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Environmental Assessment for Proposed Effluent Guidelines and Standards for the Construction and Development Category

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Acknowledgments and Disclaimer

The Construction and Development Effluent Guidelines proposed rule and support documents were prepared by the C&D Project Team: Eric Strassler, Project Manager; Jesse Pritts, P.E., Engineer; George Denning, Economist; Karen Maher, Environmental Assessor; and Michael G. Lee, Attorney. Technical support for this Environmental Assessment was provided by Tetra Tech, Inc.

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Section 1 Introduction and Background

1.1 Introduction

The U.S. Environmental Protection Agency (EPA) is proposing national effluent limitation guidelines for the construction and development (C&D) category. By establishing national standards, EPA intends to reduce the environmental impacts of construction site storm water discharges. This environmental assessment has been prepared to support the proposed rule by identifying and estimating the environmental benefits of implementing the proposal.

For purposes of the environmental assessment, *construction* is defined as the process by which land is converted from one land use to another. Hence, construction impacts are a result of how the land is converted, not a result of what the land becomes.[1] *Land development* is defined in this document as the conversion of land from a pre-development condition such as rural land use to a post-development condition such as urban land use. The impacts from the land development industry originate from the post-development condition (what the land use becomes), which causes adverse environmental effects that were not present in the pre-development condition.

Adverse environmental impacts attributable to the C&D industries have been well documented and include (but are not limited to) alteration of stream flow patterns, change in river channels, and reduction in the water quality of receiving waters as a result of increased generation and transport of sediment. Aquatic habitats also can be damaged as a result of reduced water quality and altered hydrology. These environmental impacts can in turn cause additional environmental and economic damage by increasing the frequency and magnitude of flooding events in vulnerable areas.

The purpose of this document is to describe the methods used to evaluate and quantify such impacts as they occur under the current regulatory framework and might occur under the proposed effluent guidelines. This report also presents estimates of the environmental benefits that would accrue from implementation of the proposed technology controls. As discussed later in the document, however, the environmental assessment and the associated Economic Analysis of the proposed rule (EPA, 2002) only partially capture the full range of potential benefits that would derive from implementing the proposed regulations. Not all categories of environmental impacts from C&D activities can be quantified and therefore some are not amenable to monetization procedures. These additional categories of environmental benefits are evaluated in only a qualitative manner.

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1. The term *impact* is used to denote negative conditions related to elevated concentrations of pollutants, physical destruction or alteration of habitat by excessive flows, elevation of water temperature, and loss of fish spawning access due to new road crossings

The environmental assessment evaluates construction impacts for each of the three regulatory options considered in the proposal. As shown in Table 1-1, these options range from no new regulatory requirements (Option 3) to requirements for inspections and certifications of erosion and sediment controls and implementation of new storm water pollution prevention plans for certain sized sites.

Table 1-1. Regulatory Options Evaluated for Controlling Discharges from Construction Activities

Option	Description
Option 1	• Applicable to construction sites with one acre or more of disturbed land • Operators required to: - Inspect site throughout land disturbance period - Certify that the controls meet the regulatory design criteria as applicable • Amend NPDES regulations at 40 CFR Part 122 (no new effluent guideline regulations)
Option 2	• Applicable to construction sites with five acres or more of disturbed land • Operators required to: - Prepare storm water pollution prevention plan - Design, install, and maintain erosion and sediment controls - Inspect site throughout land disturbance period - Certify that the controls meet the regulatory design criteria as applicable • Creates a new effluent guidelines category at 40 CFR Part 450 and amends Part 122 regulations
Option 3	• No new regulatory requirements

The assessment, where appropriate, estimates reductions in environmental impacts attributable to EPA's proposed rule. To help the reader understand the estimated changes under the regulatory proposal, the document also summarizes the regulatory framework currently in place.

1.2 Organization of Environmental Assessment

This document first provides background information on the current regulatory framework and summarizes how the proposed regulation would alter this framework. Section 2 provides additional background information on how the C&D industries affect the environment through generation of pollutants in storm water runoff and alteration of hydrology. A detailed discussion of the methodology used to estimate environmental impacts from the C&D industries is provided in Section 3. Section 4 presents EPA's estimates of environmental impacts of construction activities under baseline conditions and under the various regulatory options evaluated for the proposed rule. Section 5 provides the references used in the analysis. The appendices are provided primarily for readers who seek further detail about how the methodology was developed.

1.3 Review of Regulatory History Related to C&D Category

This subsection describes the federal and state regulations designed to control storm water discharges from the C&D industries. It describes the regulatory framework that is currently in place.

1.3.1 Clean Water Act

Congress adopted the Clean Water Act (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 section 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 (Public Law 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). In accordance with 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 (Public Law 100-4, February 4, 1987) amended the CWA. The NPDES program was expanded by defining municipal and industrial storm water discharges as point sources. Industrial storm water dischargers, municipal separate storm sewer systems and other storm water dischargers designated by EPA must obtain NPDES permits pursuant to section 402(p) (33 U.S.C. 1342(p)).

1.3.1.1 NPDES Storm Water Permit Program

EPA's initial storm water regulations, promulgated in 1990, identified construction as one of several types of industrial activity requiring an NPDES permit. These "Phase I" storm water regulations require operators of large construction sites to apply for permits (40 CFR 122.26(b)(14)(x)). A large-site construction activity is one that:

- will disturb five acres or greater; or

- will disturb less than five acres but is part of a larger common plan of development or sale whose total land disturbing activities total five acres or greater (or is designated by the NPDES permitting authority); and
- will discharge storm water runoff from the construction site through a municipal separate storm sewer system (MS4) or otherwise to waters of the United States.

The Phase II storm water rule, promulgated in 1999, generally extends permit coverage to sites one acre or greater (40 CFR 122.26(b)(15)).

In addition to requiring permits for construction site discharges, the NPDES regulations require permits for certain MS4s. The local governments responsible for the MS4s must operate a storm water management program. The local programs regulate a variety of business activities that affect storm water runoff, including construction.

1.3.2 Other State and Local Government Storm Water Requirements

States and municipalities may have other requirements for flood control, erosion and sediment (E&S) control, and in many cases, storm water quality. Many of these provisions were enacted before the promulgation of the EPA Phase I storm water rule. All states have laws for E&S control, and these are often implemented by MS4s. A summary of existing state and local requirements is provided in the Development Document (EPA, 2002a). Key control measures used by states and municipal/regional authorities in these programs include:

- Storm water controls designed for peak discharge control
- Storm water controls designed for water quality control
- Storm water controls designed for flood control
- Specified depths of runoff for water quality control
- Percent reduction of loadings for water quality control (primarily solids and sediments)
- Numeric effluent limits for water quality control (primarily total suspended sediments, settleable solids, or turbidity)
- Control measures for biological or habitat protection
- Control measures for physical in-stream condition controls (primarily streambed and stream bank erosion).

Control measures used to reduce pollutants entering water bodies are commonly required during the construction (land disturbance) phase. Post-construction requirements for pollutant reductions are generally broader and more stringent. Typically, water quantity control measures for peak discharges and runoff volume controls that apply to post-development conditions are not required during the construction phase.

Section 2 Categories of Reported Impacts and Pollutants

2.1 Introduction

Construction and land development 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 water bodies, including sediments, metals, organic compounds, pathogens, and nutrients. Groundwater 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 storm water runoff.

Construction activities typically involve excavating and clearing existing vegetation. During the construction period, the affected land is usually denuded and the soil compacted, leading to increased storm water runoff and high rates of erosion. If the denuded and exposed areas contain hazardous contaminants, they can be carried at increased rates to surrounding water bodies by storm water 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. For example, a completed construction site typically has a greater proportion of impervious surface than the predevelopment site, leading to changes in the volume and velocity of storm water runoff. Changes in land use might also lead to new sources of pollution, such as oils and metals from motor vehicles, nutrients and pesticides from landscape maintenance, and pathogens from improperly installed or failing septic tanks. Increased pollutant loads are particularly evident when land development takes place in previously undeveloped environments. Together the short-term impacts from construction activities and the long-term impacts of development can profoundly change the environment.

The following subsections describe how pollutants associated with construction activities and land development storm water discharges can adversely affect the environment. Potential effects include impairment of water quality, destruction of aquatic life habitats, and enlargement of flood plains. To the extent possible, this analysis distinguishes between environmental impacts generated during construction and environmental impacts from post-development activities. Although in most cases the differences are in magnitude and duration (e.g., sediment runoff), environmental impairment from such contaminants as pathogens are more likely to be associated with the overall urbanization of a watershed than with the types of activities that take place during construction. The discussion of environmental impacts first evaluates the impacts of contaminated runoff and then focuses on the physical impacts of construction and land development.

2.2 Pollutants Associated With Construction and Land Development Storm Water Runoff

This subsection describes pollutants associated with construction and land development storm water runoff. The description does not represent the complete suite of contaminants that can be found in the runoff but focuses instead on those that are the most prevalent and of greatest concern to the environment. These pollutants include sediment, metals, poly-aromatic hydrocarbons (PAHs), oil, grease, and pathogens.

2.2.1 Sediment

Sediment is an important and ubiquitous constituent in urban storm water runoff. Surface runoff and raindrops detach soil from the land surface, resulting in sediment transport into streams. Sediment can be divided into three distinct subgroups: suspended solids, turbidity, and dissolved solids.

Total suspended solids (TSS) are a measure of the suspended material in water. The measurement of TSS in urban storm water allows for estimation of sediment transport, which can have significant effects locally and in downstream receiving waters.

Turbidity is a function of the suspended solids and is a measure of the ability of light to penetrate the water. Turbidity can exhibit control over biological functions, such as the ability of submerged aquatic vegetation to receive light and the ability of fish to breathe dissolved oxygen through their gills.

Total dissolved solids are a measure of the dissolved constituents in water and are a primary indication of the purity of drinking water.

2.2.1.1 Sources of Sediment

Construction Sites

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 runoff from construction sites, and results from these studies are summarized in Table 2-1. 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, 1986, cited in CWP, 2000). On a unit area basis, construction sites export sediment at 20 to 1,000 times the rate of other land uses (CWP, 2000).

Table 2-1. Studies of 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, EC Lille, and Maidment, 1997
Hamilton County, Ohio	2,950	Islam, Taphorn, and Utrata-Halcomb, 1998
Mean TSS (mg/L)	3,681	NA

Post-Development Conditions as a Source of Sediment

Sediment sources in urban environments include bank erosion, overland flow, runoff from exposed soils, atmospheric deposition, and dust (Table 2-2). Streets and parking lots accumulate dirt and grime from the wearing of the street surface, exhaust particulates, “blown-on” soil and organic matter, and atmospheric deposition. Lawn runoff primarily contains soil and organic matter. Source area monitoring data from Bannerman (1993), Waschbusch (2000), and Steuer (1997) are shown in Table 2-3. Hot spots were identified for the transport of sediment from the urban land surface, and they include streets, parking lots, and lawns.

Table 2-2. Sources of Sediment in Urban Areas

Source Area	Loading
Bank erosion	• Up to 75 percent in California and Texas studies
Overland flow	• Lawns - average value of geometric means from 4 studies: 201 mg/L
Runoff from areas with exposed soils	• Average value: 3,640 mg/L
Blown-on material and organic matter	• May account for as much as 35 to 50 percent in urban areas

Bannerman et al., 1993; Dartinguenave et al., 1997; Schueler, 1987; Steuer et al., 1997; Trimble, 1997; Waschbusch et al., 2000;

Table 2-3. Source Area Concentrations for TSS in Urban Areas

Source Area	TSS (mg/L)[a]	TSS (mg/L)[b]	TSS (mg/L)[c]	
			Monroe Basin	Harper Basin
Commercial parking lot	110	58	51	
High-traffic street	226	232	65	
Medium-traffic street	305	326	51	
Low-traffic street	175	662	68	69
Commercial rooftop	24	15	18	
Residential rooftop	36	27	15	17
Residential driveway	157	173		34
Residential lawn	262	397	59	122

[a] Steuer et al., 1997.
[b] Bannerman et al., 1993.
[c] Waschbusch et al., 2000.

Parking lots and streets are responsible not only for high concentrations of sediment but also for high runoff volumes. Normally about 90 percent of the water that falls on pavement is converted to surface runoff, whereas roughly 5 to15 percent of the water that falls on lawns is converted to surface runoff (Schueler, 1987). The source load and management model (SLAMM; Pitt and Voorhes, 1989) evaluates runoff volume and concentrations of pollutants from different urban land uses and predicts loads to the stream. When used in the Wisconsin and Michigan subwatersheds, the model estimated that parking lots and streets were responsible for more than 70 percent of the TSS delivered to the stream (Steuer, 1997; Waschbusch et al., 2000). Because basin water quality measurements were taken at pipe outfalls, bank erosion was not accounted for in the studies.

Sediment load is due to erosion caused by an increased magnitude and frequency of flows brought on by urbanization (Allen and Narramore, 1985; Booth, 1990; Hammer, 1972; Leopold, 1968). Stream bank studies by Dartinguenave et al. (1997) and Trimble (1997) determined that stream banks are large contributors of sediment in urban streams. Trimble (1997) used direct measurements of stream cross sections, sediment aggradation, and suspended sediment to determine that roughly 66.7 percent of the sediment load in San Diego Creek was a result of bank erosion. Dartiguenave et al. (1997) used a GIS- based model developed in Austin, Texas, to determine the effects of stream channel erosion on sediment loads. By effectively modeling the pollutant loads on the land surface and by monitoring the actual in-stream loads at U. S. Geological Survey (USGS) gauging stations, they were able to determine that over 75 percent of the sediment load came from the stream banks.

2.2.1.2 Receiving Waters Impacts

Sediment transport and turbidity can affect habitat, water quality, temperature, and pollutant transport, and can cause sedimentation in downstream receiving waters (Table 2-4). Suspended sediment and its resulting turbidity can reduce light for submerged aquatic vegetation. In addition, deposited sediment can cover and suffocate benthic organisms like clams and mussels, cover habitat for substrate-oriented species in urban streams, and reduce storage in reservoirs. Pollutants such as hydrocarbons and metals tend to bind to sediment and are transported with storm flow (Crunkilton et al., 1996; Novotny and Chesters, 1989). Increased turbidity also can cause stream warming by reflecting radiant energy (Kundell and Rasmussen, 1995).

Table 2-4. Sediment Impacts on Receiving Waters

Resource Affected	Impacts of Sediment	Indicator	Source
Streams	Loss of sensitive species and a decrease in fish and macroinvertebrate diversity communities	GA loss of sensitive species at 25 NTU	Kundell and Rasmussen, 1995
	Clogging of gills and loss of habitat		Leopold, 1973
	Decreased flow capacity in streams	Maryland decreased flow capacity. Increased overbank flows	Barrett and Molina, 1998
	Interference with water quality processes. Affects transport of contaminants		MacRae and Marsalek, 1992
Wetlands	Deposition of sediment	High accretion rates in a tidal wetland as a result of sediment transport in an urbanized watershed	Pasternack, 1998
	Loss of sensitive species: amphibians, plants	Loss of amphibian species	Horner, 1996
		Loss of seven wetland/SAV plant species since European development	Hilgartner, 1986
Reservoirs	Turbidity results in increased costs of treatment for drinking water	more abatement costs at >5 NTU	McCutcheon et al., 1993
	Sedimentation results in decreased storage		
Beaches	Turbidity reduces aesthetic value		Kundell and Rasmussen, 1995
	Sedimentation can result in increased accretion rates in wetlands and change plant community structure		

Table 2-4. Sediment Impacts on Receiving Waters

Resource Affected	Impacts of Sediment	Indicator	Source
Estuaries	Sedimentation		Pasternack, 1998
	Turbidity		Livingston, 1996
	Reduced light attenuation can lead to a loss of submerged aquatic vegetation (SAV)		Schiff, 1996
			Mackiernan et al., 1996
		SAV losses due to sediments and eutrophication	Short and Wyllie-Echeverria, 1996
		SAV losses in NE	Orth and Moore, 1983
		Essential habitat requirements for SAV include light attenuation, dissolved inorganic nitrogen, phosphorus and chlorophyll-*a*	Stevenson et al., 1993
		Loss of seven wetland/SAV plant species since European settlement	Hilgartner, 1986

2.2.2 Metals

Many toxic metals can be found in urban storm water, although only metals such as zinc, copper, lead, cadmium, and chromium are of concern because of their prevalence and potential for environmental harm. These metals are generated by motor vehicle exhaust, the weathering of buildings, the burning of 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, 1995). Generally the concentrations found in urban storm water 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.

2.2.2.1 Sources of Metal Runoff

Construction Sites

Construction sites are not thought to be important sources of metal contamination. Runoff from such sites could have high metals contents if the soil is already contaminated. Construction activities alone do not result in metal contamination.

Post-Development Conditions as a Source of Metals

Post-development conditions create significant sources of metal runoff in the urban environment, including streets, parking lots, and rooftops. Table 2-5 summarizes the major sources of metal runoff by metal type. Copper can be found in high concentrations on urban streets as a result of the wear of brake pads that contain copper. A study in Santa Clara, California, estimated that 50 percent of the copper released is from brake pads (Woodward-Clyde, 1992). Sources of lead include atmospheric deposition and diesel fuel, which are found consistently on streets and rooftops. Zinc in urban environments is a result of the wear of automobile tires (an estimated 60 percent of the total zinc in the Santa Clara study), paints, and the weathering of galvanized gutters and downspouts. Source area concentrations estimated by researchers in Wisconsin and Michigan are presented in Table 2-6. Actual concentrations vary considerably, and high-concentration source areas vary from study to study. A study using SLAMM for an urban watershed in Michigan estimated that most of the zinc, copper, and cadmium was a result of runoff from urban parking lots, driveways, and residential streets (Steuer, 1997).

