2.0 ENVIRONMENTAL CONCERNS ADDRESSED BY THE RULE

Storm water discharges have emerged as one of the leading causes of impairment of the Nation's surface waters (US EPA, 1998a). This chapter takes a more detailed look at the environmental problems resulting from storm water discharges that result in a need for the Phase II regulation. Specifically, Section 2.1 provides an overview of storm water discharges from construction sites and urban areas and Section 2.2 describes the potential adverse impacts of these discharges on humans, aquatic ecosystems, and wildlife**.**

2.1 Storm Water Discharges from Urban Areas and Construction Sites

Several studies reveal that storm water runoff from urban areas and construction sites can include a variety of pollutants, such as sediment, bacteria, organic nutrients, hydrocarbons, zinc, copper, cadmium, mercury, iron, nickel, oil, and grease (Barret et al., 1996). In addition, the *National Water Quality Inventory, 1996 Report to Congress*, a summary of state §305(b) reports, documents water quality impairment resulting from storm water discharges. The reports found urban runoff/storm sewer discharges to affect 13% of impaired rivers, 21% of impaired lakes, and 45% of impaired estuaries. "Impaired" waters are those not meeting water quality standards or designated beneficial uses such as drinking water supply, primary contact recreation, and aquatic life support. The reports also found construction activities (e.g., land development, road construction) to have a significant impact on rivers, lakes, and wetlands. The pollutants associated with urban area and construction site discharges are discussed in more detail below.

2.1.1 Urban Area Storm Water Discharges

Urbanization has been shown to affect both the quantity and quality of storm water runoff. In heavily populated areas, water quality impairment has been linked to human activity. Often, individuals in residential communities improperly dispose of used oil, household toxic materials, radiator fluids, and litter (e.g., disposable cups, cans, and fast food packaging) directly into storm sewer systems or in open areas where the materials can be picked up and carried by storm water runoff. Additional pollutants in runoff can include herbicides and pesticides, toxic heavy metals, organic pollutants, fecal coliform bacteria and pathogens, sediment, and air pollutants (Field and Pitt, 1990; Marsh, 1993). Sediment is a primary pollutant from construction activity, as discussed below, but it can also be contributed by urban areas as a result of road maintenance activities such as street cleaning, road resurfacing, and deicing efforts (Rhoads, 1995). Some additional pollutants such as sanitary waste and sewer main construction materials (e.g., asbestos cement, brick, cast iron, vitrified clay) are due to wastes and wastewater from non-storm water sources, commonly referred to as illicit discharges. These discharges are "illicit" because the storm water systems are not designed to accept and discharge, or to process, such wastes.

Areas associated with urban development, such as commercial and residential districts, parking lots, and roads, are mostly paved so that storm water may not infiltrate into the ground. Such surfaces are referred to as "impervious" surfaces. These areas speed runoff flows and pollutants to receiving waters. In addition, urban areas are specifically designed to efficiently carry storm water away from the community to reduce flooding and into receiving waters, further increasing the rate at which waters receive runoff. The increase in flow and frequency of high flows can lead to changes in stream channel morphology such as the widening of banks and undercutting of stream beds. Indeed, Schueler (1995) notes that urban stream channels become unstable when 10% of a watershed is impervious.

A number of studies have determined that watershed development leads to increases in peak storm water runoff, as well as to decreases in the time required for the peak to be reached. Based on a compilation of studies, Hollis (1975) estimated that the frequency of small floods could increase 10 times as a result of imperviousness covering 20% of a watershed. Small floods are described as those with a return period, or recurrence interval, of one year. For larger floods (i.e., those with a return period of 100 years), the author estimated a possible doubling in size due to imperviousness covering 30% of a watershed. Barringer et al. (1994) also observed increases in flow and flow variability in two streams in New Jersey as development occurred, although the authors could not statistically link the changes to specific causes. Yorke and Herb (1978) were able to attribute observed increases in peak flow to urbanization in the Washington, D.C., area. In summary, the relative impact of development on storm water flows decreases as the recurrence interval of the flow (i.e., the flood size) increases (Hollis, 1975).

