamble of the proposed rule, Special Trade Contractors, NAICS 238 or SIC 17, are typically subcontractors and not identified as National Pollutant Discharge Elimination System (NPDES) permittees.) Furthermore, the residential, nonresidential, and heavy construction subsectors receive the greatest emphasis because they account for the vast majority of construction projects and are responsible for most of the land disturbance in the United States.

Table 4-2. 1987 SIC Industry Groups Performing Construction Activities that Might Disturb Land

SIC Major Group 15	
Industry Group 152: General Building Contractors - Residential	
1521	General Contractors - Single-family Houses
1522	General Contractors - Residential Buildings, Other Than Single-family
Industry Group 153: Operative Builders	
1531	Operative Builders
Industry Group 154: General Building Contractors - Nonresidential	
1541	General Contractors - Industrial Buildings and Warehouses
1542	General Contractors - Nonresidential Buildings, Other Than Industrial

SIC Major Group 16	
Industry Group 161: Highway and Street Construction, Except Elevated Highways	
1611	Highway and Street Construction, Except Elevated Highways
Industry Group 162: Heavy Construction, Except Highway and Street	
1622	Bridge, Tunnel, and Elevated Highway Construction
1623	Water, Sewer, Pipeline, and Communications and Power Line
1629	Heavy Construction Not Elsewhere Classified
SIC Major Group 17	
Industry Group 179: Miscellaneous Special Trade Contractors	
1771	Concrete Work
1794	Excavation Work
SIC Major Group 65	
Industry Group 655: Land Subdividers and Developers	
6552	Land Subdividers and Developers, Except Cemeteries

Source: U.S. Census Bureau 2008b

4.2. INDUSTRY PRACTICES AND TRENDS

This section first provides a description of the types of C&D activities that result in the disturbance of land and are responsible for the potential discharge of pollutants of concern to surface waters. Then national estimates of the amount of disturbed acreage are provided. Additional information including detailed descriptions of industry size and revenues is in the document *Economic Analysis for Proposed Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-R-08-008).

4.2.1. OVERVIEW OF CONSTRUCTION LAND-DISTURBING ACTIVITIES

Constructing a building or facility involves a variety of activities, including the use of equipment that alters the site's environmental conditions. These changes include vegetation and top soil removal, regrading, and drainage pattern alteration. The following provides a brief description of typical land-disturbing activities at construction sites and the types of equipment employed.

4.2.1.1. Construction Site Preparation

Construction activities generally begin with the planning and engineering of the site and site preparation. During this stage, mobile offices, which are usually housed in trailers, are established on the construction site. The construction company uses these temporary structures to handle vital activities such as preparing and submitting applicable permits, hiring employees and subcontractors, and ensuring that proper environmental requirements are met. The entire construction yard is delineated with erosion and sediment controls installed and security measures established. The latter includes installing fences and signs to warn against trespassing and to mark dangerous areas. After the site is secured, equipment is brought to the site (and is stored there throughout the construction period).

4.2.1.2. Clearing, Excavating, and Grading

Construction on any size parcel of land almost always calls for a remodeling of the earth (Lynch and Hack 1984). Therefore, actual site construction begins with site clearing and grading. Organic material—in particular, roots—cannot support the weight of buildings and must be removed from the top layer of ground. (Some developers stockpile the organic material for use during the landscaping phase of construction rather than paying for it to be hauled from the site.) Construction contractors must ensure that earthwork activities meet local, state, and federal regulations for soil and erosion control, runoff, and other environmental controls. The size of the site, extent of water present, soil types, topography, and weather determine the kinds of equipment used in site clearing and grading (Peurifoy and Oberlender 1989). Material that will not be used on the site must be hauled away by tractor-pulled wagons, dump trucks, or articulated trucks (Peurifoy and Oberlender 1989).

Equipment used for lifting excavated and cleared materials include aerial-work platforms, forwarders, cranes, rough-terrain forklifts, and truck-mounted cranes. In addition, track loaders are used for digging and dumping earth (Caterpillar 2000; Construction Equipment On-Line 2000; Lynch and Hack 1984; Peurifoy and Oberlender 1989).

Excavation and grading are performed by several different types of machines. These tasks can also be done by hand, but this is generally more expensive (Lynch and Hack 1984). When grading a site, builders typically ensure that new grades are as close to the original as possible, to avoid erosion and storm water runoff (Lynch and Hack 1984). Proper grading also ensures a flat surface for development and drains water away from constructed buildings.

Excavation and grading equipment includes backhoes, bulldozers (including the versatile tracked bulldozer), loaders, directional drilling rigs, hydraulic excavators, motor graders, scrapers, skid-steer loaders, soil stabilizers, tool carriers, trenchers, wheel loaders, and pipeliners. Equipment selection depends on functions to be performed and specific site conditions (Caterpillar 2000; Construction Equipment On-Line 2000; Lynch and Hack 1984; Peurifoy and Oberlender 1989). Therefore, multiple types of equipment are used throughout the clearing and grading process.

Self-transporting trenching machines, wheel-type trenching machines, and ladder-type trenching machines are also used during site excavation. Self-transporting trenching machines are used to create shallow trenches, such as for underground wire and cables. This type of machine has a bulldozer blade attached to the front, is highly maneuverable, and can be used to dig narrow, shallow trenches. Wheel-type trenching machines also dig narrow trenches, most often for water mains and gas and oil pipelines. Ladder-type trenching machines are used to dig deep trenches, such as for sewer pipes. These machines might have a boom mounted at the rear. Along the boom are cutter teeth and buckets that are attached to chains. As the machine moves, it digs dirt and moves it to the sides of the newly formed trench (Peurifoy and Oberlender 1989).

Power shovels can also be used for excavating soils. They are used on all classes of earth that have not been loosened. For solid rock, prior loosening is required. As materials are excavated, they are immediately loaded onto trucks or tractor-pulled wagons and hauled from the site (Peurifoy and Oberlender 1989). Hydraulic excavators, with either a front or a back shovel, are also used to dig into the earth and to load a hauling vehicle. There are several categories of

hydraulic excavators, including backhoes, back shovels, hoes, and pull shovels. Hydraulic excavators are one of the most widely used types of excavating equipment because of their ease of use and their ability to remove the earth that caves as it is moved. They are effective excavating machines, and they are easy to use in terms of loading some a hauling vehicle (Peurifoy and Oberlender 1989).

Draglines, used to dig ditches or build levees, can transport soil within casting limits, thus eliminating the need for hauling equipment (Peurifoy and Oberlender 1989). Draglines have a bucket that hangs from a cable. The bucket is brought through the dirt and toward the operator (Lynch and Hack 1984). Draglines can be used on both wet and dry ground and can dig earth out of pits that contain water (Peurifoy and Oberlender 1989). They are most useful for making large cuts and channels below the level of the machine as well as for making valleys, mounds, slopes, and banks (Lynch and Hack 1984). Draglines have a lower output than power shovels and do not excavate rock as well as power shovels (Peurifoy and Oberlender 1989).

Draglines can be converted to clamshells by replacing the dragline bucket with a clamshell bucket. A clamshell is typically used for handling sand, gravel, crushed stone, sandy loam, and other loose materials; it is not efficient in handling compacted earth, clay, or other dense materials. A clamshell is lowered into a material, and the bucket closes on the material. It is then raised over a hauling vehicle and the materials are deposited (Peurifoy and Oberlender 1989).

Scrapers, either self-powered or drawn by tractors, dig and compact materials by taking up earth from its underside with toothed scoops and loading it into hauling vehicles. Scrapers are useful in removing earth and weak or broken rock and for excavating hills and rock faces. Some scrapers are designed for long hauls; others with good traction are used on steep slopes (Lynch and Hack 1984).

A crawler tractor, which pulls a rubber-tired self-loading scraper, is often used for short-haul distances. The crawler tractor uses a drawbar pull to load the scraper. It has good traction and can operate on muddy roads. It is, however, a slower vehicle and thus is more appropriate for shorter hauls.

heel-type tractor-pulled scrapers, which come in two- and four-wheel drive tractors, are used for longer hauling distances. Unlike the crawler tractor-pulled scrapers, the wheel-type tractor-pulled scrapers do not maintain good traction. Under such conditions, a helper tractor, such as a bulldozer, might be used (Peurifoy and Oberlender 1989).

All these machines shape and compact the earth, a crucial site preparation step. In addition, earthwork activities might require that fill be brought in. In such cases, the fill must be spread in uniform, thick layers and compacted to a specified density with an optimum moisture content. Graders and bulldozers are the most common earth-spreading machines. Machines that compact include tractor-pulled sheep's foot rollers, smooth-wheel rollers, pneumatic rollers, and vibrating rollers, among other equipment (Peurifoy and Oberlender 1989). Rollers and scarifiers are used either to compact or to break up the ground (Lynch and Hack 1984).

To remove rock, it must first be loosened and broken up—usually through drilling or blasting. Drilling equipment includes jackhammers, wagon drills, drifters, churn rills, and rotary drills;

each is designed to work on a specific size and type of rock. Dynamite and other explosives are used to loosen rock (Peurifoy and Oberlender 1989).

After the materials have been excavated and removed and the ground cleared and graded, the site is ready for construction.

4.2.2. CONSTRUCTION SITE SIZE CATEGORIES AND ESTIMATES OF AMOUNT OF DISTURBED LAND

The regulatory options evaluated apply to construction sites of all types (i.e., residential, commercial, and industrial). Because the costs for erosion and sediment control are largely driven by site size, the U.S. Environmental Protection Agency (EPA) must estimate the distribution of construction sites by size category, land use type, and geographic region to estimate the total cost of the options. In addition, estimating distribution of sites by type allows EPA to estimate the cost to each construction sector.

4.2.2.1. National Estimates of New Development

EPA used the National Land Cover Dataset (NLCD) to estimate the amount of new developed land occurring annually in the conterminous United States (CONUS) between 1992 and 2001 (see Table 3-1 and Appendix E). EPA's comparison of the 1992 and 2001 NLCD resulted in an estimated annual rate of development of approximately 590,000 acres per year. By overlaying GIS layers of states and watersheds with the NLCD data, EPA was able to estimate the annual number of acres of new development at both the state and watershed level (for state-level annual estimates of new development, see Table 4-6). EPA used the Reach File Version 1.0 (RF1) stream reach network and associated watershed boundaries for the watershed-level estimates. EPA estimated annual development rates for approximately 44,000 RF1 watersheds where a net increase in urban land cover was identified. Approximately 7,800 additional RF1 watersheds showed either no change or a minor decrease in urban land uses between 1992 and 2001. RF1 watersheds and stream reaches are employed by the USGS SPARROW water quality model—the model EPA has selected to assess potential environmental benefits of additional regulation of the industry (USGS 2008). The EPA *Environmental Impact and Benefits Assessment for Proposed Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-R-08-008) provides additional details and results of the water quality assessment performed by EPA.

Because NLCD data does not exist for Alaska, Hawaii, and the U.S. territories, EPA's analysis does not include cost, pollutant loading reduction, or environmental benefits estimates for these areas. However, the amount of development in these areas is expected to be low compared to the rest of the United States; therefore, any errors in EPA's estimates are expected to be minor.

EPA broadly characterized the acreage constructed annually into various future land uses and construction project sizes. This characterization provides a basis for developing and then using mathematical models that represent broad sectors of the industry to estimate compliance costs and pollutant loading reductions. EPA divided NOIs into three groups according to site size: small (< 10 acres), medium (10 to 30 acres), and large (> 30 acres) and three major land-use

types (residential, non-residential, and transportation). EPA determined the median project size for each of these nine groupings.

Following are the nine construction site model projects that EPA used to represent the industry:

- Large Residential – median size 33 acres
- Large Nonresidential – median size 51 acres
- Large Transportation – median size 79 acres
- Medium Residential – median size 16.7 acres
- Medium Non-Residential – median size 15 acres
- Medium Transportation – median size 16 acres
- Small Residential – median size 3 acres
- Small Nonresidential – median size 2.6 acres
- Small Transportation – median size 3 acres

These model projects were identified after reviewing more than 30,000 Notices of Intent (NOIs) submitted by permittees in 38 states (see Appendix C, Analysis of Construction Industry Trends using Notice of Intent Records). The NOI records, which serve as the basis for EPA's sector analysis were individually characterized on the basis of land use, and each of the NOI records used provided site construction acreage information.

Individually, the site project models each represent large fractions of the construction projects developed annually, and cover the major project types in the C&D industry. Table 4-3 summarizes the breakdown by number and percentage of reviewed NOI permits represented by each sector model, and the quantity and percent of constructed acreage represented by each sector model.

Table 4-3. Summary of NOI Data

	Number of NOIs	Percent of NOIs	Acres in each NOI category	Percent of total NOI acres
Small Transportation Projects	1,261	3.7%	4,496	0.8%
Small Residential Projects	8,322	24.3%	32,139	5.5%
Small Nonresidential Projects	12,915	37.7%	43,141	7.3%
Medium Transportation Projects	395	1.2%	6,884	1.2%
Medium Residential Projects	4,236	12.4%	74,322	12.6%
Medium Nonresidential Projects	3,232	9.4%	54,182	9.2%
Large Transportation Projects	407	1.2%	44,060	7.5%
Large Residential Projects	2,130	6.2%	178,803	30.4%
Large Nonresidential Projects	1,353	4.0%	149,931	25.5%
TOTALS	**34,251**		**587,958**	

As detailed in section 3.5.3, EPA has elected to use 11 indicator cities as a means to estimate construction site erosion rates and removals due to regulatory options. EPA used the nine model projects along with state-specific data on rainfall quantities and development rates to estimate costs of regulatory options.

EPA found that a small percentage of the total site acreage, according to the NOI data reviewed, was from other land use subcategories, including railroads, mines, water projects, parks, airports, and farms. Collectively, these six subcategories contain about 10 percent of the total site acreage found within the pool of NOI records. EPA did not elect to develop model projects for these additional project types. Because EPA's analysis considered all the approximately 590,000 acres estimated to be developed annually, EPA assumes that the influence of these six subcategories is captured in the analysis of the other, more common, land use types.

4.2.2.2. Distribution of Developed Acreage by Project Size

EPA's assessment of NOI records provides a basis for estimating a construction site size distribution. As detailed in Appendix C, Analysis of Construction Industry Trends using Notice of Intent Records, EPA evaluated a pool of NOI records for which site size information is available. In its analysis, EPA used only NOI records that EPA was able to characterize as being either residential, nonresidential, or transportation related. Table 4-4 summarizes the results of EPA's NOI analysis.

Table 4-4. NOI Derived Construction Site Size Distribution

Site size (acres)	0	5	10	15	20	25	30	35	40
Percent of Site Acreage Above	100.0	93.6	86.4	79.9	73.8	68.7	64.2	60.6	57.6

Information in Table 4-4 provides a basis for EPA's consideration of options that include specific site size cutoffs. For example, if an option were to apply only to sites of 10 or more acres, 86.4 percent of construction site acreage will be affected under the option requirements.

4.2.2.3. Distribution of Developed Acreage by Climate

As a part of its analysis, EPA evaluated the average annual rainfall depths across the contiguous states using the 1-km resolution United States Average Monthly or Annual Precipitation (1971–2000) PRISM Group raster data coverage (PRISM Group 2006). Generally, the larger the annual rainfall, the larger the construction site runoff volume and annual soil erosion will be. In addition, construction sites with high annual rainfall amounts also generally have larger amounts of runoff. This tends to increase the size of any controls designed to treat construction site runoff.

Some of the regulatory options EPA considered incorporated an annual precipitation cutoff, such that only construction sites in areas with annual precipitation amounts above a threshold would be required to meet specific regulatory requirements. By overlaying the PRISM data coverage with the RF1-level estimates of annual development, EPA was able to estimate the percent and quantity of annual construction that would be affected given various annual precipitation cutoffs (see Tables 3-4 and 3-5).

4.2.2.4. State-Level Estimation of Developed Acreage and Sites

Table 3-1 indicates the per-state estimated total number of acres developed on the basis of EPA's assessment of land cover changes between 1992 and 2001. To estimate the number of model projects within each state, EPA first applied the distribution of the percent of acres by model projects by category contained in Table 4-3 to each state's estimate of annual developed acres. Then, EPA divided the acres in each category by the median model project size and rounded results to whole numbers to estimate the number of model projects in each category. These results are shown in Table 4-5.

Table 4-6 indicates the total annually constructed acreage represented by the nine model projects and the acreage allocated to each state. Rounding the number of model projects to whole numbers results in a slight difference between the total national modeled acreage and the estimated total acreage produced by comparing NLCD data sets. As shown in Table 3-1, the NLCD comparison identified an annual development rate of 589,911 acres. The construction site model projects presented in Table 4-6 represents a total acreage of 589,916 acres.

The number of construction site model projects assigned to each state provides the basis for EPA's analysis of pollutant loading reductions and compliance cost estimates for the regulatory options.

4.2.2.5. Soil Texture Analysis

EPA evaluated options that incorporate applicability criteria tied to soil clay content. Clay particles in the proposal are defined as those particles that are smaller than 2 microns in diameter. To determine acres in-scope given various percent clay contents, EPA evaluated a national soils data layer (see section 3.5.4) in combination with RF1-level estimates of the amount of construction activity occurring annually. Table 4-7 indicates the annual quantity of developed acres that would be in-scope for various clay contents. Table 4-8 indicates total state acreage in-scope for various clay contents. The state and national totals in Table 4-7 do not exactly match the totals contained in Tables 3-1 and 4-6 because of incomplete GIS coverage, but the difference is minor (less than 1 percent).

4.2.2.6. Rainfall and Runoff Factor Analysis

EPA evaluated options that incorporate applicability provisions that are tied to the rainfall and runoff factor (or R-factor) contained in the Revised Universal Soil Loss Equation (RUSLE) (see section 3.5.6). To evaluate the influence of setting applicability criteria at various annual R-factor thresholds and to estimate the acres of new construction that would be in-scope given various annual R-factor thresholds, EPA overlaid GIS layers of annual R-factors with the RF1-level estimates of annual developed acres from the NLCD analysis. Tables 3-6 and 3-7 summarize developed acres that would be in-scope in each state given annual R-factor values from 10 to 100. Figure 3-15 shows annual R-factor values for the CONUS.

Table 4-5. Estimated Number of Model Construction Projects Developed Annually

	Residential			Nonresidential			Transportation			Totals
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	
Alabama	265	110	134	409	89	73	37	11	14	1,142
Arizona	249	103	126	385	84	68	35	10	13	1,073
Arkansas	155	64	78	240	52	42	22	6	8	667
California	500	208	253	774	168	137	70	20	26	2,156
Colorado	289	120	146	447	97	79	40	12	15	1,245
Connecticut	18	8	9	28	6	5	3	1	1	79
Delaware	15	6	8	23	5	4	2	1	1	65
Florida	694	288	351	1,074	234	190	97	28	36	2,992
Georgia	595	247	300	920	200	163	83	24	31	2,563
Hawaii	--	--	--	--	--	--	--	--	--	--
Idaho	103	43	52	160	35	28	14	4	5	444
Illinois	374	155	189	578	126	103	52	15	19	1,611
Indiana	226	94	114	349	76	62	32	9	12	974
Iowa	184	76	93	285	62	50	26	7	10	793
Kansas	411	171	208	636	138	113	57	16	21	1,771
Kentucky	182	76	92	282	61	50	25	7	9	784
Louisiana	234	97	118	362	79	64	33	9	12	1,008
Maine	82	34	41	127	28	22	11	3	4	352
Maryland	119	49	60	185	40	33	17	5	6	514
Massachusetts	60	25	31	94	20	17	8	2	3	260
Michigan	410	170	207	635	138	112	57	16	21	1,766
Minnesota	170	71	86	263	57	47	24	7	9	734
Mississippi	216	90	109	335	73	59	30	9	11	932
Missouri	247	103	125	382	83	68	35	10	13	1,066
Montana	118	49	59	182	40	32	16	5	6	507
Nebraska	111	46	56	172	37	30	15	4	6	477
Nevada	149	62	75	230	50	41	21	6	8	642

	Residential			Nonresidential			Transportation			Totals
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	
New Hampshire	33	14	16	50	11	9	5	1	2	141
New Jersey	78	32	39	120	26	21	11	3	4	334
New Mexico	85	35	43	132	29	23	12	3	4	366
New York	141	58	71	218	47	39	20	6	7	607
North Carolina	342	142	173	529	115	94	48	14	18	1,475
North Dakota	119	49	60	185	40	33	17	5	6	514
Ohio	317	132	160	491	107	87	44	13	17	1,368
Oklahoma	305	127	154	472	103	84	43	12	16	1,316
Oregon	133	55	67	206	45	36	19	5	7	573
Pennsylvania	292	121	147	452	98	80	41	12	15	1,258
Rhode Island	7	3	3	11	2	2	1	-	-	29
South Carolina	295	122	149	456	99	81	41	12	15	1,270
South Dakota	151	63	77	235	51	42	21	6	8	654
Tennessee	239	99	121	369	80	65	33	10	12	1,028
Texas	1,118	464	565	1,730	377	307	156	45	58	4,820
Utah	153	63	77	237	52	42	21	6	8	659
Vermont	10	4	5	16	3	3	1	-	1	43
Virginia	276	115	140	427	93	76	39	11	14	1,191
Washington	233	97	118	361	79	64	33	9	12	1,006
West Virginia	64	27	32	99	22	18	9	3	3	277
Wisconsin	138	57	70	213	46	38	19	6	7	594
Wyoming	52	21	26	80	17	14	7	2	3	222
District of Columbia	1	-	1	2	-	-	-	-	-	4
Nation	**10,758**	**4,465**	**5,434**	**16,648**	**3,620**	**2,950**	**1,503**	**431**	**557**	**46,366**

Table 4-6. Estimated Annually Developed Acreage Represented by Model Construction Projects

	Residential			Nonresidential			Transportation			Totals
	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large	
Alabama	793	1,833	4,410	1,064	1,336	3,698	111	170	1,087	14,502
Arizona	745	1,723	4,144	1,000	1,256	3,475	104	160	1,021	13,628
Arkansas	464	1,073	2,581	623	782	2,164	65	99	636	8,487
California	1,499	3,466	8,339	2,012	2,527	6,993	210	321	2,055	27,422
Colorado	865	2,001	4,814	1,162	1,459	4,037	121	185	1,186	15,830
Connecticut	55	127	306	74	93	257	8	12	75	1,007
Delaware	46	105	253	61	77	213	6	10	62	833
Florida	2,081	4,812	11,576	2,793	3,508	9,707	291	446	2,852	38,066
Georgia	1,782	4,120	9,911	2,391	3,003	8,311	249	382	2,442	32,591
Hawaii	0	0	0	0	0	0	0	0	0	0
Idaho	310	717	1,726	416	523	1,447	43	66	425	5,673
Illinois	1,121	2,592	6,235	1,504	1,889	5,228	157	240	1,536	20,502
Indiana	676	1,564	3,763	908	1,140	3,155	95	145	927	12,373
Iowa	552	1,276	3,070	741	930	2,574	77	118	756	10,094
Kansas	1,232	2,849	6,854	1,654	2,077	5,747	172	264	1,689	22,538
Kentucky	545	1,261	3,034	732	919	2,544	76	117	748	9,976
Louisiana	702	1,623	3,906	942	1,184	3,275	98	150	962	12,842
Maine	246	568	1,367	330	414	1,146	34	53	337	4,495
Maryland	357	826	1,987	480	602	1,667	50	77	490	6,536
Massachusetts	181	420	1,010	244	306	847	25	39	249	3,321
Michigan	1,230	2,844	6,841	1,651	2,073	5,736	172	263	1,686	22,496
Minnesota	510	1,180	2,838	685	860	2,379	71	109	699	9,331
Mississippi	648	1,499	3,606	870	1,093	3,023	91	139	888	11,857
Missouri	741	1,713	4,121	994	1,249	3,455	104	159	1,015	13,551
Montana	353	816	1,963	474	595	1,646	49	76	484	6,456
Nebraska	332	768	1,848	446	560	1,550	46	71	455	6,076
Nevada	446	1,031	2,480	598	752	2,080	62	95	611	8,155

	Residential			Nonresidential			Transportation			
New Hampshire	98	226	543	131	165	455	14	21	134	1,787
New Jersey	233	540	1,298	313	393	1,089	33	50	320	4,269
New Mexico	255	590	1,420	343	430	1,191	36	55	350	4,670
New York	422	976	2,348	567	712	1,969	59	90	579	7,722
North Carolina	1,024	2,369	5,698	1,375	1,727	4,778	143	219	1,404	18,737
North Dakota	357	826	1,988	480	602	1,667	50	77	490	6,537
Ohio	951	2,199	5,291	1,277	1,603	4,437	133	204	1,304	17,399
Oklahoma	915	2,115	5,088	1,228	1,542	4,266	128	196	1,254	16,732
Oregon	398	921	2,215	535	671	1,858	56	85	546	7,285
Pennsylvania	875	2,023	4,867	1,174	1,475	4,081	122	187	1,199	16,003
Rhode Island	21	48	115	28	35	96	3	4	28	378
South Carolina	884	2,044	4,917	1,186	1,490	4,123	124	189	1,212	16,169
South Dakota	454	1,050	2,527	610	766	2,119	64	97	623	8,310
Tennessee	715	1,654	3,980	960	1,206	3,338	100	153	981	13,087
Texas	3,351	7,749	18,643	4,498	5,649	15,633	469	718	4,594	61,304
Utah	459	1,060	2,551	616	773	2,139	64	98	629	8,389
Vermont	31	72	173	42	52	145	4	7	43	569
Virginia	828	1,915	4,606	1,111	1,396	3,862	116	177	1,135	15,146
Washington	699	1,617	3,890	939	1,179	3,262	98	150	959	12,793
West Virginia	192	444	1,068	258	324	896	27	41	263	3,513
Wisconsin	414	957	2,302	555	697	1,930	58	89	567	7,569
Wyoming	155	359	865	209	262	725	22	33	213	2,843
Puerto Rico	0	0	0	0	0	0	0	0	0	0
District of Columbia	4	8	20	5	6	17	1	1	5	67
Nation	**32,247**	**74,569**	**179,396**	**43,289**	**54,362**	**150,430**	**4,511**	**6,907**	**44,205**	**589,916**

4.2.2.7. Estimates of Number of Sites and Acreage Covered by Regulatory Options

EPA evaluated several regulatory options that included combinations of site size, R-factor and percent clay content. To estimate acres affected by various combinations of R-factors and clay contents, EPA combined the national clay data layer along with the R-factor data layer and RF1-level estimates of amount of development using GIS. Using the distribution of construction sites by size, EPA was able to estimate the acres that would be subject to various components of the proposed regulation. EPA estimates that under Option 1, approximately 120,700 acres per year, or approximately 20 percent of annual constructed acres, would be required to install larger sediment basins. Under Option 2, approximately 234,000 acres per year, or approximately 40 percent of annual construction acreage, would be required to meet the turbidity standard. In addition, approximately 64,000 acres, or 11 percent of annual construction acreage, would be required to install larger sediment basins under Option 2. Under Option 3, approximately 509,000 acres, or 86 percent of annual construction acreage, would be required to meet a turbidity limit. Under all three options, all areas of the country would be required to meet the best management practice requirements contained in the proposed rule. Table 4-9 summarizes the acres subject to the proposed option. Figure 4-1 generally shows areas of the country that would be required to meet the turbidity limit under Option 2. In this figure, areas in white are in areas with an annual R-factor of less than 50 or with less than 10 percent by mass of clay particles in the surface soil layer, while those areas in blue are in areas with an annual R-factor of 50 or greater and with 10 percent or more by mass of clay particles in the surface soil layer. Therefore, only areas in the blue-colored area would be considered in-scope for the turbidity limit.

Under Option 2, EPA would allow use of average annual precipitation of 20 or more inches instead of an R-factor of 50 or more as an applicability provision for the turbidity limit for areas of the country, such as Alaska, Hawaii and the U.S territories, where annual R-factor maps are not readily available or permittees have not calculated R-factors from available precipitation data. Figure 4-2 shows mean annual precipitation for Alaska for the period 1961 to 1990 (Western Regional Climate Center 2008) and Figure 4-3 shows mean annual precipitation for Hawaii for the period 1971-2000 (PRISM Group 2006). These figures provide an illustration of the areas of Alaska and Hawaii that would likely be subject to the turbidity standard. EPA expects that permitting authorities would develop detailed applicability information to address these cases.

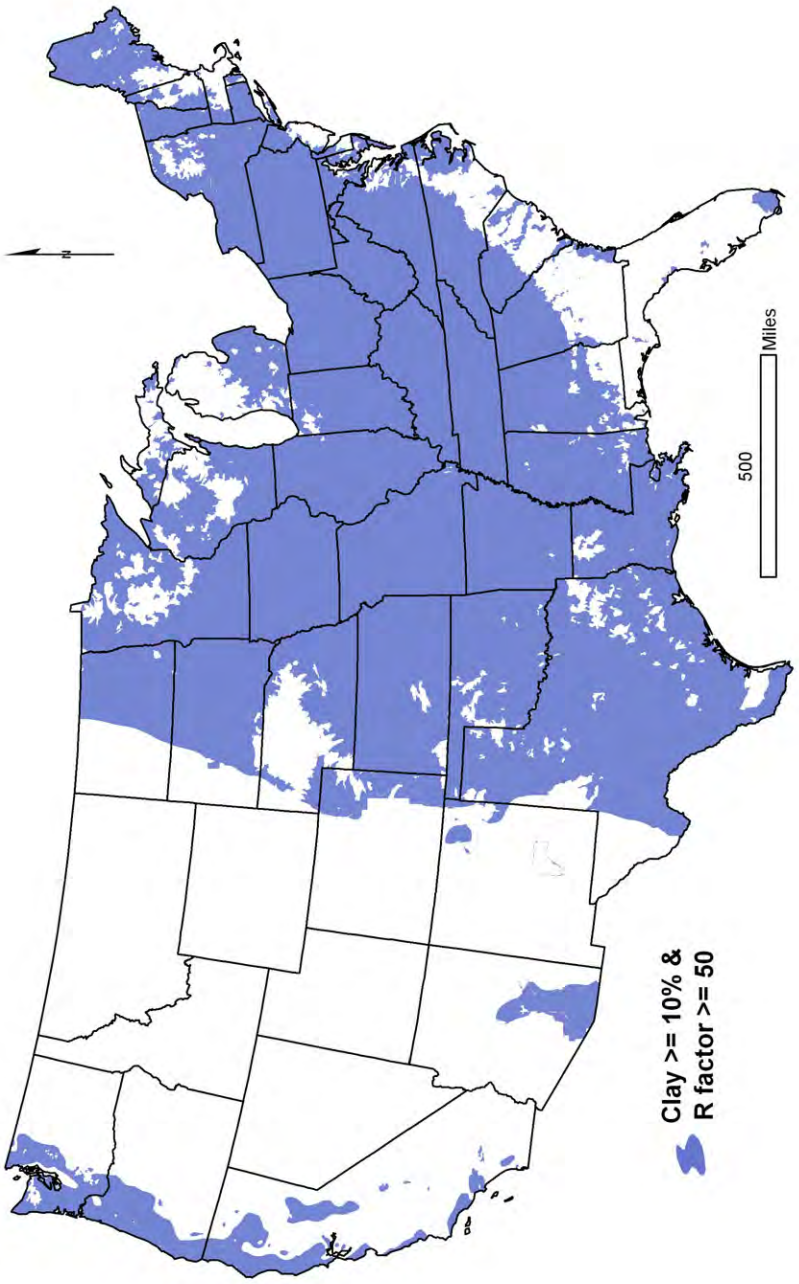

Figure 4-1. Areas of the CONUS Required to Meet Turbidity Limit.

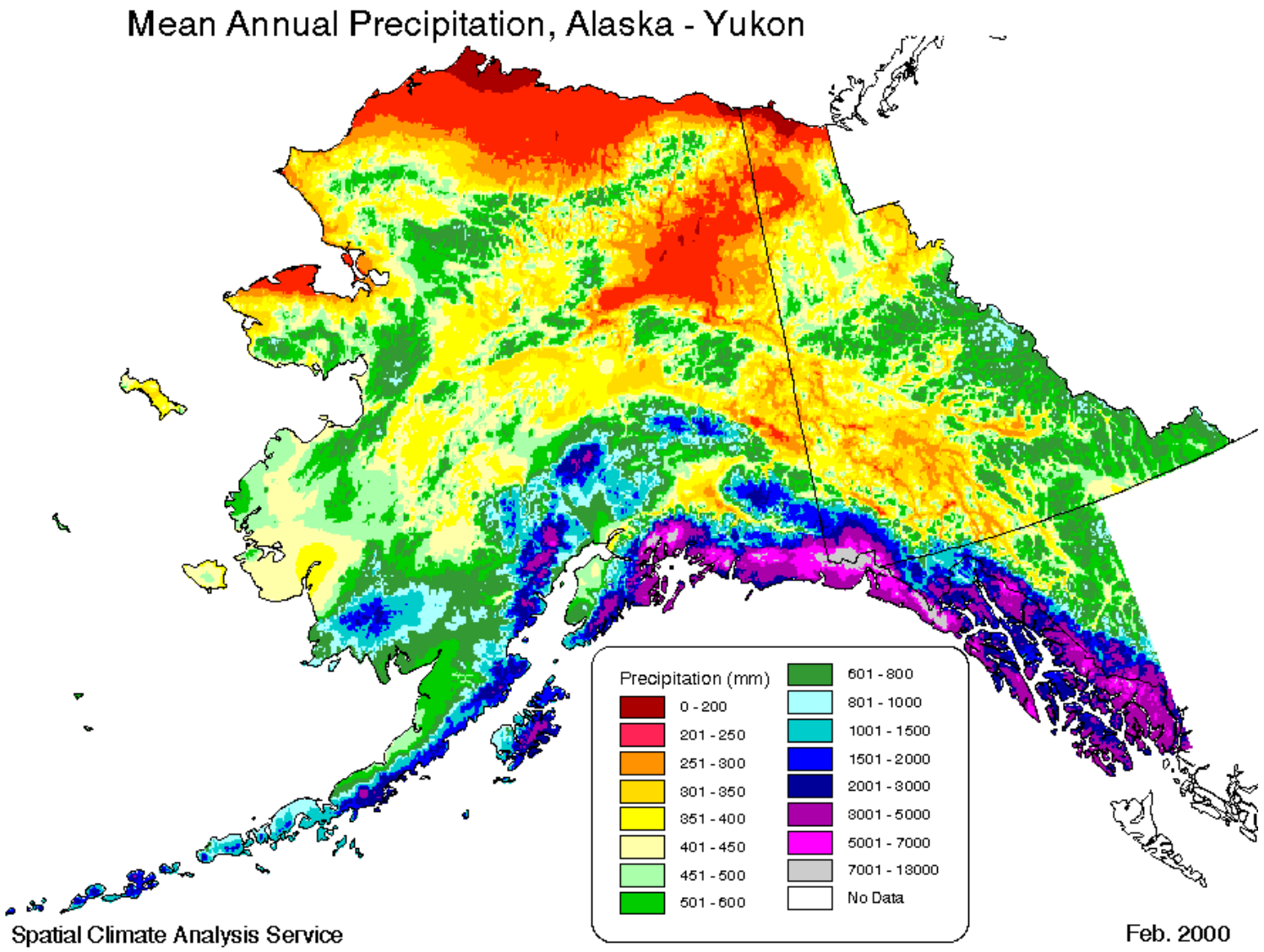

Figure 4-2. Alaska's Mean Annual Precipitation 1961 to 1990.

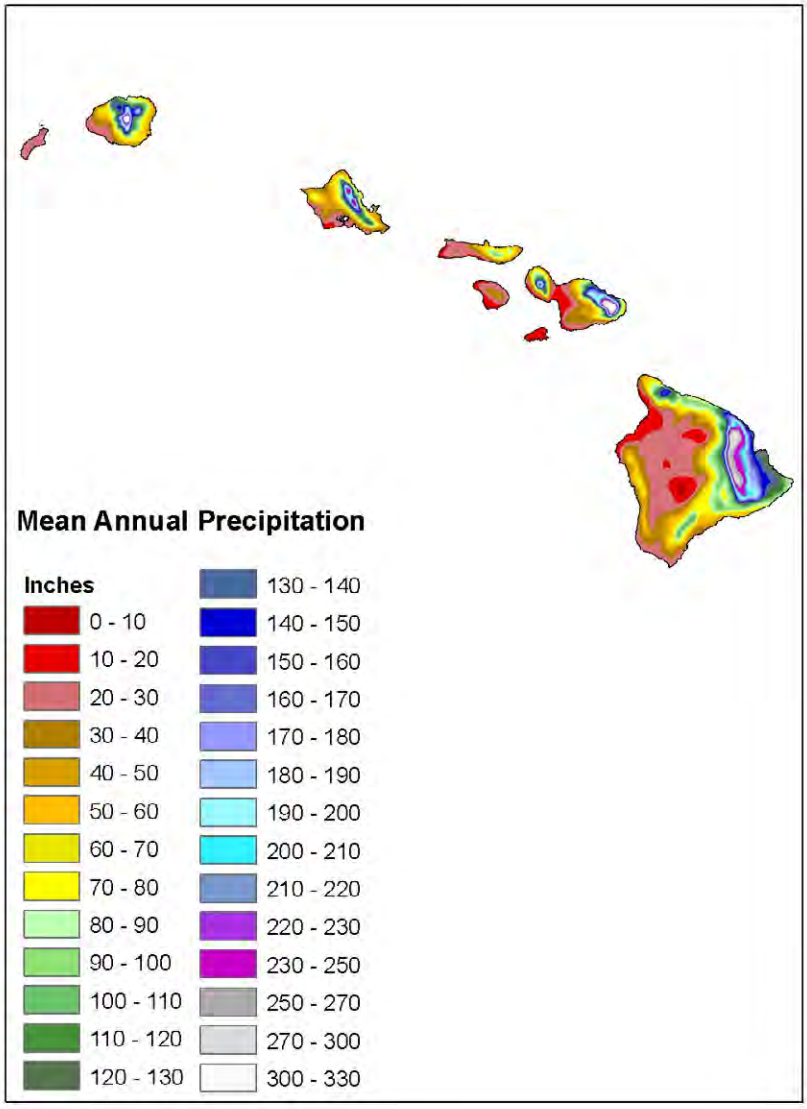

Figure 4-3. Hawaii's Mean Annual Precipitation 1971 to 2000.

Table 4-7. Annual State Developed Acres in Various Percent Clay Fractions

Percent clay =>>	0–5	5–10	10–15	15–20	20–25	25–30	> 30	State total
Alabama	71	3,755	6,822	2,905	600	129	233	14,515
Arkansas	0	100	6,581	736	418	254	412	8,500
Arizona	2	255	2,911	7,657	2,737	110	16	13,688
California	926	4,722	7,077	5,413	4,434	1,989	3,324	27,884
Colorado	5	785	3,125	6,652	3,556	1,108	756	15,988
Connecticut	30	563	440	0	--	--	--	1,033
Delaware	12	665	274	--	--	--	--	951
Florida	32,536	5,472	270	75	--	--	1	38,355
Georgia	3,217	7,857	5,956	15,402	292	11	9	32,744
Iowa	1	2	944	1,301	4,990	2,275	607	10,122
Idaho	12	298	4,466	847	63	7	0	5,692
Illinois	19	44	2,425	15,344	2,478	183	55	20,548
Indiana	1	1,286	2,123	8,519	426	5	120	12,480
Kansas	2	1,729	5,496	4,126	6,002	2,543	2,706	22,605
Kentucky	2	46	5,186	2,822	757	841	349	10,002
Louisiana	472	1,962	6,195	1,599	882	752	1,228	13,089
Massachusetts	131	2,892	225	102	--	--	--	3,350
Maryland	257	788	4,007	1,519	7	--	--	6,578
Maine	26	1,443	3,124	167	--	--	--	4,760
Michigan	6,692	8,836	4,405	2,474	76	352	128	22,963
Minnesota	588	2,557	2,744	1,896	859	528	230	9,402
Missouri	100	86	7,069	2,908	3,060	288	41	13,550
Mississippi	1	1,112	8,840	802	344	238	552	11,891
Montana	5	65	706	2,428	1,425	857	1,105	6,592
North Carolina	857	3,430	8,264	6,468	--	--	--	19,019
North Dakota	0	76	785	5,136	466	34	137	6,634
Nebraska	383	1,669	1,610	609	227	1,232	435	6,166
New Hampshire	3	1,425	379	--	--	--	--	1,807
New Jersey	437	1,894	1,776	162	--	--	--	4,270
New Mexico	30	1,266	1,750	1,433	144	69	16	4,709
Nevada	10	509	6,576	887	66	120	--	8,168

Percent clay =>>	0–5	5–10	10–15	15–20	20–25	25–30	> 30	State total
New York	229	1,566	5,233	599	129	39	72	7,868
Ohio	24	241	9,256	5,831	1,685	68	364	17,467
Oklahoma	28	982	8,455	4,168	1,571	1,200	351	16,756
Oregon	144	1,232	2,359	2,224	611	603	157	7,331
Pennsylvania	29	55	14,432	1,662	6	--	--	16,184
Rhode Island	1	212	147	--	--	--	--	360
South Carolina	2,859	8,054	4,846	690	18	5	--	16,471
South Dakota	1	111	870	3,180	1,988	1,014	1,169	8,332
Tennessee	0	87	7,392	4,799	731	104	5	13,119
Texas	553	6,130	11,371	6,815	5,140	5,511	26,495	62,016
Utah	16	518	977	6,381	431	87	1	8,411
Virginia	267	1,513	8,869	3,575	564	292	85	15,165
Vermont	1	18	500	26	11	11	12	578
Washington	65	2,471	8,307	1,714	249	3	2	12,810
Wisconsin	413	2,571	2,804	1,419	319	9	73	7,608
West Virginia	4	35	2,126	852	342	63	97	3,519
Wyoming	2	126	1,065	912	622	122	16	2,865
Total	51,465	83,510	201,562	145,239	48,726	23,055	41,358	594,916
% in Fraction	9%	14%	34%	24%	8%	4%	7%	
Cumulative % in Fraction	9%	23%	57%	81%	89%	93%	100%	

Table 4-8. State Total Acres in Various Percent Clay Fractions

Percent clay =>>	0–5	5–10	10–15	15–20	20–25	25–30	> 30	State total
Alabama	44,937	8,612,982	14,810,271	6,529,033	1,319,622	599,129	1,119,922	33,035,896
Arizona	885,828	6,781,085	20,614,063	22,498,143	7,030,190	2,566,592	915,525	61,291,426
Arkansas	1,830	403,679	22,983,199	3,844,556	1,786,895	1,334,068	3,736,017	34,090,245
California	3,505,825	22,822,008	25,404,458	20,513,830	12,023,014	4,655,984	5,754,918	94,680,037
Colorado	42,749	3,606,090	20,549,986	25,296,937	7,898,678	1,476,849	481,462	59,352,750
Connecticut	74,760	2,171,833	985,313	3,280	0	0	0	3,235,185
Delaware	26,313	1,069,896	389,888	0	0	0	0	1,486,097
Florida	29,124,995	6,042,465	509,706	89,408	0	0	1,070	35,767,644
Georgia	2,958,921	17,289,276	6,560,210	10,407,774	481,850	16,073	17,562	37,731,666
Idaho	751,490	3,141,449	19,795,382	9,657,471	715,242	229,160	247	34,290,441
Illinois	61,620	269,530	9,029,876	21,141,590	4,453,414	1,024,672	443,025	36,423,727
Indiana	24,463	1,359,624	8,403,777	11,818,540	1,533,023	20,757	136,634	23,296,817
Iowa	5,668	7,088	3,527,356	5,280,593	14,788,510	8,361,470	4,141,341	36,112,024
Kansas	452	1,878,414	18,649,413	12,485,930	8,582,328	5,521,984	5,613,986	52,732,506
Kentucky	5,785	298,726	16,345,138	5,230,883	1,598,583	1,109,831	1,338,907	25,927,854
Louisiana	2,015,854	3,725,177	10,956,136	3,204,582	2,285,703	1,714,877	5,520,495	29,422,824
Maine	131,101	5,853,138	11,127,920	657,736	0	0	0	17,769,896
Maryland	243,055	896,490	3,588,173	1,515,076	11,715	0	0	6,254,510
Massachusetts	250,591	3,375,615	620,678	899,897	0	0	0	5,146,781
Michigan	9,249,589	13,508,820	10,529,585	3,802,660	369,817	241,167	106,602	37,808,240
Minnesota	3,003,300	13,953,272	11,887,104	6,077,935	7,697,705	8,495,431	2,135,487	53,250,235
Mississippi	16,722	1,756,196	19,112,105	2,450,885	1,504,726	1,185,805	4,651,669	30,678,107
Montana	142,808	144,416	21,433,697	10,447,732	8,850,695	3,234,132	545,735	44,799,216
Montana	189,402	1,052,152	7,658,539	21,751,812	15,766,710	9,132,519	13,649,439	69,200,572
Nebraska	10,746,079	10,046,830	13,436,477	5,738,791	2,831,434	2,662,836	3,213,610	48,676,057
Nevada	92,851	2,751,452	29,807,706	21,299,211	575,110	1,029,917	0	55,556,248
New Hampshire	11,454	3,646,834	2,228,159	0	0	0	0	5,886,447
New Jersey	763,239	1,846,632	1,832,592	396,973	0	0	0	4,839,437
New Mexico	599,173	5,675,590	27,465,625	26,636,781	5,013,372	977,014	172,628	66,540,183
New York	782,650	5,977,736	21,932,781	1,826,277	434,682	92,257	201,067	31,247,451
North Carolina	1,680,960	10,585,082	12,503,521	7,162,561	0	0	0	31,932,125

Percent clay =>>	0–5	5–10	10–15	15–20	20–25	25–30	> 30	State total
North Dakota	9,884	460,300	4,893,923	31,733,223	4,732,932	944,669	1,298,372	44,073,304
Ohio	56,072	77,429	10,126,108	9,627,074	4,177,715	640,084	2,103,301	26,807,782
Oklahoma	153,668	3,075,911	21,586,652	11,715,655	4,671,183	2,698,674	889,610	44,791,352
Oregon	1,000,415	3,374,635	13,164,763	19,536,164	5,076,785	2,887,108	613,757	45,653,628
Pennsylvania	49,553	127,959	21,815,603	7,164,585	41,514	0	0	29,199,215
Rhode Island	8,896	481,255	165,637	0	0	0	0	655,788
South Dakota	66,163	1,120,777	4,613,557	14,995,151	8,102,514	5,118,772	12,966,793	46,983,728
South Carolina	2,359,317	8,242,264	7,844,711	1,272,505	42,255	7,997	0	19,769,048
Tennessee	5,436	225,022	16,800,299	8,221,207	1,336,166	359,117	154,223	27,101,470
Texas	4,112,583	13,675,458	24,105,815	26,935,881	22,802,414	19,726,369	54,209,368	165,567,887
Utah	1,669,341	3,497,268	10,975,155	31,000,753	1,224,730	179,410	17,068	48,563,724
Vermont	28,177	88,705	5,364,034	225,983	51,958	139,816	213,365	6,112,037
Virginia	309,737	2,849,990	14,290,883	7,107,094	635,585	220,665	61,282	25,475,236
Washington	133,870	4,848,745	28,176,918	5,946,099	658,862	3,244	20,016	39,787,754
West Virginia	4,632	59,519	9,098,514	3,819,661	1,858,659	134,493	552,333	15,527,811
Wisconsin	1,563,705	10,757,100	20,200,136	2,879,574	509,664	96,522	174,993	36,181,693
Wyoming	216,567	1,843,581	18,811,672	11,951,494	7,249,557	1,481,565	856,661	42,411,096
National Total	79,182,479	215,355,492	626,713,220	462,798,983	170,725,511	90,321,028	128,028,486	1,773,125,199
% in Fraction	4%	12%	35%	26%	10%	5%	7%	
Cumulative % in Fraction	4%	17%	52%	78%	88%	93%	100%	

Table 4-9. Acres Subject to Proposed Regulation

	Option 1	Option 2		Option 3		Option 1	Option 2		Option 3
		Turbidity limit	Basins				Turbidity limit	Basins	
Alaska	No Data				Nebraska	5,239	-	-	5,239
Alabama	12,598	6,726	5,872	12,598	Nevada	--	--	--	7,079
Arizona	--	898	--	11,792	New Hampshire	--	201	--	1,560
Arkansas	--	5,314	--	7,292	New Jersey	3,646	1,262	2,384	3,646
California	--	2,557	--	23,701	New Mexico	--	84	--	3,975
Colorado	13,682	1,809	11,873	13,682	New York	--	3,818	--	6,654
Connecticut	--	234	--	871	North Carolina	16,244	9,250	6,994	16,244
Delaware	--	117	--	738	North Dakota	--	2,791	--	5,635
Florida	--	201	--	32,881	Ohio	15,076	10,862	4,213	15,076
Georgia	28,168	13,653	14,515	28,168	Oklahoma	--	9,998	--	14,486
Hawaii				No Data	Oregon	--	--	--	6,273
Idaho	--	--	--	4,846	Pennsylvania	--	10,115	--	13,797
Illinois	--	12,905	--	17,708	Rhode Island	281	84	197	281
Indiana	10,725	7,039	3,686	10,725	South Carolina	--	3,422	--	13,946
Iowa	--	6,408	--	8,719	South Dakota	--	4,800	--	7,227
Kansas	--	13,218	--	19,482	Tennessee	--	8,222	--	11,268
Kentucky	--	6,296	--	8,592	Texas	--	34,111	--	53,002
Louisiana	--	6,609	--	11,054	Utah	--	--	--	7,242
Maine	--	2,010	--	3,826	Vermont	509	397	112	509
Maryland	--	3,455	--	5,635	Virginia	--	8,502	--	13,092
Massachusetts	--	201	--	2,876	Washington	--	2,791	--	11,054
Michigan	--	4,599	--	19,365	West Virginia	--	2,160	--	3,040
Minnesota	--	3,935	--	8,098	Wisconsin	6,538	2,875	3,664	6,538
Mississippi	--	6,810	--	10,216	Wyoming	2,446	--	2,446	2,446
Missouri	--	8,502	--	11,744	District of Columbia	--	--	--	33
Montana	5,551	--	5,551	5,551	**Totals**	**120,701**	**233,836**	**64,305**	**509,497**

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5. SELECTION OF POLLUTANTS FOR REGULATION

5.1. INTRODUCTION

Construction and development (C&D) activities can generate a broad range of environmental impacts by introducing new sources of contamination and by altering the physical characteristics of the affected land area. In particular, these activities can result in both short- and long-term adverse impacts on surface water quality in streams, rivers, and lakes in the affected watershed by increasing the loads of various pollutants in receiving waterbodies, including sediments, metals, organic compounds, pathogens, and nutrients. Ground water also can be adversely affected through diminished recharge capacity. Other potential impacts include the physical alteration of existing streams and rivers due to the excessive flow and velocity of stormwater runoff.

Construction activities typically involve excavating and clearing existing vegetation. During the construction period, the affected land is usually stripped and the soil compacted, leading to the potential for increased stormwater runoff and high rates of erosion. If the denuded and exposed areas contain hazardous contaminants or pollutants (either naturally occurring or from previous land uses) they can be carried at increased rates to surrounding waterbodies by stormwater runoff. Although the denuded construction site is only a temporary state (usually lasting less than 6 months), the landscape is permanently altered even after the land has been restored by replanting vegetation.

Pollutants associated with C&D stormwater discharges can adversely affect the environment in a number of ways. Potential effects include impairment of water quality, destruction of aquatic life habitats, and enlargement of floodplains. The *Environmental Impact and Benefits Assessment for Proposed Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-R-08-009) discusses the potential affects of C&D stormwater runoff on the environment. The discussion in the remainder of this section focuses on those pollutants generated at a site during active construction.

5.2. POLLUTANTS ASSOCIATED WITH CONSTRUCTION AND LAND DEVELOPMENT STORMWATER RUNOFF

There are a number of pollutants associated with C&D stormwater runoff. The description of pollutants in this subsection does not represent the complete suite of contaminants that can be found in the runoff, but focuses instead on those that are known to be the most prevalent and of greatest concern to the environment. These pollutants include sediment, metals, polycyclic aromatic hydrocarbons (PAHs), oil and grease, and pathogens.

5.2.1. SEDIMENT

Sediment is an important and ubiquitous constituent in urban stormwater runoff. Surface runoff and raindrops detach soil from the land surface, resulting in sediment transport into streams and rivers. Sediment and turbidity can affect habitat, water quality, temperature, pollutant transport, and can cause sedimentation in downstream receiving waters. The effects of excess sediment in

the water include direct physical effects such as reducing visibility and light in the water column, physical abrasion of plant surfaces, clogging gill openings, and entombing of eggs and fry in redds. Effects can also be indirect, as in changes to the chemical composition (e.g., pH, hardness) of the water, light penetration or turbidity, and/or temperature profile, which in turn affect primary productivity with repercussions in terms of fish behavior, and overall community profiles and trophic structure.

Sediment level measurement can be divided into several distinct subgroups:

- Total suspended solids (TSS) are a dry weight measure of the suspended particulate material in water. The measurement of TSS in urban stormwater allows for estimation of sediment transport, which can have significant effects locally and in downstream receiving waters. TSS is typically measured in milligrams per liter (mg/L).
- Turbidity is a function of the suspended solids and is a measure of the ability of light to penetrate the water. Turbidity readings are somewhat dependent on particle size, shape, and color. Turbidity is typically measured in Nephelometric Turbidity Units (NTUs). Turbidity can exhibit control over biological functions, such as the ability of submerged aquatic vegetation to receive light.
- Total dissolved solids are a measure of the dissolved constituents in water and are a primary indication of the purity of drinking water.
- Settleable solids, expressed as milliliters per liter (mL/L), are a measure of the solids that will settle to the bottom of a cone-shaped container (called an Imhoff cone) in a 60-minute period. Settleable solids are primarily a measure of particles that can be removed by sedimentation.
- Suspended Sediment Concentration (SSC) is a measure similar to TSS; however, there are differences in the two analytical methods. SSC is determined by measuring the dry weight of all sediment from a known volume of sample. TSS is measured by filtering a subsample and measuring the weight of the dried solids. SSC and TSS values from the same sample can vary greatly, especially as the fraction of sand-sized particles in a sample increases. This is due primarily to the subsampling procedure involved in TSS calculations where typically a pipette is used to withdraw a subsample from the sample container. This procedure might not capture a representative fraction of larger particles in the subsample. The U.S. Geological Survey (USGS) has analyzed differences attributable to the two methods and determined that SSC is a more appropriate measure of the mass of solids in natural-water samples (Gray et al. 2000). This may also apply to stormwater discharges, especially if a significant fraction of sand-sized particles are present.

Erosion from construction sites can be a significant source of sediment pollution to nearby streams. A number of studies have shown high concentrations of TSS in uncontrolled runoff from construction sites, and results from these studies are summarized in Table 5-1. One study, conducted in 1986, calculated that construction sites are responsible for an estimated export of 80 million tons of sediment into receiving waters each year (Goldman et al. 1986). On a unit area basis, construction sites can export sediment at 20 to 1,000 times the rate of other land uses **(**Schueler 1997).

Table 5-1. Studies of Uncontrolled Soil Erosion as TSS from Construction Sites

Site	Mean Inflow TSS Concentration (mg/L)	Source
Seattle, Washington	17,500	Horner, Guerdy, and Kortenhoff 1990
SR 204	3,502	Horner, Guerdy, and Kortenhoff 1990
Mercer Island	1,087	Horner, Guerdy, and Kortenhoff 1990
RT1	359	Schueler and Lugbill 1990
RT2	4,623	Schueler and Lugbill 1990
SB1	625	Schueler and Lugbill 1990
SB2	415	Schueler and Lugbill 1990
SB4	2,670	Schueler and Lugbill 1990
Pennsylvania Test Basin	9,700	Jarrett 1996
Georgia Model	1,500–4,500	Sturm and Kirby 1991
Maryland Model	1,000–5,000	Barfield and Clar 1985
Uncontrolled Construction Site Runoff (MD)	4,200	York and Herb 1978
Austin, Texas	600	Dartiguenave, ECLille, and Maidment 1997
Hamilton County, Ohio	2,950	Islam, Taphorn, and Utrata-Halcomb 1998
Mean TSS (mg/L)	3,681	N/A

N/A – Not Applicable

5.2.2. METALS

Many toxic metals can be found in urban stormwater, although typically only metals such as zinc, copper, lead, cadmium, and chromium have been identified in the literature as being of primary concern because of their prevalence in urban stormwater runoff and their potential for environmental harm. These metals are generated by motor vehicle exhaust, weathering of buildings, burning fossil fuels, atmospheric deposition, and other common urban activities.

Metals can bioaccumulate in stream environments, resulting in plant growth inhibition and adverse health effects on bottom-dwelling organisms (Masterson and Bannerman 1994). Generally the concentrations found in urban stormwater are not high enough for acute toxicity (Field and Pitt 1990). Rather, it is the cumulative effect of the concentration of these metals over time and the buildup in the sediment and animal tissue that are of greater concern.

Construction sites are not thought to be important sources of metals contamination. Runoff from such sites could have high metals contents if the soil is already contaminated. Construction activities alone do not usually result in metals contamination, although there is little data available on this subject.

5.2.3. PAHs, AND OIL AND GREASE

Petroleum-based substances such as oil and grease and PAHs are found frequently in urban stormwater runoff. Many constituents of PAHs and oil and grease, such as pyrene and benzo[b]fluoranthene, are carcinogens and toxic to downstream biota (Menzie-Cura &

Associates 1995). Oil and grease and PAHs normally travel attached to sediment and organic carbon. Downstream accumulation of these pollutants in the sediments of receiving waters such as streams, lakes, and estuaries is of concern.

Construction activities during site development are not believed to be major contributors of these contaminants to stormwater runoff. Improper operation and maintenance of construction equipment at construction sites, as well as poor housekeeping practices (e.g., improper storage of oil and gasoline products and construction materials), could lead to leakage or spillage of products that contain hydrocarbons.

5.2.4. PATHOGENS

Microbes are commonly found in urban stormwater. Although not all microbes are harmful, several species such as the pathogens *Cryptosporidium* and *Giardia* can directly cause diseases in humans. The presence of bacteria such as fecal coliform bacteria, fecal streptococci, and *Escherichia coli* (i.e., *E. coli*) indicates a potential health risk. High levels of these bacteria can result in beach closings, restrictions on shellfish harvest, and increased treatment for drinking water to decrease the risk of human health problems.

Construction site activities are not believed to be major contributors to pathogen contamination of surface waters. The only potential known source of pathogens from construction sites are portable septic tanks used by construction workers. These systems, however, are typically self-contained, although leaks or spills could result in releases.

5.3. SELECTION OF POLLUTANTS FOR REGULATION

When determining which pollutants to consider for regulation, the U.S. Environmental Protection Agency (EPA) applied the following priorities for discharges from the C&D industry:

- Focus on pollutants directly attributable to the industry, using indicator pollutants where necessary
- Focus on pollutants most commonly encountered under most settings, (i.e., not to preconstruction site contamination issues or accidental discharges)
- Focus on pollutants that are most manageable given the current suite of available technologies
- Focus on pollutants that can be addressed under the authority of effluent guidelines

In support of the 2002 and 2004 regulatory efforts, EPA conducted an extensive evaluation of the literature to identify pollutants present in stormwater discharges from C&D sites. While the literature contains extensive information on pollutants present in stormwater discharges from urban areas, there were little data available on pollutants present in stormwater discharges from construction sites during the active phase of construction other than for sediment, TSS, and turbidity. This is not surprising, because construction site stormwater management is primarily concerned with controlling solids from exposed soil areas. There is the potential for other pollutants to be discharged from construction sites depending on factors such as prior land uses. For example, if the prior land use was agriculture, there is the potential for discharge of

pollutants such as nutrients and pesticides. Likewise, areas of redevelopment that occur on sites where previous land uses included industry could discharge pollutants such as organics and metals. In addition, pollutants such as metals and nutrients can be present in native site soils, and could be discharged from construction sites. Also, high pH can result from stormwater being exposed to freshly placed concrete. However, EPA was not able to identify sufficient data in the literature to warrant development of controls specific to pollutants other than sediment, TSS, and turbidity in stormwater discharges from active construction sites. Although EPA identified other pollutants of concern for this industry, EPA did not develop regulatory options specifically targeted at controlling each of these individual pollutants.

Instead, EPA chose to develop regulatory options using an indicator pollutant, turbidity. While turbidity might not correlate well with TSS, design of management systems for controlling turbidity will likely result in control of other pollutants such as TSS, nutrients, and metals that are present in the solid-phase (attached to sediments). In addition, turbidity, unlike TSS, can be measured with relative ease in the field using hand-held turbidity meters or automated in-line turbidity meters. An in-line turbidity meter, coupled with a data logger, can offer real-time data on turbidity levels in stormwater discharges.

Particles that contribute to turbidity can be of such a fine grain that they will not be removed by the mechanisms whereby most best management practices operate, mainly settling and filtration. Hence, EPA's proposal rule focuses on active treatment of stormwater runoff using polymers to remove turbidity, as well as TSS and other pollutants. Section 7.1.6 discusses active treatment systems designed to reduce and/or remove these fine colloidal particles.

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6. LIMITATIONS AND STANDARDS: DATA SELECTION AND CALCULATION

6.1. INTRODUCTION

This section describes the data selection and statistical methodology used by the U.S. Environmental Protection Agency (EPA) in calculating the proposed limitations for the Construction and Development (C&D) point source category. As described in this section, the proposed effluent limitations and standards are based on long-term average effluent values and variability factors that account for variation in treatment performance within a particular treatment technology over time. For simplicity, the following discussion refers only to effluent limitations guidelines; however, the discussion also applies to new source standards.

EPA is proposing a daily maximum limitation for turbidity, and Section 6.2 briefly describes the pollutant parameter. Section 6.3 provides an overview of EPA's criteria typically used to select data sets for limitations presented in final rules (*final limitations*). Section 6.4 describes the available discharge data and applies the criteria to select data as the basis of the proposed limitation. Section 6.5 presents procedures for averaging data to obtain daily values used in the limitations calculations. Section 6.6 provides an overview of the limitations, percentile basis, calculations, monitoring, and compliance related to the limitations. Section 6.7 summarizes the steps used to calculate the limitations. Section 6.8 provides references.

EPA also is considering a limitation on pH. Such a limitation would not be developed using the statistical methodology described below. Instead, EPA typically establishes a range of acceptable values from 6 to 9 standard units to protect against extreme acidity or alkalinity.

6.2. TURBIDITY

As described in Section 5, there are a number of pollutants associated with discharges from C&D sites. EPA is proposing effluent limitations for turbidity, which is generally accepted as a good measure of the presence of those pollutants and the quality of the stormwater being discharged from the C&D site. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the sample caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms. See Title 40 of the *Code of Federal Regulations* (CFR) 136.3. The more total particulates in the water, the murkier it becomes and the higher the turbidity measurement.

Turbidity is measured in nephelometric turbidity units (NTU). The instrument used for measuring it is called nephelometer or turbidimeter, which measures the intensity of light scattered at 90 degrees as a beam of light passes through a water sample. For turbidity, the current CFR Part 136[1] approved methods are based on nephelometric equipment: EPA Method 180.1 Rev 2.0 (USEPA 1993); Standard Methods (18^{th}, 19^{th}, 20^{th}, and 21^{st} editions) 2130 B; ASTM D1889-94 (ASTM 1993); and USGS I-3860-85 (USGS 1989). Nephelometers are relatively unaffected by small differences in design parameters, and therefore, are specified as the standard instrument for measuring low turbidities. Turbidimeters of nonstandard design, such as forward-scattering devices, might be more sensitive than nephelometers to the presence of larger particles but have not been generally approved by EPA for wastewater monitoring. Regardless of the measuring equipment used, turbidity should be determined as soon as possible after the sample is collected, because sample preservation is not practical. If storage is required, refrigerate or cool to 4 degrees Celcius (^{o}C) to minimize microbiological decomposition of solids. For best results, measure turbidity without altering the original sample conditions such as temperature or pH. Gently agitate all samples before examination to ensure a representative measurement.

A turbidity measurement may be used to provide an estimation of the total suspended solids (TSS) concentration. Engineering references (e.g., American Society of Civil Engineers (ASCE) and American Water Works Association (AWWA) 2005) cite conversion factors for turbidity to TSS values.

6.3. OVERVIEW OF DATA REVIEW AND CRITERIA

As described in Section 6.4, EPA qualitatively reviewed all the data before selecting a (large) subset to calculate the proposed limitations. For the final rule, in addition to reviewing the data used as the basis for the proposed limitations, EPA also will review data provided by commenters and other sources. As part of this review for the final C&D limitations, EPA intends to reevaluate its exclusions and inclusions of data and seek additional information about the sites used as a basis for the proposed limitations. EPA also intends to apply following criteria in determining if the proposal data and any additional data are appropriate to use as the basis for the final rule. EPA has used these or similar criteria in developing limitations and standards for other industries.

One criterion requires that the influents and effluents from the treatment components represent typical wastewater from the industry, with no incompatible wastewater from other sources (e.g., sanitary wastes). Application of this criterion results in EPA selecting only those facilities or sites where the commingled wastewaters did not result in substantial dilution, more concentrated wastewaters, or wastewaters with different types of pollutants than those generated by C&D wastewater. As part of this criterion, EPA also will consider whether to include concentration data for wastewaters that were recycled for further treatment. For example, some sites may be required to meet stringent water quality limits. If the treatment system does not meet some

[1] EPA publishes laboratory analytical methods that are used by industries and municipalities to analyze the chemical, physical, and biological components of wastewater and other environmental samples that are required by regulations under the authority of the Clean Water Act. All these methods are published as regulations in the *Code of Federal Regulations* (CFR) at Title 40 Part 136.

predetermined value, the treated waters can be recycled through the treatment system one or more additional times to remove more solids before eventual discharge. As the basis for the proposed limitation, EPA has excluded data reported to be during recycling periods. EPA does not consider additional treatment necessary to comply with the *national* limitation, and thus, the data would not be appropriate to use as a basis for the limitation. (However, if a site is subject to local limits or other requirements, then it may be required to perform additional treatment to meet those other requirements.)

A second criterion ensures that the pollutants were present in the influent at sufficient concentrations to evaluate treatment effectiveness. To evaluate whether the data meet this criterion, EPA might consider using a *long-term average test* for sites where EPA possesses paired influent and effluent data. EPA has used such comparisons in developing regulations for other industries (e.g., iron and steel point source category). The test looks at the influent concentrations to ensure that a pollutant is present at sufficient concentration to evaluate treatment effectiveness. If a pollutant fails the test (i.e., was not present at a treatable concentration), EPA excludes the data for that pollutant at that facility from its long-term average and variability calculations. Because the retention time of the treatment system is relatively short, in developing the final rule, EPA also might consider excluding an effluent concentration that corresponds to an influent concentration reported as zero NTU. By applying the long-term average test and/or verifying that influent includes measureable solid content, EPA would ensure that its limitations resulted from treatment and not simply the absence of turbidity in the wastestream. If industry supplies EPA with effluent data but not the corresponding influent data, EPA might choose to use the effluent data, if it is confident that turbidity would have been present at high concentrations at the site. This approach would satisfy EPA's objective of including as much data from as many sites as possible in its calculations.

A third criterion generally requires that the site demonstrate good operation of the model treatment technology. EPA generally determines whether a site meets this criterion on the basis of personal visits, discussions with site management, or comparison to the performance of treatment systems at other sites. EPA often contacts sites to determine whether data submitted were representative of normal operating conditions for the facility and equipment. As a result of this review, EPA typically eliminates facilities that experience repeated operating problems with their treatment systems. EPA also excludes data if the measurements have substantially greater values or more variability than data from other sites. Section 6.6.6 describes a potential application of this criterion.

A fourth criterion typically requires that the data cannot represent periods of treatment upsets or shut-down periods. This criterion sometimes results in the exclusion of periods when the site first starts operating the equipment (*start-up*). As result of this criterion, EPA could exclude certain time periods and other outliers in the data from an otherwise well-operated site.

EPA has not included the size of the site as a criterion, because the site size and water flow determine the size of the treatment system, rather than its performance.

6.4. DATA SELECTED AS BASIS FOR PROPOSED LIMITATIONS

The proposed long-term averages, variability factors, and limitations are based on data provided by three sources. The following sections describe the data sources, summarize the data submitted by the three sources, and present the results of EPA's data review.

6.4.1. DATA SOURCES

EPA evaluated more than 6,600 turbidity measurements in determining the basis for the proposed limitation. The data were from 19 treatment systems at 17 sites in three states. The data were provided by two vendors (Clear Creek Systems, Inc., and Cascade EcoSolutions) and a state environmental agency (Oregon Department of Environmental Quality [ODEQ]). Table 6-1 identifies the data sources, the site name or location, and the abbreviations used to identify the sites throughout Section 6 and the data listings in Appendix G. For two sites, 4 and WLCPO, each with two treatment systems, the abbreviation is appended with *SYS1* or *SYS2* to distinguish between the systems.

Table 6-1. Data Sources and Site Identification

Source	Site name or location	Abbreviation
Clear Creek Systems, Inc.	California, Oregon, and Washington	2
		3
		4
		6
		8
		11
		BZR08
		SC05
		SC08
Cascade EcoSolutions	Beacon Hill Reservoir Burying Project	BHRBP
	Brightwater Waste Water Treatment Plant	BWWTP
	WSDOT SR-522 Road Improvement Project (Elliot Road)	ELLRD
	Lakeside	LSIDE
	Seatac Airport	SEAAIR
	Sound Transit Central Link Light Rail	STCLLR
Oregon Department of Environmental Quality	West Linn Corporate Park	WLCPO
	Hoodview Estates	HEO

6.4.1.1. Clear Creek Systems, Inc.

Clear Creek Systems, Inc., is a vendor that designs, installs, and monitors treatment systems for stormwater and construction runoff. The vendor provided influent and effluent measurements from nine sites in three western states: California, Oregon, and Washington. The influent measurements were taken from the stormwater running off the construction site before being treated. The effluent measurements are from the stormwater treated with EPA's model technology. (Gannon 2008a, 2008b, 2008c, 2008d). The vendor did not provide any additional information about the sites (e.g., exact location, site size, typical rainfall). It identified the sites as

2, 3, 4, 6, 8, 11, BZR08, SC05, and SC08. Site 4 had two treatment systems and EPA analyzed the data separately for each system as explained in Section 6.5.2.