Table 2-5. Metal Sources and Hot Spots in Urban Areas

Metal	Sources	Hot Spots
Zinc	Tires, fuel combustion, galvanized pipes and gutters, road salts *Estimate of 60% from tires*[a]	Parking lots, rooftops, and streets
Copper	Auto brake linings, pipes and fittings, algacides, and electroplating *Estimate of 50% from brake pads*[a]	Parking lots, commercial roofs, and streets
Lead	Diesel fuel, paints, and stains	Parking lots, rooftops, and streets
Cadmium	Component of motor oil; corrodes from alloys and plated surfaces	Parking lots, rooftops, and streets
Chromium	Found in exterior paints; corrodes from alloys and plated surfaces	More frequently found in industrial and commercial runoff

[a] Woodward-Clyde, 1992 (Santa Clara, CA, study)
Sources: Barr, 1997; Bannerman et al., 1993; Steuer, 1997

Table 2-6. Metal Source Area Concentrations in Urban Areas (in ug/L)

Source Area	Diss. Zinc	Total Zinc	Diss. Copper	Diss. Copper	Total Copper	Diss. Lead	Diss. Lead	Total Lead	Total Lead	Total Lead
Citation	(a)	(b)	(a)	(b)	(b)	(a)	(c)	(a)	(c)	(b)
Commercial parking lot	64	178	10.7	9	15			40		22
High-traffic street	73	508	11.2	18	46	2.1	1.7	37	25	50
Medium-traffic street	44	339	7.3	24	56	1.5	1.9	29	46	55
Low-traffic street	24	220	7.5	9	24	1.5	0.5	21	10	33
Commercial rooftop	263	330	17.8	6	9	20		48		9
Residential rooftop	188	149	6.6	10	15	4.4		25		21
Residential driveway	27	107	11.8	9	17	2.3		52		17
Residential lawn	na	59	na	13	13	na		na		na
Basin outlet	23	203	7.0	5	16	2.4		49		32

na : not available
Sources: (a) Steuer 1997; (b) Bannerman 1993; (c) Waschbusch, 1996, cited in Steuer, 1997

2.2.2.2 Metals Impacts on Receiving Waters

Downstream effects of metal transported to receiving waters, such as lakes and estuaries, have been studied extensively. Selected studies on metal impacts on receiving waters are summarized in Table 2-7. Although evidence exists for the buildup of metals in deposited sediments in receiving waters and for bioaccumulation in aquatic species (Bay et al., 2000; Livingston, 1996), specific effects of these concentrations on submerged aquatic vegetation and other biota are not well understood.

Table 2-7. Metals Impacts on Receiving Waters

Resource Affected	Impacts of Metals	Evidence
Streams	• Chronic toxicity due to in-stream concentrations and accumulation in sediment • Bioaccumulation in aquatic species • Acute toxicity at certain concentrations	Chronic toxicity increased during longer-duration studies, i.e., 7/14/21-day studies (Crunkilton, 1996); Delayed toxicity (Ellis, 1986/1987); Baseflow toxicity (Mederios, 1983); Resuspension of metals during storms accounting for some toxicological effects (Heaney and Huber, 1978); Bioaccumulation in crayfish (Masterson & Bannerman, 1994)
Reservoirs/ Lakes	• Accumulation of metals in sediment	Bioaccumulation levels in bottom-feeding fish were found to be influenced by the metal levels of the bottom sediments of storm water ponds (Campbell, 1995).
Estuaries	• Accumulation of metals in sediment • Loss of SAV	Tampa Bay (Livingston, 1996); San Diego (Schiff 1996); SAV losses in northeast San Francisco Bay (Orth and Moore, 1983)

2.2.3 PAHs, and Oil and Grease

Petroleum-based substances such as oil and grease and poly-aromatic hydrocarbons (PAHs) are found frequently in urban storm water. Many constituents of PAHs and oil and grease, such as pyrene and benzo[b]fluoranthene, are carcinogens and toxic to downstream biota (Menzie-Cura and Assoc., 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.

2.2.3.1 Sources of PAHs, and Oil and Grease

Construction Sites

Construction activities during site development are not believed to be major contributors of these contaminants to storm water 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), could lead to leakage or spillage of products that contain hydrocarbons, but these incidents would likely be small in magnitude and managed before off-site contamination could occur.

Post-Development Conditions as a Source of PAHs, and Oil and Grease

In most storm water runoff, concentrations of PAHs and oil and grease are typically below 5 mg/L but concentrations tend to increase in commercial and industrial areas. Hot spots for these pollutants in the urban environment include gas stations, commuter parking lots, convenience stores, residential parking areas, and streets (Schueler, 1994). Schueler and Shepp (1993) found concentrations of pollutants in oil/grit separators in the Washington Metropolitan area and determined that gas stations had significantly higher concentrations of hydrocarbons and a greater presence of toxic compounds than streets and residential parking lots. A study of source areas in an urban watershed in Michigan (which excluded gas stations) showed that high concentrations from commercial parking lots contributed 64 percent of the estimated hydrocarbon loads (Steuer et al., 1997).

2.2.3.2 Receiving Water Impacts

Toxicological effects from PAHs and oil and grease are assumed to be reduced by their attachment to sediment (lessened availability) and by photodegradation (Schueler, 1994). Evidence of possible impacts on the metabolic health of organisms exposed to PAHs and of bioaccumulation in streams and other receiving waters does not exist (Masterson and Bannerman, 1994; MacCoy and Black, 1998); however, crayfish from Lincoln Creek, analyzed in the Masterson and Bannerman study, had a PAH concentration of 360 micrograms per kilogram—much higher than the concentration known to be carcinogenic. The crayfish in the control stream did not have detectable levels of PAHs. Known effects of PAHs on receiving waters are summarized in Table 2-8. Long-term effects of PAHs in sediments of receiving waters call for additional study.

Table 2-8. Effects of PAHs and Oil and Grease on Receiving Waters		
Resource Affected	**Impacts of PAHs and Oil and Grease**	**Citations**
Streams	• Possible chronic toxicity due to in-stream concentrations and accumulation in sediment • Bioaccumulation in aquatic species • Acute toxicity at certain concentrations	Bioaccumulation in crayfish tissue studies (Masterson and Bannerman, 1994); Potential metabolic costs to organisms (Crunkilton et al., 1996); delayed toxicity (Ellis, 1986/1987); Baseflow toxicity (Mederios, 1983)
Reservoirs	• Accumulation of PAHs in sediment	Sediment contamination may result in a decrease in benthic diversity and transfer of PAHs to fish tissue (Schueler, 2000-CWP); Elevated levels of PAHs found in pond muck layer (Gavens et al., 1982)
Estuaries	• Accumulation of PAHs in sediment • Potential loss of SAV • Accumulation of PAHs in fish and shellfish tissue	Tampa Bay (Livingston, 1996); San Diego, San Francisco Bay (Schiff, 1996)

2.2.4 Pathogens

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

2.2.4.1 Sources of Pathogens

Construction Sites

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 and are not connected to the land surface. Any leaks from them would likely be identified and addressed quickly.

Post-Development Conditions as a Source of Pathogen Runoff

Coliform sources include pets, humans, and wild animals. Source areas in the urban environment for direct runoff include lawns, driveways, and streets. Dogs have high concentrations of coliform bacteria in their feces and have a tendency to defecate in close proximity to impervious surfaces (Schueler, 1999). Many wildlife species also have been found to contribute to high fecal concentrations. Essentially, any species that is present in significant numbers in a watershed is a potential pathogen source. Source identification studies, using methods such as DNA fingerprinting, have attributed high coliform levels to such species as rats in urban areas, ducks and geese in storm water ponds, dogs, and even raccoons (Blankenship, 1996; Lim and Oliveri, 1982; Pitt et al., 1988; Samadapour and Checkowitz, 1998).

Indirect surface storm water runoff sources include leaking septic systems, illicit discharges, sanitary sewer overflows (SSOs), and combined sewer overflows (CSOs). These sources have the potential to deliver high concentrations of coliforms to receiving waters. Illicit connections from businesses and homes to the storm drainage system can discharge sewage or washwater into receiving waters. Leaking septic systems are estimated to constitute 10 to 40 percent of all systems. Inspection is the best way to determine whether a system is failing (Schueler, 1999).

There is also evidence that these bacteria can survive and reproduce in stream sediments and in storm sewers. During a storm event, they are resuspended and add to the in-stream bacteria load. Source area studies reported that end-of-pipe concentrations were an order of magnitude higher than any source area on the land surface; therefore, it is likely that the storm sewer system itself acts as a source (Bannerman, 1993; Steuer et al., 1997). Resuspension of fecal coliform bacteria from fine stream sediments during storm events has been reported in New Mexico (NMSWQB, 1999). The sediments in the storm sewer system and in streams may be significant contributors to the fecal coliform load. This area of research certainly warrants more attention to determine whether these sources can be quantified and remediated.

Giardia and *Cryptosporidium* in urban storm water are also a concern. There is evidence that urban watersheds and storm events might have higher concentrations of *Giardia* and *Cryptosporidium* than other surface waters (Stern, 1996). (See Table 2-9.) The primary sources of these pathogens are humans and wildlife. Although *Cryptosporidium* is found in less than 50 percent of storm water samples, data suggest that high *Cryptosporidium* values may be a concern for drinking water supplies. Both pathogens can cause serious gastrointestinal problems in humans (Bagley et al., 1998).

Table 2-9. Percentage Detection of *Giardia* Cysts and *Cryptosporidium* Oocysts in Subwatersheds and Wastewater Treatment Plant Effluent in the New York City Water Supply Watersheds

Source Water Sampled (No. of sources/No. of samples)	Percent Detection			
	Total *Giardia*	Confirmed *Giardia*	Total *Cryptosporidium*	Confirmed *Cryptosporidium*
Wastewater effluent (8/147)	41.5	12.9	15.7	5.4
Urban subwatershed (5/78)	41.0	6.4	37.2	3.9
Agricultural subwatershed (5/56)	30.4	3.6	32.1	3.6
Undisturbed subwatershed (5/73)	26.0	0.0	9.6	1.4

Source: Stern et al., 1996.

2.2.4.2 Receiving Water Impacts

Fecal coliform bacteria, fecal streptococci, and *E. coli* are consistently found in urban storm water runoff. Their presence indicates that human or other animal waste is also present in the water and that other harmful bacteria, viruses, or protozoans might be present as well. Concentrations of these indicator organisms in urban storm water are highly variable even within a given monitoring site. Data for fecal coliform bacteria illustrate this variability: site concentrations range from 10 to 500,000 most probable number per 100 milliliters (MPN/100mL) (Schueler, 1999).

Concentrations in urban storm water typically far exceed the 200 MPN/100 mL threshold set for human contact recreation. The mean concentration of fecal coliform bacteria in urban storm water for 34 studies across the United States was 15,038 MPN/100mL (Schueler, 1999). Another national database of 1,600 samples (mostly Nationwide Urban Runoff Program data collected in the 1980s), estimates the mean concentration at 20,000 MPN/100 mL (Pitt, 1998). Fecal streptococci concentrations for 17 urban sites had a mean of 35,351 MPN/100 mL (Schueler, 1999). Transport occurs primarily as a result of direct surface runoff, failing septic systems, SSOs, CSOs, and illicit discharges.

Human health can be affected by bacterial impacts on receiving waters when bacteria standards for water contact recreation, shellfish consumption, or drinking water are violated. Epidemiological studies from Santa Monica Bay have documented frequent sickness in people who swim near outfalls (SMBRP, 1996). Documented illnesses include fever, ear infections, gastroenteritis, nausea, and flu-like symptoms. Table 2-10 describes the effects of bacteria and protozoan problems on different receiving waters.

Table 2-10. Effects of Bacteria on Receiving Waters

Resource Affected	Impacts of Bacteria	Citations
Streams	• Human health issues	More than 80,000 miles of streams and rivers in non-attainment because of high fecal coliform levels (USEPA, 1998a)
Reservoirs	• Contamination of water supply	Increased treatment cost of drinking water due to bacteria contamination (USEPA, 1996)
Beaches	• Human health issues	More than 4,000 beach closings or advisories (USEPA, 1998b)
Estuaries	• Closing of shellfish beds • Beach closings	Nearly 4% of all shellfish beds restricted or conditional harvest due to high bacteria levels (NOAA 1992); More than 4,000 beach closings or advisories (USEPA, 1998b)

2.3 Physical Impacts of Construction and Land Development Activities

This subsection describes the physical impacts of construction activities and development conditions, which include hydrologic, geomorphic, habitat structure, thermal, and direct channel impacts. These impacts are most visible on the urban stream. Construction and land development impacts on stream systems are described for each of these impact categories (Table 2-11). Site differences of these impacts are also noted. Because it is very difficult to differentiate between physical impacts that occur during construction and impacts that result from post-development conditions, the discussion addresses physical impacts from a broader perspective. It does not differentiate between short-term effects arising and site construction activities from long-term impacts of post-development conditions.

Physical changes are often precipitated by changes in hydrology that result when permeable rural and forest land is converted to impervious surfaces like pavement and rooftops and relatively impermeable urban soils. The conversion causes a fundamental change in the hydrologic cycle because a greater fraction of rainfall is converted to surface runoff. This change in the basic hydrologic cycle causes a series of other impacts (Table 2-11). The stream immediately begins to adjust its size, through channel erosion, to accommodate larger flows. Streams normally increase their cross-sectional area by incising, widening, or often both. This process of channel response to increases in impervious surfaces accelerates sediment transport and destroys habitat. In addition, urbanization frequently leads to alteration of natural stream channels, such as straightening or lining with concrete or rock to transport water away from developed areas more quickly. Finally, impervious surfaces also absorb heat, thereby increasing stream temperatures during runoff events.

Table 2-11. Physical Impacts on Streams

Impact Class	Specific Impacts	Cause(s)
Hydrologic	• Increased runoff volume • Increased peak flood flow • Increased frequency of "bankfull" event • Decreased baseflow	• Paving over natural surfaces • Compaction of urban soils
Geomorphic	• Sediment transport modified • Channel area increase to accommodate larger flows	• Modified flows • Channel modification • Construction
Habitat structure	• Stream embeddedness • Loss of large woody debris • Changes in pool/riffle structure	• Modified flows • Stream channel erosion • Loss of riparian area
Thermal	• Increased summer temperatures	• Heated pavement • Storm water ponds • Loss of riparian area
Channel modification	• Channel hardening • Fish blockages • Loss of first and second order streams through storm drain enclosure	• Direct modifications to the stream system.

Figure 2-1 depicts the impacts of land development on the stream channel. At low levels of imperviousness, the stream has a stable channel, contains large woody debris, and has a complex habitat structure. As urbanization increases, the stream becomes increasingly unstable, increases its cross-sectional area to accommodate increased flows, and loses habitat structure. In highly urbanized areas, stream channels are often modified through channelization or channel hardening. These physical changes are often accompanied by decreased water quality.

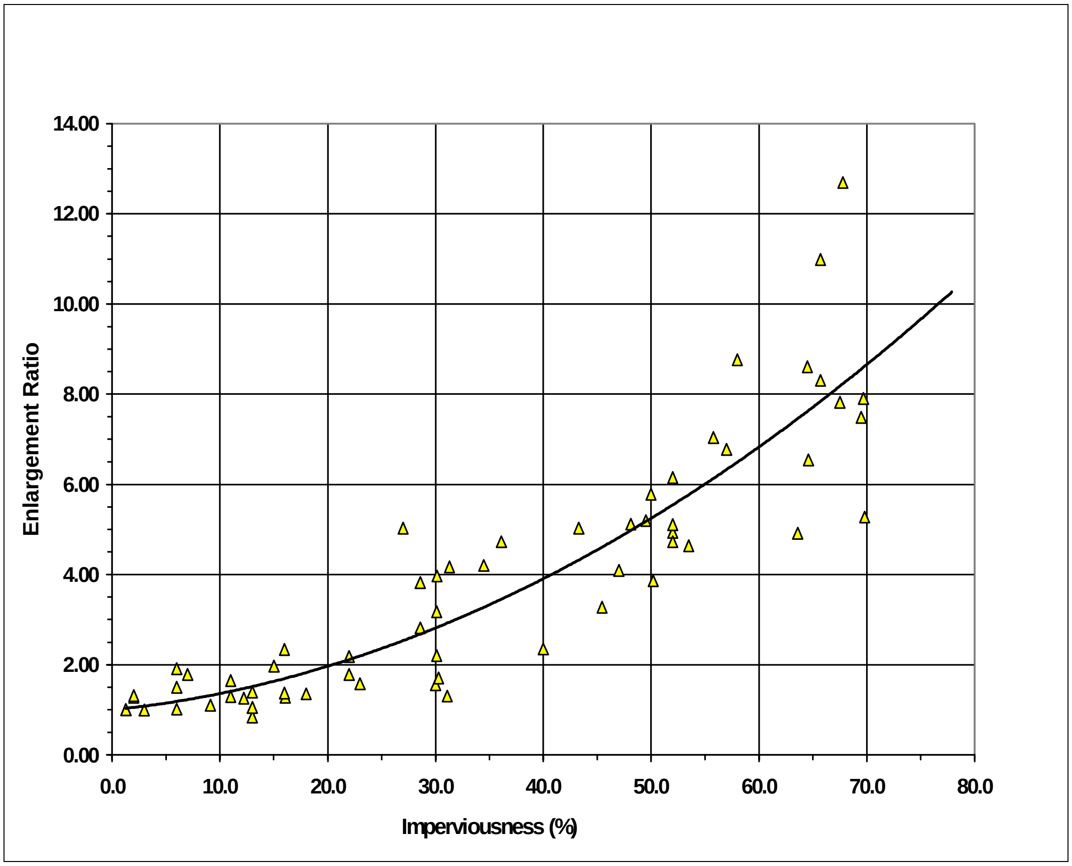


Figure 2-1. Ultimate Channel Enlargement
(Claytor and Brown, 2000; MacRae and DeAndrea, 1999)

2.3.1 Hydrologic Impacts

The increased runoff volume that results from land development alters the hydrograph, from its predeveloped condition (Figure 2-2). The resulting hydrograph accommodates larger flows with higher peak-flow rates. Because storm drain conveyance systems (e.g., curbs, gutters) improve the efficiency with which water is delivered to the stream, the hydrograph is also characterized by a more rapid time of concentration and peak discharge. Finally, the flow in the stream between events can actually decrease because less rainfall percolates into the soil surface to feed the stream as baseflow. The resulting hydrologic impacts include increased runoff volume, increased flood peaks, increased frequency and magnitude of bankfull storms, and decreased baseflow volumes.