2.1.2 Construction Site Storm Water Discharges

Construction fundamentally alters natural landscapes (Toy and Hadley, 1987). During construction, earth is compacted, excavated and displaced, and vegetation is removed. These activities increase runoff and erosion, thus increasing sediments transported to receiving waters. Although erosion and sedimentation are natural processes, when land is disturbed by construction activities, surface erosion increases 10 fold on sites formerly used for crop agriculture, 200 times on sites formerly under pasture, and 2,000 times on sites formerly forested (Toy and Hadley, 1987). In addition to sediment, construction activities also yield pollutants such as pesticides, petroleum products, construction chemicals, solvents, asphalts, and acids that can contaminate storm water runoff (Marsh, 1993).

Numerous studies have examined the increases in sediment loads resulting from storm water runoff. For example, Daniel et al. (1979) monitored three residential construction sites in southeastern Wisconsin and determined that annual sediment yields were more than 19 times greater than yields from agricultural areas. Yorke and Herb (1978) studied nine sub-basins in the Maryland portion of the Anacostia watershed for more than a decade to determine the impacts of changing land use and land cover on runoff and sediment. Average annual suspended sediment yields from construction sites ranged from seven to 100 tons per acre, as compared to cultivated land and forest/grassland, which yielded 0.65 to 4.3 tons per acre and 0.07 to 0.45 tons per acre, respectively. A 1970 study conducted by the National Association of Counties Research Foundation found the potential impacts of urban and suburban development to be even more dramatic. The Foundation concluded that sediment yields from construction areas could be as much as 500 times the levels detected in rural areas.

2.2 Potential Adverse Effects of Storm Water Discharges to Humans, Aquatic Life, and Wildlife

The impacts of storm water runoff from developed and developing areas on humans, aquatic ecosystems, and wildlife can be explored within the context of the hydrologic cycle. When it rains, water is intercepted by vegetation and consequently, is absorbed by the soil. The water then infiltrates into soil pores, subsurface flows, and groundwater aquifers. When soils become saturated, the water runs off land areas and into surface waters. As development of a watershed occurs, soils are compacted and covered with impervious surfaces such as roads, parking lots, and buildings. The vegetative cover that intercepts the initial portion of rainfall and enhances filtration is reduced. Together, the development activities reduce the filtration rates of soils, and subsequent rainfall onto these impervious areas is converted into runoff.

Many studies provide documentation of the impacts of storm water discharges on humans, aquatic life, and other wildlife, including impacts to small streams. The potential impacts of these discharges include increased bacterial contamination, increased turbidity, increased toxic sediments, decreased dissolved oxygen concentrations, and alterations in stream channel morphology and habitat. In turn, these in-stream conditions can have a considerable impact on the abundance and diversity of aquatic species. The level of impact is site-specific and depends on site imperviousness, the type of receiving waters, acreage of land disturbance, topography, soil type, and resource sensitivity. The nature of the impact also varies temporally throughout the land development process, with significant differences observed between the site clearing phase and post development conditions. Exhibit 2–1 summarizes environmental concerns and impacts associated with urban storm water runoff, as compiled by Horner et al. (1994) and selected impacts are discussed in detail below.

2.2.1 Human Health Impacts

Bacterial contamination of waters used for swimming can threaten the health of swimmers. A recent epidemiological study of Santa Monica Bay examined the incidence of disease among swimmers near storm drain outfalls and swimmers 400 yards away from the outfalls (Haile, et al., 1996). The results indicated that those who swam near storm drain outfalls experienced significant increases in the incidence of gastrointestinal and respiratory diseases, as well as related symptoms. The study found human pathogens to be the cause of the illnesses and related symptoms. The study also indicated that illegal connections, leaking sewer lines, malfunctioning septic systems, illegal dumping from recreational vehicles, or direct human sources such as campers or transients are possible sources of pathogen contamination into storm drain systems.

Nationally, beach closings and swimming advisories are typically based on elevated levels of bacteria indicative of human pathogens that can cause illness. These wastes can enter the water via storm sewer systems, sewage treatment plants, and polluted storm water runoff. In 1996, approximately 83% of beach closings and advisories were due to bacteria levels that exceeded beach water quality standards (NRDC, 1997). An estimated 14% of beach closings were in response to a known pollution event, and 4% were precautionary beach closures due to rain that carried pollution into coastal waters. Furthermore, 414 closings and advisories in 1996 were prompted by urban storm water runoff.[1] Five of these closings lasted more than 12 weeks.