6.4.1.2. Cascade EcoSolutions

A second vendor, Cascade EcoSolutions, provided data for six sites in Washington State. The vendor provides the chitosan-based flocculants used by service providers to treat turbid stormwater.

For three sites, the vendor provided turbidity measurements via a ChitoVan Performance Review Data Set (Cascade EcoSolutions 2008) without specific details about the treatment and sites. It identifies the three sites as Beacon Hill Reservoir Burying Project, Brightwater Waste Water Treatment Plant, and Sound Transit Central Link Light Rail. All three are in the Seattle, Washington, area.

For the other three sites, the vendor provides detailed information about the treatment and sites in an engineering report (Minton 2006). The vendor provided a separate Engineering Report Data file (Cascade EcoSolutions 2008) corresponding to the three sites described in the report. The specifications with regard to effluent quality for the three sites are to "achieve performance goals of a minimum of 95% reduction of NTU turbidity, a maximum discharge of 10 NTU turbidity, and a discharge pH within a range of 6.5–8.5. If these values are exceeded at any time the responsible site operating personnel shall immediately take appropriate corrective actions" (Minton 2006 page 26). When the data did not meet the specifications, they were automatically recycled. Pages 9 to 11 of the report describes the treatment system in more detail:

> Chitosan-Enhanced Sand Filtration is a stand-alone treatment technology for stormwater from construction sites. Chitosan acetate coagulates fine suspended sediments, producing larger particles, enhancing their retention by the treatment system. . . .
>
> Stormwater is initially retained in a holding basin, which serves two functions. It provides pretreatment by one and possible two modes. The common pretreatment mode is simple gravity settling of sediment entering with the untreated stormwater.
>
> **System components**
>
> The second pretreatment mode is the addition of chitosan acetate as the stormwater enters the basin. This is done only if the incoming stormwater is extremely turbid, in excess of 600 NTU and if all source control measures have been found incapable of reducing the turbidity below that value. The second function is to equalize the flow rate. Moderating the incoming flow allows the CESF-FT to operate at an essentially constant flow rate.
>
> The filters are periodically backwashed automatically to remove filtered sediment from each pod to maintain the hydraulic capacity of the sand. This feature allows the treatment system to operate on a continuous flow-through basis. As shown in Figure 1 [not reproduced in this document], the system typically has four filter

pods. The system is equipped with automated sensors for turbidity and pH. If the discharge requirements are not met for either, the treated stormwater is recycled to the holding basin, to receive treatment again. Chitosan acetate is added immediately before the filters.

The CESF-FT consists of these components.

Stormwater holding basin(s): Alternatively called the detention/pretreatment basin, these may be either temporary or an element of the permanent drainage system (i.e., detention basin), and may be either ponds or mobile storage tanks.

Pretreatment: Axiomatic to the treatment system is good site erosion control. The objective is to keep the turbidity of the untreated stormwater less than 600 NTU. When the turbidity of the stormwater entering the holding basin exceeds this value, chitosan acetate is added as the stormwater enters the basin or a pretreatment tank that follows the basin. The latter has been the more common practice. The pretreated water then enters the basin or tank where the coagulated sediment settles.

Influent pump: Stormwater is pumped from the holding basin to the filter units.

Liqui-Floc injection system: Consists of the following: precision, variable output metering pump, feed and suction tubing, Liqui-Floc product storage container.

Discharge piping or structure: Site and flow rate specific.

Sand filtration units: Various sizes and capacities are shown in Table 1 (NSS, 2004b). The sand size specification (NSS, 2004b) is presented in Table 2, consistent with Ecology (2003b, 2004) requirements. The filters are operated in the range of 5 to 10 GPM/ft^2 of media. Eighteen (18) inches of sand is used.

Backwash system: The sand filters are periodically backwashed to retain their hydraulic capacity. The frequency of backwashing is controlled by a timing mechanism, causing backwashing to occur on a regulator schedule. The control system also contains a default value for pressure loss through the filter. If the default value is reached before the preset time has passed, backwashing occurs. This commonly indicates a need to inspection and possibly maintenance of the filters.

Backwash holding tank: The dirty backwash water does not directly enter the holding basin. Rather, it first enters either a small cell located in the holding basin (separated from the remainder of the basin by a silt curtain) or a separate tank. This keeps most of the filtered sediment from entering the larger basin.

Influent and effluent turbidity and pH monitoring units: These meters continuously sample the influent and effluent, and directly control the recycle valve. Data are stored.

Recycle system: If either the effluent turbidity or pH meter indicates that the quality of the effluent has strayed outside the specified discharge requirements, a value automatically shifts to recycle the stormwater back to the holding basin. Action is then taken to redress the cause.

The report also provides a detailed description of the three sites:

Lakeside Housing Development ("LSIDE")

The project was located immediately east of NE 65th and 188th Lane NE. in Redmond. Stormwater from the site normally drains east to a natural wetland, then to Evans Creek. However, because of the sensitive nature of Evans Creek, all treated stormwater generated during the construction period was pumped to the SR 202 stormwater drainage system, which discharges directly to Lake Sammamish. The CESF-FT facility at the Lakeside Housing Project did not require pretreatment. . . . .

All stormwater runoff from disturbed portions of the site was directed, via open channels and storm drains, to the stormwater holding basin, which has a capacity of approximately 1 million gallons. Treated water from the CESF-FT facility was directed to two treated water holding tanks so that the water could be tested prior to discharge.

Chitosan (1% solution of chitosan acetate) was injected into a 6-inch pipe about 50-feet upstream of the sand filter at 0.3 to 0.8 milligrams per liter (mg/L), varying with the turbidity of the water. The dose rate of chitosan was calibrated by timing the uptake of chitosan (through the metering pump) from a graduated cylinder and noting the flow rate of water from the sand filter. (Page 13 Cascade EcoSolutions 2008)

SeaTac International Airport Third Runway ("SEAAIR"):

Over 14 million cubic yards of fill dirt are being brought to the west side of Sea-Tac International Airport to form the foundation for the new runway, distributed on 150 acres. There are seven individual CESF-FT units placed at four separate locations, each with holding basins. Their combined capacity is 3,500 GPM. Stormwater can be pumped between ponds to maximize the use of the total capacity of the units. Discharge is to Miller Creek.

Stormwater runoff commonly enters the holding basins at a turbidity level above 1,000 NTU, sometimes as high as 3,000 NTU. The Conditional Use Designation document (Ecology, 2004) limits the chitosan acetate dose rate to 1 mg/L. The contractor was able to keep the dosage within 1 mg/L, despite the high turbidity, by splitting usage between pretreatment and treatment before the filters. At this site, pretreatment occurred in a pretreatment tank immediately following the holding basin, not in the holding basin. (Page 14 Cascade EcoSolutions 2008)

The recycle volume for Unit 4 at the SeaTac Airport site ranged from 17 to 27% during the first three months of operation (December 2004 through February

2005). The startup of the Airport site was complex because of the number of systems involved, the short time frame within which the systems had to be installed, and the occurrence of an extreme storm event that nearly exceeded the total capacity of the treatment systems. The most serious mechanical problem was due to the internal corrosion of the chitosan storage tanks, which caused small pieces of corrosion debris to clog the chitosan metering pumps stopping the flow of the treatment agent. When the chitosan stopped flowing the treatment failed and the systems went into recycle mode while operators dismantled and cleaned the metering pumps. This problem was repeated frequently until the chitosan storage tanks were replaced with non-corrosive tanks. Once this problem was corrected the systems ran as designed and no further problems were encountered. (Pages 30-31 Cascade EcoSolutions 2008)

WSDOT SR-522 Road Improvement Project (Elliot Road, "ELLRD"):

The Washington Department of Transportation (WSDOT) is widening SR-522 between the Echo Lake Road and a bridge across the Snohomish River. The project site is about 125 acres: Discharge is to the Snohomish River. . . . Two 500 GPM units were deployed, one each at the Echo Lake interchange and at Elliott Road just south of the bridge over the Snohomish River.

Turbidity levels of incoming stormwater varied significantly, less than 60 NTU to greater than 1,400 NTU. High turbidities were due to the frequent blasting of shale on the project site. Therefore, chitosan acetate was added to the high-turbidity stormwater immediately prior to the holding basin. It was effective, typically reducing the turbidity in the basin to less than 60 NTU. Ecology (2003b, 2004) limits the dose rate to 1 mg/L. A variance was requested for this site, allowing an aggregate dosage of 3 mg/L, but with 1 mg/L remaining as the immediate dosage before the filters. In practice, about 2.5 mg/L was used in pretreatment when required, added as the runoff entered the basin, and 0.5 mg/L was used immediately prior to the sand filters.

Disturbance of the sedimentary shale rock created a high pH (as high as 9.6) in dewatered groundwater and stormwater. Liquid carbon dioxide was added at the pretreatment station to control pH as it entered the basin. Another adverse condition was extensive algal blooms occurring in the basin. The atypical growth of algae increased the pH of the stored stormwater, necessitating the placement of carbon dioxide as dry ice in the basin. The algae growth was the result of a combination of low turbidity (with pretreatment), sunlight penetration, and elevated phosphorus concentrations. The latter was believed due blasting explosives. The treatment system removed the algae from the water without damage to the filters. (Pages 16-17 Cascade EcoSolutions 2008)

The SR522 site reflected what may be the most extreme site conditions that the CESF-FT system will experience. Difficulties were faced throughout the treatment period, not just during startup.

- The pH varied from 6.5 to 9.5 based due to the nature of site work and algal production in the holding basin.
- The turbidity varied rapidly from nearly clean to above several thousands NTU.
- The volume of water occasionally exceeded the system's capacity, particularly when the turbidity was very high. Pretreatment became a critical factor.

The considerably higher recycle times on the WSDOT SR522 project reflect the fact that this difficult site required times where the system was intentionally put into recycle while dosing with chitosan in an effort to reduce the turbidity of the holding basin before treatment. Because of the nature of the project (linear highway project) there were times when the turbidity rose to thousands of NTU without warning. During these times the only way to reduce the turbidity was to recycle the water while adding chitosan.

The Consultant noted during the field visit that while there is a flow meter on the discharge line, the data are not recorded. There is therefore no direct record that recycle occurs each time the discharge limits are not met. Rather, it is presumed that it occurs based on the records of the turbidity and pH, measured immediately in the discharge of the filter system, and the activation of the alarm system. The above calculations were made through the examination of the record on turbidity and pH. Where either or both parameters were outside the discharge specifications, it was presumed that recycle occurred. Since recycle occurs automatically, it can only be presumed that the recycle valve functioned satisfactorily in all instances. For this reason, the Consultant has recommended that the discharge flow be recorded (Page 31 Cascade EcoSolutions 2008).

Additional information about SeaTac and ELLRD:[2]

If a pH or turbidity excursion causes the system cause to go into recycle, the operator measures the parameters to determine which is out of compliance. If the pH is too low, the system is kept in recycle while food-grade sodium bicarbonate is added. If the holding pond is large, this may require shutting down the system, and mixing water in the pond with pumps until the desired pH is achieved. The system is restarted in recycle mode. Once the pH is within acceptable limits the system is put back on line. If the pH is too high, dry ice is hand broadcast into the holding pond until the pH is acceptable. If high pH continues (e.g. extensive concrete pouring), an automated liquid carbon dioxide injection system may be installed. This system reads the incoming and outgoing pH, and automatically adjusts the rate of carbon dioxide injection. Such a system was installed for a period of time on the WSDOT SR522 project due to the high pH caused by the disturbance of alkaline sedimentary shale material by construction.

[2] Page 23 notes that turbidity and pH were not monitored continuously at the Lakeside site.

If the turbidity exceeds the preset limits, one of three adjustments are made: increasing the chitosan dose in a pretreatment settling tank, reducing the flow rate of the system to allow more settling time, or more extensive treatment. If, for example, the holding pond suddenly experiences a significant increase in turbidity due to site work or heavy precipitation, the common adjustment is to continue in the recycle mode while additional chitosan is added to the stormwater as it enters the basin. If this approach is not adequate due to extreme turbidity the system is shut down, pumps recirculate the entire holding pond contents while adding chitosan to reduce the turbidity to levels consistent with filtration (<500 NTU). If this approach is necessary, Department of Ecology and the project contractor are contacted. A plan is developed consistent with Ecology's regulations and project needs. Typically a quantity of additional chitosan is estimated based on jar testing; that quantity is added while recirculating (mixing) the holding pond with pumps. Once the turbidity has been reduced to acceptable levels the system is restarted in the recycle mode until it has been determined that the effluent turbidity limits can be met. Once this occurs the system is put back on line. Normally, the holding pond is tested for residual chitosan to ensure there is no excess chitosan present. The actions are documented in a report, summarizing the cause of the problem and the methods used to bring the system back into compliance. (Page 21 Cascade EcoSolutions 2008).

6.4.1.3. Oregon Department of Environmental Quality

ODEQ was the source for two other sites: the West Linn Corporate Park and Hoodview Estates. Both are in Oregon. The West Linn Corporate Park has two treatment systems, and EPA analyzed the data separately for each system as explained in Section 6.5.2. The ODEQ Web site (Jurries no date) describes each site:

West Linn Corporate Park ("WLCPO"):

Approximately 24.0 acres of land on slope with minimal overburden on bedrock drained to the Blankenship Road roadside ditch. This ditch then drained into a 48" diameter pipe drain that discharged the storm water into the I-205 roadside drainage ditch at the end of 13th Street, where it terminated in a cul-de-sac next to the I-205 freeway. Sandbags in the end of the 48" diameter pipe prevented the turbid storm water from discharging into the roadside ditch. Two pumps in parallel picked up the storm water and delivered it to the first Frac tank for the addition and mixing of the flocculant. Sumalchlor 50, manufactured by Summit Research Labs, was the flocculant selected due to its relative ability to be pH insensitive and showed rapid settling in lab tests. Sumalchlor-50 is an inorganic coagulant with a short residence life in the water being treated and the aluminum compounds will quickly hydrolyze to form inert aluminum hydroxide…

A 1 year, 24 hour storm with a total rainfall of 1" was the design storm event for this system. A review of PDX rainfall data for March through June, 1992-1996, found that of the 610 days in these months, only twice was there more than 1" of rainfall in 24 hours. This storm generated a peak-anticipated flow of 1.28 cfs (575 gallons per minute) at the outfall of the 48" pipe. Utilization of the 48" pipe as a

detention pipe allowed the peak pumping requirements to be approximately 300 gpm without overflowing the sandbags.

The first Frac tank was the place where coagulation and flocculation took place. The prescribed amount of the flocculant was injected and mixed the water for a set time in a 17,000-gallon Frac tank. This system was controlled by input volume and had the capacity to mix and treat approximately 500 gpm.

Pumps were used to evacuate the mixed storm water and distribute it to the settling tanks. The extraction system at 450 gpm was designed to exceed the input capability.

Two baffled 17,000-gallon Frac tanks, which received the water from the mixing tank were used for settling. These tanks allowed soil particles to settle and clean water to discharge via gravity from a four-inch outlet, located approximately four and one-half feet above the bottom of the tank. The discharge was piped into the adjoining stream. Discharge sampling was conducted at this point.

Hoodview Estates ("HEO"):

In 2000, another similar system was installed on the Hoodview Estates [emphasis added] site off SW Salamo Road in West Linn. This system used only a single tank for adding and mixing the flocculant. The underground water quality detention tank was used for upstream detention and a pond was used for settling after the tank. The discharge from the pond was to a stream, which discharged into Tanner Creek.

6.4.2. SUMMARY OF DATA SUBMITTED FOR REVIEW

Table 6-2 provides a summary of the reported turbidity measurements in effluent from the 19 systems at the 17 sites. EPA received more than 6,600 measurements of turbidity, and they are provided in Listing 1 of Appendix G. (DCN 45054 provides the data in an electronic spreadsheet file.)

As a first step in developing a database for further review, EPA excluded data points that appeared to be typographical errors or reported in an unusual format. These values were not included in any summaries or listings in this technical development document. The vendor has resolved most of the discrepancies (Gannon 2008d), and EPA will incorporate his corrections during its data review for the final limitations. In particular, EPA excluded the following:

- Typographical errors:
  - Site 4 (System #2): ".3.4" (1/9/2005)
  - Site 11: ".6.87" (12/29/2004). (According to the vendor, the value should be 6.87.)

- Data with unusual formats were excluded. This format resulted in some cells in the spreadsheet having more than one measurement. The vendor states that EPA should use the first number and delete the one after the slash:
  - Site 2: ".88/6.5" (1/6-7/2005), "1.76/6" (1/8/2005).
  - Site 11: 104 effluent measurements specified as two numbers separated by a slash, such as "1.52/.86". These types of measurements were most prevalent on the following dates: 1/21/2005, 2/17/2005, and 2/19/2005 through 3/3/2005.

EPA then examined the remaining reported values. As shown in the summary in Table 6-2, there were 6,537 measurements ranging from a reported value of zero (at several systems) to 1,936 NTU (at Site 2). The arithmetic averages at each system ranged from 0.46 (SC05) to 21.38 NTU (HEO).

Table 6-2. Summary of Reported Turbidity Measurements (NTU) in Effluent

Site/System	Number of measurements	Arithmetic average	Standard deviation	Minimum	Median	Maximum
2	1,067	4.85	60.29	0.2	1.62	1,936
3	106	1.93	3.45	0	0.96	26
4_SYS1	87	2.05	4.28	0.08	0.69	23
4_SYS2	82	2.92	6.26	0.17	0.94	40
6	66	4.72	9.24	0.1	1.96	46.5
8	99	12.15	13.21	0.37	8.44	71.6
11	411	4.09	6.94	0	1.36	38.7
BHRBP	493	1.17	1.53	0	0.6	9.2
BWWTP	104	1.87	0.81	0	1.9	6
BZR08	38	1.11	1.07	0.21	0.83	6.5
ELLRD	2,081	6.90	13.13	0.13	3.42	164.06
HEO	3	21.38	6.44	13.95	25	25.2
LSIDE	714	3.07	0.98	0.76	3.17	5.18
SC05	30	0.46	0.34	0.03	0.34	1.85
SC08	124	1.19	1.26	0.033	0.71	7.3
SEAAIR	813	3.62	8.24	0.37	1.32	93.66
STCLLR	203	0.66	0.71	0	0.5	5.7
WLCPO_SYS1	9	19.48	12.22	4.9	19.5	36.1
WLCPO_SYS2	7	14.66	10.08	1	19.87	24.5
ALL	6,537	4.58	25.88	0	1.93	1,936

In addition to the effluent measurements, Listing 1 in Appendix G provides influent measurements for reference and comparison purposes. Also, as explained in Section 6.3, EPA might consider the influent concentrations for each system in selecting data sets for the final rule. The influent values are measurements of the stormwater running before treatment. By comparing the influent and effluent values, EPA can evaluate the effectiveness of that treatment system. In creating a summary of the listing in Table 6-3, EPA incorporated the following changes:

- Influent measurements of "1000+" (Sites 6 and SC08) and "over 1000" (Site 8) were set equal to 1,000.

- An influent measurement of "44.6.5" (Site 4) was set equal to 44.6.
- Influent measurements of "90-10" (Site 4 on 1/17/2005) and "246/306" (Site BZR08 on 1/25/2008) were excluded.
- Influent measurements reported as zero NTU were excluded. For the final rule, EPA also might consider excluding the effluent values associated with zero NTU concentrations in the influent.

Influent values of 99.9 NTU were left unchanged, but they indicate a maximum reading on the turbidity meter, and thus, the concentrations are likely to have been greater than 100 NTU.

Table 6-3. Summary of Reported Turbidity Measurements (NTU) in Influent

Site/System	Number of measurements	Arithmetic average	Standard deviation	Minimum	Median	Maximum
2	24	2,720.9	1,329.7	853	2,124	4,816
3	37	130.0	109.8	6.6	99.9	381
4_SYS1	22	409.4	269.0	10.2	452.5	985
4_SYS2	22	409.4	269.0	10.2	452.5	985
6	12	549.4	234.4	209	516.5	1,000
8	15	586.2	326.8	204	473	1,000
11	65	159.9	147.8	1.08	142	1,020
BHRBP	490	50.0	71.0	0.3	32.9	709.9
BWWTP	104	113.6	57.4	2.7	135.3	284
BZR08	7	330.4	94.6	149	348	420
ELLRD	1,730	42.1	37.5	1.82	33.2	182.77
HEO	3	604.0	121.7	466	650	696
LSIDE	714	253.1	139.3	44	223.5	917
SC05	6	255.5	51.9	210	230.5	331
SC08	62	767.8	201.0	234	742	1,536
SEAAIR	335	104.7	30.7	24.51	107.14	201.44
STCLLR	196	66.0	46.6	4.7	57.3	293.9
WLCPO_SYS1	9	194.5	131.2	78.1	136.1	472
WLCPO_SYS2	9	194.5	131.2	78.1	136.1	472
ALL	3,862	131.7	276.3	0.3	63.6	4,816

6.4.3. DATA REVIEW AND EXCLUSIONS

This section describes EPA's review of the data, identifies data issues, and explains the rationale for excluding certain data points from the limitations calculations. EPA focused its review on the performance and operating conditions of the treatment systems. By applying the criteria described in Section 6.3, EPA excluded values from eight systems that may not represent typical wastewater from the industry, did not demonstrate good operation of the technology, or were the result of upsets (criteria 1, 3 and 4).

EPA considers recycled wastewater to differ from typical influents from this industry (criterion 1). As a consequence, EPA excluded effluent data reported to be during recycle modes:

- 350 effluent measurements from *Site ELLRD*. These types of measurements were most prevalent on the following dates: 5/20/2005, 5/21/2005, and 5/23/2005 through 5/27/2005.
- 62 effluent measurements from *Site SEAAIR*. These types of measurements were most prevalent on the following dates: 4/1/2005 and 4/16/2005.

For the final rule, EPA will reevaluate its assumption for values reported as zero. If the values indicate measurements below detection, EPA may use one of the alternative statistical methods described in Appendix I to model the mixture of detected and non-detected measurements. For the proposal, EPA considered zero values to be associated with shutdown periods (criterion 4), and thus, excluded:

- Four zero values from *Site 3* on 1/1/2005. The next lowest measurement at this site was 0.04 NTU on 1/3/2005.
- One zero value from *Site 11* on 2/17/2005. The next lowest measurement at this site was 0.21 NTU on 1/22/2005.
- 85 zero values from *Site BHRBP*. The next lowest measurement at this site was 0.2 NTU.
- Seven zero values from *Site BWWTP*. The next lowest measurement at this site was 0.6 NTU on 3/2/2007.
- 22 zero values from *Site STCLLR*. The next lowest measurement at this site was 0.1 NTU.

EPA considers extreme values to be associated with treatment upset (criterion 4) or less than optimal treatment (criterion 3), and thus excluded three values from *Site 2*:

- 1,936 NTU on 11/9/2004. EPA retained the other five measurements reported on this day that all had values less than 17 NTU.
- 355 NTU on 1/29-30/2005. EPA retained the other six measurements reported for this time period that all had values less than 4 NTU.
- 87 NTU on 4/1/2005 that was the only measurement reported for the day. It was over three times higher than the next highest measurement (26.4 NTU on 11/8/2004) at the site.

In calculating the proposed limitations, EPA retained the following data measurements that appeared to be questionable. EPA intends to reevaluate their inclusions and/or correct the values before calculating the final limitations:

- Site 2: Several entries on 3/23/2005 are single integers and "5" is repeated seven times. Other measurements for this site generally were reported with one or more decimal places, not integer values. (According to the vendor, the values are in error.

Because the dataset also include the corrected values, EPA will exclude the integer values during its data review for the final rule.)

- Site SC08: The value on 2/13/2008 appears as "0.033" (The vendor confirmed that the correct value is "0.33" NTU.)

Table 6-4 summarizes the data after EPA's review and exclusions. These data were used as the basis of the proposed limitations, the other tables in Section 6, and Listing 2 in Appendix G. (DCN 45054 provides the data in an electronic spreadsheet file.) From the original set of more than 6,600 measurements, EPA retained 6,003 measurements after incorporating the data exclusions described in this section and Section 6.4.2. The 6,003 data values range from 0.033 (Site SC08) to 71.6 (Site 8). The arithmetic average is 2.87.

Table 6-4. Summary of Reported Turbidity Measurements (NTU) in Effluent (After All Reviews)

Site/System	Number of measurements	Arithmetic average	Standard deviation	Minimum	Median	Maximum
2	1,064	2.63	3.15	0.2	1.61	26.4
3	102	2.00	3.50	0.04	1	26
4_SYS1	87	2.05	4.28	0.08	0.69	23
4_SYS2	82	2.92	6.26	0.17	0.94	40
6	66	4.72	9.24	0.1	1.96	46.5
8	99	12.15	13.21	0.37	8.44	71.6
11	410	4.10	6.94	0.21	1.36	38.7
BHRBP	408	1.42	1.58	0.2	0.8	9.2
BWWTP	97	2.00	0.66	0.6	1.9	6
BZR08	38	1.11	1.07	0.21	0.83	6.5
ELLRD	1,731	3.26	2.41	0.13	2.78	9.99
HEO	3	21.38	6.44	13.95	25	25.2
LSIDE	714	3.07	0.98	0.76	3.17	5.18
SC05	30	0.46	0.34	0.03	0.34	1.85
SC08	124	1.19	1.26	0.033	0.71	7.3
SEAAIR	751	1.76	1.67	0.37	1.24	9.49
STCLLR	181	0.74	0.71	0.1	0.6	5.7
WLCPO_SYS1	9	19.48	12.22	4.90	19.5	36.1
WLCPO_SYS2	7	14.66	10.08	1	19.87	24.5
ALL	6,003	2.87	3.93	0.033	1.8	71.6

6.5. DATA AVERAGING PRIOR TO LIMITATION CALCULATIONS

The proposed limitations for turbidity, as presented in today's notice, are provided as the maximum daily discharge limitation. Definitions provided in 40 CFR 122.2 state that the "maximum daily discharge limitation" is the "highest allowable *daily discharge*." "Daily discharge" is defined as the 'discharge of a pollutant' measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling.

The data sources sometimes provided more than one measurement for a single day from a treatment system. To obtain data that are appropriate for calculating limitations, EPA generally averages the data to obtain a single value for each day at the treatment system. This section describes EPA's conventions for using multiple measurements at each treatment (Section 6.5.1), from multiple systems at a single site (Section 6.5.2), and field duplicates (Section 6.5.3).

6.5.1. DAILY VALUES FOR EACH TREATMENT SYSTEM

To be consistent with the daily discharge definition, EPA arithmetically averaged all measurements (i.e., 6,003 from Table 6-4) recorded for each uniquely reported time period (e.g., 12/21/2004, 12/21-22/2004) from each treatment system before calculating the proposed limitations. EPA refers to this averaged value as the *daily value*. When the date was reported as a range of consecutive dates (e.g., 12/21-22/2004), EPA assumed that the data had been reported for a single 24-hour period and calculated a single daily value for the range. In this example, the site would have two daily values for an overlapping period: one value for 12/21/2004 and another for 12/21–22/2004. EPA might modify this approach for the final rule so that no values are associated with overlapping time periods.

Listing 2 of Appendix G identified the 466 daily values obtained from arithmetically averaging the 6,003 values summarized in Table 6-4. Table 6-5 provides a summary of the daily values. From the 19 treatment systems at the 17 sites, EPA observed a minimum daily value of 0.08 (Site 4, system #1) to a maximum of 38.75 NTU (Site 8).

Table 6-5. Summary of Daily Values of Turbidity (NTU) in Effluent

Site/System	Number of daily values	Arithmetic average	Standard deviation	Minimum	Median	Maximum
2	131	2.77	2.80	0.35	1.91	15.78
3	21	1.75	1.96	0.45	1.00	7.63
4_SYS1	19	2.80	5.39	0.08	0.77	23.00
4_SYS2	19	4.03	7.56	0.46	1.23	33.20
6	18	4.00	7.19	0.38	2.29	32.25
8	18	12.24	12.67	0.40	7.87	38.75
11	42	3.74	4.52	0.55	2.14	23.21
BHRBP	23	1.52	1.37	0.33	1.13	6.28
BWWTP	8	2.05	0.89	0.90	1.94	3.97
BZR08	9	1.26	0.50	0.57	1.10	2.21
ELLRD	19	3.37	1.02	1.76	3.24	5.23
HEO	3	21.38	6.44	13.95	25.00	25.20
LSIDE	75	3.02	0.79	1.16	3.10	4.82
SC05	6	0.42	0.13	0.30	0.41	0.61
SC08	13	1.25	0.74	0.65	1.08	3.34
SEAAIR	9	1.73	0.67	0.52	1.83	2.51
STCLLR	17	0.88	0.59	0.42	0.64	2.17
WLCPO_SYS1	9	19.48	12.22	4.90	19.50	36.10
WLCPO_SYS2	7	14.66	10.08	1.00	19.87	24.50
ALL	466	3.70	5.72	0.08	2.07	38.75

6.5.2. MULTIPLE TREATMENT SYSTEMS

While the other sites had data for a single treatment system, Site 4 and Site WLCPO each had two different treatment systems (or *lines*). In calculating the proposed limitations, EPA analyzed the data from each treatment system separately. This is consistent with EPA's practice for other industrial categories. As a consequence of EPA's review of the data for the final rule, EPA might continue to consider each treatment system separately, or might determine that the measurements at the two treatment systems should be averaged for each day to produce one value for each site. For the final rule, EPA also intends to consider the vendor's recommendation of selecting the maximum value from the reported measurements for the multiple lines during the same time period (Gannon 2008d). One consideration will be the impact on variability estimates. For example, it is possible that selecting the maximum value would decrease the variability estimates such that they might not represent typical operations.

For sites with flow values corresponding to the individual measurements, EPA also might consider flow-weighting the two treatment systems in calculating the daily average to give more weight to the larger system to better represent the site conditions.

The following example calculates a flow-weighted value for Day 1 at Site X with two treatment systems. The data are as follows:

Day	Treatment system (i)	Concentration (NTU)	Flow (gpm)
1	1	10	1
1	2	0.1	100

The flow-weighted value for Day 1 is then calculated as follows:

$$Day\,1\,Value = \frac{\sum_{i=1}^{2} concentration_i \times flow_i}{\sum_{i=1}^{2} flow_i} = \frac{(10\ NTU \times 1\ gpm) + (0.1\ NTU \times 100\ gpm)}{1\ gpm + 100\ gpm} = 0.198\ NTU$$

The resulting flow-weighted daily value is equal to 0.198 NTU. If EPA instead had selected the maximum value, the daily value of 10 NTU would have been selected from the stream with a relatively small portion of the site's discharges. Alternatively, if EPA had selected an arithmetic average without regard to the disparity in flows, the daily value would have been 5.05 NTU, a turbidity level that is 50 times greater than the vast majority of the site's discharge. In contrast, the flow-weighted value might better portray the overall discharge from the site by accounting for the relative impact of each stormwater stream.

6.5.3. FIELD DUPLICATES

Although the measurements used for the proposed limitations did not include any field duplicates, EPA realizes that industry may provide such measurements for EPA's consideration

for the final rule. Field duplicates are two samples collected for the same sampling point at approximately the same time, flagged as duplicates for a single sample point, and measured separately. Because the analytical data from each duplicate pair characterize the same conditions at that time at a single sampling point, EPA typically averages the data to obtain one data value for those conditions.

6.6. LIMITATIONS

The proposed limitations for turbidity, as presented in today's notice, are provided as the maximum daily discharge limitation. This section describes the statistical percentile basis of the limitation (Section 6.6.1), the concepts and calculations for the long-term average and the variability factor (Sections 6.6.2 and 6.6.3), calculation for the limitation (Section 6.6.4), engineering review of the results (Section 6.6.5), importance of comments in determining the value of the final limitation (Section 6.6.6), monitoring considerations (Section 6.6.7), and compliance with the final limitations (Section 6.5.8).

6.6.1. STATISTICAL PERCENTILE BASIS FOR LIMITATIONS

The daily maximum limitation is an estimate of the 99th percentile of the distribution of the daily measurements. EPA calculates the daily maximum limitation on the basis of a percentile chosen with the intention, on one hand, to accommodate reasonably anticipated variability within the control of the site and, on the other hand, to reflect a level of performance consistent with the Clean Water Act requirement that these effluent limitations be based on well-operated and maintained facilities. The percentile for the daily maximum limitation is estimated using the product of the long-term average and the variability factor. For the proposed rule, EPA estimated the long-term average and variability factor using a statistical model based on the lognormal distribution as described in Appendix H. (Appendix I describes other distributions and models that EPA might consider for the final regulations.) EPA estimates the percentile for the daily maximum limitation using the product of the long-term average and the variability factor.

6.6.2. LONG-TERM AVERAGE

In the first of two steps in estimating the different types of limitations, EPA determines an average performance level (the *long-term average*) that a site with well-designed and operated model technologies (which reflect the appropriate level of control) is capable of achieving. This long-term average is calculated from the data from the sites using the model technology. The proposed long-term average of 2.77 NTU is the median value of 19 long-term averages collected from the 19 treatment systems at 17 sites. The long-term averages ranged from a minimum of 0.43 NTU (Site SC05) to a maximum of 21.86 NTU (Site HEO). The median is the midpoint of the 19 values, and thus, nine of the system-specific averages are above the proposed long-term average and nine are below, as shown in Table 6-6. EPA expects that all sites subject to the limitations will design and operate their treatment systems to achieve the long-term average performance level on a consistent basis because sites with well-designed and operated model technologies have demonstrated that this can be done.

Table 6-6. System-Specific Long-Term Averages Used in Limitation Calculations

Site/System	Long-term average (NTU)	Rank (smallest = 1)
2	2.77	10 (Median)
3	1.65	6
4_SYS1	2.54	9
4_SYS2	3.44	13
6	3.58	14
8	17.93	16
11	3.59	15
BHRBP	1.50	5
BWWTP	2.07	8
BZR08	1.27	4
ELLRD	3.39	12
HEO	21.86	19
LSIDE	3.04	11
SC05	0.43	1
SC08	1.25	3
SEAAIR	1.80	7
STCLLR	0.87	2
WLCPO_SYS1	20.94	18
WLCPO_SYS2	19.99	17
Median	2.77	

In its evaluation of the long-term average, EPA also considered a separate data submission with the average, minimum, and maximum values observed at 17 sites (see Clear Creek Systems, Inc., 2008 data files *Data from Some Sites 2005-06 Season* and *Chitosan Treatment Results 2005* DCN 43003). Clear Creek Systems provided these summary data (*summary data set*) in addition to a data set with individual measurements described in Section 6.4.1.1. From the available information, EPA was not able to tell if any sites were reported in both data sets. Although some sites have the same identifiers, the summary statistics (e.g., average) are not the same. The summary data set identifies the sites by number: 1, 2, …, 11, with what appears to be two sets of 1, 2, …, 6. Because the two sets appear to differ, Table 6-7 distinguishes between them by assigning different identifiers, A, B, …, F, to the second set. As shown in Table 6-7, the values in the summary data set ranged from a minimum of 0.02 NTU (Site 9) to a maximum of 84 NTU (Site F). The averages reported for each site ranged from 1.5 NTU (Site C) to 12.15 NTU (Site 8). Ten sites had larger average values than the long-term average basis for the limitation. Because most sites had maximum values indicating extreme discharges, which do not reflect proper operation of the model technology, EPA expects that the averages without the extreme discharges would be much closer in value to the long-term average basis for the limitation.

Table 6-7. Summary Statistics Used to Evaluate Long-Term Average

Site	Reported summary statistics (NTU)		
	Average	**Minimum**	**Maximum**
1	1.9	0.1	26
2	4.85	0.2	26.4
3	1.93	0.04	26
4	2.49	0.08	40
5	3.14	0.89	16.9
6	4.72	0.1	46.5
7	5.45	0.08	56.4
8	12.15	0.37	71.6
9	2.01	0.02	68
10	4.5	0.13	59.5
11	4.09	0.21	38.7
A	2.5	0.2	37
B	2.8	0.1	72.2
C	1.5	0.4	51.4
D	4.8	0.4	20
E	5.4	0.2	41
F	2.5	0.1	84

6.6.3. VARIABILITY FACTOR

EPA acknowledges that variability around the long-term average results from normal operations. This variability means that occasionally sites can discharge at a level that is greater than the long-term average. This variability also means that sites can occasionally discharge at a level that is considerably lower than the long-term average. Consequently, in the second step of developing a limitation, EPA determines an allowance for the variation in pollutant concentrations when processed through well-designed and operated treatment systems. This allowance for variance incorporates all components of variability including process and wastewater generation, sample collection, shipping, storage, and analytical variability. This allowance is incorporated into the limitations through the use of the *variability factors*, which are calculated from the data from the sites using the model technology. The proposed variability factor of 4.58 is the arithmetic average (or mean) of 19 variability factors collected from the 17 sites also used as the basis of the proposed long-term average. Table 6-8 provides the 19 system-specific variability factors. The variability factors ranged from a minimum of 1.96 (Site LSIDE) to a maximum of 10.85 (Site 8), and were calculated as shown in Appendix H.

Table 6-8. System-Specific Variability Factors Used in Limitation Calculations

Site/System	Daily Variability Factor (VF_1)
2	5.39
3	4.41
4_SYS1	9.09
4_SYS2	7.36
6	6.15
8	10.85
11	5.48
BHRBP	4.28
BWWTP	2.43
BZR08	2.36
ELLRD	2.04
HEO	2.08
LSIDE	1.96
SC05	1.97
SC08	2.66
SEAAIR	2.89
STCLLR	3.06
WLCPO_SYS1	4.54
WLCPO_SYS2	7.97
Mean	4.58

In its evaluation of the proposed daily variability factor, EPA examined TSS limitations promulgated during the past 10 years, because it has not recently promulgated limitations for turbidity. Experts generally consider turbidity and TSS to be related and adequately controlled by many different types of treatment systems. Each regulation used data from well-operated and controlled treatment processes in determining the variability of TSS. As shown in Table 6-9, the values for the variability factors are relatively close in value, ranging from 2.9 to 5.4, with an arithmetic average of 4.1. Because the C&D technology is a relatively simple one, EPA concluded that the relatively large value of 4.58 for the proposed variability factor still ensures a level of control that EPA considers possible for a simple technology.

Table 6-9. TSS Variability Factors in Recent Regulations

Category	Subcategory	Option	Value
Centralized Waste Treatment (USEPA 2000)	Organics	4	4.8
	Oils	9	2.9
	Metals	3	3.2
		4	3.6
Waste Combustors (USEPA 1999b)	Commercial Hazardous Waste Combustor		4.2
Iron and Steel (USEPA 2002)	Coke By-Products	BAT1	4.6
	Other	DRI_BPT	3.5
		FORGING	4.4
Landfills (USEPA 1999a)	1) Hazardous and 2) Non-Hazardous*		4.4
Pulp, Paper, and Paperboard, Cluster Rule (USEPA 1997)	bleached papergrade kraft and soda		3.11
Transportation Equipment Cleaning (Science Applications International Corporation. 2000)	Barge/Chemical & Petroleum	1	4.7
	Food Direct	2	5.4

*The variability factors for both subcategories were based on the same data.

6.6.4. CALCULATION OF THE PROPOSED LIMITATION

EPA calculated the value of the daily maximum limitation (13 NTU) using the product of the proposed long-term average (2.77 NTU) and daily variability factor (4.58):

$$\begin{aligned} \textit{Daily Maximum Limitation} &= \textit{Long-Term Average} \times \textit{Variability Factor} \\ &= \textit{(2.77 NTU)} \times \textit{(4.58)} \\ &= \textit{13 NTU} \end{aligned}$$

EPA rounded the value of the limitation to two significant digits (i.e., 13 NTU). EPA generally uses a rounding procedure where values of five and above are rounded up and values of four and below are rounded down. For example, a value of 12.7 would be rounded to 13, while a value of 12.4 would be rounded to 12.

As a consequence of using the long-term average and variability factor as the basis of the limitation, sites that are designed and operated to achieve long-term average levels should be capable of compliance with the limitations, which incorporate variability, at all times.

6.6.5. ENGINEERING REVIEW

In conjunction with the statistical methods, EPA performs an engineering review to verify that the limitations are reasonable based on the design and expected operation of the control

technologies and the site conditions. For the final rule, EPA will perform a more in-depth examination of the range of performance by the data sets used to calculate the limitations. Data from some sites demonstrate the best available technology. Data from other sites could demonstrate the same technology but not the best demonstrated design and operating conditions for that technology. For these sites, EPA will evaluate the degree to which the site can upgrade its design, operating, and maintenance conditions to meet the limitations. If such upgrades are not possible, EPA will modify the limitations to reflect the lowest levels that the technologies can reasonably be expected to achieve. EPA recognizes that, as a result of the proposed limitation, some dischargers might need to improve treatment systems, erosion and sediment controls, and/or treatment system operations to consistently meet the effluent limitation. EPA determined that this consequence is consistent with the Clean Water Act statutory framework, which requires that discharge limitations reflect the best available technology.

To evaluate the value of the proposed limitation, EPA compared the value of the proposed limitation to the daily values used to calculate the limitation. In most instances where the effluent turbidity was higher than the proposed turbidity limit, the data indicated sudden jumps in turbidity levels, which suggested that the treatment system was not being operated properly. EPA evaluated the performance at each system:

- Ten of the 19 systems (Sites 3, SC05, SC08, BZR08, BHRBP, BWWTP, ELLRD, LSIDE, SEAAIR, and STCLLR) had all the daily values less than the proposed limitation. This is consistent with what is expected from the 99th percentile basis of the statistical methodology.

- Site 2 had 3 of 131 (or two percent) daily values greater than the proposed limitation, which is consistent with what is expected from the 99th percentile basis of the statistical methodology. In addition, all three values (15.78, 13.21, and 13.04 NTU) occurred during the same week in 2004 (11/5/2004, 11/8/2004, and 11/9/2004). Two of the three are extremely close in value to the proposed limitation. Because the three values are close in time and at the start of the reported monitoring dates, it is possible that they reflect start-up conditions rather than normal operating conditions. EPA also notes that on one of the three days (11/9/2004), the site had the highest effluent reading of 1936 NTU reported by any site at any time. EPA will reconsider their inclusion as the basis for the final limitation.

- At Site 4, both systems had only one value in 19 (or 5 percent) greater than the proposed limitation, which also is consistent with what is expected from the 99th percentile basis of the statistical methodology. However, both large values (23 NTU and 33.2 NTU) occurred on the same date (2/8/2005) and were an order of magnitude greater than any other daily value. Because the values substantially differ from the others, EPA does not consider the values to be representative of normal operations at the site and will consider their exclusion from final limitation calculations.

- Site 6 also had only one value, 32.25 NTU, in 18 (or 6 percent) greater than the proposed limitation, which is consistent with what is expected from the 99th percentile basis of the statistical methodology. However, this value also is an order of magnitude greater than the other daily values and occurred on a holiday (1/1/2005). Because its value substantially differs from the others, EPA also does not consider

this value to reflect normal operations at the site and will consider its exclusion from final limitation calculations.

- Site 8 had 6 of 18 values greater than the proposed limitation, the majority of which occurred in the week of 1/11/2005 to 1/15/2005. The values exceeding the proposed limitation ranged from 14.17 to 38.75 NTU, with the majority of values being greater than 20 NTU. EPA might exclude the data as the basis of the final limitation because it does not appear to represent a well-operated and controlled treatment system (see criterion 3 in Section 6.3). Its turbidity concentrations, on average, are an order of magnitude greater than most other sites with same treatment system. In addition, it has a system-specific variability factor (10.85) that is more than twice the value (4.58) used as the basis of the limitation and is the most variable discharge observed at any site.
- Site 11 had 3 of 42 values greater than the proposed limitation. The three values (14.06, 15.12, and 23.21 NTU) occurred during the first week of the reported monitoring. It is possible that the system was experiencing fluctuations due to start-up operations. The remaining values range from 0.55 to 7.66 NTU. EPA generally does not consider start-up operations to represent normal operations, and thus, might exclude the data from final limitation calculations.
- All three of the values for Site HEO (25.2, 25, and 13.95 NTU) were greater than the proposed limitation. For the final rule, EPA will consider whether the data represent a well-operated system.
- At site WLCPO, system 1 had five of nine values and system 2 had four of seven values greater than the proposed limitation. The values that exceeded the proposed limitation from system 1 ranged from 19.5 to 36.1 NTU. The values from system 2 ranged from 19.87 to 24.5 NTU. For the final rule, EPA will consider whether the data represent a well-operated system.

Table 6-10 provides a summary of this comparison. As a result of this comparison for the proposed limitation and engineering review of the data, EPA concluded that the statistical distributional assumptions appear to be appropriate for these data.

Table 6-10. Daily Values Greater Than Daily Maximum Limitation

Site/System	Number of daily values	Daily values greater than daily maximum limitation of 13 NTU	
		Number of values	Percent of total number
2	131	3	2.3%
3	21	0	0.0%
4_SYS1	19	1	5.3%
4_SYS2	19	1	5.3%
6	18	1	5.6%
8	18	6	33.3%
11	42	3	7.1%
BHRBP	23	0	0.0%
BWWTP	8	0	0.0%
BZR08	9	0	0.0%
ELLRD	19	0	0.0%
HEO	3	3	100.0%
LSIDE	75	0	0.0%
SC05	6	0	0.0%
SC08	13	0	0.0%
SEAAIR	9	0	0.0%
STCLLR	17	0	0.0%
WLCPO_SYS1	9	5	55.6%
WLCPO_SYS2	7	4	57.1%
Total	**466**	**27**	**5.8%**

6.6.6. IMPORTANCE OF COMMENTS

Because of the importance of comments to EPA's decisions for the final rule, EPA has provided its data in the proposed rulemaking record and explained its criteria for reviewing data. Because its review process could result in changes to the proposed regulation, EPA encourages sites to provide comments and data even if the operators consider the regulatory requirements in the proposed rule to be reasonable. It is possible, as a consequence of new data, that EPA would revise its approach and/or calculate different values for the performance limitations and standards without additional opportunity for comment. Courts have upheld this practice. In Marathon Oil v EPA, 564 F.2d 1253, 1272 (9th Cir. 1977), the Court determined that

> Petitioners, in case 75-3795, also note that the Administrator's decision ignores the recommendation of the EPA's Draft Development Document that the standard be set at 57/85 mg/l. An agency, however, is clearly free to reject an early conclusion after further study and reflection. All that is important is, as developed above, that the final permit standards in this case are supported by substantial

> evidence. Cf. Consolo v. FMC, 383 U.S. 607, 620, 86 S.Ct. 1018, 16 L.Ed.2d 131 (1966).

More recently, in American Coke and Coal Chemicals Institute v. Environmental Protection Agency, 452 F.3d 930, 940 (D.C. Cir. 2006). The Court determined that

> Similarly, EPA's decision in the final rule to use the three additional episodes expanded the scope of the relevant database, but in light of EPA's statement in the Proposed Development Document that it might reconsider its exclusion of these other datasets, this possibility was noticed and made available for possible comment…Although the final limitation is more stringent than had been initially proposed, the limitation is calculated according to the announced procedure and thus is not "surprisingly distant" from the limitation presaged in the NOPR…

In the data review for the final rule, EPA plans to conduct a thorough review of the data used for the proposal and any additional data available to it. In evaluating the data to determine if they should be used as the basis of the final limitation, EPA intends to apply the criteria described in Section 6.3. As a consequence of applying the criteria, EPA might include or exclude data in a different manner than the proposal. For example, Table 6-6 indicates that 4 systems (8, HEO, WLCPO_SYS1, and WLCPO_SYS2) have long-term averages an order of magnitude greater than the other 15 systems. In addition, Table 6-8 indicates that Site 8 has the most variable discharges of the 19 systems. By applying its criterion (#3) that the site must demonstrate good operation of the model treatment technology, EPA might determine that the four sites do not provide this demonstration, and thus, should be excluded as the basis of the final limitation. Assuming that EPA makes no other changes (which is unlikely), the final limitation would have a value of 8.5 NTU instead of the proposed value of 13 NTU. Rather than tacitly agreeing to the proposed limitation, if an operator agrees that the proposed limitation of 13 NTU is reasonable but has concerns about meeting a more stringent limitation; the operator might wish to provide comments and data that support a limitation of 13 NTU.

6.6.7. MONITORING CONSIDERATIONS

Effluent guidelines act as a primary mechanism to control the discharge of pollutants to waters of the United States. Once finalized, the proposed C&D regulations would be applied to C&D sites through incorporation in individual National Pollutant Discharge Elimination System (NPDES) permits or a general permit issued by EPA or authorized states or tribes under section 402 of the Clean Water Act. In complying with the final rule, the number of measurements required each day would be determined by the permit authority. While the actual monitoring requirements will be determined by the permitting authority, in developing the proposed limitation, the Agency has assumed that sites will report one value for every day that the discharge occurs to be consistent with permit definitions provided in 40 CFR 122.2 that define the "maximum daily discharge limitation" as the "highest allowable 'daily discharge.'"

EPA recognizes that some sites regularly monitor multiple times throughout the day to ensure that the treatment system is operating properly. In addition, because turbidity can be measured real-time, it is possible to use an automated turbidity meter in conjunction with a data logger to obtain data during the entire period of discharge. While EPA agrees that such monitoring is

appropriate, EPA would, however, discourage the practice of allowing the number of monitoring samples to vary arbitrarily merely to allow a site to achieve a desired average concentration, i.e., a value below the limitation that day. EPA expects that enforcement authorities would prefer, or even require, monitoring samples at some regular, predetermined frequency. As explained below, if a site has difficulty complying with the limitation on an ongoing basis, the site should improve its equipment, operations, and/or maintenance.

In similar situations when it has assumed daily monitoring for other industries, EPA typically has statistically evaluated the data for possible autocorrelation. When data are said to be positively autocorrelated, it means that measurements taken at specific time intervals (such as 1 day or 2 days apart) are related. For example, positive autocorrelation would be present in the data if the final effluent concentration of turbidity was relatively high one day and was likely to remain at similar high values the next and possibly succeeding days. To evaluate autocorrelation, generally, the statistical analysis requires at least a 50-day period with measurements from every day during the period.[3] It is sometimes possible to estimate autocorrelation from datasets with gaps between measurements. Consequently, in developing the final limitations, EPA might consider whether available statistical strategies for missing data provide reasonable results for autocorrelation in the C&D effluent datasets. In EPA's experience, autocorrelation generally tends to have only a slight effect on the estimate of the long-term average and the daily variability factor, and thus, the maximum daily limitation. (Autocorrelation tends to affect monthly average limitations more noticeably.)

6.6.8. COMPLIANCE

EPA promulgates limitations that sites are capable of complying with at all times by properly operating and maintaining their processes and treatment technologies. However, the issue of exceedances or excursions (values that exceed the limitations) is often raised. Comments often suggest that EPA include a provision that a facility is in compliance with permit limitations if its discharge does not exceed the specified limitations, with the exception that the discharge may exceed the monthly average limitations 1 month out of 20 and the daily average limitations 1 day out of 100. This issue was, in fact, raised in other rules, including EPA's final Organic Chemicals, Plastics, and Synthetic Fibers (OCPSF) rulemaking. EPA's general approach in that case for developing limitations based on percentiles was the same as this rule and was upheld in Chemical Manufacturers Association v. U.S. Environmental Protection Agency, 870 F.2d 177, 230 (5th Cir. 1989). The Court determined the following:

> EPA reasonably concluded that the data points exceeding the 99th and 95th percentiles represent either quality-control problems or upsets because there can be no other explanation for these isolated and extremely high discharges. If these data points result from quality-control problems, the exceedances they represent are within the control of the plant. If, however, the data points represent exceedances beyond the control of the industry, the upset defense is available.

[3] Box and Jenkins (1976), a classic textbook on time series analyses, states that "It is normally supposed that successive values of the time series under consideration … are available for analysis. If possible, at least 50 and preferably 100 observations should be used." (page 18)

More recently, this issue was raised in EPA's Phase I rule for the pulp and paper industry. In that rulemaking, EPA used the same general approach for developing limitations based on percentiles that it had used for the OCPSF rulemaking and for the proposed CAAP rule. This approach for the monthly average limitation was upheld in National Wildlife Federation et al. v. Environmental Protection Agency, 286 F.3d 554, 573 (D.C. Cir. 2002). The Court determined that:

> EPA's approach to developing monthly limitations was reasonable. It established limitations based on percentiles achieved by facilities using well-operated and controlled processes and treatment systems. It is therefore reasonable for EPA to conclude that measurements above the limitations are due to either upset conditions or deficiencies in process and treatment system maintenance and operation. EPA has included an affirmative defense that is available to mills that exceed limitations due to an unforeseen event. EPA reasonably concluded that other exceedances would be the result of design or operational deficiencies. EPA rejected Industry Petitioners' claim that facilities are expected to operate processes and treatment systems so as to violate the limitations at some pre-set rate. EPA explained that the statistical methodology was used as a framework to establish the limitations based on percentiles. These limitations were never intended to have the rigid probabilistic interpretation that Industry Petitioners have adopted. Therefore, we reject Industry Petitioners' challenge to the effluent limitations.

As that Court recognized, EPA's allowance for reasonably anticipated variability in its effluent limitations, coupled with the availability of the upset defense, reasonably accommodates acceptable excursions. Any further excursion allowances would go beyond the reasonable accommodation of variability and would jeopardize the effective control of pollutant discharges on a consistent basis and/or bog down administrative and enforcement proceedings in detailed fact-finding exercises, contrary to congressional intent. See, for example, Rep. No. 92-414, 92d Congress, 2d Sess. 64, reprinted in *A Legislative History of the Water Pollution Control Act Amendments of 1972* (at 1482); *Legislative History of the Clean Water Act of 1977* (at 464-65).

More recently, for EPA's rule for the iron and steel industry, EPA's selection of percentiles was upheld in American Coke and Coal Chemicals Institute v. Environmental Protection Agency, 452 F.3d 930, 945 (D.C. Cir. 2006). The Court determined that

> The court will not second-guess EPA's expertise with regard to what the maximum effluent limits represent. See Nat'l Wildlife, 286 F.3d at 571-73. As EPA explains in the Final Development Document, the daily and monthly average effluent limitations are not promulgated with the expectation that a plant will operate with an eye toward barely achieving the limitations. Final Development Document at § 14.6.2. Should a plant do so, it could be expected to exceed these limits frequently because of the foreseeable variation in treatment effectiveness. Rather, the effluent limitations are promulgated with the expectation that plants will be operated with an eye towards achieving the equivalent of the LTA for the BAT-1 model technology. *Id.* However, even operated with the goal of achieving the BAT-1 LTA, a plant's actual results will vary. EPA's maximum daily

> limitations are designed to be forgiving enough to cover the operations of a well-operated model facility 99% of the time, while its maximum monthly average limitations are designed to be forgiving enough to accommodate the operations of a well-operated model facility 95% of the time. See id. EPA's choice of percentile distribution represented by its maximum effluent limitation under the CWA represents an expert policy judgment that is not arbitrary or capricious.

EPA expects that sites will comply with promulgated limitations *at all times*. If the exceedance is caused by an upset condition, the site would have an affirmative defense to an enforcement action if the requirements of 40 CFR 122.41(n) are met. If the exceedance is caused by a design or operational deficiency, EPA has determined that the site's performance does not represent the appropriate level of control (best available technology for existing sources; best available demonstrated technology for new sources). For promulgated limitations and standards, EPA has determined that such exceedances can be controlled by diligent process and wastewater treatment system operational practices such as frequent inspection and repair of equipment, use of backup systems, and operator training and performance evaluations.

6.7. SUMMARY OF STEPS USED TO DERIVE THE PROPOSED LIMITATIONS

This section summarizes the steps used to derive the proposed limitations for turbidity:

Step 1 EPA calculated daily averages from the individual measurements for each treatment system.

Step 2 EPA calculated the *system-specific long-term averages* and *daily variability factors* for each of the 19 systems that had the model technology.

Step 3 EPA calculated the *long-term average* of 2.77 NTU as the median of the site long-term averages. (See Table 6-6.) EPA expects that all sites subject to the limitations will design and operate their treatment systems to achieve the long-term average performance level on a consistent basis.

Step 4 EPA calculated the *variability factor* of 4.58 as the mean of the system-specific variability factors. (See Table 6-8) If a site operates its treatment system to meet the relevant long-term average, EPA expects the site to be able to meet the limitations. The variability factor assures that normal fluctuations in a site's treatment are accounted for in the limitation. By accounting for these reasonable excursions above the long-term average, EPA's use of variability factors results in limitations that are generally well above the actual long-term averages.

Step 5 EPA calculated the *daily maximum limitation* of 13 NTU using the product of the long-term average (2.77 NTU) and the daily variability factor (4.58).

Step 6 EPA *compared* the daily maximum limitations to the site daily values used to develop the proposed limitations. (See Table 6-10.) EPA usually performs this comparison to determine whether it used appropriate distributional assumptions for the data used to develop the limitations. This comparison considers whether the curves EPA used

provide a reasonable *fit* to the actual effluent data or if there was an engineering or process reason for an unusual discharge. Although the fact that the Agency performs such an analysis before promulgating limitations might give the impression that EPA expects occasional exceedances of the limitations, this conclusion is incorrect. EPA promulgates limitations that facilities are capable of complying with at all times by properly operating and maintaining their treatment technologies. After performing an engineering evaluation of the larger values, EPA concluded that the proposed limitation was reasonable.

6.8. REFERENCES

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7. TECHNOLOGY ASSESSMENT

This technology assessment is intended to determine the amount and quality of data available to describe the performance of currently used site runoff control practices, the ability of each practice to effectively control impacts due to runoff, and the design criteria or standards currently used to size each practice to ensure effective control of runoff.

7.1. REVIEW OF HISTORICAL APPROACHES TO EROSION AND SEDIMENT CONTROL

Most early sediment control was related to agriculture and was installed as a way to maintain our natural resource base. On-site control was the primary emphasis, attempting to prevent erosion rather than trap sediment. Strategies were developed to minimize exposure of bare soil to the erosive power of rainfall and runoff, using aboveground cover management, residue management, strip cropping, and terracing to limit the length of overland flow. Impacts to receiving streams and downstream areas had not yet been identified as an issue. In the 1960s concern began to be expressed about the quantities of sediment in streams and reservoirs, and sediment was first identified as a pollutant. Initially, the major focus of sediment control was on the surface mining industry with the passage of the Clean Water Act and then the Surface Mining, Reclamation, and Control Act (SMRCA) (PL 95-87). The first approach taken to sediment control was a design standard, requiring a sediment detention basin with a 24-hour detention time; total suspended solids (TSS) standards of 35 milligrams per liter (mg/L) average and 70 mg/L peak were also promulgated but were not typically enforced. The U.S. Environmental Protection Agency (EPA) later evaluated the TSS standard and moved to a settleable solids standard of 0.5 mL/L, based on a modeling effort that showed that it was not possible to trap fine sediments, but that a 0.5 mL/L settleable solids standard could be met with a reasonably sized sediment basin (Ettinger and Lichty 1979).

In the late 1960s and early 1970s, sediment in streams and waterways originating from urban construction sites became an issue, which was then addressed in the Clean Water Act. EPA developed a list of best management practices (BMPs) and standards for their construction (USEPA 1971). In general, these standards were adopted from those of other agencies and were not based on studies related to urban runoff.

In 1987 the Clean Water Act was amended to include stormwater discharges from urban areas. The Phase I National Pollutant Discharge Elimination System (NPDES) stormwater regulations were published in 1990, requiring all municipalities with Municipal Separate Storm Sewer Systems (MS4) serving populations greater than 100,000, construction sites 5 acres and larger, and certain industrial sites to obtain a permit. The permit required the development of a stormwater pollution prevention plan (SWPPP) that typically included a stormwater and sediment control plan. In 1999 the Phase II NPDES stormwater regulations were published, extending permit coverage to construction sites of 1 acre or larger and municipalities with populations greater than 50,000 (or populations greater than 10,000 where population density is more than 1,000 people per square mile). The regulations allow use of general permits in lieu of individual site or facility permits. The degree of oversight of construction varies widely among the states.

In the past two decades, increased concern at the local level has been focused on sediment pollution of streams and waterways, particularly originating from construction, while less concern has been focused on the effects of increased construction on stormwater and chemical production. Much of this government concern originated from the Phase I and Phase II NPDES stormwater regulations. A number of states and their local agencies have developed standards and BMPs for sediment control, most of which do not have a scientific basis but were adopted from other agencies. Some states, however, did conduct studies that gave their standards some scientific basis. For example, Maryland evaluated its BMP standards in the 1980s by using modeling techniques, and the state changed its sediment basin standards to account for the effects of surface area on the trapping efficiency in sediment ponds. On the basis of typical soils in the region and modeling studies, the state adopted a surface area to peak discharge ratio of 0.01 cubic feet per second (cfs) per acre as a criterion (Barfield and Clar 1985; McBurnie et al. 1990). Maryland was thus the first state to use a design criterion that was related to the overflow rate. Other states also used some of Maryland's results (Smolen et al. 1988).

Recent efforts have moved closer to an effluent standard approach. South Carolina conducted a detailed analysis and published regulations that required a trapping efficiency or settleable solids standard (SCDHEC 1995). In addition, results from a detailed model were used to develop simplified design aids (Hayes and Barfield 1995; Holbrook et al. 1998). Some municipalities are following suit to develop scientifically based standards of their own. For example, in 1998 Louisville, Kentucky (Hayes et al. 2001) developed standards and design aids for stormwater and sediment control, following the example of South Carolina.

There are no examples in which an integrated approach to stormwater and sediment control has been used on construction sites. The closest analog is the Cumulative Hydrologic Impact Analysis (CHIA) required in surface mining by the SMRCA. SMRCA requires each applicant for a surface mining permit to conduct a hydrologic impact analysis. Subsequently, the regulatory authority is required to conduct a CHIA for the entire watershed. Note that although a CHIA is required, it is seldom undertaken on a scale that is useful.

Many of the advances in sediment control have been based on the capability to predict, a priori, the ability of a given design to meet a standard. For example, when the settleable solids standard was developed for surface mining, most regulatory authorities adopted it with the requirement that permit applicants would demonstrate through the use of widely accepted computer models that the proposed design would meet the settleable solids standard.

Most of the early work in modeling sediment production stemmed from efforts in the 1950s to develop a soil loss equation that would apply to the entire nation and allow evaluation of alternative erosion control practices. This led to the relationship known as the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1965) and its subsequent derivative, the Revised USLE (RUSLE) (Renard et al. 1994). These efforts focus on erosion control; thus, the relationships do not predict sediment yield. A flurry of efforts in the late 1970s and early 1980s lead to the development of sediment yield relationships such as the Modified USLE (MUSLE) (Williams, No Date), the CREAMS model (Knisel 1980), SEDCAD (Warner et al. 1999), and SEDIMOT II (Wilson et al. 1982) and its derivatives. The MUSLE and CREAMS models did not include methods to evaluate the impact of sediment trapping structures, but SEDIMOT II contained relationships developed at the University of Kentucky to predict the impact of

reservoirs (Ward et al. 1977; Wilson and Barfield 1984), check dams (Hirschi 1981), and vegetative filter strips (Hayes et al. 1984). The MUSLE, SEDCAD and SEDIMOT II models were based on single storms, while the CREAMS model was based on continuous simulation modeling. Details on these models can be found in Haan et al. (1994).

More recently, modeling has improved, resulting in several new relationships. The WEPP watershed model is one example of a continuous simulation approach. It includes computational procedures for a wide variety of sediment control structures (Lindley et al. 1998). Another example of a single storm-based model is SEDIMOT III (Barfield et al. 1996), which modifies the earlier SEDIMOT II model to include channel erosion routines and a wide variety of sediment control techniques. A significant drawback in the SEDIMOT III and WEPP models is that they do not have a good technique for predicting the impact of filter fence, which is the most common technique used today for sediment control. The authors of SEDCAD have attempted to provide algorithms to represent (silt) filter fence removals, although work remains before global acceptance in the literature.

Concerns for changes in geomorphology resulting from flow alterations have resulted in several modeling approaches. Early efforts were focused on what is known as the regime theory, in which changes in channel property are linked, qualitatively, to changes in flow. Examples include models of Lane (1955) and Schumm (1977). In addition, some statistically based models were developed, but they are not universally applicable (Blench 1970; Simons and Albertson 1960). More recently, models have been developed using physically based concepts to predict changes in geomorphology as related to changes in flow. The models of Chang (1988) are good examples. It is possible to predict, to a limited extent, the change in channel properties as affected by changes in flow.

The impact of changes in flow and geomorphology on habitat is one major area in which information is lacking. Although this deficiency can be addressed qualitatively, it is not possible to predict quantitatively how a given change in geomorphology will affect habitat. Additional information is needed to develop a strategy on the basis of the integrated assessment approach.

7.2. CONTROL TECHNIQUES

The following section presents a discussion of the commonly used erosion and sediment control practices. Information on applicability, design and installation criteria, maintenance considerations and effectiveness are presented, when available. This section does not discuss proprietary and vendor-supplied BMPs, many of which are variations of conventional BMPs such as sediment barriers, filters, and erosion control and prevention practices.

7.2.1. EROSION CONTROL AND PREVENTION

7.2.1.1. Planning, Staging, Scheduling

General Description

A construction sequence schedule is a specified work schedule that coordinates the timing of land-disturbing activities and the installation of erosion and sediment control measures. The goal of a construction sequence schedule is to reduce on-site erosion and off-site sedimentation by

performing land-disturbing activities and installing erosion and sediment control practices in accordance with a planned schedule (Smolen et al. 1988).

Construction site phasing involves disturbing only part of a site at a time to prevent erosion from dormant parts (Claytor 1997). Grading activities and construction are completed and soils are effectively stabilized on one part of the site before grading and construction begin at another part. This differs from the more traditional practice of construction site sequencing, in which construction occurs at only one part of the site at the time, but site grading and other site-disturbing activities typically occur simultaneously, leaving portions of the disturbed site vulnerable to erosion. Construction site phasing must be incorporated into the overall site plan early on. Elements to consider when phasing construction activities include the following (Claytor 1997):

- Managing runoff separately in each phase
- Determining whether water and sewer connections and extensions can be accommodated
- Determining the fate of already completed downhill phases
- Providing separate construction and residential accesses to prevent conflicts between residents living in completed stages of the site and construction equipment working on later stages (USEPA 2000)

Applicability

Construction sequencing can be used to plan earthwork and erosion and sediment control activities at sites where land disturbances might affect water quality in a receiving waterbody.

Design and Installation Criteria

Construction sequencing schedules should, at a minimum, include the following (NCDNR 1988; MDE 1994):

- The erosion and sediment control practices that are to be installed
- The principal development activities
- The measures that should be installed before other activities are started
- The compatibility with the general contract construction schedule Table 7-1 summarizes other important scheduling considerations in addition to those listed above

Effectiveness

Construction sequencing can be an effective tool for erosion and sediment control because it ensures that management practices are installed where necessary and when appropriate. A comparison of sediment loss from a typical development and from a comparable phased project showed a 42 percent reduction in sediment export in the phased project (Claytor 1997).

Table 7-1. Scheduling Considerations for Construction Activities

Construction activity	Schedule consideration
Construction survey stakeout	Before initiating any construction activity a construction survey stakeout should be conducted. The stakeout should identify the limits of disturbance and location of control structures, especially perimeter controls.
Pre-construction meeting between owner, contractor, and regulatory agency	This meeting should take place before any construction activity begins at the site. The survey stakeout is reviewed, especially the limits of disturbance and location of controls.
Construction access—entrance to site, construction routes, areas designated for equipment parking	This is the first land-disturbing activity. As soon as construction takes place, any bare areas should be stabilized with gravel and temporary vegetation.
Clearing and grading required for the installation of controls	In conjunction with the construction access, the clearing and grading required for the installation of erosion and sediment controls should take place.
Sediment traps and barriers—basin traps, silt fences, outlet protection	After the construction site has been accessed, principal basins should be installed, with the addition of more traps and barriers as needed during grading.
Runoff control—diversions, perimeter dikes, water bars, outlet protection	Install key practices after the installation of principal sediment traps and before land grading. Additional runoff control measures can be installed during grading.
Runoff conveyance system—stabilize streambanks, storm drains, channels, inlet and outlet protection, slope drains	If necessary, stabilize streambanks as soon as possible, and install the principal runoff conveyance system with runoff control measures. The remainder of the systems can be installed after grading.
Land clearing and grading—site preparation (cutting, filling, and grading; sediment traps; barriers; diversions; drains; surface roughening)	Implement major clearing and grading after installing principal sediment and key runoff control measures, and install additional control measures as grading continues. Clear borrow and disposal areas as needed and mark trees and buffer areas for preservation.
Surface stabilization—temporary and permanent seeding, mulching, sodding, riprap	Immediately apply temporary or permanent stabilizing measures to any disturbed areas where work has been either completed or delayed.
Building construction—buildings, utilities, paving	During construction, install any erosion and sediment control measures that are needed.
Landscaping and final stabilization—adding topsoil, trees, and shrubs; permanent seeding; mulching; sodding; riprap	This is the last construction phase. Stabilize all open areas, including borrow and spoil areas, and remove and stabilize all temporary control measures.

Limitations

Weather and other unpredictable variables can affect construction sequence schedules. The proposed schedule and a protocol for making changes resulting from unforeseen problems should be plainly stated in an applicable erosion and sediment control plan.

Maintenance

The construction sequence should be followed throughout the project, and the written erosion and sediment control plan should be modified before any changes in construction activities are executed. The plan can be updated if a site inspection indicates the need for additional erosion and sediment control as determined by contractors, engineers, or developers.

Cost

Construction sequencing is a low-cost BMP because it requires a limited amount of a contractor's time to provide a written plan for coordinating construction activities and management practices. Additional time might be needed to update the sequencing plan if the current plan is not providing sufficient erosion and sediment control.

Although little research has been done to assess the costs of phasing versus conventional construction costs, it is known that it will be possible to implement successful phasing for a larger project (Claytor 1997).

7.2.1.2. Vegetative Stabilization

Vegetation can be used during construction to stabilize and protect soil exposed to the erosive forces of water, as well as post-construction to provide a filtration mechanism for stormwater pollutants. The following discussion refers to vegetative stabilization as a construction BMP that stabilizes and protects soil from erosion.