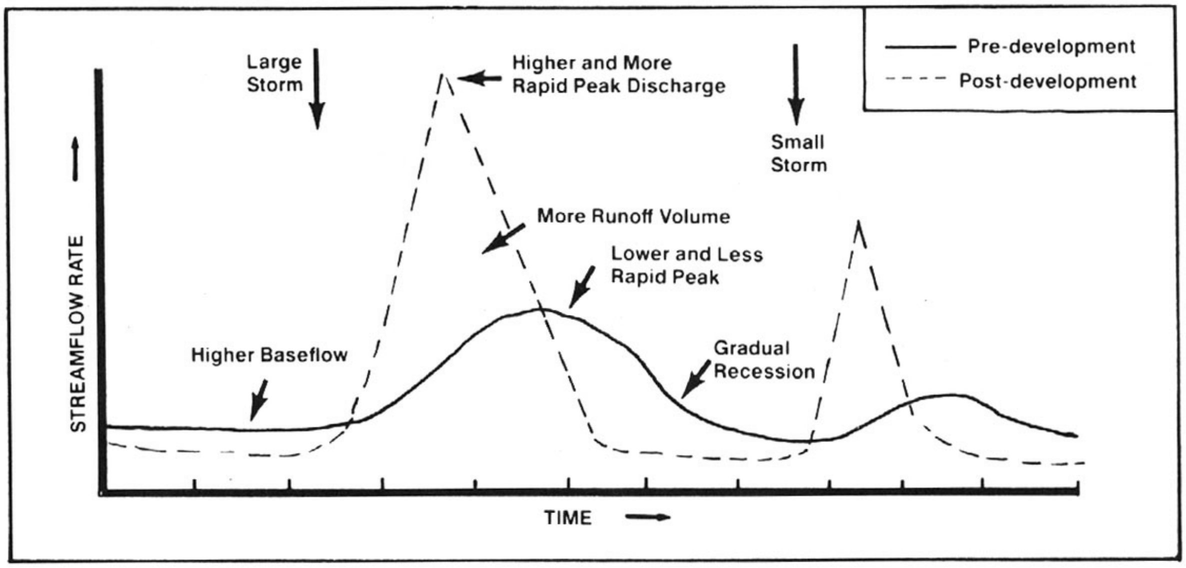


Figure 2-2. Altered Hydrograph in Response to Urbanization
(Schueler, 1987)

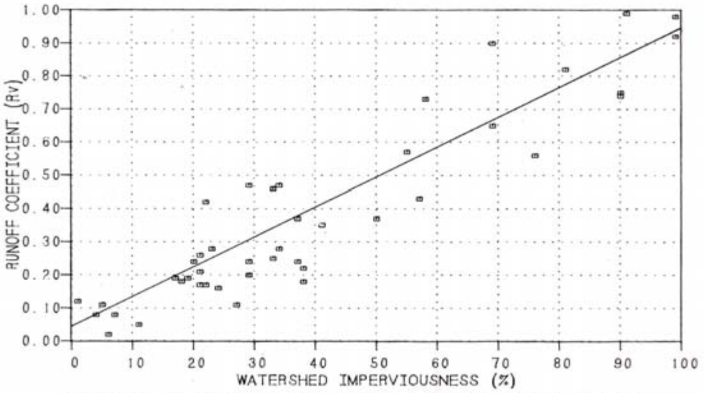
2.3.1.1 Increased Runoff Volume

Impervious surfaces and urban land use changes alter infiltration rates and increase runoff volumes. Table 2-12 shows the difference in runoff volume between a meadow and a parking lot. The parking lot produces approximately 15 times more runoff than a meadow for the same storm event. Schueler (1987) demonstrated that runoff values increase significantly with the impervious surfaces in a watershed (Figure 2-3). The increased volume of water from urban areas is the greatest single cause of the negative impacts of urban storm water on receiving waters. The volume causes channel erosion and loss of habitat stability, as well as an increase in the total load of many pollutants such as sediment and nutrients.

Table 2-12. Hydrologic Differences Between a Parking Lot and a Meadow

Hydrologic or Water Quality Parameter	Parking Lot	Meadow
Runoff coefficient	0.95	0.06
Time of concentration (minutes)	4.8	14.4
Peak discharge, 2-yr, 24-h storm (ft^3/s)	4.3	0.4
Peak discharge rate, 100-yr storm (ft^3/s)	12.6	3.1
Runoff volume from 1-in. storm (ft^3)	3,450	218
Runoff velocity @ 2-yr storm (ft/sec)	8	1.8

Key Assumptions: 2-yr, 24-hr storm = 3.1 in.; 100-yr storm = 8.9 in.
Parking Lot: 100% imperviousness; 3% slope; 200-ft flow length; hydraulic radius = 0.03; concrete channel; suburban Washington ‘C’ values
Meadow: 1% impervious; 3% slope; 200-ft flow length; good vegetative condition; B soils; earthen channel
Source: Schueler, 1987.



NOTE: 44 small urban catchments monitored during the national NURP study. (For mean values, see Table A.5).

Figure 2-3. Runoff Coefficient Versus Impervious Cover
(Schueler, 1987).

Construction activities also cause fundamental modifications in native soils. The compaction of urban soils and the removal of topsoil during construction decreases the infiltration capacity of the soil, resulting in a corresponding increase in runoff (Schueler, 2000). The bulk density is a measure of soil compaction, and Table 2-13 shows the values for different aspects of urbanization.

Table 2-13. Comparison of Bulk Density for Undisturbed Soils and Common Urban Conditions

Undisturbed Soil Type or Urban Condition	Surface Bulk Density (grams/cubic centimeter)
Peat	0.2 to 0.3
Compost	1.0
Sandy Soils	1.1 to 1.3
Silty Sands	1.4
Silt	1.3 to 1.4
Silt Loams	1.2 to 1.5
Organic Silts/Clays	1.0 to 1.2
Glacial Till	1.6 to 2.0
Urban Lawns	1.5 to 1.9
Crushed Rock Parking Lot	1.5 to 1.9
Urban Fill Soils	1.8 to 2.0
Athletic Fields	1.8 to 2.0
Rights of Way and Building Pads (85%)	1.5 to 1.8
Rights of Way and Building Pads (95%)	1.6 to 2.1
Concrete Pavement	2.2

Note: Shading indicates “urban” conditions.
Source: Schueler, 2000.

2.3.1.2 Increased Flood Peaks

Increased flow volume increases peak flows. Data from Sauer et al. (1983) suggest that peak flow from large flood events (10-year to 100-year storm events) increases substantially with urbanization. The paper presents results of a survey of urban watersheds throughout the United States and predicts flood peaks based on watershed impervious cover and a “basin development factor” that reflects watershed characteristics such as the amount of curb and gutter, and channel modification. These data suggest that at 50 percent impervious cover, the peak flow for the 100-year event can be as much as twice that in an equivalent rural watershed. Data from Seneca Creek in Montgomery County, Maryland, suggest a similar trend. The watershed experienced significant growth during the 1950s and 1960s. Comparison of gauge records from 1961 to 1990 to those from 1931 to 1960 suggests that the peak 10-year flow event increased from 7,300 to 16,000 cfs, an increase of more than 100 percent (Leopold, 1994).

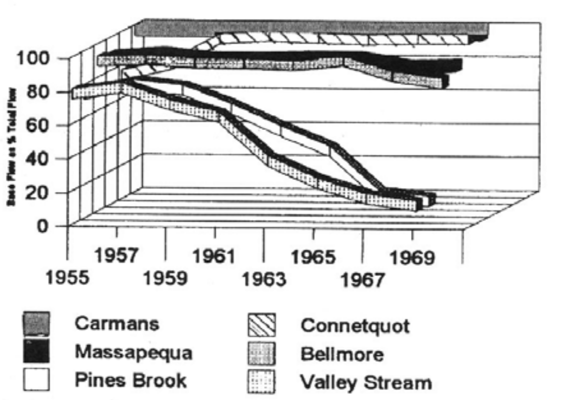
2.3.1.3 Increased Frequency and Volume of Bankfull Flows

Stream channel morphology is more influenced by frequent (1- to 2-year) storm events, or “bankfull” flows, than by large flood events. Hollis (1975) demonstrated that urbanization increased the frequency and magnitude of these smaller-sized runoff events much more than the larger events. Data from this study suggest that streams increase their 2-year bankfull discharge by two to five times after development takes place. Many other studies have documented the increase in flow associated with impervious cover. A study by Guay (1995) compared the 2-year flows events before and after development in an urban watershed in Parris Valley, California, in the 1970s and in the 1990s. The impervious level of 9 percent in the 1970s increased to 22.5 percent by the 1990s. The 2-year discharge more than doubled from 646 cfs to 1,348 cfs. A 13 percent change in impervious cover resulted in a doubling of the 2-year peak flow.

A significant impact of land development is the frequency with which the bankfull event occurs. Leopold (1994) observed a dramatic increase in the frequency of the bankfull event in Watts Branch, an urban subwatershed in Rockville, Maryland. This watershed also experienced significant development between the 1950s and 1960s. A comparison of gauge records indicated that the bankfull storm event frequency increased from two to seven times per year from 1958 to 1987.

2.3.1.4 Changes in Baseflow

Land development results in a smaller recharge to groundwater and a corresponding decrease in stream flow during dry periods (baseflow). Only a small amount of evidence, however, documents this decrease in baseflow. Spinello and Simmons (1992) demonstrated that baseflow in two urban Long Island streams went dry seasonally as a result of urbanization (Figure 2-4). Another study in North Carolina could not conclusively determine that urbanization reduced baseflow in some streams in that area (Evett et al., 1994). It is important to note, however, that groundwater flow paths are often complex. Water supplying baseflow feeding the stream can be from deeper aquifers or can originate in areas outside the surface watershed boundary. In arid and semiarid areas, watershed managers have reported that baseflow actually increases in urban areas. Increased infiltration from people watering their lawns and return flow from sewage treatment plants are two possible sources (Caraco, 2000). Recharge of clean groundwater is important in these communities, and managers would rather see clean water infiltrated than transported as surface water during storm events.



Notes:
Carmans and Connetquot: Rural/suburban, watersheds are unsewered
Bellmore and Massapequa: Moderately urbanized, not sewered until 1989
Valley Stream and Pine Brook: Urbanized and densely populated watersheds, sewer systems completed in 1960s
1953-1964: Period of sanitary sewer construction in eastern Nassau County
1962-1966: Drought years

Figure 2-4. Baseflow in Response to Urbanization: Nassau County, NY
(Spinello and Simmons, 1992)

2.3.2 Impacts on Geomorphology/Sediment Transport

Changes in hydrology, combined with additional sediment sources from construction and modifications to the stream channel, result in changes to the geomorphology of stream systems. These impacts include increased, and sometimes decreased, sediment transport and channel enlargement to accommodate larger flows.

2.3.2.1 Increased Transport of Sediment

The increased frequency of bankfull (1- to 2-year) storms causes more “effective work” (as defined by Leopold), causing greater sediment transport and bank erosion to take place within the channel. For the same storm event, the increased volume results in a greater amount of total stress above the critical shear stress required to move bank sediment (Figure 2-5). This effect is compounded by the fact that smaller, more frequent storm events also cause flows in excess of the stress required to move sediment.

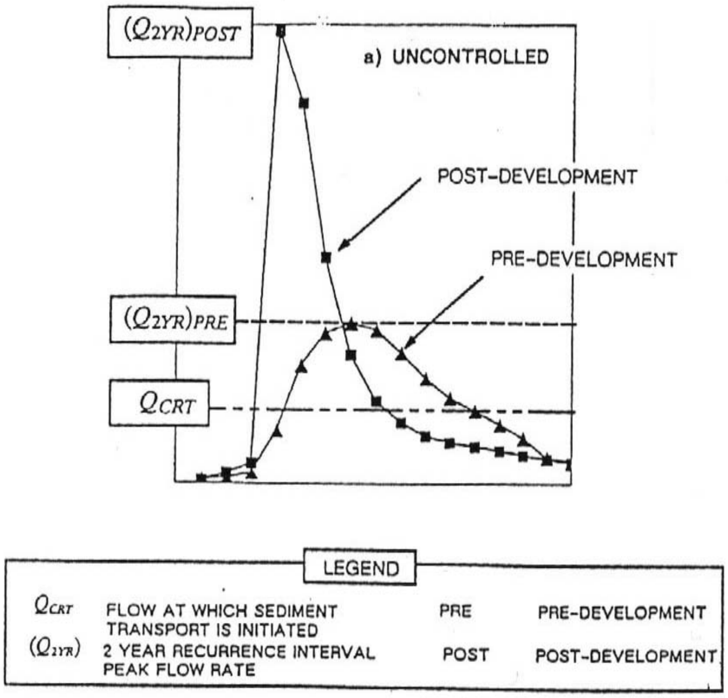
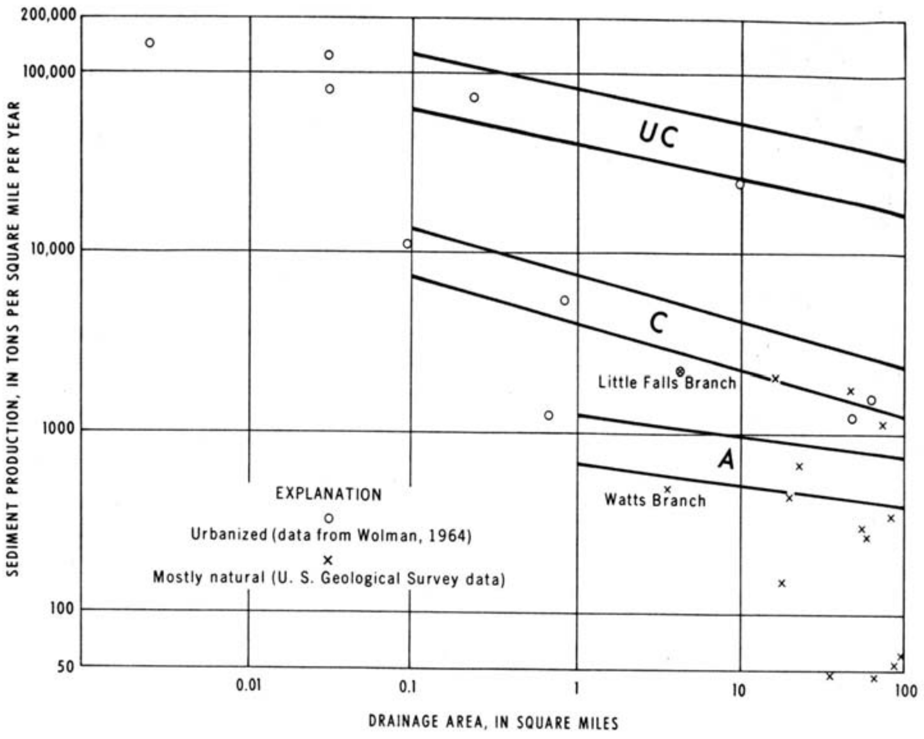


Figure 2-5. Increased Shear Stress from an Urban Hydrograph
(Schueler, 1987)

The result of this change in effective work on stream banks is increased channel erosion. Studies in California (Trimble, 1997) and Austin, Texas (Dartinguenave et al., 1997) suggest that 60 to 75 percent of the sediment transport in urban watersheds is from channel erosion as compared to estimates of between 5 percent and 20 percent for rural streams (Collins et al., 1997; Walling and Woodward, 1995). If the sediment is not deposited in the channel at obstructions, it is transported downstream to receiving waters such as lakes, estuaries, or rivers. The result can be reduced storage and habitat due to the filling of these water bodies.

The clearing and grading of land for new construction at the outset of urbanization is another source of sediment in urban streams. Figure 2-6 (from Leopold, 1968) illustrates the difference in sediment from uncontrolled and controlled construction sites.



Annual sediment production per square mile for urbanized and natural areas. Zones: *A*, agricultural; *C*, under construction; *UC*, under construction and undiluted.

Figure 2-6. Sediment Production from Construction Sites
(Leopold, 1968)

2.3.2.2 Decreased Sediment Transport

Decreased sediment transport off the land surface itself can result after urbanization as natural drainage and first-order channels are replaced by storm drains and pipes (Figure 2-7). Channel erosion downstream might result when any export of sediment is not replaced by diminished upstream sediment supply. Ultimately, after significant erosion has taken place, the downstream channel will have adjusted to its post-development flow regime and sediment transport will be reduced. Hence, the stability of the land surface and the piping of drainage channels limit storm water's exposure to sediment and reduce the sediment supply.