[1] A closing may be due to one or more sources; therefore, the total number of closings in 1996 independent of source may be less.

Exhibit 2–1. Adverse Impacts Associated with Urban Runoff

Resource/ Water Use	Concern	Potential Negative Impact on Resource/Water Use	Cause
Ground Water	Lower dry-season reserves	Lower dry-season base flow in water courses Lower drinking-water reserves	Increased impervious catchment surface area
Aquatic Habitat	Erosion	Physical destruction of habitat	Peak discharge, high runoff volume
	Fluctuating water levels and velocities	Altered thermal and mixing characteristics Reduced habitat diversity Erosion	High peak discharges and runoff volumes Low dry-season groundwater reserves
	Low dry-season base flow	Elimination of spawning beds Reduced habitat Reduced dilution capacity	Low dry-season groundwater reserves
	Sedimentation	Smothering of bottom communities and spawning beds Filling of storm water impoundments Transport of particulate-associated pollutants	Erosion Suspended solids
	Turbidity	Lower dissolved oxygen, reduced prey capture, clogging of fish gills	Suspended solids
	Low dissolved oxygen	Lethal and nonlethal stress to aquatic organisms	Biodegradable organic material
	Metals, organic contaminants, chlorides	Lethal and nonlethal stress to fish and other aquatic organisms in water column and bottom sediments	Urban pollution
	Increased water temperature	Lethal and nonlethal stress to sensitive cold water aquatic organisms	Biodegradable organic material
	Bacteria	Diseases of aquatic organisms Shellfish contamination	Fecal contamination
	Eutrophication	Algae blooms and nuisance aquatic plant growth Low dissolved oxygen Odors	Nutrient enrichment
Public Water Supply	Lower dry-season reserves	Reduced water supply	Lower dry season groundwater reserves
Wildlife Habitat	Flooding and erosion	Physical destruction of environment Dewatering and flooding of key habitat areas at critical times Reduction in streambank cover vegetation	High peak discharges and runoff volumes Sedimentation
Recreation and Aesthetics	Nature enjoyment	See Aquatic Habitat and Wildlife Habitat under the Resource/Water Use column	See Aquatic Habitat and Wildlife Habitat
Agricultural, Residential, and Industrial Land Use	Flooding and erosion	Public safety Damage to crops and farmland Damage to buildings and contents Reduction of useable land area	High peak discharges and runoff volumes Sedimentation

Source: Horner et al. (1994).

2.2.2 Aquatic Life and Wildlife Impacts

As noted earlier in this chapter, urban storm water runoff is a significant source of water quality impairment. As a result, pollutants carried in storm water or the impacts associated with increased flows are leading causes of impairment, as summarized in Exhibit 2–2. These pollutants and impacts in storm water can have a broad range of interrelated effects on aquatic habitats and organisms.

Exhibit 2–2. Five Leading Causes of Water Quality Impairment

Rank	Rivers	Lakes	Estuaries
1	Siltation	Nutrients	Nutrients
2	Nutrients	Metals	Pathogens
3	Pathogens	Siltation	Priority toxic organic chemicals
4	Oxygen-depleting substances	Oxygen-depleting substances	Oxygen-depleting substances
5	Pesticides	Noxious aquatic plants	Oil and grease

Source: US EPA (1998a).

Aquatic habitats and organisms can also suffer as a result of changing physical and ecological conditions in watersheds. Prior to development, physical and ecological conditions in watersheds are in a state of dynamic equilibrium. This means that the physical and ecological systems have adjusted to the rainfall patterns and the natural landscape changes occurring in the watershed that define natural flows. These flows determine the shape and slope of waterways. However, when watershed disturbances occur, such as those associated with development, flows are altered. Typically, peak flows increase. The increase in peak flow causes changes in the stream channel morphology and increases the amount of sediment and pollution transported to receiving waters. The effects of sedimentation, pollution, and excessive nutrients on habitat are discussed below.

Sedimentation

The National Water Quality Inventory 1996 Report to Congress identified sedimentation to be the leading pollutant or process affecting American rivers. It is the third leading pollutant or process impacting lakes, and the ninth leading pollutant impacting estuaries. Exhibit 2–3 summarizes the adverse impacts associated with sedimentation and sediment related pollutants as presented by Paterson et al. (1993). The following discussion presents additional studies that identify various environmental impacts of sediment related pollution.