General Description

Vegetative stabilization measures employ plant material to protect soil exposed to the erosive forces of water and wind. Selected vegetation can reduce erosion by more than 90 percent (Fifield 1999). Natural plant communities that are adapted to the site provide a self-maintaining cover that is less expensive than structural alternatives. Plants provide erosion protection to vulnerable surfaces by the following (Heyer, No Date):

- Protecting soil surface from the impact of raindrops
- Holding soil particles in place
- Maintaining the soil's capacity to absorb water
- Using living root systems to hold soil in place, increasing overall bank stability
- Directing flow velocity away from the streambank
- Acting as a buffer against abrasive transported materials
- Causing sediment deposition, which reduces sediment load and reestablishes the streambank

The designer should be aware of and respond to local conditions that could influence the development of vegetative stabilization measures. As with any planting design, climate, maintenance practices, the availability of plant material (including native species), and many

other factors will influence such considerations as plant or seed mix selection, installation methods, and project scheduling.

Slope Stabilization. On slopes, the goal of vegetative stabilization is not only to reduce surface erosion, but also to prevent slope failure. Vegetation should provide dense coverage to protect soils from the direct impact of precipitation and help intercept runoff. A variety of plants should be used to provide root systems that are distributed throughout all levels of the soil, increasing slope shear strength and giving plants a greater ability to remove soil moisture. Uniform mats of shallow rooting plants should be avoided because, while such plants might increase runoff infiltration, they cannot remove soil moisture beyond the surface level, leaving slopes potentially saturated and prone to slippage. Shallow, interlocking root systems could also increase the size of a soil slippage by holding together and pulling down a larger area of slope after a small section has given way. Large trees that have become unstable can also pull down slopes and should be removed. Using plants with low water requirements can reduce the potential for soil saturation from irrigation.

Swale Stabilization. On swales, the goal of vegetative stabilization is to prevent erosion within the swale, where runoff is concentrated and flows at higher velocities. If natural stream channels are involved, vegetation with deep root systems should be preserved, or if absent, planted above the channel to help maintain the channel banks. More information is provided in the subsequent section dealing with grass-lined swales.

Surface Stabilization. On large, flat areas, the goal of vegetative stabilization is to reduce the loss of surface soil from sheet erosion. Vegetation should provide complete coverage to reduce the force of precipitation, which can shift soil particles to seal openings in the soil, reducing infiltration and increasing runoff. Vegetation should also provide many stem penetrations to slow runoff and increase infiltration. Deep rooting plants are less critical for erosion control in flat areas than on slopes because soils are not subject to the same forces that can cause slippage on a slope. However, trees and shrubs can increase infiltration, lessening the buildup of runoff, and transpire large volumes of water, reducing soil saturation.

In areas susceptible to wind erosion, the goal of vegetative stabilization is to establish direct protection of the soil. Vegetation should provide dense and continuous surface cover. Binding the soil deeply is generally not a requirement. The ideal vegetation for this purpose is grass, which forms a mat of protection. In areas where the vegetation is developed, the grass generally has high maintenance requirements. In less developed, open areas, unmown grass, including perennial native species, can be used to provide protection. Trees and shrubs also can provide protection from the wind.

Shoreline Stabilization. In lakes and ponds, the goal of vegetative stabilization is to prevent erosion of the shoreline. Wetland plants anchor the bottom of the lake or pond adjacent to the shore and help dissipate the erosive energy of waves. An important consideration in planting along shorelines is the need to establish favorable conditions for plant establishment and growth. These include the proper grading of side slopes and the control of upland erosion to prevent the buildup of silt and associated pollutants in the water. Designers should maintain awareness of regulatory requirements that might influence vegetation projects in a wetland environment (USAF 1998).

Vegetation used for shoreline stabilization work should be native material selected because of strength, resiliency, vigor, and ability to withstand periodic inundation. Woody vegetation with short, dense, flexible tops and large root systems works well. Other important factors include rapid initial growth, ability to reproduce, and resistance to disease and insects.

According to Heyer (No Date), most streambank stabilization plantings have used various willows, including black willow (*Salix nigra*), sandbar willow (*S. interior*), meadow willow (*S. petiolaris*), heartleaf willow (*S. rigida*), and Ward willow (*S. caroliniana*). The size used depends on the severity of the erosion and the type of bank to be stabilized.

Most tree revetment projects used either eastern red cedar (*Juniperus virginiana*) or hardwoods such as northern pin oak (*Quercus ellipsoidalis*). Important suggestions include the following:

- Choose trees with many limbs and branches to trap as much sediment as possible.
- Select decay-resistant trees.
- Use recently cut trees—dead trees are more brittle and likely to break apart.
- The tree size-diameter of the tree crown should be about two-thirds of the height of the eroding bank.
- Cut off any trunk without limbs.
- Place the tree revetments overlapping, butt end pointing upstream.
- Begin and end revetments at stable points along the bank.
- Choose an anchoring system according to the bank material to be stabilized and the weight of the object to be anchored.

Vegetative measures for streambank stabilization offer an alternative to structural measures and are becoming well known as bioengineering techniques for streambanks. Using vegetative material for streambank stabilization could be the first step in the reestablishment of the riparian forest, which is essential for long-term stability of the streamside and floodplain areas. Each site must be evaluated separately as to the feasibility of using natural material (Heyer, No Date).

Vegetative streambank stabilization, with the goal of protecting streambanks from the erosive forces of flowing water, is generally applicable where bankfull flow velocity does not exceed 6 ft/sec and soils are erosion resistant (Smolen 1988). Table 7-2 includes general guidelines for maximum allowable velocities in streams to be protected by vegetation.

Table 7-2. Conditions Where Vegetative Streambank Stabilization Is Acceptable

Frequency of bankfull flow	Maximum allowable velocity for highly erodible soil	Maximum allowable velocity for erosion-resistant soil
> 4 times/yr	4 ft/sec	5 ft/sec
1 to 4 times/yr	5 ft/sec	6 ft/sec
< 1 time/yr	6 ft/sec	6 ft/sec

Source: Smolen 1988

Temporary Vegetative Stabilization. Temporary vegetative cover such as rapidly growing annuals and legumes can be used to establish a temporary vegetative cover. Such covers are recommended for areas that (Fifield 1999)

- Will not be brought to final grade within 30 days or are likely to be redisturbed
- Require seeding of cut and fill slopes under construction
- Require stabilization of soil storage areas and stockpiles
- Require stabilization of temporary dikes, dams, and sediment containment systems
- Require development of cover or nursery crops to assist with establishing perennial grasses

Examples of temporary vegetation include wheat, oats, barley, millet, and sudan grass. Temporary seeding might not be effective in arid or semi-arid regions where seasonal lack of moisture prevents germination. It might be necessary to use a mixture of warm and cool season grasses to ensure germination. Mulching and geotextiles can be used to help provide temporary stabilization with vegetation, particularly in situations where establishing cover could be difficult.

Permanent Vegetative Stabilization. Permanent vegetative cover such as a perennial grass or a legume cover can be used to establish a permanent vegetative cover. Permanent vegetation is recommended for the following (Fifield 1999):

- Final graded or cleared areas where permanent vegetative cover is needed to stabilize the soil
- Slopes designated to be treated with erosion control blankets
- Grass-lined channels or waterways designed to be protected with channel liners

The following subsections discuss the various types or means of providing vegetative stabilization

Grass-lined Channels

General Description

Grass-lined channels, or swales, convey stormwater runoff through a stable conduit. Vegetation lining the channel reduces the flow velocity of concentrated runoff. Grassed channels are usually not designed to control peak runoff loads by themselves and are often used in combination with other BMPs such as subsurface drains and riprap stabilization.

Applicability

Grassed channels should be used in areas where erosion-resistant conveyances are needed, such as in areas with highly erodible soils and slopes of less than 5 percent. They should be installed only where space is available for a relatively large cross-section. Grassed channels have a limited ability to control runoff from large storms and should not be used in areas where velocity

exceeds 5 feet per second unless they are on erosion-resistant soils with dense groundcover at the soil surface.

Design and Installation Criteria

Because of their ease of construction and low cost, vegetation-lined waterways are frequently used for diversion and collection ditches. The U.S. Department of Agriculture's (USDA's) Soil Conservation Service's (SCS) *Engineering Field Manual* (1979) recommends the maximum permissible velocities for individual site conditions shown in Table 7-3.

Table 7-3. Maximum Permissible Velocities for Individual Site Conditions for Grass Swales

Site location	Velocity
Areas where only a sparse cover can be established or maintained because of shale, soils, or climate	3.00 ft/sec (0.91 m/sec)
If the vegetation is to be established by seeding	3.00 to 4.00 ft/sec (0.91 to 1.22 m/sec)
Areas where a dense, vigorous sod is obtained quickly or where the runoff can diverted out of the waterway while the vegetation is being established	4.00 to 5.00 ft/sec (1.22 to 1.52 m/sec)

Source: USDA 1979

Grassed waterways typically begin eroding in the invert of the channel if the velocity exceeds the sheer strength of the vegetation soil interface. Once the erosion process has started, it will continue until an erosion-resistant layer is encountered. If erosion of a channel bottom is occurring, rock or stone should be placed in the eroded area or the design should be changed (UNEP 1994).

Grassed waterways on construction land must be able to carry peak runoff events from snowmelt and rainstorms (in some areas limited to up to 1 cubic meter of water per second). The size of the waterway depends on the size of the area to be drained. A typical grassed waterway cross-section is parabolic with a nearly flat-bottom, a bottom width of 3 m, and channel depth of at least 30 cm. Side slopes usually rise about 1 m for every 10 m horizontal distance but could be as steep as a 1 m rise for every 2 m of horizontal distance. The waterway should follow the natural drainage path if possible (Vanderwel and Abday 1998). The design should be site-specific and be derived using well-established procedures.

Lined channels are a means of carrying water to lower elevations along steep parts of a waterway. Those portions of the waterway are precisely shaped and carefully lined with heavy-duty erosion control matting (a geotextile product). The lining is covered with a layer of soil and seeded to grass. The resulting channel is highly resistant to erosion. Lined channels are appropriate for waterways that only carry water occasionally and have slopes of up to 10 percent. Companies that sell geotextile products provide detailed information on installation of their products (Vanderwel and Abday 1998). The design should be site-specific and be derived using well-established procedures. No standard procedure is available for evaluating the effectiveness of geotextile liners for pollutant removal.

Grass-lined channels should be sited in accordance with the natural drainage system and should not cross ridges. The channel design should not have sharp curves or significant changes in slope. The channel should not receive direct sedimentation from disturbed areas and should be sited only on the perimeter of a construction site to convey relatively clean stormwater runoff. They should be separated from disturbed areas by a vegetated buffer or other BMP to reduce sediment loads.

Although exact design criteria should be based on local conditions, basic design recommendations for grassed channels include the following:

- Construction and vegetation of the channel should occur before grading and paving activities begin.
- Design velocities should be less than 5 ft/sec.
- Geotextiles can be used to stabilize vegetation until it is fully established.
- Covering the bare soil with sod or geotextiles can provide reinforced stormwater conveyance immediately.
- Triangular-shaped channels should be used with low velocities and small quantities of runoff; parabolic grass channels are used for larger flows and where space is available; trapezoidal channels are used with large flows of low velocity (low gradient).
- Outlet stabilization structures might be needed if the runoff volume or velocity has the potential to exceed the capacity of the receiving area.
- Channels should be designed to convey runoff from a 10-year storm without erosion.
- The sides of the channel should be sloped less than 3:1, with V-shaped channels along roads sloped 6:1 or less for safety.
- All trees, bushes, stumps, and other debris should be removed during construction.

Effectiveness

Grass-lined channels can effectively transport stormwater from construction areas if they are designed for expected flow volumes and velocities and if they do not receive sediment directly from disturbed areas. The primary function is to carry the flow at a higher velocity without eroding or overtopping the channel.

Limitations

Grassed channels, if improperly installed, can alter the natural flow of surface water and have adverse impacts on downstream waters. Additionally, if the design capacity is exceeded by a large storm event, the vegetation might not be sufficient to prevent erosion and the channel might be destroyed. Clogging with sediment and debris reduces the effectiveness of grass-lined channels for stormwater conveyance.

Maintenance

Maintenance requirements for grass channels are relatively minimal. During the vegetation establishment period, the channels should be inspected after every rainfall. Other maintenance activities that should be carried out after vegetation is established are mowing, litter removal, and spot vegetation replacement. The most important objective in the maintenance of grassed channels is the maintaining of a dense and vigorous growth of turf. Periodic cleaning of vegetation and soil buildup in curb cuts is required so that water flow into the channel is unobstructed. During the growing season, channel grass should be cut no shorter than the level of design flow, and the cuttings should be removed promptly.

Cost

Costs of grassed channels range according to depth, with a 1.5-foot-deep, 10-foot-wide grassed channel estimated to cost between $6,395 and $17,075 per trench, while a 3-foot-deep, 21-foot-wide grassed channel is estimated at $12,909 to $33,404 per trench (SWRPC 1991).

As an alternative cost approximation, grassed channel construction costs can be developed using unit cost values. Shallow trenching (1 to 4 feet deep) with a backhoe in areas not requiring dewatering can be performed for $4 to $5 per cubic yard of removed material (R.S. Means 2000). Assuming no disposal costs (i.e., excavated material is placed on either side of the trench), only the cost of fine grading, soil treatment, and grassing (approximately $2 per square yard of earth surface area) should be added to the trenching cost to approximate the total construction cost. Site-specific hydrologic analysis of the construction site is necessary to estimate the channel conveyance requirement; however, it is not unusual to have flows on the order of 2 to 4 cfs per acre served. For channel velocities between 1 and 3 feet per second, the resulting range in the channel cross-section area can be as low as 0.67 square foot per acre drained to as high as 4 square feet per acre. If the average channel flow depth is 1 foot, the low estimate for grassed channel installation is $0.27 per square foot of channel bottom per acre served per foot of channel length. The high estimate is $1.63 per square foot of channel bottom per acre served per foot of channel length.

Seeding

General Description

Permanent seeding is used to control runoff and erosion on disturbed areas by establishing perennial vegetative cover from seed. It is used to reduce erosion, decrease sediment yields from disturbed areas, and provide permanent stabilization. This practice is both economical and adaptable to different site conditions, and it allows selection of the most appropriate plant materials. Seeding is a BMP that is particularly susceptible to local conditions such as the climatic conditions, physical and chemical characteristics of the soil, topography, and time of year.

Applicability

Permanent seeding is well suited in areas where permanent, long-lived vegetative cover is the most practical or most effective method of stabilizing the soil. Permanent seeding can be used on roughly graded areas that will not be regraded for at least a year. Vegetation controls erosion by protecting bare soil surfaces from displacement by raindrop impacts and by reducing the velocity

and quantity of overland flow. The advantages of seeding over other means of establishing plants include lower initial costs and labor inputs.

Design and Installation Criteria

Areas to be stabilized with permanent vegetation must be seeded or planted 1 to 4 months after the final grade is achieved unless temporary stabilization measures are in place. Successful plant establishment can be maximized with proper planning; consideration of soil characteristics; selection of plant materials that are suitable for the site; adequate seedbed preparation, liming, and fertilization; timely planting; and regular maintenance. Climate, soils, and topography are major factors that dictate the suitability of plants for a particular site. The soil on a disturbed site might require amendments to provide sufficient nutrients for seed germination and seedling growth. The surface soil must be loose enough for water infiltration and root penetration. Soil pH should be between 6.0 and 6.5 and can be increased with liming if soils are too acidic. Seeds can be protected with mulch to retain moisture, regulate soil temperatures, and prevent erosion during seedling establishment.

Seedbed preparation is critical in established vegetation. Spraying seeds on a scraped slope will generally not provide satisfactory results. Typical seedbed preparation will begin with a soil test to determine the amount of lime or fertilizer that should be added. In addition, tillage should be performed that will break up clods so that seed contact can be established. When the seed is applied, it should be covered and lightly compacted. Natural or synthetic mulch is recommended to provide surface stabilization until the vegetation is established. In addition to providing surface stabilization, the mulch will also retard evaporation and encourage rapid growth. A suitable tack to hold the mulch might be necessary if the mulch is not otherwise anchored. Mulch as an erosion control practice is covered in a subsequent sub-section.

Depending on the amount of use permanently seeded areas receive, they can be considered high- or low-maintenance areas. High-maintenance areas are mowed frequently, limed and fertilized regularly, and either (1) receive intense use (for example, athletic fields) or (2) require maintenance to an aesthetic standard (for example, home lawns). Grasses used for high-maintenance areas are long-lived perennials that form a tight sod and are fine-leaved. High-maintenance vegetative cover is used for homes, industrial parks, schools, churches, and recreational areas.

Low-maintenance areas are mowed infrequently or not at all and do not receive lime or fertilizer on a regular basis. Plants must be able to persist with minimal maintenance over long periods of time. Grass and legume mixtures are favored for these sites because legumes fix nitrogen from the atmosphere. Sites suitable for low-maintenance vegetation include steep slopes, streambanks or channel banks, some commercial properties, and *utility* turf areas such as road banks.

Effectiveness

Seeding that results in a successful stand of grass has been shown to remove between 50 and 100 percent of TSS from stormwater runoff, with an average removal of 90 percent (USEPA 1993).

Limitations

The effectiveness of permanent seeding can be limited because of the high erosion potential during establishment, the need to reseed areas that fail to establish, limited seeding times depending on the season, and the need for stable soil temperature and soil moisture content during germination and early growth. Permanent seeding does not immediately stabilize soils—temporary erosion and sediment control measures should be in place to prevent off-site transport of pollutants from disturbed areas. Use of mulches or geotextiles or both could improve the likelihood of successfully establishing vegetation.

Maintenance

Grasses should emerge within 4 to 28 days and legumes within 5 to 28 days after seeding. A successful stand should exhibit the following:

- Vigorous dark green or bluish green seedlings—not yellow
- Uniform density, with nurse plants, legumes, and grasses well intermixed
- Green leaves—perennials remaining throughout the summer, at least at the plant bases

Seeded areas should be inspected for failure, and necessary repairs and reseeding should be made as soon as possible. If a stand has inadequate cover, the choice of plant materials and quantities of lime and fertilizer should be reevaluated. Depending on the condition of the stand, areas can be repaired by overseeding or reseeding after complete seedbed preparation. If the timing is bad, an annual grass seed can be overseeded to temporarily thicken the stand until a suitable time for seeding perennials. Consider seeding temporary, annual species if the season is not appropriate for permanent seeding. If vegetation fails to grow, the soil should be tested to determine whether low pH or nutrient imbalances are responsible. Local NRCS or county extension agents can also be contacted for seeding and soil testing recommendations.

On a typical disturbed site, full plant establishment usually requires refertilization in the second growing season. Soil tests should be used to determine whether more fertilizer needs to be added. Do not fertilize cool season grasses in late May through July. Grass that looks yellow might be nitrogen deficient. Nitrogen fertilizer should not be used if the stand contains more than 20 percent legumes.

Cost

Seeding costs range from $200 to $1,000 per acre and average $400 per acre. Maintenance costs range from 15 to 25 percent of initial costs and average 20 percent (USEPA 1993). R.S. Means (2000) indicates the cost of mechanical seeding to be approximately $900 per acre and demonstrates that the coverage cost varies with the seed type, seeding approach and scale (total acreage to be seeded). For example, hydro or water-based seeding for grass is estimated to be $700 per acre, but seeding of *field* grass species is only $540 per acre (Costs include materials, labor, and equipment, with profit and overhead). If surface preparation is required, the installation costs increase. R.S. Means suggests the cost of fine grading, soil treatment, and grassing is approximately $2 per square yard.

Sodding

General Description

Sodding is a permanent erosion control practice that involves laying a continuous cover of grass sod on exposed soils. In addition to stabilizing soils, sodding can reduce the velocity of stormwater runoff. Sodding can provide immediate vegetative cover for critical areas and stabilize areas that cannot be vegetated by seed. It can also stabilize channels or swales that convey concentrated flows and reduce flow velocities. While sodding is not as dependent as seeding on local conditions, it does depend on soil and climatic conditions to be successful. Watering immediately after installation and occasionally until establishment is generally beneficial.

Applicability

Sodding is appropriate for any graded or cleared area that might erode, requiring immediate vegetative cover. Locations particularly well suited to sod stabilization are the following:

- Waterways and channels carrying intermittent flow
- Areas around drop inlets that require stabilization
- Residential or commercial lawns and golf courses where prompt use and aesthetics are important
- Steeply sloped areas

Design and Installation Criteria

Sodding eliminates the need for seeding and mulching and produces more reliable results with less maintenance. Sod can be laid during times of the year when seeded grasses can fail. The sod must be watered frequently within the first few weeks of installation. Some seedbed preparation is recommended, including smoothing to provide contact between the sod and the soil surface and soil testing to determine liming and fertilizer application rates. Because sod provides instantaneous cover, mulches are not typically recommended, but anchoring might be appropriate on steep slopes.

The type of sod selected should be composed of plants adapted to site conditions. Sod composition should reflect environmental conditions as well as the function of the area where the sod will be laid. The sod should be of known genetic origin and be free of noxious weeds, diseases, and insects. The sod should be machine cut at a uniform soil thickness of 15 to 25 mm at the time of establishment (this does not include top growth or thatch). Soil preparation and addition of lime and fertilizer could be needed—soils should be tested to determine whether amendments are needed. Sod should be laid in strips perpendicular to the direction of water flow and staggered in a brick-like pattern. The corners and middle of each strip should be stapled firmly. Jute or plastic netting can be pegged over the sod for further protection against washout during establishment.

Areas to be sodded should be cleared of trash, debris, roots, branches, stones, and clods larger than 2 inches in diameter. Sod should be harvested, delivered, and installed within a period of 36

hours. Sod not transplanted within this period should be inspected and approved before its installation.

Limitations

Compared to seed, sod is more expensive and more difficult to obtain, transport, and store. Care must be taken to prepare the soil and provide adequate moisture before, during, and after installation to ensure successful establishment. If sod is laid on poorly prepared soil or unsuitable surface, the grass will die quickly because it is unable to root. Sod that is not adequately irrigated after installation can cause root dieback because grass does not root rapidly and is subject to drying.

Effectiveness

Sod has been shown to remove between 98 and 99 percent of TSS in runoff (USEPA 1993). It is therefore a highly effective management practice for erosion and sediment control.

Maintenance

Watering is very important to maintain adequate moisture in the root zone and to prevent dormancy, especially within the first few weeks of installation, until it is fully rooted. Mowing should not result in the removal of more than one-third of the shoot. Grass height should be maintained to be 2–3 inches long. After the first growing season, sod might require fertilization or liming.

Permanent, fine turf areas require yearly fertilization. Warm-season grass should be fertilized in late spring to early summer, and cool-season grass in late winter and again in early fall.

Cost

Average installation costs of sod average $0.20 per square foot and range from $0.10 to $1.10 per square foot; maintenance costs are approximately 5 percent of installation costs (USEPA 1993). R.S. Means (2000) indicates the sodding ranges between $250 and $750 per 1,000 square feet for 1-inch deep bluegrass sod on level ground, depending on the size of the area treated (unit costs value are for orders over 8,000 square feet and less than 1000 square feet, respectively). Bent grass sod values range between $350 and $500 per 1,000 square feet; again the lower value is more likely for most construction sites because it is for large area applications. (Costs include materials, labor, and equipment, with profit and overhead).

Mulching

General Description

Mulching is a temporary erosion control practice in which materials such as grass, hay, wood chips, wood fibers, straw, or gravel are placed on exposed or recently planted soil surfaces. Mulching is highly recommended as a stabilization method and is most effective when anchored in place until vegetation is well established. In addition to stabilizing soils, mulching can reduce the velocity of stormwater runoff. When used in combination with seeding or planting, mulching can aid plant growth by holding seeds, fertilizers, and topsoil in place; by preventing birds from eating seeds; by retaining moisture; and by insulating plant roots against extreme temperatures.

Mulch mattings are materials such as jute or other wood fibers that are formed into sheets and are more stable than loose mulch. They can also be easily unrolled during the installation process and are particularly useful in steeper areas or in channels. Netting can be used to stabilize soils while plants are growing, although netting does not retain moisture or insulate against extreme temperatures. Mulch binders consist of asphalt or synthetic materials that are sometimes used instead of netting to bind loose mulches, but these have been found to have limited usefulness.

Applicability

Mulching is often used in areas where temporary seeding cannot be used because of environmental constraints. Mulching can provide immediate, effective, and inexpensive erosion control. On steep slopes and critical areas such as waterways, mulch matting is used with netting or anchoring to hold it in place. Mulches can be used on seeded and planted areas where slopes are steeper than 2:1 or where sensitive seedlings require insulation from extreme temperatures.

Design and Installation Criteria

When possible, organic mulches should be used for erosion control and plant material establishment. Suggested materials include loose straw, netting, wood cellulose, or agricultural silage. All materials should be free of seed, and loose hay or straw should be anchored by applying tackifier, stapling netting over the top, or crimping with a mulch crimping tool. Materials that are heavy enough to stay in place do not need anchoring (for example, gravel). Steepness of the slope will also affect the extent of anchoring the mulch. Other examples include hydraulic mulch products with 100 percent post-consumer paper content, yard trimming composts, and wood mulch from recycled stumps and tree parts. Inorganic mulches such as pea gravel or crushed granite can be used in unvegetated areas.

Mulches might or might not require a binder, netting, or tacking. All straw and loose materials must have a binder to hold them in place. Mulch materials that float away during storms can clog drainage ways and lead to flooding. The extent of binding depends on the type of mulch applied. Effective use of netting and matting material requires firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material. Grading is not necessary before mulching.

There must be adequate coverage, or erosion, washout, and poor plant establishment will result. If an appropriate tacking agent is not applied or if it is applied in an insufficient amount, mulch will not withstand wind and runoff. The channel grade and liner must be appropriate for the amount of runoff or the channel bottom will erode. Also, hydromulch should be applied in spring, summer, or fall to prevent deterioration of the mulch before plants can become established. Table 7-4 presents guidelines for installing mulches, but local conditions could warrant additional requirements.

Effectiveness

Mulching effectiveness varies with the type of mulch used and local conditions such as rainfall and runoff amounts. Percent soil loss reduction for different mulches ranges from 53 to 99.8 percent and associated water velocity reductions range from 24 to 78 percent (Harding 1990). Table 7-5 shows soil loss and water velocity reductions for different mulch treatments.

Table 7-4. Typical Mulching Materials and Application Rates

Material	Rate per acre	Requirements	Notes
Organic mulches			
Straw	1–2 tons	Dry, unchopped, unweathered; avoid weeds.	Spread by hand or machine; must be tacked or tied down.
Wood fiber or wood cellulose	0.5–1 ton		Use with hydroseeder; can be used to tack straw. Do not use in hot, dry weather.
Wood chips	5–6 tons	Air dry. Add fertilizer N, 12 lb/ton.	Apply with blower, chip handler, or by hand. Not for fine turf areas.
Bark	35 yd^3	Air dry, shredded or hammermilled, or chips.	Apply with mulch blower, chip handler, or by hand. Do not use asphalt tack.
Nets and mats			
Jute net	Cover area	Heavy, uniform; woven of single jute yarn. Used with organic mulch.	Withstands water flow.
Excelsior (wood fiber) mat	Cover area		
Fiberglass roving	0.5–1 ton	Continuous fibers of drawn glass bound together with a non-toxic agent.	Apply with compressed air ejector. Tack with emulsified asphalt at a rate of 25-35 gal/1,000 ft2 .

Table 7-5. Measured Reductions in Soil Loss for Different Mulch Treatments

Mulch characteristics	Soil loss reduction (%)	Water velocity reduction (%) relative to bare soil
100% wheat straw/top net	97.5%	73%
100% wheat straw/two nets	98.6%	56%
70% wheat straw/30% coconut fiber	98.7%	71%
70% wheat straw/30% coconut fiber	99.5%	78%
100% coconut fiber	98.4%	77%
Nylon monofilament/two nets	99.8%	74%
Nylon monofilament/rigid/bonded	53.0%	24%
Vinyl monofilament/flexible/bonded	89.6%	32%
Curled wood fibers/top net	90.4%	47%
Curled wood fibers/two nets	93.5%	59%
Antiwash netting (jute)	91.8%	59%
Interwoven paper and thread	93.0%	53%
Uncrimped wheat straw–2,242 kg/ha	84.0%	45%
Uncrimped wheat straw–4,484 kg/ha	89.3%	59%

Source: Harding 1990, as cited in USEPA 1993

Limitations

Mulching, matting, and netting might delay seed germination because the cover changes soil surface temperatures. The mulches themselves are subject to erosion and could be washed away in a large storm if not sufficiently anchored with netting or tacking. Maintenance is necessary to ensure that mulches provide effective erosion control.

Maintenance

Mulches must be anchored to resist wind displacement. Netting should be removed when protection is no longer needed and disposed of in a landfill or composted. Mulched areas should be inspected frequently to identify areas where mulch has loosened or been removed, especially after rain storms. Such areas should be reseeded (if necessary) and the mulch cover replaced immediately. Mulch binders should be applied at rates recommended by the manufacturer. If washout, breakage, or erosion occurs, surfaces should be repaired, reseeded, and remulched, and new netting should be installed. Inspections should be continued until vegetation is firmly established.

Cost

The costs of seed and mulch average $1,500 per acre and range from $800 to $3,500 per acre (USEPA 1993). R.S. Means (2000) estimates the cost of power mulching to be $22.50 per 1,000 square feet, for large volume applications. In addition, hydro- and mechanical seeding are approximately $700 to $900 per acre. Coverage cost varies with the seed type, seeding approach, and scale (total acreage to be seeded). For example, hydro or water-based seeding for grass is estimated to cost $700 per acre, but seeding of *field* grass species is only $540 per acre. (Costs include materials, labor, and equipment, with profit and overhead.) If surface preparation is required, the installation costs increase. R.S. Means (2000) suggests the cost of fine grading, soil treatment, and grassing is approximately $2 per square yard of earth surface area.

Vegetated Buffer Strips

General Description

Vegetated buffers are areas of either natural or established vegetation that are maintained to protect the water quality of neighboring areas. Buffer zones reduce the velocity of stormwater runoff, provide an area for the runoff to permeate the soil, allow ground water recharge, and act as filters to catch sediment. The reduction in velocity also helps to prevent soil erosion.

Applicability

Vegetated buffers can be used in any area that is able to support vegetation, but they are most effective and beneficial on floodplains, near wetlands, along streambanks, and on steep, unstable slopes. They are also effective in separating land use areas that are not compatible and in protecting wetlands or waterbodies by displacing activities that could be sources of nonpoint source pollution.

Design and Installation Criteria

To establish an effective vegetative buffer, the following guidelines should be followed:

- Soils should not be compacted.
- Slopes should be less than 5 percent.
- Buffer widths should be determined after careful consideration of slope, vegetation, soils, depth to impermeable layers, runoff sediment characteristics, type and quantity of stormwater pollutants, and annual rainfall.
- Buffer widths should increase as slope increases.
- Zones of vegetation (native vegetation in particular), including grasses, deciduous and evergreen shrubs, and understory and overstory trees, should be intermixed.
- In areas where flows are concentrated and velocities are high, buffer zones should be combined with other structural or nonstructural BMPs as a pretreatment.

Vegetated strips have been studied extensively, with emphasis placed on their effectiveness in removing sediment and other pollutants. Vegetated strips are most appropriate at sites where sediment loads are relatively low, because high sediment loads will cause large quantities of deposition along the leading edge of the vegetation. This deposition will cause the flow to divert around the vegetation in a concentrated flow pattern, which will cause short-circuiting and greatly reduce removal efficiency. Variability in vegetation density and uniformity often causes similar problems. Removal efficiency depends on a combination of slope, length, and width of the filter; density of the vegetation; sediment characteristics, hydraulics of the flow; and infiltration. The interaction of these variables is complex and prevents the process from being reduced to a simple relationship except on a local basis. For site-specific local conditions, methods have been developed that allow trapping to be related to strip length and slope.

Effectiveness

Considerable data have been collected on the effectiveness of buffer strips for specific conditions. Numerous factors such as infiltration rate, flow depth, slope, dimensions of the buffer, density and type of vegetation, sediment size, and sediment density impact removal rates. Recent studies show that even short vegetative buffers can trap high percentages of sediment and certain chemicals. A significant concern is whether flow is allowed to concentrate, which will greatly reduce the travel time through the buffer and prevent the removal of pollutants.

Several researchers have measured greater than 90 percent reductions in sediment and nitrate concentrations; buffer/filter strips do a reasonably good job of removing phosphorus attached to sediment, but are relatively ineffective in removing dissolved phosphorus (Gillman 1994). However, because the hydraulics of flow through buffer strips are not well defined and can vary considerably by site conditions, it is difficult to consistently estimate the effectiveness of buffer strips.

Limitations

Vegetated buffers require plant growth before they can be effective, and land must be available on which to plant the vegetation. If land costs are very high, buffer zones might not be cost-effective. Although vegetated buffers help to protect water quality, they usually do not effectively mitigate concentrated stormwater flows to neighboring or downstream wetlands.

Maintenance

Keeping the vegetation in vegetated buffers healthy requires routine maintenance, which (depending on species, soil types, and climatic conditions) can include weed and pest control, mowing, fertilizing, liming, irrigating, and pruning. Inspection and maintenance are most important when buffer areas are first installed. Once established, vegetated buffers do not require much maintenance beyond the routine procedures listed earlier and periodic inspections of the areas, especially after any heavy rainfall and at least once a year. Inspections should focus on encroachment, gully erosion, density of vegetation, evidence of concentrated flows through the areas, and any damage from foot or vehicular traffic. If there are more than 6 inches of sediment in one place, it should be removed.

Cost

Conceptual cost estimates for grassed buffer strips can be made on the basis of square footage using unit cost values. R.S. Means (2000) estimates the cost of fine grading, soil treatment, and grassing to be $2 per square yard. This cost estimate is based on application of traditional lawn seed. The cost for field seed is lower than lawn seed, reducing the coverage price. Where gently sloping areas just need to be grassed with acceptable species, the cost can be as low as $0.38 per square yard.

7.2.1.3. Non-Vegetative Stabilization

Non-vegetative practices can also be used during construction to stabilize and protect soil exposed to the erosive forces of water, as well as post-construction to provide a filtration mechanism for stormwater pollutants. Non-vegetative stabilization techniques operate on the same principles as vegetative stabilization, however these practices use a variety of synthetic on natural materials (such as coconut fiber) to stabilize exposed soils. Non-vegetative practices are particularly useful as temporary stabilization measures until vegetative practices have had a chance to become established. The following discussion refers to non-vegetative stabilization as a construction BMP that stabilizes and protects soil from erosion. There are a variety of proprietary and vendor-supplied materials in this category, which are not discussed in detail.

Geotextiles

General Description

Geotextiles are porous fabrics also known as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles are manufactured by weaving or bonding fibers made from synthetic materials such as polypropylene, polyester, polyethylene, nylon, polyvinyl chloride, glass, and various mixtures of these materials. As a synthetic construction material, geotextiles are used for a variety of purposes such as separators, reinforcement, filtration and drainage, and erosion control (USEPA 1992). Some geotextiles are made of

biodegradable materials such as mulch matting and netting. Mulch mattings are jute or other wood fibers that have been formed into sheets and are more stable than normal mulch. Netting is typically made from jute, wood fiber, plastic, paper, or cotton and can be used to hold the mulching and matting to the ground. Netting can also be used alone to stabilize soils while the plants are growing; however, it does not retain moisture or temperature well.

Geotextiles can aid in plant growth by holding seeds, fertilizers, and topsoil in place. Fabrics are relatively inexpensive for certain applications—a wide variety of geotextiles exist to match the specific needs of the site.

Applicability

Geotextiles can be used for erosion control by using it alone. Geotextiles can be used as matting, which is used to stabilize the flow of channels or swales or to protect seedlings on recently planted slopes until they become established. Matting can be used on tidal or streambanks where moving water is likely to wash out new plantings. They can also be used to protect exposed soils immediately and temporarily, such as when active piles of soil are left overnight.

Geotextiles are also used as separators. An example of such a use is geotextile as a separator between riprap and soil. This *sandwiching* prevents the soil from being eroded from beneath the riprap and maintaining the riprap's base.

Design and Installation Criteria

Many types of geotextiles are available. Therefore, the selected fabric should match its purpose. State or local requirements, design procedures, and any other applicable requirements should be considered. In the field, important concerns include regular inspections to determine whether cracks, tears, or breaches are present in the fabric and to identify when repairs should be made. Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material.

Effectiveness

A geotextile's effectiveness depends on the strength of the fabric and proper installation. For example, when protecting a cut slope with a geotextile, it is important to properly anchor the fabric using appropriate length and spacing of wire staples. This will ensure that it will not be undermined by a storm event.

Limitations

Geotextiles (primarily synthetic types) have the potential disadvantage of being sensitive to light and must be protected before installation. Some geotextiles might promote increased runoff and can blow away if not firmly anchored. Depending on the type of material used, geotextiles might need to be disposed of in a landfill, making them less desirable than vegetative stabilization. If the fabric is not properly selected, designed, or installed, the effectiveness can be reduced drastically.

Maintenance

Regular inspections should be made to determine whether cracks, tears, or breaches have formed in the fabric—it should be repaired or replaced immediately. It is necessary to maintain contact between the ground and the geotextile at all times.

Cost

Costs for geotextiles range from $0.50 to $10.00 per square yard depending on the type chosen (SWRPC 1991). Geosynthetic turf reinforcement mattings (TRMs) are widely used for immediate erosion protection and long-term vegetative reinforcement, usually for steeply sloped areas or areas exposed to runoff flows. The Erosion Control Technology Council (a geotextile industry support association) estimates TRMs cost approximately $7.00 per square yard (installed) for channel protection (Lancaster et al. 2002). Channel protection is one of the most demanding of installations (much more demanding than general coverage of denuded area). Honningford (2002) estimated the cost to install a simple soil blanket (or rolled erosion control product), seed, and fertilizer to be $1.00 per square yard.

Erosion Control Matting

General Description

Erosion control mats can be either organic or made from a synthetic material. A wide variety of products exist to match the specific needs of the site. Organic mats are made from such materials as wood fiber, jute net, and coconut coir fiber. Unlike organic matter, synthetic mats are constructed from non-biodegradable materials and remain in place for many years. These organic mats are classified as TRMs and Erosion Control and Revegetation Mats (ECRMs) (USDOT 1995).

Erosion control matting aids in plant growth by holding seeds, fertilizers, and topsoil in place. Matting can be used to stabilize the flow of channels or swales or to protect seedlings on recently planted slopes until they become established. Matting can be used on tidal or streambanks where moving water is likely to wash out new plantings. It can also be used to protect exposed soils immediately and temporarily, such as when active piles of soil are left overnight.

Applicability

Mulch mattings, netting, and filter fabrics are particularly useful in steep areas and drainage swales where loose seed is vulnerable to being washed away or failing to survive dry soil (UNEP 1994). Erosion control mats can also be used to separate riprap and soil. This results in a *sandwiching* effect, maintaining the riprap's base and preventing the soil beneath from being eroded.

Design and Installation Criteria

Matting is especially recommended for steep slopes and channels (UNEP 1994). Many types of erosion control mats are available. Therefore, the selected product should match its purpose. Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil, and erosion will occur underneath the material.

Wood fiber or curled wood mat consists of curled wood with fibers, 80 percent of which are 150 mm or longer, with a consistent thickness and even distribution of fiber over the entire mat. The top side of the mat is covered with a biodegradable plastic mesh. The mat is placed in the channel or on the slope parallel to the direction of flow and secured with staples and check slots. This is applied immediately after seeding operations (USDOT 1995).

Jute net consists of jute yarn, approximately 5 mm in diameter, woven into a net with openings that are approximately 10 by 20 mm (or 0.40 to 0.79 inches). The jute net is loosely laid in the channel parallel to the direction of flow. The net is secured with staples and check slots at intervals along the channel. Placement of the jute net is done immediately after seeding operations (USDOT 1995).

Coconut blankets are constructed of biodegradable coconut fibers that resist decay for 5 to 10 years to provide long, temporary erosion control protection. The materials are often encased in ultraviolet stabilized nets and sometimes have a composite, polypropylene structure to provide permanent turf reinforcement. These materials are best used for waterway stabilization and slopes that require longer periods to stabilize (USDOT 1995).

Within the synthetic mat category are TRMs and ECRMs. TRMs are three-dimensional polymer nettings or monofilaments formed into a mat. They have sufficient thickness (> 13 mm or 0.5 inch) and void space (> 90 percent) to allow for soil filling and retention. The mat acts as a traditional mat to protect the seed and increase germination. As the turf establishes, the mat remains in place as part of the root structure. This gives the established turf a higher strength and resistance to erosion (USDOT 1995).

ECRMs are composed of continuous monofilaments bound by heat fusion or stitched between nettings. They are thinner than TRMs and do not have the void space to allow for filling of soil. They act as permanent mulch and allow vegetation to grow through the mat (USDOT 1995).

Effectiveness

The effectiveness of erosion control matting depends on the strength of the material and proper installation. For example, when protecting a cut slope with an erosion control mat, it is important to anchor the mat properly. This will ensure that it will not be undermined by a storm event.

While erosion control blankets can be effective, their performance varies. Some general trends are that organic materials tend to be the most effective (Harding 1990) and that thicker materials are typically superior (Fifield 1999), but there are exceptions to both of these trends. Information about product testing of blankets is generally lacking. One notable exception is the Texas Department of Transportation, which publishes the findings of their testing program in the form of a list of acceptable and unacceptable materials for specific uses.

Limitations

Erosion control mats (primarily synthetic types) are sensitive to light and for this reason must be protected before installation. Some erosion control mats might cause an increase in runoff or blow away if not firmly anchored. Erosion control mats might need to be properly disposed of in a landfill, depending on the type of material. Effectiveness could be reduced if the fabric is not properly selected, designed, or installed.

Maintenance

Regular inspections are necessary to determine whether cracks, tears or breaches have formed in the fabric. Contact between the ground and erosion control mat should be maintained at all times and trapped sediment removed after each storm event.

Cost

Costs for erosion control mats range from $0.50 to $10.00 per square yard depending on the type chosen (SWRPC 1991). Geosynthetic TRMs are widely used for immediate erosion protection and long-term vegetative reinforcement, usually for steeply sloped areas or areas exposed to runoff flows. The Erosion Control Technology Council (a geotextile industry support association) estimates that TRMs cost approximately $7.00 per square yard (installed) for channel protection (ECTC 2002a). Channel protection is one of the most demanding of installations (much more demanding than general coverage of denuded area). The ECTC estimates the cost to install a simple soil blanket (or rolled erosion control product), seed, and fertilizer to be $1.00 per square yard (ECTC 2002b).

Topsoiling

General Description

Topsoiling is the placement of a surface layer of soil enriched in organic matter over a prepared subsoil to provide a suitable soil medium for vegetative growth on areas with poor moisture, low nutrient levels, undesirable pH, and/or the presence of other materials that would inhibit the establishment of vegetation. Advantages of topsoil include its high organic matter content and friable consistency and its water-holding capacity and nutrient content. The texture and friability of topsoil are usually more conducive to seedling emergence and root growth. In addition to being a better growth medium, topsoil is often less erodible than subsoils, and the coarser texture of topsoil increases infiltration capacity and reduces runoff. During construction, topsoil is often removed from the project area and stockpiled. It is replaced on areas to be grassed or landscaped during the final stages of the project.

Applicability

Conditions where topsoiling applies include the following:

- Where a sufficient supply of quality topsoil is available
- Where the subsoil or areas of existing surface soil present the following problems:
  - The structure, pH, or nutrient balance of the available soil cannot be amended by reasonable means to provide an adequate growth medium for the desired vegetation
  - The soil is too shallow to provide adequate rooting depth or will not supply necessary moisture and nutrients for growth of desired vegetation
  - The soil contains substances toxic to the desired vegetation
- Where high quality turf or ornamental plants are desired
- Where slopes are 2:1 or flatter

Design and Installation Criteria

The topsoil should be uniformly distributed over the subsoil to a minimum compacted depth of 50 mm (2 inches) on slopes steeper than 3:1 and 100 mm (4 inches) on flatter slopes. Thicknesses of 100 to 150 mm are preferred for vegetation establishment via seeding. The topsoil should not be placed while in a frozen or muddy condition or when the subsoil is excessively wet, frozen, or in a condition that is detrimental to proper grading or seedbed preparation. The final surface should be prepared so that any irregularities are corrected and depressions and water pockets do not form. If the topsoil has been treated with soil sterilants, it should not be placed until the toxic substances have dissipated (USDOT 1995). Table 7-6 summarizes the cubic yards of topsoil required for application to various depths.

Table 7-6. Cubic Yards of Topsoil Required for Application to Various Depths

Depth (inches)	Per 1,000 Sq Ft	Per acre
1	3.1	134
2	6.2	268
3	9.3	403
4	12.4	536
5	15.5	670
6	18.6	804

Source: Smolen et al. 1988.

On slopes and areas that will not be mowed, the surface could be left rough after spreading topsoil. A disk can be used to promote bonding at the interface between the topsoil and subsoil (Smolen et al. 1988).

Effectiveness

No information is available describing the effectiveness of applying topsoil as a BMP.

Limitations

Limitations of applying topsoil can include the following:

- Topsoil spread when conditions are too wet, resulting in severe compaction
- Topsoil mixed with too much unsuitable subsoil material, resulting in poor vegetation establishment
- Topsoil contaminated with soil sterilants or chemicals, resulting in poor or no vegetation establishment
- Topsoil not adequately incorporated or bonded with the subsoil, resulting in poor vegetation establishment and soil slippage on sloping areas
- Topsoiled areas not protected, resulting in excessive erosion

Maintenance

Newly topsoiled areas should be inspected frequently until the vegetation is established. Eroded or damaged areas should be repaired and revegetated.

Cost

Topsoiling costs are a function of the price of topsoil, the hauling distance, and the method of application. R.S. Means (2000) reports unit cost values of $3 and $4 per square yard, for 4 and 6 inches of topsoil cover, respectively. This price is for furnishing and placing of topsoil, and includes materials, labor, and equipment, with profit and overhead.

7.2.2. WATER HANDLING PRACTICES

7.2.2.1. Earth Dike

General Description

An earth dike is a temporary or permanent ridge of soil designed to channel water to a desired location. Dikes are used to divert the flow of runoff by constructing a ridge of soil that intercepts and directs the runoff to the desired outlet or alternative management practice, such as a pond. This practice serves to reduce the length of a slope for erosion control and protect downslope areas. An earth dike can be used to prevent runoff from going over the top of a cut and eroding the slope, directing runoff away from a construction site or building; to divert clean water from a disturbed area; or to reduce a large drainage area into a more manageable size. Dikes should be stabilized with vegetation after construction (NAHB, No Date).

Applicability

Earth dikes are applicable to all areas; the size of the dike is correlated to the size of the drainage area (NAHB, No Date).

Design and Installation Criteria

The location of dikes should take into consideration outlet conditions, existing land use, topography, length of slope, soils, and development plans. The capacity of earth dikes and diversions should be suitable for the area that is being protected, including adequate freeboard, or extra depth that is added as a safety margin. For homes, schools, and industrial buildings, the recommended design frequency storm is 50 years and the freeboard is 0.5 feet (NAHB, No Date).

Earth dikes can be employed as a perimeter control. For small sites, a compacted 2-foot-tall dike is usually suitable, if hydroseeded. Larger dikes will actually divert runoff to another portion of the site, usually to a downstream sediment trap or basin. Therefore, the designer should ensure that they have the capacity for the 10-year storm event and that the channel created behind the dike is properly stabilized to prevent erosion (Brown and Schueler 1997). In addition, the downstream structure must be sized to handle the flow from the dike. Dikes should be designed using standard hydrologic and hydraulic calculations and certified by a professional hydrologist or engineer. Diversion dikes should be installed before the majority of the soil-disturbing activity. As soon as the dike form is completed, it should be machine compacted, fertilized, and either seeded and mulched or sodded. Excavated materials should be properly stockpiled for

future use or disposed of properly. Dikes should have an outlet that functions with a minimum of erosion. Depending on site conditions and outlet structures, the runoff directed by dikes might need to be conveyed to a sediment-trapping device, such as a sediment basin or detention pond. As grades increase over 4 percent, geotextile material or sod could be required to control erosion. Slopes greater than 8 percent could require riprap. Dikes can be removed when stabilization of the drainage area and outlet are complete (NAHB, No Date). Dike design criteria must incorporate site-specific conditions, as dimensions depend on expected flows, soil types, and climatic conditions. All of these inputs vary tremendously over different sections of the country.

Effectiveness

No information has been found on the effectiveness of earth dikes used as BMPs, although terraces often have sediment removal rates of up to 90 percent.

Limitations

An erosion-resistant lining in the channel might be needed to prevent erosion in the channel caused by excessive grade. In addition, the channel should be deepened and the grade realigned if there is overtopping caused by sediment in the channel where the grade decreases or reverses. If overtopping occurs at low points in the ridge where the diversion crosses the shallow draw, the ridge should be reconstructed with a positive grade toward the outlet at all points. Finally, if there is erosion at the outlet, an outlet stabilization structure should be installed; if sedimentation occurs at the diversion outlet, a temporary sediment trap should be installed.

Maintenance

An earth dike should be inspected for signs of erosion after every major rain event. Any repairs and/or revegetation should be completed promptly (NAHB, No Date). The following actions can be taken to properly maintain an earth dike:

- Remove debris and sediment from the channel immediately after the storm event.
- Repair the dike to its original height.
- Check outlets and make necessary repairs to prevent gully formation.
- Clean out sediment traps when they are 50 percent full.
- Once the work area has been stabilized, remove the diversion ridge, fill and compact the channel to blend with the surrounding area, and remove sediment traps, disposing of unstable sediment in a designated area.

Cost

The cost of an earth dike depends on the design and materials used. Small dikes can cost approximately $2.00 per linear foot, while larger dikes can cost approximately $2.00 per cubic yard. Earth dikes can cost approximately $4.50 per linear foot (NAHB, No Date).

An alternative means to estimate conceptual costs for earthen dikes is to use unit cost values and a rough estimate of the quantities needed. Shallow trenching (1 to 4 feet deep) with a backhoe in areas not requiring dewatering can be performed for $4 to $5 per cubic yard of removed material

(R.S. Means 2000). On the basis of this value, $2 per linear foot provides for 11 square feet of flow area and $4.50 per linear foot provides for 24 square feet of flow area. This suggests that the size of the dike is required before specifying a cost, which requires a site-specific hydrologic evaluation. On the basis of standards for Virginia, most small drainage areas (made up of 5 acres or less) require 18-inch tall diversion dikes with a 4.5-foot base. Assuming the excavation volume equals the volume of the dike, the resulting excavation volume is approximately 7 cubic feet per linear foot, which (conservatively) equates to $1.03 to $1.30 per linear foot for construction costs.

If the earthen dikes are to be permanent, additional costs are incurred to vegetate the dike. R.S. Means (2000) estimates the cost of fine grading, soil treatment, and grassing is approximately $2 per square yard of earth surface area. This adds approximately $6 per linear foot of dike. Where gently sloping areas just need to be grassed with acceptable species, the cost can be as low as $0.38 per square yard.

7.2.2.2. Temporary Swale

General Description

The term swale (grassed channel, dry swale, wet swale, biofilter) refers to a series of vegetated, open channel management practices designed specifically to treat and attenuate stormwater runoff for a specified water quality volume. As stormwater runoff flows through these channels, it is treated by filtering through the vegetation in the channel, filtering through a subsoil matrix, and/or infiltrating into the underlying soils. Variations of the grassed swale include the grassed channel, dry swale, and wet swale. The specific design features and methods of treatment differ in each of these designs, but all are improvements on the traditional drainage ditch and incorporate modified geometry and other features for use of the swale as a treatment and conveyance practice.

Applicability

Grassed swales can be applied in most situations with some restrictions and are very well suited for treating highway or residential road runoff because they are linear practices. Perimeter dikes/swales should be limited to a drainage area of no more than 0.8 hectare and usually work best on gently sloping terrain. Perimeter dikes might not work well on moderate slopes, and they should never be established on slopes exceeding 20 percent (UNEP 1994).

Regional Applicability. Grassed swales can be applied in most regions of the country. In arid and semi-arid climates, however, the value of these practices needs to be weighed against the water needed to irrigate them.

Ultra-Urban Areas. Ultra-urban areas are densely developed urban areas in which little pervious surface exists. Grassed swales are generally not well suited to ultra-urban areas because they require a relatively large area of pervious surface.

Stormwater Hot Spots. Stormwater hot spots are areas where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those commonly found in stormwater. A typical example is a gas station or convenience store. With the exception of the dry swale design, hot spot runoff should not be directed toward grassed channels. These

practices either infiltrate stormwater or intersect the ground water, making use of the practices for hot spot runoff a threat to ground water quality.

Stormwater Retrofit. A stormwater retrofit is a stormwater management practice (usually structural), put into place after development has occurred, to improve water quality, protect downstream channels, reduce flooding, or meet other specific objectives. One retrofit opportunity using grassed swales modifies existing drainage ditches. Ditches have traditionally been designed to convey stormwater away from roads as quickly as possible. In some cases, it might be possible to incorporate features to enhance pollutant removal or infiltration such as check dams (for example, small dams along the ditch that trap sediment, slow runoff, and reduce the longitudinal slope). Because grassed swales cannot treat a large area, using this practice to retrofit an entire watershed would be expensive because of the number of practices needed to manage runoff from a significant amount of the watershed's land area.

Cold Water (Trout) Streams. Grassed channels are a good treatment option in watersheds that drain to cold water streams. These practices do not retain water for a long period of time and often induce infiltration. As a result, standing water will not typically be subjected to warming by the sun in these practices.

Design and Installation Criteria

Temporary swales should be designed using standard hydrologic and hydraulic calculations. Designs should be certified by a professional hydrologist, engineer, or other appropriate professional.

Perimeter dikes/swales should be established before any major soil-disturbing activity takes place. Dikes should be compacted with construction equipment to the design height plus 10 percent to allow for settlement. If they are to remain in place for longer than 10 days, they should be stabilized using vegetation, filter fabric, or other material. Diverted water should be directed to a sediment trap or other sediment treatment area (UNEP 1994).

In addition to the broad applicability concerns described above, designers need to consider conditions at the site level. In addition, they need to incorporate design features to improve the longevity and performance of the practice while minimizing the maintenance burden.

Siting Considerations

In addition to considering the restrictions and adaptations of grassed swales to different regions and land uses, designers must ensure that this management practice is feasible at the site in question. Depending on the design option, grassed channels can be highly restricted practices based on site characteristics.

Drainage Area. Grassed swales generally should treat small drainage areas of less than 5 acres. If the practices are used to treat larger areas, the flows and volumes through the swale become too large to achieve stormwater treatment through infiltration and filtration.

Slope. Grassed swales should be used on sites with relatively flat slopes (less than 4 percent). Runoff velocities within the channel become too high on steeper slopes. This can cause erosion and does not allow for infiltration or filtration in the swale.

Soils /Topography. Grassed swales can be used on most soils, with some restrictions on the most impermeable soils. In the dry swale, a fabricated soil bed replaces on-site soils to ensure that runoff is filtered as it travels through the soils of the swale.

Ground Water. The depth to ground water depends on the type of swale used. In the dry swale and grassed channel options, designers should separate the bottom of the swale from the ground water by at least 2 feet to prevent a moist swale bottom or contamination of ground water. In the wet swale option, treatment is enhanced by a wet pool, which is maintained by intersecting the water table.

Design Considerations

Although the grass swale has different design variations, including the grassed channel, dry swale, and wet swale, some design considerations are common to all three. One similarity is their cross-sectional geometry. Swales should generally have a trapezoidal or parabolic cross-section with relatively flat side slopes (flatter than 3:1). Designing the channel with flat side slopes maximizes the wetted perimeter, which is the length along the edge of the swale's cross-section where runoff flowing through the swale is in contact with the vegetated sides and bottom of the swale. Increasing the wetted perimeter slows runoff velocities and provides more contact with vegetation to encourage filtering and infiltration. Another advantage to flat side slopes is that runoff entering the grassed swale from the side receives some pretreatment along the side slope. The flat bottom of all three should be between 2 and 8 feet wide. The minimum width ensures an adequate filtering surface for water quality treatment, and the maximum width prevents braiding (the formation of small channels within the swale bottom).

Another similarity among all three designs is the type of pretreatment needed. A small forebay should be used at the inflow area of the swale to trap incoming sediments. A pea gravel diaphragm (a small trench filled with river run gravel) should be used to pretreat runoff entering along the sides of the swale.

Two other features designed to enhance the treatment ability of grassed swales are a flat longitudinal slope (generally between 1 and 2 percent) and a dense vegetative cover in the channel. The flat slope helps to reduce the velocity of flow in the channel. Dense vegetation also helps reduce velocities, protect the channel from erosion, and act as a filter to treat stormwater runoff. During construction, it is important to stabilize the channel before the turf has been established, either with a temporary grass cover or with the use of natural or synthetic erosion control products.

In addition to treating runoff for water quality, grassed swales need to convey larger storms safely. Typical designs allow the runoff from the 2-year storm to flow through the swale without causing erosion. Swales should also have the capacity to pass larger storms (typically a 10-year storm) safely.

The length of the swale necessary to infiltrate runoff can be calculated by using a mass balance of runoff and infiltration for a triangular-shaped cross-sectional area.

Design Variations

The following discussion identifies three different variations of open channel practices, including the grassed channel, the dry swale, and the wet swale.

Grassed Channel. (Discussed in more length in subsection 7.5.1.2.1) Of the three grassed swale designs, grassed channels are the most similar to a conventional drainage ditch, with the major differences being flatter side slopes and longitudinal slopes and a slower design velocity for water quality treatment of small storm events. Of all the grassed swale options, grassed channels are the least expensive, but they also provide the least reliable pollutant removal performance. The best application of a grassed channel is as pretreatment to other stormwater treatment practices.

One major difference between the grassed channel and most of the other structural practices is the method used to size the practice. Most water quality practices for stormwater management are sized by volume. This method sets the volume available in the practice equal to the water quality volume, or the volume of water to be treated in the practice. The grassed channel, on the other hand, is a flow rate-based design. On the basis of the peak flow from the water quality storm (this varies from region to region but a typical value is the 1-inch storm), the channel should be designed so that runoff takes, on average, 10 minutes to flow from the top to the bottom of the channel. A procedure for this design can be found in *Design of Storm Water Filtering Systems* (CWP 1996).

Dry Swales. Dry swales are similar in design to bioretention areas. These practices incorporate a fabricated soil bed into their design. The existing soil is replaced with a sand/soil mix that meets minimum permeability requirements. An underdrain system is used under the soil bed. This system is a gravel layer that encases a perforated pipe. Stormwater treated in the soil bed flows through the bottom into the underdrain, which conveys this treated stormwater to the storm drain system. Dry swales are a relatively new design, but studies of swales with a native soil similar to the man-made soil bed of dry swales suggest high pollutant removal rates.

Wet Swales. Wet swales intersect the ground water and behave similarly to a linear wetland cell. This design variation incorporates a shallow permanent pool and wetland vegetation to provide stormwater treatment. This design also has potentially high pollutant removal. One disadvantage of the wet swale is that its use in residential or commercial settings is unpopular because the shallow standing water in the swale is sometimes viewed as a potential nuisance by property owners.

Regional Variations

Cold Climates. In cold or snowy climates, swales can serve a dual purpose by acting as both a snow storage/treatment practice and a stormwater management practice. This dual purpose is particularly relevant when swales are used to treat road runoff. If used for this purpose, swales should incorporate salt-tolerant vegetation, such as creeping bentgrass.

Arid Climates. In arid or semi-arid climates, swales should be designed with drought-tolerant vegetation, such as buffalo grass. As pointed out in the Applicability discussion, the value of vegetated practices for water quality needs to be weighed against the cost of water needed to maintain them in arid and semi-arid regions.

Effectiveness

Swales act to control peak discharges in two ways. First, the grass reduces runoff velocity, depending on the length and slope of the swale. Second, a portion of the stormwater runoff volume passes through the swale and infiltrates into the soil. Table 7-7 summarizes grassed swale pollutant removal efficiencies.

Table 7-7. Grassed Swale Pollutant Removal Efficiency Data

Study	Grassed swale removal efficiencies						
	TSS	**TP**	**TN**	**NO_3**	**Metals**	**Bacteria**	**Type**
Goldberg 1993	67.8	4.5	--	31.4	42–62	-100	Grassed channel
Seattle Metro and Washington Department of Ecology 1992	60	45	--	-25	2–16	-25	Grassed channel
Seattle Metro and Washington Department of Ecology 1992	83	29	--	-25	46–73	-25	Grassed channel
Wang et al. 1981	80	--	--	--	70–80	--	Dry swale
Dorman et al. 1989	98	18	--	45	37–81	--	Dry swale
Harper 1988	87	83	84	80	88–90	--	Dry swale
Kercher, Landon, and Massarelli 1983	99	99	99	99	99	--	Dry swale
Harper 1988	81	17	40	52	37–69	--	Wet swale
Koon 1995	67	39	--	9	-35 to 6	--	Wet swale
Yousef et al. 1985	--	8	13	11	14–29	--	Drainage channel
Yousef et al. 1985	--	-19.5	8	2	41–90	--	Drainage channel
Welborn and Veenhuis 1987	0	-25	-25	-25	0	--	Drainage channel
Yu, Barnes, and Gerde 1993	68	60	--	--	74	--	Drainage channel
Dorman et al. 1989	65	41	--	11	14–55	--	Drainage channel
Pitt and McLean 1986	0	--	0	--	0	0	Drainage channel
Oakland 1983	33	-25	--	--	20–58	0	Drainage channel
Dorman et al. 1989	-85	12	--	-100	14–88	--	Drainage channel

Limitations

Common problems associated with swales include excessive erosion along unlined channels (usually because of excessive grade), erosion or sedimentation at the outlet point, or overtopping of the dike at low points (UNEP 1994).

Additional limitations of the grass swale include the following:

- Grassed swales cannot treat a very large drainage area.

- Swales do not appear to be effective at reducing bacteria.
- Wet swales can become a nuisance because of mosquito breeding.
- If designed improperly (for example, improper slope), grassed channels will have very little pollutant removal.
- A thick vegetative cover is needed for these practices to function properly.

Maintenance

As with any BMP, swales must be maintained to continue to effectively remove pollutants. Maintenance can include occasional mowing, fertilizing, and liming. In addition, any areas that become damaged by erosion should be immediately repaired and replanted. The swales should be protected from concentrated flows and be checked periodically for downstream obstructions.

Cost

To produce a conceptual cost approximation, grassed channel construction costs can be developed using unit cost values. Shallow trenching (1 to 4 feet deep) with a backhoe in areas not requiring dewatering can be performed for $4 to $5 per cubic yard of removed material (R.S. Means 2000). Assuming no disposal costs (i.e., excavated material is placed on either side of the trench), only the cost of fine grading, soil treatment, and grassing (approximately $2 per square yard) should be added to the trenching cost to approximate the total construction cost. Site-specific hydrologic analysis of the construction site is necessary to estimate the channel conveyance requirement and the desired retention time in the swale. It is not unusual to have flows on the order of 2 to 4 cfs per acre served.

For a design channel velocity of 1 foot per second, the resulting range in the channel cross-section area can be as low as 2 but as high as 4 square feet per acre drained. If the average channel flow depth is 1 foot, then the low estimate for grassed channel installation is $0.74 per square foot of channel bottom per acre served per foot of channel length. The high estimate is $1.48 per square foot of channel bottom per acre served per foot of channel length.

Table 7-8 summarizes additional costs of grass swales.

Table 7-8. Average Annual Operation and Maintenance Costs for a Grass Swale

Component	Estimated unit cost ($)	$ for swale size: 0.5m deep 0.3m bottom width 3m top width	$ for swale size: 1m deep 1m bottom width 7m top width	Comments
Mowing	0.89/100 m^2	145.0	241.0	Mow 2-3 times per year
General grass care	8.8/100 m^2	162.98	274.0	Grass maintenance area is (top width + 3 m) x length
Debris/litter removal	0.51/m^2	93.0	93.0	
Reseeding/ fertilization	0.35/m^2	5.9	10.37	Area revegetated is 1% of maintenance area per year

Component	Estimated unit cost ($)	$ for swale size: 0.5m deep 0.3m bottom width 3m top width	$ for swale size: 1m deep 1m bottom width 7m top width	Comments
Inspection and general administration	0.74/m^2	231.0	231.0	Inspection once per year
TOTAL		638.0	850.0	

Source: Ellis 1998.

7.2.2.3. Temporary Storm Drain Diversion

General Description

A temporary storm drain diversion is a pipe that reroutes an existing drainage system to discharge flow into a sediment trap or basin. This practice reduces the amount of sediment-laden runoff from construction sites that enters waterbodies without treatment. Temporary storm drain diversions can be used when a permanent stormwater drainage system has not yet been installed. It should be recognized that diversion channels can also be installed but are not considered in the following discussion.

Applicability

A temporary storm drain diversion should be used to temporarily redirect discharge to a permanent outfall and should remain in place until the area draining to the storm sewer is no longer disturbed. Temporary storm drain diversions can also be combined with other structures and used as a sediment-trapping device when the completion of a permanent outfall has been delayed; alternatively, a sediment trap can be placed below a permanent outfall to remove sediment before the final flow discharge.

Design and Installation Criteria

Because the diversion is only temporary, the layout of piping and the overall impact of the diversion's installation on post-construction drainage patterns must be considered. Once construction is completed, the temporary diversion should be moved to restore the original system. The following activities should be done at this time:

- The storm drain should be flushed before the sediment trap is removed.
- The outfall should be stabilized.
- Graded areas should be restored.
- State or local requirements should be checked for more detailed requirements and an appropriate professional should certify that the design meets local hydrologic and hydraulic requirements.

Effectiveness

If installed properly to capture the bulk of runoff from a construction site, temporary storm drain diversions can be effective in reducing the discharge of sediment-laden, untreated water to

waterbodies. When used in combination with other erosion and sediment control practices such as minimized clearing or vegetative and chemical stabilization, the level of pollution from a construction site can be substantially reduced or eliminated.

Limitations

Installation of a temporary storm drain diversion can result in the disturbance of existing storm drainage patterns. Care must be taken to ensure that the original system is properly restored once the temporary system is removed. The most common source of problems is excessive velocity at the outlet. Installation of an outlet stabilization structure is typically required and can be constructed of riprap, reinforced concrete, geotextile linings, or a combination.

Maintenance

Once installed, temporary storm drain diversions require very little maintenance. Frequent inspection and maintenance of temporary storm drain systems, especially after large storms, should ensure that pipe clogging does not occur and that runoff from the site is being successfully diverted. After removal of the temporary diversion, the permanent storm drain system should be carefully inspected to ensure that drainage patterns have not been altered by the temporary system.

Cost

Depending on the size of the construction site, a temporary storm drain diversion can be costly. Costs include those associated with materials needed to construct the diversion and sediment trap or basin (mainly piping, concrete, and gravel), and also labor costs for installation and removal of the system, all of which could involve excavation, re-grading, and inspections. On the basis of the variety of conditions that can affect storm drain diversion designs, typical costs per installation are not presented here. However, site-specific cost estimates can be produced using unit cost values along with site-specific quantity estimates. R.S. Means (2000) indicates a range of pipe costs for surface placement, between $5.00 per linear foot for 4-inch diameter PVC piping, and $9.20 per linear foot for 10-inch diameter PVC piping. On construction sites, temporary inlets and outlets are usually formed by small rock-lined depressions. Assuming 4 cubic yards of crushed rock (1.5-inch mean diameter) per opening, an inlet and outlet combine to add approximately $200 per pipe installation, based on $25 per cubic yard of stone (R.S. Means 2000).

7.2.2.4. Pipe Slope Drain

General Description

Pipe slope drains are used to reduce the risk of erosion on slopes by discharging runoff to stabilized areas. Consisting of a metal or plastic flexible pipe if temporary, or pipes or paved chutes if permanent, these drains carry surface runoff from the top to the bottom of a slope that has already been damaged by erosion or is at high risk for erosion. These drains are also used to drain saturated slopes that have the potential for soil slides.

Applicability

Temporary slope drains can be used on most disturbed slopes to eliminate gully erosion problems resulting from concentrated flows discharged at a diversion outlet. Slope drains should be used as a temporary measure for as long as the drainage area remains disturbed. They will need to be moved once construction is complete and a permanent storm drainage system is established. Appropriate restoration measures will then need to be taken, such as adjusting grades and flushing sediment from the pipe before it is removed (UNEP 1994).

Design and Installation Criteria

Pipe slope drains can be placed directly on the ground or buried under the surface. The inlet should be at the top of the slope and should be fitted with an apron, attached with a watertight connection. Filter cloth should be placed under the inlet to prevent erosion. Flexible pipes, which are positioned on top of the ground, should be securely anchored with grommets placed 10 feet on center. The outlet at the bottom of the slope should also be stabilized with riprap. The riprap should be placed along the bottom of a swale that leads to a sediment-trapping structure or another stabilized structure.

Slope drain pipe sizes are based on drainage area and the size of the design storm. Pipes should be connected to a diversion ridge at the top of the slope by covering it with compacted fill material where it passes through the ridge. Discharge from a slope drain should be to a sediment trap, sediment basin, or other stabilized outlet (UNEP 1994).

Pipe slope drains should be installed perpendicular to the contour down the slope, and the design should be able to handle the peak runoff for the 10-year storm. Recommendations of slope drain diameter are summarized in Table 7-9 (NAHB, No Date).

Recently graded slopes that do not have permanent drainage measures installed should have a temporary slope drain and a temporary diversion installed. A temporary slope drain used in conjunction with a diversion conveys stormwater flows and reduces erosion until permanent drainage structures are installed.

The following are design recommendations for temporary slope drains:

- The drain should consist of heavy-duty material manufactured for the purpose and have grommets for anchoring at a spacing of 10 feet or less.
- Minimum slope drain diameters should be observed for varying drainage areas.