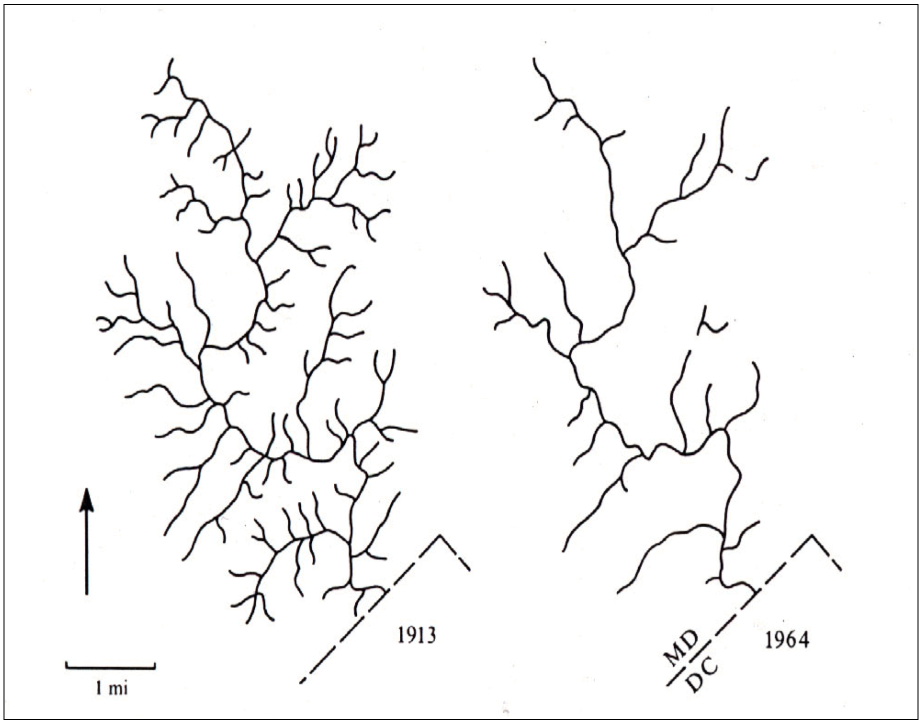


Figure 2-7. Drainage Network of Rock Creek, Maryland Before and After Urbanization
(Dunne and Leopold, 1978)

2.3.2.3 Increase in Size of Channel

Channels increase their cross-sectional area to respond to higher and more frequent urban flows. In post-development urban watersheds, the increase in frequency of this channel-forming event normally causes sediment transport to be greater than sediment supply. The channel widens (and/or downcuts) in response to this change in sediment equilibrium (Allen and Narramore, 1985; Booth, 1990 Hammer, 1977; Morisawa and LaFlure, 1979;). Some research suggests that over time channels will reach an “ultimate enlargement,” relative to a predeveloped condition, and that impervious cover can predict this enlargement ratio (MacRae and DeAndrea, 1999). This was shown in Figure 2-3, which depicted the relationship between ultimate stream channel enlargement and impervious cover for alluvial streams, based on data from Texas, Vermont, and Maryland. Figure 2-8 shows the channel expansion that has taken place and is projected to occur in Watts Branch near Rockville, Maryland, in response to urbanization.

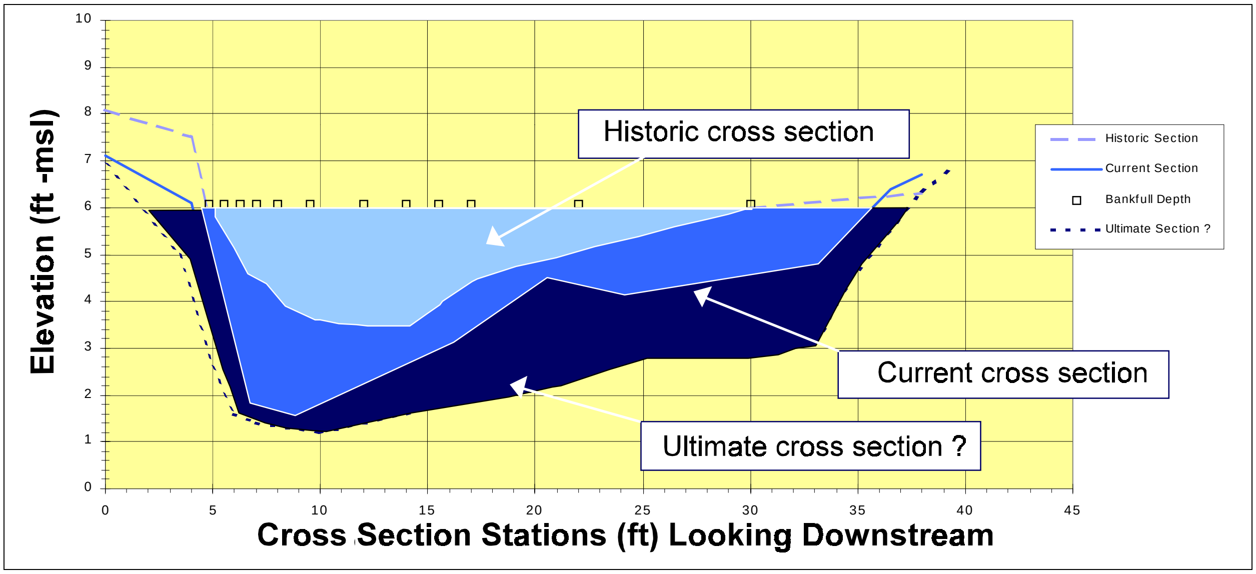


Figure 2-8. Channel Enlargement in Watts Branch, Maryland (Schueler, 1987)

Note: Cross sections have been overlaid for illustration purposes only. Actual sections do not share the same datum.

Stream channels expand by incision, widening, or both. Incision occurs when the stream downcuts and the channel expands in the vertical direction. Widening occurs when the sides of the channel erode and the channel expands horizontally. Either method results in increased transport of sediment downstream and degradation of habitat. Channel incision is often limited by grade control from bedrock, large substrate, bridges, or culverts. These structures impede the downward erosion of the stream channel and limit incision. In substrates such as sand, gravel, and clay, however, stream incision can be of greater concern (Booth, 1990).

Channel widening more frequently occurs when streams have grade control and the stream cuts into its banks to expand its cross-sectional area. Urban channels frequently have artificial grade control due to the frequent culverts and road crossings. These are often areas where sediment can accumulate as a result of undersized culverts and bridge crossings.

2.3.3 Changes in Habitat Structure

Land development results in many changes in habitat structure, including embeddedness, decreased riffle/pool quality, and loss of large woody debris (LWD). Increased sedimentation due to clearing and grading during construction resulting from bank erosion can significantly reduce the amount of habitat for substrate-oriented species.

2.3.3.1 Embeddedness

Increased sediment transport from construction and land development can fill the interstitial spaces between rocks and riffles, which are important habitat for macroinvertebrates and fish species, such as darters and sculpins. The stream bottom substratum is a critical habitat for trout and salmon egg incubation and embryo development (May et al., 1997).

2.3.3.2 Large Woody Debris (LWD)

The presence and stability of LWD is a fundamental habitat parameter. LWD can form dams and pools, trap sediment and detritus, provide stabilization to stream channels, dissipate flow energy, and promote habitat complexity (Booth et al., 1996). For example, depending on the size of the woody debris and the stream, the debris can create plunge, lateral, scour, and backwater pools, short riffles, undercut banks, side channels, and backwaters, and create different water depths (Spence et al., 1996). The runoff generated in urban watersheds from small storms can be enough to transport LWD. Maxted et al. (1994) found that woody debris were typically buried under sand and silt in urban streams. In addition, the clearing of riparian vegetation limits an important source of large woody debris. Horner et al. (1996) present evidence from the Pacific Northwest (Figure 2-9) that LWD in urban streams decreases with increased imperviousness.

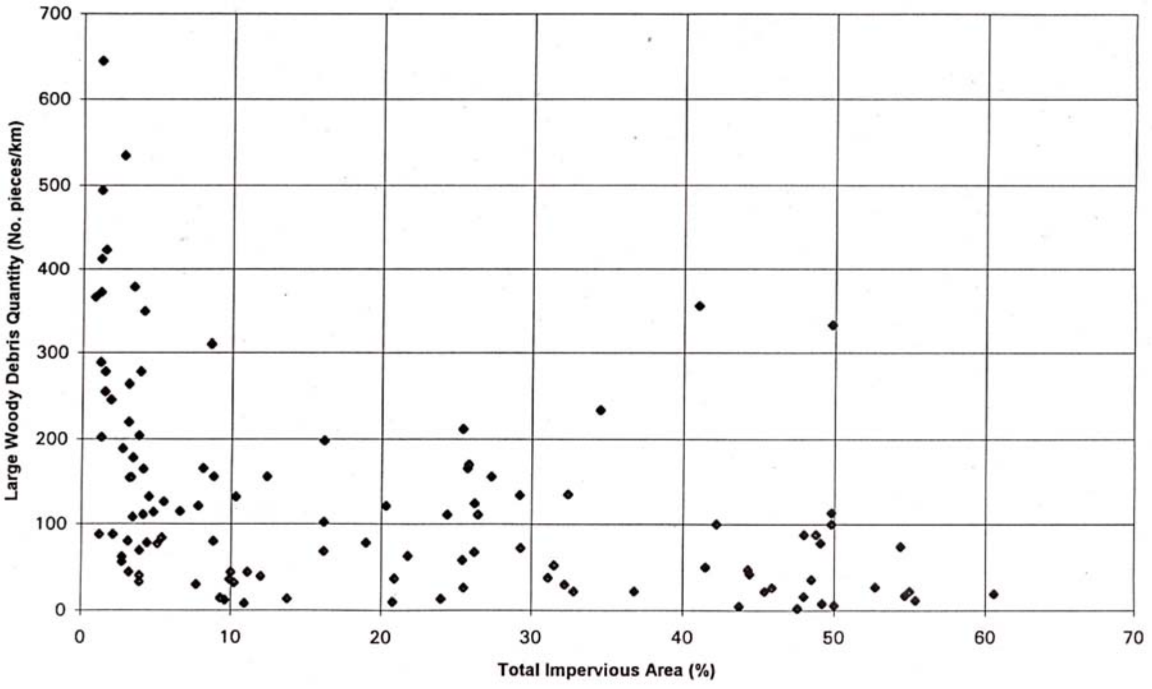


Figure 2-9. Large Woody Debris as a Function of Watershed Imperviousness
(Horner et al., 1996)

2.3.3.3 Changes in Stream Features

Habitat diversity is a key factor in maintaining a diverse and well-functioning aquatic community. The complexity of the habitat results in increased niches for aquatic species. Sediment and increases in flow can reduce the residual depths in pools and decrease the diversity of habitat features such as pools, riffles, and runs. Richey (1982) and Scott et al. (1986) reported an increase in the prevalence of glides and a corresponding altered pool/riffle sequence due to urbanization.

2.3.4 Thermal Impacts

Summer in-stream temperatures have been shown to increase significantly (5 to 12 degrees) in urban streams because of direct solar radiation, runoff from heat-absorbing pavement, and discharges from storm water ponds (Galli, 1991). Increased water temperatures can prevent temperature-sensitive species from surviving in urban streams. Figure 2-10 shows the increase in water temperature resulting from urbanization.

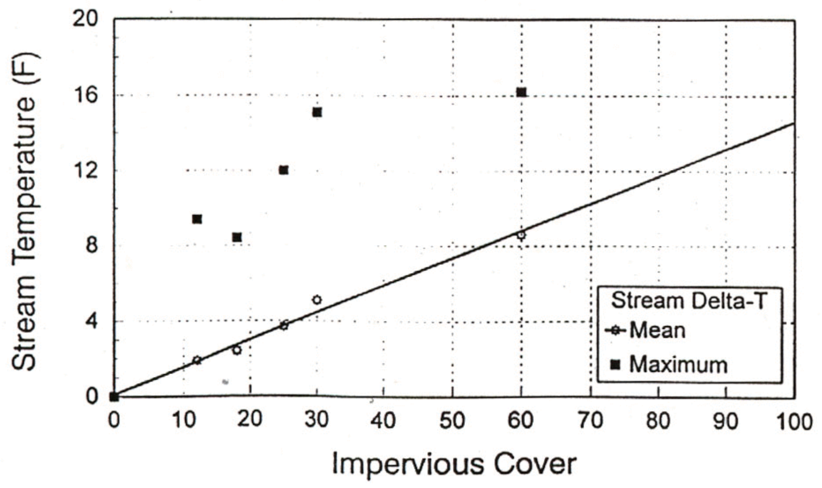


Figure 2-10. Stream Temperature Increase in Response to Urbanization
(Galli, 1991)

Water temperature in headwater streams is strongly influenced by local air temperatures. Galli (1991) reported that stream temperatures throughout the summer are higher in urban watersheds, and the degree of warming appears to be directly related to the imperviousness of the contributing watershed. Over a 6-month period, five headwater streams in the Maryland Piedmont that have different levels of impervious cover were monitored. Each urban stream had mean temperatures that were consistently warmer than that of a forested reference stream, and the size of the increase appeared to be a direct function of watershed imperviousness. Other factors, such as a lack of riparian cover and ponds, were also shown to amplify stream warming, but the primary contributing factor appeared to be watershed impervious cover.

2.3.5 Direct Channel Impacts

2.3.5.1 Channel Straightening and Hardening/Reduction in First-Order Streams

Channel straightening and hardening includes the addition of riprap or concrete to the channel, the straightening of natural channels, and the piping of first-order and ephemeral streams. Although this conversion process often becomes necessary to control runoff from urbanized areas, adverse impacts often occur downstream. In a national study of urban watersheds in 269 gauged basins, Sauer et al. (1983) determined that channel straightening and channel lining (hardening)—along with the percentage of curbs and gutters, streets, and storm sewers—were the dominant land use variables affecting storm flow. These variables all affect the efficiency with which water is transported to the stream channel. Maintaining this efficiency increases the velocities needed for storm water to exceed critical shear stress velocities, eroding the channel. These factors also considerably degrade any natural habitat for stream biota.

2.3.5.2 Fish Blockages

Infrastructure associated with urbanization—such as bridges, dams, and culverts—can have a considerable effect on the ability of fish to move freely upstream and downstream in the watershed. This in turn can have localized effects on small streams, where nonmigratory fish species can be inhibited by the blockage from recolonizing areas after acutely toxic events. Anadromous fish species such as shad, herring, salmon, and steel head also can be blocked from making the upstream passage that is critical for their reproduction.

2.3.6 Site Differences in Physical Impacts

Site differences that can affect physical impacts include location of the impervious surfaces, presence of vegetation, and soil type within the watershed. Location of the impervious development can be instrumental in the timing of runoff in a watershed. If the development is at the bottom of the watershed, peak flow from the urbanized area will likely have passed downstream before the flow peaks from the upper watersheds reach the urbanized area (Sauer et al., 1983). Vegetation can reduce channel erosion from storm flows. A study in British Columbia showed that meander bends with vegetation were five times less likely to experience significant erosion from a major flood than similar non-vegetated meander bends (Beeson and Doyle, 1995). The types and porosity of soils are also important in determining runoff characteristics from the land surface and erosion potential of the channels. Allen and Narramore

(1985) showed that channel enlargement in chalk channels was from 12 to 67 percent greater than in shale channels near Dallas, Texas. They attributed the differences to greater velocities and shear stress in the chalk channels.

Section 3 Description of Assessment Methodology

3.1 Introduction

This section describes EPA's methodology to assess the environmental impacts of the construction and development category. The methodology was used by EPA to quantify the potential environmental and economic benefits that would result from implementation of the proposed regulatory options. These quantified benefits are enumerated in Section 4 of this document.

The methodology described in this section focuses on impacts related to pollutant loadings discharged from construction sites. EPA used total suspended solids (TSS) to indicate pollutant-related benefits for proposed options.

3.2 Methodology to Estimate Pollutant Loadings from Construction Runoff Water Discharges

EPA's methodology for estimating construction site pollutant loadings builds upon the methodology used in the *Economic Analysis of the Final Phase II Storm Water Rule* (USEPA, 1999). This report (referred to herein as the Phase II EA):

- Estimated the annual number of construction sites or starts covered under Phase I and Phase II programs

- Developed detailed "model construction sites" to represent a range of construction site types, sizes and locations to estimate national construction site TSS loadings (3 site sizes, 5 slopes, and 15 climatic regions)

- Estimated suspended solids loadings with and without a suite of BMPs.

The Phase II EA estimated that in the absence of any controls, construction sites on average generate approximately 40 tons of TSS per acre per year. In addition, the Phase II EA estimated that properly designed, installed and maintained erosion and sediment (E&S) control BMPs, in combination, can potentially achieve a 90 to 95 percent reduction in sediment runoff. The suite of E&S BMPs evaluated in EPA's Phase II EA is shown in Table 3-1.

Table 3-1. Common Construction Erosion and Sediment Control BMPs

BMP Description	Erosion Control[a]	Sediment Control[b]
Silt Fence	Yes	
Runoff Diversion	Yes	
Mulch	Yes	
Seed and Mulch	Yes	
Construction Entrance		Yes
Stone Check Dam		Yes
Sediment Trap		Yes
Sediment Pond		Yes

a. Erosion controls are those distributed throughout the site to help retain soil in place.
b. Sediment controls are intended to intercept eroded soils preventing runoff from the construction site.

The analysis conducted by EPA indicates that environmental benefits would be achieved by implementing procedures that ensure good E&S practices and that establish design criteria and installation for construction site BMPs. The suite of BMPs considered by EPA in its effluent guidelines development is presented in Table 3-2.

Table 3-2. Site BMPs Evaluated by EPA For Effluent Guidelines Development

BMP Description	Application Rationale
Design/Installation Criteria	
Sediment Basins	Standardization to 3,600 cubic feet of storage per watershed acre for sites ≥ 10 acres.
Sediment Traps	Applicable to sites ≥ 10 acres.
Mulch	Mulching of any denuded surface would be required within 2 weeks of final grade.
PAM[a]	PAM would be used as a temporary stabilization method until final cover can be installed. EPA assumed that PAM is appropriate for 20 percent of construction sites.
Site Administration BMPs	
E&S Site Inspections and Certification	(a) Certify completion of SWPPP, (b) Certify installation of BMPs, (c) Conduct inspections every 14 days, (d) Remove sediment from basins and traps periodically, and (e) Certify that the site has been stabilized prior to filing NOT.