Table 7-9. Recommended Pipe/Tubing Sizes for Slope Drains

Maximum drainage area (acres)	Pipe/tubing diameter[1] (inches)	Pipe/tubing diameter[2] (inches)	Pipe/tubing diameter[3] (inches)
0–0.5			
0.5	12	12	8
0.75			10
1.0			12
1.5	18	18	Individually designed

Maximum drainage area (acres)	Pipe/tubing diameter[1] (inches)	Pipe/tubing diameter[2] (inches)	Pipe/tubing diameter[3] (inches)
2.5	21		
3.5	24	24	
5.0	30		

[1] UNEP 1994.
[2] USDOT 1995.
[3] IDNR 1992.

- The entrance to the pipe should consist of a standard flare end section of corrugated metal. The corrugated metal pipe should have watertight joints at the ends. The rest of the pipe is typically corrugated plastic or flexible tubing, although for flatter, shorter slopes, a polyethylene-lined channel is sometimes used.
- The height of the diversion at the pipe should be the diameter of the pipe plus 0.5 foot.
- The outlet should be placed at a reinforced or erosion-resistant location.

Temporary slope drains should be designed to adequately convey runoff for a desired frequency storm, typically either 2 years or 10 years depending on local regulations. Both the size and the spacing can be determined on the basis of the contributing drainage area. Drains are spaced at intervals corresponding to the specified drainage areas. For larger drainage areas and critical locations, the drains should be sized on an individual basis (USDOT 1995).

Slope drains should be constructed in conjunction with diversion berms such that the berms are not overtopped. At the pipe inlet, the top of the berm should be a minimum of 300 mm (11.81 inches) higher than the top of the pipe. The entrance should be constructed of a standard flared end section or a Tee section if designed properly. The entrance should be placed in a sump that is depressed 150 mm (5.90 inches) (USDOT 1995).

The outlet of the slope drain must be protected with a riprap apron. If the slope drain is draining a disturbed area and sufficient right-of-way is available, the drain could empty into a sediment trap (USDOT 1995). Table 7-10 summarizes slope drain characteristics.

Effectiveness

There is no information on the effectiveness of pipe slope drains.

Table 7-10. Slope Drain Characteristics

Capacity	2-year frequency, 24-hour-duration storm event
Material	Strong, flexible pipe, such as heavy duty, nonperforated, corrugated plastic
Inlet section	Standard *T* or *L* flared-end section with metal toe plate
Connection to ridge at top of slope	Compacted fill over pipe with minimum dimensions, 1.5-foot depth, 4-foot top width, and 6 inches higher than ridge
Outlet	Pipe extends beyond toe of slope and discharges into a sediment trap or basin unless contributing drainage area is stable

Source: IDNR 1992.

Limitations

The area drained by a temporary slope drain should not exceed 5 acres. Physical obstructions substantially reduce the effectiveness of the drain. A common slope drain problem is overtopping of the inlet due to an undersized or blocked pipe, or erosion at the outlet point due to insufficient protection (UNEP 1994). Other concerns are failures from overtopping because of inadequate pipe inlet capacity and reduced diversion channel capacity and ridge height.

- Washout—A washout along a pipe due to seepage and piping can be caused by inadequate compaction, insufficient fill, or installation that might be too close to the edge of the slope.
- Overtopping caused by undersized or blocked pipe—The drainage area might be too large.
- Overtopping caused by improper grade of channel and ridge—A positive grade should be maintained.
- Overtopping caused by poor entrance conditions and trash buildup at the pipe inlet—Deepen and widen the channel at the pipe entrance and frequently inspect and clear the inlet.
- Erosion at outlet—The pipe should be extended to a stable grade or an outlet stabilization structure is needed.
- Displacement or separation of pipe—The pipe should be tied down and the joints secured.

Maintenance

Pipe slope drains must be inspected after each significant runoff event for evidence of erosion and uncontrolled runoff. Any repairs to the drain should be made immediately. Significant amounts of sediment trapped at the outfall should also be removed in a timely manner and disposed of properly (NAHB, No Date).

The following actions should be taken to properly maintain a pipe slope drain (IDNR 1992):

- Inspect slope drains and supporting diversions once a week and after every storm event.
- Check the inlet for sediment or trash accumulation; clear and restore to proper entrance condition.
- Check the fill over the pipe for settlement, cracking, or piping holes; repair immediately.
- Check for holes where the pipe emerges from the dike; repair immediately.
- Check the conduit for evidence of leaks or inadequate anchoring; repair immediately.
- Check the outlet for erosion or sedimentation; clean and repair, or extend if necessary.
- Once slopes have been stabilized, remove the temporary diversions and slope drains, and stabilize all disturbed areas.

Cost

The cost of pipe slope drains and their installation varies with the design and materials used. Site-specific cost estimates can be produced using unit cost values with site-specific quantity estimates.

R.S. Means (2000) indicates a range of pipe costs for surface placement between $5.00 per linear foot for 4-inch diameter PVC piping, and $9.20 per linear foot for 10-inch diameter PVC piping. On construction sites, temporary inlets and outlets are usually formed by small rock-lined depressions. Assuming 4 cubic yards of crushed rock (1.5-inch mean diameter) per opening, an inlet and outlet together add approximately $200 per pipe installation, based on $25 per cubic yard of stone (R.S. Means 2000).

7.2.2.5. Stone Check Dam

General Description

A check dam is a small temporary barrier constructed across a drainage channel or swale to reduce the velocity of the flow. By reducing the flow velocity, the erosion potential is reduced, detention times are lengthened, and more sediments are able to settle out of the water column. Check dams can be constructed of stone, gabions, treated lumber, or logs (NAHB, No Date).

Check dams are inexpensive and easy to install. They can be used permanently to settle sediment, reduce the velocity of runoff, and provide aeration. However, the use of check dams in a channel should not be a substitute for the use of other sediment-trapping and erosion control measures. As with most other temporary structures, check dams are most effective when used in combination with other stormwater and erosion and sediment control measures.

Applicability

Check dams are commonly used (1) in channels that are degrading but where permanent stabilization is impractical because of their short period of usefulness and (2) in eroding channels where construction delays or weather conditions prevent timely installation of erosion-resistant linings (IDNR 1992).

Check dams are also useful in steeply sloped swales, in small channels, in swales where adequate vegetative protection cannot be established, or in swales or channels that will be used for a short period of time where it is not practical to line the channel or implement other flow control practices (USEPA 1993). In addition, check dams are appropriate where temporary seeding has been recently implemented but has not had time to fully develop and take root. The contributing drainage area should range from 2 to 10 acres. Check dams should be used only in small open channels that will not be overtopped by flow once the dams are built and should not be built in stream channels, either intermittent or perennial (UNEP 1994).

Design and Installation Criteria

Check dams can be constructed from a number of different materials. Most commonly, they are made of rock, logs, sandbags, or straw bales. Rock or stone is often preferred because of its cost-effectiveness and longevity. Logs and straw bales will decay with time and are not recommended because they can cause waterway blockage if they fail. When using rock or stone, the material diameter should be 2 to 15 inches. The stones should be extended 18 inches beyond the banks, and the side slopes should be 2:1 or flatter. Lining the upstream side of the dam with a foot of 1- to 2-inch gravel can improve the efficiency of the dam (NAHB, No Date). Logs should have a diameter of 6 to 8 inches. Regardless of the material used, careful construction of a check dam is necessary to ensure its effectiveness.

The distance between rock check dams will vary depending on the slope of the ditch, with closer spacing when the slope is steeper. The size of stone used in the check dam should also vary with the expected design velocity and discharge. As velocity and discharge increase, the rock size should also increase. For most rock check dams, 3 inches to 12 inches is a suitable stone size. To improve the sediment-trapping efficiency of check dams, a filter stone can be applied to the upstream face. A well-graded coarse aggregate that is less than 1 inch in size can be used as a filter stone.

All check dams should have a maximum height of 3 feet. The center of the dam should be at least 6 inches lower than the edges. This design creates a weir effect that helps to channel flows away from the banks and prevent further erosion. Additional stability can be achieved by implanting the dam material approximately 6 inches into the sides and bottom of the channel (VDCR 1995).

When installing more than one check dam in a channel, outlet stabilization measures should be installed below the final dam in the series. Because this area is likely to be vulnerable to further erosion, riprap or some other stabilization measure is highly recommended.

Effectiveness

Field experience has shown that rock check dams are more effective than silt fences or straw bales to stabilize wet-weather ditches (VDCR 1995). Straw bales have been shown to have very low trapping efficiencies and should not be used for check dams. For long channels, check dams are most effective when used in a series, creating multiple barriers to sediment-laden runoff.

Limitations

Check dams should not be used in perennial streams unless approved by an appropriate regulatory agency (USEPA 1992; VDCR 1995). Because the primary function of check dams is to slow runoff in a channel, they should not be used as a stand-alone substitute for other sediment-trapping devices. Also, leaves have been shown to be a significant problem, as they clog check dams; therefore, increased inspection and maintenance might be necessary in the fall. Common problems with check dams include channel bypass and severe erosion when overtopped and ineffectiveness due to accumulated sediment and debris. When designing check dams, the fact that they will reduce the capacity of a channel to transmit stormwater runoff and thus will need to be sized appropriately should be taken into account (UNEP 1994). The check dam could also kill grass linings in the channel if the water level remains high after it rains or if there is significant sedimentation. In addition, a check dam might reduce the hydraulic capacity of the channel and create turbulence, which erodes the channel banks (NAHB, No Date).

Maintenance

Check dams should be inspected periodically to ensure that they have not been repositioned as a result of stormwater flow. In addition, the center of a check dam should always be lower than its edges. Additional stone might have to be added to maintain the correct height. Sediment should not be allowed to accumulate to more than half the original dam height. Any required maintenance should be performed immediately. When check dams are removed, care must be taken to remove all dam materials to ensure proper flow within the channel. The channel should subsequently be seeded for stabilization (NAHB, No Date).

Cost

The cost of check dams varies according to the material used for construction and the width of the channel to be dammed. In general, it is estimated that check dams constructed of rock cost about $100 per dam (USEPA 1992). Brown and Schueler (1997) estimated that a rock check dam would cost approximately $62 per installation, including the cost for filter fabric bedding. Other materials, such as logs and sandbags, might be a less expensive alternative, but they could require higher maintenance costs.

7.2.2.6. Lined Waterways

General Description

Lined channels convey stormwater runoff through a stable conduit. Vegetation lining the channel reduces the flow velocity of concentrated runoff. Lined channels usually are not designed to control peak runoff loads by themselves and are often used in combination with other BMPs such as subsurface drains and riprap stabilization. Where moderately steep slopes require drainage, lined channels can include excavated depressions or check dams to enhance runoff

storage, decrease flow rates, and enhance pollutant removal. Peak discharges can be reduced through temporary detention in the channel. Pollutants can be removed from stormwater by filtration through vegetation, by deposition, or in some cases by infiltration of soluble nutrients into the soil. The degree of pollutant removal in a channel depends on the residence time of the water in the channel and the amount of contact with vegetation and the soil surface, but pollutant removal is not generally the major design criterion.

Often construction increases the velocity and volume of runoff, which causes erosion in newly constructed or existing urban runoff conveyance channels. If the runoff during or after construction will cause erosion in a channel, the channel should be lined or flow control practices instituted. The first choice of lining should be grass or sod because this reduces runoff velocity and provides water quality benefits through filtration and infiltration. If the velocity in the channel would erode the grass or sod, one can use riprap, concrete, or gabions (USEPA 2000). Geotextile materials can be used in conjunction with either grass or riprap linings to provide additional protection at the soil-lining interface.

Applicability

Lined channels typically are used in residential developments, along highway medians, or as an alternative to curb and gutter systems. Grass-lined channels should be used to convey runoff only where slopes are 5 percent or less. These channels require periodic mowing, occasional spot-seeding, and weed control to ensure adequate grass cover (UNEP 1994).

Lined channels should be used in areas where erosion-resistant conveyances are needed, such as in areas with highly erodible soils and slopes of less than 5 percent. They should be installed only where space is available for a relatively large cross-section. Grassed channels have a limited ability to control runoff from large storms and should be used with the recommended allowable velocities for the specific soil types and vegetative cover.

Design and Installation Criteria

The design of a lined waterway requires proper determination of the channel dimensions. It must ensure that (1) the velocity of the flowing water will not wash out the waterway and that (2) the capacity of the waterway is sufficient to carry the surface flow from the watershed without overtopping.

Vegetation-Lined Channels. Grass-lined channels have been previously discussed in detail and are only summarized in this section. The allowable velocity of water in the waterway depends upon the type, condition, and density of the vegetation, as well as the erosive characteristics of the soil. Uniformity of vegetative cover is important because the stability of the most sparsely covered area determines the stability of the channel. Grasses are a better vegetative cover than legumes because grasses resist water velocity more effectively.

Vegetative-lined channels can have triangular, parabolic, or trapezoidal cross-sections. Side slopes should not exceed 3:1 to facilitate the establishment, maintenance, and mowing of vegetation. A dense cover of hardy, erosion-resistant grass should be established as soon as possible following grading. This might necessitate the use of straw mulch and the installation of protective netting until the grass becomes established. If the intent is to create opportunities for runoff to infiltrate into the soil, the channel gradient should be kept near zero, the channel bottom

must be well above the seasonal water table, and the underlying soils should be relatively permeable (generally, with an infiltration rate greater than 2 centimeters [0.78 inches] per hour).

Rock-Lined Channels. Riprap-lined channels can be installed on somewhat steeper slopes than grass-lined channels. They require a foundation of filter fabric or gravel under the riprap. Generally, side slopes should not exceed 2:1, and riprap thickness should be 1.5 times the maximum stone diameter. Riprap should form a dense, uniform, well-graded mass (UNEP 1994).

Lined channels should be sited in accordance with the natural drainage system and should not cross ridges. The channel design should not have sharp curves or significant changes in slope. Channels should not receive direct sedimentation from disturbed areas and should be established only on the perimeter of a construction site to convey relatively clean stormwater runoff. They should also be separated from disturbed areas by a vegetated buffer or other BMP to reduce sediment loads.

Basic design recommendations for lined channels include the following:

- Construction and vegetation of the channel should occur before grading and paving activities begin.
- Design velocities should be less than 5 feet per second.
- Geotextiles can be used to stabilize vegetation until it is fully established.
- Covering the bare soil with sod or geotextiles can provide reinforced stormwater conveyance immediately.
- Triangular-shaped channels should be used with low velocities and small quantities of runoff; parabolic grass channels are used for larger flows and where space is available; trapezoidal channels are used with large flows of low velocity (low slope).
- Outlet stabilization structures might be needed if the runoff volume or velocity has the potential to exceed the capacity of the receiving area.
- Channels should be designed to convey runoff from a 10-year storm without erosion.
- The sides of the channel should be sloped less than 3:1, with V-shaped channels along roads sloped 6:1 or less for safety.
- All trees, bushes, stumps, and other debris should be removed during construction.

Effectiveness

Lined channels can effectively transport stormwater from construction areas if they are designed for expected flow volumes and velocities and if they do not receive sediment directly from disturbed areas.

Limitations

Lined channels, if improperly installed, can alter the natural flow of surface water and have adverse impacts on downstream waters. Additionally, if the design capacity is exceeded by a large storm event, the vegetation might not be sufficient to prevent erosion and the channel might

be destroyed. Clogging with sediment and debris reduces the effectiveness of grass-lined channels for stormwater conveyance.

Common problems in lined channels include erosion of the channel before vegetation is fully established and gullying or head cutting in the channel if the grade is too steep. In addition, trees and brush tend to invade lined channels, causing maintenance problems.

Riprap-lined channels can be designed to safely convey greater runoff volumes on steeper slopes. However, they should generally be avoided on slopes exceeding 10 percent because stone displacement, erosion of the foundation, or channel overflow and erosion resulting from a channel that is too small can occur. Thus, channels established on slopes greater than 10 percent will usually require protection with rock gabions, concrete, or other highly stable and protective surfaces (UNEP 1994).

Maintenance

Maintenance requirements for lined channels are relatively minimal. During the vegetation establishment period, the channels should be inspected after every rainfall. Other maintenance activities that should be carried out after vegetation is established are mowing, litter removal, and spot vegetation repair. The most important objective in the maintenance of lined channels is maintaining a dense and vigorous growth of turf. Periodic cleaning of vegetation and soil buildup in curb cuts is required so that water flow into the channel is unobstructed. During the growing season, channel grass should be cut no shorter than the level of design flow, and the cuttings should be removed promptly.

Cost

Costs of grassed channels range according to depth, with a 1.5-foot-deep, 10-foot-wide grassed channel estimated at $6,395 to $17,075 per trench, while a 3-foot-deep, 21-foot-wide grassed channel is estimated at $12,909 to $33,404 per trench (SWRPC 1991).

EPA also refers readers to the discussion of costs for grass-lined channels, which contains many of the design and cost elements required for installing lined waterways. Designers have a range of options for lining new channels. Geosynthetic TRMs can be used for immediate erosion protection in channels exposed to runoff flows. The Erosion Control Technology Council (a geotextile industry support association) suggests TRMs cost approximately $7.00 per square yard (installed) for channel protection (ECTC 2002a). R.S. Means indicates machine-placed riprap costs of approximately $40 per cubic yard. The riprap maximum size is typically between 6 and 12 inches, depending on the channel design velocity. A cubic yard of riprap will cover between 36 and 18 square feet of channel bed for these riprap sizes (assuming depth of riprap is 1.5 times the maximum size). These estimates suggest that riprap lining will be between $10 and $20 per square foot of channel (costs include materials, labor, and equipment, with overhead and profit).

7.2.3. SEDIMENT TRAPPING DEVICES

The devices listed under this group of BMPs trap sediment primarily through impounding water and allowing for settling to occur (Haan et al. 1994). Silt fence, super silt fence, straw bale dikes, sediment traps, and sediment basins all control flow through a porous flow control system such as filter fabric or straw bales or they use a dam to impound water with a pipe, open channel, or

rock fill outlet. The filtering capacity of silt fence (filter fabric) contributes only a small amount of trapping, but serves to make the fence less porous and hence increases ponding. For steady-state flows, the trapping that occurs behind the flow control device can be shown to be directly proportional to the surface area and indirectly proportional to flow through the system (Haan et al. 1994). The ratio of the surface area to flow is known as the overflow rate, and trapping in such systems is predicted by the ratio of overflow rate to particle settling velocity. Although flows in nature are inherently non-steady-state and more complex than steady-state systems, studies have shown that the best predictor of trapping in such systems is still the ratio of settling velocity to overflow rate (Hayes et al. 1984). In the case of non-steady-state, the overflow rate is best defined by the ratio of peak discharge to surface area (Hayes et al. 1984; McBurnie et al. 1990).

The amount of trapping in these structures depends on the size of the structure, flow rates into the system, hydraulics of the flow control system, the size distribution of the sediment flowing into the structure, and the chemistry of the sediment-water system (Haan et al. 1994). Trapping can be enhanced by chemical treatment of flows into the structure, but the impacts have not been widely defined for varying mineralogy and chemistry of the sediment-water system (Haan et al. 1994; Tapp and Barfield 1986). Recent studies have been conducted on the application of polyacrylamides (PAM) to disturbed areas for enhancing settling (Benik et al. 1998; Masters et al. 2000; Roa-Espinosa et al. 2000), but results have not been definitive. No known studies have evaluated the effects of PAM application to disturbed areas on settling in sediment trapping devices.

Sediment flowing into sediment trapping devices is composed of primary particles and aggregated particles. Aggregates are formed when clays, silts, and sands are cemented together to form larger particles that have settling velocities far greater than those of any individual particles alone, although the degree of aggregation depends on the amount of cementing material present (typically clays and organic matter). Because the aggregates have higher settling velocities than primary particles, the degree of aggregation that is present has a large effect on the trapping that occurs. Procedures are available to measure the combined size distribution of aggregate and primary particle size distribution (Barfield et al. 1979; Haan et al. 1994). Procedures are also available to predict particle size distributions of aggregates and primary particles (Foster et al. 1985).

In the absence of chemical treatment, the sediment that can be captured in sediment trapping devices is typically the larger settleable solids. To trap the smaller size clay particles, structures with surface areas larger than the construction site itself would have to be built in many cases (Barfield 2000). Chemical treatment can be used to reduce the size captured, but it has not been adopted on a wide scale because of the cost and complexity of the operation (Tapp et al. 1981).

Sediment trapping devices also provide some stormwater detention by virtue of detaining flows long enough to allow sediment to settle out and be deposited. However, to operate as a stormwater detention structure, the design should include adequate volume for detention.

Virtually all the available information on sediment trapping structures, both theoretical and experimental, is on impacts to receiving waters and not downstream effects. In a very limited analysis, Barfield (2000) combined the SEDIMOT II computer model together with the

FLUVIAL model to theoretically evaluate the effect of sediment trapping structures on downstream geomorphology in a Puerto Rican watershed.

7.2.3.1. Silt Fence

General Description

Silt fences are used as temporary sediment barriers consisting of filter fabric anchored across and supported by posts. Their purpose is to retain sediment from small disturbed areas by reducing the velocity of sediment-laden runoff and promoting sediment deposition (Smolen et al. 1988). Silt fences capture sediment by ponding water and allowing for deposition, not by filtration. Silt fence fabric first screens silt and sand from runoff, resulting in clogging of the lower part of the fence. The pooling water allows sediments to settle out of the runoff. Silt fences work best in conjunction with temporary basins, traps, or diversions.

Applicability

Silt fences are generally placed at the toe of fills, along the edge of waterways, and along the site perimeter. The fences should not be used in drainage areas with concentrated and high flows, in large drainage areas, or in ditches and swales where concentrated flow is present.

The drainage area for the fence should be selected on the basis of design storms and local hydrologic conditions so that the silt fence is not expected to overtop. A typical design calls for no greater than one-quarter acre of drainage area per 100 feet of fence, but this is highly variable depending on climate. The fence should be stable enough to withstand runoff from a 10-year peak storm. Table 7-11 lists the maximum slope length specified by the U.S. Department of Transportation (USDOT). These slope lengths should be based on sediment load and flow rates. This would mean that the values given below should be adjusted for climatic conditions instead of *one size fits all* to ensure maximum effectiveness.

Table 7-11. Maximum Slope Lengths for Silt Fences

Slope (%)	18-inch (460 mm) fence	30-inch (760 mm) fence
≤ 2	250 ft (75 m)	500 ft (150 m)
5	100 ft (30 m)	250 ft (75 m)
10	50 ft (15 m)	150 ft (45 m)
20	25 ft (8 m)	70 ft (21 m)
25	20 m (6 ft)	55 ft (17 m)
30	15 ft (5 m)	45 ft (14 m)
35	15 ft (5 m)	40 ft (12 m)
40	15 ft (5 m)	35 ft (10 m)
45	10 ft (3 m)	30 ft (9 m)
50	10 ft (3 m)	25 ft (8 m)

Source: USDOT 1995.

Typical standards and specifications call for the silt fence to be on fairly level ground and follow the land contour, although it is recognized that a slight slope can occur along the fence in spite of

the best installation practices. Runoff can move down the contour until a weak spot occurs in the buried toe and undercuts the fence. Alternatively, flow might move to a low spot where it accumulates and causes an overtopping. In either case, trapping by the silt fence is essentially zero, and flows will then have been concentrated, causing downslope erosion.

Design and Installation Criteria

Design criteria are of two types:

- Hydrologic design for a required trapping of sediment and flow rate to pass the design storm
- Selection of appropriate installation criteria such that the silt fence will perform as designed

Hydrologic Design

The fence should be designed to pass the design storm without causing damage while trapping the required amount of sediment. It is necessary to use either a database or some type of model to develop the appropriate hydrologic design. Efforts to model the sediment trapping that occurs through the use of a silt fence have resulted in models that predict the settling in the ponded area upstream from the fence (Barfield et al. 1996; Lindley et al. 1998). The results from model simulations show that trapping depends primarily on the surface area of the impounded water and the flow rate through the filter. The models use a clear water flow rate, typically specified by the manufacturer, to predict discharge. However, numerous studies have shown that sediment laden flows cause clogging of the geotextiles used to construct the fence, depending on the opening size and size of the sediment (Britton et al. 2001; Wyant 1980; Barrett et al. 1995; Fisher and Jarret 1984). Thus, results from model studies to date are suspect and need to be modified to account for the effects of clogging on flow rate. Barfield et al., (2001) developed a model of flow rate using conditional probability concepts, but the results have not been experimentally verified.

Design aids have been developed for silt fence, using simulations from the SEDIMOT III model (Hayes and Barfield 1995). In the model, predictions are made about trapping efficiency using the ratio of settling velocity for the d_{15} of the eroded sediment, divided by the ratio of discharge to ponded surface area.[4] The design aids yield conservative estimates as compared to the SEDIMOT III model, but the database used for generating the design aid is based on the assumption that clogging does not affect flow rates. The discussion above shows that assumption to be erroneous.

SEDCAD takes the approach of using a slurry flow rate, not a clean water flow rate, when it simulates fence effectiveness, reporting slurry rates ranging between 0.1 and 15 gpm/sq. ft. On the basis of this discussion, one can conclude that it is difficult to predict with accuracy the trapping efficiency of silt fence under a given set of conditions. In addition, the quality of installation and maintenance are important to the long-term performance of the fence. The best available estimate of sediment trapping obtained from modeling of hydrologic events should be applied with care in any site design problem.

[4] d_{15}:15 percent by weight of suspended solids are smaller than those that are trapped by this device; similarly d_{50} indicates that 50 percent by weight of suspended solids are smaller than those trapped

Installation Criteria

General installation criteria for the silt fence should incorporate the following factors:

- The fabric must have sufficient strength to counter forces created by contained water and sediment (Sprague 1999).
- The posts must have sufficient strength to counter the forces transferred to them by the fabric (Sprague 1999).
- The fabric must be installed to ensure that the loads are all adequately transferred through the fabric to the posts or the ground without overstressing (Sprague 1999).
- The fence must be designed on the basis of site-specific hydrologic and soil conditions such that it will not overtop during design events.
- The fence must be installed (anchored) with a buried toe of sufficient depth so that it does not become detached from the soil surface.
- In general, the fence requires a metal wire backing to provide sufficient strength to prevent failure from the weight of trapped sediment and to prevent the toe of the fabric from being removed from the ground.
- Maximum drainage area behind the fence should be determined on the basis of the local rainfall and the infiltration characteristics of the soil and cover.

Silt fence material is typically synthetic filter fabric or a pervious sheet of polypropylene, nylon, polyester, or polyethylene yarn. The fabric should have ultraviolet ray inhibitors and stabilizers to provide for a minimum useful construction life of 6 months or the duration of construction, whichever is greater. The height of the fence fabric should not exceed 3 feet. If standard strength filter fabric is used, it should be reinforced with a wire fence, extending down into the trench that buries the toe. The wire should be of sufficient strength to support the weight of the deposited sediment and water. In general, a minimum 14 gauge and a maximum mesh spacing of 6 inches is called for (Smolen et al. 1988). Typical requirements for the silt fence physical properties, as specified in selected local BMP standards and specifications, are presented in Table 7-12.

Table 7-12. Typical Requirements for Silt Fence Fabric

Physical property	Requirements	
	Woven fabric	**Non-woven fabric**
Filtering Efficiency	85%	85%
Tensile Strength at 20% (maximum) Elongation	Standard Strength—30 pound/linear inch Extra Strength—50 pound/linear inch	Standard Strength—50 pound/linear inch Extra Strength—70 pound/linear inch
Slurry Flow Rate	0.3 gallon/square feet/minute	4.5 gallons/square feet/minute
Water Flow Rate	15 gallons/square feet/minute	220 gallon/square feet/minute
UV Resistance	70%	85%

Source: NCDNR 1988; IDNR 1992.

It should be pointed out that these numbers, particularly the flow rates, can vary widely depending on the local soil condition because of possible clogging of the filter material.

Material for the posts used to anchor the filter fabric can be constructed of either wood or steel. Wooden stakes should be buried at a depth sufficient to keep the fence, when loaded with sediment and water, from falling over. The depth of burial should depend on post diameter and soil strength characteristics when saturated. Many standards and specifications set a minimum post length of 5 feet with 4-inch diameter for posts composed of softwood (e.g., pine) and 2-inch diameter for posts composed of hardwood (e.g., oak) (Smolen et al. 1988). Steel posts should also be designed on the basis of local wet soil strength characteristics. Some standards and specifications for these posts set a minimum weight of 1.33 pounds per linear feet with a minimum length of 4 feet. Steel posts should also have projections to adhere filter fabric to the post (Smolen et al. 1988).

A silt fence should be erected continuously from a single roll of fabric to eliminate unwanted gaps in the fence. If a continuous roll of fabric is not available, the fabric should overlap from both directions only at posts with a minimum overlap of 6 inches and be rolled together with a special flexible rod to keep the ends from separating. Fence posts should be spaced at a distance on the basis of wet soil strength characteristics and post size and strength; generally, the posts are spaced approximately 4 to 6 feet apart. If standard strength fabric is used in combination with wire mesh, the spacing can be larger. Typically, standards and specifications call for the posts to be no more than 10 feet apart. If extra-strength fabric is used without wire mesh reinforcement, some standards call for the support posts to be spaced no more than 6 feet apart (VDCR 1995). Again, this spacing should depend on wet soil strength characteristics and post size.

A silt fence must provide sufficient storage capacity or be stabilized over flow outlets such that the storage volume of water will not overtop the fence. The return period event (size of the rainfall event managed) used for design is typically a prerogative of the regulatory agency. For temporary fences, a 2-year storm event is typically used as a design standard. Fences that will be in place for 6 months or longer are commonly designed for a 10-year storm event (Sprague 1999). The space behind the fence used for impoundment volume must be sufficient to adequately contain the sediment that will be deposited. Each storm will deposit sediment behind the fence, and after a period of time, the amount of sediment accumulated will render the fence useless. Frequency of fence management is a function of its sizing (i.e. whether the fence was installed for a 2-year or a 10-year storm event) (Sprague 1999) and the amount of erosion that occurs in the area draining to the fence.

Effectiveness

The performance of silt fences has not been well defined. Laboratory studies using carefully controlled conditions have shown trapping efficiencies in the range of 40 to 100 percent, depending on the type of fabric, overflow rate, and detention time (Barrett et al. 1995; Wyant 1980; Wishowski et al. 1998). Field studies have been limited and quite inadequate; however, the results show that field-trapping efficiencies are very low. In fact, Barrett et al. (1995) obtained a value of zero percent trapping averaged over several samples with a standard error of 26 percent. Barrett et al. (1995) cite the following reasons for the field tests not showing the expected results:

- Inadequate fabric splices
- Sustained failure to correct fence damage resulting from overtopping
- Large holes in the fabric
- Under-runs due to inadequate *toe-ins*
- Silt fence damaged and partially covered by the temporary placement of stockpiles of materials

Silt fences are effective at removing large particle sediment, primarily aggregates, sands, and larger silts. Sediment is removed through impounding of water to slow velocity. It is argued that the silt fence will not contribute to a reduction in small particle sediment and is not effective against other pollutants (WYDEQ 1999). EPA (1993) reports the following effectiveness ranges for silt fences constructed of filter fabric: average TSS removal of 70 percent, sand removal of 80 to 90 percent, silt-loam removal of 50 to 80 percent, and silt-clay-loam removal of 0 to 20 percent. However, the EPA numbers from the Nationwide Urban Runoff Program should not be considered to apply to every location. The actual trapping will vary widely for a given design because of differences in hydrologic regimes and soil types.

The advantages of using silt fences include minimal labor requirement for installation, low cost, high efficiency in removing sediment, durability, and sometimes reuse (Sprague 1999). Silt fences are the most readily available and cost-effective control options where options like diversion are not possible. Silt fences are also a popular choice because contractors have used them extensively and their familiarity makes silt fence use more likely for future construction activities. The visibility of a silt fence is also an advantage (i.e., the fence is *advertising* the use of erosion and sediment control practices). In addition, the silt fence visibility makes site inspection easier for contractors and government inspectors (CWP 1996).

Limitations

Silt fences should not be installed along areas where rocks or other hard surfaces will prevent uniform anchoring of fence posts and entrenching of the filter fabric because an insufficient anchor will greatly reduce their effectiveness and might create runoff channels. In addition, open areas where wind velocity is high could present a maintenance challenge, as high winds might accelerate deterioration of the filter fabric (Smolen et al. 1988). When the pores of the silt fence fabric become clogged with sediment, pools of water are likely to form uphill of the fence. Siting and design of the silt fence should account for this problem, and care should be taken to avoid unnecessary diversion of stormwater from these pools which might cause further erosion damage. Silt fences can act as a diversion if placed slightly off-contour and can control shallow, uniform flows from small, disturbed areas and deliver sediment-laden water to deposition areas.

Silt fences will sag or collapse if a site is too large, if too much sediment accumulates, if the approach slope is too steep, or if the fence was not adequately supported. If the fence bottom is not properly installed or the flow velocity is too fast, fence undercuts or blowouts can occur because of excess runoff. Erosion around the end of the fence can occur if the fence ends do not extend upslope to prevent flow around the fence (IDNR 1992).

Maintenance

Site operators should inspect silt fences after each rainfall event to ensure they are intact and that there are no gaps at the fence-ground interface or tears along the length of the fence. If gaps or tears are found, they should be repaired or the fabric should be replaced immediately. Accumulated sediments should be removed from the fence base when the sediment reaches one-third to halfway up the height of the fence. Sediment removal should occur more frequently if accumulated sediment is creating a noticeable strain on the fabric, and there is the possibility that the fence could fail from a sudden storm event.

Cost

There is a wide range of data on installation costs for silt fences. EPA estimates these costs at approximately $6.00 per linear foot (USEPA 1992) while Southeastern Wisconsin Regional Planning Commission (SWRPC) estimates unit costs between $2.30 and $4.50 per linear foot (SWRPC 1991). Silt fences have an annual maintenance cost that is 100 percent of installation cost (Brown and Schueler 1997). These values are significantly greater than that reported by R.S. Means (2000), which indicates a 3-foot-tall silt fence installation cost between $0.68 and $0.92 per linear foot (for favorable and challenging installations). It should be noted that the R.S. Means value covers just a single installation, without the expected costs of maintenance (e.g., removal of collected sediment). In addition, the type of silt fence fabric employed will also affect the total installation costs.

7.2.3.2. Super Silt Fence

General Description

Super silt fence is a modification of a standard silt fence. The two central differences between the standard silt fence and the super silt fence is that the super silt fence has toe that is buried more deeply and the backing material is chain link fence held in place by steel posts—a concept that originated in Maryland. The Maryland super silt fence requires a Geotextile Class F fabric over a chain link fence to intercept sediment-laden runoff from small drainage areas. The super silt fence provides a barrier that can collect and hold debris and soil more effectively than a standard silt fence, preventing material from entering critical areas. It is best used where the installation of a dike would destroy sensitive areas, woods, and wetlands.

Applicability

Super silt fences can be used in the same conditions as a silt fence. Fences should follow the contour of the land. Table 7-13 lists the distance a super silt fence should be from a slope to ensure maximum effectiveness (MDE 1994).

Table 7-13. Slope Lengths for Super Silt Fences

Slope (%)	Slope length	
	Minimum	**Maximum**
0–10	Unlimited	Unlimited
10–20	200 feet	1,500 feet
20–33	100 feet	1,000 feet
33–50	100 feet	500 feet
50+	50 feet	250 feet

Design and Installation Criteria

As with the standard silt fence, design criteria are of two types, hydrologic design for a required trapping of sediment and flow rate to pass the design storm and selection of appropriate installation criteria such that the silt fence will perform as designed.

Hydrologic Design

Hydrologic design criteria are the same as the criteria for the standard silt fence.

Installation Criteria

The criteria used for the Maryland super silt fence indicate the following, although they have not been tested with field data:

- The fence should be placed as close to the contour as possible, with no section of the silt fence exceeding a grade of 5 percent for a distance of more than 50 feet.
- Fabric should be no more than 42 inches in height and should be held in place with a 6-foot chain link fence.
- Fabric should be attached to the steel pole using wire ties or staples. Fabric should be securely fastened to the chain link fence with ties spaced every 24 inches at the top and midsection.
- Fabric should be embedded into the ground at a minimum of 8 inches.
- Edges of fabric should overlap by 6 inches.

Table 7-14 describes the physical properties of Geotextile class F fabric (MDE 1994).

Table 7-14. Minimum Requirements for Super Silt Fence Geotextile Class F Fabric

Physical properties	Requirements
Tension Strength	50 pounds/inch
Tensile Modulus	20 pounds/inch
Flow Rate	0.3 gallon/ft2/minute
Filtering Efficiency	75%

Effectiveness

Performance data have not been collected for super silt fences. The fences have been proposed for locations within a sensitive watershed, or where site conditions prohibit the use of a standard silt fence. However, until performance data are collected under field conditions, effectiveness is speculative.

Limitations

Super silt fences are not as likely to fail structurally as are standard silt fences, but they are more expensive than standard silt fences.

Maintenance

Maintenance requirements for super silt fences are generally the same as for standard silt fences.

Cost

The cost of the super silt fence is more than the standard silt fence because of deeper burial at the toe and the cost of chain linked fencing. R.S. Means (2000) indicates a rental price of $10 to $11 per linear foot of chain linked fence for periods up to 1 year. Overall, rental is expected for most construction site installation because rental rates are approximately half the price of permanent chain link fencing.

7.2.3.3. Straw Bale Dike

General Description

The straw bale dike is a temporary measure used to trap sediment from small, sloping disturbed areas. It is constructed of straw bales (not hay bales) wedged tightly together and placed along the contour downslope of disturbed areas. The bales are placed in a shallow excavation, and the upslope side is sealed with soil. Stakes are driven through the bales into the soil to help hold the bales in place. The dike works by impounding water, which allows sediment to settle out in the upslope area (Haan et al. 1994). Straw bale dikes are recommended for short duration application and are usually effective for less than 3 months because of rapid decomposition (USDOT 1995).

Applicability

Straw bale dikes are generally placed at the toe of fills to provide for a broad shallow sediment pool. The dikes should not be used in drainage areas with concentrated and high flows, in large drainage areas, or in ditches and swales. The location of the straw bale dike should be fairly level, at least 10 feet from the toe, and should follow the land contour. Table 7-15 lists the distance a straw bale dike should be placed from a slope to ensure maximum effectiveness.

Table 7-15. Maximum Land Slope and Distances above a Straw Bale Dike

Land slope (%)	Maximum distance above dam (ft)
Less than 2%	100
2%–5%	75
5%–10%	50
10%–20%	25
More than 20%	15

Source: USDOT 1995.

Design and Implementation Criteria

Hydrologic Design

Hydrologic design dictates the structure necessary to withstand a storm without causing damage while trapping the required amount of sediment. Either a database or some type of model is needed to find the appropriate design. Efforts to model the sediment trapping that occurs in straw bale dikes have resulted in models that predict the settling in the ponded area upstream from the dike (Barfield et al. 1996; Lindley et al. 1998). The results from model simulations show that trapping depends primarily on the surface area of the impounded water and flow rate through the filter. The models use a clear water slurry flow rate to predict discharge. It is anticipated, on the basis of visual observations, that sediment will clog the straw bale barrier, reducing the slurry flow rate. Thus, results from model studies to date are suspect and need to be modified to account for the effect of clogging on flow rate.

Installation Criteria

The USDOT's BMP Manual and the Indiana BMP Manual call for bales to be

- Anchored by driving two 36-inch long (minimum) steel rebars or 2 x 2-inch hardwood stakes through each bale
- Sized according to the standard bale size of 14 inches x 18 inches x 35 inches
- Placed in an excavated trench at least 4 inches deep, a bale's width, and long enough that the end bales are somewhat upslope of the sediment pool
- Abutted tightly against each other
- Sized so that impounded water depth should not exceed 1.5 feet

The USDOT BMP Manual does not require that straw bale dikes be designed; however, the Indiana Manual limits the drainage area to one-quarter acre per 100 feet of dam and the total drainage area draining to a straw bale dike to 2 acres.

Effectiveness

The information on performance of straw bale dikes is very limited. In laboratory studies of bales at varying orientations, Kouwen (1990) found that trapping efficiencies ranged from 60 to 100 percent. While field data on trapping have not been collected, bales deteriorate rapidly and need to be replaced frequently. Because of these problems, the use of straw bale dikes as a perimeter control is not recommended, except in special circumstances. Only 27 percent of erosion and sediment control experts rated the straw bale dike as an effective erosion and sediment control practice, although its use was still allowed in half of the communities surveyed (Brown and Caraco 1997).

Limitations

Straw bale dikes should not be used as a diversion, in streams, in channels, or in areas with concentrated flow. The bales are not recommended for paved areas because of the inability to anchor the bales (IDNR 1992).

Care must be taken to ensure that the bales are not installed in an area where there is a concentrated flow of runoff, in a drainage area that is too large, or on an excessive slope (IDNR 1992). Under these conditions, erosion around the end of the bales, overtopping and undercutting of the bales, and bale collapsing and dislodging are likely to occur. Overtopping will also occur if the storage capacity is underestimated and where provisions are not made for safe bypass of storm flow (IDNR 1992). Undercutting will occur if the bales are not entrenched at least 4 inches and backfilled with compacted soil or were not abutted or chinked properly. Straw bale dikes are likely to collapse or dislodge if the bales are not adequately staked, or if too much sediment is allowed to accumulate before cleanout (IDNR 1992).

Maintenance

For the straw bale dike to be most effective, it is important to replace deteriorated bales when appropriate.

Cost

The cost of straw bale dikes is relatively low, making their use attractive. R.S. Means (2000) indicates a staked straw bale unit cost of $2.61 per linear foot (Costs include materials, labor, and equipment, with profit and overhead).

7.2.3.4. Sediment Trap

General Description

A sediment trap is a temporary control device used to intercept sediment-laden runoff and to trap sediment to prevent or reduce off-site sedimentation. It is normally a more temporary type of structure than a sediment pond and is constructed to control sediment on the construction area during a selected phase of the construction operation. A sediment trap can be formed by excavation and/or embankments constructed at designated locations accessible for cleanout. The outlet for a sediment trap is typically a porous rock fill structure, which serves to detain the flow, but a pipe structure can also be used. A temporary sediment trap can placed be in a drainageway, at a storm drain inlet, or at other points of discharge from a disturbed area. They can be

constructed independently or in conjunction with diversions and can be used in most drainage situations to prevent excessive siltation of pipe structures (USEPA 1992).

Applicability

Sediment traps can simplify the stormwater control plan design process by trapping sediment at specific spots at a construction site (USEPA 1992). They should be installed as early in the construction process as possible and are primarily effective as a short-term solution to trapping sediment from construction sites (WYDEQ 1999). Natural drainage patterns should be noted, and sites where runoff from potential erosion can be directed into the traps should be selected. Traps are most effective when capturing runoff from areas where 2 to 5 acres drain to one location. Sediment traps should not be located in areas where their failure resulting from excess runoff can lead to further erosive damage of the landscape. Alternative diversion pathways should be designed to accommodate these potential overflows. Traps should be accessible for clean-out and located so that they do not interfere with construction activity. In addition, the traps are easily adaptable to most conditions.

Design and Implementation Criteria

Hydrologic Design

A sediment trap should be designed to maximize surface area and sediment settling. This will increase the effectiveness of the trap and decrease the likeliness of backup during and after periods of high runoff intensity. The design of a trap includes determining the storage volume, surface area, dimensions of spillway or outlet, and elevations of embankment (USDOT 1995). Sediment traps should be designed to meet a 2-year, 24-hour storm event, but the selection of a return period varies among regulatory agencies (IDNR 1992).

Storage volume is created by a combination of excavation of land and construction of an embankment to detain runoff (USDOT 1995). Trap storage volume and length of spillway are determined as a function of the runoff volume and rate for the design storm. These parameters will vary depending on return period rainfall and watershed hydrologic characteristics. Some standards specify a storage volume per acre disturbed. For example, Smolen et al. (1988) specified that approximate storage capacity of each trap should be at least 67 cubic yards per acre disturbed draining into the trap, but more recent guidelines suggest 134 cubic yards per acre of drainage area (VDCR 2001). Any national standard, however, should be based on runoff volume and peak discharge to be generally applicable. Local regulations can translate this into applicable volume and area standards.

A more important criterion than storage volume relates to sediment trapping. If a trapping efficiency is specified, as in the case of South Carolina (SCDHEC 1995), it is necessary to design for trapping efficiency. If a TSS or settleable solids effluent criterion is adopted (SCDHEC 1995), settleable solids must be estimated. In both cases, a national standard should address how to estimate trapping efficiency or settleable solids. Efforts to model the sediment trapping that occurs in sediment traps have resulted in models that predict the settling in the ponded area (Barfield et al. 1996; Lindley et al. 1998). The results from model simulations show that trapping depends primarily on surface area of the impounded water and flow rate through the rock fill outlet. In fact, the ratio of peak outflow rate to surface area is the best simple predictor of trapping. The models use a modification of the Herrera and Felton (1991)

relationship developed by Haan et al. (1994) to predict discharge rates. The predicted flow rates do not take into account clogging that can occur in rock fill. No models or procedures are available to estimate this clogging or its effect on flow criteria.

Design aids have also been developed for sediment traps, using simulations from the SEDIMOT III (Barfield et al. 2001; Hayes et al. 2001). In the model, predictions are made of trapping efficiency using the ratio of settling velocity for the d_{15} of the eroded sediment, divided by the ratio of discharge to ponded surface area. The design aid yields conservative estimates, but the database used for generating the design aid is based on the assumption that flow rates are not affected by clogging. This latter assumption is not likely to be a critical issue but should be addressed in future research.

Installation Specifications

USDOT standards call for the embankment to be constructed of compacted earth, at a maximum height of 5 feet (1.5 meters), a width of 4 to 5 feet (1.2 meters), and side slopes of 2:1or flatter. These values might change as a result of local criteria and with changing soil characteristics. Temporary vegetation should be applied to the embankment.

Two types of outlet structures are typically used for sediment traps, a rock outlet and a pipe outlet. Spillways of large stones or aggregate are the most common type of outlet designed for sediment traps. The crest of the spillway should be constructed 1 foot below the top of the embankment and the spillway depth 1.5 feet below the top of the embankment. Weir length of the spillway is determined on the basis of the contributing drainage area (Table 7-17) (USDOT 1995). The outlet apron should be a minimum of 5 feet long, and situated on level ground with a filter fabric foundation to ensure exit velocity of drainage to receiving stream is nonerosive (IDNR 1992).

The length of the rock outlet should be determined on the basis of peak discharge required and rock characteristics, typically rock diameter. Flow rate calculations can be made with the relationship of Herrera and Felton (1991) as modified by Haan et al. (1994). Alternatively, the USDOT has specified the weir length for a given drainage area as shown in Table 7-16. However, the values should be adjusted for each climatologic area to account for local hydrologic and return period rainfall.

Table 7-16. Weir Length for Sediment Traps

Contributing drainage area	Weir length (ft)
1	4
2	5
3	6
4	10
5	12

Source: USDOT 1995.

The pipe outlet, constructed of corrugated metal or PVC pipe riser, is an alternative to the rock outlet. Pipe diameter is based on the peak discharge rate required. To obtain appropriate freeboard, the top of pipe should be placed 1.5 feet below embankment elevation. Perforated pipe is sometimes used. USDOT suggests perforations of 1-inch (25 mm) diameter holes or 0.5 x 6 inch (13 x 15 mm) slits in the upper two-thirds of the pipe; however, the discharge should be calculated for this pipe specification to ensure that it matches the required peak discharge.

The pipe should be placed vertically and horizontally above wet storage elevation (USDOT 1995). Riprap should be used as an outlet protection and placed at the outlet of the barrel to prevent scour from occurring (USDOT 1995). A stable channel should be provided to convey discharge to the receiving channel (USDOT 1995).

Effectiveness

If it is assumed that the flow can be accurately controlled by the rock fill outlet, sediment traps should operate as effectively as sediment basins, with trapping efficiencies reduced as a result of smaller surface areas. The NURP study (USEPA 1993), Stahre and Urbonas (1990), and Haan, et al., (1994), report that sediment basins effectively trapped sediment and chemicals as shown in Table 7-17.

Table 7-17. Range of Measured Pollutant Removal for Sediment Detention Basins

Item	Removable percentage
Total suspended solids (TSS)	50%–70%
Total phosphorus (TP)	10%–20%
Nitrogen	10%–20%
Organic matter	20%–40%
Lead	75%–90%
Zinc	30%–60%
Hydrocarbons	50%–70%
Bacteria	50%–90%

Source: Stahre and Urbonas 1990.

Information on the actual effectiveness of sediment traps is limited. The discussion should start first with the flow hydraulics of the rock fill outlet typically employed as a principal spillway for sediment traps. Procedures for estimating flow through rock fill have been developed by Herra and Felton (1991) to estimate flow as a function of average rock diameter, standard deviation of rock size, and flow length. If these parameters could be controlled in an actual situation, the flow could be accurately predicted. However, given that standard construction practices consist of end-dumping the rock fill in place, one would expect little correlation between design and construction and the actual discharge and trapping efficiency would be expected to be dramatically different from the design. This analysis does not mean that sediment traps are ineffective, but that a given design could not be guaranteed to meet the effluent criteria, even though the predictions indicate compliance. Sediment trapping efficiency is a function of surface area and inflow rate (Smolen et al. 1988). Those traps that provide pools with large length-to-width ratios have a greater chance of success.

Sediment traps remove larger-sized sediment, primarily sized from silt to sands, by slowing water velocity and allowing for sediment settling in ponded water (Haan et al. 1994). Although sediment traps allow for settling of eroded soils, because of their short detention periods for stormwater they typically do not remove fine particles such as silts and clays without chemical treatment. Sediment settling ability is related to the square of the particle size; halving particle sizes quadruples the time needed to achieve settlement (WYDEQ 1999). To increase overall effectiveness, traps should be constructed in smaller areas with low slopes. Sediment traps are typically designed to remove only sediment from surface water, but some non-sediment pollutants are trapped as well (Haan et al. 1994).

Limitations

Common concerns associated with sediment traps are included in Table 7-18.

Table 7-18. Common Concerns Associated with Sediment Traps

Common concern	Result
Inadequate spillway size	Results in overtopping of the dam and possible failure of the structure
Omission or improper installation of geotextile fabric	Results in piping under the sides or bottom of the stone and outlet section
Low point in embankment caused by inadequate compaction and settling	Results in overtopping and possible failure
Stone outlet apron does not extend to stable grade	Results in erosion below the dam
Stone size too small or backslope too steep	Results in stone displacement
Inadequate vegetative protection	Results in erosion of embankment
Inadequate storage capacity	Results in a less than adequate settling time (can also be caused by an insufficient amount of sediment being removed from the basin
Contact slope between stone spillway and earth embankment too steep	Results in piping failure
Outlet pipe installed in vertical side of trench	Results in piping failure of embankment
Corrugated tubing used as outlet pipe	Results in crushed pipe and inadequate outlet capacity

Source: IDNR 1992.

Maintenance

The primary maintenance consideration for temporary sediment traps is the removal of accumulated sediment from the basin, which must be done periodically to ensure the continued effectiveness of the sediment trap. Sediments should be removed when the basin reaches approximately 50 percent sediment capacity.

A sediment trap should be inspected after each rainfall event to ensure that the trap is draining properly. Inspectors should also check the structure for damage from erosion or piping. The

depth of the spillway should be checked and maintained at a minimum of 1.5 feet below the low point of the trap embankment.

Cost

The cost of installing temporary sediment traps ranges from $0.20 to $2.00 per cubic foot of storage (about $1,100 per acre of drainage). EPA estimated the following costs for sediment traps, which vary as a function of the volume of storage: $513 for 1,800 cubic yards, $1,670 for 3,600 cubic yards, and $2,660 for 5,400 cubic yards (USEPA 1993). Evaluation of a series of more recent data sources (USEPA 2003) indicated that sediment traps have an average cost of $0.30 per cubic foot of storage. In addition, it has been reported that a sediment trap has an annual maintenance cost of 20 percent of installation cost (Brown and Schueler 1997).

7.2.3.5. Sediment Basin

General Description

A sediment basin is a stormwater detention structure formed by constructing a dam across a drainageway or excavating a storage volume at other suitable locations and using it to intercept sediment-laden runoff. Sediment basins are generally larger and more effective in retaining sediment than temporary sediment traps and typically remain active throughout the construction period. Jurisdictions that require post-development flow to be less than or equal to predevelopment flow during construction could employ the designed detention facilities as a temporary sediment basin during construction.

When sediment basins are designed properly, they can control sediment pollution through the following functions (Faircloth 1999):

- Sediment-laden runoff is caught to form an impoundment of water and create conditions where sediment will settle to the bottom of the basin.
- Treated runoff is released with less sediment concentration than when it entered the basin.
- Storage is provided for accumulated sediment, and resuspension by subsequent storms is limited.

Applicability

Sediment basins should be located at a convenient concentration point for sediment-laden flows (NCDNR 1988). Ideal sites are areas where natural topography allows a pond to be formed by constructing a dam across a natural swale; such sites are preferred to those that require excavation (Smolen et al. 1988).

Sediment basins are also applicable in drainage areas where it is anticipated that other erosion controls, such as sediment traps, will not be sufficient to prevent off-site transport of sediment. Choosing to construct a sediment basin with either an earthen embankment or a stone/rock dam will depend on the materials available, location of the basin, and desired capacity for stormwater runoff and settling of sediments.

Rock dams are suitable where earthen embankments would be difficult to construct or where riprap is readily available. Rock structures are also desirable where the top of the dam structure is to be used as an emergency overflow outlet. These riprap dams are best for drainage areas of less than 50 acres. Earthen damming structures are appropriate where failure of the dam will not result in substantial damage or loss of property or life. If properly constructed, sediment basins with earthen dams can handle stormwater runoff from drainage basins as large as 100 acres.

Design and Implementation Criteria

Hydrologic Design

A sediment basin can be constructed by excavation or by erecting an earthen embankment across a low area or drainage swale. Sediment basins can be designed to drain completely during dry periods, or they can be constructed so that a shallow, permanent pool of water remains between storm events. Depending on the size of the basin constructed, the basin might be subject to additional regulation, particularly state and federal regulations related to dam safety.

Sediment basins can be used for any size watershed, but USDOT recommends a drainage area range of 5 to 100 acres (USDOT 1995). Components of a sediment basin that must be considered in the hydrologic design include the following (Haan et al. 1994):

- A sediment storage volume sized to contain the sediment trapped during the life of the structure or between cleanouts
- A permanent pool volume (if included) above the sediment storage to protect trapped sediment and prevent resuspension as well as providing a first flush of discharge that has been subjected to an extended detention period
- A detention volume that contains storm runoff for a period sufficient to trap the necessary quantity of suspended solids
- A principal spillway that can be a drop-inlet pipe and barrel, a trickle tube, or other type of controlled release structure
- An emergency spillway that is designed to handle excessive runoff from the rarer events and prevent overtopping

The following recommended procedures for conducting the hydrologic design are summarized from Haan et al. (1994).

Sediment Storage Volume. This volume should be sufficient to store the sediment trapped during the life of the structure or between cleanouts. Sediment storage volume can be calculated on the basis of sediment yield using relationships such as the RUSLE with an appropriate delivery ratio (Renard et al. 1994) or a computer model such as SEDIMOT III (Barfield et al. 1996) or SEDCAD (Warner et al. 1999). Many design specifications, however, base the sediment storage volume on a volume per acre disturbed. For example, Pennsylvania specifies a sediment storage volume of 1,000 cubic feet per acre drained (see DCN 43050, *Pennsylvania Erosion and Sediment Pollution Control Program Manual*). This volume is highly site-specific, depending on rainfall distributions, soil types, and construction techniques.

Permanent Pool Volume. Providing a first flush of discharge that has been subjected to an extended detention period can help to minimize degradation of water quality and justify some permanent pool. The recommended capacity of the permanent pool varies with the regulatory agency. USDOT, for example, recommends 67 cubic yards per acre (126 m^3/ha) (USDOT 1995). This standard has been adopted by many states as well. If an effluent criterion such as allowable peak TSS or peak settleable solids is used, the final design of both permanent pool and detention volume should be selected only after using a computer model to predict the expected peak effluent concentrations.

Detention Volume. Storm runoff must be contained for a period of time sufficient to trap the necessary quantity of suspended solids. Because inflow is occurring simultaneously with outflow, the detention time for each plug of flow is different and should be considered individually. The size of the detention volume, as stated above, should also be developed in concert with determining the size of the permanent pool volume as well as the size of the principal spillway. When effluent TSS and settleable solids criteria are used, the size of the detention volume and permanent pool volume should be determined through a computer model calculation of expected effluent concentrations for a given design. The return period used to size the detention volume depends on the regulatory agency, but a return period of 10 years is typical for sediment basins that eventually become stormwater detention ponds (i.e., are used to limit future flooding due to stormwater). EPA's review of state construction site regulations found the majority of states specify detention volume in terms of cubic feet per acre that drains to the sediment basin. State design values range between 1,800 and 5,400 cubic feet per acre, with 3,600 cubic feet per acre or expected runoff from the local 2-year, 24-hour storm event as the typical value.

Principal Spillway. The principal spillway is a hydraulic outlet structure sized to provide the appropriate outflow rate to meet the effluent or trapping efficiency criteria. The principal spillway should have a dewatering device that slowly releases water contained in the detention storage over an extended period of time and at a rate determined to trap the required amount of sediment and/or provide for the appropriate effluent concentration in the design storm. The more common outlet structures are the drop-inlet structure and the trickle tube. Sizing of the principal spillway should follow standard design procedures with respect to hydrology and sediment considerations, but sizing the structure to simply pass the design storm is inappropriate and will not result in meeting an effluent or trapping efficiency standard. The size to be used in a given structure should be determined on the basis of the effluent or trapping efficiency standard being targeted and site-specific hydrologic and soil conditions. Appropriate design will require the use of a computer model such as SEDIMOT III (Barfield et al. 1996) or design aids such as those developed for South Carolina (Hayes and Barfield 1995). In general, the design is developed to maximize surface area, which will minimize peak discharge. Because failure of the dam could result in downstream damage, the design should be done and certified by a licensed engineer with expertise in hydrologic computation.

It has been proposed that a surface skimmer made of PVC, aluminum, or stainless steel and designed to prevent trash from clogging can also be used to replace conventional principal spillways. The skimmer puts the basin drain just below the water surface, allowing for a constant head rather than variable head from the bottom. It is proposed that the skimmer allows water to be released from the top of the basin, which would be the cleanest water, and that the skimmer properly regulates the filling and draining of the basin (Faircloth 1999). The skimmer floats on

the surface of the basin and rises as water in the basin rises during a storm. After the storm, the skimmer slowly releases water from the basin. As the basin drains, the skimmer settles to the bottom, draining the entire pool except for a pool directly under the skimmer. The skimmer can be attached directly to an outlet pipe that drains through the dam or can be attached to an outlet pipe through a riser. A single hole placed just above the sediment cleanout level can also dewater the basin slowly.

Emergency Spillway. Because overtopping of the dam can cause failure and downstream damage, an emergency spillway is necessary to handle excessive runoff from the larger, less frequent events and prevent overtopping. The design storm for the emergency spillway will depend on the hazard classification of the sediment basin. Typical return periods vary between 25 and 100 years, with 25 years recommended by USDOT. Sizing of the emergency spillway is typically accomplished to simply transmit the rare event without eroding the base of the spillway. Procedures for making the hydrologic and hydraulic computations are summarized in Haan et al. (1994). Again, because failure of the dam could result in downstream damage, the design should be done and certified by a licensed engineer with expertise in hydrologic computation.

Installation Criteria

The embankment for permanent sediment basins should be designed using standard geotechnical construction techniques. The fill is typically constructed of earthen fill material placed and compacted in continuous layers over the entire length of the fill. USDOT recommends 6- to 8-inch layers (USDOT 1995). The embankment should be stabilized with vegetation after construction of the basin. A cutoff trench should be excavated along the centerline of the dam to prevent excessive seepage beneath the dam and be sized using standard geotechnical computations. USDOT recommends that a minimum depth of the cutoff trench should be approximately 2 feet (600 mm), the height should be to the riser crest elevation, the minimum bottom width should be 4 feet (1.2 m) or wide enough for compaction equipment, and slopes should be no steeper than 1:1.

Sediment basins can also be constructed with rock dams in a design that is similar to a sediment basin with an earthen embankment. It is important to remember that rock fill is highly heterogeneous and that flow rates calculated with any available procedure are not likely to match those that will actually occur. Because sediment trapping is inversely proportional to flow rate, the trapping efficiency will be affected significantly. No data are available to determine the variability of rock fill in actual installations so that confidence intervals can be placed on predicted flow rates. Such data should be collected and the confidence intervals calculated before recommending the use of rock dams as outlets on any structures other than sediment traps.

Effectiveness

The effectiveness of a sediment basin depends primarily on the sediment particle size and the ratio of basin surface area to inflow rate (Smolen et al. 1988; Haan et al. 1994). Basins with a large surface area-to-volume ratio will be most effective. Studies by Barfield and Clar (1985) showed that a surface area-to-peak discharge ratio of 0.01 acre per cubic foot would trap more than 75 percent of the sediment coming from the Coastal Plain and Piedmont regions in Maryland. This efficiency might vary for other regions of the country and should not be used as a

national standard. Studies by Hayes et al. (1984) and Stevens et al. (2001), however, show that similar relationships can be developed for other locations.

Laboratory data collected on pilot-scale facilities are available on the trapping efficiency of sediment basins, effluent concentrations, dead storage and flow patterns, and the effects of chemical flocculants on sediment trapping (Tapp et al. 1981; Wilson and Barfield 1984; Griffin et al. 1985; Jarrett 1999; Ward et al. 1977, 1979). In general, the laboratory studies show that pilot-scale ponds can be expected to trap 70 to 90 percent of sediment, depending on the sediment characteristics, pond volume, and flow rate. The trapping efficiency and effluent concentration are, in general, related to the overflow rate and can be reasonably well predicted using a plug flow model (Ward et al. 1977, 1979) and a Continuously Stirred Tank Reactor (CSTR) model (Wilson et al. 1982; Wilson et al. 1984). Extensive field-scale data are available on long-term trapping efficiency in stormwater detention basins in which the annual trapping efficiency is related to the annual capacity inflow ratio of the basin. These structures are not representative of those used for sediment ponds but would be representative of those used for regional detention. A more limited database is available on single storm sediment trapping in the larger structures (Ward, et al. 1979) and on a field laboratory structure at Pennsylvania State University (Jarret et al. 1999).

For maximum trap efficiency, Smolen et al. (1988) recommend the following:

- Allow the largest surface area possible, maximize the length-to-width ratio of the basin to prevent short circuiting, and ensure use of the entire design settling area.
- Locate inlets for the basin at the maximum distance from the principal spillway outlet.
- Allow the maximum reasonable time to detain water before dewatering the basin.
- Reduce the inflow rate into the basin and divert all sediment-free runoff.

Jarett (1999) has shown that the smaller the depth of the basin, the more sediment is discharged. A 0.15-meter-deep (0.49-foot-deep) basin lost twice as much sediment as a 0.46-meter-deep (1.5-foot-deep) basin. Jarrett also found that the performance of a sediment basin will increase with the use of a skimmer in the principal spillway. The sediment discharged was 1.8 times greater with only a perforated riser than with a skimmer in the principal spillway. In addition, increasing the dewatering time, which will allow for more sediment deposition, decreases the sediment loss from the basin (Jarett 1999).

Limitations

Neither a sediment basin with an earthen embankment nor a rock dam should be used in areas of continuously running water (live streams). The use of sediment basins is not intended for areas where failure of the earthen or rock dam will result in loss of life, damage to homes or other buildings, or interference with the use of public roads or utilities.

Because sediment basins are usually temporary structures, they are often designed poorly and rarely receive adequate attention and maintenance. As a result, these basins will not achieve the function for which they were designed, especially when conventional outlets cannot properly

meter outflow to create an impoundment, thus allowing rapid release of sediment-laden water from the bottom of the basin to escape (Faircloth 1999).

Common concerns associated with sediment basins are included in Table 7-19.

Table 7-19. Common Concerns Associated with Sediment Basins

Common concern	Result
Improper compaction, omission of anti-seep collar, leaking pipe joints, or use of unsuitable soil	Results in piping failure along conduit
Inadequate vegetation or improper grading and sloping	Results in erosion of spillway or embankment slopes
Inadequate compaction or use of unsuitable soil	Results in slumping or settling of embankment
Steep side slopes	Results in bank failure due to slumping
Inadequate outlet protection	Results in erosion and caving below principal spillway
Basin not located properly for access	Results in difficult, ineffective, and costly maintenance
Sediment not properly removed	Results in inadequate storage capacity and potential resuspension
Lack of anti-flotation	Results in the riser and barrel being blocked with debris
Principal and emergency spillway on design plans	Results in improper disposal of accumulated sediment
Gravel clogging the dewatering system	Results in safety or health hazard from pond water
Principal spillway too small	Results in frequent operation of emergency spillway and increased erosion potential

Source: IDNR 1992.

Maintenance

Routine inspection and maintenance of sediment basins is essential to their continued effectiveness. Basins should be inspected after each storm event to ensure proper drainage from the collection pool and determine the need for structural repairs. Erosion from the earthen embankment or stones moved from rock dams should be repaired or replaced immediately.

Sediment basins must be located in an area that is easily accessible to maintenance crews for removal of accumulated sediment. Sediment should be removed from the basin when its storage capacity has reached approximately 50 percent. Trash and debris from around dewatering devices should be removed promptly after rainfall events.

Cost

If constructing a sediment basin with less than 50,000 cubic feet of storage space, the cost of installing the basin ranges from $0.20 to $1.30 per cubic foot of storage (approximately $1,100 per acre of drainage) with an average cost of approximately $0.60 per cubic foot of storage

(USEPA 1993). If constructing a sediment basin with more than 50,000 cubic feet of storage space, the cost of installing the basin ranges from $0.10 to $0.40 per cubic foot of storage (approximately $550 per acre of drainage) with an average cost of approximately $0.30 per cubic foot of storage (USEPA 1993). A review of state highway project bids and county bonding estimates conducted in 2003 confirmed this value of $0.30 per cubic foot (USEPA 2003). Annual maintenance costs are 25 percent of installation costs (Brown and Schueler 1997).

R.S. Means (2000) suggests the cost to remove the eroded sediment collected in a small basin during construction is approximately $4 per cubic yard (this value includes a 100 percent surcharge for wet excavation). Disposal of material on-site will result in an additional cost that can be computed only from site-specific conditions. The cheapest management of dredged material is application to land areas adjacent to the basin followed with application of a vegetative cover.

7.2.4. OTHER CONTROL PRACTICES

7.2.4.1. Stone Outlet Structure

Description

A stone outlet structure is a temporary stone dike installed in conjunction with and as a part of an earth dike. The purpose of the stone outlet structure is to impound sediment-laden runoff, provide a protected outlet for an earth dike, provide for diffusion of concentrated flow, and allow the area behind the dike to dewater slowly. The stone outlet structure can extend across the end of the channel behind the dike or be placed in the dike itself. In some cases, more than one stone outlet structure can be placed in a dike.

Applicability

Stone outlet structures apply to any point of discharge where there is a need to discharge runoff at a protected outlet or to diffuse concentrated flow for the duration of the period of construction. The drainage area to this practice is typically limited to one-half acre or less to prevent excessive flow rates. The stone outlet structure should be located so as to discharge onto an already stabilized area or into a stable watercourse. Stabilization should consist of complete vegetative cover and paving that are sufficiently established to be erosion resistant.

Design and Installation Criteria

Design criteria are of two types, hydrologic design for a required trapping of sediment and/or flow rate to pass the design storm; and selection of appropriate installation criteria such that the stone outlet will perform as designed.

Hydrologic Design

The hydrologic design should be based on the design storm and standard hydraulic calculations. It should include the following considerations:

- Design rainfall and design storm. The design storm should be specified by the regulatory authority. Typically a return period of 2 to 5 years is used. Runoff rates

should be calculated with standard hydrologic procedures as allowed by the regulatory authority.

- Drainage area. The drainage area to this structure is typically limited to less than half an acre to ensure that the flow rates are not excessive.
- Length of crest and height of stone fill. The crest length and height of stone fill should be of sufficient size to transmit the design storm without overtopping. The volume of water stored behind the dike can be estimated, but would require routing the storm flow in the design storm. Flow through the stone outlet can be calculated using the relationships of Herrera and Felton (1991) as modified by Haan et al. (1994). The height of the fill should be small enough to prevent excessive flow velocities through the stone fill and prevent undercutting.
- Outlet stabilization. The discharge from the stone outlet should be stabilized with vegetated waterways or riprap until the flow reaches a stable channel. Design of the stabilized outlet should follow procedures presented earlier.

Installation Criteria Specifications

A stone outlet structure should conform to the following specifications:

- The outlet should be composed of 2- to 3-inch stone or recycled concrete, but clean gravel can be used if stone is not available.
- The crest of the stone dike should be at least 6 inches lower than the lowest elevation of the top of the earth dike and should be level.
- The stone outlet structure should be embedded into the soil a minimum of 4 inches.
- The minimum length of the crest of the stone outlet structure should be 6 feet.
- The baffle board should extend 1 foot into the dike and 4 inches into the ground and be staked in place.
- The drainage area to this structure should be less than half an acre.

7.2.4.2. Rock Outlet Protection

Description

Rock outlet structures are rocks that are placed at the outfall of channels or culverts to reduce the velocity of flow in the receiving channel to nonerosive rates.

Applicability

This practice applies where discharge velocities and energies at the outlets of culverts are sufficient to erode the next downstream reach and is applicable to outlets of all types such as sediment basins, stormwater management ponds, and road culverts.

Design and Installation Criteria

Hydrologic Design

Hydrologic design consists primarily of selecting the design runoff rate and sizing outlet protection. Standard hydrologic calculations should be used with an appropriate return period storm for the outlet being protected (typical return periods range from 2 to 10 years).

The process for sizing outlet protection involves selecting the type and geometry of the outlet protection and the size of the rock lining. The outlet protection could consist of a plunge pool (scour hole), an apron-type arrangement, or an energy dissipation basin (Haan et al. 1994). The design of each differs. Plunge pools are typically used for outlet pipes that are elevated above the water surface. Aprons are used for other types of outlets. Plunge pool geometry is based on the flow rate, pipe size and slope, tailwater depth, and size of the riprap lining (Haan et al. 1994). Apron dimensions are determined by the ratio of the tailwater depth to pipe diameter (Haan et al. 1994). Energy dissipation basins are used as an alternative to the plunge pool. Dimensions are a function of the brink depth in the pipe at the design flow, pipe diameter, and size of riprap (Haan et al. 1994). The size of the rock lining is a function of the discharge, pipe size, tailwater depth, and geometry selected. Details on sizing the rock are given in Haan et al. (1994).

The design method presented here applies to the sizing of rock riprap and gabions to protect a downstream area. It does not apply to rock lining of channels or streams. The design of rock outlet protection depends entirely on the location. Pipe outlets at the top of cuts or on slopes steeper than 10 percent cannot be protected by rock aprons or riprap sections due to reconcentration of flows and high velocities encountered after the flow leaves the apron.

Installation Criteria

The following criteria should be considered:

- Bottom grade: The outlet protection apron should be constructed with zero slope along its length. There should be no obstruction at the end of the apron. The elevation of the downstream end of the apron should be equal to the elevation of the receiving channel or adjacent ground.
- Alignment: The outer protection apron should be located so that there are no beds in the horizontal alignment.
- Materials: The outlet protection can be accomplished using rock riprap or gabions. Riprap should be composed of a well-graded mixture of stone sized so that 50 percent of the pieces, by weight, should be larger than the size determined using charts. The minimum d_{50} size to be used should be 9 inches. A well-graded mixture is defined as a mixture composed primarily of larger stone sizes but with a sufficient mixture of other sizes to fill the smaller voids between the stones. The diameter of the largest stone in such a mixture should be 2 times the size selected in Table 7-20 (MDE 1994).
- Thickness: Riprap specification values are summarized in Table 7-20.

Table 7-20. Riprap Sizes and Thicknesses

	D_{50} (inches)	D_{100} (inches)	Thickness (inches)
Class I	9.5	15	19
Class II	16	24	32
Class III	23	34	46

Source: USDOT 1995

- Stone Quality: Stone for riprap should consist of field stone or rough-hewn quarry stone. The stone should be hard and angular and of a quality that will not disintegrate on exposure to water or weathering. The specific gravity of the individual stones should be at least 2.5. Recycled concrete equivalent can be used, provided it has a density of at least 150 pounds per cubic foot and does not have any exposed steel or reinforcing bars.

- Filters: A layer of material placed between the riprap and the underlying soil surface can prevent soil movement into and through the riprap to prevent piping, reduce uplift pressure, and collect water. Riprap should have a filter placed under it in all cases. A filter can be of two general forms: a gravel layer or a geotextile.

- Gabions: Gabion baskets can be used as rock outlet protection, provided they are made of hexagonal triple twist mesh with heavily galvanized steel wire. The maximum lined dimension of the mesh opening should not exceed 4.5 inches. The area of the mesh opening should not exceed 10 square inches. Gabions should be fabricated in such a manner that the sides, ends, and lid can be assembled at the construction site into a rectangular basket of the specified sizes.

  Gabions should be of a single unit construction and should be installed according to the manufacturer's specifications. Foundation conditions should be the same as for placing rock riprap. Geotextiles should be placed under all gabions, and gabions must be keyed in to prevent undermining of the main gabion structure.

- The subgrade for the filter, riprap, or gabion should be prepared to the required lines and grades. Any fill required in the subgrade should be compacted to a density of approximately that of the surrounding undisturbed material.

- The rock or gravel should conform to the specified grading limits when installed in the riprap or filter, respectively.

- Geotextiles should be protected from punching, cutting, or tearing. Any damage other than occasional small holes should be repaired by placing another piece of geotextile fabric over the damaged part or by completely replacing the geotextile fabric. All overlaps, whether for repairs or for joining two pieces of geotextile fabric, should be a minimum of 1 foot in length.

- Stone for the riprap or gabion outlets can be placed by equipment. They should be constructed to the full course thickness in one operation and in such a manner as to avoid displacement of underlying materials. Care should be taken to ensure that the

stone is not placed so that rolling would cause segregation of stone by size, i.e., the stone for riprap or gabion outlets should be delivered and placed in a manner that will ensure that it is reasonably homogeneous, with smaller stones filling the voids between larger stones. Riprap must be placed so as to prevent damage to the filter blanket or geotextile fabric. Hand placement will be required to the extent necessary to prevent damage to the permanent works.

- Stone should be placed so that it blends in with the existing ground and the depth to the stone surface is sufficient to transmit the flow without spilling over onto the unprotected surface.

Effectiveness

There is no information on the effectiveness of rock outlet structures.

Limitations

Common problems with rock outlet structures include the following:

- If the foundation is not excavated deeply or wide enough, the flow cross-section could be restricted, resulting in erosion around the apron and scour holes at the outlet. Also, the riprap apron should be placed on a suitable foundation to prevent downstream erosion.
- If the riprap that is installed is smaller than specified, rock displacement might result; selectively grouting over the rock materials could stabilize the installation.
- If the riprap is not extended enough to reach a stable section of the channel, downstream erosion could result.
- If a filter is not installed under the riprap, stone displacement and erosion of the foundation might result.

Maintenance

Once a riprap outlet has been installed, the maintenance needs are very low. It should be inspected after high flows to see if scour has occurred beneath the riprap, if flows have occurred outside the boundaries of the riprap and caused scour, or if any stones have been dislodged. Repairs should be made immediately.

Cost

R.S. Means (2000) indicates machine-placed riprap costs of approximately $40 per cubic yard. For a riprap maximum size between 15 and 24 inches, a cubic yard of riprap will cover between 13.5 and 17 square feet at channel bed (assuming depth of riprap as given in Table 5-22). This suggests that riprap lining will be between $21 and $27 per square foot of outlet (includes materials, labor, and equipment, with overhead and profit). R.S. Means (2000) provides a cost range for gabions ($2.80 to $9 per square foot of coverage) for stone fill depths of 6 to 36 inches, respectively. These costs include all costs of materials, labor, and installation.

7.2.4.3. Sump Pit

Description

A sump pit is a temporary pit from which pumping is conducted to remove excess water while minimizing sedimentation. The purpose of the sump pit is to filter water being pumped to reduce sedimentation to receiving streams.

Applicability

Sump pits are constructed when water collects and must be pumped away during excavating, cofferdam dewatering, maintenance or removal of sediment traps and basins, or other uses as applicable, such as for concrete wash out.

Design and Installation Criteria

Hydrologic Design

The only hydrologic calculation is determining the expected flow rate and volume to be handled. This should follow standard hydrologic computational procedures based on design rainfall, surface and soil conditions, and the size of the pump.

Installation Criteria and Specifications

The number of sump pits and their locations should be determined by the designer and included on the plans. Contractors can relocate sump pits to optimize use, but discharge location changes should be coordinated with inspectors.

A perforated, vertical standpipe should be wrapped with 1/2-inch hardware cloth and geotextiles and then placed in the center of an excavated pit, which is then backfilled with filter material ranging from clean gravel to stone. Water is then pumped from the center of the standpipe to a suitable discharge area such as into a sediment trap, sediment basin, or stabilized area.

A sump pit should conform to the following specifications:

- Pit dimensions are variable, with the minimum diameter being twice the diameter of the standpipe.
- The standpipe should be constructed by perforating a 12- to 36-inch diameter pipe, then wrapping it with 1/2-inch hardware cloth and geotextiles. The perforations should be 1/2-inch slits or 1-inch diameter holes placed 6 inches on center.
- The standpipe should extend 12 to 18 inches above the lip of the pit or riser crest elevation (basin dewatering), and filter material should extend 3 inches minimum above the anticipated standing water level.

Effectiveness

There is no information on the effectiveness of the sump pit.

Limitations

The sump pit must be properly maintained and pumped regularly to avoid clogging.

Maintenance

To maintain, sump pits must be removed and reconstructed when water can no longer be pumped out of the standpipe.

Cost

R.S. Means (2000) provides information appropriate for assessing a wide range of dewatering scenarios (i.e., different sump sizes, dewatering durations, and discharge conditions). In general, installing earthen sump pits are listed as costing approximately $1.50 per cubic foot of sump volume. Piping to and away from the sump ranges from $30 to $60 per linear foot. Pump rentals and operation range between $150 and $500 per day of pumping, depending on the rate of dewatering. All costs include materials, labor, and equipment, with overhead and profit.

7.2.4.4. Sediment Tank

Description

A sediment tank is a compartmented container through which sediment-laden water is pumped to trap and retain sediment before pumping the water to drainageways, adjoining properties, and rights-of-way below the sediment tank site.

Applicability

A sediment tank should be used on sites where excavations are deep and space is limited, such as urban construction, where direct discharge of sediment-laden water to streams and storm drainage systems should be avoided.

Design and Installation Criteria

The location of sediment tanks should facilitate easy cleanout and disposal of the trapped sediment to minimize interference with construction activities and pedestrian traffic. The tank size should be determined according to the storage volume of the sediment tank, with 1 cubic foot of storage for each gallon per minute of pump discharge capacity.

Effectiveness

There is no information on the effectiveness of sediment tanks.

Limitations

The sediment tank does not provide any natural infiltration; thus, the trapped sediment and stormwater must be disposed of properly.

Maintenance

To facilitate maintenance of sediment tanks, they need to be located with easy access for regular pump out. The rate at which a tank is pumped depends on site-specific considerations such as rainfall and sediment loads to the system. Regular inspections will help to determine pump out frequency and prevent overloading and failure of the system.

Cost

There is no information on the cost of sediment tanks.

7.2.4.5. Stabilized Construction Entrance

Description

The purpose of stabilizing entrances to a construction site is to minimize the amount of sediment leaving the area as mud attached to tires. Installing a pad of gravel over filter cloth where construction traffic leaves a site can help stabilize a construction entrance. As a vehicle drives over the gravel pad, mud and other sediments are removed from the vehicle's wheels (sometimes by washing) and off-site transport of sediment is reduced. The gravel pad also reduces erosion and rutting on the soil beneath the stabilization structure. The fabric reduces the amount of rutting caused by vehicle tires by spreading the vehicle's weight over a larger soil area than just the tire width. The filter fabric also separates the gravel from the soil below, preventing the gravel from being ground into the soil.

Applicability

Stabilized construction entrances typically are installed at locations where construction traffic leaves or enters an existing paved road. However, the applicability of site entrance stabilization should be extended to any roadway or entrance where vehicles will access or leave the site.

From a public relations point of view, stabilizing construction site entrances can be a worthwhile exercise. If the site entrance is the most publicly noticeable part of a construction site, stabilized entrances can improve the appearance to passersby and improve public perception of the construction project by reducing the amount of mud tracked onto adjacent streets.

Design and Installation Considerations

Hydrologic Design

Not applicable.

Installation Criteria and Specifications

All entrances to a site should be stabilized before construction begins and further disturbance of the site area occurs. The stabilized site entrances should be long enough and wide enough so that the largest construction vehicle that will enter the site will fit in the entrance with room to spare. If many vehicles are expected to use an entrance in any one day, the site entrance should be wide enough for the passage of two vehicles at the same time with room on either side of each vehicle. For optimum effectiveness, a rock construction entrance should be at least 50 feet long and at least 10 to 12 feet wide (USEPA 1992). If a site entrance leads to a paved road, the end of entrance should be *flared* (made wider as in the shape of a funnel) so that long vehicles do not go off the stabilized area when turning onto or off of the paved roadway.

If a construction site entrance crosses a stream, swale, roadside channel, or other depression, a bridge or culvert should be provided to prevent erosion from unprotected banks.

Stone and gravel used to stabilize the construction site entrance should be large enough so that nothing is carried off-site with vehicle traffic. In addition, sharp-edged stone should be avoided to reduce the possibility of puncturing vehicle tires. Stone or gravel should be installed at a depth of at least 6 inches for the entire length and width of the stabilized construction entrance.

Effectiveness

Stabilizing construction entrances to prevent sediment transport off-site is effective only if all entrances to the site are stabilized and maintained. Also, stabilizing construction site entrances might not be very effective unless a wash rack is installed and routinely used (Corish 1995), although this can be problematic for sites with multiple entrances that have high vehicle traffic.

Limitations

Although stabilizing a construction entrance is a good way to help reduce the amount of sediment leaving a site, some sediment can still be deposited from vehicle tires onto paved surfaces. To further reduce the chance that these sediments will pollute stormwater runoff, sweeping of the paved area adjacent to the stabilized entrance is recommended.

For sites using wash stations, a reliable water source to wash vehicles before leaving the site might not be initially available. In such a case, water might have to be trucked to the site at an additional cost. Discharge from the wash station should be directed to an appropriate sediment control structure.

Maintenance

Stabilization of site entrances should be maintained until the remainder of the construction site has been fully stabilized. Stone and gravel might need to be periodically added to each stabilized construction site entrance to maintain its effectiveness. Soil that is tracked off-site should be swept up immediately and disposed of properly.

For sites with wash racks at each site entrance, sediment traps will have to be constructed and maintained for the life of the project. Maintenance will entail the periodic removal of sediment from the traps to ensure their continued effectiveness.

Cost

Without a wash rack, construction site entrance stabilization costs range from $1,000 to $4,000. On average, the initial construction cost is approximately $2,000 per entrance. When maintenance costs are included, the average total annual cost for a 2-year period is approximately $1,500. If a wash rack is included in the construction site entrance stabilization, the initial construction costs range from $1,000 to $5,000, with an average initial cost of $3,000 per entrance. Total annual cost, including maintenance for an estimated 2-year life span, is approximately $2,200 per year (USEPA 1993).

7.2.4.6. Land Grading

Description

Land grading involves reshaping the ground surface to planned grades as determined by an engineering survey, evaluation, and layout. Land grading provides more suitable topography for

buildings, facilities, and other land uses and helps to control surface runoff, soil erosion, and sedimentation both during and after construction.

Applicability

Land grading is applicable to sites with steep topography or easily erodible soils because it stabilizes slopes and decreases runoff velocity. Grading activities should maintain existing drainage patterns as much as possible.

Design and Installation Criteria

Before grading activities begin, decisions should be made regarding the steepness of cut-and-fill slopes and how the slopes will be protected from runoff, stabilized, and maintained. A grading plan should be prepared that establishes which areas of the site will be graded, how drainage patterns will be directed, and how runoff velocities will affect receiving waters. The grading plan also includes information regarding when earthwork will start and stop, establishes the degree and length of finished slopes, and dictates where and how excess material will be disposed of (or where borrow materials will be obtained if needed). Berms, diversions, and other stormwater practices that require excavation and filling should also be incorporated into the grading plan.

One low-impact development technique that can be incorporated into a grading plan is site fingerprinting. This involves clearing and grading only those areas necessary for building activities and equipment traffic. Adhering to strict limits of clearing and grading helps to maintain undisturbed temporary or permanent buffer zones in the grading operation and provides a low-cost sediment control measure that will help reduce runoff and off-site sedimentation. The lowest elevation of the site should remain undisturbed to provide a protected stormwater outlet before storm drains or other construction outlets are installed.

Effectiveness

Land grading is an effective means of reducing steep slopes and stabilizing highly erodible soils when implemented with stormwater management and erosion and sediment control practices in mind. Land grading is not effective when drainage patterns are altered or when vegetated areas on the perimeter of the site are destroyed.

Limitations

Construction sites are routinely graded to prepare a site for buildings and other structures. Improper grading practices that disrupt natural stormwater patterns can lead to poor drainage, high runoff velocities, and increased peak flows during storm events. Clearing and grading of the entire site without vegetated buffers promotes off-site transport of sediments and other pollutants. Grading plans should be designed with erosion and sediment control and stormwater management goals in mind; grading crews should be carefully supervised to ensure that the plan is implemented as intended.

Maintenance

All graded areas and supporting erosion and sediment control practices should be periodically checked, especially after heavy rainfalls. All sediment should be promptly removed from diversions or other stormwater conveyances. If washouts or breaks occur, they should be

repaired immediately. Prompt maintenance of small-scale eroded areas is essential to prevent these areas from becoming significant gullies.

Cost

Land grading is practiced at virtually all construction sites—additional site planning to incorporate stormwater and erosion and sediment controls in grading plans can require several hours of planning by a certified engineer or landscape architect. Extra time might be required to excavate diversions and construct berms, and fill materials might be needed to build up low-lying areas or fill depressions.

Where grading is performed to manage on-site stormwater, R.S. Means (2000) suggests the cost of fine grading, soil treatment, and grassing to be approximately $2 per square yard of earth surface area. Shallow excavation/trenching (1 to 4 feet deep) with a backhoe in areas not requiring dewatering can be performed for $4 to $5 per cubic yard of removed material. Larger scale grading requires a site-specific assessment of an alternative grading apparatus and a detailed fill/excavation material balance to retain as much soil on site as possible.

7.2.4.7. Temporary Access Waterway Crossing

Description

A temporary stream crossing is a structure erected to provide a safe and stable way for construction vehicle traffic to cross a running watercourse. The primary purpose of such a structure is to provide streambank stabilization, to reduce the risk of damaging the streambed or channel, and to reduce the risk of sediment loading from construction traffic. A temporary stream crossing could be a bridge, culvert, or ford.

Applicability

Temporary stream crossings are applicable wherever heavy construction equipment must be moved from one side of a stream channel to the other or where lighter construction vehicles will cross the stream a number of times during the construction period. In either case, an appropriate method for ensuring the stability of the streambanks and preventing large-scale erosion is necessary.

A bridge or culvert is the best choice for most temporary stream crossings. If properly designed, each can support heavy loads, and materials used to construct most bridges and culverts can be salvaged after they are removed. Fords are appropriate in steep areas subject to flash flooding, where normal flow is shallow or intermittent across a wide channel. Fords should be used only where stream crossings are expected to be infrequent.

Design and Installation Criteria

Because of the potential for stream degradation, flooding, and safety hazards, stream crossings should be avoided on a construction site whenever possible. Consideration should be given to alternative site access routes before arrangements are made to erect a temporary stream crossing. If it is determined that a stream crossing is necessary, an area where the potential for erosion is low should be selected. The stream crossing structure should be installed during a dry period if possible to reduce sediment transport into the stream.

If needed, over-stream bridges are generally the preferred temporary stream crossing structure. The expected load and frequency of the stream crossing, however, will govern the selection of a bridge as the correct choice for a temporary stream crossing. These types of temporary bridges usually cause minimal disturbance to a stream's banks and cause the least obstruction to stream flow and fish migration. They should be constructed only under the supervision and approval of a qualified engineer.

As general guidelines for constructing temporary bridges, clearing and excavation of the stream shores and bed should be kept to a minimum. Sufficient clearance should be provided for floating objects to pass under the bridge. Abutments should be parallel to the stream and be placed on stable banks. If the stream is less than 8 feet wide at the point where a crossing is needed, no additional in-stream supports should be used. If the crossing is to extend across a channel wider than 8 feet (as measured from the top of one bank to the other), the bridge should be designed with one in-water support for each 8 feet of stream width.

A temporary bridge should be anchored by steel cable or chain on one side only to a stable structure on shore. Examples of anchoring structures include trees with a large diameter, large boulders, and steel anchors. By anchoring the bridge on one side only, there is a decreased risk of causing a downstream blockage or flow diversion if a bridge is washed out.

When constructing a culvert, filter cloth should be used to cover the streambed and streambanks to reduce settlement and improve the stability of the culvert structure. The filter cloth should extend a minimum of 6 inches and a maximum of 1 foot beyond the end of the culvert and bedding material. The culvert piping should not exceed 40 feet in length and should be of sufficient diameter to allow for complete passage of flow during peak flow periods. The culvert pipes should be covered with a minimum of 1 foot of aggregate. If multiple culverts are used, at least 1 foot of aggregate should separate the pipes.

Fords should be constructed of stabilizing material such as large rocks.

Effectiveness

Both temporary bridges and culverts provide an adequate path for construction traffic crossing a stream or watercourse.

Limitations

Bridges can be considered the greatest safety hazard of all temporary stream crossing structures if not properly designed and constructed. Bridges can also prove to be more costly in terms of repair costs and lost construction time if they wash out or collapse (Smolen et al. 1988).

The construction and removal of culverts are usually very disturbing to the surrounding area, and erosion and downstream movement of sediments are often great. Culverts can also create obstructions to flow in a stream and inhibit fish migration. Depending on their size, culverts can be blocked by large debris and are therefore vulnerable to frequent blockage and washout.

If given a choice between building a bridge or a culvert as a temporary stream crossing, a bridge is preferred because of the relative minimal disturbance to streambanks and the opportunity for unimpeded flow through the channel. The approaches to fords often have high erosion potential.

In addition, excavation of the streambed and approach to lay riprap or other stabilization material causes major stream disturbance. Mud and other debris are transported directly into the stream unless the crossing is used only during periods of low flow.

Maintenance

Temporary stream crossings should be inspected at least once a week and after all significant rainfall events. If any structural damage is reported to a bridge or culvert, construction traffic should be excluded until appropriate repairs are made. Streambank erosion should be repaired immediately.

Fords should be inspected closely after major storm events to ensure that stabilization materials remain in place. If the material has moved downstream during periods of peak flow, the lost material should be replaced immediately.

Cost

In general, temporary bridges are more expensive to design and construct than culverts. Bridges are also associated with higher maintenance and repair costs should they fail. Temporary bridging costs vary as a function of the width of the bridge span and the amount of time the bridge is installed. If the bridging is permanent, a mean cost of $50 per square foot for an 8-foot wide steel arch bridge (no foundation costs included) can be used for conceptual cost estimation (R.S. Means 2000). If rental bridging is employed, rates are probably on the order of 20 to 50 percent of the bridge (permanent) cost but will vary according to the rental duration and mobilization distance.

7.2.4.8. Dust Control

General Description

Dust control measures are practices that help reduce ground surface and air movement of dust from disturbed soil surfaces. Construction sites are good candidates for dust control measures because land disturbance from clearing and excavation generates a large amount of soil disturbance and open space for wind to pick up dust particles. To illustrate this point, research at construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction (WDEC 1992). These airborne particles pose a dual threat to the environment and human health. First, dust can be carried off-site, thereby increasing soil loss from the construction area and increasing the likelihood of sedimentation and water pollution. Second, blowing dust particles can contribute to respiratory health problems and create an inhospitable work environment.

Applicability

Dust control measures are applicable to any construction site where dust is created and there is the potential for air and water pollution from dust traveling across the landscape or through the air. Dust control measures are particularly important in arid or semiarid regions where soil can become extremely dry and vulnerable to transport by high winds.

Also, dust control measures should be implemented on all construction sites where there will be major soil disturbances or heavy construction activity, such as clearing, excavation, demolition,

or excessive vehicle traffic. Earthmoving activities are the major source of dust from construction sites, but traffic and general disturbances can also be major contributors (WDEC 1992).

The specific dust control measures implemented at a site will depend on the topography, land cover, soil characteristics and amount of rainfall at the site.

Design and Installation Criteria

When designing a dust control plan for a site, the amount of soil exposed will dictate the quantity of dust generation and transport. Therefore, construction sequencing and disturbing small areas at one time can greatly reduce problematic dust from a site. If land must be disturbed, additional temporary stabilization measures should be considered before disturbance.

A number of methods can be used to control dust from a site. The following is a brief list of control measures and their design criteria. Not all control measures will be applicable to a given site. The owner, operator, and contractors responsible for dust control should determine which practices accommodate their needs on the basis of specific site and weather conditions.

Sprinkling/Irrigation: Sprinkling the ground surface with water until it is moist is an effective dust control method for haul roads and other traffic routes (Smolen et al. 1988). This practice can be applied to almost any site.

Vegetative Cover: In areas not expected to handle vehicle traffic, vegetative stabilization of disturbed soil is often desirable. Vegetative cover provides protection to surface soils and slows wind velocity at the ground surface, thus reducing the potential for dust to become airborne.

Mulch: Mulching can be a quick and effective means of dust control for a recently disturbed area (Smolen et al. 1988).

Wind Breaks: Wind breaks are barriers (either natural or constructed) that reduce wind velocity and therefore reduce the possibility of carrying suspended particles. Wind breaks can be trees or shrubs left in place during site clearing or constructed barriers such as a wind fence, snow fence, tarp curtain, hay bale, crate wall, or sediment wall (USEPA 1992).

Tillage: Deep tillage in large open areas brings soil clods to the surface where they rest on top of dust, preventing it from becoming airborne.

Stone: Stone can be an effective dust deterrent for construction roads and entrances.

Spray-on Chemical Soil Treatments (palliatives): Examples of chemical adhesives include anionic asphalt emulsion, latex emulsion, resin-water emulsions, and calcium chloride. Chemical palliatives should be used only on mineral soils. When considering chemical application to suppress dust, consideration should be taken as to whether the chemical is biodegradable or water-soluble and what effect its application could have on the surrounding environment, including waterbodies and wildlife.

Table 7-21 shows application rates for some common spray-on adhesives as recommended by Smolen et al. (1988).

Table 7-21. Application Rates for Spray-On Adhesives

Spray on adhesive	Water dilution	Type of nozzle	Application (gal/acre)
Anionic Asphalt Emulsion	7:1	Coarse spray	1,200
Latex Emulsion	12.5:1	Fine spray	235
Resin in Water	4:1	Fine spray	300

Source: Smolen et al. 1988.

Effectiveness

Sprinkling/Irrigation: Not available.

Vegetative Cover: Not available.

Mulch: Mulch can reduce wind erosion by up to 80 percent.

Wind Breaks/Barriers: For each foot of vertical height, an 8- to 10-foot deposition zone develops on the leeward side of the barrier. The barrier density and spacing will change its effectiveness at capturing windborne sediment.

Tillage: Roughening the soil can reduce soil losses by approximately 80 percent.

Stone: The sizes of the stone can affect the amount of erosion that will take place. In areas of high wind, small stones are not as effective as 20-cm stones.

Spray-on Chemical Soil Treatments (palliatives): Effectiveness of polymer stabilization methods ranges from 70 to 90 percent.

Limitations

In areas where evaporation rates are high, water application to exposed soils could require near constant attention. If water is applied in excess, runoff can result from the site and possibly create conditions where vehicles can track mud onto public roads.

Chemical applications should be used sparingly and only on mineral soils (not high organic content soils) because their misuse can create additional surface water pollution from runoff or can contaminate ground water if infiltrated. Chemical applications can also present a health risk if excessive amounts are used.

Maintenance

Because dust controls are dependent on specific site conditions including the weather, inspection and maintenance are unique for each site. Generally, however, dust control measures involving application of either water or chemicals require more monitoring than structural or vegetative controls to remain effective. If structural controls are used, they should be inspected for deterioration regularly to ensure that they are still achieving their intended purpose.

Cost

Chemical dust control measures can vary widely in cost depending on specific needs of the site and level of dust control desired. One manufacturer of a chloride product estimated a cost of $1,089 per acre for application to road surfaces but cautioned that cost estimates without a specific site evaluation can be inaccurate.

7.2.4.9. Storm Drain Inlet Protection

Description

Storm drain inlet protection measures are controls that help prevent soil and debris from on-site erosion from entering storm drain inlets. Typically, these measures are temporary controls that are implemented before large-scale disturbance of the surrounding site. These controls are advantageous because their implementation allows storm drains to be used during even the early stages of construction activities. The early use of storm drains during project development significantly reduces the occurrence of future erosion problems (Smolen et al. 1988).

Three temporary control measures to protect storm drain drop inlets are as follows:

- Excavation around the perimeter of the drop inlet
- Fabric barriers around inlet entrances
- Block and gravel protection

Excavation around a storm drain inlet creates a settling pool to remove sediments. Weep holes protected by gravel are used to drain the shallow pool of water that accumulates around the inlet. A filter fabric barrier erected around an inlet can create an effective shield to sediment while allowing water to flow into the storm drain. This type of barrier can slow runoff velocity while catching soil and other debris at the drain inlet. Block and gravel inlet protection uses standard concrete blocks and gravel to form a barrier to sediments while permitting water runoff through select blocks that are laid sideways. In addition to these materials, limited temporary stormwater drop inlet protection can also be achieved with the use of straw bales or sandbags to create barriers to sediment.

For permanent storm drain drop inlet protection after the surrounding area has been stabilized, sod can be installed as a barrier to slow stormwater entry to storm drain inlets and capture sediments from erosion. This final inlet protection measure can be used as an aesthetically pleasing way to slow stormwater velocity near drop inlet entrances and remove sediments and other pollutants from runoff.

A new technology that uses an insert trap into the inlet itself has been developed (Adams et al. 2000). This technique showed good results on initial tests, trapping more than 50 percent of the incoming sediment in flows typical of those into urban storm drains. This technique is being further developed with a pending patent application.

Applicability

All temporary controls should have a drainage area no greater than 1 acre of drainage area per inlet. It is also important for temporary controls to be constructed before disturbing the surrounding landscape. Excavated drop inlet protection and block and gravel inlet protection are applicable to areas of high flow where overflow is anticipated into the storm drain. Fabric barriers are recommended for smaller, relatively flat drainage areas (slopes less than 5 percent leading to the storm drain).

Temporary drop inlet control measures are often used in combination with each other and with other stormwater control techniques.

Design and Installation Considerations

Hydrologic Design

Hydrologic computations are not necessary with present technologies. A specified limitation of 1 drainage acre per inlet limits flow rates, dependent on local rainfall and runoff considerations.

Installation Criteria and Specifications

The following criteria should be followed until future research establishes better techniques:

- With the exception of sod drop inlet protection, these controls should be installed before any soil disturbance in the drainage area.
- Excavation around drop inlets should be dug a minimum of 1 foot deep (2 feet maximum) with a minimum excavated volume of 35 cubic yards per acre disturbed. Side slopes leading to the inlet should be no steeper than 2:1. The shape of the excavated area should be designed such that the dimensions fit the area from which stormwater is anticipated to drain. For example, the longest side of an excavated area should be along the side of the inlet expected to drain the largest area.
- Fabric inlet protection is essentially a filter fence placed around the inlet. The fabric should not be used as a stand-alone sediment control measures. To increase inlet protection effectiveness, these practices should be used in combination with other measures, such as small impoundments or sediment traps (USEPA 1992). Temporary storm drain inlet protection is not intended for use in drainage areas larger than 1 acre. Generally, stormwater inlet protection measures are practical for relatively low sediment and low volume flows.
- Frequent maintenance of storm drain controls is necessary to prevent clogging. If sediment and other debris clog the water intake, drop intake control measures can actually cause erosion in unprotected areas.

Maintenance

All temporary control measures must be checked after each storm event. To maintain the sediment capacity of the shallow settling pools created from these techniques, accumulated sediment should be removed from the area around the drop inlet (i.e., from the excavated area, around the fabric barrier, or around the block structure) when the sediment storage is reduced by

approximately 50 percent. Additional debris should be removed from the shallow pools periodically.

Weep holes in excavated areas around inlets can become clogged and prevent water from draining from the shallow pools that form. Should this happen, unclogging the water intake can be difficult and costly.

Cost

The cost of implementing storm drain drop inlet protection measures will vary depending on the control measure chosen. Generally, initial installation costs range from $50 to $150 per inlet, with an average cost of $100 (USEPA 1993). Maintenance costs can be high (annually, up to 100 percent of the initial construction cost) because of frequent inspection and repair needs. The SWRPC has estimated that the cost of installation of inlet protection devices ranges from $106 to $154 per inlet (SWRPC 1991).

7.2.4.10. Polyacrylamide (PAM)

General Description

The term *polyacrylamide* (PAM) is a generic term that refers to a broad class of compounds. There are hundreds of specific PAM formulations, and all have unique properties that depend on polymer chain length and number and kinds of functional group substitutions along the chain. PAMs are classified according to their molecular weight and ionic charge and are available in solid, granular, liquid, or emulsion forms.

The effectiveness of PAMs to prevent or reduce erosion is due to its affinity for soil particles, largely via coulombic and Van der Waals attraction. These surface attractions enhance particle cohesion, stabilizing soil structure against shear-induced detachment and transport in runoff. In a soil application, PAM aggregates soil particles, increasing pore space and infiltration capacity and resulting in reduced runoff. These larger particle aggregates are less susceptible to raindrop and scour erosion, thus reducing the potential to mobilize sediments.

Applicability

Because of ease in application, PAM is well suited as a short-term erosion prevention BMP, especially for areas with limited access or steep slopes that hinder personnel from applying other cover materials. PAM can be used to augment other cover practice BMPs, though it can be effective when applied alone. Thus, the ease of application, low maintenance, and relatively low cost associated with PAM make it a practical solution to soil stabilization during construction.

Application Criteria

PAM can be applied to soil through either a dry granular powder or a liquid spray form. Optimal application rates to prevent erosion on construction sites are generally less than 1 kg/ha (approximately 1 lb/ac) (Tobiason et al. 2000). However, the concentration required can vary for specific soil properties and construction phases. WDOT (2002) suggests a dosage of 60 mg/L for roadway erosion and sediment control. This is higher than the rate recommended by the University of Nebraska for an agricultural application (10 parts per million). To put this into

context, one half pound of PAM in 1,000 gallons of water results in a PAM concentration of 60 mg/L, which treats 1 acre of exposed soil according to WDOT recommendations.

Effectiveness

A study performed in Dane County, Wisconsin, analyzed 15-meter-square plots for runoff and sediment yield on a construction site. The study concluded that when a solution of PAM-mix with mulch/seeding was applied to dry soil and compared with the control (no PAM-mix application to dry soil), an average reduction of 93 percent in sediment yield was found. The lowest performance (average reduction in sediment yield of 77 percent) occurred when PAM-mix in solution was applied to moist soil. The application of dry PAM-mix to dry soil reduced sediment by 83 percent and decreased runoff by 16 percent when compared to the control. The results show that regardless of the application method, PAM-mix was effective in reducing sediment yield in the test plots (Roa-Espinosa et al. 2000).

A second study performed in Washington analyzed the runoff from three different construction sites: an erosion control test facility, a highway construction site, and an airport runway. Table 7-22 summarizes the 225 samples analyzed by Tobiason et al. (2000).

Table 7-22. Turbidity Reduction Values from PAM

	Volume (m^3)	Turbidity reduction (%)
Maximum	350	99.97
Median	285	97.6
Minimum	133	46

Limitations

PAMs are most commonly produced as dry granules. They completely dissolve and remain dissolved if mixed properly. If added too quickly or if not stirred vigorously, the granules rapidly form nondissolvable gels on contact with water or collect in low turbulence areas as syrupy concentrations that dissolve slowly in an uncontrolled pattern over a period of hours or days (Sojka and Lentz. 1994). In addition, when spilled on hard surfaces, PAM solutions are extremely slippery and hazardous to foot and vehicle traffic. PAM dust is highly hygroscopic and, if inhaled, could impair breathing. Certain neutral and cationic PAMs at very high exposure levels produce irritation in humans and are somewhat toxic to certain aquatic organisms; therefore, PAM should be used in strict compliance with state and federal label requirements.

Cost

The cost of PAM ranges from $1.25 per pound to $5.00 per pound (Entry et al. 1999). The cost of PAM application depends on the system employed. PAM can be used in a centralized treatment system (e.g., at a sedimentation basin) to treat larger areas, or dispersed in granular or liquid form. In Tobiason et al. (2000), the startup costs for the batch treatment system amounted to $90,000. Monthly expenses averaged $18,000 for operations and maintenance and $13,000 for materials and equipment. The total costs for this phase totaled about $245,000, less than 1 percent of total construction costs. If dispersed through irrigation systems (for agriculture), the

seasonal cost of PAM treatment is $9 to $15 per acre (Kay-Shoemake et al. 2000), where a season probably requires between 5 and 10 applications.

For construction sites, it is more likely that PAM would be applied as an additive to the hydroseed mix and applied when final grade is established and cover vegetation is installed. There are numerous suppliers who provide PAM as a low-cost additive for hydroseeding, suggesting PAM application costs can be incorporated into that of hydroseeding ($540 to $700 per acre depending on which seed is applied). An additional cost would be incurred to sample site soils to customize the dosage and delivery mechanisms for individual sites. In addition, reapplication of PAM in granular or liquid form to areas with rill development (poor vegetation cover) would require additional funds. Where reapplication of granular PAM is used, R.S. Means (2000) suggests a cost of approximately $5 per 1,000 square feet for spreading soil admixtures by hand.

7.2.5. ADVANCED TREATMENT AND CONTROL TECHNOLOGIES

7.2.5.1. Active Treatment Systems (ATS) Technologies

EPA researched technologies available for treating construction stormwater runoff, with the specific goal of identifying technologies that could reliably meet an effluent turbidity limit. EPA primarily identified active treatment systems (ATS) that use coagulation/flocculation and filtration for treating stormwater runoff from active construction sites as the most reliable technology. Technologies used at construction sites to control suspended sediment and turbidity in stormwater runoff from discharging typically include erosion control, storage/containment, gravitational settling, chemical treatment (i.e., coagulation/flocculation), and filter media. For an ATS to be effective, many (if not all) of the above mentioned treatment technologies need to be incorporated into an ATS before treated effluent discharge. This section provides an ATS process description and costs and discusses applicability, demonstration status, and limitations. Treatment chemical addition and filtration are separately discussed in detail in subsequent sections.

ATS Process Description and Costs

EPA assumed that the key components of an ATS would include the following:

- On-site storage by using a combination of sediment basins, tanks or other impoundments
- Chemical addition (see Section 7.2.5.2)
- Mix tank/clarification tank
- Media filtration (see Section 7.2.5.3)
- Instrumentation (e.g., monitoring of influent and effluent)

The ATS capital costs include purchased (or leased) equipment cost, including ancillary equipment (e.g., piping, valves, and controllers), delivery cost, and installation/construction cost (including labor and site work). The ATS annual (operation and maintenance) costs include

treatment chemicals, operating labor and material, maintenance labor and material, energy, waste disposal, monitoring, and rented equipment.

The ATS are typically equipped with automated instrumentation to monitor water quality, flow rate, and dosage control for both influent and effluent flows. Following the coagulation/flocculation process, the densified floc is settled out via gravitational settling, skimming, or media filtration (e.g., sand, gravel, bag filters).

EPA determined that some vendors offer gel socks containing treatment chemical, often for pretreatment of stormwater runoff. For example, the StormKlear Gel-Floc™ is a fabric sock containing a flake form of chitosan that slowly dissolves as the influent stormwater flows over it. The gel sock is typically anchored within the influent pipe of the ATS.

An ATS can be in either a batch or flow-through design, as described in Table 7-23. The ATS design depends upon factors including: existing structures (e.g., detention basins, storm sewer systems, sump areas), influent turbidity, flow rate, and space limitations. Clear Creek Systems, Inc., in a comment letter to the California State Water Resources Control Board (Gannon 2007) regarding the draft construction general permit, stated that "Batch treatment is a relatively outdated and inefficient method of operations."

Table 7-23. ATS Operating Modes

Operation mode	Description
Batch (Pump-Treat-Hold-Test Release)	Stormwater runoff is collected, stored or contained in a basin or tank until treatment is complete before discharging.
Flow-through or continuous treatment	Involves pumping stormwater runoff from a collection, storage or containment basin, treating the water, and directly discharging.

Source: ATS Industry Task Force 2007.

Figure 7-1 presents a general ATS batch operating mode process diagram. The batch treatment process incorporates a period of time for treatment in a settling, mixing, and/or holding tank(s) before discharge. This is different from the continuous flow or *flow-through* treatment process in which treatment and discharge occurs continuously. Figure 7-2 shows an ATS using continuous mode.

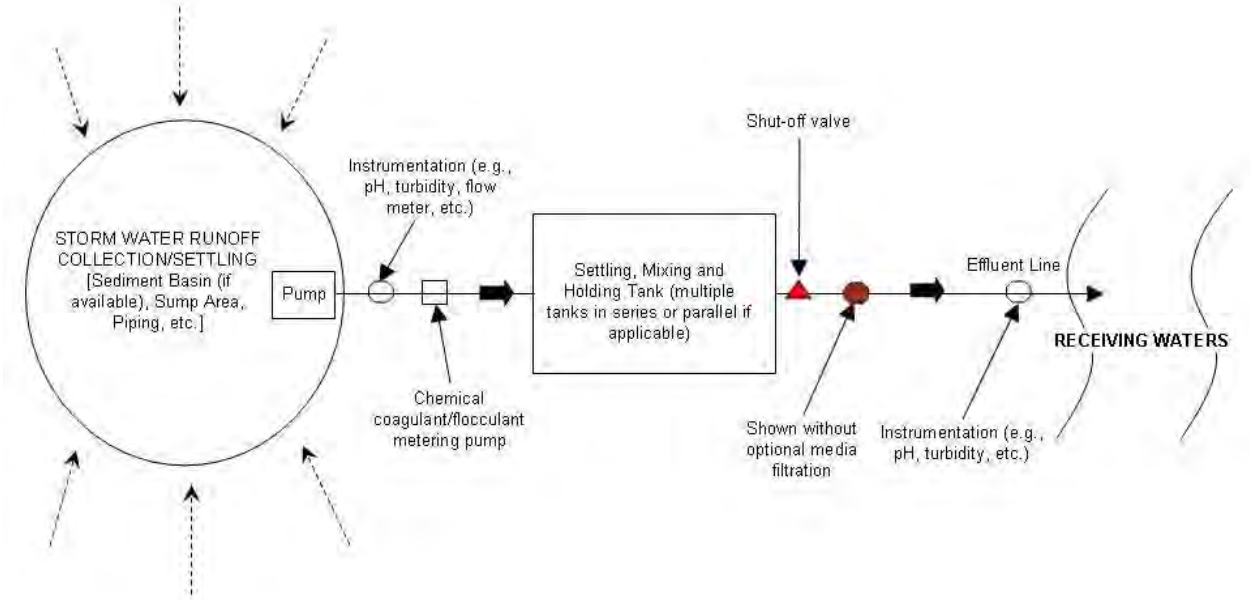

Figure 7-1. General ATS Batch Operating Mode

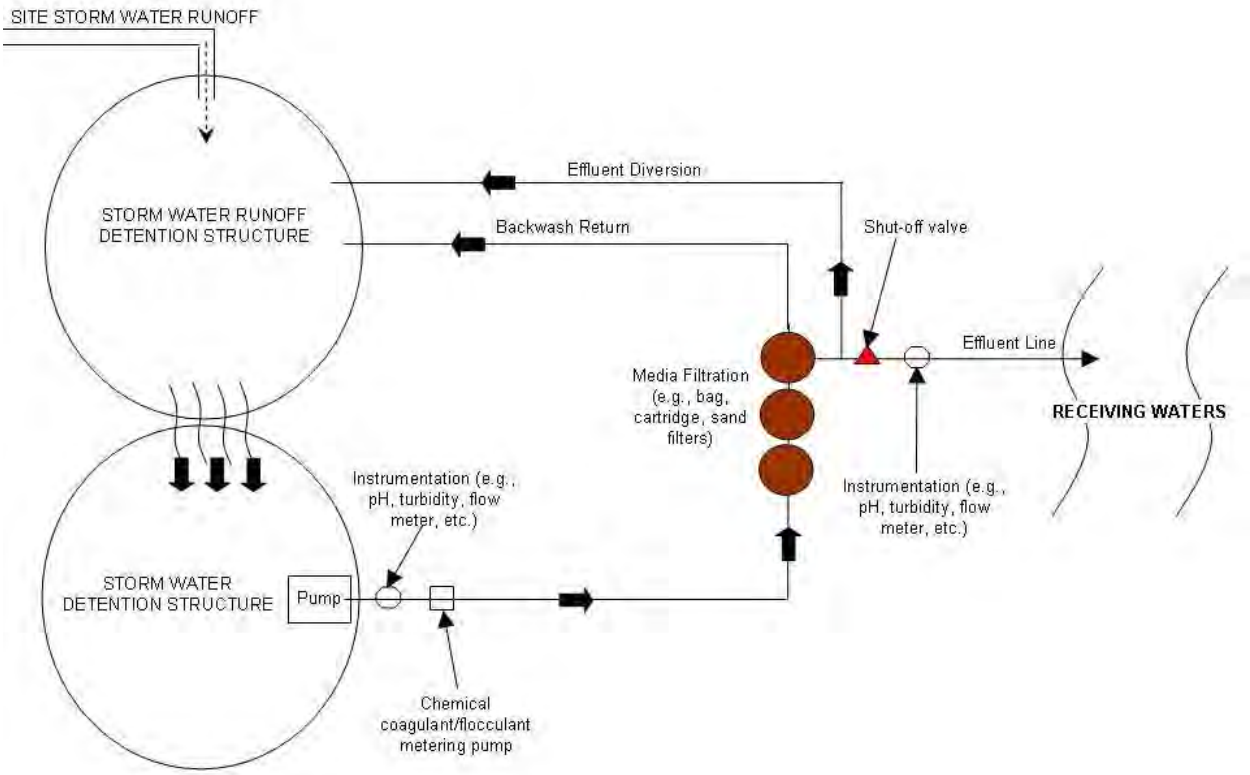

Figure 7-2. Flow-through ATS Operating Mode

ATS Applicability

The ATS is well suited as a method of runoff control when traditional BMPs are not capable of meeting numeric standards. ATS provides quick and efficient removal of fine-grained, suspended sediment or colloidal particles and can be custom tailored for site-specific requirements. Gravitational settling of fine or colloidal soil particles can have limited effectiveness and might not be completed in a timely manner. Therefore, ATS could be necessary to enhance small particulate solids removal and minimize project timelines and costs. The ATS can minimize potential adverse environmental impacts to receiving water through automated water quality measurements. ATS generally produces very low turbidity values (often < 10 nephelometric turbidity units [NTU]) in the effluent discharge.

The vendors contacted by EPA stated that ATS were typically meeting discharge standards of 10 NTU or less. Therefore, ATS would work well for a low NTU standard. Vendors reported little cost savings in designing an ATS for higher, less stringent, NTU limits (e.g., 50, 100, 150, 200, 250 NTU).

Demonstration Status

EPA determined from information obtained from vendor calls that ATS using chemical treatment with polymer coagulation/flocculation was prevalent in the industry. The majority of the vendors contacted are using the polymer chitosan in conjunction with gravitational settling and filtration for the treatment of stormwater runoff. EPA did not obtain information on how many of these systems are batch or flow-through treatment systems. The polymer Diallydimethyl-ammonium chloride (DADMAC) was also used frequently by vendors. Following the chemical treatment, media filtration is commonly used. Sand filters in combination with small micron (e.g., 0.5) particulate filters appeared to be the media of choice by many of the vendors for removing the floc material and polishing. However, bag and cartridge filters are also being used either as a stand-alone treatment or in combination with the sand filters for treatment purposes. Many of the treatment technologies used are very site-specific according to the water quality (i.e., turbidity, chemical composition) and footprint available.

The vendors contacted have implemented ATS primarily in the northwest (California, Oregon, and Washington). Washington State's Department of Ecology (WDEC) has a new technology evaluation program in which vendors complete a Chemical Technology Assessment Protocol – Ecology (CTAPE) for new and emerging technologies. Following a performance evaluation, vendors may receive a conditional use designation (CUD) or a general use level designation (GULD) for a particular chemical treatment technology. For construction sites, WDEC has approved conditional use or general use designations for Chitosan-enhanced sand filtration using StormKlear™ Liquifloc™, FlocClear™, and Chitovan™ chemical treatments. Table 7-24 shows known or draft state ATS requirements or recommendations at the time of this writing.

Table 7-24. ATS State Requirements/Recommendations

State	ATS requirements and/or recommendations
California (draft permit)	This draft NPDES construction general permit provides specific requirements for dischargers who choose to use an ATS. ATS shall be designed to capture and treat a volume equivalent to the runoff from a 10-year, 24-hour storm event in a 72-hour period with a runoff coefficient of 1.0. ATS shall include residual tests certified by a California State laboratory. Effluent toxicity testing and instrumentation must be utilized. Numeric standards: All discharges - pH lower 6.0 to upper 9.0 All other than ATS - 1000 NTU For ATS discharges - 10 NTU (daily flow-weighted average) and 20 NTU any single sample (notes that soil particles smaller than 20 microns (i.e., finer than medium silt) do not settle easily using conventional methods). Basin sizing At a minimum, be designed for an 80% reduction of suspended soil particles having a diameter of 20 microns or larger. Minimum of 3,600 ft3/acre or 2-year 24-hour storm (perforated riser sized to discharge the runoff volume over a 24 to 72-hour period). Referenced California Storm Water BMP Handbook Construction, Sediment Basin SE-2, January 2004.
Oregon	Mr. Dennis Jurries with the Oregon Department of Environmental Quality (DEQ) stated that ATS is not required; however, for sites with difficulty reaching water quality standards, it is recommended that a chitosan-enhanced sand filtration treatment be implemented. Water Quality Requirements If discharging to a 303(d) listed waterbody or a waterbody with a TMDL for sediment and turbidity, sampling for turbidity is required to meet a 160 NTU benchmark. If unable to meet benchmark then an Action Plan utilizing a BMP such as water treatment utilizing electro-coagulation, chemical flocculation or filtration shall be implemented.
Washington	BMP C250 Construction Storm Water Chemical Treatment states that formal written approval from the Department of Ecology is required for the use of chemical treatment regardless of site size. Through the use of the Washington CTAPE, new technology evaluation program, the following have been accepted with use designations: Construction Site Treatment Technologies Chitosan-Enhanced Sand Filtration Using StormKlear™ LiquiFloc™ (GULD) Chitosan-Enhanced Sand Filtration Using FlocClear™(GULD and CUD) Chitosan Enhanced Sand Filtration Using ChitoVan™ (CULD and GULD) Water Tectonics Electrocoagulation Subtractive Technology (CUD) GULD – General Use Level Designation CUD – Conditional Use Designation Water Quality Requirements Sites that disturb more than 1 acre are required to sample for turbidity. Turbidity benchmark of 25 NTU or for 25 to 250 NTU implement BMPs and revise SWPPP. >250 NTU no more than 5 NTU over background if less than 50 NTU, or no more than 10% over background if background is 50 NTU or greater.

ATS Limitations

Treatment chemicals must have the proper dose and contact time to avoid potential toxicity in effluent discharges. Many of the polymers used in ATS precipitate only in a designated pH range (e.g., 6.5 to 8.5).

ATS Costs

EPA obtained ATS costs (i.e., chitosan-enhanced sand filtration) from three vendors. The ATS costs associated with the treatment of active construction site stormwater runoff, as provided by vendors, is included in Table 7-25. For estimating compliance costs for the regulation, EPA used a value of $0.02 per gallon treated. EPA also added costs for providing storage for impounding runoff from the 2-year/24-hour storm event as an approximation of the additional costs for storage that might be required on-site. The costs associated with ATS vary by site-specific factors such as turbidity, available footprint area for basins and/or equipment, effluent discharge requirements, etc. In addition to the data provided by vendors, EPA obtained cost data on specific projects incorporating ATS from several reports. Table 7-26 summarizes ATS costs for a number of case studies reflecting varying site sizes and different system configurations.

Table 7-25. Summary of Preliminary Vendor Costs

Cost type		Cost (2008 dollars)	Source
Total Cost	Large Site	$0.005/gal	StormKlear
	Small Site	$0.01/gal	
Total Cost	Large/Small	$0.01 - 0.03/gal	Clear Water
Labor	Large Site	$1,250/Mgal	Clear Creek
	Small Site	$5,000/Mgal	
Chemical	All Sites	$1,000 - $8,000/Mgal	
Equipment Rental (18 month rental)	10-acre Site	$130,000	
	50-acre Site	$250,000	
	100-acre Site	$500,000	

For additional details on ATS and on ATS costing, see DCNs 43000 through 43011 and Section 9.

Table 7-26. Summary of Advanced Treatment System Case Studies

Project	Type of ATS*	Approximate treated volume	Project duration (months)	Project size (acres)	Cost per gallon
City of Redmond	CESF	1 million gallons	2.5	32	$10.22 per thousand gallons
City of Redmond (2 sites)	Electrocoagulation	6.2 million gallons	Unknown	8 and 23 acres	$5.83 and $8.00 per thousand gallons
Confidential Builder Project #1	CESF	~ 100 million gallons	Unknown	>500	$16.00 per thousand gallons
Confidential Builder Project #2	DADMAC	~ 15 million gallons		~ 300 acres	$36.00 per thousand gallons

*CESF = Chitosan-Enhanced Sand Filtration, DADMAC = Diallyldimethyl Ammonium Chloride

7.2.5.2. ATS Coagulation/Flocculation

The effective design of an ATS relies heavily on an analysis of site conditions (e.g., land use, soils, toxins, water chemistry, flowrate, receiving water chemistry). Coagulants and flocculants function as the primary treatment process used in ATS. Treatment chemical addition to influent stormwater runoff is to destabilize the suspended particles by various mechanisms, aggregating into larger particles that are easier to remove through settling or filtering. Coagulation is the reduction of the net electrical repulsive forces at particle surfaces by adding coagulating chemicals, whereas flocculation is the agglomeration of the destabilized particles by chemical joining and bridging.

The coagulants/flocculants are typically added to the influent via an injection pump in a metered dose just upstream of the clarifier tank or basin. The treatment chemicals are allowed to mix to maximize the formation of a dense floc. Proper dosing of the treatment chemicals is critical to minimize toxicity, maximize system efficiency, and ensure proper effluent water quality. The optimum dose is very site-specific (e.g., varying with changing types of soils, flow rate) and should be based on a series of jar tests.

Water treatment chemicals are predominately water soluble and classified as cationic (positively charged), anionic (negatively charged), nonionic (neutral), or amphoteric (changeable depending on the pH of water). Table 7-27 lists common coagulants, regulatory status, and available residual tests. Several of these common coagulants and toxicity information is discussed below.

Table 7-27. Examples of Some Commonly Available Coagulants

Coagulant	Chitosan	PAC	DADMAC	PAM	PASS	Alum
Description	Chitosan acetate based cationic biopolymer	Poly-aluminum chloride	Diallyl-dimethyl-ammonium chloride	Poly-acrylamide	Poly-aluminum chloride Silica/sulfate modified	Aluminum sulfate
Regulatory status	Approved in Washington	N/A	N/A	Approved in Florida, New Hampshire	N/A	Approved in Florida
Approved dosage (or dosage where no toxic effects are observed)	N/A	N/A	N/A	Florida has no limit New Hampshire has limit of ½ of NOEC[2] or IC25[3]	N/A	No limit
Residual test available[1]	Presence/ absence	Presence/absence and quantitative				
Method detection limit of residual	0.1 mg/L presence/ absence	<0.5 mg/L presence/absence 0.5 mg/L quantitative				

[1] Residual tests can be presence/absence tests or quantitative tests. A presence/absence test verifies that a chemical is or is not present at or above a method detection limit; it does not quantify (with a numerical value) how much is present above the method detection limit. A quantitative test yields the concentration of the chemical at or above the method detection limit; it t typically yields a concentration in mg/L.
Source: ATS Industry Task Force 2007.
[2] NOEC: No Observed Effect Concentration. Highest concentration of effluent where the effect (e.g., reproduction) is not significantly different from the control.
[3] IC25: 25 Percent Inhibition Concentration. Concentration causing a 25 percent reduction in the effect.
N/A – Not Available

Chitosan acetate

This polymer is widely used at active construction sites in ATS for stormwater runoff. Specifically, Washington, Oregon, and California have had numerous projects using this polymer. It is an approved, general-use-level designated polymer for treating construction site runoff in Washington State. Chitosan is derived from chitin, the major component of crustacean shells and is a cationic polyelecrolyte. It is a very plentiful natural polymer with supply stemming from shellfish wastes. Chitosan is able to coagulate/flocculate non-polar hydrocarbons (e.g., oil), suspended sediment, and to chelate heavy metals (Nichols 1997).

Table 7-28 presents information from several studies regarding toxicity of chitosan acetate to aquatic organisms, chemical hazard information, and filter pass-through results.

Table 7-28. Chitosan Acetate Study Results

Vendor/source	Results
MacPherson 2006a (references Nautilus Environmental, Redmond, Washington 2004)	Toxicity. Chitosan acetate (1% solution) was reported to have an LC50 for Daphnia pulex of 1,370 mg/L, 642 mg/L for fathead minnow, and 168 mg/L for rainbow trout in clean water and 452 mg/L in 500 NTU water.
Bullock et al. 2000	Toxicity. The toxicity of chitosan has generally been considered to be non-toxic; however, Chitosan when dissolved in acetic acid and added to a culture system at 1.0 parts per million (ppm) to remove organic solids was found to have acute toxicity to rainbow trout, related to gill lesions and the severity was dose dependent.
ProTech GCS 2004	Toxicity. ProTech GCS in conjunction with GE Betz conducted research on the polymer chitosan (1% solution). The test was conducted using > 1000 NTU water from a Sacramento, CA project site. Survival rates for *daphnia magna*, rainbow trout, and fathead minnow were 100 percent at a dose of 1,100 ppm and 2,200 ppm.
MacPherson 2006b	Toxicity/Filter pass-through. Chitosan is trapped in the sand filter and not released into the receiving water.
Blandford 2006	Filter pass-through. A study evaluating the retention of chitosan acetate in a mixed media filter (anthracite, sand, and garnet) was conducted by GE Betz. The results upon a side-by-side comparison for Klaraid™ PC 1192 (DADMAC) with chitosan acetate demonstrated that both products pass through a standard mixed media filter without any retention within the layers of the filter.
Ray 2001	Hazard. This polymer is listed as Resource Conservation and Recovery Act (RCRA) hazardous due to the acidity (at a pH of about 4).
	Hazard. Chitosan acetate (1% solution) has a pH of 3.9 to 4.0 and is reported to be mildly irritating to the eyes.
Mirsky (Boise State University) 2007	Residual Tests. The Natural Site Solutions (NSS) 2004 Residual Chitosan Test (RCT) field test procedure showed that blank samples could not be distinguished visually from samples containing chitosan acetate. These test results indicate that the NSS 2004 RCT cannot be employed by field technicians to determine the presence or absence of chitosan in treatment system effluent.

Diallydimethyl-ammonium chloride (DADMAC)

This polymer is also used in ATS for treating construction site stormwater runoff. DADMAC is considered to be water soluble over a wide pH range. It has a high affinity for suspended sediment but can have the ability to pass through treatment media to the receiving water (MacPherson 2006a).

Table 7-29 presents information from several studies regarding toxicity of DADMAC to aquatic organics, and filter pass-through results.

Table 7-29. DADMAC Acetate Study Results

Vendor/source	Results
Macpherson 2006a	Toxicity. Tramfloc, Inc. reports *daphnia magna*, 48-hour LC50 of 0.23 mg/L for the Tramfloc Polydadmac 552, 553 and 557 products; however, aquatic toxicity is reduced by factors of 10 to 100 times in the presence of 5 to 10 mg/L organics found in most surface waters.
Macpherson 2006a	Filter pass-through. High affinity for suspended sediment but might have the ability to pass through treatment media to the receiving water
ProTech GCS, Inc., in conjunction with GE Betz	Toxicity. Demonstrated that, on a dose/response basis, DADMAC reduced >1000 NTU water to 2 NTU at a dose of 25 ppm. In addition, aquatic toxicity testing revealed a 95%, 100%, and 100% survival rate for *daphnia magna*, rainbow trout, and fathead minnow, respectively. The ProTech and GE study reported that the polymer DADMAC was the most economical for its removal of suspended sediment and disposal costs.

Polyacrylamide (PAM)

PAM are a broad class of compounds that include cationic (positively charged) and anionic (negatively charged) polyacylamides. PAM are water soluble over a wide pH range and exhibit a high affinity for suspended sediment.

Table 7-30 presents information from several studies regarding toxicity of PAM to aquatic organics and hazard information.

Table 7-30. PAM Study Results

Vendor/source	Results
(see Section 7.2.4.10)	Toxicity. At very high doses irritation in humans and a toxicity to certain aquatic organisms can be observed; however, in general PAMs are considered to be non-toxic to aquatic organisms.
	Hazard. PAM in the solid state has highly hygroscopic dust and, if inhaled, could impair breathing.
MacPherson 2006a	Toxicity. Anionic PAM's are not expected to be toxic to aquatic life at normal dose rates (LC50 for most aquatic species is greater than 100 mg/L).

PAMs have been approved for use in Florida and New Hampshire (ATS Industry Task Force 2007). In California, Washington, Michigan, and Oregon, cationic PAM cannot be used for construction site soil stabilization practices (MacPherson 2006a).

Aluminum-Based Coagulants

The aluminum-based coagulants do not appear to be as widely used in ATS at construction sites for stormwater runoff. Table 7-31 presents aluminum toxicity on aquatic organisms. Note that

aluminum floc will be in various aluminum complexes, which can become aqueous aluminum dependent on time and site-specific physical and environmental conditions (e.g., pH, temperature, hardness and alkalinity, release of trapped sediment).

Table 7-31. Aluminum-based Coagulant Study Results

Vendor/source	Results
MacPherson 2006a	Toxicity. Specifically, studies with juvenile striped bass indicate that this species is extremely sensitive to several forms of aqueous aluminum (referenced Driscoll et al. 1980; Palawski et al. 1985; Skogheim and Rosseland 1986; Rosselan et al. 1992).
	Toxicity. An *in situ* study (Hall et al. 1985) with larval striped bass found 90 to 99% mortality in river water with 0.48 to 4.1 mg/L aluminum and pH levels between 6.0 and 6.8
	Toxicity. Klauda et al., (1989) supported the theory that monomeric aluminum (mAl), the inorganic fraction, was potentially the most toxic to early life stages of migratory fish.
Sutherland 1999 (references Oughton 1992)	Toxicity. Polymers created from aluminum and water collect on gills and limit respiration.
ProTech GCS, Inc., in conjunction with GE Betz	Toxicity. ProTech GCS and GE Betz conducted a study using the coagulant/flocculant Aluminum Chlorhydroxide and found that at optimum dose (75 ppm) survival rates for Daphnia Magna, rainbow trout, and Fathead minnow were 95%, 100%, and 95%, respectively. At two times the optimum dose (150 ppm) results were similar, showing no increased toxicity.
MacPherson 2006a	Hazard. These aluminum-based water treatment agents also pose a risk to human eyes and skin if not properly handled.

7.2.5.3. ATS Filtration

Filtration is a final treatment step in ATS designed to remove residual, low concentrations of target pollutants before discharge. Multimedia filtration (mixed-media filtration) is one of the oldest and most widely applied types of filtration for the removal of suspended solids from aqueous liquid streams. This form of filtration uses a bed of granular particles as the filter medium. Granular media filters are used to remove suspended solids from construction stormwater after chemical addition creates a floc to filter. The bed can consist of one type of medium (e.g., sand) of the same particle size, or multiple particle sizes. Different types of media (e.g., sand and gravel, sand and anthracite) with differing densities and different particle sizes compose the bed of a multimedia filter. Multimedia filters can be more efficient but more expensive and complex than single-media filters. For this reason, sand filters are most commonly used in construction ATS. The filter bed is contained within a basin or tank and is supported by an underdrain system, which allows the filtered liquid to be drawn off while retaining the filter medium in place. As suspended particle-laden water passes through the bed of the filter medium, particles are trapped on top of and within the bed. Once the pressure drop across the filter is large enough to impede flow, the filter is backwashed and the backwash water is typically re-circulated to the influent flow.

Vendors are also marketing bag and cartridge filters that can be used as a final filtration step. Bag filters are available in a range of pore sizes, and cartridge filters are available with various media types. These filters can be used as a final polishing step before discharge.

7.2.5.4. Other Emerging Treatment Technologies

While EPA's analysis was based primarily on chitosan-enhanced filtration, there are several other advanced technologies available to treat construction site stormwater runoff. Work in recent years has focused on a number of passive, PAM-based systems to enhance pollutant removal in sediment basins. PAM, available in *floc logs*, has also seen increased placement in conveyance channels. As water flows through the channel, PAM dissolves and the turbulence in the channel aids in the flocculation process. Flocs can then settle out in sediment control devices, such as check dams, sediment traps or basins. In addition, electrocoagulation has been successfully used on a number of construction sites to meet turbidity limits. At least one vendor is also using a tube settler coupled with polymer addition before filtration to aid in sediment removal. Other recent advancements include using a skimmer to enhance sediment removal in sediment basins, and using porous baffles in sediment basins to reduce turbulence and increase removal efficiencies. North Carolina now requires skimmers on all sediment basins, and the North Carolina Department of Transportation has developed draft standards for the use of porous baffles in sediment basins (See DCNs 43083 and 43045, NCDOT draft baffles standards and *North Carolina Erosion and Sediment Control Planning and Design Manual* with requirements for skimmers). McLaughlin demonstrated the ability to meet a 50-NTU limit at a research site in North Carolina by adding PAM to a basin equipped with baffles and a surface skimmer (see DCN 43082, *The Potential for Substantial Improvements in Sediment and Turbidity Control*).

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8. REGULATORY DEVELOPMENT AND RATIONALE

In this section, the methodology used by U.S. Environmental Protection Agency (EPA) to develop regulatory options for the construction and development (C&D) industry is described. This section discusses the regulatory options evaluated for the proposed rule. The costs of regulatory options are discussed in Section 9 of this document. A description of the estimated pollutant reductions expected for each regulatory option is presented in Section 10. The C&D industry financial analyses can be found in the EPA's *Economic Analysis of Proposed Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-R-08-008). This section also includes discussion of EPA's Best Conventional Pollutant Control Technology (BCT) cost-reasonableness analysis.

8.1. DEVELOPMENT OF REGULATORY OPTIONS

EPA considered a series of regulatory options. These options were designed to control the discharge of sediment, stormwater and other pollutants from sites when construction is taking place. EPA considered a range of options that incorporate varying levels of control strategies. The following discussion presents various options that EPA considered.

8.2. OPTIONS CONTAINED IN THE PROPOSAL

8.2.1. OPTION 1 – COMBINATION OF BEST MANAGEMENT PRACTICE (BMP) STANDARDS AND SEDIMENT BASIN SIZING

Option 1 would establish minimum sizing criteria for sediment basins used at construction sites with 10 or more disturbed acres draining to one location. Under this option, permittees would be required to install sediment basins that provide either 3,600 cubic feet per acre of runoff storage, or be designed to store runoff from the local 2-year, 24-hour storm event. This option also includes requirements for implementing a variety or erosion and sediment controls on all construction sites that are required to obtain a permit.

8.2.2. OPTION 2 – COMBINATION OF BMP STANDARDS FOR ALL SITES AND TURBIDITY STANDARD FOR SELECTED SITES

Option 2 contains the same requirements as Option 1. In addition, construction sites of 30 or more acres would be required to meet a numeric turbidity limit in stormwater discharges from the site. This requirement would apply if the construction site is in an area where the rainfall runoff erosivity factor (R factor) as defined in the Revised Universal Soil Loss Equation (RUSLE) is greater than or equal to 50 and if the soils present on the construction site contain 10 percent or more by mass of soil particles smaller than 2 microns in diameter.

8.2.3. OPTION 3 – COMBINATION OF BMP STANDARDS FOR ALL SITES AND TURBIDITY STANDARD FOR ALL SITES 10+ ACRES

Option 3 contains the same requirements as Option 1. Option 3 also requires all sites with 10 or more acres of disturbed land to meet a numeric turbidity standard, regardless of the R-factor or soil types.

8.3. OTHER OPTIONS EVALUATED

In addition to the three options discussed in the proposal, EPA considered a number of other options. The various option parameters that EPA considered are as follows.

8.3.1. SITE SIZE

EPA's proposed option requires turbidity limits only on sites 30 acres or larger. EPA also considered other site size cutoffs, such as 10 acres, 20 acres, and 40 acres.

8.3.2. ANNUAL PRECIPITATION

EPA considered annual precipitation as a potential applicability provision for the turbidity standard. EPA evaluated annual precipitation cutoffs of 10, 20, 30, and 40 inches per year. EPA considered annual precipitation as an applicability provision based on the assumption that construction sites in arid areas should not need to install active treatment systems to meet a turbidity limit when the likelihood of appreciable precipitation is very small. Because of the expense of equipment rental, it might be costly for construction sites in arid areas to have the equipment on-site to be prepared for storm events, and the likely pollutant removals in these areas would be very small. EPA chose not to base the applicability provision on annual precipitation, but instead based it on the RUSLE R-factor. The R-factor takes into consideration both rainfall energy and intensity.

8.3.3. SOIL PARAMETERS

EPA considered soil properties as a potential applicability provision. Soil is a complex mixture of a variety of minerals and organic materials composed of a range particle sizes, ranging from large boulders and cobbles, to sand-sized particles to very small clay and silt-sized particles. There are a number of soil classification systems in existence, but according to ASTM, sand-sized particles range from 75 microns to 4.75 millimeters, while silts range from 5 microns to 75 microns, and clays range from 1 micron to 5 microns in diameter. Particles smaller than 1 micron in diameter are referred to as colloids. The U.S. Department of Agriculture (USDA) uses a different classification system. USDA, in data published in soil surveys, characterizes clay particles as being smaller than 2 microns, silt particles as being between 2 microns and 50 microns, and sand as being between 50 microns and 2 millimeters. Generally, large particles such as sands and coarse and medium silts in stormwater runoff from construction sites are easily removed by conventional BMPs such as silt fence and sediment basins and traps. This is because these particles settle very easily in a short amount of time, on the order of a few seconds to a few hours. However, very small particles, such as fine silts and clays, generally will not settle in a sediment basin. Detention times on the order of weeks or even years might be required for many

of these particles to settle. To remove these small particles, some sort of chemical addition or filtration is usually needed. Because soils containing predominately larger-diameter particles would be expected to be treated to a high degree in conventional BMPs such as sediment basins, EPA evaluated clay content (using USDA's classification, which defines clay as the percentage by mass of particles smaller than 2 microns) as a factor in determining applicability of a numeric turbidity limit. The logic of this approach is to make the turbidity limit apply only on sites that have the highest likelihood of discharging significant quantities of fine-grained particles. EPA evaluated a range of clay contents as potential applicability provisions. Sites with less than the specified amount of clay particles would not be required to meet the turbidity standard. Table 8-1 illustrates the percentage of national developed acres that would be required to meet the turbidity standard given various percent clay content cutoffs. State level estimates are in Table 4-6 and 4-7. These results are based on evaluation of geographic information system soil data for the conterminous United States from the Earth System Science Center (2006) at Pennsylvania State University (http://www.soilinfo.psu.edu/index.cgi?index.html) (see Figure 3-13) combined with RF1-level estimates of the annual amount of construction occurring (see Appendix E). To develop these estimates, EPA evaluated only the surface soil layer of this data set.