[a] PAM: Polyacrylamide

Implementing these BMPs as part of the proposed Option 1 is expected to achieve benefits due to:

- Higher installation rates because certification would be required;
- Certification of BMP implementation that creates a verifiable record of site E&S controls;
- Higher BMP maintenance frequency due to proposed inspection requirements.

In addition, Option 2 is expected to achieve additional benefits due to:

- Shorter no-control periods due to more timely application of erosion BMPs;
- Standardization of design/sizing criteria (Codification of BMP designs under Option 2 would result in higher removal efficiencies).

Under the proposed options EPA estimates increased efficiency, as measured by the pounds of eroded material retained on construction sites, to range from 5 to 15 percent for Option 1 and 20 percent for Option 2. The lower and upper percentages of net performance for Option 1 yield upper and lower bounds of reductions in construction site loadings discharged to the environment, respectively. These ranges indicate potential additional reductions in suspended solid discharges as a result of regulatory implementation, and do not account for states with equivalent construction programs and for acres not covered by the proposed guidelines. To account for these two factors, EPA developed additional steps to lower its estimates of TSS loadings reductions.

For Option 2, EPA also reduced the estimated loadings to discount sites between 1 and 5 acres in size. These sites would not be regulated under proposed Option 2 effluent guidelines, and constitute approximately 15 percent of annually developed acreage. EPA discounted TSS loadings reductions estimates by 15 percent to account for the fact that these sites would not be affected by Option 2.

As detailed in Appendix A, EPA performed an evaluation of state construction general permits and regulations to estimate the percentage of national acreage developed annually that is currently covered under regulation that is equivalent to or exceeds the proposed option levels. EPA evaluated states, focusing on those with annual developed acreage greater than 50,000 acres. Overall, EPA estimated that approximately 41 percent of developing acreage is currently subject to regulatory requirements equivalent to or exceeding those under Options 1 and 2. EPA surveyed the following four proposed requirements:

1. 3,600 cubic feet per acre storage requirement for sediment basins on sites ≥ 10 acres
2. Certification of BMPs at installation
3. 14-day or more frequent inspection
4. 14-day cover for erosion and dust control.

To account for states currently performing at or above the levels designated under Option 1and 2, EPA reduced estimated TSS loading estimates by 41 percent to remove states with equivalent programs. The results of EPA’s loadings assessment are provided in Section 4.

3.3 Characterizing the Nation’s Stream Network

To evaluate environmental impacts related to stream size and length, EPA characterized stream densities in 19 "ecoregions" for the contiguous United States (Figure 3-1). Detailed methodologies are explained in Appendix B. The 19 ecoregions were developed based on the stream density of large river systems, a relatively coarse assessment. Next, EPA performed a characterization or inventory to estimate a typical stream density within each region, and to define a statistically “standard” watershed for each ecoregion. EPA first determined the stream network based on stream orders[1], assessing approximately 100,000 acres in each ecoregion. The analysis estimated the average number, acreage, slope, and length of streams, as well as the ratio of stream orders and their drainage area. EPA used those data to estimate the total stream miles in each ecoregion's standard watershed. Because EPA focused on land development, regional stream densities were established through spatial and statistical averaging of actual stream networks at the developing fringe of existing metropolitan areas.

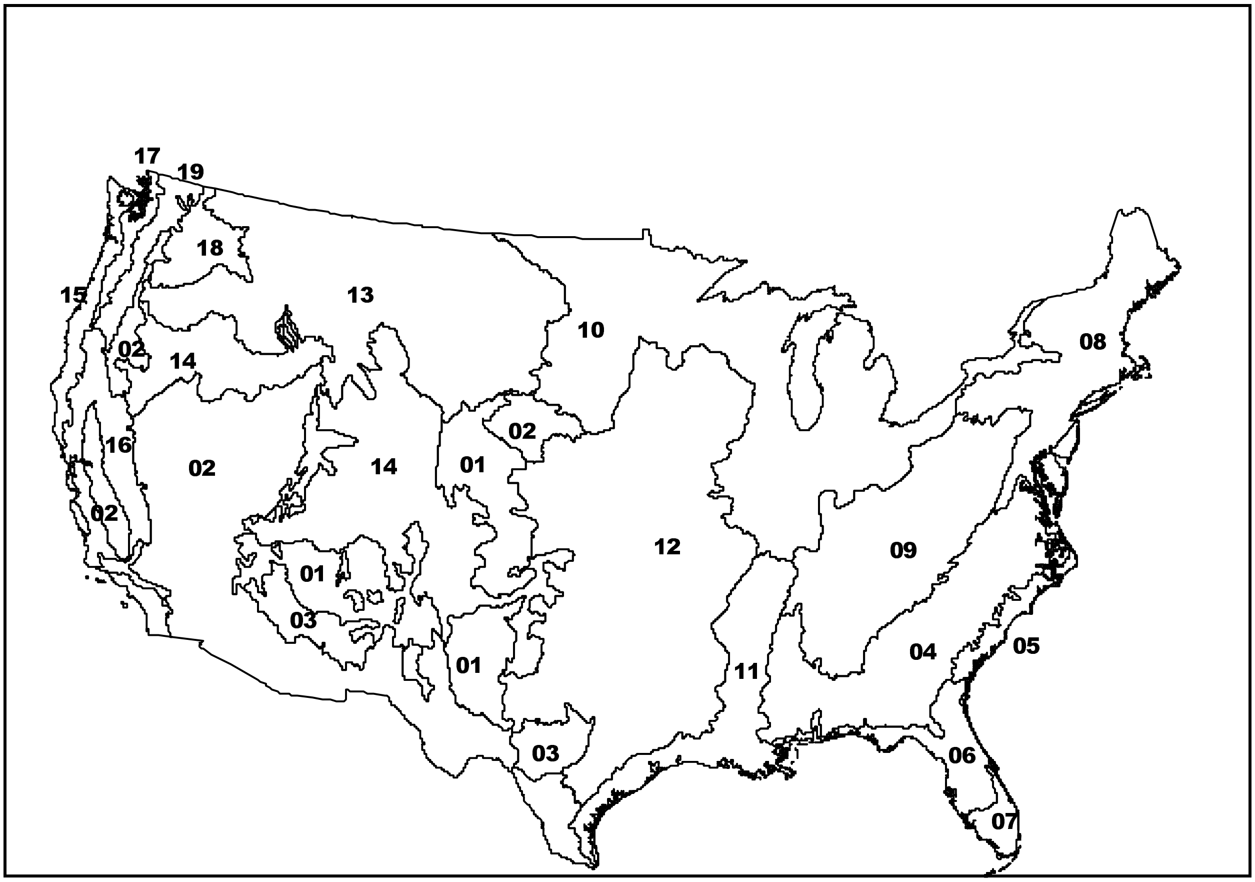


Figure 3-1. Ecoregions for Stream Inventorying

Only one metropolitan area was analyzed for each ecoregion because of the extensive amount of data processed to define stream networks based on 30 meter digital elevation data for 100,000 acres.

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[1] Stream Order is a hierarchal ordering of streams based on the degree of branching. A first order stream is an unbranched or unforked stream. Two first-order streams flow together to make a second-order stream; two second- order streams combine to make a third-order stream. First-order watersheds in EPA's ecoregion-specific standard watersheds occupy between 20 and 50 acres.

EPA's stream inventory focused on relatively small watersheds that terminate in a small perennial stream (e.g., a fourth-order stream in the mid-Atlantic area). Intermittent and small perennial streams are expected to be the water bodies most adversely affected by the activities of the construction and land development industry. Less emphasis was placed on the inventory and evaluation of larger perennial rivers (i.e., greater than fifth-order in the mid-Atlantic area) because they potentially have more pollutant sources and isolating the benefits of the proposed effluent guidelines in these water bodies could potentially be difficult.

The results of EPA's assessment of stream information in each of the 19 ecoregion standard watersheds are presented in Table 3-3. In general, whenever EPA determined it should to estimate impacts related to the total mileage of streams located within a defined acreage, EPA used these values to convert the acreage to stream miles on the basis of stream order. Information in the table (i.e., number and stream length) was also used to scale-up the impacts on a stream order basis.

Table 3-3. Results of the National Stream Survey

Eco-Region	Reach Order	Number of Segments Analyzed	General Ratio of Stream Orders*	Average Segment Length, ft	Average Slope of River, ft/ft	Average Watershed Acreage per Segment	Drainage Area Ratio of Upstream Channels to the Downstream Channel**
1	1	608	87	428	3.06%	53.07	0
	2	104	15	1,078	1.75%	273.35	5.15
	3	22	3	3,323	1.07%	1,597.67	5.84
	4	7	1	6,914	0.81%	6,425.88	4.02
2	1	742	82	499	11.25%	45.78	0
	2	166	18	1,185	7.37%	228.24	4.99
	3	34	4	2,801	5.25%	1,194.55	5.23
	4	9	1	4,297	4.51%	4,434.78	3.71
3	1	829	92	423	3.11%	53.08	0
	2	179	20	1,017	2.00%	266.69	5.02
	3	35	4	2,307	1.29%	1,316.02	4.93
	4	9	1	9,367	0.62%	8,283.03	6.29

Table 3-3. Results of the National Stream Survey

Eco-Region	Reach Order	Number of Segments Analyzed	General Ratio of Stream Orders*	Average Segment Length, ft	Average Slope of River, ft/ft	Average Watershed Acreage per Segment	Drainage Area Ratio of Upstream Channels to the Downstream Channel**
4	1	961	120	309	2.81%	29.55	0
	2	209	26	591	1.62%	129.62	4.39
	3	45	6	1,259	1.03%	556.92	4.3
	4	8	1	6,411	0.50%	4,417.34	7.93
5	1	862	86	434	0.52%	57.35	0
	2	201	20	825	0.40%	398.05	6.94
	3	47	5	1,751	0.28%	2,119.32	5.32
	4	10	1	3,835	0.17%	6,114.79	2.89
6	1	961	120	371	4.37%	29.55	0
	2	209	26	779	3.20%	138.31	4.68
	3	45	6	1,372	2.45%	554.87	4.01
	4	8	1	4,724	1.13%	3,369.25	6.07
7	1	862	86	351	6.22%	42.56	0
	2	201	20	954	3.21%	229.2	5.39
	3	47	5	2,028	1.81%	1,096.47	4.78
	4	10	1	5,850	0.84%	5,447.43	4.97
8	1	638	80	302	1.08%	27.43	0
	2	141	18	612	0.72%	123.19	4.49
	3	35	4	1,340	0.52%	580.24	4.71
	4	8	1	3,058	0.31%	2,112.57	3.64
9	1	645	81	356	0.43%	27.31	0
	2	123	15	631	0.50%	127.26	4.66
	3	28	4	2,170	0.34%	845.78	6.65
	4	8	1	7,322	0.14%	5,134.48	6.07

Table 3-3. Results of the National Stream Survey

Eco-Region	Reach Order	Number of Segments Analyzed	General Ratio of Stream Orders*	Average Segment Length, ft	Average Slope of River, ft/ft	Average Watershed Acreage per Segment	Drainage Area Ratio of Upstream Channels to the Downstream Channel**
10	1	1,238	88	306	3.35%	30.89	0
	2	275	20	742	2.05%	158.44	5.13
	3	59	4	1,421	1.27%	691.2	4.36
	4	14	1	4,392	0.70%	4,339.58	6.28
11	1	1,050	105	353	3.71%	30.89	0
	2	198	20	859	2.04%	158.44	5.13
	3	41	4	1,595	1.29%	691.2	4.36
	4	10	1	3,241	0.81%	4,339.58	6.28
12	1	960	80	376	14.71%	34.1	0
	2	215	18	801	9.29%	155.93	4.57
	3	50	4	2,162	5.95%	867.6	5.56
	4	12	1	3,054	4.15%	3,082.49	3.55
13	1	753	63	272	22.47%	21.96	0
	2	161	13	587	14.88%	107.42	4.89
	3	43	4	1,311	9.97%	497.52	4.63
	4	12	1	6,152	3.77%	3,738.79	7.51
14	1	933	72	427	5.78%	37.21	0
	2	194	15	865	3.50%	171.65	4.61
	3	44	3	1,635	2.38%	720.88	4.2
	4	13	1	2,073	1.35%	2,563.73	3.56
15	1	1,424	129	381	3.86%	31.84	0
	2	290	26	697	2.29%	143.06	4.49
	3	58	5	1,469	2.05%	545.11	3.81
	4	11	1	3,315	1.07%	2,680.10	4.92

Table 3-3. Results of the National Stream Survey

Eco-Region	Reach Order	Number of Segments Analyzed	General Ratio of Stream Orders*	Average Segment Length, ft	Average Slope of River, ft/ft	Average Watershed Acreage per Segment	Drainage Area Ratio of Upstream Channels to the Downstream Channel**
16	1	1,009	72	463	8.12%	39.77	0
	2	224	16	1,064	5.09%	191.81	4.82
	3	53	4	2,170	3.92%	888.83	4.63
	4	14	1	4,309	2.56%	4,293.71	4.83
17	1	464	77	464	20.60%	57.02	0
	2	79	13	1,605	14.51%	395.06	6.93
	3	21	4	3,018	9.47%	1,823.06	4.61
	4	6	1	5,392	4.27%	6,881.95	3.77
18	1	251	84	381	3.86%	31.84	0
	2	50	17	697	2.29%	143.06	4.49
	3	13	4	1,469	2.05%	545.11	3.81
	4	3	1	3,315	1.07%	2,680.10	4.92
19	1	457	65	463	8.12%	39.77	0
	2	102	15	1,064	5.09%	191.81	4.82
	3	27	4	2,170	3.92%	888.83	4.63
	4	7	1	4,309	2.56%	4,293.71	4.83

Notes:
A stream “segment” is a single stream reach between upstream and downstream confluence points.
* The “General Ratio of Stream Orders” value indicates the number of streams of “X” order found in a single fourth order watershed.
** The “Drainage Area Ratio of Upstream Channels to the Downstream Channel” indicates the ratio of drainage areas based on full watershed area of each stream order.

3.3.1 Characterizing the Stream Network within Developing Acreage

Although the information contained in the table can be used to convert acreage into estimated stream miles for the 19 ecoregions it is not sufficient to estimate the number of stream miles contained within the land area developed each year. To calculate that estimate, EPA first estimates the number of acres developed and the geographic region in which the developing acres are located. EPA used geographically linked annual development rates in the U.S. from the National Resources Inventory (NRI) (USDA, 2000). The NRI captures data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, selected conservation practices, and related resource attributes at more than 800,000 scientifically selected sample sites. NRI estimated the development rate for hundreds of individual watersheds that cover the contiguous states. To estimate the annual development rate for each of the 19 ecoregions, EPA summed the development rates of all watersheds within the boundary of each ecoregion.

The NRI was used for assessing the impacts of the construction and land development industry because it provides a consistent and periodic national assessment of land development trends and employs a standard methodology for the entire nation. In addition, the NRI also provides information on land use prior to development (e.g., the acres of farm land converted into residential use). EPA's analysis of the most current NRI information available (rates of land development from 1992 to 1997) is shown in Table 3-4, which shows that the current rate of land development is approximately 2 million acres per year.

Table 3-4. Land Development Annually in Ecoregions (Adapted from USDA, 2000)

Ecoregion	Acres Developed Annually	Percent of National Total	Miles of Streams Within Developed Acres
1	64,236	2.9%	134
2	91,015	4.1%	303
3	34,424	1.6%	61
4	338,378	15.2%	957
5	67,107	3.0%	137
6	127,511	5.7%	387
7	42,321	1.9%	82
8	252,790	11.4%	1,075
9	330,635	14.9%	805
10	326,850	14.7%	686
11	97,386	4.4%	181
12	249,748	11.3%	757
13	35,090	1.6%	113
14	38,822	1.7%	152
15	11,093	0.5%	42
16	57,947	2.6%	149
17	28,799	1.3%	58
18	12,592	0.6%	47
19	12,607	0.6%	32
Totals	**2,219,352**		**6,160**

Values provided indicate total acres developed. Approximately, sites ≤ 1 acres constitute 2 percent of acres developed, and sites between 1 and 5 acres constitute 15% of the acres developed.

Table 3-4 also provides EPA's estimate of the miles of stream contained within the acres developed annually. When estimating the total miles of stream per ecoregion by stream order, EPA first estimated the number of fourth-order watersheds developed. For example, in ecoregion 19, the number of acres developed annually (12,607) was divided by the number of acres in a fourth-order watershed (4,293) to yield the number of developed watersheds (2.9). This number was then multiplied by the average number of feet per fourth-order stream (4,309) and by the stream order ratio (1) to yield the number of feet of fourth-order streams in developed areas (12,496). In order to find the total number of stream feet for the ecoregion, these steps are repeated for third, second and first order streams and the sum taken of each order of stream feet.

3.3.2 Characterizing the Flow Conditions in Stream Network

Table 3-5 shows the estimated division of perennial and intermittent streams by stream order for each ecoregion. The designations provided in Table 3-5 are based on best professional judgment. EPA notes that third- and fourth-order streams in relatively arid areas of the nation could be perennial due to small dams and lakes; however, the analysis assumes they are intermittent in nature.

Table 3-5. Characterization of Stream Orders for Ecoregions

Ecoregion	1st Order	2nd Order	3rd Order	4th Order
1	I	I	I	I
2	I	I	I	I
3	I	I	I	P
4	I	I	P	P
5	I	I	P	P
6	I	I	P	P
7	I	I	P	P
8	I	I	P	P
9	I	I	P	P
10	I	I	P	P
11	I	I	P	P
12	I	I	P	P
13	I	I	I	I
14	I	I	I	I
15	I	I	P	P
16	I	I	P	P
17	I	I	P	P
18	I	I	I	I
19	I	I	P	P
20	I	I	P	P

P = Perennial; I = Intermittent

EPA estimated the total miles of intermittent and perennial streams based on a cross-product of information on Tables 3-3, 3-4 and 3-5 (total stream lengths by order, ecoregion development rates, and perennial/intermittent assumptions, respectively). The results of this calculation are shown in Table 3-6.

Table 3-6. Characterization of Stream Length by Flow Type for Ecoregions

Ecoregion	Geographic Name	Baseline Conditions	
		Perennial Stream Miles	Intermittent Stream Miles
1	Midwest	0	134
2	Southwest Arid	0	303
3	Southwest	7	54
4	Coastal Atlantic	196	762
5	Atlantic Shoreline	25	112
6	North Florida	77	310
7	South Florida	19	63
8	New England	197	878
9	Appalachia	198	608
10	Great Lakes Region	147	539
11	Mississippi Outlet	38	143
12	Mississippi West	159	598
13	Upper Midwest & Dakotas	0	113
14	Midwest Central	0	152
15	Pacific Coastal Region	8	34
16	Southern California	32	117
17	Willamette Valley	13	45
18	Eastern Washington	0	47
19	Sierras	7	25
Total		**1,123**	**5,036**

3.3.3 Converting Stream Miles into Impact Estimates

Inventorying stream information for each of the ecoregions and estimating the miles of stream contained within urbanizing acreage provides a basis for estimating impacts that are proportional to stream length. EPA developed data sets which indicate stream type (perennial or intermittent), stream order, and location (ecoregion). The data, however, are not sufficiently customized at the local/regional level to permit detailed environmental modeling of stream impacts on an ecoregion basis. Hence, EPA estimated environmental changes at the national level.

Table 3-6 shows national and ecoregion-specific estimates of the river miles contained within the acres developed annually, if all acres developed were within a single watershed. Additional adjustment is necessary to account for the fact that development is not consolidated in a single land mass but rather is dispersed among areas not currently under construction. See Figure 3-2. To estimate the miles of streams potentially impacted under baseline conditions, EPA considered a range of assumptions about the ratio of construction to non-construction area within watersheds. As shown in Figure 3-2, EPA assumed that an area of 10 times larger than the total area under construction is also impacted from runoff from construction in addition to runoff from urban areas, forests and agriculture.

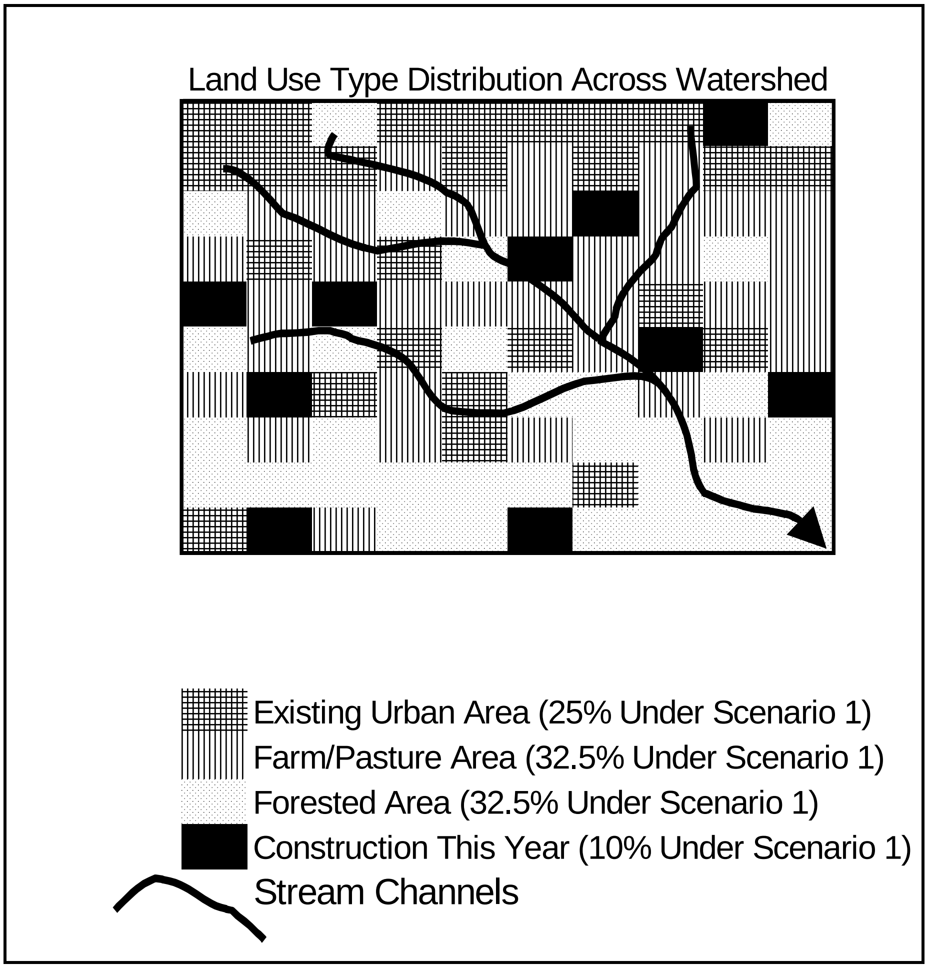

Figure 3-2. Land Use Distribution of a Watershed.

Given this assumption, a construction rate of 2.2 million constructed acres per year means that streams dispersed in 22 million acres of land area are potentially impacted by construction site runoff in combination with runoff from urban, forested and farm land. Based on EPA's assessment of stream lengths contained in the 19 ecoregions and the rates of development in each ecoregion, EPA estimates that roughly 10,000 perennial stream miles and 36,000 intermittent stream miles are potentially affected by construction site runoff annually (Table 3-7).

Table 3-7. Estimated Miles of Streams Potentially Affected by One Year's Construction

Ecoregion	Geographic Name	2.2 Million Acres (Acreage Constructed Annually)		22 Million Acres (Assumed Land Area Containing Acreage Constructed Annually)	
		Perennial Stream Miles	Intermittent Stream Miles	Perennial Stream Miles	Intermittent Stream Miles
1	Midwest	-	107	0	1,070
2	Southwest Arid	-	242	0	2,420
3	Southwest	7	43	70	430
4	Coastal Atlantic	196	609	1,960	6,090
5	Atlantic Shoreline	25	90	250	900
6	North Florida				
7	South Florida				
8	New England	197	702	1,970	7,020
9	Appalachia	198	486	1,980	4,860
10	Great Lakes Region	147	431	1,470	4,310
11	Mississippi Outlet				
12	Mississippi West	159	478	1,590	4,780
13	Upper Midwest & Dakotas	-	91	0	910
14	Midwest Central	-	121	0	1,210
15	Pacific Coastal Region	8	27	80	270
16	Southern California	32	93	320	930
17	Willamette Valley	13	36	130	360

Table 3-7. Estimated Miles of Streams Potentially Affected by One Year's Construction

Ecoregion	Geographic Name	2.2 Million Acres (Acreage Constructed Annually)		22 Million Acres (Assumed Land Area Containing Acreage Constructed Annually)	
		Perennial Stream Miles	Intermittent Stream Miles	Perennial Stream Miles	Intermittent Stream Miles
18	Eastern Washington	-	38	0	380
19	Sierras	7	20	70	200
Total		989	3,614	9,890	36,140

Notes:
- EPA assumed that all streams within fourth-order watersheds are intermittent in regions 1, 2, 13, 14, and 18.
- Total values reflect a 20 percent reduction in intermittent stream miles to account for streams that are expected to be converted into below grade pipe systems. Values also discount stream miles in Ecoregions 6, 7, and 11 because these systems are greatly influenced by man-made channel networks and natural wetland systems (i.e., are less hierarchal in nature).

EPA then developed a simple stream model to assess potential changes in TSS concentrations during wet-weather periods for the estimated 61 thousand miles of streams receiving discharges from construction sites annually. EPA evaluated three development scenarios to estimate the range of potential TSS reductions in streams within watersheds experiencing construction runoff, as shown in Table 3-8. The three development scenarios are intended to represent low, moderate, and high levels of urbanization, over which construction activities are superimposed. EPA used a simple mass balance approach to estimate in stream TSS concentrations, as follows:

1. Estimate the average annual runoff from each land use condition, from construction acreage affected, and not affected by proposed guideline options.

2. Estimate the average annual TSS loading from each land use condition, based on EPA-estimated or literature reported event mean concentration (EMC) for TSS.

3. Estimate national average change in the in-stream concentration of TSS using land use fractions given in each of the three scenarios in Table 3-8. This assessment is performed for all 2.2 million acres developed annually, based on the total estimated runoff volume in a single (typical) rainfall year.

Table 3-8, also shows the allocation of regulated construction sites for Options 1 and 2. Under Option 1, approximately 0.2 percent of the watershed is assumed to be covered by construction sites less than 1 acres in size. The runoff from these acres is not affected by Option 1 proposed requirements. Under Option 2, approximately 1.7 percent of the watershed is assumed to be covered by construction sites less than 5 acres in size. The runoff from these acres are not affected by Option 2 proposed requirements. Runoff coefficients (Table 3-9) indicate the portion of rainfall that leaves the area as runoff. The remainder is assumed to infiltrate into the ground or evaporate. Values were selected based on EPA estimates of percent imperviousness, values reported in literature, and best professional judgement.

Table 3-8. Active Construction Site Runoff Scenarios for Option 1 and Option 2

Land Use Conditions	Land Use Coverage Scenarios		
	Low Urbanization	Moderate Urbanization	High Urbanization
Existing Urban Area	25.0%	50.0%	75.0%
Forested	32.6%	20.1%	7.6%
Farm	32.6%	20.1%	7.6%
Sites Regulated Under Option 1	9.80%	9.80%	9.80%
Sites Not Affected by Option 1	0.20%	0.20%	0.20%
Sites Regulated Under Option 2	8.27%	8.27%	8.27%
Sites Not Affected by Option 2	1.73%	1.73%	1.73%

Table 3-9. Runoff Coefficients for Land Uses

Land Use Conditions	Runoff Coefficients
Existing Urban Area	0.46
Forested	0.05
Farm	0.15
Construction[a]	0.80

a. Includes sites regulated under Option 1, not affected by Option 1, regulated under Option 2, and not affected by Option 2.

EPA's simple in-stream model estimates the potential reduction in TSS concentration during wet-weather periods. EPA's approach does not taken into account the contributions of base flow and base flow loads (i.e., that entering streams due to groundwater) during wet-weather periods. Excluding this base flow results in an overestimation of actual TSS concentrations.

Because rainfall conditions affect the results of EPA's assessment, an evaluation of approximately 30 years of rainfall records for 1,200 rainfall gauges was performed to identify a typical rainfall year for each of the 19 ecoregions.[2] Based on this evaluation, EPA estimated that the national average rainfall depth falling on construction sites is approximately 34.8 inches per year. This estimate is a weighted average, based on the acres developed in each ecoregion.

Table 3-10 presents the event mean concentrations (EMCs) used by EPA to estimate the range of TSS loadings. In selecting EMC values, EPA used values from the literature that would help create reasonable upper and lower bound estimates. High and low effectiveness estimates for construction site effluent concentrations were matched with lower bound and upper bound EMCs, respectively, for other land uses. For example, lower bound and upper bound EMC values for urban runoff (141 and 224 mg/L) were assumed to bracket urban concentrations, and to indicate TSS annual loadings. Only forested area EMCs were held constant for both lower and upper bound estimates. In terms of annual TSS yield, EPA's assumed EMCs for urban areas correspond to 0.26 and 0.41 tons per acre per year. Annual TSS yield for farm/pasture, equates to 0.15 and 3.0 tons per acre per year (Corsi et al., 1997; Novotny and Chesters, 1981; Horner et al., 1986; Horner, 1992; and Sonzogni et al., 1980).

EPA assumed that construction sites not affected by the proposed effluent guidelines would discharge TSS in concentrations similar to those estimated under baseline conditions. This assumption may overestimate TSS loadings estimates associated with Option 2 for sites between 1 and 5 acres. The results of EPA's simple national in stream model, based on the data and assumptions described above, are provided in Section 4.

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[2] EPA defined a "typical rainfall year" as having a total rainfall depth within 10 percent of the average for the ecoregion, and not containing a single rainfall event with greater than a 2-year storm.

Table 3-10. Runoff EMCs for Acres Within a Watershed
(TSS in mg/L)

Land Use Condition	Lower Bound		Upper Bound	
	Option 1	Option 2	Option 1	Option 2
Urban Area	141	141	224	224
Forested/Pasture	152	152	152	152
Farm	254	254	5,071	5,071
Regulated Construction Sites	2,613	1,843	6,529	5,081
Construction Sites Not Affected by Regulations	3,765	3,765	6,914	6,914

Notes:
- Urban TSS Concentrations are from USEPA, 1993
- Option 1 high and low effectiveness assumes construction BMPs are installed/operated so resulting capture of TSS generation is 80 and 50% of TSS generation, respectively.
- Option 2 high and low effectiveness assumes construction BMPs are installed/operated so resulting capture of TSS generation is 90 and 70% of TSS generation, respectively.

Section 4 Environmental Benefits Assessment of Evaluated Regulatory Options

This section presents the Agency's estimates of the environmental benefits that would result from implementation of erosion and sediment controls during construction activities. EPA evaluated 3 regulatory options for controlling discharges from active construction sites. Table 4-1 describes each of the options.

Table 4-1. Regulatory Options Evaluated for Controlling Discharges from Construction Activities

Option	Description
Option 1	• Applicable to construction sites with one acre or more of disturbed land • Operators required to: - Inspect site throughout land disturbance period - Certify that the controls meet the regulatory design criteria as applicable • Amend NPDES regulations at 40 CFR Part 122 (no new effluent guideline regulations)
Option 2	• Applicable to construction sites with five acres or more of disturbed land • Operators required to: - Prepare storm water pollution prevention plan - Design, install, and maintain erosion and sediment controls - Inspect site throughout land disturbance period - Certify that the controls meet the regulatory design criteria as applicable • Creates a new effluent guidelines category at 40 CFR Part 450 and amends Part 122 regulations
Option 3	• No new regulatory requirements

The following subsections present Agency estimates of regulatory conditions for suspended solids loadings and resulting improvements to the environment, including stream habitat.

4.1 Total Suspended Solids Loadings

Construction projects involve a series of temporary activities (e.g., land clearing, grubbing, building), and, with the exception of large-scale facilities, these projects generally have a duration of less than a year. During the construction period, erosion and sediment control (ESC) BMPs are employed to minimize pollutant discharges.

EPA used three criteria as a basis for selecting which pollutants to use as indicators of construction site pollutant loadings: (1) pollutants that correlate strongly with the construction activities, (2) toxic pollutants should be considered only if dissolved concentrations are high, and (3) proposed effluent guidelines would significantly reduce loadings from current levels. Based on these criteria, EPA selected eroded soils/sediment loadings (e.g., measured by TSS and14 turbidity) as the indicator of construction site pollutant loadings. Other runoff constituents are either present in low concentrations or account for such a small proportion of the total discharge that conventional treatment would not prove effective in removing additional levels beyond that attained in treating the suspended solid component.

Table 4-2 presents EPA's estimates of construction site loadings reductions under Options 1, 2 and 3 in terms of tons of TSS per year.

Table 4-2. Estimated TSS Loadings Reductions for Proposed Regulatory Options

		Option 1	Option 2	Option 3
Lower bound estimates	**Incremental Percent TSS captured by BMPs**	5%	25%	0
	Annual reductions (tons)	2,637,569	11,126,639 [a]	0
Upper bound estimates	**Incremental Percent TSS captured by BMPs**	15%	25%	0
	Annual reductions (tons)	7,912,707	11,126,639 [a]	0

a. Option 2 reductions were reduced by approximately 15 percent to account for sites between 1 and 5 acres in size not covered by this option.

As shown in the table, EPA estimates that under Option 1, construction sites would increase the removal rate of TSS by approximately 5 to 15 percent. The projected increase in net performance of construction site BMPs under Option 2 is about 25 percent. These estimates were developed using the Agency's engineering judgement, but are based on the following assumptions:

- Regulatory options would require that sediment ponds are certified at the time of installation to ensure they are built as designed

- Implementation of the proposal would result in more effective selection, installation and O&M of ESC BMPs due to inspection and certification of site activities.

- Option 2 would result in shorter duration of exposure for un-managed denuded areas

The regulatory options loadings were generated using three factors: total annual number of acres developed, tons per year of suspended solids per acre of land undergoing development, and incremental improvement in BMP performance under the regulatory options. As described in Section 3, NRI data were used to estimate that approximately 2.2 million acres are developed annually and the estimate of 40 tons per acre generation of TSS at construction sites was based on the Phase II Storm Water Economic Assessment (EPA, 1999).

Estimated annual sediment loadings reductions from implementation of EPA's proposed alternatives range from 0 tons (Option 3: no new regulations) to approximately 11 million tons per year for Option 2.

4.2 Total Suspended Solid In-Stream Concentrations

Although the Agency did not attempt to quantify aquatic losses (e.g., fish kills, habitat loss), it did estimate how construction loadings impact in-stream concentration levels of TSS in receiving water bodies.