Table 8-1. Percent of Developed Acres Required to Meet Turbidity Limits for Various Clay Contents

Soil percent clay content	Percent of developed acres covered
> 5%	91%
> 10%	77%
> 15%	43%
> 20%	19%
> 25%	11%
> 30%	7%

8.4. BCT COST-REASONABLENESS ASSESSMENT

This section presents a summary of the BCT methodology and the results of the two-part cost-reasonableness test. In considering whether to propose BCT limits more stringent than the requirements being proposed for Best Practicable Control Technology (BPT), EPA considered whether technologies are available that would achieve greater removals of conventional pollutants than the proposed BPT effluent limitations guidelines. EPA also considered whether those technologies are cost-reasonable according to the BCT cost test, which compares the incremental removals and costs associated with BCT limitations to benchmarks associated with BPT and publicly owned treatment works (POTWs).

8.4.1. BACKGROUND ON THE BCT COST TEST

In 1977 Congress amended the Clean Water Act to include section 304(b)(4)(B). This provision specifies that, among other factors, the assessment of BCT effluent limitations must include consideration of

> . . .the reasonableness of the relationship between the costs of attaining a reduction in effluents and the effluent reduction benefits derived, and the comparison of the cost and level of reduction of such pollutants from the discharge of publicly owned treatment works to the cost and level of reduction of such pollutants from a class or category of industrial sources. . .

Accordingly, EPA developed the *BCT methodology* to determine whether it is *cost-reasonable* for an industry category or subcategory to control conventional pollutants at a level more stringent than would be achieved by BPT effluent limitations.

The BCT methodology was originally published on August 29, 1979, along with the promulgation of BCT effluent limitations guidelines for a number of industry sectors (44 *Federal Register* [FR] 50732). The crux of the methodology was a comparison of the costs of removing conventional pollutants for an average-sized POTW. The Fourth Circuit of the U.S. Court of Appeals remanded the BCT regulation and directed EPA to develop an industry cost test in addition to the POTW test. EPA subsequently proposed a revised BCT methodology in 1982 that addressed the industry cost test (47 FR 49176; October 29, 1982). In 1984 EPA again addressed the BCT methodology and proposed to base the POTW benchmark on model plant costs (49 FR 37046; September 20, 1984). The final BCT methodology was published in 1986, maintaining the basic approach of the 1982 proposed BCT methodology and adopting the use of the new model POTW data (51 FR 24974; July 9, 1986). These guidelines state that the BCT cost analysis "...answers the question of whether it is 'cost reasonable' for industry to control conventional pollutants at a level more stringent than BPT effluent limitations already require." See 51 FR at 24974. Conventional pollutants are biochemical oxygen demand (BOD), total suspended solids (TSS), oil and grease, fecal coliform, and pH.

The final BCT methodology incorporates two cost tests to establish cost reasonableness: the POTW test and the industry cost-effectiveness test. Each of these tests is compared with established benchmarks, the derivation of which is described in detail in the 1986 FR notice. The BCT cost methodology is described in more detail in the following section.

8.4.2. CALCULATION OF THE BCT COST TEST

POTW Test

The first part of the BCT cost test is the POTW test. The POTW test compares the cost per pound of conventional pollutants removed by industrial dischargers in upgrading from BPT to BCT candidate technologies, to the cost per pound of removing conventional pollutants in upgrading POTWs from secondary treatment to advanced secondary treatment.

To *pass* the POTW test, the cost per pound of conventional pollutant discharges removed in upgrading from BPT to the candidate BCT must be less than the POTW benchmark. The POTW

benchmark presented in the 1986 *Federal Register* notice is $0.25 per pound (in 1976 dollars) for industries in which the cost per pound of pollutant reduction is based on long-term performance data. EPA used cost index data from RS Means Historical Cost Indices to update this POTW benchmark to 2008$ according to the following equation:

$$\frac{\text{Index for 2008}}{\text{Index for 1976}} \times \textit{Cost in 1976\$} = \textit{Cost in 2008\$}$$

$$\frac{173.0}{46.9} \times \$0.25 = \$0.92$$

Using estimated reductions for TSS, EPA then calculated the incremental costs per pound of conventional pollutant removed ($/lb) for each candidate BCT technology option. If any candidate technology option passes the first part of the BCT cost test (i.e., is less than the inflation-adjusted value of $0.92 in 2008 dollars), the technology is further evaluated in the second part of the test (R.S. Means 2008). EPA used only TSS pollutant reductions for the cost test calculations, because of the limited data available. However, EPA expects that discharges of oil and grease and fecal coliform would be minimal from construction sites. EPA also expects that BOD, where present, would be removed along with TSS. Because all options pass both parts of the BCT cost test, it is not necessary to develop estimates for reductions for the other conventional pollutants. The results of the POTW test are presented in Table 8-2.

Table 8-2. POTW Cost Test Results

BCT option	Total annual costs and conventional pollutant removals		Incremental costs and conventional pollutant removals, relative to the proposed BPT[a]			POTW cost test result (< $0.92/lb)
	Cost (million $) (2008$)	Pollutant removals (million lbs)	Cost (million $) (2008$)	Pollutant removals (million lbs)	Cost per pound ($/lb)	
1	132	670	0	0	0	Pass
2	1,891	26,426	1,759	25,756	0.068	Pass
3	3,798	50,412	3,666	49,742	0.074	Pass

[a] Option 1 is equal to the proposed BPT effluent limitations. Therefore, all incremental values are calculated relative to Option 1.

Industry Cost-Effectiveness Test

The second part of the BCT cost test is the industry cost-effectiveness test, which computes the ratio of two incremental costs. The first of these incremental costs is the cost per pound of conventional pollutants removed in upgrading from BPT to the BCT candidate technology. This value serves as the numerator of the ratio. The second incremental cost, which serves as the denominator of the ratio, is the cost per pound of conventional pollutants removed by BPT relative to no treatment (i.e., this value compares raw wasteload to pollutant load after application of BPT). This ratio is compared to an industry cost benchmark, which is based on POTW cost and pollutant removal data. The industry cost benchmark is also a ratio of two

incremental costs: the cost per pound to upgrade a POTW from secondary treatment to advanced secondary treatment, divided by the cost per pound to initially achieve secondary treatment. If the industry cost-effectiveness test is lower than the industry cost benchmark of 1.29 (i.e., the normalized cost increase must be less than 29 percent), the candidate BCT technology passes this part of the cost test. The calculation and results of the industry cost-effectiveness test are presented in Tables 8-3 and 8-4. Because both Options 2 and 3 fail the second part of the BCT cost test, BCT is set equal to BPT, which is Option 1.

Table 8-3. Cost and Pollutant Removals for the Proposed BPT

	Total annual costs (million $) (2008$)	**Conventional pollutant removals (million lbs)**	**BPT cost per pound ($/lb)**
Baseline	1,019	74,460	
Option 1 Incremental	132	670	
Total BPT	1,152	75,131	0.015

Table 8-4. Industry Cost-Effectiveness Test Results

BCT option	**Incremental cost per pound to upgrade from BPT to BCT ($/lb)**	**Calculated ratio**	**Industry cost-effectiveness test result (< 1.29)**
1	0	0	Pass
2	0.068	4.46	Fail
3	0.074	4.81	Fail

8.5. REFERENCES

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9. ESTIMATING INCREMENTAL COSTS FOR THE PROPOSED REGULATION

9.1. OVERVIEW

This section presents the approach that the U.S. Environmental Protection Agency (EPA) used for estimating the incremental costs associated with the regulatory options considered for the Construction and Development (C&D) industry. This section also includes discussion on the selection and development of cost model inputs; components of cost; and the methodology for estimating costs, including an overview of the C&D Cost Spreadsheet Model. The economic analyses conducted for the industry are described in the document *Economic Analysis for Final Action for Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-R-08-008).

EPA's first step in estimating national costs for each proposed option was developing an array of model construction sites (i.e., small, medium and large transportation; small, medium and large residential; small, medium and large nonresidential) that reasonably represent common construction site features, and factors related to state regulations, topography, and hydrology. EPA developed per-site costs for each model construction site using national average unit costs for control technologies. For discussion on the development of model construction sites, see Section 9.3.1.

To scale the model construction site costs to the state and national level, EPA estimated the number of projects in each state for each land-use category by determining the area in each state for each land-use category and dividing by the land-use category model site area. EPA determined the area for each land-use category from Notice of Intent (NOI) data and developed state-specific estimates by incorporating data on new construction acreage developed annually, obtained from the National Land Cover Dataset (NLCD) (For a discussion of development rates, see Section 9.3.2).

When developing state-specific costs for the regulatory options, EPA considered current state requirements (for discussion of state requirements, see Section 9.2) and evaluated incremental costs above these existing requirements. A more detailed description of baseline and incremental costs is included in Section 9.4.

The most significant input parameter in estimating the size and cost of treatment equipment for model construction sites is the volume of rainfall requiring treatment. EPA estimated the amount of stormwater runoff requiring treatment using both the drainage area of the model site, state-specific rainfall estimates, and runoff coefficients to estimate the volume of rainfall converted to runoff and requiring subsequent treatment. For a discussion of rainfall data and runoff coefficient development, see Section 9.3.2.

National level costs were calculated by summing the contiguous state costs, and costs for the District of Columbia. Costs for Alaska and Hawaii, as well as the U.S. territories were not estimated because EPA lacked data on the annual amount of new construction acreage in these

areas. However, assuming a small amount of construction occurs in these areas, EPA expects that these values would be low in comparison to the national costs.

The total costs of the options considered are presented in Table 9-1.

Table 9-1. Estimated Total Annual Costs of Regulatory Options for the C&D Industry

Regulatory option	Annual cost (millions 2008 dollars)
Option 1	$132
Option 2	$1,891
Option 3	$3,797

9.2. ANALYSIS OF STATE EQUIVALENCY

EPA analyzed state requirements to evaluate costs from this proposed rulemaking that are in excess of costs from current state requirements. EPA did not conduct a survey of states or municipalities to determine baseline requirements because of Paperwork Reduction Act requirements. EPA collected and evaluated state erosion and sediment control and stormwater permits and regulations, as well as erosion and sediment control and stormwater BMP design and guidance manuals, from searching state Web sites. EPA specifically compiled sediment basin requirements, soil stabilization requirements, and numeric standards for all 50 states and the District of Columbia from these sources.

EPA performed similar analyses of state requirements as part of the 2002 and 2004 regulatory efforts for the C&D industry. The results of the previous EPA analyses are provided in the respective technical development documents (TDDs) supporting the 2002 proposed rule and 2004 final action (hereinafter referred to as the 2002 TDD and 2004 TDD, respectively). In 2007 EPA performed another search to update the state requirements for erosion and sediment controls.

EPA organized all the state requirements information by its source documentation (i.e., EPA's 2007 state literature search, the 2004 TDD, and the 2002 TDD). EPA developed a revised summary of state requirements, including sediment basin storage volume, sediment basin design parameters, numeric standards, and soil stabilization requirements. For EPA's summary of requirements by state, and the source documentation, see Appendix A.

Where information was not available from EPA's 2007 state literature search, EPA defaulted to previously documented state regulation inputs/assumptions, including (in order of preference): (1) information contained in the March 2004 *Development Document for Final Action for Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-B-04-001), and (2) information contained in the June 2002 *Development Document for Proposed Effluent Guidelines and Standards for the Construction and Development Category* (EPA-821-R-02-007). In several instances, when it was unclear how a specific state requirement was implemented, EPA used best professional judgment to estimate the state requirement. For

example, where a state program specified the use of a sediment basin but did not specify a sediment basin size (or other design standards that could be used to estimate sediment basin size), it was assumed that the basin size requirement was 1,800 cubic feet per acre (cf/acre).

9.3. DEVELOPMENT OF MODEL CONSTRUCTION SITES AND SELECTION OF INDICATOR CITIES

9.3.1. MODEL CONSTRUCTION SITES

As discussed in Section 4.2.2, EPA developed nine model projects from an analysis of NOI data. The six sectors or construction site model projects that EPA used to represent the industry follow:

- Large Residential – median size 33 acres
- Large Nonresidential – median size 51 acres
- Large Transportation – median size 79 acres
- Medium Residential – median size 16.7 acres
- Medium Nonresidential – median size 15 acres
- Medium Transportation – median size 16 acres
- Small Residential – median size 3 acres
- Small Nonresidential – median size 2.6 acres
- Small Transportation – median size 3 acres

EPA based its costing on both the size of sediment basins needed, the annual volume of runoff being treated, and assumptions regarding the extent of site area disturbed and the duration of land disturbance. Table 9-2 presents a summary of EPA's model project cost assumptions.

EPA assumed for costing purposes that only 90 percent of each construction site would be denuded and producing stormwater runoff that would require treatment. This assumption is to account for portions of the site that do not drain to a centralized location, such as sheet flow through a silt fence on the project perimeter. In addition, this assumption concerning the percentage of the site that is disturbed is an attempt to account for the changing nature of construction activities on a site over time. For example, during initial clearing and grading activities, nearly 100 percent of the construction site could be disturbed. However, this condition might exist for only a few weeks. Once roads, parking lots (in nonresidential projects) and building structures are installed and soils on the site are stabilized, it is likely that stormwater runoff from these stabilized portions of the site would be separated from stormwater from disturbed areas of the site and diverted around sediment basins and temporary treatment systems. Also, for many projects, it is likely that some portion of the site would not be disturbed, such as areas maintained as green/open space, forest preservation areas, and vegetated stream buffers. Therefore, assuming that 100 percent of the site is disturbed for the entire portion of the project would likely result in overestimation of costs of regulatory options. A 90 percent assumption, while still somewhat conservative, allows for an upper-bound estimate of area disturbed.

EPA assumed that all projects would be disturbed, on average, for a period of 9 months. EPA believes that 9 months is a somewhat conservative assumption of the amount of time that these

projects would be disturbing land. Specifically, on most smaller projects, earth-disturbing activities and soil stabilization would likely be completed in a period of a few months.

EPA notes that these assumptions, while useful for modeling, likely vary considerably among actual construction projects. However, because EPA lacks data on the typical duration of disturbed soils at construction projects and the duration that treatment would need to be in place, this modeling approach provides a reasonable, if somewhat conservative, means of estimating runoff volumes requiring treatment and incremental compliance costs of the proposed regulation.

Table 9-2. Model Project Cost Assumptions

Project description	Median site size (acres)	% of site disturbed	Duration of disturbance (months)
Large Residential	33	90%	9
Large Nonresidential	51	90%	9
Large Transportation	79	90%	9
Medium Residential	16.7	90%	9
Medium Nonresidential	15	90%	9
Medium Transportation	16	90%	9
Small Residential	3	90%	9
Small Nonresidential	2.6	90%	9
Small Transportation	3	90%	9

9.3.2. ESTIMATION OF RAINFALL DEPTHS AND RUNOFF VOLUMES

To calculate sediment basin sizing under various regulatory scenarios and to determine runoff volumes for costing treatment systems, EPA evaluated several references to determine rainfall depths for a series of design storm return periods for one indicator city in each state (for a discussion of this analysis, see section 3.5.3 and Appendix D). The storm depths for each indicator city were used as point estimates for rainfall depths in each respective state. Using these storm depths, EPA estimated runoff coefficients for each state using the process described in TR-55 (USDA 1986). EPA estimated a runoff curve number using the Soil Conservation Service runoff curve number equation:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in)
I_a = initial abstraction (in) = 0.2S

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)}$$

$$S = \frac{1000}{CN} - 10$$

Using the values contained in TR-55 for Curve Numbers for Developing Urban Areas in Table 9-3, (from TR-55, Table 2-2a), along with the 2-year, 24-hour storm depths in Table 3-3, EPA calculated runoff coefficients for the four hydrologic soils groups in each state for the 2-year, 24-hour storm event. Using data on the prevalence of soils by hydrologic soil groups obtained from STATSGO for each state (see Table 3-8), EPA then calculated a weighted runoff coefficient for each state for the 2-year, 24-hour storm event. These results are summarized in Table 9-3 and were used to determine the required sediment basins size for capturing runoff from the 2-year, 24-hour storm event in each state. EPA also calculated the weighted runoff coefficient for the 10-year, 6-hour storm, which was used to estimate volumes for various alternative sediment basin sizing requirements based on removing a specified particle size fraction. These results are presented in Table 9-4. The rainfall analysis data is DCN 43095 and the STATSGO soils data evaluation is DCN 43096 in the Administrative record.

9.3.3. ESTIMATION OF SEDIMENT BASIN VOLUMES AND ATS TREATMENT VOLUMES

The runoff coefficient values, coupled with state precipitation estimates, allowed EPA to determine sediment basin sizing for each of the model sites for various design scenarios (such as calculating runoff from the 2-year, 24-hour storm)

For estimating average annual runoff volumes for each model site in each state, EPA multiplied the average annual precipitation in each state by the site size and a runoff coefficient of 0.4. This value of 0.4 was chosen as a reasonable estimate of the percent of average rainfall that would be converted to runoff. EPA acknowledges that this approach likely overestimates runoff volumes (and hence, volumes requiring treatment and associated treatment costs) since many smaller storm events would not produce any, or very little, runoff. This approach also does not account for precipitation that falls as snow. It also assumes that the entire disturbed area is in a "newly graded areas" state, as defined by TR-55, for the entire duration of the project. In reality, site areas during various states of the construction project would be in various states, ranging from bare soil, to temporarily stabilized with mulch, to vegetated. As a result, curve numbers could be much lower and associated runoff volumes could be much lower. However, this approach does allow for a reasonable, albeit conservative, estimate of treatment volumes for determining compliance costs. EPA multiplied the average annual runoff volumes for each model project by 0.75 to account for the assumption that each project would require treatment for 9 months, and hence would be treating 75 percent of the average annual runoff volume. This analysis does not account for seasonal variations in rainfall - EPA assumed that precipitation would be evenly distributed over the year.

Table 9-3. State Runoff Coefficients for 2-Year, 24-Hour Storm Events

	2-year, 24-hour storm depth (inches)	Runoff coefficient for A soils	Runoff coefficient for B soils	Runoff coefficient for C soils	Runoff coefficient for D soils	% A soils	% B soils	% C soils	% D soils	Weighted runoff coefficient 2-year, 24-hour storm
Alabama	4.50	0.49	0.67	0.78	0.85	8.7%	41.2%	28.8%	21.3%	0.72
Arizona	1.40	0.12	0.31	0.47	0.61	4.7%	38.6%	17.2%	39.5%	0.44
Arkansas	4.10	0.46	0.64	0.76	0.83	0.6%	28.3%	35.9%	35.1%	0.75
California	2.00	0.22	0.42	0.58	0.70	10.9%	32.2%	18.4%	38.5%	0.54
Colorado	2.00	0.22	0.42	0.58	0.70	7.2%	46.7%	24.6%	21.4%	0.51
Connecticut	3.10	0.37	0.56	0.70	0.79	9.1%	41.1%	35.9%	13.9%	0.63
Delaware	3.26	0.38	0.58	0.71	0.80	20.8%	30.9%	13.4%	34.9%	0.63
Florida	4.75	0.51	0.68	0.79	0.86	18.1%	6.3%	8.6%	67.0%	0.78
Georgia	3.70	0.43	0.62	0.74	0.82	6.6%	53.1%	16.9%	23.5%	0.67
Idaho	1.20	0.08	0.25	0.42	0.56	4.4%	46.8%	23.1%	25.7%	0.36
Illinois	2.85	0.34	0.54	0.68	0.77	1.4%	44.5%	27.0%	27.1%	0.64
Indiana	2.95	0.35	0.55	0.69	0.78	3.5%	32.6%	41.8%	22.1%	0.65
Iowa	3.25	0.38	0.58	0.71	0.80	0.9%	66.0%	11.6%	21.5%	0.64
Kansas	3.50	0.41	0.60	0.73	0.81	3.8%	58.0%	19.5%	18.7%	0.66
Kentucky	3.00	0.36	0.55	0.69	0.78	0.1%	42.7%	44.9%	12.3%	0.64
Louisiana	5.25	0.54	0.70	0.80	0.87	1.7%	14.4%	28.9%	55.1%	0.82
Maine	2.80	0.33	0.53	0.67	0.77	7.7%	12.9%	43.9%	35.5%	0.66
Maryland	3.16	0.37	0.57	0.70	0.79	10.0%	38.6%	26.4%	25.0%	0.64
Massachusetts	3.10	0.37	0.56	0.70	0.79	23.9%	16.6%	34.4%	25.2%	0.62
Michigan	2.40	0.28	0.48	0.63	0.74	29.0%	28.7%	12.9%	29.4%	0.52
Minnesota	2.75	0.33	0.53	0.67	0.77	8.3%	37.4%	15.4%	38.9%	0.63
Mississippi	4.45	0.49	0.66	0.78	0.85	2.3%	32.3%	38.6%	26.9%	0.75
Missouri	3.45	0.40	0.60	0.72	0.81	1.0%	40.1%	39.8%	19.0%	0.68
Montana	1.30	0.10	0.28	0.45	0.58	2.9%	39.5%	27.2%	30.4%	0.41
Nebraska	3.00	0.36	0.55	0.69	0.78	31.9%	53.6%	3.0%	11.5%	0.52
Nevada	1.00	0.05	0.20	0.36	0.50	5.6%	26.4%	17.7%	50.3%	0.37
New Hampshire	2.80	0.33	0.53	0.67	0.77	17.1%	24.8%	41.4%	16.6%	0.60

	2-year, 24-hour storm depth (inches)	Runoff coefficient for A soils	Runoff coefficient for B soils	Runoff coefficient for C soils	Runoff coefficient for D soils	% A soils	% B soils	% C soils	% D soils	Weighted runoff coefficient 2-year, 24-hour storm
New Jersey	3.31	0.39	0.58	0.71	0.80	12.5%	32.8%	25.1%	29.6%	0.66
New Mexico	1.54	0.15	0.34	0.50	0.63	5.6%	41.9%	16.5%	36.0%	0.46
New York	2.90	0.35	0.54	0.68	0.78	9.6%	18.5%	51.1%	20.7%	0.64
North Carolina	3.34	0.39	0.59	0.72	0.80	7.9%	48.8%	16.5%	26.8%	0.65
North Dakota	1.90	0.21	0.41	0.57	0.69	4.7%	56.1%	16.6%	22.6%	0.49
Ohio	2.62	0.31	0.51	0.66	0.76	0.6%	16.8%	54.6%	28.0%	0.66
Oklahoma	3.70	0.43	0.62	0.74	0.82	6.8%	44.5%	22.3%	26.4%	0.68
Oregon	2.50	0.30	0.50	0.64	0.75	5.2%	32.1%	37.1%	25.6%	0.61
Pennsylvania	3.23	0.38	0.58	0.71	0.80	6.0%	28.4%	54.2%	11.5%	0.66
Rhode Island	3.20	0.38	0.57	0.71	0.79	15.3%	35.7%	32.4%	16.5%	0.62
South Carolina	3.62	0.42	0.61	0.73	0.82	11.9%	41.8%	19.5%	26.8%	0.67
South Dakota	2.25	0.26	0.46	0.62	0.73	2.9%	45.2%	11.5%	40.4%	0.58
Tennessee	3.37	0.40	0.59	0.72	0.80	0.1%	53.6%	30.4%	15.9%	0.66
Texas	3.90	0.44	0.63	0.75	0.83	5.1%	27.2%	24.5%	43.2%	0.73
Utah	1.40	0.12	0.31	0.47	0.61	5.3%	36.2%	16.2%	42.3%	0.45
Vermont	2.40	0.28	0.48	0.63	0.74	4.9%	18.0%	54.3%	22.8%	0.61
Virginia	3.11	0.37	0.56	0.70	0.79	1.7%	53.7%	32.3%	12.3%	0.63
Washington	2.00	0.22	0.42	0.58	0.70	6.6%	53.4%	24.2%	15.8%	0.49
West Virginia	2.56	0.30	0.50	0.65	0.75	7.3%	21.5%	54.2%	17.0%	0.61
Wisconsin	2.80	0.33	0.53	0.67	0.77	14.4%	46.8%	18.1%	20.7%	0.58
Wyoming	1.60	0.16	0.35	0.51	0.64	4.5%	40.5%	19.5%	35.5%	0.48
District of Columbia	3.16	0.37	0.57	0.70	0.79	10.0%	38.6%	26.4%	25.0%	0.64

Table 9-4. State Runoff Coefficients for 10-Year, 6-Hour Storm Events

	10-year, 6-hour storm depth (inches)	Runoff coefficient for A soils	Runoff coefficient for B soils	Runoff coefficient for C soils	Runoff coefficient for D soils	% A soils	% B soils	% C soils	% D soils	Weighted runoff coefficient 10-year, 6-hour storm
Alabama	4.60	0.50	0.67	0.78	0.85	8.7%	41.2%	28.8%	21.3%	0.73
Arizona	1.57	0.15	0.34	0.51	0.64	4.7%	38.6%	17.2%	39.5%	0.48
Arkansas	4.35	0.48	0.66	0.77	0.84	0.6%	28.3%	35.9%	35.1%	0.76
California	1.70	0.17	0.37	0.53	0.66	10.9%	32.2%	18.4%	38.5%	0.49
Colorado	2.30	0.27	0.47	0.62	0.73	7.2%	46.7%	24.6%	21.4%	0.55
Connecticut	3.25	0.38	0.58	0.71	0.80	9.1%	41.1%	35.9%	13.9%	0.64
Delaware	3.44	0.40	0.59	0.72	0.81	20.8%	30.9%	13.4%	34.9%	0.65
Florida	5.25	0.54	0.70	0.80	0.87	18.1%	6.3%	8.6%	67.0%	0.79
Georgia	4.20	0.47	0.65	0.76	0.84	6.6%	53.1%	16.9%	23.5%	0.70
Idaho	4.80	0.51	0.68	0.79	0.86	0.0%	0.0%	0.0%	0.0%	0.00
Illinois	1.20	0.08	0.25	0.42	0.56	4.4%	46.8%	23.1%	25.7%	0.36
Indiana	3.30	0.39	0.58	0.71	0.80	1.4%	44.5%	27.0%	27.1%	0.67
Iowa	3.12	0.37	0.57	0.70	0.79	3.5%	32.6%	41.8%	22.1%	0.66
Kansas	3.54	0.41	0.60	0.73	0.81	0.9%	66.0%	11.6%	21.5%	0.66
Kentucky	3.90	0.44	0.63	0.75	0.83	3.8%	58.0%	19.5%	18.7%	0.68
Louisiana	3.09	0.37	0.56	0.70	0.79	0.1%	42.7%	44.9%	12.3%	0.65
Maine	5.75	0.57	0.73	0.82	0.88	1.7%	14.4%	28.9%	55.1%	0.83
Maryland	2.90	0.35	0.54	0.68	0.78	7.7%	12.9%	43.9%	35.5%	0.67
Massachusetts	3.32	0.39	0.58	0.71	0.80	10.0%	38.6%	26.4%	25.0%	0.65
Michigan	3.30	0.39	0.58	0.71	0.80	23.9%	16.6%	34.4%	25.2%	0.64
Minnesota	2.70	0.32	0.52	0.66	0.76	29.0%	28.7%	12.9%	29.4%	0.55
Mississippi	3.10	0.37	0.56	0.70	0.79	8.3%	37.4%	15.4%	38.9%	0.66
Missouri	4.70	0.51	0.68	0.79	0.85	2.3%	32.3%	38.6%	26.9%	0.76
Montana	3.85	0.44	0.63	0.75	0.83	1.0%	40.1%	39.8%	19.0%	0.71
Nebraska	1.10	0.07	0.23	0.39	0.53	2.9%	39.5%	27.2%	30.4%	0.36
Nevada	3.52	0.41	0.60	0.73	0.81	31.9%	53.6%	3.0%	11.5%	0.57
New Hampshire	1.29	0.10	0.28	0.44	0.58	5.6%	26.4%	17.7%	50.3%	0.45

	10-year, 6-hour storm depth (inches)	Runoff coefficient for A soils	Runoff coefficient for B soils	Runoff coefficient for C soils	Runoff coefficient for D soils	% A soils	% B soils	% C soils	% D soils	Weighted runoff coefficient 10-year, 6-hour storm
New Jersey	3.20	0.38	0.57	0.71	0.79	17.1%	24.8%	41.4%	16.6%	0.63
New Mexico	3.55	0.41	0.60	0.73	0.81	12.5%	32.8%	25.1%	29.6%	0.67
New York	1.77	0.19	0.38	0.55	0.67	5.6%	41.9%	16.5%	36.0%	0.50
North Carolina	3.10	0.37	0.56	0.70	0.79	9.6%	18.5%	51.1%	20.7%	0.66
North Dakota	3.54	0.41	0.60	0.73	0.81	7.9%	48.8%	16.5%	26.8%	0.66
Ohio	2.50	0.30	0.50	0.64	0.75	4.7%	56.1%	16.6%	22.6%	0.57
Oklahoma	2.80	0.33	0.53	0.67	0.77	0.6%	16.8%	54.6%	28.0%	0.67
Oregon	4.25	0.47	0.65	0.77	0.84	6.8%	44.5%	22.3%	26.4%	0.72
Pennsylvania	2.90	0.35	0.54	0.68	0.78	5.2%	32.1%	37.1%	25.6%	0.64
Rhode Island	3.38	0.40	0.59	0.72	0.80	6.0%	28.4%	54.2%	11.5%	0.67
South Carolina	3.40	0.40	0.59	0.72	0.81	15.3%	35.7%	32.4%	16.5%	0.64
South Dakota	3.85	0.44	0.63	0.75	0.83	11.9%	41.8%	19.5%	26.8%	0.68
Tennessee	2.75	0.33	0.53	0.67	0.77	2.9%	45.2%	11.5%	40.4%	0.63
Texas	3.31	0.39	0.58	0.71	0.80	0.1%	53.6%	30.4%	15.9%	0.66
Utah	4.55	0.49	0.67	0.78	0.85	5.1%	27.2%	24.5%	43.2%	0.77
Vermont	1.27	0.10	0.27	0.44	0.58	5.3%	36.2%	16.2%	42.3%	0.42
Virginia	2.70	0.32	0.52	0.66	0.76	4.9%	18.0%	54.3%	22.8%	0.64
Washington	3.29	0.39	0.58	0.71	0.80	1.7%	53.7%	32.3%	12.3%	0.65
West Virginia	1.40	0.12	0.31	0.47	0.61	6.6%	53.4%	24.2%	15.8%	0.38
Wisconsin	2.56	0.30	0.50	0.65	0.75	7.3%	21.5%	54.2%	17.0%	0.61
Wyoming	3.15	0.37	0.57	0.70	0.79	14.4%	46.8%	18.1%	20.7%	0.61
District of Columbia	1.90	0.21	0.41	0.57	0.69	4.5%	40.5%	19.5%	35.5%	0.53

For each state, EPA calculated sediment basin sizes on the basis of the following sizing criteria:

- 3,600 cubic feet per acre (cf/acre)
- Runoff from the 2-year, 24-hour storm
- Removal of a design particle size

The 3,600 cf/acre criteria is a requirement in the EPA Construction General Permit for construction sites with a common drainage area of 10 or more disturbed acres. Calculation of required basin size is simply based on the size of the disturbed area of the site draining to the basin.

To determine the size for a basin designed to capture runoff from the 2-year, 24-hour storm, EPA calculated the runoff coefficient for one indicator city in each state for the 2-year, 24-hour storm event (see Table 9-5). By multiplying these runoff coefficients by the associated 2-year, 24-hour storm depth and the site size, EPA calculated the basin size required in each state for each model project.

For the design particle size standard, EPA used an approach outlined in the California Stormwater Quality Association's (CSQA's) *Stormwater BMP Handbook: Construction* (http://www.cabmphandbooks.com/Construction.asp) (CSQA 2003) to calculate sediment basin sizes required to remove particles of 10, 15 and 20 microns. EPA based these calculations on the average 10-year, 6-hour storm event intensity. The intensity (in inches per hour) was determined by dividing the 10-year, 6-hour storm depth (see Table 3-3) by the storm duration (6 hours).

The approach contained in the CSQA handbook is based on the settling velocity of particles as determined by Stokes' Law, which states that the settling velocity (*Vc)* is a function of the density of the particle (ρs) and the fluid (ρ_f), the acceleration due to gravity (g), the diameter of the particle (d) and the dynamic viscosity of the fluid (μ).

$$V_c = \frac{g(\rho_s - \rho_f)d^2}{18\mu}$$

Stokes' Law is generally valid for Reynolds numbers less than 1 (quiescent conditions) and for spherical particles.

Once the settling velocity of the design particle size is determined (called the terminal settling velocity), sediment basins can be sized so that all particles with a settling velocity equal to or greater than the terminal velocity can be removed. This is accomplished by calculating the surface area (A) of the basin for a specified flow rate (Q) using the following equation:

$$A = \frac{Q}{V_c}$$

The approach in the CSQA handbook uses a site-specific soil grain size determined using a wet sieve analysis for determining the terminal settling velocity, and the design flowrate is based on the 10 year, 6-hour rainfall event. The option described in this handbook is illustrated in Figure 9-1.

Sediment basin(s) shall be designed using the standard equation:
A_s=1.2Q/Vs
Where:
A_s = Minimum surface area for trapping soil particles of a certain size
V_s = Settling velocity of the design particle size chosen
Q = C I A
Where
Q = Discharge rate measured in cubic feet per second
C = Runoff coefficient
I = Precipitation intensity for the 10-year, 6-hour rain event in inches per hour
A = Area draining into the sediment basin in acres
The design particle size shall be the smallest soil grain size determined by wet sieve analysis, or the fine silt sized (0.01 mm [or 0.0004 in.]) particle, and the V_s used shall be 100 percent of the calculated settling velocity.

Figure 9-1. CSQA Settling Velocity Criteria for Sizing Sediment Basins

Using the CSQA approach, EPA calculated sediment basin sizes required to remove 100 percent of particles larger than 10, 15, and 20 microns in each state based on the 10-year, 6-hour storm intensity. EPA used a particle density of 2,650 kg/m^3, and the density and viscosity of water at 20 degrees Celsius (°C) (ρ_f =998.2 kg/m^3, μ = 0.001 N·S/m^3). Values for C were taken from Table 9-4.

Table 9-5 presents estimates of sediment basin sizing used for each state for the options considered. This table also contains the basin size EPA used for baseline calculations. For Option 1, EPA evaluated sediment basin sizes of 3,600 cf/acre.

Table 9-6 summarizes the treatment volumes for each state for each of the nine model projects. For the active treatment system (ATS) options, EPA also calculated storage requirements for runoff from the 2-year, 24-hour storm. Where this value was greater than the sediment basin sizing requirements under a given state's baseline sediment basin sizing, EPA calculated additional costs to provide the incremental storage volume for the 2-year, 24-hour storm over baseline.

Table 9-5. Sediment Basin Sizes for States

	Baseline sediment basin size (cf/acre)	2-year, 24-hour runoff sediment basin size (cf/acre)	20-micron basin size (cf/acre)	15-micron basin size (cf/acre)	10-micron basin size (cf/acre)
Alabama	1,800	11,798	3,382	6,013	13,530
Arizona	3,600	2,254	709	1,260	2,836
Arkansas	3,600	11,179	3,326	5,914	13,306
California	3,660	3,898	929	1,652	3,717
Colorado	1,800	3,685	1,188	2,113	4,754
Connecticut	3,600	7,043	2,071	3,681	8,283
Delaware	3,600	7,487	2,216	3,939	8,863
Florida	3,600	13,371	4,145	7,368	16,579
Georgia	1,800	9,019	2,871	5,104	11,485
Hawaii	12,868	--	--	--	--
Idaho	3,600	1,585	445	790	1,778
Illinois	6,494	6,591	2,141	3,805	8,562
Indiana	1,800	6,968	2,067	3,674	8,267
Iowa	3,600	7,536	2,302	4,093	9,208
Kansas	3,600	8,337	2,605	4,632	10,422
Kentucky	3,600	7,004	2,023	3,597	8,094
Louisiana	3,600	15,638	4,804	8,540	19,215
Maine	3,600	6,744	1,959	3,483	7,836
Maryland	3,600	7,353	2,167	3,852	8,667
Massachusetts	7,307	6,977	2,083	3,703	8,332
Michigan	3,600	4,530	1,429	2,541	5,717
Minnesota	6,172	6,247	1,975	3,511	7,901
Mississippi	3,600	12,147	3,598	6,397	14,393
Missouri	3,600	8,574	2,684	4,771	10,734
Montana	1,800	1,948	462	822	1,849
Nebraska	1,800	5,680	1,869	3,323	7,476
Nevada	3,600	1,350	488	868	1,953
New Hampshire	6,333	6,064	1,944	3,456	7,775
New Jersey	1,800	7,886	2,372	4,217	9,489
New Mexico	3,600	2,570	828	1,473	3,313
New York	3,600	6,776	2,032	3,612	8,126
North Carolina	1,800	7,884	2,344	4,167	9,375
North Dakota	3,600	3,361	1,240	2,205	4,962
Ohio	1,800	6,261	1,877	3,336	7,507
Oklahoma	9,296	9,184	2,959	5,260	11,835
Oregon	3,600	5,495	1,788	3,178	7,151
Pennsylvania	5,000	7,754	2,276	4,046	9,103
Rhode Island	1,800	7,239	2,157	3,835	8,628
South Carolina	13,168	8,756	2,612	4,643	10,447
South Dakota	3,600	4,745	1,626	2,891	6,506
Tennessee	8,196	8,095	2,230	3,964	8,920
Texas	9,969	10,403	3,404	6,051	13,615
Utah	3,600	2,284	581	1,033	2,324
Vermont	1,800	5,345	1,687	2,998	6,746

	Baseline sediment basin size (cf/acre)	2-year, 24-hour runoff sediment basin size (cf/acre)	20-micron basin size (cf/acre)	15-micron basin size (cf/acre)	10-micron basin size (cf/acre)
Virginia	3,600	7,141	2,119	3,767	8,475
Washington	3,600	3,575	702	1,248	2,808
West Virginia	3,600	5,679	1,593	2,832	6,371
Wisconsin	2,770	5,884	1,857	3,301	7,426
Wyoming	1,800	2,770	923	1,640	3,690
Puerto Rico	1,800	--	--	--	--
District of Columbia	7,503	7,353	2,167	3,852	8,667

9.4. ESTIMATION OF COSTS

EPA estimated costs for the three options using two costing elements: sediment basins costs and treatment costs. The components of the estimated costs are discussed below.

9.4.1. COMPONENTS OF COST

The components of the capital and annual costs and the terminology used in developing these costs are presented below. Section 7 discusses costs of individual BMPs not directly used to estimate compliance costs for the proposed regulations.

9.4.1.1. Capital Costs

The capital costs consist of two major components: direct capital costs and indirect capital costs. The direct capital costs include the following:

- Purchased equipment cost, including ancillary equipment (e.g., piping, valves, controllers);
- Delivery cost; and
- Installation/construction cost (including labor and site work).

Indirect capital costs consist of engineering, contingency, contractor fees, and the like. These costs together with the direct capital costs form the total capital investment. Indirect costs are often estimated as a percentage of the total direct capital cost.

Table 9-6. Model Project Treatment Volumes (million gallons)

	Small			Medium			Large		
	Residential	**Nonresidential**	**Transportation**	**Residential**	**Nonresidential**	**Transportation**	**Residential**	**Nonresidential**	**Transportation**
Alabama	1.077	0.935	1.079	6.004	5.393	5.752	11.864	18.335	28.366
Arizona	0.170	0.148	0.170	0.948	0.851	0.908	1.872	2.894	4.477
Arkansas	1.046	0.908	1.047	5.830	5.237	5.586	11.520	17.804	27.544
California	0.404	0.351	0.405	2.252	2.023	2.157	4.450	6.877	10.639
Colorado	0.292	0.254	0.293	1.629	1.463	1.561	3.220	4.976	7.698
Connecticut	0.976	0.847	0.977	5.438	4.884	5.210	10.745	16.606	25.691
Delaware	0.945	0.820	0.946	5.267	4.731	5.046	10.408	16.086	24.885
Florida	1.362	1.182	1.364	7.592	6.819	7.274	15.003	23.186	35.870
Georgia	1.117	0.969	1.119	6.226	5.593	5.965	12.304	19.015	29.417
Hawaii	0.402	0.349	0.402	2.239	2.011	2.145	4.425	6.838	10.579
Idaho	0.249	0.216	0.249	1.388	1.246	1.330	2.742	4.238	6.556
Illinois	0.726	0.630	0.727	4.046	3.634	3.876	7.994	12.355	19.113
Indiana	0.872	0.756	0.873	4.859	4.364	4.655	9.601	14.838	22.955
Iowa	0.696	0.604	0.696	3.877	3.482	3.714	7.660	11.838	18.315
Kansas	0.806	0.699	0.807	4.491	4.034	4.303	8.875	13.716	21.220
Kentucky	0.989	0.858	0.990	5.511	4.950	5.280	10.890	16.830	26.037
Louisiana	1.291	1.120	1.293	7.196	6.463	6.894	14.219	21.975	33.996
Maine	0.915	0.794	0.916	5.101	4.582	4.887	10.080	15.579	24.101
Maryland	0.929	0.806	0.930	5.177	4.650	4.960	10.230	15.809	24.458
Massachusetts	0.932	0.808	0.933	5.192	4.663	4.974	10.259	15.855	24.528
Michigan	0.665	0.577	0.666	3.708	3.330	3.552	7.326	11.322	17.516
Minnesota	0.632	0.548	0.632	3.521	3.162	3.373	6.957	10.752	16.633
Mississippi	1.153	1.000	1.154	6.425	5.771	6.156	12.696	19.621	30.355
Missouri	0.807	0.700	0.808	4.497	4.039	4.308	8.886	13.733	21.245
Montana	0.259	0.225	0.259	1.442	1.295	1.382	2.850	4.404	6.814
Nebraska	0.622	0.540	0.623	3.467	3.114	3.321	6.850	10.587	16.378
Nevada	0.084	0.073	0.084	0.468	0.420	0.448	0.924	1.428	2.209
New Hampshire	0.884	0.767	0.885	4.925	4.424	4.719	9.732	15.041	23.269
New Jersey	1.033	0.896	1.034	5.754	5.168	5.513	11.370	17.571	27.184
New Mexico	0.340	0.295	0.340	1.892	1.700	1.813	3.739	5.779	8.941

	Small			Medium			Large		
	Residential	**Nonresidential**	**Transportation**	**Residential**	**Nonresidential**	**Transportation**	**Residential**	**Nonresidential**	**Transportation**
New York	0.811	0.704	0.812	4.519	4.059	4.329	8.929	13.800	21.350
North Carolina	0.949	0.823	0.950	5.288	4.749	5.066	10.449	16.148	24.982
North Dakota	0.353	0.307	0.354	1.969	1.769	1.887	3.892	6.015	9.305
Ohio	0.830	0.720	0.831	4.626	4.156	4.433	9.142	14.129	21.858
Oklahoma	0.721	0.625	0.722	4.018	3.609	3.849	7.939	12.269	18.981
Oregon	0.895	0.776	0.896	4.985	4.478	4.777	9.852	15.225	23.554
Pennsylvania	0.914	0.793	0.915	5.095	4.576	4.881	10.068	15.560	24.072
Rhode Island	0.983	0.853	0.984	5.478	4.920	5.248	10.824	16.729	25.880
South Carolina	0.999	0.866	1.000	5.565	4.998	5.331	10.996	16.994	26.291
South Dakota	0.354	0.307	0.354	1.971	1.770	1.888	3.894	6.018	9.310
Tennessee	1.013	0.879	1.014	5.645	5.071	5.409	11.155	17.240	26.671
Texas	0.715	0.620	0.715	3.982	3.576	3.815	7.868	12.160	18.812
Utah	0.320	0.277	0.320	1.782	1.601	1.708	3.522	5.443	8.421
Vermont	0.747	0.648	0.748	4.163	3.739	3.989	8.226	12.714	19.669
Virginia	0.887	0.769	0.887	4.940	4.437	4.733	9.762	15.087	23.341
Washington	0.775	0.672	0.776	4.317	3.878	4.136	8.531	13.184	20.396
West Virginia	0.941	0.816	0.942	5.243	4.709	5.023	10.360	16.011	24.770
Wisconsin	0.691	0.600	0.692	3.853	3.461	3.692	7.614	11.767	18.204
Wyoming	0.324	0.281	0.324	1.804	1.620	1.728	3.565	5.509	8.523
Puerto Rico	1.115	0.968	1.116	6.215	5.582	5.954	12.280	18.979	29.361
District of Columbia	0.917	0.796	0.918	5.110	4.590	4.896	10.098	15.606	24.144

9.4.1.2. Annual Costs

As with capital costs, the annual costs have both a direct and an indirect component, and include the following:

- Raw material costs - chemicals and other materials used in the treatment processes (e.g., chitosan, polymers);
- Operating labor and material costs - the labor and materials directly associated with operation of the process equipment;
- Maintenance labor and material costs - the labor and materials required for repair and routine maintenance of the equipment;
- Rental equipment costs;
- Energy costs - calculated on the basis of total energy requirements; and
- Waste disposal - recurring waste disposal costs (e.g., filtration media replacement).

Indirect annual costs include monitoring, taxes, insurance, and amortization. Monitoring is the periodic analysis of wastewater effluent samples to ensure that discharge limitations are being met.

9.4.1.3. Total Project Cost

EPA calculated total project cost from the C&D Cost Spreadsheet Model. The Agency assumed a duration of 9 months for each model project.

9.4.2. BASELINE AND INCREMENTAL COSTS

EPA estimated the costs for the current sediment basins at each model site (baseline) on the basis of the state requirements analysis. The C&D Cost Spreadsheet Model uses baseline costs to determine the incremental costs attributable to each regulatory option.

EPA calculated incremental costs as the difference between baseline and post-compliance costs, using the following equation:

$$\text{Total Costs}_{\text{Incremental}} = \text{Total Costs}_{\text{Option}} - \text{Total Costs}_{\text{Baseline}}$$

For example, if a state specified a design basin size of 3,600 cf/acre (baseline) and an EPA Option specified 3,600 cf/acre (Option 1), the incremental cost for Option 1 in that state would be zero. If the option cost exceeds the baseline cost, only the cost exceeding the baseline cost is incremental. If the baseline cost exceeds the option cost, there is no incremental cost.

9.4.3. SOURCES AND STANDARDIZATION OF COST DATA

EPA used literature values for sediment basin costs and vendor data for the chemical-enhanced filtration numeric standard costs (see Sections 3.2 and 3.5.5).

Capital and annual cost data were standardized to 2008 dollars on the basis of the *Engineering News-Record* (ENR) Construction Cost Index (CCI). The sediment basin cost reference used by EPA was based on a study completed in 1989. The ENR CCI in 1989 was 4,615 and the value in February of 2008 was 8,084. EPA adjusted sediment basin costs obtained in 1989 dollars to 2008 dollars by increasing costs by 57 percent (8084/4615 = 1.57). Vendor data was obtained early in the year 2008 so no standardization was necessary to arrive at year 2008 costs.

9.4.4. C&D COST SPREADSHEET MODEL

EPA developed a cost spreadsheet model to estimate compliance costs for the C&D technology options, taking into account existing sediment basin requirements specified by states. Table 9-7 presents descriptions for each individual worksheet included in the C&D Cost Spreadsheet Model.

Table 9-7. C&D Cost Spreadsheet Model Worksheets

Worksheet	Description
NLCD Data	National Land Cover Data (NLCD). Shows acres developed and changes in developed acres by state. An Annual Rate of Development, NLCD 1992 - 2001 (acres) is calculated and used in the "State Projects" worksheet to estimate acres by model site by state.
Project Distribution	Presents the median site size in acres for each model project and the distribution of projects by project type, based on an analysis of NOI data.
State Projects	Number of acres/projects by model site by state.
Option Parameters	Contains key input parameters for costing options (i.e., baseline and option sediment basin sizes, as well as annual precipitation data, which is the basis for calculating runoff volumes for the turbidity standard options).
Cost Inputs	Cost assumptions for sediment basin costs.
Settling Velocity defaults	Presents constants and non-state-specific settling velocity calculations.
Baseline Calcs	Calculations for alternate sediment basin baseline calculations (California, New York, Washington, and Wisconsin). Updates the alternate baseline calculations in the Option Parameters worksheet - Sediment Basin Sizing (alternate cf/acre) column.
Key Equations	Provides key equations and defines variables (Rational Equation, Stokes' Law, and Cost Indices).
Small Residential	For each model project site type, presents baseline and option costs, as well as option costs incremental to baseline.
Medium Residential	
Large Residential	
Large Residential	
Small Nonresidential	
Medium Nonresidential	
Large Nonresidential	

Worksheet	Description
Small Transportation	
Medium Transportation	
Large Transportation	
Final Option 1	Summarizes incremental costs by option.
Final Option 2	
Final Option 3	
Size Cutoffs	Presents data on distribution of projects by project sizes as a basis for determining acres in-scope for site size cutoffs greater than 10 acres
Clay Content	Presents percent of acres in various percent clay content fractions based on national soils GIS data
R Cutoffs	Presents estimates of the % of acres within various R-factor categories and the number of projects subject to Option 2 requirements.
Runoff Coefficients	Contains calculations for determining state-specific curve numbers
Design Storms	Presents data on various design storms for indicator cities
HSG	Presents state hydrologic soil group estimates based on national soils GIS data.
Summary	Presents summaries of state and national costs by option.

9.4.5. ESTIMATION OF COSTS FOR SEDIMENT TRAPS AND BASINS

Descriptions of sediment traps and basins, including design criteria, performance, and costs, are described in detail in Sections 7.2.3. This section describes EPA's rationale in selecting costs for sediment basins and traps.

9.4.5.1. Sediment Basin and Trap Cost Similarities

Sediment basins and traps are generally similar in design but have several significant differences. Sediment basins are usually viewed as a final attempt to treat stormwater runoff before discharging and are also often modified near the end of the construction period to serve as post-construction stormwater runoff controls. Sediment basins are typically used for larger drainage areas than sediment traps. Sediment basins usually are larger in size and use a semi-permanent outlet structure (e.g., perforated riser pipe). Sediment traps on the other hand, are typically small, temporary structures used for detaining sediment-laden runoff from smaller drainage areas. Note that EPA used the terminology sediment trap for sites smaller than 10 acres and sediment basin for sites larger than 10 acres (EPA's smallest modeled project sizes are approximately 3 acres). Because none of EPA's options contain requirements for sites smaller than 10 acres to install sediment traps of any particular size, EPA did not estimate any incremental compliance costs for sites smaller than 10 acres.

9.4.5.2. Temporary Sediment Basin Construction Costs

EPA 1993 referenced the Southeastern Wisconsin Regional Planning Commission's 1991 Costs of Urban Nonpoint Source Water Pollution Control Measures (SWRPC 1991) for estimating costs of temporary sediment basins. Costs include site preparation (e.g., grading, excavation, place and compact fill), site development (e.g., riprap, temporary basin inlet and outlet

structures), and contingencies. Temporary basins are a generally less expensive option as compared to permanent basins (e.g., SWRPC assumed temporary basin inlet and outlet costs to be one-half of permanent detention basin inlet and outlet costs). Table 9-8 summarizes the cost data EPA used for estimating sediment basin costs. EPA used the average value of $0.30 per cubic foot of storage for calculating incremental costs for sediment basins and for storage volumes required for ATS. EPA adjusted all sediment basin costs from 1989 dollars to 2008 dollars.

Table 9-8. Sediment Basin Construction Cost Data

Cost data source	Cost	Basin size range of validity	Basis year
USEPA (1993), original reference is SWRPC (1991). Numerous sources reference this data. Many of these sources adjusted USEPA (1993) to other basis years.	$0.10 to $0.40 per cubic foot of storage, average of $0.30.	12,000 ft^3 to 195,000 ft^3 SWRPC (1991)	1989

9.4.5.3. Sediment Basin Annual Operation and Maintenance (O&M) Costs

EPA 1993 estimates annual O&M costs for temporary sediment basins (associated with runoff from active construction sites) as 25 percent of construction costs. EPA used this value to estimate annual O&M costs for sediment basins.

9.4.6. ACTIVE TREATMENT SYSTEMS

EPA obtained ATS costs from three vendors. Two of the vendors (Clear Water and Storm Klear) provided cost data on a dollars per gallon basis, which included consideration of all associated costs (equipment rental, treatment chemicals, labor, and O&M). A third vendor, Clear Creek, provided base equipment rental costs as well as a cost per gallon for treatment chemicals and a cost per gallon for labor. EPA also collected several references that contained example project information. Vendors stated that ATS typically cost between $0.01 and $0.03 per gallon treated, and the case studies in the literature generally confirmed these values.

EPA elected to use a value of $0.02 per gallon to estimate ATS costs. For each of the model construction sites in each state, EPA estimated annual volumes of runoff by multiplying average annual precipitation by the runoff coefficient calculated for each state (see Table 9-7). By applying the ATS cost of $0.02 per gallon, EPA estimated the costs of employing ATS for each of the nine model projects in each state.

EPA recognizes that the use of ATSs will require storage and pretreatment of captured stormwater runoff from a site; therefore, in evaluating ATS costs, EPA assumed that storage would be required on-site for pretreatment and for temporary storage before treatment. Options 2 and 3 require treating all runoff produced by the 2-year, 24-hour storm. EPA determined the amount of storage necessary to hold runoff from the 2-year, 24-hour storm for each model site in each state. By comparing to existing state sediment basin requirements, EPA was able to determine any additional storage volumes in each state needed to provide the required 2-yer, 24-

hour storage under Options 2 and 3. EPA used the sediment basin cost information in Table 9-8 to estimate storage costs for Options 2 and 3. EPA updated storage costs to year 2008 dollars.

Tables 9-9 through 9-14 summarize the ATS costs per project for each of the six model projects in each state. These tables also include incremental costs for storage (adjusted to year 2008 dollars). EPA did not estimate ATS costs for the three small model projects, because none of EPA's options would require these sites to meet a numeric turbidity limit.

Table 9-9. ATS Costs for Large Residential Model Projects

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Alabama	$237,281	329,934	$217,003	$454,283
Arizona	$37,447	--	--	$37,447
Arkansas	$230,406	250,107	$164,499	$394,905
California	$88,991	5,981	$3,934	$92,925
Colorado	$64,391	62,205	$40,913	$105,305
Connecticut	$214,903	113,619	$74,729	$289,632
Delaware	$208,168	128,271	$84,366	$292,533
Florida	$300,057	322,443	$212,076	$512,133
Georgia	$246,073	238,227	$156,685	$402,758
Hawaii	$88,497	--	--	$88,497
Idaho	$54,843	--	--	$54,843
Illinois	$159,885	--	--	$159,885
Indiana	$192,023	170,544	$112,169	$304,192
Iowa	$153,203	129,888	$85,429	$238,633
Kansas	$177,507	156,321	$102,815	$280,321
Kentucky	$217,800	112,332	$73,882	$291,683
Louisiana	$284,379	397,254	$261,280	$545,659
Maine	$201,606	103,752	$68,239	$269,845
Maryland	$204,593	123,849	$81,457	$286,051
Massachusetts	$205,177	--	--	$205,177
Michigan	$146,526	30,690	$20,185	$166,711
Minnesota	$139,139	--	--	$139,139
Mississippi	$253,919	282,051	$185,509	$439,428
Missouri	$177,716	164,142	$107,959	$285,675
Montana	$56,995	4,884	$3,212	$60,207
Nebraska	$137,003	128,040	$84,214	$221,217
Nevada	$18,477	--	--	$18,477
New Hampshire	$194,647	--	--	$194,647
New Jersey	$227,393	200,838	$132,094	$359,487
New Mexico	$74,788	--	--	$74,788
New York	$178,589	104,808	$68,934	$247,523
North Carolina	$208,974	200,772	$132,051	$341,025
North Dakota	$77,836	--	--	$77,836
Ohio	$182,843	147,213	$96,824	$279,667
Oklahoma	$158,777	--	--	$158,777
Oregon	$197,031	62,535	$41,130	$238,161

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Pennsylvania	$201,361	90,882	$59,774	$261,135
Rhode Island	$216,489	179,487	$118,051	$334,540
South Carolina	$219,921	--	--	$219,921
South Dakota	$77,879	37,785	$24,852	$102,731
Tennessee	$223,102	--	--	$223,102
Texas	$157,362	--	--	$157,362
Utah	$70,438	--	--	$70,438
Vermont	$164,530	116,985	$76,943	$241,473
Virginia	$195,247	116,853	$76,856	$272,103
Washington	$170,615	--	--	$170,615
West Virginia	$207,204	68,607	$45,124	$252,328
Wisconsin	$152,275	109,230	$71,842	$224,117
Wyoming	$71,298	32,010	$21,053	$92,351
Puerto Rico	$245,605	--	--	$245,605
District of Columbia	$201,966	--	--	$201,966

Table 9-10. ATS Costs for Medium Residential Model Projects

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Alabama	$120,078	166,967	$109,816	$229,895
Arizona	$18,950	--	--	$18,950
Arkansas	$116,599	126,569	$83,247	$199,846
California	$45,035	3,027	$1,991	$47,026
Colorado	$32,586	31,480	$20,705	$53,290
Connecticut	$108,754	57,498	$37,817	$146,571
Delaware	$105,345	64,913	$42,694	$148,040
Florida	$151,847	163,176	$107,323	$259,170
Georgia	$124,528	120,557	$79,292	$203,820
Hawaii	$44,785	--	--	$44,785
Idaho	$27,754	--	--	$27,754
Illinois	$80,911	--	--	$80,911
Indiana	$97,175	86,306	$56,764	$153,940
Iowa	$77,530	65,731	$43,232	$120,763
Kansas	$89,829	79,108	$52,030	$141,860
Kentucky	$110,220	56,847	$37,389	$147,609
Louisiana	$143,913	201,035	$132,223	$276,136
Maine	$102,025	52,505	$34,533	$136,558
Maryland	$103,537	62,675	$41,222	$144,759
Massachusetts	$103,832	--	--	$103,832
Michigan	$74,151	15,531	$10,215	$84,366
Minnesota	$70,413	--	--	$70,413
Mississippi	$128,498	142,735	$93,879	$222,377
Missouri	$89,935	83,066	$54,634	$144,569

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Montana	$28,843	2,472	$1,626	$30,469
Nebraska	$69,332	64,796	$42,617	$111,949
Nevada	$9,351	--	--	$9,351
New Hampshire	$98,503	--	--	$98,503
New Jersey	$115,074	101,636	$66,848	$181,922
New Mexico	$37,847	--	--	$37,847
New York	$90,377	53,039	$34,885	$125,262
North Carolina	$105,753	101,603	$66,826	$172,579
North Dakota	$39,390	--	--	$39,390
Ohio	$92,529	74,499	$48,999	$141,528
Oklahoma	$80,351	--	--	$80,351
Oregon	$99,710	31,647	$20,814	$120,524
Pennsylvania	$101,901	45,992	$30,249	$132,150
Rhode Island	$109,556	90,831	$59,741	$169,297
South Carolina	$111,293	--	--	$111,293
South Dakota	$39,412	19,122	$12,576	$51,988
Tennessee	$112,903	--	--	$112,903
Texas	$79,635	--	--	$79,635
Utah	$35,646	--	--	$35,646
Vermont	$83,262	59,202	$38,938	$122,200
Virginia	$98,807	59,135	$38,894	$137,701
Washington	$86,341	--	--	$86,341
West Virginia	$104,858	34,719	$22,835	$127,693
Wisconsin	$77,060	55,277	$36,357	$113,417
Wyoming	$36,081	16,199	$10,654	$46,735
Puerto Rico	$124,291	--	--	$124,291
District of Columbia	$102,207	--	--	$102,207

Table 9-11. ATS Costs for Large Nonresidential Projects

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Alabama	$366,707	509,898	$335,368	$702,074
Arizona	$57,872	--	--	$57,872
Arkansas	$356,082	386,529	$254,226	$610,308
California	$137,532	9,244	$6,080	$143,612
Colorado	$99,514	96,135	$63,229	$162,743
Connecticut	$332,122	175,593	$115,490	$447,612
Delaware	$321,714	198,237	$130,383	$452,097
Florida	$463,724	498,321	$327,753	$791,478
Georgia	$380,294	368,169	$242,150	$622,445
Hawaii	$136,768	--	--	$136,768
Idaho	$84,757	--	--	$84,757

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Illinois	$247,095	--	--	$247,095
Indiana	$296,763	263,568	$173,353	$470,116
Iowa	$236,769	200,736	$132,027	$368,796
Kansas	$274,328	241,587	$158,895	$433,224
Kentucky	$336,600	173,604	$114,182	$450,782
Louisiana	$439,494	613,938	$403,796	$843,291
Maine	$311,572	160,344	$105,461	$417,033
Maryland	$316,190	191,403	$125,889	$442,079
Massachusetts	$317,091	--	--	$317,091
Michigan	$226,449	47,430	$31,195	$257,644
Minnesota	$215,034	--	--	$215,034
Mississippi	$392,420	435,897	$286,696	$679,116
Missouri	$274,653	253,674	$166,845	$441,498
Montana	$88,084	7,548	$4,964	$93,048
Nebraska	$211,731	197,880	$130,149	$341,880
Nevada	$28,556	--	--	$28,556
New Hampshire	$300,817	--	--	$300,817
New Jersey	$351,425	310,386	$204,146	$555,570
New Mexico	$115,582	--	--	$115,582
New York	$276,002	161,976	$106,534	$382,536
North Carolina	$322,960	310,284	$204,078	$527,038
North Dakota	$120,292	--	--	$120,292
Ohio	$282,575	227,511	$149,637	$432,212
Oklahoma	$245,383	--	--	$245,383
Oregon	$304,503	96,645	$63,565	$368,068
Pennsylvania	$311,194	140,454	$92,379	$403,572
Rhode Island	$334,573	277,389	$182,443	$517,016
South Carolina	$339,877	--	--	$339,877
South Dakota	$120,359	58,395	$38,407	$158,766
Tennessee	$344,795	--	--	$344,795
Texas	$243,196	--	--	$243,196
Utah	$108,858	--	--	$108,858
Vermont	$254,273	180,795	$118,912	$373,185
Virginia	$301,745	180,591	$118,777	$420,523
Washington	$263,677	--	--	$263,677
West Virginia	$320,224	106,029	$69,737	$389,961
Wisconsin	$235,334	168,810	$111,029	$346,363
Wyoming	$110,187	49,470	$32,537	$142,724
Puerto Rico	$379,572	--	--	$379,572
District of Columbia	$312,129	--	--	$312,129

Table 9-12. ATS Costs for Medium Nonresidential Projects

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Alabama	$107,855	149,970	$98,638	$206,492
Arizona	$17,021	--	--	$17,021
Arkansas	$104,730	113,685	$74,772	$179,502
California	$40,451	2,719	$1,788	$42,239
Colorado	$29,269	28,275	$18,597	$47,866
Connecticut	$97,683	51,645	$33,968	$131,651
Delaware	$94,622	58,305	$38,348	$132,970
Florida	$136,390	146,565	$96,398	$232,788
Georgia	$111,851	108,285	$71,221	$183,072
Hawaii	$40,226	--	--	$40,226
Idaho	$24,928	--	--	$24,928
Illinois	$72,675	--	--	$72,675
Indiana	$87,283	77,520	$50,986	$138,269
Iowa	$69,638	59,040	$38,831	$108,469
Kansas	$80,685	71,055	$46,734	$127,419
Kentucky	$99,000	51,060	$33,583	$132,583
Louisiana	$129,263	180,570	$118,764	$248,027
Maine	$91,639	47,160	$31,018	$122,657
Maryland	$92,997	56,295	$37,026	$130,023
Massachusetts	$93,262	--	--	$93,262
Michigan	$66,603	13,950	$9,175	$75,778
Minnesota	$63,245	--	--	$63,245
Mississippi	$115,418	128,205	$84,322	$199,740
Missouri	$80,780	74,610	$49,072	$129,852
Montana	$25,907	2,220	$1,460	$27,367
Nebraska	$62,274	58,200	$38,279	$100,553
Nevada	$8,399	--	--	$8,399
New Hampshire	$88,476	--	--	$88,476
New Jersey	$103,360	91,290	$60,043	$163,403
New Mexico	$33,995	--	--	$33,995
New York	$81,177	47,640	$31,334	$112,511
North Carolina	$94,988	91,260	$60,023	$155,011
North Dakota	$35,380	--	--	$35,380
Ohio	$83,110	66,915	$44,011	$127,121
Oklahoma	$72,171	--	--	$72,171
Oregon	$89,560	28,425	$18,696	$108,255
Pennsylvania	$91,528	41,310	$27,170	$118,698
Rhode Island	$98,404	81,585	$53,660	$152,064
South Carolina	$99,964	--	--	$99,964
South Dakota	$35,400	17,175	$11,296	$46,696
Tennessee	$101,410	--	--	$101,410
Texas	$71,528	--	--	$71,528
Utah	$32,017	--	--	$32,017
Vermont	$74,786	53,175	$34,974	$109,760

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Virginia	$88,749	53,115	$34,935	$123,683
Washington	$77,552	--	--	$77,552
West Virginia	$94,184	31,185	$20,511	$114,694
Wisconsin	$69,216	49,650	$32,656	$101,871
Wyoming	$32,408	14,550	$9,570	$41,978
Puerto Rico	$111,639	--	--	$111,639
District of Columbia	$91,803	--	--	$91,803

Table 9-13. ATS Costs for Large Transportation Projects

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Alabama	$567,317	788,842	$518,833	$1,086,150
Arizona	$89,531	--	--	$89,531
Arkansas	$550,880	597,983	$393,302	$944,183
California	$212,770	14,301	$9,406	$222,176
Colorado	$153,954	148,727	$97,820	$251,774
Connecticut	$513,813	271,653	$178,670	$692,483
Delaware	$497,710	306,684	$201,711	$699,421
Florida	$717,409	770,932	$507,054	$1,224,462
Georgia	$588,338	569,579	$374,621	$962,958
Hawaii	$211,589	--	--	$211,589
Idaho	$131,124	--	--	$131,124
Illinois	$382,270	--	--	$382,270
Indiana	$459,110	407,755	$268,187	$727,296
Iowa	$366,295	310,550	$204,254	$570,549
Kansas	$424,402	373,749	$245,821	$670,223
Kentucky	$520,740	268,576	$176,646	$697,387
Louisiana	$679,924	949,798	$624,697	$1,304,620
Maine	$482,021	248,062	$163,154	$645,174
Maryland	$489,164	296,112	$194,757	$683,922
Massachusetts	$490,559	--	--	$490,559
Michigan	$350,330	73,377	$48,261	$398,591
Minnesota	$332,670	--	--	$332,670
Mississippi	$607,097	674,358	$443,536	$1,050,633
Missouri	$424,904	392,449	$258,119	$683,023
Montana	$136,270	11,677	$7,680	$143,951
Nebraska	$327,561	306,132	$201,348	$528,909
Nevada	$44,178	--	--	$44,178
New Hampshire	$465,382	--	--	$465,382
New Jersey	$543,675	480,185	$315,825	$859,500
New Mexico	$178,812	--	--	$178,812
New York	$426,991	250,586	$164,814	$591,806

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
North Carolina	$499,638	480,028	$315,721	$815,359
North Dakota	$186,098	--	--	$186,098
Ohio	$437,160	351,973	$231,498	$668,658
Oklahoma	$379,622	--	--	$379,622
Oregon	$471,084	149,516	$98,339	$569,422
Pennsylvania	$481,435	217,291	$142,915	$624,350
Rhode Island	$517,605	429,137	$282,250	$799,855
South Carolina	$525,810	--	--	$525,810
South Dakota	$186,202	90,341	$59,418	$245,621
Tennessee	$533,418	--	--	$533,418
Texas	$376,238	--	--	$376,238
Utah	$168,410	--	--	$168,410
Vermont	$393,376	279,701	$183,963	$577,339
Virginia	$466,818	279,385	$183,756	$650,573
Washington	$407,925	--	--	$407,925
West Virginia	$495,405	164,033	$107,887	$603,292
Wisconsin	$364,076	261,159	$171,768	$535,844
Wyoming	$170,466	76,533	$50,337	$220,803
Puerto Rico	$587,220	--	--	$587,220
District of Columbia	$482,882	--	--	$482,882

Table 9-14. ATS Costs for Medium Transportation Projects

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Alabama	$115,045	159,968	$105,213	$220,259
Arizona	$18,156	--	--	$18,156
Arkansas	$111,712	121,264	$79,757	$191,469
California	$43,147	2,900	$1,907	$45,055
Colorado	$31,220	30,160	$19,837	$51,057
Connecticut	$104,195	55,088	$36,232	$140,427
Delaware	$100,930	62,192	$40,905	$141,834
Florida	$145,482	156,336	$102,825	$248,307
Georgia	$119,308	115,504	$75,969	$195,277
Hawaii	$42,908	--	--	$42,908
Idaho	$26,590	--	--	$26,590
Illinois	$77,520	--	--	$77,520
Indiana	$93,102	82,688	$54,385	$147,487
Iowa	$74,280	62,976	$41,420	$115,701
Kansas	$86,064	75,792	$49,850	$135,913
Kentucky	$105,600	54,464	$35,822	$141,422
Louisiana	$137,881	192,608	$126,681	$264,562
Maine	$97,748	50,304	$33,086	$130,834
Maryland	$99,197	60,048	$39,494	$138,691
Massachusetts	$99,480	--	--	$99,480

	ATS cost	Storage volume over baseline (cubic feet)	Storage cost	Total cost per project
Michigan	$71,043	14,880	$9,787	$80,830
Minnesota	$67,462	--	--	$67,462
Mississippi	$123,112	136,752	$89,944	$213,056
Missouri	$86,166	79,584	$52,344	$138,509
Montana	$27,634	2,368	$1,557	$29,192
Nebraska	$66,426	62,080	$40,831	$107,256
Nevada	$8,959	--	--	$8,959
New Hampshire	$94,374	--	--	$94,374
New Jersey	$110,251	97,376	$64,046	$174,297
New Mexico	$36,261	--	--	$36,261
New York	$86,589	50,816	$33,422	$120,011
North Carolina	$101,321	97,344	$64,025	$165,345
North Dakota	$37,739	--	--	$37,739
Ohio	$88,651	71,376	$46,945	$135,596
Oklahoma	$76,983	--	--	$76,983
Oregon	$95,530	30,320	$19,942	$115,472
Pennsylvania	$97,629	44,064	$28,982	$126,611
Rhode Island	$104,964	87,024	$57,237	$162,201
South Carolina	$106,628	--	--	$106,628
South Dakota	$37,760	18,320	$12,049	$49,809
Tennessee	$108,171	--	--	$108,171
Texas	$76,297	--	--	$76,297
Utah	$34,152	--	--	$34,152
Vermont	$79,772	56,720	$37,306	$117,078
Virginia	$94,665	56,656	$37,264	$131,929
Washington	$82,722	--	--	$82,722
West Virginia	$100,462	33,264	$21,878	$122,341
Wisconsin	$73,830	52,960	$34,833	$108,663
Wyoming	$34,569	15,520	$10,208	$44,776
Puerto Rico	$119,081	--	--	$119,081
District of Columbia	$97,923	--	--	$97,923

Option 2 establishes a turbidity limit for construction sites larger than 30 acres that have an R-factor ≥ 50 and if the soils contain ≥ 10 percent clay particles, by mass. To determine acres in-scope for this option, EPA first determined the acres within each state that were located in areas with an R-factor ≥ 50 and with soils that contain ≥ 10 percent clay particles. EPA calculated these estimates by combining the soils data, R-factor data and RF1-level estimates of development using GIS. Table 9-15 shows the state-level and national estimates of the percent of each state's developed acres that fall into various combinations of R-factor and % clay content.