Because in-stream concentrations of TSS result from mixtures of point and nonpoint sources that cannot cannot be readily separated, EPA estimated in-stream TSS concentrations for three different land use scenarios that assumed 10 percent of the land area was under construction and 90 percent was distributed among three types of land uses: forest, farm and urban. As shown in Table 4-3, the land use scenarios were developed to characterize different levels of urbanization, ranging from 25 percent urban in scenario 1 to 75 percent urban in scenario 3. EPA's analysis does not assess in-stream settling and resuspension. In addition, there are other sources of TSS that have not been included in the analysis, such as loads resulting from commercial point source discharges and loads resulting from increased stream bank erosion related to higher stream flow rates and velocities in urbanizing water bodies. TSS loadings (section 4.1) were used in conjunction with different event mean concentration (EMC) values, runoff coefficients, and ESC BMP efficiency rates to generate TSS in-stream concentrations, as described in section 3.3.3.

Table 4-3. Development Scenarios Used to Estimate Impacts of Regulatory Options

Development Scenario	Land Use Proportions
1. Low Urbanization	25% Urban, 10% Construction, 32.5% Farm, 32.5% Forest
2. Moderate Urbanization	50% Urban, 10% Construction, 20% Farm, 20% Forest
3. High Urbanization	75% Urban, 10% Construction, 7.5% Farm, 7.5% Forest

Different land use scenarios were evaluated because of the differences in TSS characteristics that result as land becomes developed from rural to urban conditions. The high urban conditions contribute the lowest levels of TSS while the low urbanization contribute the highest levels of

TSS. This can be explained by the fact that forest and farm practices generate higher levels of sediment runoff and urbanized areas create more storm water runoff, diluting TSS concentrations.

Table 4-4 shows the estimated concentration reductions in TSS from the regulatory options. Reductions in TSS concentrations under Option 1 are estimated to range from 68 to 348 mg/L. TSS concentrations under Option 2 would decrease from 276 to 489 mg/L. The larger reductions from regulatory Option 2 reflect the more stringent proposed requirements resulting in higher ESC BMP effectiveness. Reductions from the lower bound comparisons are higher than reductions in the upper bound comparisons.

Table 4-4. Estimated Average In-Stream TSS Concentrations Reduction, mg/L

Development Scenario	High Effectiveness Estimates		Low Effectiveness Estimates	
	Option 1	Option 2	Option 1	Option 2
1. Low Urbanization	348	489	116	466
2. Moderate Urbanization	258	363	86	346
3. High Urbanization	205	289	68	276

Note: The results provided in this table could overestimate the differences between the effects of high and low urbanization because the study did not include discharges from commercial point sources or from increased stream bank erosion resulting from increased stream flow rates and velocities in urbanized areas. If these factors had been included, the concentrations under high urbanization would likely have been significantly higher.

4.3 Miscellaneous Impacts

Sites under construction have hydrologic responses that differ from those under pre-development conditions; both the peak discharge and duration of high discharges increase dramatically. (Appendix C describes hydrologic changes caused by construction and the effects of commonly employed sedimentation ponds on site discharge.) As a result, EPA believes that construction sites increase the potential for flooding of downstream areas above the levels found in the pre-development condition. Both Options 1 and 2 are expected to reduce flooding potential by ensuring the installation and maintenance of sedimentation ponds (if already present) that retain site runoff and help minimize flooding potential.

Poor ESC BMP implementation has an adverse impact on aesthetics of affected water bodies lowering the visual quality of streams and lakes by creating high turbidity levels. Sediment enriched runoff from failing construction site ESC BMPs convey sediment to adjacent land creating a visual nuisance and sometimes requiring clean up. Although EPA did not estimate the environmental or economic benefits associated with improvements in these conditions, EPA believes that both Option 1 and 2 would reduce these impacts significantly by requiring closer tracking of ESC BMP operation, problem identification, and problem resolution.

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Appendix A

Evaluating Pollutant Loadings from Construction Activities that Potentially Impact the Environment

Appendix A Evaluating Pollutant Loadings from Construction Activities that Potentially Impact the Environment

This appendix details aspects of the methodologies described in Section 3 to pollutant discharges that result from construction activities under two options. Specifically, it expands on the discussion presented in Section 3, providing additional information on the assumptions used by EPA in its assessment.

Estimates of Affected Area

The Phase II NPDES storm water rule economic analysis (USEPA, 1999) presented information on the size and nature of construction activities under the Phase I and II storm water programs. In addition, the Phase II economic analysis (EA) detailed an extensive analysis of pollutant loadings for a range of site sizes, soil types, land slopes, and locations. EPA's current evaluation uses the results presented in the Phase II report to update its overall estimate of national construction site loadings. EPA expects that new regulation of the construction and development (C&D) category will augment the existing state and Phase I NPDES storm water programs. In addition, new regulations will shape future development of construction programs expected under the Phase II NPDES storm water program.

EPA identified the array of potentially affected construction sites in the nation. EPA's assessment of construction site loadings is based on regulation of approximately 2.17 million acres per year. This regulated acreage estimate was calculated based on estimated national development rates from the 1997 National Resources Inventory (USDA, 2000), less the estimated acreage either occupied by sites less than 1 acre in size (not regulated) or sites which receive Phase II "R" waivers. "R" waivers are those applied for and granted under the construction general permit for sites with very low erosivity. The Phase II EA estimated the total acreage granted "R" waivers to be approximately 33 thousand acres (approximately 1.8 percent of the total constructed acreage). Based on its assessment of probable construction site size distribution, EPA estimates that another 1.7 percent of the annual constructed acreage will be on sites less than 1 acre. In addition, under Option 1, EPA is considering removing sites smaller than 5 acres. EPA estimates that approximately 18 percent of construction occurs on sites less than 5 acres in area.

EPA's Analysis of State Programs

Table A-1 presents the results of EPA's analysis of state construction programs. EPA focused on the states with the largest annual construction footprint to estimate the level of current control (i.e., not all state regulations were reviewed). As a result, the absence of a "Yes" value in Table A-1 may indicate that a construction program was not evaluated by EPA. Overall, the results in Table A-1 were converted into a ecoregion "score" or the percent of developed acreage that would gain greater management under EPA's options. Table A-2 indicates the resulting percentage of construction acreage affected by the potential effluent guidelines in each ecoregion. As expected, new BMPs required under the options (e.g., certification of sediment basins) were not found in existing state regulations, and overall, existing state requirements require option-level BMPs for approximately 30-35 percent of the acreage developed annually.

Table A-1. Assessment of State Construction Control Programs

State/Territory	Minimum of 3600 Cubic Feet per Acre Storage Requirement for Larger Sites	14-Day or More Inspection Frequency	14- Day Cover Required	States with Less than 20 Inches of Precipitation Per Year
Alabama				
Alaska	Yes	Yes	Yes	
Arizona	Yes	Yes	Yes	Yes
Arkansas				
California	Yes		Yes	Yes
Colorado				Yes
Connecticut	Yes		Yes	Yes
Delaware	Yes		Yes	Yes
District of Columbia				
Florida				
Georgia				
Hawaii				
Idaho				Yes
Illinois	Yes			
Indiana				
Iowa	Yes	Yes	Yes	
Kansas				
Kentucky				
Louisiana				
Maine				
Maryland				
Massachusetts	Yes	Yes	Yes	
Michigan				
Minnesota				

State/Territory	Minimum of 3600 Cubic Feet per Acre Storage Requirement for Larger Sites	14-Day or More Inspection Frequency	14- Day Cover Required	States with Less than 20 Inches of Precipitation Per Year
Mississippi				
Missouri				
Montana		Yes		Yes
Nebraska				
Nevada				Yes
New Hampshire	Yes	Yes	Yes	
New Jersey				
New Mexico	Yes	Yes	Yes	Yes
New York				
North Carolina				
North Dakota				Yes
Ohio		Yes	Yes	
Oklahoma	Yes			
Oregon				
Pennsylvania	Yes	Yes	Yes	
Rhode Island				
South Carolina	Yes	Yes	Yes	
South Dakota	Yes	Yes	Yes	Yes
Tennessee	Yes	Yes	Yes	
Texas	Yes	Yes	Yes	
Utah	Yes	Yes	Yes	Yes
Vermont				
Virginia	Yes	Yes	Yes	
Washington				
West Virginia	Yes		Yes	
Wisconsin				

State/Territory	Minimum of 3600 Cubic Feet per Acre Storage Requirement for Larger Sites	14-Day or More Inspection Frequency	14- Day Cover Required	States with Less than 20 Inches of Precipitation Per Year
Wyoming		Yes		Yes

Table A-2. Percentage of Acreage Developed Without Option Equivalent Requirements

Ecoregion	3600 Cubic Feet per Acre Storage in Sedimentation Basins for Larger Sites (Criterion 1)	Certification of Sediment Basins (Criterion 2)	14-Day or more frequent inspection (Criterion 3)	14- Day Cover For Wet-States, or none required for dry states (Criterion 4)	Overall Weighted Percentage of Acres Without Coverage
ER 1	28.96%	0.00%	28.25%	30.72%	24.7%
ER 2	39.16%	0.00%	57.61%	57.61%	47.1%
ER 3	0.00%	0.00%	10.66%	10.66%	8.0%
ER 4	77.06%	0.00%	77.06%	77.06%	65.5%
ER 5	65.74%	0.00%	65.74%	65.74%	55.9%
ER 6	100.00%	0.00%	100.00%	100.00%	85.0%
ER 7	100.00%	0.00%	100.00%	100.00%	85.0%
ER 8	64.45%	0.00%	68.16%	64.45%	56.6%
ER 9	50.16%	0.00%	55.30%	42.80%	43.4%
ER 10	74.51%	0.00%	81.79%	81.79%	68.8%
ER 11	71.53%	0.00%	71.70%	71.70%	60.9%
ER 12	51.80%	0.00%	65.17%	65.17%	54.1%
ER 13	89.38%	0.00%	32.32%	89.38%	47.4%
ER 14	67.34%	0.00%	53.83%	71.01%	51.4%
ER 15	62.15%	0.00%	100.00%	100.00%	81.2%
ER 16	5.65%	0.00%	100.00%	100.00%	75.6%
ER 17	100.00%	0.00%	100.00%	100.00%	85.0%
ER 18	100.00%	0.00%	100.00%	100.00%	85.0%
ER 19	100.00%	0.00%	100.00%	100.00%	85.0%
National Average Weighted by Land Developed	64%	0%	70%	69%	58.9%

Information in Table A-2 was converted into an overall national “score,” to discount estimated TSS loadings reductions by accounting for acres covered by equivalent programs. To combine the four analyzed criteria, EPA assumed that the individual contributions to reductions were 10, 15, 50, 25 percent, respectively. For example, sedimentation basins based on 3,600 cubic feet contribute 10 percent of the estimated reduction between baseline and option loadings. On a national basis, EPA estimated that approximately 41 percent of land is served by equivalent programs, and would not be affected by Option 1 or 2 requirements.

Appendix B

Inventorying of Streams Potentially Impacted By Construction Activities

Appendix B Inventorying of Streams Potentially Impacted By Construction Activities

Overview

This appendix describes EPA's effort to inventory and assess environmental impacts of construction activities. Specifically, the appendix describes, in detail, the analytical steps performed to inventory the nation's stream system and provides general background information on the rationale used to develop the inventory approach. Delineation of impacted stream environments forms the basis for assessing the future benefits of regulatory controls on construction and activities.

The objectives of this appendix are as follows:

- To describe a method to characterize streams by their hydrologic function based on regional differences

- To establish the appropriate map scale for inventorying streams based on their size and geometry (e.g., length, slope, dimensions).

Stream Characterization

Many of the impacts on streams are a function of drainage area and hydrologic regime. Producing a national summary of potentially impacted stream networks is challenging because the nature and size of streams vary significantly throughout the country. For example, watersheds that produce a minimum base flow of 1 cubic foot per second (cfs) occupy 1 square mile in the eastern United States but require 100 square miles in the arid southwest. To account for this variation, EPA divided the country into 19 large hydrologic regions and then further inventoried the streams in each region separately, based on approximate stream size categories (i.e., stream orders). Representative watersheds in each of the 19 large ecoregions in the contiguous U.S. (see Figure B-1) were inventoried to determine the average stream density for the stream orders that are the most likely impacted in each ecoregion.

EPA developed the boundaries for the 19 ecoregions based on a stream density assessment that used EPA's Reach File 1 (RF1) stream network and the 76 ecoregions developed by Omernik (1987). Figure B-2 shows the RF1 densities in terms of acres per stream mile for each of the 76 ecoregions. Combining the 76 ecoregions into the 19 ecoregions shown in Figure B-1 helps simplify the analysis while still capturing a reasonable number of regions with similar stream densities and accounts for gross changes in hydrology, land forms, soil types, and potential natural vegetation.

In general, the literature indicates that environmental sensitivity (e.g., geomorphologic changes, pollutant toxicity) is greater on smaller stream orders, from the intermittent headwater streams to small perennial streams. For most environmental impacts (except perhaps nutrient loadings), the impacts of the construction and land development industry tend to decrease with increased stream size, and the impacts tend to become confounded with other influences (e.g., other point and nonpoint source pollutant loads). For this reason, the inventory focused on relatively small watersheds (between 2 and 7 square miles) to better assess the impacts of hydrologic changes on small streams.

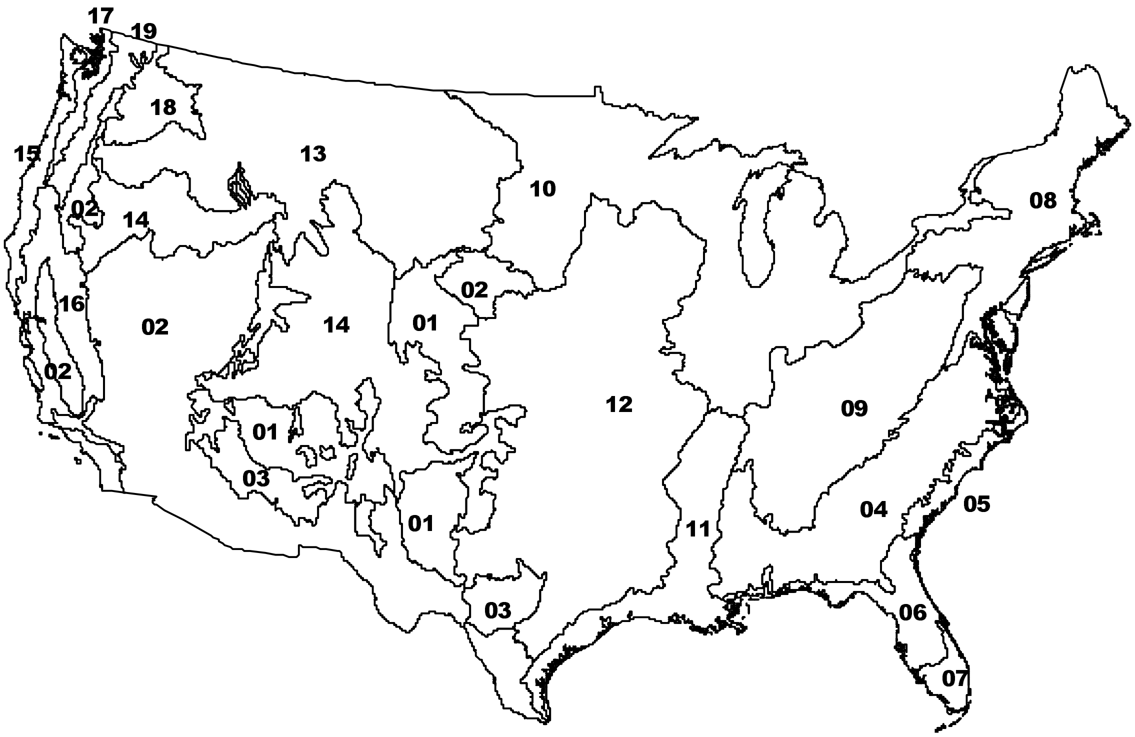

Figure B-1. Regions for Stream Inventorying

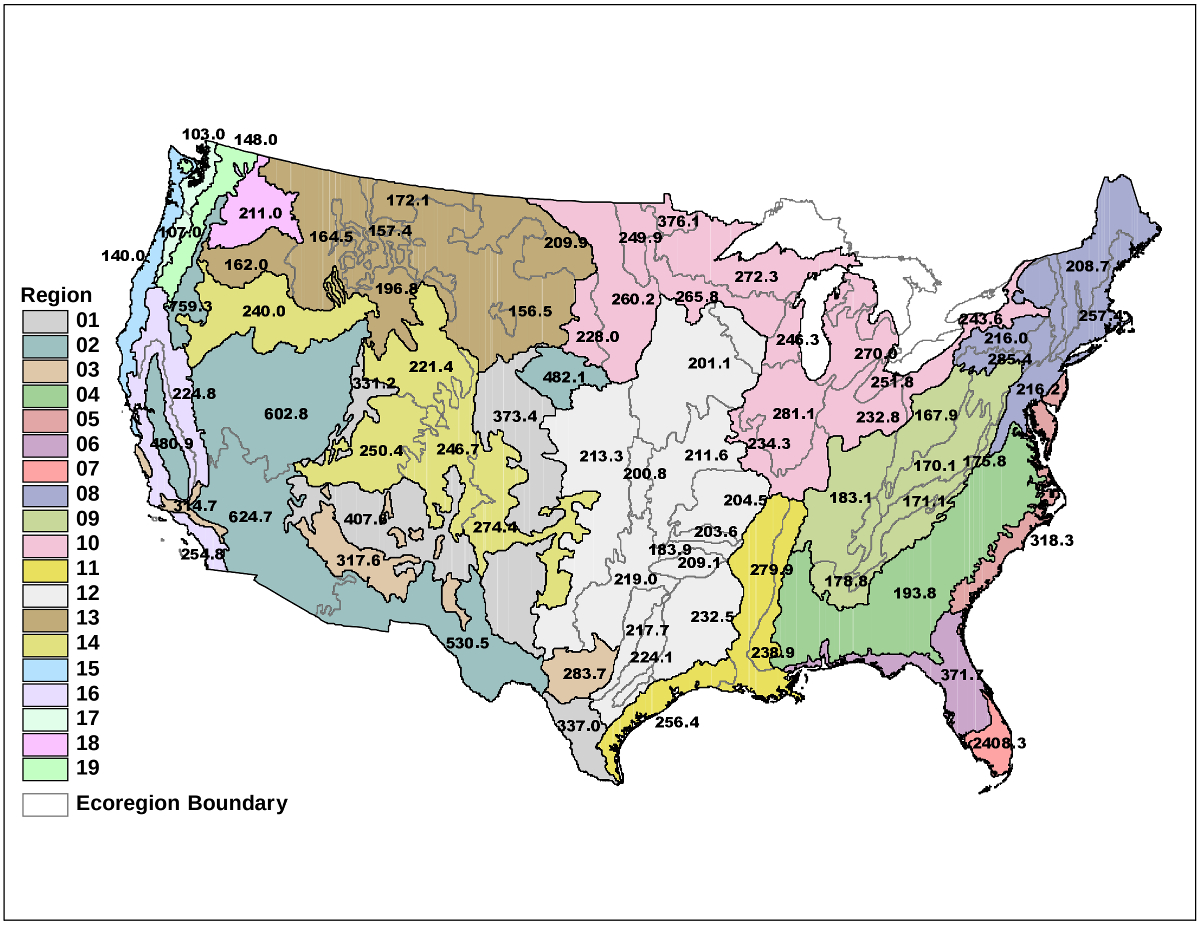

Figure B-2. Stream Densities for Omernik Ecoregions
(in units of acres per stream mile)

Because EPA focused on small streams, it was necessary to select a method by which to characterize streams by size. Historically, various schemes have been created to characterize and count streams within a drainage network, including the following:

- Stream order is determined by counting stream segments starting with the smallest stream channels found on a selected map scale.

- Stream level is determined by counting stream segments starting from the most downstream discharge point (ocean or estuary) on a selected map scale.

- Streams are characterized by physical descriptions including flow frequency (perennial or intermittent streams), size (large, medium, or small), and/or terms such as swales, creeks, and rivers.

- Watershed size is based on the scale of the map on which the watersheds are just visible.

EPA selected the first method, stream order characterization, for use in this assessment.

Map Scale Selection

Because any network of "streams" identified at the outset of a hydrologic inventory is highly dependent on the scale of the map used, selecting the appropriate scale is a critical step. Rills and swales that are obvious and identifiable on a 1:2,400-scale map are completely absent on a 1:250,000-scale map. Figure B-3 shows the streams visible on the following three scales of maps for a typical watershed (10 square miles) in northeastern Maryland:

- U.S. Geological Survey (USGS) 1:250,000-scale map or streams found in EPA's RF1 stream network

- USGS 1:100,000-scale map or streams found in EPA's Reach File V. 3 (RF3) and National Hydrography Dataset (NHD) (USGS, 2000) stream networks

- USGS 1:24,000-scale map.

The three map scales, respectively, permit successively finer viewing of stream sizes: (1) large perennial streams, (2) medium perennial to intermittent streams, and (3) larger swales and intermittent streams. Although not shown in Figure B-3, an even finer detail stream network—one based on 1:2,400-scale maps (a scale commonly used by local governments) that includes the smallest swales—can be visualized by increasing the number of 1:24,000-scale streams threefold (i.e., delineation of watersheds as small as 2 acres). Figure B-3 illustrates the importance of map scale selection:

- Inventorying stream networks based on 1:24,000-scale will include many more streams than a 1:250,000-scale inventory;

- The stream order assigned to any stream will be different based on the map scale; and

- Direct evaluation using only EPA's RF1 and RF3 hydrologic stream coverages would grossly undercount the number of streams potentially impacted.

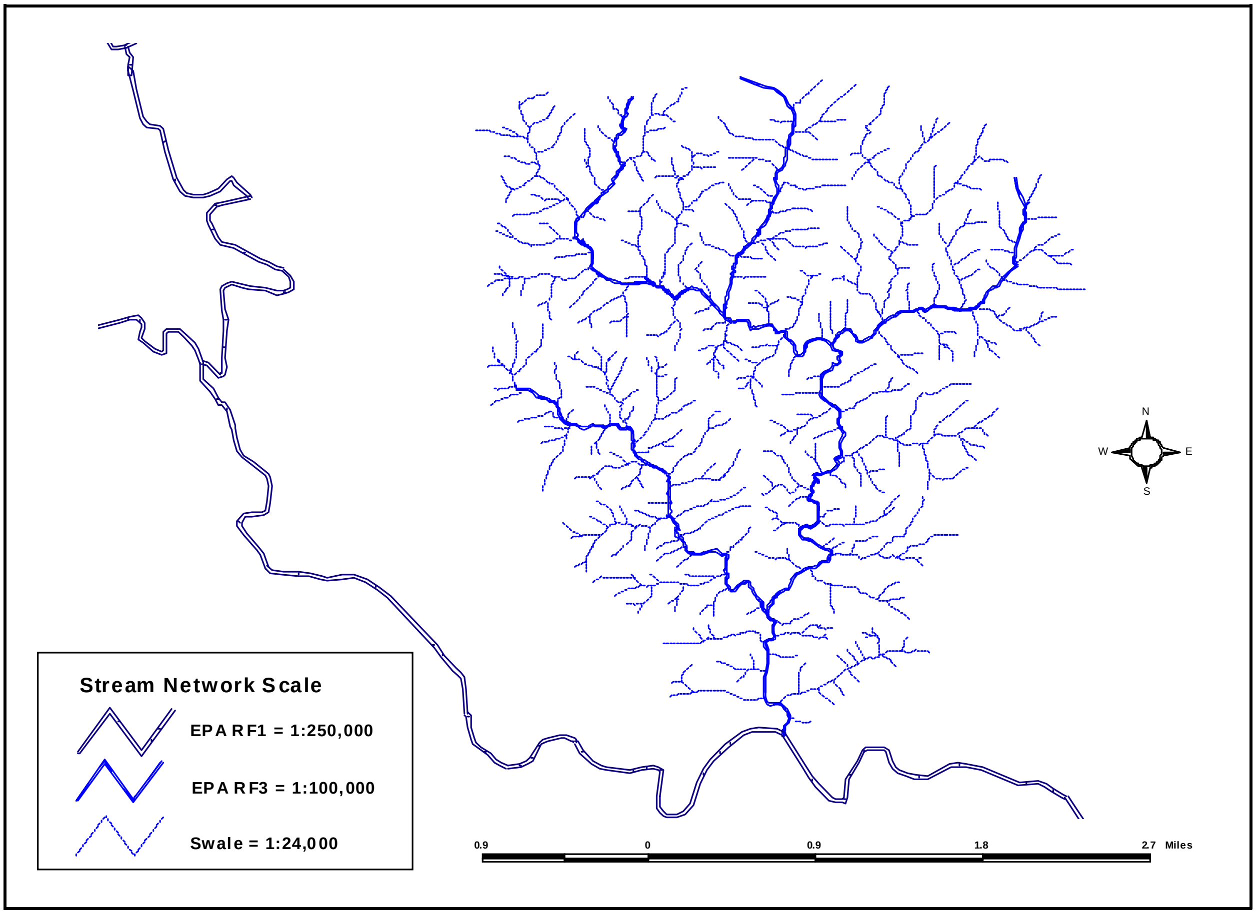

Figure B-3. Stream Networks for 1:250,000-, 1:100,000-, and 1:24,000-Scale Maps

Note: The 1:24,000-stream network shown contains more streams than the USGS identified on its 7.5-minute quadrangle maps using typical blue or dashed blue lines. This figure includes all swales that can be drawn based on contour lines given on the 1:24,000 map, resulting in an enhancement that shows two to three times more “streams” than are shown on the original map (down to watersheds approximately 10 acres in size).

Interpretation of contour lines defines a stream network based on land forms as the contours are present because streams/swales have created them. This contour-based enhancement defines a “stream” based on topography, regardless of whether or not the stream is actually drawn on the map.

Because using an increased detail of stream network (smaller map scale) requires increased effort levels, EPA developed a method that was both practical and depicted the appropriate stream level for this assessment. The amount of stream data available is extensive; the national coverage for RF1 contains 100 megabytes of data, while RF3 contains 7,400 megabytes. All of RF1 (data on just the largest rivers in the nation) can reside and be analyzed on a single microcomputer. However, the RF3 network and the similar, newer NHD are so large they can be analyzed in a microcomputer environment only when divided into 20 separate parts. Therefore, EPA assumed that a national dataset containing all streams and swales identifiable from 1:2,400-scale maps would be unworkable within the current limits of any microcomputer.

To maintain a relatively small map scale, EPA performed an inventory of streams and swales identifiable based on 1:24,000-scale maps (where swales are added manually) by first sampling representative watersheds or areas. (An actual inventory of individual swales and streams on a 1:24,000-scale for specific acreage developed in any given state in any given year is beyond current computational capabilities and the limits of available data, requiring some type of approximation or sampling technique). EPA used digital elevation maps (DEMs), which allowed EPA to process contour data, enhancing the original stream network to provide data on the larger intermittent streams (typically streams draining less than 30 acres). Because EPA's assessment of the construction industry indicates that a medium-sized construction start is approximately 20 acres, this approach is refined enough to inventory the number and size of streams potentially impacted by construction and land development activities. The number and length of streams in a larger area were then estimated by using the stream density found in the sampled watershed/area.

Appendix C

Impacts of Construction Activities on Hydrology

Appendix C Impacts of Construction Activities on Hydrology

Overview

This appendix describes hydrologic changes that result from construction and post-development activities, and focuses primarily on changes in runoff rates and soil infiltration. The general hydrologic changes caused by these industries have environmental and economic impacts.

The objectives of this appendix are:

- To demonstrate the variation in runoff rate for a 10-acre site as it changes from a forested condition into a construction condition.

- To describe the environmental benefits of current BMPs primarily designed to limit discharge from construction sites.

Methodology

A simple hydrologic model was developed to depict the hydrologic changes that result from construction and land development activities on a (10-acre) site. The size of 10-acres was chosen because it represents the typical size for a construction site. In addition, the hydrologic changes are believed to be similar to changes that result on larger sites such as 100-acre sites and 1000-acre sites.

Investigation of hydrologic changes was performed by using two hydrologic models: TR-55 and TR-20. These models use data developed over many years by USDA/Natural Resources Conservation Service (NRCS), and are among the most often employed models for the hydrologic design of hydraulic structures, such as storm drainage systems (USDA, 2002).

The 10-acre watershed was assumed to have a 50/50 mix of soils in the type B and C hydrologic soil classification, with an average ground slope of 7 percent. Time of concentration was derived based on standard TR-55 worksheets that analyze sheet flow, shallow concentrated flow, and pipe flow. For the analysis, the 2-year 24-hour SCS[1] type II rainfall event, totaling 3.2 inches of rainfall, was used to conservatively estimate the runoff hydrographs.

Multiple land use conditions (Table C-1) were evaluated to help assess the hydrologic impacts for the small 10-acre site. EPA notes that most construction sites occupying 10 acres are

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[1] The Soil Conservation Service (SCS) is the former name of the Natural Resources Conservation Service (NRCS).

equipped with a sedimentation pond, intended to minimize sediment discharge from the site. Although sediment ponds are not designed specifically shave the peak runoff rate (i.e., limit the construction site peak discharge rate to be equal to or less than the peak runoff from the forested site), these structures inherently have some capability of peak-shaving depending on the site conditions. In addition, sedimentation ponds can be built to increase its peak-shaving capability. For the purposes of this assessment, EPA assumed that a sedimentation pond (Condition 3) shaves the peak completely, as shown in Figure C-1.

Table C-1. Evaluated Hydrologic Conditions for a Typical 10-Acre Site

Land Use Condition	Description
1	Pre-development: a forested land use
2	Construction: cleared and grubbed soil surface with no vegetation and without construction runoff BMPs (No sedimentation ponds)
3	Construction: cleared and grubbed soil surface with no vegetation with storm water BMPs (a sedimentation pond that also shaves the peak runoff to match the pre-development peak flow)

The results of the analysis are presented below for each of these land use conditions.

Discussion of Runoff Results for Modeled Land Use Conditions

Figure C-1 compares the predicted runoff hydrographs for Land Use Conditions 1 through 3. The hydrographs in the figure show the large increase in runoff volume and peak runoff rate that occurs for construction sites with or without storm water BMPs that limit the peak runoff rates. This increase is caused by the removal of existing vegetation and compaction of site soils with earth moving equipment, which greatly diminishes the site's ability to absorb rainfall and limit discharge. In fact, NRCS data strongly suggest that a fully-constructed site (e.g., a residential neighborhood) produces less runoff than a denuded site under construction, even though impervious surfaces (e.g., driveways, roofs) have not yet been installed.

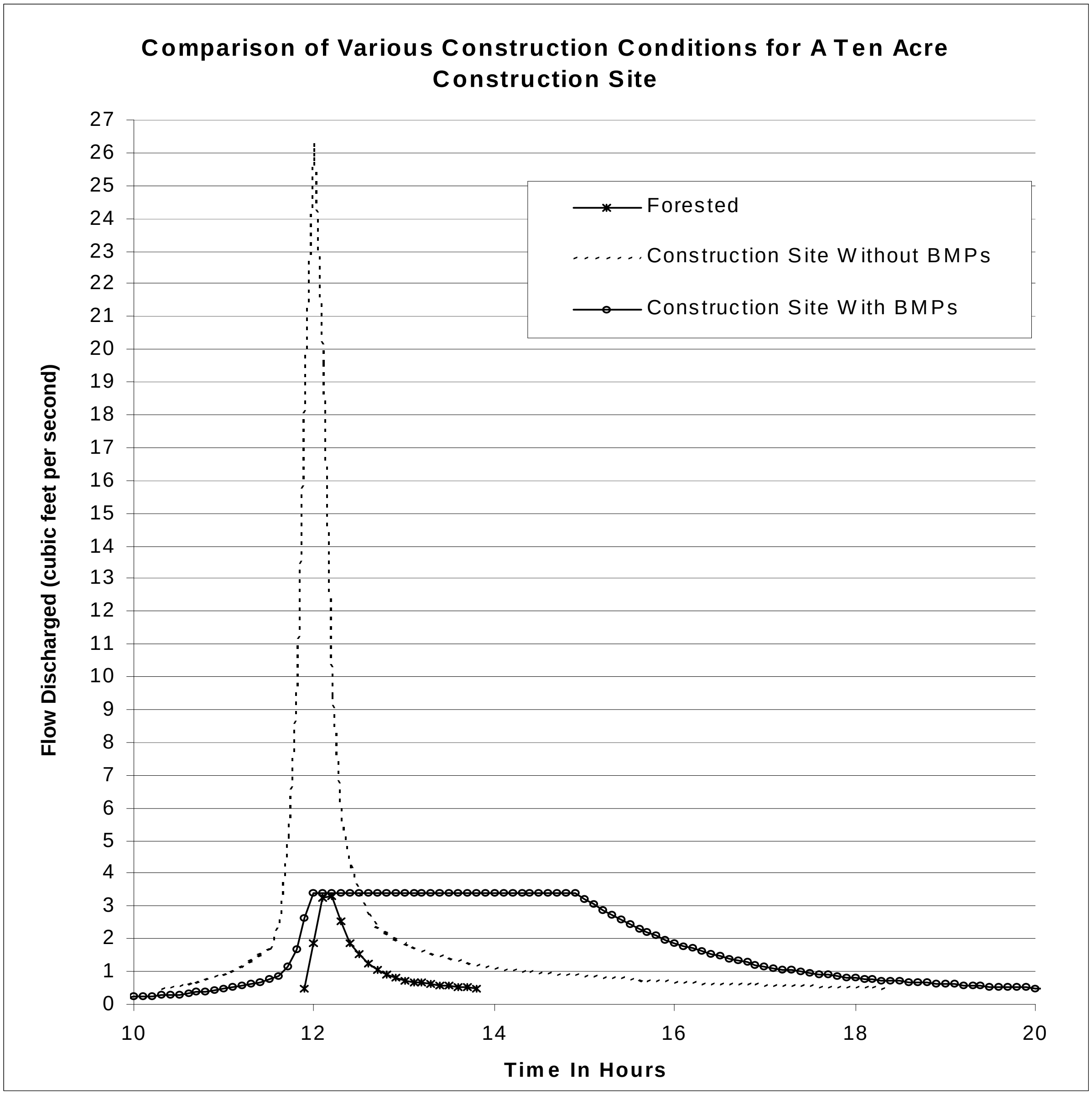

Figure C-1. Runoff Hydrographs for a 10-Acre Construction Site

Although the implementation of peak-shaving BMPs minimizes some of the flooding downstream of a construction site due to high peak flows, it does not eliminate the potential for enhanced flooding that is caused by longer durations of high-flow discharges. Table C-2 indicates that the construction site produces high flows for a much greater duration than flows originally released from the forested site. In fact, the 10-acre site that once produced a flow rate equal to or greater than 3 cubic feet per second (cfs) for only 0.2 hours will produce more than 3 cfs for 3.2 hours when peak-shaving BMPs are employed during construction. Should a 2-year storm occur during the construction period, the longer flow duration increases the chances that the discharge will be combined with downstream peak flows from other developing/developed locations to produce a flooding condition.

Table C-2. Comparison of Durations of High Flow Rates for Different Land Use Conditions

Land Use Condition	**Hours of flow equal to or greater than:**		
	3 cfs	**2 cfs**	**1 cfs**
Forested	0.2	0.3	0.8
Construction site without peak shaving BMPs	0.9	1.4	3.3
Construction site with peak shaving BMPs	3.2	4	5.7

cfs = cubic feet per second