Based on the distribution of model projects by size (see Table 4-3), EPA determined the percent of developed acres that would be in projects less than 30 acres (36.6 percent) and the acres that would be in projects equal to or greater than 30 acres (63.4 percent). By multiplying the number of acres in the R ≥ 50 and ≥ 10 percent clay content column in Table 9-15 by the quantity of

developed acres for projects larger and smaller than 30 acres, EPA was able to determine the quantity of developed acres in each state that would be subject to the Option 2 turbidity standard. These results are shown in Table 9-16. The remainder of each state's developed acres in sites ≥ 10 acres would be required to install larger sediment basins, if existing state requirements were not equivalent.

To determine costs for Option 2, EPA divided acres in-scope for the turbidity limit into the three large project categories (residential, nonresidential and transportation) according to the fraction of acres in each category, on the basis of the NOI data. EPA then divided acres in each state by the median project size of the three categories to determine the number of model projects affected. Results were rounded to whole numbers to determine the number of model projects. Table 9-16 presents the number of model projects in-scope for the turbidity requirement of Option 2. Tables 9-17 and 9-18 present estimates of acres and model projects required to install larger sediment basins under Option 2. By multiplying the number of model projects in each state by the total cost for each project to implement ATS and provide storage for runoff from the 2-year, 24-hour storm, total ATS costs for Option 2 were estimated. For sites ≥ 10 acres that are not required to meet the turbidity limit, incremental costs to install 3,600 cf/acre sediment basins were estimated if not already required by current state requirements.

Table 9-15. Developed Acres with R-Factor ≥ 50 and Clay Content ≥ 10%

	% Acres with only R < 50	% Acres with only < 10% clay	% Acres with both R < 50 and < 10% clay	% Acres with R ≥ 50 and ≥ 10% clay	Acres with R ≥ 50 and ≥ 10% clay
Alabama	0%	26%	0%	74%	10,681
Arizona	87%	0%	2%	11%	1,470
Arkansas	0%	1%	0%	99%	8,386
California	65%	2%	19%	15%	3,980
Colorado	77%	2%	3%	18%	2,828
Connecticut	0%	57%	0%	43%	428
Delaware	0%	71%	0%	29%	240
Florida	0%	99%	0%	1%	344
Georgia	0%	34%	0%	66%	21,569
Idaho	95%	0%	5%	0%	--
Illinois	0%	0%	0%	100%	20,438
Indiana	0%	10%	0%	90%	11,097
Iowa	0%	0%	0%	100%	10,091
Kansas	0%	8%	0%	92%	20,812
Kentucky	0%	0%	0%	100%	9,928
Louisiana	0%	19%	0%	81%	10,455
Maine	0%	31%	0%	69%	3,108
Maryland	0%	16%	0%	84%	5,497
Massachusetts	0%	90%	0%	10%	324
Michigan	0%	68%	0%	32%	7,283
Minnesota	0%	33%	0%	67%	6,210
Mississippi	0%	9%	0%	91%	10,746
Missouri	0%	1%	0%	99%	13,365
Montana	99%	0%	1%	0%	--

	% Acres with only R < 50	% Acres with only < 10% clay	% Acres with both R < 50 and < 10% clay	% Acres with R ≥ 50 and ≥ 10% clay	Acres with R ≥ 50 and ≥ 10% clay
Nebraska	4%	26%	7%	63%	3,817
Nevada	94%	0%	6%	0%	--
New Hampshire	0%	79%	0%	21%	375
New Jersey	0%	55%	0%	45%	1,938
New Mexico	70%	0%	27%	2%	111
New York	0%	23%	0%	77%	5,960
North Carolina	0%	23%	0%	77%	14,514
North Dakota	31%	1%	1%	68%	4,467
Ohio	0%	2%	0%	98%	17,135
Oklahoma	0%	6%	0%	94%	15,722
Oregon	34%	1%	17%	47%	3,454
Pennsylvania	0%	1%	0%	99%	15,920
Rhode Island	0%	59%	0%	41%	154
South Carolina	0%	66%	0%	34%	5,456
South Dakota	7%	1%	0%	92%	7,631
Tennessee	0%	1%	0%	99%	13,001
Texas	1%	10%	1%	88%	53,785
Utah	94%	0%	6%	0%	--
Vermont	0%	3%	0%	97%	551
Virginia	0%	12%	0%	88%	13,368
Washington	46%	9%	11%	34%	4,410
West Virginia	0%	1%	0%	99%	3,474
Wisconsin	0%	39%	0%	61%	4,600
Wyoming	96%	0%	4%	0%	--
Nation	15%	21%	2%	63%	368,763

9.4.7. SUMMARY OF OPTION COSTS

The following tables present the compliance costs estimates for each of the regulatory options. For Option 2, the costs per model project vary by whether a specific project is required to meet the turbidity requirement. Note that for all options, no incremental costs are assumed for sites smaller than 10 acres. Table 9-19 presents the costs for Option 1. Table 9-20 presents the costs for the segment of the industry required to meet the turbidity standard, Table 9-21 presents the costs for the segment of the industry required to install only larger sediment basins, and Table 9-22 presents the total costs for Option 2. Table 9-23 presents the costs for Option 3. All costs are presented in year 2008 dollars.

Table 9-16. Acres and Model Projects In-Scope for Turbidity Limit of Option 2

	Acres				Model projects			
	Large residential	Large nonresidential	Large transportation	Total acres	Large residential	Large nonresidential	Large transportation	Total projects
Alaska	Not Analyzed							
Alabama	--	--	--	--	--	--	--	--
Arizona	462	357	79	898	14	7	1	22
Arkansas	2,541	2,142	631	5,314	77	42	8	127
California	1,221	1,020	316	2,557	37	20	4	61
Colorado	858	714	237	1,809	26	14	3	43
Connecticut	132	102	--	234	4	2	--	6
Delaware	66	51	--	117	2	1	--	3
Florida	99	102	--	201	3	2	--	5
Georgia	6,567	5,508	1,578	13,653	199	108	20	327
Hawaii	Not Analyzed							
Idaho	--	--	--	--	--	--	--	--
Illinois	6,204	5,202	1,499	12,905	188	102	19	309
Indiana	3,366	2,805	868	7,039	102	55	11	168
Iowa	3,069	2,550	789	6,408	93	50	10	153
Kansas	6,336	5,304	1,578	13,218	192	104	20	316
Kentucky	3,036	2,550	710	6,296	92	50	9	151
Louisiana	3,168	2,652	789	6,609	96	52	10	158
Maine	957	816	237	2,010	29	16	3	48
Maryland	1,683	1,377	395	3,455	51	27	5	83
Massachusetts	99	102	--	201	3	2	--	5
Michigan	2,211	1,836	552	4,599	67	36	7	110
Minnesota	1,881	1,581	473	3,935	57	31	6	94
Mississippi	3,267	2,754	789	6,810	99	54	10	163
Missouri	4,059	3,417	1,026	8,502	123	67	13	203
Montana	--	--	--	--	--	--	--	--
Nebraska	1,155	969	316	2,440	35	19	4	58
Nevada	--	--	--	--	--	--	--	--
New Hampshire	99	102	--	201	3	2	--	5

	Acres				Model projects			
	Large residential	**Large nonresidential**	**Large transportation**	**Total acres**	**Large residential**	**Large nonresidential**	**Large transportation**	**Total projects**
New Jersey	594	510	158	1,262	18	10	2	30
New Mexico	33	51	--	84	1	1	--	2
New York	1,815	1,530	473	3,818	55	30	6	91
North Carolina	4,422	3,723	1,105	9,250	134	73	14	221
North Dakota	1,353	1,122	316	2,791	41	22	4	67
Ohio	5,214	4,386	1,262	10,862	158	86	16	260
Oklahoma	4,785	4,029	1,184	9,998	145	79	15	239
Oregon	1,056	867	237	2,160	32	17	3	52
Pennsylvania	4,851	4,080	1,184	10,115	147	80	15	242
Rhode Island	33	51	--	84	1	1	--	2
South Carolina	1,650	1,377	395	3,422	50	27	5	82
South Dakota	2,310	1,938	552	4,800	70	38	7	115
Tennessee	3,960	3,315	947	8,222	120	65	12	197
Texas	16,368	13,719	4,024	34,111	496	269	51	816
Utah	--	--	--	--	--	--	--	--
Vermont	165	153	79	397	5	3	1	9
Virginia	4,059	3,417	1,026	8,502	123	67	13	203
Washington	1,353	1,122	316	2,791	41	22	4	67
West Virginia	1,056	867	237	2,160	32	17	3	52
Wisconsin	1,386	1,173	316	2,875	42	23	4	69
Wyoming	--	--	--	--	--	--	--	--
Puerto Rico	Not Analyzed							
District of Columbia	Not Analyzed							
Nation	112,233	94,146	27,457	233,836	3,401	1,846	348	5,595

Table 9-17. Acres Required to Install Larger Sediment Basins Under Option 2

	Large residential	Medium residential	Large nonresidential	Medium nonresidential	Large transportation	Medium transportation	Total acres
Alaska	Not Analyzed						
Alabama	1,188	1,837	1,020	1,335	316	176	5,872
Arizona	--	--	--	--	--	--	--
Arkansas	--	--	--	--	--	--	--
California	--	--	--	--	--	--	--
Colorado	3,960	2,004	3,315	1,455	947	192	11,873
Connecticut	--	--	--	--	--	--	--
Delaware	--	--	--	--	--	--	--
Florida	--	--	--	--	--	--	--
Georgia	3,333	4,125	2,805	3,000	868	384	14,515
Hawaii	Not Analyzed						
Idaho	--	--	--	--	--	--	--
Illinois	--	--	--	--	--	--	--
Indiana	396	1,570	357	1,140	79	144	3,686
Iowa	--	--	--	--	--	--	--
Kansas	--	--	--	--	--	--	--
Kentucky	--	--	--	--	--	--	--
Louisiana	--	--	--	--	--	--	--
Maine	--	--	--	--	--	--	--
Maryland	--	--	--	--	--	--	--
Massachusetts	--	--	--	--	--	--	--
Michigan	--	--	--	--	--	--	--
Minnesota	--	--	--	--	--	--	--
Mississippi	--	--	--	--	--	--	--
Missouri	--	--	--	--	--	--	--
Montana	1,947	818	1,632	600	473	80	5,551
Nebraska	693	768	561	555	158	64	2,799
Nevada	--	--	--	--	--	--	--
New Hampshire	--	--	--	--	--	--	--
New Jersey	693	534	561	390	158	48	2,384

	Large residential	Medium residential	Large nonresidential	Medium nonresidential	Large transportation	Medium transportation	Total acres
New Mexico	--	--	--	--	--	--	--
New York	--	--	--	--	--	--	--
North Carolina	1,287	2,371	1,071	1,725	316	224	6,994
North Dakota	--	--	--	--	--	--	--
Ohio	66	2,204	51	1,605	79	208	4,213
Oklahoma	--	--	--	--	--	--	--
Oregon	--	--	--	--	--	--	--
Pennsylvania	--	--	--	--	--	--	--
Rhode Island	66	50	51	30	-	-	197
South Carolina	--	--	--	--	--	--	--
South Dakota	--	--	--	--	--	--	--
Tennessee	--	--	--	--	--	--	--
Texas	--	--	--	--	--	--	--
Utah	--	--	--	--	--	--	--
Vermont	--	67	--	45	--	--	112
Virginia	--	--	--	--	--	--	--
Washington	--	--	--	--	--	--	--
West Virginia	--	--	--	--	--	--	--
Wisconsin	924	952	765	690	237	96	3,664
Wyoming	858	351	714	255	237	32	2,446
Puerto Rico	Not Analyzed						
District of Columbia	Not Analyzed						
Totals	15,411	17,652	12,903	12,825	3,866	1,648	64,305

Table 9-18. Model Projects Required to Install Larger Sediment Basins Under Option 2

	Large residential	Medium residential	Large nonresidential	Medium nonresidential	Large transportation	Medium transportation	Total projects
Alaska	Not Analyzed						
Alabama	36	110	20	89	4	11	270
Arizona	--	--	--	--	--	--	-
Arkansas	--	--	--	--	--	--	-
California	--	--	--	--	--	--	-
Colorado	120	120	65	97	12	12	426
Connecticut	--	--	--	--	--	--	--
Delaware	--	--	--	--	--	--	--
Florida	--	--	--	--	--	--	--
Georgia	101	247	55	200	11	24	638
Hawaii	Not Analyzed						
Idaho	--	--	--	--	--	--	--
Illinois	--	--	--	--	--	--	--
Indiana	12	94	7	76	1	9	199
Iowa	--	--	--	--	--	--	--
Kansas	--	--	--	--	--	--	--
Kentucky	--	--	--	--	--	--	--
Louisiana	--	--	--	--	--	--	--
Maine	--	--	--	--	--	--	--
Maryland	--	--	--	--	--	--	--
Massachusetts	--	--	--	--	--	--	--
Michigan	--	--	--	--	--	--	--
Minnesota	--	--	--	--	--	--	--
Mississippi	--	--	--	--	--	--	--
Missouri	--	--	--	--	--	--	--
Montana	59	49	32	40	6	5	191
Nebraska	21	46	11	37	2	4	121
Nevada	--	--	--	--	--	--	--
New Hampshire	--	--	--	--	--	--	--
New Jersey	21	32	11	26	2	3	95

	Large residential	Medium residential	Large nonresidential	Medium nonresidential	Large transportation	Medium transportation	Total projects
New Mexico	--	--	--	--	--	--	--
New York	--	--	--	--	--	--	--
North Carolina	39	142	21	115	4	14	335
North Dakota	--	--	--	--	--	--	--
Ohio	2	132	1	107	1	13	256
Oklahoma	--	--	--	--	--	--	--
Oregon	--	--	--	--	--	--	--
Pennsylvania	--	--	--	--	--	--	--
Rhode Island	2	3	1	2	--	--	8
South Carolina	--	--	--	--	--	--	--
South Dakota	--	--	--	--	--	--	--
Tennessee	--	--	--	--	--	--	--
Texas	--	--	--	--	--	--	--
Utah	--	--	--	--	--	--	--
Vermont	--	4	-	3	-	-	7
Virginia	--	--	--	--	--	--	--
Washington	--	--	--	--	--	--	--
West Virginia	--	--	--	--	--	--	--
Wisconsin	28	57	15	46	3	6	155
Wyoming	26	21	14	17	3	2	83
Puerto Rico	Not Analyzed						
District of Columbia	Not Analyzed						
Totals	467	1,057	253	855	49	103	2,784

Table 9-19a. Option 1 Costs by Model Project Type and State ($2008); Transportation

State	Medium transportation			Large transportation			TOTALS TRANSPORTATION	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Alaska	Not Analyzed							
Alabama	11	$18,942	$208,364	14	$93,409	$1,307,722	25	$1,516,086
Arizona	0	--	--	0	--	--	0	--
Arkansas	0	--	--	0	--	--	0	--
California	0	--	--	0	--	--	0	--
Colorado	12	$18,942	$227,306	15	$93,409	$1,401,130	27	$1,628,437
Connecticut	0	--	--	0	--	--	0	--
Delaware	0	--	--	0	--	--	0	--
Florida	0	--	--	0	--	--	0	--
Georgia	24	$18,942	$454,613	31	$93,409	$2,895,669	55	$3,350,282
Hawaii	Not Analyzed							
Idaho	0	--	--	0	--	--	0	--
Illinois	0	--	--	0	--	--	0	--
Indiana	9	$18,942	$170,480	12	$93,409	$1,120,904	21	$1,291,384
Iowa	0	--	--	0	--	--	0	--
Kansas	0	--	--	0	--	--	0	--
Kentucky	0	--	--	0	--	--	0	--
Louisiana	0	--	--	0	--	--	0	--
Maine	0	--	--	0	--	--	0	--
Maryland	0	--	--	0	--	--	0	--
Massachusetts	0	--	--	0	--	--	0	--
Michigan	0	--	--	0	--	--	0	--
Minnesota	0	--	--	0	--	--	0	--
Mississippi	0	--	--	0	--	--	0	--
Missouri	0	--	--	0	--	--	0	--

State	Medium transportation			Large transportation			TOTALS TRANSPORTATION	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Montana	5	$1,557	$7,787	6	$7,680	$46,082	11	$53,869
Nebraska	4	$18,942	$75,769	6	$93,409	$560,452	10	$636,221
Nevada	0	--	--	0	--	--	0	--
New Hampshire	0	--	--	0	--	--	0	--
New Jersey	3	$18,942	$56,827	4	$93,409	$373,635	7	$430,461
New Mexico	0	--	--	0	--	--	0	--
New York	0	--	--	0	--	--	0	--
North Carolina	14	$18,942	$265,191	18	$93,409	$1,681,356	32	$1,946,547
North Dakota	0	--	--	0	--	--	0	--
Ohio	13	$18,942	$246,249	17	$93,409	$1,587,948	30	$1,834,196
Oklahoma	0	--	--	0	--	--	0	--
Oregon	0	--	--	0	--	--	0	--
Pennsylvania	0	--	--	0	--	--	0	--
Rhode Island	0	--	--	0	--	--	0	--
South Carolina	0	--	--	0	--	--	0	--
South Dakota	0	--	--	0	--	--	0	--
Tennessee	0	--	--	0	--	--	0	--
Texas	0	--	--	0	--	--	0	--
Utah	0	--	--	0	--	--	0	--
Vermont	0	--	--	1	$93,409	$93,409	1	$93,409
Virginia	0	--	--	0	--	--	0	--
Washington	0	--	--	0	--	--	0	--
West Virginia	0	--	--	0	--	--	0	--
Wisconsin	6	$10,797	$64,782	7	$53,243	$372,701	13	$437,483
Wyoming	2	$10,208	$20,415	3	$50,337	$151,011	5	$171,426
District of Columbia	0	--	--	0	--	--	0	--
Total Transportation	**103**		**$1,797,783**	**134**		**$11,592,019**	**237**	**$13,389,801**

Table 9-19b. Option 1 Costs by Model Project Type and State ($2008); Residential

State	Medium residential			Large residential			TOTALS RESIDENTIAL	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Alaska	Not Analyzed							
Alabama	110	$19,771	$2,174,801	134	$39,068	$5,235,149	244	$7,409,949
Arizona	0	--	--	0	--	--	0	--
Arkansas	0	--	--	0	--	--	0	--
California	0	--	--	0	--	--	0	--
Colorado	120	$19,771	$2,372,510	146	$39,068	$5,703,968	266	$8,076,478
Connecticut	0	--	--	0	--	--	0	--
Delaware	0	--	--	0	--	--	0	--
Florida	0	--	--	0	--	--	0	--
Georgia	247	$19,771	$4,883,416	300	$39,068	$11,720,482	547	$16,603,898
Hawaii	Not Analyzed							
Idaho	0	--	--	0	--	--	0	--
Illinois	0	--	--	0	--	--	0	--
Indiana	94	$19,771	$1,858,466	114	$39,068	$4,453,783	208	$6,312,249
Iowa	0	--	--	0	--	--	0	--
Kansas	0	--	--	0	--	--	0	--
Kentucky	0	--	--	0	--	--	0	--
Louisiana	0	--	--	0	--	--	0	--
Maine	0	--	--	0	--	--	0	--
Maryland	0	--	--	0	--	--	0	--
Massachusetts	0	--	--	0	--	--	0	--
Michigan	0	--	--	0	--	--	0	--
Minnesota	0	--	--	0	--	--	0	--
Mississippi	0	--	--	0	--	--	0	--
Missouri	0	--	--	0	--	--	0	--
Montana	49	$1,626	$79,655	59	$3,212	$189,525	108	$269,179

State	Medium residential			Large residential			TOTALS RESIDENTIAL	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Nebraska	46	$19,771	$909,462	56	$39,068	$2,187,823	102	$3,097,285
Nevada	0	--	--	0	--	--	0	--
New Hampshire	0	--	--	0	--	--	0	--
New Jersey	32	$19,771	$632,669	39	$39,068	$1,523,663	71	$2,156,332
New Mexico	0	--	--	0	--	--	0	--
New York	0	--	--	0	--	--	0	--
North Carolina	142	$19,771	$2,807,470	173	$39,068	$6,758,811	315	$9,566,281
North Dakota	0	--	--	0	--	--	0	--
Ohio	132	$19,771	$2,609,761	160	$39,068	$6,250,924	292	$8,860,685
Oklahoma	0	--	--	0	--	--	0	--
Oregon	0	--	--	0	--	--	0	--
Pennsylvania	0	--	--	0	--	--	0	--
Rhode Island	3	$19,771	$59,313	3	$39,068	$117,205	6	$176,518
South Carolina	0	--	--	0	--	--	0	--
South Dakota	0	--	--	0	--	--	0	--
Tennessee	0	--	--	0	--	--	0	--
Texas	0	--	--	0	--	--	0	--
Utah	0	--	--	0	--	--	0	--
Vermont	4	$19,771	$79,084	5	$39,068	$195,341	9	$274,425
Virginia	0	--	--	0	--	--	0	--
Washington	0	--	--	0	--	--	0	--
West Virginia	0	--	--	0	--	--	0	--
Wisconsin	57	$11,269	$642,357	70	$22,269	$1,558,824	127	$2,201,181
Wyoming	21	$10,654	$223,741	26	$21,053	$547,390	47	$771,131
District of Columbia	0	--	--	0	--	--	0	--
Total Residential	**1,057**		**$19,332,703**	**1,285**		**$46,442,889**	**2,342**	**$65,775,592**

Table 9-19c. Option 1 Costs by Model Project Type and State ($2008); Nonresidential

State	Medium nonresidential			Large nonresidential			TOTALS NONRESIDENTIAL	
	# Projects	Cost per Project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Alaska	Not Analyzed							
Alabama	89	$17,758	$1,580,489	73	$60,378	$4,407,612	162	$5,988,101
Arizona	0	--	--	0	--	--	0	--
Arkansas	0	--	--	0	--	--	0	--
California	0	--	--	0	--	--	0	--
Colorado	97	$17,758	$1,722,556	79	$60,378	$4,769,881	176	$6,492,437
Connecticut	0	--	--	0	--	--	0	--
Delaware	0	--	--	0	--	--	0	--
Florida	0	--	--	0	--	--	0	--
Georgia	200	$17,758	$3,551,661	163	$60,378	$9,841,654	363	$13,393,315
Hawaii	Not Analyzed							
Idaho	0	--	--	0	--	--	0	--
Illinois	0	--	--	0	--	--	0	--
Indiana	76	$17,758	$1,349,631	62	$60,378	$3,743,451	138	$5,093,082
Iowa	0	--	--	0	--	--	0	--
Kansas	0	--	--	0	--	--	0	--
Kentucky	0	--	--	0	--	--	0	--
Louisiana	0	--	--	0	--	--	0	--
Maine	0	--	--	0	--	--	0	--
Maryland	0	--	--	0	--	--	0	--
Massachusetts	0	--	--	0	--	--	0	--
Michigan	0	--	--	0	--	--	0	--
Minnesota	0	--	--	0	--	--	0	--
Mississippi	0	--	--	0	--	--	0	--
Missouri	0	--	--	0	--	--	0	--
Montana	40	$1,460	$58,405	32	$4,964	$158,862	72	$217,267

State	Medium nonresidential			Large nonresidential			TOTALS NONRESIDENTIAL	
	# Projects	Cost per Project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Nebraska	37	$17,758	$657,057	30	$60,378	$1,811,347	67	$2,468,405
Nevada	0	--	--	0	--	--	0	--
New Hampshire	0	--	--	0	--	--	0	--
New Jersey	26	$17,758	$461,716	21	$60,378	$1,267,943	47	$1,729,659
New Mexico	0	--	--	0	--	--	0	--
New York	0	--	--	0	--	--	0	--
North Carolina	115	$17,758	$2,042,205	94	$60,378	$5,675,555	209	$7,717,760
North Dakota	0	--	--	0	--	--	0	--
Ohio	107	$17,758	$1,900,139	87	$60,378	$5,252,907	194	$7,153,046
Oklahoma	0	--	--	0	--	--	0	--
Oregon	0	--	--	0	--	--	0	--
Pennsylvania	0	--	--	0	--	--	0	--
Rhode Island	2	$17,758	$35,517	2	$60,378	$120,756	4	$156,273
South Carolina	0	--	--	0	--	--	0	--
South Dakota	0	--	--	0	--	--	0	--
Tennessee	0	--	--	0	--	--	0	--
Texas	0	--	--	0	--	--	0	--
Utah	0	--	--	0	--	--	0	--
Vermont	3	$17,758	$53,275	3	$60,378	$181,135	6	$234,410
Virginia	0	--	--	0	--	--	0	--
Washington	0	--	--	0	--	--	0	--
West Virginia	0	--	--	0	--	--	0	--
Wisconsin	46	$10,122	$465,623	38	$34,416	$1,307,793	84	$1,773,416
Wyoming	17	$9,570	$162,686	14	$32,537	$455,520	31	$618,206
District of Columbia	0	--	--	0	--	--	0	--
Total Nonresidential	**855**		**$14,040,960**	**698**		**$38,994,416**	**1,554**	**$53,035,376**

Table 9-20. Option 2 Costs for Sites Required to Meet Turbidity Standard ($2008)

State	Transportation			Large residential			Large nonresidential			TOTALS	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Alabama	10	$1,086,150	$10,861,500	98	$454,283	$44,519,762	53	$702,074	$37,209,931	161	$92,591,194
Arizona	1	$89,531	$89,531	14	$37,447	$524,252	7	$57,872	$405,104	22	$1,018,887
Arkansas	8	$944,183	$7,553,461	77	$394,905	$30,407,705	42	$610,308	$25,632,942	127	$63,594,107
California	4	$222,176	$888,705	37	$92,925	$3,438,242	20	$143,612	$2,872,241	61	$7,199,188
Colorado	3	$251,774	$755,321	26	$105,305	$2,737,918	14	$162,743	$2,278,407	43	$5,771,645
Connecticut	0	$692,483	--	4	$289,632	$1,158,526	2	$447,612	$895,225	6	$2,053,751
Delaware	0	$699,421	--	2	$292,533	$585,067	1	$452,097	$452,097	3	$1,037,164
Florida	0	$1,224,462	--	3	$512,133	$1,536,398	2	$791,478	$1,582,955	5	$3,119,353
Georgia	20	$962,958	$19,259,168	199	$402,758	$80,148,893	108	$622,445	$67,224,015	327	$166,632,076
Hawaii	0	$211,589	--	0	$88,497	--	0	$136,768	--	0	--
Idaho	0	$131,124	--	0	$54,843	--	0	$84,757	--	0	--
Illinois	19	$382,270	$7,263,130	188	$159,885	$30,058,340	102	$247,095	$25,203,656	309	$62,525,126
Indiana	11	$727,296	$8,000,261	102	$304,192	$31,027,629	55	$470,116	$25,856,358	168	$64,884,248
Iowa	10	$570,549	$5,705,488	93	$238,633	$22,192,831	50	$368,796	$18,439,791	153	$46,338,110
Kansas	20	$670,223	$13,404,452	192	$280,321	$53,821,677	104	$433,224	$45,055,267	316	$112,281,395
Kentucky	9	$697,387	$6,276,480	92	$291,683	$26,834,802	50	$450,782	$22,539,112	151	$55,650,394
Louisiana	10	$1,304,620	$13,046,203	96	$545,659	$52,383,233	52	$843,291	$43,851,115	158	$109,280,551
Maine	3	$645,174	$1,935,523	29	$269,845	$7,825,500	16	$417,033	$6,672,527	48	$16,433,550
Maryland	5	$683,922	$3,419,608	51	$286,051	$14,588,593	27	$442,079	$11,936,121	83	$29,944,322
Massachusetts	0	$490,559	--	3	$205,177	$615,530	2	$317,091	$634,182	5	$1,249,713
Michigan	7	$398,591	$2,790,135	67	$166,711	$11,169,632	36	$257,644	$9,275,190	110	$23,234,957
Minnesota	6	$332,670	$1,996,017	57	$139,139	$7,930,944	31	$215,034	$6,666,040	94	$16,593,001
Mississippi	10	$1,050,633	$10,506,327	99	$439,428	$43,503,385	54	$679,116	$36,672,275	163	$90,681,988
Missouri	13	$683,023	$8,879,300	123	$285,675	$35,138,029	67	$441,498	$29,580,351	203	$73,597,680
Montana	0	$143,951	--	0	$60,207	--	0	$93,048	--	0	--
Nebraska	4	$528,909	$2,115,634	35	$221,217	$7,742,578	19	$341,880	$6,495,722	58	$16,353,934
Nevada	0	$44,178	--	0	$18,477	--	0	$28,556	--	0	--
New	0	$465,382	--	3	$194,647	$583,940	2	$300,817	$601,635	5	$1,185,575

State	Transportation			Large residential			Large nonresidential			TOTALS	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Hampshire											
New Jersey	2	$859,500	$1,719,000	18	$359,487	$6,470,760	10	$555,570	$5,555,703	30	$13,745,464
New Mexico	0	$178,812	--	1	$74,788	$74,788	1	$115,582	$115,582	2	$190,370
New York	6	$591,806	$3,550,834	55	$247,523	$13,613,779	30	$382,536	$11,476,078	91	$28,640,690
North Carolina	14	$815,359	$11,415,025	134	$341,025	$45,697,303	73	$527,038	$38,473,781	221	$95,586,109
North Dakota	4	$186,098	$744,392	41	$77,836	$3,191,263	22	$120,292	$2,646,414	67	$6,582,069
Ohio	16	$668,658	$10,698,529	158	$279,667	$44,187,367	86	$432,212	$37,170,271	260	$92,056,167
Oklahoma	15	$379,622	$5,694,323	145	$158,777	$23,022,673	79	$245,383	$19,385,235	239	$48,102,231
Oregon	3	$569,422	$1,708,267	32	$238,161	$7,621,165	17	$368,068	$6,257,150	52	$15,586,582
Pennsylvania	15	$624,350	$9,365,254	147	$261,135	$38,386,861	80	$403,572	$32,285,795	242	$80,037,910
Rhode Island	0	$799,855	--	1	$334,540	$334,540	1	$517,016	$517,016	2	$851,556
South Carolina	5	$525,810	$2,629,051	50	$219,921	$10,996,029	27	$339,877	$9,176,686	82	$22,801,766
South Dakota	7	$245,621	$1,719,346	70	$102,731	$7,191,179	38	$158,766	$6,033,119	115	$14,943,644
Tennessee	12	$533,418	$6,401,013	120	$223,102	$26,772,296	65	$344,795	$22,411,657	197	$55,584,966
Texas	51	$376,238	$19,188,136	496	$157,362	$78,051,495	269	$243,196	$65,419,627	816	$162,659,258
Utah	0	$168,410	--	0	$70,438	--	0	$108,858	--	0	--
Vermont	1	$577,339	$577,339	5	$241,473	$1,207,363	3	$373,185	$1,119,555	9	$2,904,257
Virginia	13	$650,573	$8,457,453	123	$272,103	$33,468,658	67	$420,523	$28,175,020	203	$70,101,131
Washington	4	$407,925	$1,631,698	41	$170,615	$6,995,208	22	$263,677	$5,800,904	67	$14,427,810
West Virginia	3	$603,292	$1,809,877	32	$252,328	$8,074,483	17	$389,961	$6,629,334	52	$16,513,694
Wisconsin	4	$535,844	$2,143,375	42	$224,117	$9,412,922	23	$346,363	$7,966,347	69	$19,522,645
Wyoming	0	$220,803	--	0	$92,351	--	0	$142,724	--	0	--
Puerto Rico	0	$587,220	--	0	$245,605	--	0	$379,572	--	0	--
District of Columbia	0	$482,882	--	0	$201,966	--	0	$312,129	--	0	--
National Totals	**348**		**$214,199,156**	**3,401**		**$875,243,539**	**1,**846		**$734,647,534**	**5,**595	**$1,824,090,229**

Table 9-21a. Option 2 Costs for Projects Installing Larger Sediment Basins ($2008); Transportation

State	Medium transportation			Large transportation			TOTALS TRANSPORTATION	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Alaska	Not Analyzed							
Alabama	11	$18,942	$208,364	4	$93,409	$373,635	15	$581,999
Arizona	0	--	--	0	--	--	0	--
Arkansas	0	--	--	0	--	--	0	--
California	0	--	--	0	--	--	0	--
Colorado	12	$18,942	$227,306	12	$93,409	$1,120,904	24	$1,348,211
Connecticut	0	--	--	0	--	--	0	--
Delaware	0	--	--	0	--	--	0	--
Florida	0	--	--	0	--	--	0	--
Georgia	24	$18,942	$454,613	11	$93,409	$1,027,496	35	$1,482,108
Hawaii	Not Analyzed							
Idaho	0	--	--	0	--	--	0	--
Illinois	0	--	--	0	--	--	0	--
Indiana	9	$18,942	$170,480	1	$93,409	$93,409	10	$263,888
Iowa	0	--	--	0	--	--	0	--
Kansas	0	--	--	0	--	--	0	--
Kentucky	0	--	--	0	--	--	0	--
Louisiana	0	--	--	0	--	--	0	--
Maine	0	--	--	0	--	--	0	--
Maryland	0	--	--	0	--	--	0	--
Massachusetts	0	--	--	0	--	--	0	--
Michigan	0	--	--	0	--	--	0	--
Minnesota	0	--	--	0	--	--	0	--
Mississippi	0	--	--	0	--	--	0	--
Missouri	0	--	--	0	--	--	0	--

State	Medium transportation			Large transportation			TOTALS TRANSPORTATION	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Montana	5	$1,557	$7,787	6	$7,680	$46,082	11	$53,869
Nebraska	4	$18,942	$75,769	2	$93,409	$186,817	6	$262,586
Nevada	0	--	--	0	--	--	0	--
New Hampshire	0	--	--	0	--	--	0	--
New Jersey	3	$18,942	$56,827	2	$93,409	$186,817	5	$243,644
New Mexico	0	--	--	0	--	--	0	--
New York	0	--	--	0	--	--	0	--
North Carolina	14	$18,942	$265,191	4	$93,409	$373,635	18	$638,825
North Dakota	0	--	--	0	--	--	0	--
Ohio	13	$18,942	$246,249	1	$93,409	$93,409	14	$339,657
Oklahoma	0	--	--	0	--	--	0	--
Oregon	0	--	--	0	--	--	0	--
Pennsylvania	0	--	--	0	--	--	0	--
Rhode Island	0	--	--	0	--	--	0	--
South Carolina	0	--	--	0	--	--	0	--
South Dakota	0	--	--	0	--	--	0	--
Tennessee	0	--	--	0	--	--	0	--
Texas	0	--	--	0	--	--	0	--
Utah	0	--	--	0	--	--	0	--
Vermont	0	--	--	0	--	--	0	--
Virginia	0	--	--	0	--	--	0	--
Washington	0	--	--	0	--	--	0	--
West Virginia	0	--	--	0	--	--	0	--
Wisconsin	6	$10,797	$64,782	3	$53,243	$159,729	9	$224,511
Wyoming	2	$10,208	$20,415	3	$50,337	$151,011	5	$171,426
District of Columbia	0	--	--	0	--	--	0	--
Total Transportation	**103**		**$1,797,783**	**49**		**$3,812,943**	**152**	**$5,610,725**

Table 9-21b. Option 2 Costs for Projects Installing Larger Sediment Basins ($2008); Residential

State	Medium residential			Large residential			TOTALS RESIDENTIAL	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Alaska	Not Analyzed							
Alabama	110	$19,771	$2,174,801	36	$39,068	$1,406,458	146	$3,581,258
Arizona	0	--	--	0	--	--	0	--
Arkansas	0	--	--	0	--	--	0	--
California	0	--	--	0	--	--	0	--
Colorado	120	$19,771	$2,372,510	120	$39,068	$4,688,193	240	$7,060,703
Connecticut	0	--	--	0	--	--	0	--
Delaware	0	--	--	0	--	--	0	--
Florida	0	--	--	0	--	--	0	--
Georgia	247	$19,771	$4,883,416	101	$39,068	$3,945,896	348	$8,829,312
Hawaii	Not Analyzed							
Idaho	0	--	--	0	--	--	0	--
Illinois	0	--	--	0	--	--	0	--
Indiana	94	$19,771	$1,858,466	12	$39,068	$468,819	106	$2,327,285
Iowa	0	--	--	0	--	--	0	--
Kansas	0	--	--	0	--	--	0	--
Kentucky	0	--	--	0	--	--	0	--
Louisiana	0	--	--	0	--	--	0	--
Maine	0	--	--	0	--	--	0	--
Maryland	0	--	--	0	--	--	0	--
Massachusetts	0	--	--	0	--	--	0	--
Michigan	0	--	--	0	--	--	0	--
Minnesota	0	--	--	0	--	--	0	--
Mississippi	0	--	--	0	--	--	0	--
Missouri	0	--	--	0	--	--	0	--
Montana	49	$1,626	$79,655	59	$3,212	$189,525	108	$269,179

State	Medium residential			Large residential			TOTALS RESIDENTIAL	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Nebraska	46	$19,771	$909,462	21	$39,068	$820,434	67	$1,729,896
Nevada	0	--	--	0	--	--	0	--
New Hampshire	0	--	--	0	--	--	0	--
New Jersey	32	$19,771	$632,669	21	$39,068	$820,434	53	$1,453,103
New Mexico	0	--	--	0	--	--	0	--
New York	0	--	--	0	--	--	0	--
North Carolina	142	$19,771	$2,807,470	39	$39,068	$1,523,663	181	$4,331,133
North Dakota	0	--	--	0	--	--	0	--
Ohio	132	$19,771	$2,609,761	2	$39,068	$78,137	134	$2,687,897
Oklahoma	0	--	--	0	--	--	0	--
Oregon	0	--	--	0	--	--	0	--
Pennsylvania	0	--	--	0	--	--	0	--
Rhode Island	3	$19,771	$59,313	2	$39,068	$78,137	5	$137,449
South Carolina	0	--	--	0	--	--	0	--
South Dakota	0	--	--	0	--	--	0	--
Tennessee	0	--	--	0	--	--	0	--
Texas	0	--	--	0	--	--	0	--
Utah	0	--	--	0	--	--	0	--
Vermont	4	$19,771	$79,084	0	--	--	4	$79,084
Virginia	0	--	--	0	--	--	0	--
Washington	0	--	--	0	--	--	0	--
West Virginia	0	--	--	0	--	--	0	--
Wisconsin	57	$11,269	$642,357	28	$22,269	$623,530	85	$1,265,887
Wyoming	21	$10,654	$223,741	26	$21,053	$547,390	47	$771,131
District of Columbia	0	--	--	0	--	--	0	--
Total Residential	**1,057**		**$19,332,703**	**467**		**$15,190,613**	**1,524**	**$34,523,317**

Table 9-21c. Option 2 Costs for Projects Installing Larger Sediment Basins ($2008); Nonresidential

State	Medium nonresidential			Large nonresidential			TOTALS NONRESIDENTIAL	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Alaska	Not Analyzed							
Alabama	89	$17,758	$1,580,489	20	$60,378	$1,207,565	109	$2,788,054
Arizona	0	--	--	0	--	--	0	--
Arkansas	0	--	--	0	--	--	0	--
California	0	--	--	0	--	--	0	--
Colorado	97	$17,758	$1,722,556	65	$60,378	$3,924,586	162	$5,647,142
Connecticut	0	--	--	0	--	--	0	--
Delaware	0	--	--	0	--	--	0	--
Florida	0	--	--	0	--	--	0	--
Georgia	200	$17,758	$3,551,661	55	$60,378	$3,320,803	255	$6,872,465
Hawaii	Not Analyzed							
Idaho	0	--	--	0	--	--	0	--
Illinois	0	--	--	0	--	--	0	--
Indiana	76	$17,758	$1,349,631	7	$60,378	$422,648	83	$1,772,279
Iowa	0	--	--	0	--	--	0	--
Kansas	0	--	--	0	--	--	0	--
Kentucky	0	--	--	0	--	--	0	--
Louisiana	0	--	--	0	--	--	0	--
Maine	0	--	--	0	--	--	0	--
Maryland	0	--	--	0	--	--	0	--
Massachusetts	0	--	--	0	--	--	0	--
Michigan	0	--	--	0	--	--	0	--
Minnesota	0	--	--	0	--	--	0	--
Mississippi	0	--	--	0	--	--	0	--
Missouri	0	--	--	0	--	--	0	--
Montana	40	$1,460	$58,405	32	$4,964	$158,862	72	$217,267

State	Medium nonresidential			Large nonresidential			TOTALS NONRESIDENTIAL	
	# Projects	Cost per project ($)	Total cost ($)	# Projects	Cost per project ($)	Total cost ($)	# Projects	Total costs ($)
Nebraska	37	$17,758	$657,057	11	$60,378	$664,161	48	$1,321,218
Nevada	0	--	--	0	--	--	0	--
New Hampshire	0	--	--	0	--	--	0	--
New Jersey	26	$17,758	$461,716	11	$60,378	$664,161	37	$1,125,877
New Mexico	0	--	--	0	--	--	0	--
New York	0	--	--	0	--	--	0	--
North Carolina	115	$17,758	$2,042,205	21	$60,378	$1,267,943	136	$3,310,148
North Dakota	0	--	--	0	--	--	0	--
Ohio	107	$17,758	$1,900,139	1	$60,378	$60,378	108	$1,960,517
Oklahoma	0	--	--	0	--	--	0	--
Oregon	0	--	--	0	--	--	0	--
Pennsylvania	0	--	--	0	--	--	0	--
Rhode Island	2	$17,758	$35,517	1	$60,378	$60,378	3	$95,895
South Carolina	0	--	--	0	--	--	0	--
South Dakota	0	--	--	0	--	--	0	--
Tennessee	0	--	--	0	--	--	0	--
Texas	0	--	--	0	--	--	0	--
Utah	0	--	--	0	--	--	0	--
Vermont	3	$17,758	$53,275	0	--	--	3	$53,275
Virginia	0	--	--	0	--	--	0	--
Washington	0	--	--	0	--	--	0	--
West Virginia	0	--	--	0	--	--	0	--
Wisconsin	46	$10,122	$465,623	15	$34,416	$516,234	61	$981,857
Wyoming	17	$9,570	$162,686	14	$32,537	$455,520	31	$618,206
District of Columbia	0	--	--	0	--	--	0	--
Total Nonresidential	**855**		**$14,040,960**	**253**		**$12,723,239**	**1,108**	**$26,764,199**

Table 9-22. Option 2 Total Costs ($2008)

State	Transportation		Residential		Nonresidential		TOTALS	
	# Projects	Total cost ($)	# Projects	Total cost ($)	# Projects	Total cost ($)	# Projects	Total costs ($)
Alaska	Not Analyzed							
Alabama	25	$11,443,499	244	$48,101,021	162	$39,997,985	431	$99,542,505
Arizona	1	$89,531	14	$524,252	7	$405,104	22	$1,018,887
Arkansas	8	$7,553,461	77	$30,407,705	42	$25,632,942	127	$63,594,107
California	4	$888,705	37	$3,438,242	20	$2,872,241	61	$7,199,188
Colorado	27	$2,103,531	266	$9,798,620	176	$7,925,548	469	$19,827,700
Connecticut	0	--	4	$1,158,526	2	$895,225	6	$2,053,751
Delaware	0	--	2	$585,067	1	$452,097	3	$1,037,164
Florida	0	--	3	$1,536,398	2	$1,582,955	5	$3,119,353
Georgia	55	$20,741,276	547	$88,978,205	363	$74,096,479	965	$183,815,960
Hawaii	Not Analyzed							
Idaho	0	--	0	--	0	--	0	--
Illinois	19	$7,263,130	188	$30,058,340	102	$25,203,656	309	$62,525,126
Indiana	21	$8,264,150	208	$33,354,914	138	$27,628,637	367	$69,247,701
Iowa	10	$5,705,488	93	$22,192,831	50	$18,439,791	153	$46,338,110
Kansas	20	$13,404,452	192	$53,821,677	104	$45,055,267	316	$112,281,395
Kentucky	9	$6,276,480	92	$26,834,802	50	$22,539,112	151	$55,650,394
Louisiana	10	$13,046,203	96	$52,383,233	52	$43,851,115	158	$109,280,551
Maine	3	$1,935,523	29	$7,825,500	16	$6,672,527	48	$16,433,550
Maryland	5	$3,419,608	51	$14,588,593	27	$11,936,121	83	$29,944,322
Massachusetts	0	--	3	$615,530	2	$634,182	5	$1,249,713
Michigan	7	$2,790,135	67	$11,169,632	36	$9,275,190	110	$23,234,957
Minnesota	6	$1,996,017	57	$7,930,944	31	$6,666,040	94	$16,593,001
Mississippi	10	$10,506,327	99	$43,503,385	54	$36,672,275	163	$90,681,988
Missouri	13	$8,879,300	123	$35,138,029	67	$29,580,351	203	$73,597,680
Montana	11	$53,869	108	$269,179	72	$217,267	191	$540,315

State	Transportation		Residential		Nonresidential		TOTALS	
	# Projects	Total cost ($)	# Projects	Total cost ($)	# Projects	Total cost ($)	# Projects	Total costs ($)
Nebraska	10	$2,378,221	102	$9,472,474	67	$7,816,940	179	$19,667,634
Nevada	0	--	0	--	0	--	0	--
New Hampshire	0	--	3	$583,940	2	$601,635	5	$1,185,575
New Jersey	7	$1,962,644	71	$7,923,863	47	$6,681,580	125	$16,568,087
New Mexico	0	--	1	$74,788	1	$115,582	2	$190,370
New York	6	$3,550,834	55	$13,613,779	30	$11,476,078	91	$28,640,690
North Carolina	32	$12,053,851	315	$50,028,436	209	$41,783,929	556	$103,866,215
North Dakota	4	$744,392	41	$3,191,263	22	$2,646,414	67	$6,582,069
Ohio	30	$11,038,187	292	$46,875,264	194	$39,130,788	516	$97,044,238
Oklahoma	15	$5,694,323	145	$23,022,673	79	$19,385,235	239	$48,102,231
Oregon	3	$1,708,267	32	$7,621,165	17	$6,257,150	52	$15,586,582
Pennsylvania	15	$9,365,254	147	$38,386,861	80	$32,285,795	242	$80,037,910
Rhode Island	0	--	6	$471,989	4	$612,911	10	$1,084,900
South Carolina	5	$2,629,051	50	$10,996,029	27	$9,176,686	82	$22,801,766
South Dakota	7	$1,719,346	70	$7,191,179	38	$6,033,119	115	$14,943,644
Tennessee	12	$6,401,013	120	$26,772,296	65	$22,411,657	197	$55,584,966
Texas	51	$19,188,136	496	$78,051,495	269	$65,419,627	816	$162,659,258
Utah	0	--	0	--	0	--	0	--
Vermont	1	$577,339	9	$1,286,447	6	$1,172,830	16	$3,036,615
Virginia	13	$8,457,453	123	$33,468,658	67	$28,175,020	203	$70,101,131
Washington	4	$1,631,698	41	$6,995,208	22	$5,800,904	67	$14,427,810
West Virginia	3	$1,809,877	32	$8,074,483	17	$6,629,334	52	$16,513,694
Wisconsin	13	$2,367,887	127	$10,678,809	84	$8,948,204	224	$21,994,900
Wyoming	5	$171,426	47	$771,131	31	$618,206	83	$1,560,763
District of Columbia	0	--	0	--	0	--	0	--
National Totals	**500**	**219,809,881**	**4,925**	**$909,766,855**	**2,954**	**$761,411,733**	**8,379**	**$1,890,988,470**

Table 9-23. Option 3 Total Costs ($2008)

State	Transportation		Residential		Nonresidential		TOTALS	
	# Projects	Total cost ($)	# Projects	Total cost ($)	# Projects	Total cost ($)	# Projects	Total costs ($)
Alaska	Not Analyzed							
Alabama	25	$17,628,945	244	$86,162,397	162	$69,629,239	431	$173,420,580
Arizona	23	$1,345,467	229	$6,670,144	152	$5,365,074	404	$13,380,685
Arkansas	14	$8,702,276	142	$43,592,754	94	$34,967,066	250	$87,262,096
California	46	$6,677,679	461	$33,291,528	305	$26,770,977	812	$66,740,185
Colorado	27	$4,389,284	266	$21,769,316	176	$17,499,697	469	$43,658,297
Connecticut	2	$832,910	17	$3,779,253	11	$3,027,966	30	$7,640,129
Delaware	2	$841,255	14	$3,228,505	9	$2,473,237	25	$6,542,996
Florida	64	$51,033,234	639	$254,399,523	424	$204,853,025	1127	$510,285,782
Georgia	55	$34,538,351	547	$171,171,039	363	$138,072,854	965	$343,782,244
Hawaii	Not Analyzed							
Idaho	9	$761,981	95	$4,045,231	63	$3,245,690	167	$8,052,902
Illinois	34	$8,425,928	344	$42,759,490	229	$34,607,789	607	$85,793,207
Indiana	21	$10,054,943	208	$49,148,281	138	$39,655,633	367	$98,858,857
Iowa	17	$6,515,393	169	$31,370,785	112	$25,164,891	298	$63,051,069
Kansas	37	$16,249,287	379	$82,564,796	251	$66,538,067	667	$165,352,151
Kentucky	16	$7,266,433	168	$38,053,093	111	$30,626,676	295	$75,946,202
Louisiana	21	$18,036,499	215	$91,172,950	143	$73,564,710	379	$182,774,160
Maine	7	$2,973,199	75	$15,706,604	50	$12,609,113	132	$31,288,916
Maryland	11	$4,796,986	109	$24,256,244	73	$19,789,517	193	$48,842,747
Massachusetts	5	$1,670,636	56	$8,956,273	37	$7,255,794	98	$17,882,702
Michigan	37	$9,663,677	377	$48,851,355	250	$39,313,469	664	$97,828,501
Minnesota	16	$3,466,257	157	$16,965,305	104	$13,711,552	277	$34,143,113
Mississippi	20	$13,474,464	199	$67,911,621	132	$54,648,881	351	$136,034,966
Missouri	23	$10,264,391	228	$50,599,974	151	$40,799,589	402	$101,663,954
Montana	11	$1,009,661	108	$5,045,205	72	$4,072,216	191	$10,127,083

State	Transportation		Residential		Nonresidential		TOTALS	
	# Projects	Total cost ($)	# Projects	Total cost ($)	# Projects	Total cost ($)	# Projects	Total costs ($)
Nebraska	10	$3,602,478	102	$17,537,778	67	$13,976,862	179	$35,117,118
Nevada	14	$407,172	137	$1,965,536	91	$1,590,727	242	$3,963,436
New Hampshire	3	$1,025,139	30	$4,493,388	20	$3,680,590	53	$9,199,117
New Jersey	7	$3,960,890	71	$19,841,487	47	$15,915,456	125	$39,717,833
New Mexico	7	$824,031	78	$4,540,554	52	$3,644,228	137	$9,008,812
New York	13	$4,862,707	129	$24,839,333	86	$20,206,898	228	$49,908,938
North Carolina	32	$16,991,295	315	$83,503,502	209	$67,367,869	556	$167,862,666
North Dakota	11	$1,305,281	109	$6,600,231	73	$5,384,815	193	$13,290,327
Ohio	30	$13,129,936	292	$63,428,448	194	$51,204,463	516	$127,762,847
Oklahoma	28	$6,997,738	281	$34,656,220	187	$28,045,802	496	$69,699,760
Oregon	12	$4,563,317	122	$22,585,641	81	$18,121,919	215	$45,270,877
Pennsylvania	27	$10,884,586	268	$54,377,034	178	$43,918,177	473	$109,179,796
Rhode Island	0	--	6	$1,511,512	4	$1,338,160	10	$2,849,672
South Carolina	27	$9,166,690	271	$46,345,930	180	$37,426,485	478	$92,939,104
South Dakota	14	$2,263,821	140	$11,185,553	93	$9,049,679	247	$22,499,052
Tennessee	22	$7,482,722	220	$38,172,832	145	$30,524,474	387	$76,180,028
Texas	103	$25,255,152	1029	$125,859,943	684	$101,627,167	1816	$252,742,262
Utah	14	$1,552,194	140	$7,669,400	94	$6,236,950	248	$15,458,544
Vermont	1	$577,339	9	$1,696,162	6	$1,448,836	16	$3,722,337
Virginia	25	$10,559,242	255	$53,929,973	169	$43,462,256	449	$107,951,471
Washington	21	$5,639,595	215	$28,507,669	143	$23,001,980	379	$57,149,245
West Virginia	6	$2,176,899	59	$11,522,196	40	$9,542,571	105	$23,241,666
Wisconsin	13	$4,402,884	127	$22,152,966	84	$17,847,878	224	$44,403,728
Wyoming	5	$751,962	47	$3,382,569	31	$2,711,764	83	$6,846,295
District of Columbia	0	--	2	$201,966	0	--	2	$201,966
National Totals	**988**	**$379,002,205**	**9,899**	**$1,891,979,488**	**6,570**	**$1,525,538,727**	**17,457**	**$3,796,520,420**

9.5. REFERENCES

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10. ESTIMATING POLLUTANT LOAD REDUCTIONS

10.1. OVERVIEW OF APPROACH

The U.S. Environmental Protection Agency (EPA) based its analysis of construction and development (C&D) site pollutant loads on 1 year's worth of construction acreage and assumes the average construction duration as either 9 months or 12 months, depending on the model project.[5] Any controls/technologies evaluated by EPA are assumed to be employed for the entire construction period for purposes of estimating load reductions.

In general, reductions in pollutant loads are derived on the basis of a critical size particle, or the smallest particle that reasonably is expected to be captured by a control/technology at a site. The percentage of eroded material captured is determined on the basis of the fraction of eroded soil larger than the critical particle. Any C&D site soils eroded that are smaller than the critical particle size are discharged from the site.

EPA used regional estimates of per-acre eroded soil (based on 11 indicator cities) with state-specific levels of controls to estimate per-state pollutant discharges. The sum of individual state discharges provides the national total estimate of pollutant discharges under current (baseline) conditions and under the options considered. The load allocation spreadsheet is DCN 43091 and the spreadsheet estimating construction site loads is DCN 43092 in the Administrative Record.

10.2. ANALYSIS OF SOIL CHARACTERISTICS BY REGION

EPA used estimates of soil characteristics for a number of indicator cities to characterize broader soil types across the nation. This case-study approach, while limited in its coverage, does provide sufficient information for EPA to generally estimate pollutant generation and load reductions nationwide. EPA expects to collect additional data to better characterize soil characteristics across the United States to update the model to operate at a Reach File Version 1.0 (RF1)-level scale. However, this analysis was not complete at the time of proposal.

As discussed in Section 3.5.4, EPA used U.S. Department of Agriculture's (USDA's) STATSGO soil database to help evaluate the question of *how much and what size* soil is originating from C&D sites. As shown in Table 10-1, EPA used STATSGO to inventory soils present on between 0.5 million and 5 million acres in the area surrounding each indicator city. The intent was to identify soil types and soil characteristics in each city's developing fringe. Nationally, 2,175 STATSGO statistical units were individually evaluated, in combination providing soil data for 20 million acres. The soils at each indicator city were represented by between 74 and 501 STASTSGO statistical units. The STATSGO soil data evaluation is DCN 43096 in the Administrative Record.

[5] Note that EPA's cost analysis assumed a 9-month project duration. Because of an oversight, the load analysis assumed a 9-month duration for some projects and a 12-month duration for other projects.

Table 10-1. Summary of STATSGO Evaluation of Indicator City Locations

Indicator city	Total acreage extracted from STATSGO representing the indicator city	Number of STATSGO statistical units evaluated
Albany, NY	720,741	239
Atlanta, GA	5,311,422	130
Boise, ID	465,617	93
Chicago, IL	2,676,561	501
Dallas, TX	3,054,633	161
Denver, CO	1,344,782	151
Kansas City, KS	1,924,721	268
Las Vegas, NV	858,166	100
Manchester, NH	484,354	101
Seattle, WA	814,413	74
Washington, DC	2,580,084	357
Grand Total	20,235,494	2,175

Table 10-2 indicates the dominant or common soil texture classes/surface covers reported by STATSGO for the area evaluated surrounding each indicator city. As expected, the dominant soil classes vary among the cities.

Table 10-2. Indicator City Surface Soil Characterization

Indicator city	Percent of land area for the common soil texture classes [1,2]										
	C	CL	L	LS	RO	S	SCL	SIC	SICL	SIL	SL
Albany, NY	0.0%	0.0%	3.4%	9.2%	0.7%	0.0%	0.0%	0.0%	6.7%	74.4%	5.6%
Atlanta, GA	0.0%	8.6%	6.1%	0.0%	0.0%	0.0%	27.4%	0.0%	0.0%	0.4%	57.5%
Boise, ID	0.0%	0.0%	40.2%	5.1%	1.2%	0.0%	0.0%	0.0%	0.9%	24.7%	27.9%
Chicago, IL	0.0%	1.1%	8.7%	4.5%	0.0%	1.1%	0.0%	1.0%	21.1%	60.2%	2.3%
Dallas, TX	44.6%	15.3%	3.2%	3.3%	0.0%	0.0%	0.0%	11.4%	2.2%	0.2%	19.9%
Denver, CO	1.7%	22.7%	19.8%	6.2%	2.1%	0.0%	0.0%	0.0%	0.1%	0.2%	47.2%
Kansas City, KS	0.0%	3.0%	0.6%	0.4%	1.5%	0.0%	0.0%	3.3%	33.8%	52.4%	5.1%
Las Vegas, NV	0.0%	2.5%	2.5%	3.7%	0.5%	0.0%	0.3%	0.0%	0.5%	1.9%	88.1%
Manchester, NH	0.0%	0.0%	0.0%	17.7%	2.7%	0.1%	0.0%	0.0%	0.0%	0.2%	79.3%
Seattle, WA	0.0%	0.0%	22.0%	2.2%	0.6%	0.4%	0.0%	0.0%	1.3%	20.7%	52.8%
Washington, DC	0.0%	0.5%	14.7%	3.1%	0.8%	0.0%	0.0%	2.4%	11.0%	47.0%	20.3%

[1] USDA STATSGO Definitions: C = Clay, CL = Clay loam, L = Loam, LS = Loamy Sand, RO Rock Outcrop, S = Sand, SCL = Sandy Clay Loam, SIC = Silty Clay, SICL = Silty Clay Loam, SIL = Silt Loam, SL = Sandy Loam.
[2] Infrequent/less common soil classes are included in computed percentages.

Table 10-3 presents a summary of key STATSGO soil data for each indicator city. The data shown are spatially averaged, such that soil parameter values representing larger areas have a greater influence than values representing smaller areas. Some of the Table 10-3 data serve as a basis for developing hybrid soil particle size distributions for each indicator city (for more detailed information, see Appendix F – Evaluating Soil Nature and Soil Erosion Representative of Major U.S. Metropolitan Areas). The indicator city-specific hybrid soil particle size distribution is the distribution obtained if all soil texture classes surrounding each indicator city (as shown in Table 10-2) are homogenized into a single composite soil. As a result, it represents the collective array of particle sizes, proportional to their presence at each indicator city.

Table 10-3. Summary of STATSGO Soil Data Extraction for Indicator Cities

Indicator city	Average clay percentage	Average silt percentage	Average sand percentage	Average RUSLE K[1]	Average percent passing #200 sieve (sub-75 microns)[2]	Average percent passing #40 sieve (sub-300 microns)[2]
Albany, NY	17%	43%	40%	0.37	60%	75%
Atlanta, GA	19%	26%	55%	0.26	45%	77%
Boise, ID	17%	41%	43%	0.34	57%	76%
Chicago, IL	24%	57%	20%	0.31	80%	92%
Dallas, TX	38%	35%	27%	0.33	73%	89%
Denver, CO	19%	25%	56%	0.27	44%	63%
Kansas City, KS	27%	66%	7%	0.33	93%	96%
Las Vegas, NV	12%	16%	72%	0.31	28%	47%
Manchester, NH	6%	33%	61%	0.23	39%	62%
Seattle, WA	10%	31%	59%	0.29	41%	58%
Washington, DC	16%	39%	45%	0.33	55%	74%

[1] The Revised Universal Soil Loss Equation (RUSLE) K is a soil erodibility factor that represents both susceptibility of soil to erosion and the rate of runoff. Generally, soils high in clay and coarse textured tend to have low K values. Soils having a high silt content are the most erodible of all soils and tend to have higher K values

[2] *Percent Passing* values are equal to the percent of the total soil sample (by weight) that is smaller than the opening of the sieve. As a result it is possible to estimate the fraction of a soil sample that is larger or smaller based on the sieve used by the soil laboratory to process the soil sample.

STATSGO reports some soil parameters only in terms of a low and a high value, or the range observed when more detailed data sources were compiled. For example, for each of the 239 statistical units for Albany, STATSGO provides the lowest-reported and highest-reported values for some soils parameters. Where STATSGO provides a range of values, EPA generally used the average of the high and low values in subsequent computations (e.g., the average values provided in Table 10-3).

As discussed in Section 10.3, EPA used the Revised Universal Soil Loss Equation (RUSLE) to estimate annual soil yield from construction sites. The *K* factor (soil erosivity) is an important parameter in RUSLE, and STATSGO provides location-specific values in its dataset. Table 10-3 indicates the spatially averaged K computed for each of the indicator cities.

Table 10-4 indicates spatially averaged lowest-reported and highest-reported slope data, and presents slope values EPA computed from the STATSGO data. The lowest-reported and highest-reported slopes indicate the extremes, but not the more common conditions likely to occur in a given area. Therefore, EPA computed three slopes values from the STATSGO data—values that reflect regional slope tendencies but offer a more central estimate of the slopes expected to occur at construction sites.

Table 10-4. Slope Ranges from STATSGO and Computed Regional Slope Ranges for Estimating Soil Erosion Yield

	STATSGO reported (percent)		Computed slopes (percent)		
Indicator city	**Average of lowest reported slopes**	**Average of highest reported slopes**	**Low end**	**Average**	**High end**
Albany, NY	4.72%	12.06%	6.55%	8.39%	10.22%
Atlanta, GA	7.55%	15.18%	9.46%	11.37%	13.28%
Boise, ID	7.71%	18.71%	10.46%	13.21%	15.96%
Chicago, IL	2.39%	6.25%	3.35%	4.32%	5.28%
Dallas, TX	1.17%	5.62%	2.28%	3.40%	4.51%
Denver, CO	3.38%	17.83%	6.99%	10.61%	14.22%
Kansas City, KS	4.26%	8.87%	5.41%	6.57%	7.72%
Las Vegas, NV	5.60%	16.98%	8.45%	11.29%	14.14%
Manchester, NH	3.24%	9.59%	4.83%	6.42%	8.00%
Seattle, WA	10.89%	25.76%	14.60%	18.32%	22.04%
Washington, DC	6.59%	14.74%	8.63%	10.67%	12.71%

For its analysis, EPA used the average of the lowest-reported and highest-reported slope values for each indicator city to produce an *average* estimate of soil slope/erosion. A low-end estimate of soil erosion was computed on the basis of the value halfway between the lowest-reported slope value and the computed average slope value. A high-end estimate of soil erosion was computed on the basis of the value halfway between the highest-reported slope value and the computed average slope value.

For most of its analysis of the C&D industry, EPA used the computed average slope value for each region to obtain a central estimate. The computed low-end and high-end slope values provide an indication of how natural and geographic variation may affect any results.

10.3. ESTIMATION OF SOIL EROSION RATES

Table 10-5 summarizes the data sources EPA used to obtain indicator city-specific RUSLE factors customized to the nine construction model projects described in Section 9.3.1. Further details of EPA's RUSLE application are provided in Appendix F – Evaluating Soil Nature and Soil Erosion Representative of Major U.S. Metropolitan Areas.

Table 10-5. Data Sources and Data Processing to Obtain RUSLE Factors

RUSLE term	Definition	Source of information	Processing for model project erosion estimation
C	Cover-management Factor	SEDCAD 4 Documentation[1]	Globally set to a value of 1.0 across all indicator cities and model projects. This value is for a denuded soil surface.
P	Support Practice Factor	SEDCAD 4 Documentation[1]	Globally set to a value of 0.9 across all indicator cities and model projects. This value represents a *Roughed and Irregularly Tracked* soil surface.
K	Soil Erodibility Factor	STATSGO[2]	Spatially averaged value determined from soils data for each indicator city.
R	Rainfall-Runoff Erosivity Factor	RUSLE2 Database[3]	Value provided for indicator city used the R reported for the specific city. If not available, then the R reported for an adjacent county was used.
LS	Slope Length Factor	Length factor obtained through assessment of model project geometry; regional slope ranges obtained from STATSGO[2]	Length and regional slope values were combined to determine LS value, on the basis of the assumption of a high ratio of rill-to-interrill erosion.

[1] SEDCAD 4 Documentation (Warner et al. 1999)
[2] STATSGO Soil Data Coverage
[3] RUSLE 2 ARS Version Jan 19 2005, Program Database

Tables 10-6a through 10-6d provide EPA's estimates of erosion rates (low-end, average, and high-end) for the 11 indicator cities. Note that the per acre erosion rates are the same for large transportation, medium transportation and small transportation model projects. This occurs because the overland flow length selected for modeling are the same across these models (200 feet). Matching overland flow length is the reason why the per acre yield estimates match for small residential and small nonresidential model projects. Each of the model projects predict a different amount of eroded soil discharge at their outlet points, even if they have the same yield per acre rate. This occurs because the median site size differs between the nine model construction projects.

Table 10-6a. Estimated Soil Eroded from Large Transportation, Medium Transportation and Small Transportation Model Construction Projects (Tons Per Acre)

Indicator city	Low-end estimate	Average estimate	High-end estimate
Albany, NY	47.05	62.03	82.98
Atlanta, GA	159.12	211.69	265.75
Boise, ID	5.09	7.20	9.38
Chicago, IL	28.80	37.97	47.46
Dallas, TX	34.77	53.15	72.45
Denver, CO	10.70	18.59	29.58
Kansas City, KS	73.38	90.99	109.07
Las Vegas, NV	6.32	9.78	13.55
Manchester, NH	21.18	29.04	37.19
Seattle, WA	82.42	112.12	142.41
Washington, DC	96.50	133.58	173.39

Table 10-6b. Estimated Soil Eroded from Large and Medium Residential Model Construction Projects (Tons Per Acre)

Indicator city	Low-end estimate	Average estimate	High-end estimate
Albany, NY	65.72	89.58	120.62
Atlanta, GA	229.69	310.64	395.42
Boise, ID	7.41	10.71	14.19
Chicago, IL	37.88	51.10	65.03
Dallas, TX	44.19	70.00	97.97
Denver, CO	15.04	27.11	42.79
Kansas City, KS	100.76	127.13	154.60
Las Vegas, NV	9.04	14.34	20.28
Manchester, NH	28.79	40.48	52.88
Seattle, WA	123.69	171.70	221.73
Washington, DC	138.15	194.91	256.99

Table 10-6c. Estimated Soil Eroded from Large and Medium Nonresidential Model Construction Projects (Tons Per Acre)

Indicator city	Low-end estimate	Average estimate	High-end estimate
Albany, NY	73.79	100.24	137.33
Atlanta, GA	260.88	354.85	453.87
Boise, ID	8.45	12.30	16.39
Chicago, IL	41.66	56.64	72.54
Dallas, TX	48.03	77.02	108.64
Denver, CO	16.92	30.90	49.21
Kansas City, KS	112.47	142.76	174.49
Las Vegas, NV	10.23	16.37	23.32
Manchester, NH	32.02	45.43	59.75
Seattle, WA	142.39	199.06	258.54
Washington, DC	156.46	222.21	294.57

Table 10-6d. Estimated Soil Eroded from Small Nonresidential and Small Residential Model Construction Projects (Tons Per Acre)

Indicator city	Low-end estimate	Average estimate	High-end estimate
Albany, NY	53.75	71.50	96.33
Atlanta, GA	184.20	246.67	311.38
Boise, ID	5.91	8.44	11.07
Chicago, IL	32.12	42.75	53.81
Dallas, TX	38.26	59.32	81.68
Denver, CO	12.26	21.60	33.57
Kansas City, KS	83.27	103.97	125.57
Las Vegas, NV	7.29	11.39	15.92
Manchester, NH	23.94	33.15	42.79
Seattle, WA	96.90	132.89	169.91
Washington, DC	111.34	155.30	202.85

When RUSLE is applied to an agricultural situation, and/or where the slope length is long, it is expected that some eroded soil particles will deposit as they move along the flow path. Such is the case where water flow moves eroded particles along a crop row cut into a farm field's topographic contour. The rough bottom and flat slope at the base of the row provides opportunity for the recapture of eroded soil particles. The ratio of soil discharged to eroded (moved) soil is referred to as the delivery ratio.

For C&D sites, EPA elected to assume a delivery ratio of 1 (i.e., 100 percent of the eroded soil particles would be transported to sediment controls). For construction sites this is justified in part by the tendency to install efficient flow systems (e.g., drainage channels and conduits) that are

designed to convey flow efficiently to sediment controls and off of the site. This convention helps ensure the construction site work schedule is affected as little as possible by precipitation.

EPA acknowledges that many types of construction site controls, (e.g., silt fences and check dams) do capture some sand and silt-sized and larger soil particles when they are properly placed and maintained within the flow path. Therefore, a delivery ratio of 1 would tend to overestimate the quantity of these larger particles reaching sediment basins. However, because EPA's model estimates removals on the basis of a specific particle size, removal of these larger particles are accounted for in EPA's baseline analysis of existing industry practices. However, fine silt and clay-sized particles are less likely to be removed by conventional erosion and sediment controls. Therefore, EPA is assuming a delivery ratio of 1 is appropriate.

Table 10-7 shows the range of average yield per acre in terms of clay, silt, and sand fractions across all model construction projects; values that are based on the average slope for each indicator city. In general, the larger the particle size, the easier it is to remove with controls that employ settling (e.g., sediment basins). Where clays and silts dominate, technologies that either provide extended duration settling or provide assisted settling or filtration (i.e., active treatment systems) are likely required to obtain high percentages of removal.

Table 10-7. Estimated Range of Average Annual Construction Site Yield for Model Construction Projects

Indicator city	Tons of clay per acre per year	Tons of silt per acre per year	Tons of sand per acre per year	Tons of all soil particles per acre per year
Albany, NY	13–23	32–59	30–55	74–137
Atlanta, GA	50–86	68–118	143–250	261–454
Boise, ID	1–3	3–7	4–7	8–16
Chicago, IL	10–17	24–41	8–15	42–73
Dallas, TX	18–41	17–38	13–29	48–109
Denver, CO	3–9	4–12	9–28	17–49
Kansas City, KS	30–47	74–115	8–12	112–174
Las Vegas, NV	1–3	2–4	7–17	10–23
Manchester, NH	2–4	11–20	20–36	32–60
Seattle, WA	14–26	44–80	84–153	142–259
Washington, DC	25–47	61–115	70–133	156–295

Table 10-7 also shows the influence of climate on construction site soil yield. In general, the dryer the climate, the lower the soil yields. Climates like Denver, Colorado, and Las Vegas, Nevada, are expected to produce order-of-magnitude lower levels of estimated construction site yield than wetter climates like Atlanta, Georgia.

EPA used the estimates of construction site soil erosion for the 11 indicator cities as point estimates for surrounding states. Table 10-8 lists the states/commonwealths represented by each

of the indicator cities. This analysis does not include consideration of construction activities in Hawaii and Alaska and does not evaluate any of the U.S. territories.

Table 10-8. Allocation of States/Commonwealths/Territories to Representative Indicator City

State	Indicator city	State	Indicator city
Alabama	Atlanta, GA	New Jersey	Albany, NY
Arizona	Las Vegas, NV	New Mexico	Dallas, TX
Arkansas	Dallas, TX	New York	Albany, NY
California	Las Vegas, NV	North Carolina	Atlanta, GA
Colorado	Denver, CO	North Dakota	Denver, CO
Connecticut	Manchester, NH	Ohio	Chicago, IL
Delaware	Washington, DC	Oklahoma	Dallas, TX
Florida	Atlanta, GA	Oregon	Seattle, WA
Georgia	Atlanta, GA	Pennsylvania	Washington, DC
Idaho	Boise, Id	Rhode Island	Manchester, NH
Illinois	Chicago, IL	South Carolina	Atlanta, GA
Indiana	Chicago, IL	South Dakota	Denver, CO
Iowa	Kansas City, KS	Tennessee	Atlanta, GA
Kansas	Kansas City, KS	Texas	Dallas, TX
Kentucky	Atlanta, GA	Utah	Denver, CO
Louisiana	Dallas, TX	Vermont	Manchester, NH
Maine	Manchester, NH	Virginia	Washington, DC
Maryland	Washington, DC	Washington	Seattle, WA
Massachusetts	Manchester, NH	West Virginia	Washington, DC
Michigan	Chicago, IL	Wisconsin	Chicago, IL
Minnesota	Chicago, IL	Wyoming	Denver, CO
Mississippi	Atlanta, GA	Alaska	Not analyzed
Missouri	Kansas City, KS	Hawaii	Not analyzed
Montana	Denver, CO	Puerto Rico	Not analyzed
Nebraska	Kansas City, KS	Virgin Islands	Not analyzed
Nevada	Las Vegas, NV	Pacific Islands	Not analyzed
New Hampshire	Manchester, NH	District of Columbia	Washington, DC

Table 10-9 indicates EPA's range of state-specific erosion estimates. The values shown are for the amount of sediment/soil eroded over the course of construction, before any controls are implemented. For each state, EPA assumed commercial sites were under construction for 9 months, and transportation and residential model projects were under construction for 12 months. EPA notes that these values are not consistent with the cost analysis. EPA intends to address this discrepancy in the analysis in support of the final rule. Table 10-9 values are based on land development rates for each state (see Section 4.2.2). The per-state values provided are based on combining the estimated erosion for the nine representative model construction projects in proportion to their representation of the total constructed acreage (see Section 4.2.2.2).

Table 10-9. Estimated Annual Construction Site Soil Erosion by State without Any Controls (Tons of Sediment)

State	Low-end estimate	Average estimate	High-end estimate
Alabama	2,677,452	3,619,612	4,605,936
Arizona	99,137	157,191	222,253
Arkansas	303,376	479,765	670,144
California	199,374	316,126	446,975
Colorado	191,931	345,612	545,180
Connecticut	23,745	33,360	43,542
Delaware	91,860	129,560	170,785
Florida	7,035,985	9,511,807	12,103,674
Georgia	6,022,396	8,141,561	10,360,053
Hawaii	--	--	--
Idaho	33,728	48,724	64,535
Illinois	627,225	845,292	1,075,040
Indiana	378,926	510,661	649,450
Iowa	819,781	1,033,744	1,256,578
Kansas	1,829,978	2,307,564	2,804,944
Kentucky	1,847,692	2,497,868	3,178,521
Louisiana	459,149	726,111	1,014,247
Maine	104,136	146,325	191,011
Maryland	727,199	1,025,409	1,351,442
Massachusetts	76,955	108,130	141,149
Michigan	687,714	926,819	1,178,733
Minnesota	284,889	383,947	488,313
Mississippi	2,190,787	2,961,684	3,768,715
Missouri	1,101,274	1,388,667	1,687,968
Montana	77,954	140,382	221,455
Nebraska	493,180	621,909	755,976
Nevada	59,257	93,957	132,846
New Hampshire	41,888	58,853	76,822
New Jersey	227,188	306,017	416,467
New Mexico	167,391	264,698	369,718
New York	408,187	549,837	748,307
North Carolina	3,465,838	4,685,375	5,962,067
North Dakota	79,201	142,609	224,947
Ohio	532,390	717,501	912,531
Oklahoma	597,718	945,275	1,320,405
Oregon	725,168	1,006,263	1,299,055
Pennsylvania	1,779,085	2,508,754	3,306,533
Rhode Island	9,039	12,702	16,582
South Carolina	2,988,373	4,039,899	5,140,703
South Dakota	100,709	181,338	286,039
Tennessee	2,415,493	3,265,502	4,155,365

State	Low-end estimate	Average estimate	High-end estimate
Texas	2,190,671	3,464,421	4,839,209
Utah	101,623	182,987	288,642
Vermont	13,563	19,049	24,858
Virginia	1,686,403	2,378,049	3,134,251
Washington	1,273,027	1,766,496	2,280,503
West Virginia	392,908	554,024	730,170
Wisconsin	231,875	312,486	397,414
Wyoming	34,525	62,167	98,060
District of Columbia	2,881	4,071	5,374
National Total	47,910,224	65,930,155	85,163,488

10.4. ESTIMATION OF SEDIMENT REMOVAL EFFICIENCIES

When estimating sediment removal efficiencies, EPA considered several factors:

- The limits of the technology/controls
- Minimum design sizing requirements that affect the volume of construction site runoff treated, and the degree of treatment provided
- The percentage of total construction acreage managed with a technology/control

EPA considered all these factors to estimate state-specific removal efficiencies for current or baseline controls, and for the regulatory options considered. EPA's proposed option is specifically designed to remove fine silts and clay-sized particles that, once mobilized, typically cannot be effectively managed using conventional BMPs that rely on settling. On the basis of soil characteristics at 11 indicator cities, clays and silts combine to make up between 28 and 93 percent of eroded soil from construction sites.

Estimating the performance of the variety of erosion and sediment controls likely to be employed at construction sites, given the array of site conditions, site geometries, soil types and rainfall conditions nationally is an extremely complicated undertaking. Models do exist (such as SEDCAD and SEDIMOT III) that can be used to estimate, for a given set of site conditions and for a given storm event, the sediment generation, sediment transport and sediment removals through BMPs. However, a significant amount of data regarding site conditions, watershed parameters and design features of various control structures is needed. Given the range of possible conditions nationally, EPA determined that basing a national loading reductions estimate on an input parameter-intensive model such as SEDCAD was not feasible for this analysis. Therefore, EPA developed a relatively straightforward approach to estimate loading reductions estimates for the regulatory options considered. In summary, EPA's technology analysis makes the following assumptions to obtain per-state and national reductions:

- Pollutant removals are estimated for TSS only, although reductions in other construction site pollutants associated with sediment, such as nutrients and metals, will likely occur through the application of control technologies.

- Construction denudes 90 percent of the total site acreage; the remaining portion of the site is undisturbed.
- The entire disturbed area remains disturbed for the duration of the project. (Note that this likely results in an overestimation of both costs and loads, since projects are expected to stabilize portions of the site once construction activities have temporarily or permanently ceased.)
- 100 percent of construction site runoff is discharged at a single point for sites larger than 5 acres and 100 percent of eroded material will be transported to sediment basins for sites larger than 5 acres.
- All construction site runoff is processed through sediment basins (i.e., no bypass) unless specifically noted in the technology application description.
- Any proposed technology or design minimums are uniformly applied to residential, nonresidential, and transportation construction projects unless the technology would not be required because of site size, R-factor, or soil clay content applicability provisions.
- No adjustments are made to account for poor installation and/or poor maintenance of controls.
- The duration of construction site activities is assumed to be 1 year for residential and transportation projects and 9 months for commercial projects.[6]
- Technologies/controls are assumed to operate for the entire duration of construction.

The following summarizes EPA's approach to estimating the removal efficiency of individual sediment basin designs:

- Removal of sediment is based on a critical particle size (i.e., the particle that will settle in a sediment basin for a given storm size)
- 100 percent of the soil particles larger than the critical particle would be captured, and 100 percent of soil particles smaller than the critical particle are released
- The average storm intensity for the 10-year, 6-hour storm event (one selected for each state) is the basis for estimating the critical particle size for each sediment basin design
- The average annual removal efficiency for all events is equal to the removal efficiency computed given the average intensity for the 10-year, 6-hour event

[6] EPA's costing analysis assumed a 9-month duration for small transportation projects. Because of an oversight, the loadings methodology did not incorporate these assumptions. As a result, the loading estimates for the small transportation model projects are overestimates, because they are based on a 12-month duration. However, because these projects comprise only a small amount of national developed acres, the error in the national loadings estimates are small (less than 1 percent). EPA intends to correct this oversight for the analysis in support of the final rule.

EPA determined the critical particle size for one indicator city in each state using Stokes' Law and the approach contained in the January 2003 California Stormwater Quality Association's (CSQA's) *California Stormwater Best Management Practices Handbook - Construction* (http://www.cabmphandbooks.com/Construction.asp) for designing sediment basins. The CSQA handbook provides a process for relating a design flow rate, a critical particle size, and the sediment basin volume.

The CSQA standard is based on the settling velocity of particles as determined by Stokes' Law, which states that the settling velocity (V_c) is a function of the density of the particle (ρ_s) and the fluid (ρ_f), the acceleration due to gravity (g), the diameter of the particle (d) and the dynamic viscosity of the fluid (μ).

$$V_c = \frac{g(\rho_s - \rho_f)d^2}{18\mu}$$

Stokes' Law is generally valid for Reynolds numbers less than 1 (quiescent conditions) and for spherical particles.

After the settling velocity of the design particle size is determined (called the terminal settling velocity), sediment basins can be sized so that all particles with a settling velocity equal to or greater than the terminal velocity can be removed. This is accomplished by calculating the surface area (A) of the basin for a specified flow rate (Q) using the following equation:

$$A = \frac{Q}{V_c}$$

The calculation is based on the terminal settling velocity for a design particle size, and the design flowrate is based on the 10-year, 6-hour rainfall event. The option described in the CSQA manual is illustrated in Figure 10-1.

Using this methodology, EPA calculated the critical particle size that would be removed in one indicator city in each state on the basis of the rainfall intensity for the 10-year, 6-hour storm event. Basin volumes were based on the current requirements for sediment basin sizing contained in each state's general permit. EPA used a particle density of 2,650 kg/m^3, a fluid density of 1,000 kg/m^3, a dynamic viscosity of 0.001 kg/m·s, and a sediment basin depth of 6 feet for all calculations. The runoff coefficient used in each state was the runoff coefficient calculated for the 10-year, 6-hour storm event (see Table 9-4). Table 10-10 summarizes the critical particle size removed in each state for the 10-year, 6-hour storm event under current state baseline conditions. Table 10-11 summarizes the critical particle size removed in each state for the 10-year, 6-hour event given the sediment basin sizing criteria contained in Option 1 (smaller than the 2-year, 24-hour storm runoff or 3,600 cubic feet per acre [cf/acre]). As mentioned above, EPA assumed that the critical particle size removed for all storm events under baseline conditions and under Option 1 is equal to the critical particle size removed for the 10-year, 6-hour storm event—any particles smaller than the critical particle size would pass through the sediment basin and be discharged.

Sediment basin(s) shall be designed using the standard equation:

$A_s = 1.2\ Q / V_s$

where:

A_s = Minimum surface area for trapping soil particles of a certain size
V_s = Settling velocity of the design particle size chosen
$Q = C\ I\ A$

where

Q = Discharge rate measured in cubic feet per second
C = Runoff coefficient
I = Precipitation intensity for the 10-year, 6-hour rain event in inches per hour
A = Area draining into the sediment basin in acres

Figure 10-1. CSQA Settling Velocity Criteria for Sizing Sediment Basins

Table 10-10. Critical Particle Sizes Removed Under Baseline Conditions.

State	Indicator city	Baseline sediment basin volume (cf/acre)	10-year, 6-hour storm depth (inches)	10-year, 6-hour storm intensity (in/hr)	Critical particle size removed (microns)
Alabama	Montgomery	1,800	4.60	0.77	27.5
Arizona	Phoenix	3,600	1.57	0.26	9.2
Arkansas	Little Rock	3,600	4.35	0.73	19.4
California	Sacramento	3,660	1.70	0.28	9.5
Colorado	Denver	1,800	2.30	0.38	16.9
Connecticut	Hartford	3,600	3.25	0.54	15.3
Delaware	Dover	3,600	3.44	0.57	15.9
Florida	Tallahassee	3,600	5.25	0.88	21.7
Georgia	Atlanta	1,800	4.20	0.70	25.8
Hawaii	Honolulu	12,868	4.80	0.80	10.7
Idaho	Boise	3,600	1.20	0.20	7.0
Illinois	Chicago	6,494	3.30	0.55	11.7
Indiana	Indianapolis	1,800	3.12	0.52	21.7
Iowa	Des Moines	3,600	3.54	0.59	16.3
Kansas	Kansas City	3,600	3.90	0.65	17.4
Kentucky	Frankfort	3,600	3.09	0.52	15.1
Louisiana	Baton Rouge	3,600	5.75	0.96	23.3
Maine	Augusta	3,600	2.90	0.48	14.8
Maryland	Baltimore	3,600	3.32	0.55	15.7
Massachusetts	Boston	7,307	3.30	0.55	11.1
Michigan	Lansing	3,600	2.70	0.45	13.0
Minnesota	St. Paul	6,172	3.10	0.52	11.5
Mississippi	Jackson	3,600	4.70	0.78	20.1

State	Indicator city	Baseline sediment basin volume (cf/acre)	10-year, 6-hour storm depth (inches)	10-year, 6-hour storm intensity (in/hr)	Critical particle size removed (microns)
Missouri	Kansas City	3,600	3.85	0.64	17.6
Montana	Helena	1,800	1.10	0.18	9.5
Nebraska	Lincoln	1,800	3.52	0.59	21.3
Nevada	Las Vegas	3,600	1.29	0.22	8.1
New Hampshire	Manchester	6,333	3.20	0.53	11.7
New Jersey	Hightstown	1,800	3.55	0.59	23.3
New Mexico	Santa Fe	3,600	1.77	0.30	10.0
New York	Albany	3,600	3.10	0.52	15.2
North Carolina	Charlotte	1,800	3.54	0.59	23.1
North Dakota	Bismarck	3,600	2.50	0.42	12.7
Ohio	Columbus	1,800	2.80	0.47	20.7
Oklahoma	Oklahoma City	9,296	4.25	0.71	11.6
Oregon	Salem	3,600	2.90	0.48	14.5
Pennsylvania	Philadelphia	5,000	3.38	0.56	13.6
Rhode Island	Providence	1,800	3.40	0.57	22.2
South Carolina	Columbia	13,168	3.85	0.64	9.1
South Dakota	Pierre	3,600	2.75	0.46	14.1
Tennessee	Nashville	8,196	3.31	0.55	10.5
Texas	Fort Worth	9,969	4.55	0.76	11.7
Utah	Salt Lake City	3,600	1.27	0.21	7.8
Vermont	Montpelier	1,800	2.70	0.45	19.8
Virginia	Arlington	3,600	3.29	0.55	15.5
Washington	Seattle	3,600	1.40	0.23	7.8
West Virginia	Charleston	3,600	2.56	0.43	13.3
Wisconsin	Madison	2,770	3.15	0.53	17.5
Wyoming	Cheyenne	1,800	1.90	0.32	15.1
Puerto Rico	San Juan	1,800	4.42	0.74	27.0
District of Columbia	District of Columbia	7,503	3.32	0.55	11.0

Table 10-11. Critical Particle Sizes Removed Under Option 1

State	3,600 cubic feet per acre Basin (microns)	2-year, 24-hour Runoff Basin (microns)
Alabama	19.4	10.7
Arizona	9.2	11.7
Arkansas	19.4	11.0
California	9.7	9.3
Colorado	12.0	11.8

State	3,600 cubic feet per acre Basin (microns)	2-year, 24-hour Runoff Basin (microns)
Connecticut	15.3	11.0
Delaware	15.9	11.0
Florida	21.7	11.3
Georgia	18.3	11.5
Hawaii	20.2	10.7
Idaho	7.0	10.6
Illinois	15.9	11.7
Indiana	15.3	11.0
Iowa	16.3	11.2
Kansas	17.4	11.4
Kentucky	15.1	10.8
Louisiana	23.3	11.2
Maine	14.8	10.8
Maryland	15.7	11.0
Massachusetts	15.4	11.1
Michigan	13.0	11.6
Minnesota	15.2	11.5
Mississippi	20.1	11.0
Missouri	17.6	11.4
Montana	6.7	9.1
Nebraska	15.0	12.0
Nevada	8.1	13.2
New Hampshire	15.1	11.7
New Jersey	16.4	11.1
New Mexico	10.0	11.9
New York	15.2	11.1
North Carolina	16.3	11.0
North Dakota	12.7	13.1
Ohio	14.6	11.1
Oklahoma	18.5	11.6
Oregon	14.5	11.8
Pennsylvania	16.0	10.9
Rhode Island	15.7	11.1
South Carolina	17.2	11.0
South Dakota	14.1	12.2
Tennessee	15.7	10.5
Texas	19.8	11.7
Utah	7.8	9.7
Vermont	14.0	11.5
Virginia	15.5	11.0
Washington	7.8	7.8
West Virginia	13.3	10.6

State	3,600 cubic feet per acre Basin (microns)	2-year, 24-hour Runoff Basin (microns)
Wisconsin	14.8	11.5
Wyoming	10.7	12.1
Puerto Rico	19.1	10.8
District of Columbia	15.7	11.0

To translate the critical particle size removed into loading reduction estimates for the regulatory options, EPA estimated the proportion of each state's sediment load that would be above and below the critical particle size on the basis of the hybrid particle size distributions developed from the soils data collected for each of the 11 indicator cities described in Section 10.3. As described in Appendix G, EPA used data from STATSGO to determine the percent of sand, silt and clay present in the surface soils in the area surrounding each indicator city. Using an approach described by Skaggs et al. (2001), EPA developed particle size distributions from the STATSGO data. Figure 10-2 illustrates the particle size distributions developed from the STATSGO data for each of the 11 indicator cities. By comparing the critical particle size removed for a given sediment basin criteria with the particle size distribution for the given indicator city, EPA was able to estimate the percentage of soil by mass that would be larger and smaller than the critical particle size. For example, Figure 10-3 illustrates the incremental removal for Georgia when increasing sediment basin size from a baseline of 1,800 cf/acre to either 3,600 cf/acre or runoff from the 2-year/24-hour storm. Under baseline conditions, approximately 35.4 percent of the soil particles are less than 25.8 microns, which is the critical particle size for a 1,800 cf/acre basin. For a 3,600 cf/acre basin, the critical particle size removed is 18.3 microns. Approximately 33.3 percent of the soil particles are smaller than 18.3 microns. So, when moving from a baseline basin to a 3,600 cf/acre basin, approximately 2.1 percent of the soil mass would be removed. The critical particle size for a 2-year/24-hour runoff basin is 11.5 microns, which corresponds to approximately 30.9 percent finer. This corresponds to 4.5 percent of the soil mass being removed over baseline conditions.

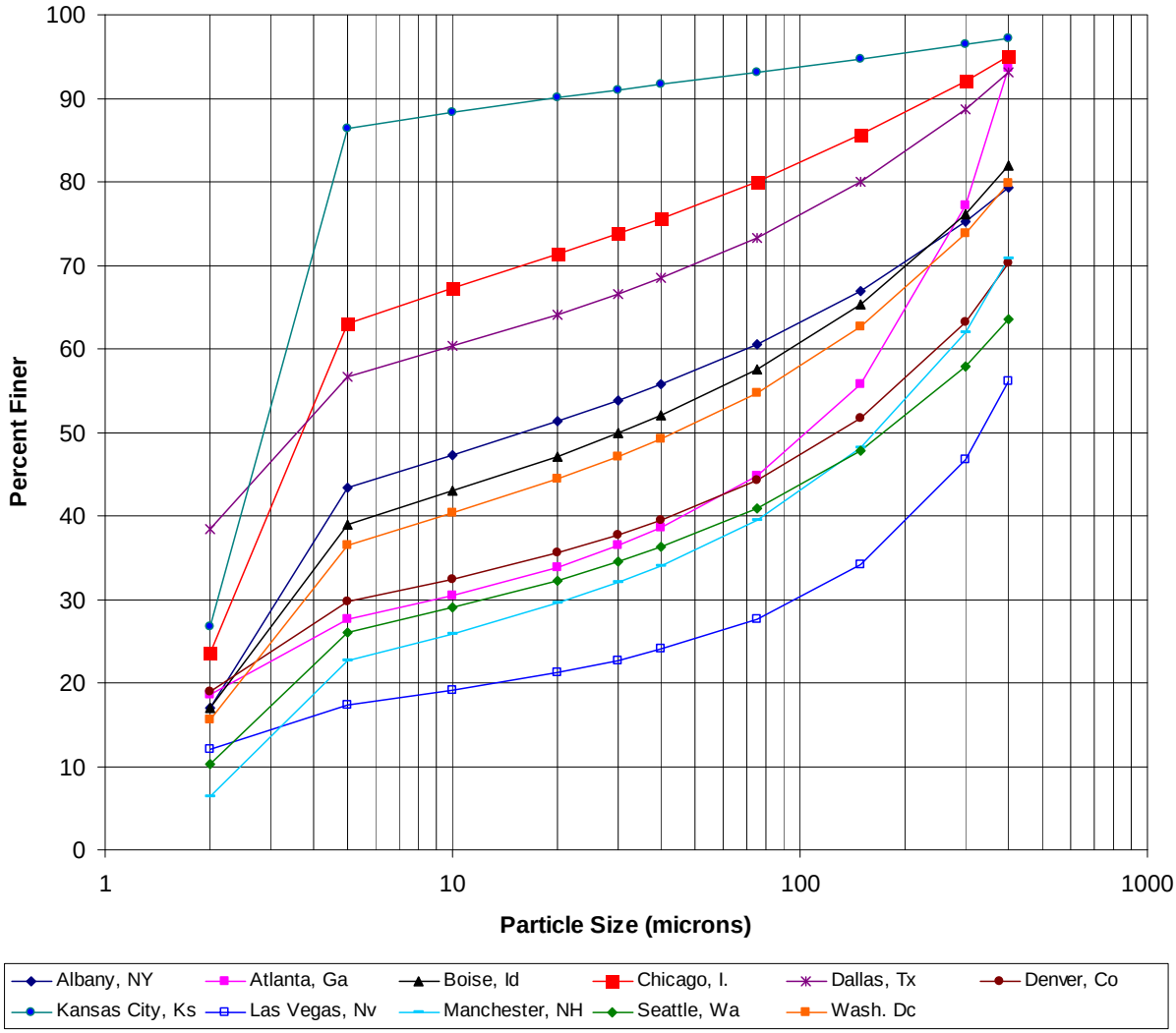

Figure 10-2. Indicator City Soil Particle Size Distributions.

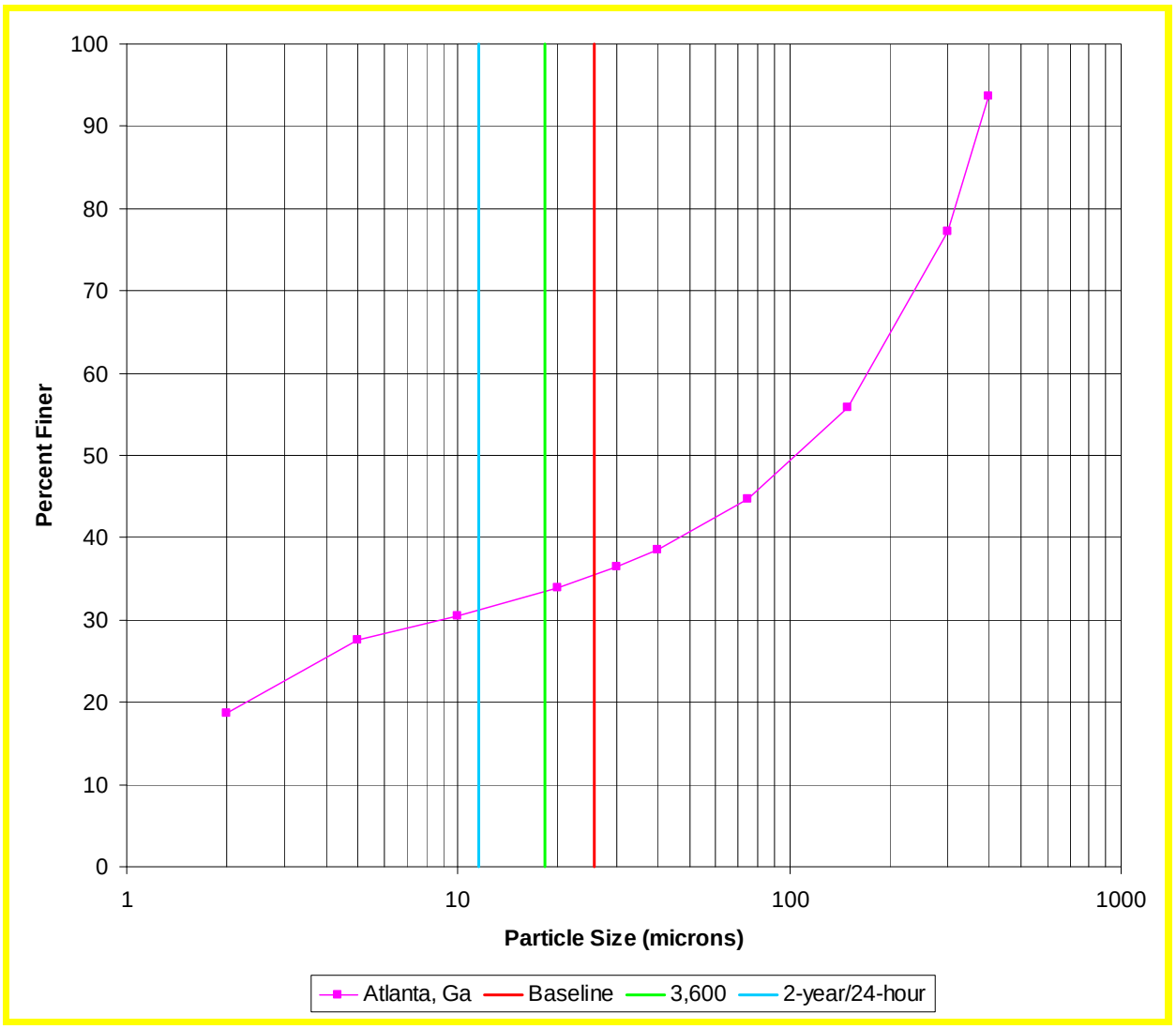

Figure 10-3. Illustration of Sediment Removal Efficiency for Baseline and Regulatory Options.

By coupling the percent of soil removed with the per-acre estimates of sediment generation in Tables 10-6 and the corresponding model site sizes, EPA was able to estimate sediment generation and removal under baseline conditions and under Option 1.

EPA acknowledges that this approach to estimating removal rates due to sediment basins is likely an underestimate because some fraction of the soil particles smaller than the critical particle size will be captured in a sediment basin. Some fraction of the smaller-than-critical soil particles will enter the basin low in the water column and as a result will have to settle only a very short distance before reaching the bottom of the basin. EPA is neglecting this partial capture in its assessment of pollutant removals.

EPA also acknowledges that by using the average intensity for the 10-year, 6-hour event to estimate removal rates, it is potentially underestimating the average annual removal rates for smaller-intensity storms. It is very probable that all rainfall events during the construction period will be less intense than the 10-year, 6-hour design event, and many rainfall events will be completely retained within sediment basins and traps. By using a relatively large storm event intensity as the basis for estimating removal efficiency for all storm events, the loadings analysis tends to over-predict the amount of discharged sediment under baseline conditions and under the regulatory options that rely on sediment basins for most storm events, given average annual precipitation values. However, this approach likely underestimates sediment discharged for larger and higher-intensity storm events. The loading analysis also does not account for flows from large storm events that would overtop the basin and exit via the emergency spillway. There is also the potential for large variability in baseline loadings estimates, since EPA is using RUSLE and these calculations are based on average annual conditions. In addition, EPA's assumptions regarding the percentage of the site that is disturbed and the duration of exposed soils are important factors in estimating sediment generation (and, incidentally, compliance costs). Also, by using the parent soil particles size distribution instead of the eroded soil particle size distribution, EPA is ignoring any differences between soil present on the site and soil that would actually be eroded and transported. Also, EPA's analysis of soil data looks only at the surface soil layer. So, any difference between surface soils and soils actually disturbed and exposed on the site would introduce error. In total, EPA expects that, on average, this approach provides a reasonable method of estimating removal rates in sediment basins. In actuality, a number of factors such as basin geometry, water temperature, inlet and outlet configuration, particle size distribution of eroded sediments, the degree to which the basin has been dewatered, and the quantity of sediment accumulation present in the basin will affect actual basin performance. However, modeling all these parameters in detail is not feasible.

To estimate removals for sites implementing turbidity controls under Options 2 and 3, EPA assumed that, because of the high level of sediment removal attributable to active treatment systems (ATS), that discharges from ATS would remove essentially all of the sediment contained in the stormwater runoff from sites implementing turbidity controls for all storm events up to the 2-year, 24-hour storm event. EPA acknowledges that this results in an overestimate of the actual removals for sites implementing turbidity controls under Options 2 and 3 because some sediment will still be present in the discharge. However, this approach is expected to provide a reasonable estimation of the removals attributable to these options. To estimate removals for individual model projects for Options 2 and 3, EPA estimated the acres and number of model sites (accounting for the site size, R-factor and clay content applicability provisions of Option 2) expected to be subject to turbidity controls under these options. By estimating the percentage of sediment mass below the baseline critical particle size (reflecting the quantity not removed by baseline sediment basins) and multiplying these state-level estimates by the per-acre sediment generation for the associated indicator city and the site size estimates for the model project, EPA was able to estimate the total sediment load removed by these options. For sites under Option 2 that are not required to meet the turbidity limit but are required to install larger sediment basins, removals were calculated using the same approach as Option 1.

Table 10-12 indicates the percentage of eroded soil estimated to be released from sediment basins, which are sized to different design levels. The baseline condition indicates the quantity of sediment that is estimated to occur for current state design requirements. For some states,

baseline releases will match releases estimated for other design standards. For example, Arizona requires designs based on 3,600 cf/acre, and so Table 10-12 indicates the same percent release in the second and third columns. Oklahoma requires designs to manage the 2-year, 24-hour event runoff under baseline conditions, so Table 10-12 indicates the same release in the second and fourth columns.

Table 10-12. Percent of Eroded Construction Site Sediment Released from Sediment Basins

	Percent of sediment release				
State	**Baseline**	**3,600 cu. ft. per acre**	**Treating 2-yr, 24-hr runoff**	**Capture 10 microns (diameter) or greater**	**Capture 20 microns (diameter) or greater**
Alabama	35.86	33.74	30.71	30.40	33.87
Arizona	18.70	18.70	19.40	19.09	21.18
Arkansas	63.74	63.74	60.75	60.29	64.12
California	19.09	19.11	19.02	19.09	21.18
Colorado	34.67	33.12	32.98	32.45	35.58
Connecticut	28.08	28.08	26.30	25.91	29.49
Delaware	43.05	43.05	40.80	40.33	44.40
Florida	34.17	34.17	30.89	30.40	33.87
Georgia	35.37	33.32	30.95	30.40	33.87
Idaho	41.00	41.00	43.25	42.93	47.09
Illinois	67.98	69.71	67.98	67.22	71.30
Indiana	71.65	69.58	67.72	67.22	71.30
Iowa	89.54	89.54	88.61	88.35	90.03
Kansas	89.69	89.69	88.63	88.35	90.03
Kentucky	32.31	32.31	30.73	30.40	33.87
Louisiana	64.77	64.77	60.83	60.29	64.12
Maine	27.68	27.68	26.27	25.91	29.49
Maryland	42.91	42.91	40.79	40.33	44.40
Massachusetts	26.34	28.12	26.34	25.91	29.49
Michigan	68.89	68.89	67.90	67.22	71.30
Minnesota	67.90	69.48	67.90	67.22	71.30
Mississippi	33.80	33.80	30.79	30.40	33.87
Missouri	89.67	89.67	88.64	88.35	90.03
Montana	32.42	31.02	32.34	32.45	35.58
Nebraska	90.32	89.50	88.70	88.35	90.03
Nevada	18.09	18.09	19.60	19.09	21.18
New Hampshire	26.51	27.93	26.51	25.91	29.49
New Jersey	52.12	50.06	47.80	47.29	51.24
New Mexico	60.01	60.01	60.96	60.29	64.12
New York	49.52	49.52	47.80	47.29	51.24
North Carolina	34.73	32.77	30.79	30.40	33.87
North Dakota	33.24	33.24	33.27	32.45	35.58

State	Percent of sediment release				
	Baseline	**3,600 cu. ft. per acre**	**Treating 2-yr, 24-hr runoff**	**Capture 10 microns (diameter) or greater**	**Capture 20 microns (diameter) or greater**
Ohio	71.17	69.12	67.75	67.22	71.30
Oklahoma	60.96	63.58	60.96	60.29	64.12
Oregon	30.52	30.52	29.60	29.02	32.28
Pennsylvania	42.02	42.98	40.78	40.33	44.40
Rhode Island	30.17	28.23	26.33	25.91	29.49
South Carolina	29.96	33.07	30.80	30.40	33.87
South Dakota	33.65	33.65	33.11	32.45	35.58
Tennessee	30.62	32.60	30.62	30.40	33.87
Texas	61.00	63.83	61.00	60.29	64.12
Utah	31.42	31.42	32.49	32.45	35.58
Vermont	29.16	27.32	26.47	25.91	29.49
Virginia	42.86	42.86	40.81	40.33	44.40
Washington	28.63	28.63	28.49	29.02	32.28
West Virginia	41.89	41.89	40.65	40.33	44.40
Wisconsin	70.32	69.55	67.89	67.22	71.30
Wyoming	33.92	32.43	33.05	32.45	35.58
District of Columbia	40.79	42.91	40.79	40.33	44.40

10.5. CALCULATION OF NATIONAL LOADINGS AND REMOVALS BY REGULATORY OPTION

To estimate pollutant removals under the regulatory options, EPA compared the baseline removal estimates with the removal estimates attributable to the specific technology or sizing criteria. Whenever an existing state baseline requirement was more stringent than a regulatory option, EPA assumed the state would retain its current requirement (i.e., there would be no backsliding by states). States with less stringent requirements would upgrade their requirements to meet the new national regulatory standard.

EPA computed its national estimates of construction site pollutant removals and discharged loads by doing the following:

- Estimating the per-state tonnage of eroded soil for each of the nine model construction sites (large and small residential, nonresidential, and transportation projects)
- Computing option-specific per-state removals using the more effective of either baseline controls or the proposed technology/sizing criteria (i.e.; if baseline sizing was more stringent than the option, the removals for baseline were used)

- Estimating the per-state construction acreage managed under each regulatory option after site-size and soil-based applicability criteria were applied (i.e., separating acreage managed at baseline from that managed with new requirements)
- Multiplying the per-state acreage by the appropriate estimated removal rate to first compute the tons captured and then the tons discharged for baseline conditions and each regulatory option
- Summing baseline and regulatory option-specific per-state values to produce total national estimates of tons discharged under baseline conditions and incremental removals and tons discharged for each regulatory option

Table 10-13 provides EPA's estimates for baseline conditions. Note, the low-end and high-end estimates reflect the influence of construction site land slope (see Table 10-4). EPA analyzed a range of slopes specific to eleven indicator cities (each of which represents a series of states) to evaluate the influence of regional variations in site conditions into the assessment of regulatory options.

Table 10-13. Estimated Annual State Baseline Construction Site Discharged Loads

Region	State	Tons of total suspended solids (TSS) discharged per year		
		Low-end estimate	Average estimate	High-end estimate
4	Alabama	960,240	1,298,136	1,651,871
9	Arizona	18,539	29,396	41,563
6	Arkansas	193,385	305,823	427,180
9	California	38,055	60,339	85,315
8	Colorado	66,549	119,835	189,031
1	Connecticut	6,668	9,368	12,227
3	Delaware	39,544	55,772	73,519
4	Florida	2,403,934	3,249,830	4,135,374
4	Georgia	2,130,195	2,879,769	3,664,477
10a	Idaho	13,829	19,977	26,460
5	Illinois	426,382	574,622	730,803
5	Indiana	271,507	365,897	465,342
7	Iowa	734,051	925,638	1,125,169
7	Kansas	1,641,291	2,069,633	2,515,730
4	Kentucky	597,047	807,139	1,027,079
6	Louisiana	297,384	470,292	656,914
1	Maine	28,822	40,499	52,867
3	Maryland	312,014	439,965	579,853
1	Massachusetts	20,269	28,481	37,178
5	Michigan	473,775	638,498	812,044
5	Minnesota	193,442	260,704	331,569
4	Mississippi	740,394	1,000,925	1,273,668
7	Missouri	987,488	1,245,187	1,513,564
8	Montana	25,274	45,515	71,801

Region	State	Tons of total suspended solids (TSS) discharged per year		
		Low-end estimate	**Average estimate**	**High-end estimate**
7	Nebraska	445,418	561,679	682,762
9	Nevada	10,719	16,996	24,030
1	New Hampshire	11,105	15,603	20,367
2	New Jersey	118,417	159,506	217,075
6	New Mexico	100,448	158,840	221,861
2	New York	202,130	272,274	370,554
4	North Carolina	1,203,557	1,627,056	2,070,404
8	North Dakota	26,325	47,400	74,767
5	Ohio	378,914	510,663	649,470
6	Oklahoma	364,364	576,232	804,908
10b	Oregon	221,339	307,137	396,504
3	Pennsylvania	747,537	1,054,130	1,389,341
1	Rhode Island	2,727	3,833	5,003
4	South Carolina	895,454	1,210,539	1,540,390
8	South Dakota	33,884	61,013	96,240
4	Tennessee	739,655	999,939	1,272,427
6	Texas	1,336,326	2,113,323	2,951,954
8	Utah	31,933	57,500	90,701
1	Vermont	3,955	5,554	7,247
3	Virginia	722,808	1,019,253	1,343,368
10b	Washington	364,481	505,767	652,932
3	West Virginia	164,573	232,058	305,839
5	Wisconsin	163,061	219,749	279,472
8	Wyoming	11,712	21,088	33,264
3	District of Columbia	1,175	1,661	2,192
National Total		**20,922,096**	**28,700,030**	**37,003,670**

Comparison of baseline loads (Table 10-12) with values of sediment generation in the absence of controls (Table 10-9) indicates the per-state and national removal rates for current baseline requirements. Overall, EPA estimates that current state baseline controls result in a national reduction of approximately 56 percent of the construction-site eroded soil load.

Table 10-13 presents EPA's estimate of total national TSS releases from construction sites under three options developed for the proposed rule. Table 10-14 provides EPA's per-state estimates for the tons of eroded sediment that would be captured for each of the options. Three estimates are provided for each of the options; estimates reflecting the influence of land slope (i.e., low-end, average, and high-end slopes).

Table 10-13a. Estimated Annual Option 1 Construction Site Discharged Loads

Region	State	Tons of total suspended solids (TSS) discharged per year[1]		
		Low-end estimate	Average estimate	High-end estimate
4	Alabama	910,336	1,230,580	1,565,810
9	Arizona	18,539	29,396	41,563
6	Arkansas	193,385	305,823	427,180
9	California	38,055	60,339	85,315
8	Colorado	63,935	115,115	181,570
1	Connecticut	6,668	9,368	12,227
3	Delaware	39,544	55,772	73,519
4	Florida	2,403,934	3,249,830	4,135,374
4	Georgia	2,021,762	2,732,984	3,477,485
10a	Idaho	13,829	19,977	26,460
5	Illinois	426,382	574,622	730,803
5	Indiana	264,667	356,662	453,579
7	Iowa	734,051	925,638	1,125,169
7	Kansas	1,641,291	2,069,633	2,515,730
4	Kentucky	597,047	807,139	1,027,079
6	Louisiana	297,384	470,292	656,914
1	Maine	28,822	40,499	52,867
3	Maryland	312,014	439,965	579,853
1	Massachusetts	20,269	28,481	37,178
5	Michigan	473,775	638,498	812,044
5	Minnesota	193,442	260,704	331,569
4	Mississippi	740,394	1,000,925	1,273,668
7	Missouri	987,488	1,245,187	1,513,564
8	Montana	25,220	45,417	71,645
7	Nebraska	441,892	557,227	677,344
9	Nevada	10,719	16,996	24,030
1	New Hampshire	11,105	15,603	20,367
2	New Jersey	114,297	153,946	209,498
6	New Mexico	100,448	158,840	221,861
2	New York	202,130	272,274	370,554
4	North Carolina	1,143,920	1,546,328	1,967,563
8	North Dakota	26,325	47,400	74,767
5	Ohio	369,366	497,770	633,047
6	Oklahoma	364,364	576,232	804,908
10b	Oregon	221,339	307,137	396,504
3	Pennsylvania	747,537	1,054,130	1,389,341
1	Rhode Island	2,574	3,616	4,721
4	South Carolina	895,454	1,210,539	1,540,390
8	South Dakota	33,884	61,013	96,240
4	Tennessee	739,655	999,939	1,272,427

Region	State	Tons of total suspended solids (TSS) discharged per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
6	Texas	1,336,326	2,113,323	2,951,954
8	Utah	31,933	57,500	90,701
1	Vermont	3,735	5,245	6,843
3	Virginia	722,808	1,019,253	1,343,368
10b	Washington	364,481	505,767	652,932
3	West Virginia	164,573	232,058	305,839
5	Wisconsin	161,493	217,631	276,775
8	Wyoming	11,448	20,613	32,512
3	District of Columbia	1,175	1,661	2,192
National Total		**20,675,215**	**28,364,884**	**36,574,844**

[1] Tons of TSS discharged annually after reductions due to current state required construction site controls.

Table 10-13b. Estimated Annual Option 2 Construction Site Discharged Loads

Region	State	Tons of total suspended solids (TSS) discharged per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
4	Alabama	475,718	642,241	816,311
9	Arizona	17,234	27,321	38,625
6	Arkansas	69,908	109,960	153,008
9	California	34,450	54,611	77,202
8	Colorado	56,532	101,743	160,432
1	Connecticut	4,816	6,761	8,819
3	Delaware	32,087	45,239	59,617
4	Florida	2,389,759	3,230,641	4,110,929
4	Georgia	1,154,208	1,558,587	1,981,401
10a	Idaho	13,829	19,977	26,460
5	Illinois	150,812	202,536	256,870
5	Indiana	111,336	149,631	189,884
7	Iowa	256,726	322,866	391,586
7	Kansas	655,301	824,538	1,000,455
4	Kentucky	208,809	281,586	357,568
6	Louisiana	140,904	222,080	309,465
1	Maine	15,872	22,263	29,023
3	Maryland	140,723	198,057	260,627
1	Massachusetts	18,982	26,668	34,808
5	Michigan	374,347	504,244	641,042
5	Minnesota	110,008	148,043	188,067
4	Mississippi	302,068	407,567	517,779
7	Missouri	353,800	444,984	539,732
8	Montana	25,220	45,417	71,645
7	Nebraska	261,604	329,553	400,258

Region	State	Tons of total suspended solids (TSS) discharged per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
9	Nevada	10,719	16,996	24,030
1	New Hampshire	9,590	13,469	17,577
2	New Jersey	80,640	108,528	147,600
6	New Mexico	98,910	156,401	218,447
2	New York	100,534	135,173	183,694
4	North Carolina	569,177	768,311	976,440
8	North Dakota	14,603	26,229	41,302
5	Ohio	134,411	180,515	228,948
6	Oklahoma	143,079	225,213	313,538
10b	Oregon	152,594	211,588	272,992
3	Pennsylvania	262,172	368,637	484,715
1	Rhode Island	1,896	2,662	3,473
4	South Carolina	698,055	943,325	1,199,984
8	South Dakota	13,600	24,377	38,330
4	Tennessee	259,677	350,189	444,690
6	Texas	578,523	911,270	1,269,302
8	Utah	31,933	57,500	90,701
1	Vermont	1,385	1,938	2,522
3	Virginia	306,259	430,958	567,018
10b	Washington	282,135	391,315	504,985
3	West Virginia	58,231	81,880	107,665
5	Wisconsin	97,924	131,801	167,454
8	Wyoming	11,448	20,613	32,512
3	District of Columbia	650	915	1,204
National Total		**11,293,197**	**15,486,916**	**19,960,737**

[1] Tons of TSS discharged annually after reductions due to current state required construction site controls.

Table 10-13c. Estimated Annual Option 3 Construction Site Discharged Loads

Region	State	Tons of total suspended solids (TSS) discharged per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
4	Alabama	116,014	155,311	196,001
9	Arizona	2,253	3,517	4,914
6	Arkansas	25,217	39,071	53,777
9	California	4,627	7,224	10,092
8	Colorado	8,151	14,357	22,295
1	Connecticut	815	1,128	1,456
3	Delaware	4,745	6,616	8,639
4	Florida	290,328	388,670	490,497
4	Georgia	257,369	344,547	434,814
10a	Idaho	1,661	2,369	3,106

Region	State	Tons of total suspended solids (TSS) discharged per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
5	Illinois	54,335	72,269	90,947
5	Indiana	34,563	45,970	57,851
7	Iowa	91,377	114,061	137,466
7	Kansas	204,147	254,825	307,118
4	Kentucky	71,996	96,383	121,635
6	Louisiana	38,650	59,884	82,423
1	Maine	3,610	4,997	6,447
3	Maryland	37,930	52,886	69,056
1	Massachusetts	2,529	3,500	4,517
5	Michigan	60,435	80,382	101,157
5	Minnesota	24,703	32,856	41,347
4	Mississippi	89,460	119,763	151,140
7	Missouri	122,752	153,223	184,665
8	Montana	3,108	5,475	8,503
7	Nebraska	55,490	69,266	83,481
9	Nevada	1,305	2,038	2,847
1	New Hampshire	1,384	1,915	2,471
2	New Jersey	14,496	19,274	25,958
6	New Mexico	13,036	20,197	27,799
2	New York	24,970	33,199	44,712
4	North Carolina	145,235	194,430	245,368
8	North Dakota	3,236	5,700	8,851
5	Ohio	48,272	64,204	80,798
6	Oklahoma	47,423	73,476	101,131
10b	Oregon	26,169	35,873	45,851
3	Pennsylvania	90,853	126,679	165,411
1	Rhode Island	340	470	607
4	South Carolina	108,136	144,764	182,691
8	South Dakota	4,153	7,316	11,361
4	Tennessee	89,290	119,535	150,852
6	Texas	173,786	269,262	370,609
8	Utah	3,918	6,901	10,716
1	Vermont	466	646	833
3	Virginia	87,599	122,142	159,486
10b	Washington	42,992	58,935	75,330
3	West Virginia	19,844	27,670	36,130
5	Wisconsin	20,715	27,553	34,674
8	Wyoming	1,431	2,520	3,914
3	District of Columbia	335	468	611
National Total		**2,575,647**	**3,493,716**	**4,462,352**

[1] Tons of TSS discharged annually after reductions because of current state required construction site controls.

Table 10-14a. Estimated Annual Option 1 Construction Site Eroded Sediment Captured

Region	State	Tons of total suspended solids (TSS) captured per year[1]		
		Low-end estimate	Average estimate	High-end estimate
4	Alabama	1,767,117	2,389,031	3,040,126
9	Arizona	80,598	127,795	180,691
6	Arkansas	109,990	173,941	242,964
9	California	161,319	255,786	361,660
8	Colorado	127,996	230,497	363,610
1	Connecticut	17,077	23,992	31,315
3	Delaware	52,316	73,787	97,266
4	Florida	4,632,051	6,261,977	7,968,300
4	Georgia	4,000,634	5,408,576	6,882,568
10a	Idaho	19,899	28,746	38,075
5	Illinois	200,843	270,670	344,237
5	Indiana	114,259	153,999	195,871
7	Iowa	85,730	108,105	131,409
7	Kansas	188,687	237,931	289,215
4	Kentucky	1,250,645	1,690,729	2,151,442
6	Louisiana	161,764	255,819	357,333
1	Maine	75,314	105,826	138,144
3	Maryland	415,185	585,444	771,589
1	Massachusetts	56,685	79,649	103,971
5	Michigan	213,939	288,321	366,688
5	Minnesota	91,446	123,243	156,744
4	Mississippi	1,450,393	1,960,759	2,495,047
7	Missouri	113,786	143,480	174,404
8	Montana	52,734	94,965	149,810
7	Nebraska	51,288	64,682	78,632
9	Nevada	48,538	76,961	108,816
1	New Hampshire	30,783	43,250	56,455
2	New Jersey	112,891	152,071	206,969
6	New Mexico	66,943	105,858	147,858
2	New York	206,057	277,564	377,753
4	North Carolina	2,321,918	3,139,047	3,994,503
8	North Dakota	52,876	95,209	150,179
5	Ohio	163,024	219,732	279,483
6	Oklahoma	233,354	369,043	515,497
10b	Oregon	503,829	699,126	902,551
3	Pennsylvania	1,031,548	1,454,625	1,917,192
1	Rhode Island	6,465	9,086	11,862
4	South Carolina	2,092,920	2,829,360	3,600,313
8	South Dakota	66,824	120,325	189,798
4	Tennessee	1,675,837	2,265,563	2,882,938

Region	State	Tons of total suspended solids (TSS) captured per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
6	Texas	854,345	1,351,098	1,887,255
8	Utah	69,690	125,487	197,942
1	Vermont	9,829	13,805	18,015
3	Virginia	963,596	1,358,796	1,790,883
10b	Washington	908,546	1,260,729	1,627,570
3	West Virginia	228,334	321,966	424,331
5	Wisconsin	70,383	94,855	120,639
8	Wyoming	23,077	41,554	65,548
3	District of Columbia	1,706	2,410	3,182
National Total		**27,235,009**	**37,565,271**	**48,588,644**

[1] Tons of TSS captured annually because of management technologies.

Table 10-14b. Estimated Annual Option 2 Construction Site Eroded Sediment Captured

Region	State	Tons of total suspended solids (TSS) captured per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
4	Alabama	2,201,734	2,977,371	3,789,625
9	Arizona	81,903	129,869	183,628
6	Arkansas	233,468	369,805	517,137
9	California	164,924	261,514	369,772
8	Colorado	135,399	243,869	384,748
1	Connecticut	18,929	26,599	34,723
3	Delaware	59,773	84,320	111,169
4	Florida	4,646,226	6,281,166	7,992,745
4	Georgia	4,868,188	6,582,973	8,378,653
10a	Idaho	19,899	28,746	38,075
5	Illinois	476,413	642,756	818,170
5	Indiana	267,590	361,030	459,566
7	Iowa	563,055	710,878	864,992
7	Kansas	1,174,677	1,483,026	1,804,489
4	Kentucky	1,638,883	2,216,282	2,820,953
6	Louisiana	318,245	504,031	704,782
1	Maine	88,264	124,062	161,988
3	Maryland	586,476	827,351	1,090,815
1	Massachusetts	57,973	81,462	106,341
5	Michigan	313,367	422,574	537,690
5	Minnesota	174,881	235,904	300,245
4	Mississippi	1,888,719	2,554,117	3,250,937
7	Missouri	747,474	943,683	1,148,236
8	Montana	52,734	94,965	149,810
7	Nebraska	231,576	292,355	355,718

Region	State	Tons of total suspended solids (TSS) captured per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
9	Nevada	48,538	76,961	108,816
1	New Hampshire	32,298	45,384	59,245
2	New Jersey	146,548	197,489	268,867
6	New Mexico	68,481	108,297	151,272
2	New York	307,652	414,665	564,613
4	North Carolina	2,896,661	3,917,064	4,985,627
8	North Dakota	64,598	116,380	183,644
5	Ohio	397,979	536,986	683,583
6	Oklahoma	454,639	720,062	1,006,867
10b	Oregon	572,575	794,675	1,026,062
3	Pennsylvania	1,516,913	2,140,118	2,821,818
1	Rhode Island	7,143	10,040	13,110
4	South Carolina	2,290,318	3,096,574	3,940,720
8	South Dakota	87,109	156,961	247,709
4	Tennessee	2,155,815	2,915,312	3,710,675
6	Texas	1,612,148	2,553,152	3,569,907
8	Utah	69,690	125,487	197,942
1	Vermont	12,178	17,111	22,335
3	Virginia	1,380,144	1,947,091	2,567,233
10b	Washington	990,892	1,375,181	1,775,518
3	West Virginia	334,676	472,144	622,505
5	Wisconsin	133,951	180,686	229,960
8	Wyoming	23,077	41,554	65,548
3	District of Columbia	2,231	3,156	4,171
National Total		**36,617,027**	**50,443,239**	**65,202,751**

[1] Tons of TSS captured annually due to management technologies.

Table 10-14c. Estimated Annual Option 3 Construction Site Eroded Sediment Captured

Region	State	Tons of total suspended solids (TSS) captured per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
4	Alabama	2,561,438	3,464,301	4,409,936
9	Arizona	96,884	153,673	217,340
6	Arkansas	278,158	440,694	616,367
9	California	194,747	308,902	436,883
8	Colorado	183,780	331,255	522,885
1	Connecticut	22,930	32,231	42,086
3	Delaware	87,115	122,943	162,146
4	Florida	6,745,657	9,123,137	11,613,177
4	Georgia	5,765,027	7,797,013	9,925,239
10a	Idaho	32,068	46,354	61,429

Region	State	Tons of total suspended solids (TSS) captured per year[1]		
		Low-end estimate	**Average estimate**	**High-end estimate**
5	Illinois	572,889	773,023	984,093
5	Indiana	344,364	464,691	591,600
7	Iowa	728,404	919,683	1,119,112
7	Kansas	1,625,831	2,052,739	2,497,826
4	Kentucky	1,775,696	2,401,485	3,056,886
6	Louisiana	420,498	666,227	931,824
1	Maine	100,526	141,328	184,564
3	Maryland	689,269	972,522	1,282,386
1	Massachusetts	74,426	104,629	136,632
5	Michigan	627,279	846,437	1,077,576
5	Minnesota	260,186	351,091	446,966
4	Mississippi	2,101,327	2,841,921	3,617,575
7	Missouri	978,523	1,235,443	1,503,303
8	Montana	74,845	134,907	212,952
7	Nebraska	437,690	552,643	672,495
9	Nevada	57,952	91,919	130,000
1	New Hampshire	40,504	56,938	74,351
2	New Jersey	212,692	286,743	390,509
6	New Mexico	154,355	244,501	341,920
2	New York	383,217	516,638	703,595
4	North Carolina	3,320,603	4,490,945	5,716,699
8	North Dakota	75,965	136,909	216,096
5	Ohio	484,118	653,297	831,733
6	Oklahoma	550,296	871,799	1,219,275
10b	Oregon	699,000	970,390	1,253,203
3	Pennsylvania	1,688,232	2,382,075	3,141,122
1	Rhode Island	8,699	12,232	15,976
4	South Carolina	2,880,238	3,895,134	4,958,012
8	South Dakota	96,556	174,022	274,678
4	Tennessee	2,326,203	3,145,967	4,004,513
6	Texas	2,016,886	3,195,160	4,468,600
8	Utah	97,706	176,086	277,926
1	Vermont	13,097	18,404	24,024
3	Virginia	1,598,804	2,255,907	2,974,765
10b	Washington	1,230,034	1,707,560	2,205,173
3	West Virginia	373,063	526,354	694,041
5	Wisconsin	211,160	284,934	362,740
8	Wyoming	33,095	59,647	94,147
3	District of Columbia	2,546	3,603	4,764
National Total		**45,334,577**	**62,436,439**	**80,701,136**

[1] Tons of TSS captured annually due to management technologies.

Table 10-15 provides the reductions in eroded sediment discharged from the nation's construction sites based on a comparison of baseline and option controls.

Table 10-15. Reductions in Estimated National Construction Site Discharged Material from Baseline Discharge Levels (Million Tons of TSS per Year) for Regulatory Options

	Low-end estimate	Average estimate	High-end estimate
	Load reduction (million tons TSS)		
Option 1	0.25	0.34	0.43
Option 2	9.63	13.21	17.04
Option 3	18.35	25.21	32.54
	Percent load reduction		
Option 1	1.2%	1.2%	1.2%
Option 2	46.0%	46.0%	46.1%
Option 3	87.7%	87.8%	87.9%

EPA's evaluation of Option 1 estimates that it would reduce baseline C&D TSS discharges by approximately 1 percent. It should be noted that many of the states currently requiring 1,800 cf/acre basins either have relatively low levels of construction rates, and/or have conditions that are less likely to produce erosion (low rainfall and low erosive soils).

Option 2 produces an approximately 46 percent reduction in TSS, relative to baseline loads. This reduction occurs because ATS is estimated to be required on approximately 40 percent of developed acres nationwide to meet the turbidity limit. In addition, under Option 2, approximately 11 percent of developed acres are required to install larger sediment basins.

As expected, the C&D discharge loads for Option 3 are the lowest of the options considered. Option 3 requires a turbidity limit for all sites larger than 10 acres, regardless of location or soil nature. This is estimated to affect approximately 86 percent of developed acres nationwide. Because ATS is assumed to remove 100 percent of TSS on the acres applied, the load values shown in Table 10-13c are the baseline loads associated with all C&D sites smaller than 10 acres in size. Option 3 is expected to reduce baseline construction site TSS loads by approximately 88 percent.

As described in Section 3.5.1, EPA used the River Reach File as the foundation for summarizing land cover change in drainage area units (or watersheds). EPA allocated the expected TSS loads under baseline conditions and under each regulatory option evaluated to individual RF1s which served as the basis for input to the U.S.Geological Survey SPARROW model to determine the extent of potential water quality improvements attributable to each of the regulatory options being considered by EPA for the proposed rule. Loads were allocated to RF1s on the basis of the amount of development occurring within each RF1, with consideration of RF1 percent clay content and R-factors. Loads were distributed to a total of 43,885 RF1s. The *Environmental Impact and Benefits Assessment for Proposed Effluent Guidelines and Standards for the*

Construction and Development Category (EPA-821-R-08-009 discusses the results of the SPARROW modeling and the potential benefits of the regulatory options).

10.6. REFERENCES

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11. NON-WATER QUALITY ENVIRONMENTAL IMPACTS

Sections 304(b) and 306(b) of the Clean Water Act require the U.S. Environmental Protection Agency (EPA) to consider non-water quality environmental impacts (including energy requirements) associated with effluent limitations guidelines and standards. In accordance with these requirements, EPA has considered the potential impacts of the proposed regulation on energy consumption, solid waste generation, and air emissions. The estimates of these impacts for the construction and development (C&D) industry are summarized in Sections 11.1, 11.2, and 11.3.

11.1. ENERGY REQUIREMENTS

EPA considered the additional energy requirements attributable to the regulatory options (Section 11.1.1) and the production of treatment chemicals (Section 11.1.2), and compared the option energy requirements with the energy requirements of the C&D industry (Section 11.1.3).

11.1.1. ENERGY REQUIREMENTS ATTRIBUTABLE TO THE REGULATORY OPTIONS

EPA estimates that additional energy requirements attributable to the regulatory options being considered are the result of the operation of pumps and generators (diesel) that would be needed as part of the regulatory options that require use of advanced treatment technologies (Options 2 and 3). Table 11-1 presents estimates of energy usage by regulatory option considered under this proposal.

Table 11-1. Estimated Energy Consumption by Regulatory Option

Option	Incremental energy consumption required
2	22 million gallons of diesel fuel
3	45 million gallons of diesel fuel

Under Option 1, no significant additional energy requirements would be expected. Option 1 involves installing larger sediment basins and installing a range of best management practices. These requirements are not expected to result in a significant increase in energy requirements. Additional excavation would be required in some states to install larger basins; however, EPA has not quantified energy requirements for construction equipment because equipment used would be highly site-specific. As described further in Sections 7.1.5.3.4 and 7.1.5.3.5, sediment traps and basins are designed such that all stormwater runoff flows through the basins by gravity. Because gravity flow is assumed, no additional energy would be required for sediment basin operations.

Options 2 and 3 involve the use of advanced treatment systems, including coagulation and flocculation followed by filtration, which require additional energy usage. EPA assumed that diesel powered generators and pumps would be used to operate active treatment systems (ATS). For a 500-gallon-per-minute (GPM) system, fuel consumption is approximately 10 gallons per hour (Rain for Rent 2008). EPA estimates that under Option 2, total stormwater treatment

volumes would be about 65.6 billion gallons per year, while under Option 3, the total treatment volumes would be approximately 135.5 billion gallons per year. At 500 GPM, total system run time (not counting recirculation) for Option 2 would be approximately 2.2 million hours, while under Option 3, the total system run time would be approximately 4.5 million hours. Therefore, diesel fuel consumption under Option 2 would be approximately 22 million gallons, while under Option 3, consumption would be approximately 45 million gallons. As with Option 1, some additional excavation would be required under Option 2 and 3 to install larger sediment basins and storage for ATS; however, EPA has not quantified energy requirements because equipment usage would be highly site-specific.

11.1.2. TREATMENT CHEMICAL PRODUCTION

EPA considered the availability and additional energy consumption from treatment chemicals. Section 11.1.2.1 describes chitosan, the basis for EPA's Best Available Technology Economically Achievable (BAT) option, and Section 11.1.2.2 describes polyacrylamides.

11.1.2.1. Chitosan

Chitosan is derived from chitin, the major component of crustacean shells and is a cationic polyelecrolyte. Chitosan (poly-D-glucosamine) is one of the most common polymers found in nature (USEPA 2003). Chitin is the second most abundant natural fiber after cellulose and is similar to cellulose in many respects (Hennen 1996). Global Industry Analysts, Inc., estimates that the global chitin market will exceed 51.4 thousand metric tons (113 million pounds) by 2012 (Global Industry Analysts, Inc. 2008). The United States could produce approximately 30 percent of the worldwide shellfish harvest each year (Hennen 1996). Therefore, EPA estimates that the U.S. chitin market could approach 34 million pounds by 2012.

Minton (2006) reported an average chitosan acetate dose rate of 2 milligrams per liter (mg/L). Minton (2006) noted that the Washington State Department of Ecology specifies a maximum dosage of 1 mg/L, but that variances are granted for turbidities greater than 600 nephelometric turbidity units (NTU). Minton (2006) reported chitosan acetate dosages as high as 3 mg/L. Table 11-2 presents the amount of chitosan acetate required from applying a 2 mg/L chitosan acetate dosage to the stormwater volumes requiring treatment from Section 11.1.1.

Table 11-2. Maximum Chitosan Acetate Required under EPA Options

Option	Stormwater treated (billions of gallons)	Chitosan acetate required (millions of pounds)
2	65.6	1.1
3	135.5	2.3

The amount of chitosan acetate in Table 11-2 represents a fraction of the total chitin market. In addition, EPA expects the amount of chitosan would be less than the amount presented in Table 11-2 because many construction sites would use other treatment chemical alternatives, including polyacrylamide, described in Section 11.1.2.2.

Because chitosan is manufactured from crustacean shells, additional energy consumption from chitosan production and usage is expected to be minimal.

11.1.2.2. Polyacrylamide (PAM)

Polyacrylamides (PAM) are a broad class of compounds that include cationic (positively charged) and anionic (negatively charged) PAM. PAM are water soluble over a wide pH range and exhibit a high affinity for suspended sediment. PAM are derived from acrylamide, of which 94 percent is used as PAM (ICIS Chemical Business 2008). U.S. demand for PAM is presented in Table 11-3.

Table 11-3. US Acrylamide / PAM Demand*

Year	Acrylamide demand (million lbs)	PAM demand (million lbs)
2007	253	238
2011(projected)	290	273

* U.S. demand equals production plus imports less exports
Source: ICIS Chemical Business 2008

Polymers such as PAM are produced from petroleum, so additional PAM consumption to treat construction site stormwater runoff would result in increased petroleum consumption. However, consumption on construction sites is not expected to significantly increase demand for acrylamide.

11.1.3. COMPARISON OF OPTION ENERGY REQUIREMENTS TO CONSTRUCTION INDUSTRY

Table 11-4 presents an estimate for construction industry fuel consumption based on the 2002 census.

Table 11-4. 2002 Energy Use in NAICS Category 23

Census Category	NAICS category 23	2002 unit cost	NAICS category 23 Energy Use (millions of gallons)
Gasoline and diesel fuel	$10,953,670,000[a]	$1.32/gallon[b]	8,300

[a] U.S. Census Bureau 2002.
[b] Energy Information Administration 2002.

Table 11-5 presents estimates of energy usage by regulatory option considered under this proposal, compared to the total annual diesel and gasoline consumption in NAICS Category 23 (Construction).

Table 11-5. Estimated Incremental Energy Usage by Regulatory Option

Option	Option diesel consumption (millions of gallons)	Fraction of NAICS category 23 Energy (gallons)
Option 2	22	0.003
Option 3	45	0.005

Options 2 and 3 correspond to approximately 0.3 and 0.5 percent of the NAICS 23 construction category fuel consumption, respectively. EPA does not expect any adverse impacts to occur as a result of the small incremental energy requirements for the proposed regulation.

11.2. AIR EMISSIONS IMPACTS

The Agency believes that none of the regulatory options for this rule would generate significant air emissions.

According to the Construction Industry Compliance Assistance Compliance Summary Tool (http://www.cicacenter.org/cs.cfm) there are no federal Clean Air Act (CAA) requirements that apply to the C&D industry. CAA requirements are implemented primarily by states through their State Implementation Plans (SIPs). Following are examples of construction-related emissions that might require a state permit under an SIP:

- Nitrogen oxides (NOx) and fine particulates from construction equipment diesel engines
- Dust from vehicle traffic, from loading and unloading of construction materials at transfer points, and from conveyor systems transporting building materials
- Visible stack emissions from off-road equipment
- Volatile organic compounds (VOCs) from paint and cleaning solvents

To the extent that usage of heavy construction equipments would be expected to increase from installing larger sediment basins, or portable generators or diesel powered pumps are used to power ATS, there would be an increase in fine particulate matter, VOCs, and NOx, and other pollutants, as well as increased CO_2 emissions, as estimated below.

EPA estimated air emissions on the basis of emission factors from diesel generators, the primary source of construction site air emissions. A 135-kilowatt generator (210 horsepower [hp]) generator would consume approximately 10 gallons of diesel per hour (Diesel Supply and Service, no date). EPA multiplied the total system run time presented in Section 11.1 by the emission factors from a 210-hp diesel generator (interpolated from 2008 generator set emission factors (lbs/hr) from the California South Coast Air Quality Management District (SC AQMD 2008)). Table 11-6 presents the estimated incremental air emissions by regulatory option.

Table 11-6. Estimated Incremental Air Emissions by Regulatory Option (Pounds/Year)

Option	Reactive organic gases (ROG)	Carbon monoxide (CO)	Nitrogen oxides (NOx)	Sulfuric oxides (SOx)	Particulate matter (PM)	Carbon dioxide (CO^2)	Methane (CH^4)
Option 2	393,303	1,408,976	4,087,478	4,169	156,025	370,542,245	35,487
Option 3	839,558	2,549,305	10,298,884	10,800	314,837	959,885,201	75,752

Because construction air emissions are primarily from fuel combustion, EPA estimates that the increase in air emissions relative to the construction industry air emissions would be similar to the estimates for the fraction of construction industry fuel consumption (i.e., Options 2 and 3 correspond to approximately 0.3 and 0.5 percent of the NAICS 23 construction category).

11.3. SOLID WASTE GENERATION

Solid waste generated at C&D sites include treatment residuals generated as part of coagulation and flocculation from active treatment systems. These can include spent cartridge or bag filters, or filter media (usually sand). EPA did not quantify solid waste generated from spent cartridge or bag filters, because it is not clear whether permittees would require cartridge or bag filters as a final finishing step after ATS. Sediment removed from sediment basins and ATS, including sediment containing polymers, can generally be used as fill material on the construction site. Therefore, EPA expects that solid waste generation would be minimal.

11.4. REFERENCES

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