Degradation and destruction of benthic habitat and organisms. When sediment falls out of suspension in the water column it accumulates on stream and riverbeds. Many benthic organisms depend on certain habitat conditions for survival, such as small crevices between rocks for protection of eggs and fry or hard substrates for attachment. When sediment covers streambeds, this critical habitat can be degraded or destroyed. Sedimentation can smother organisms such as fish eggs and fry, shellfish, and insects. In addition, many benthic organisms

Exhibit 2–3. Impacts Associated with Sediment and Sediment-Related Pollutants

Type of Impact	Comments
In-stream impacts Destruction or degradation of aquatic habitat and wildlife	Aquatic wildlife may be adversely affected in a variety of ways. Benthic communities may be directly damaged when sediments fall out and blanket the community. Benthic macrophytes may be destroyed, and the diversity and productivity of such communities may be reduced as a result (Crawford and Lenat, 1989). High concentrations of suspended sediments may abrade and damage fish gills, increasing their susceptibility to infection and disease (Abel, 1989). Survival rates for fish eggs may be reduced and spawning areas may be destroyed (West et al., 1982). High turbidity levels reduce both plankton and aquatic plant production. Nutrient and toxic enrichment of suspended sediments may adversely affect fish and other organisms directly and through secondary effects, including food chain disruptions, eutrophication, and toxic bioaccumulation/biomagnification effects (Simmons, 1987; Novotny and Chesters, 1989). In addition, a variety of additive, antagonistic, and synergistic effects are possible, depending on the types and amount of sediment delivered, the physical condition of the water body (e.g., depth, temperature, pH, and salinity), and the existing biological conditions (e.g., richness and diversity) (Mason, 1981).
Accelerated loss of storage in lakes and reservoirs	Accelerated deposition of sediment may reduce the effective life of water storage reservoirs by filling dead and active storage areas more rapidly than anticipated (Crowder, 1987). This problem tends to be most pronounced in smaller reservoirs and in regions with naturally high rates of erosion (Dendy, 1968).
Increased navigational obstruction and craft deterioration	Sedimentation of harbors and navigational channels reduces the shipping and boating capacity of those facilities, increases the likelihood of accidents, and requires expensive dredging to keep those facilities usable. In addition, suspended sediments may accelerate the wear and maintenance requirements for ship propellers and cooling systems of marine motors (Clark et al., 1985).
Diminished water recreational experiences	Sediment pollution may diminish, inhibit, or endanger water-related recreational activities. Excessive turbidity and sedimentation may contribute to boating, swimming, and diving accidents by obscuring submerged hazards or as a result of shoaling. In addition, sediment pollution may also decrease the quality of sport fishing by reducing fish populations, displacing more highly valued game fish with less desirable but more sediment-tolerant species, and turbidity may decrease the opportunities for making a catch (Clark et al., 1985).
Reduced aesthetic and preservation values	Aesthetic and preservation values are those that people gain through indirect use and the knowledge that uses are available for themselves, for future generations, or just existent (Walsh et al., 1984). Most water-related recreational activities involve people picnicking, walking, or playing near the water. Turbidity and sedimentation may diminish the indirect water recreational experience as a result (Clark et al., 1985). Likewise, people's preservation benefits are diminished when siltation and turbidity degrade valued water bodies.
Increased hydroelectric facility impairment	The major concerns for hydroelectric facilities are the loss of storage capacity, the blockage of inflow access for plant generation, and increased maintenance because of wearing of plant structures and machinery (e.g., the penstock and turbine runner). Additional concerns include downstream channel degradation and modification due to the interruption of natural bedload deposition (Fan and Springer, 1990).

Exhibit 2–3. Impacts Associated with Sediment and Sediment-Related Pollutants

Type of Impact	Comments
Accelerated stream bank erosion	Coarse sediment deposits in the form of channel bars often cause nearby bank erosion (Neill and Yaremko 1989). In addition, hydrogeologic alterations caused by urbanization and agricultural activities may increase streambank erosion in several ways, including: increasing downstream flood peaks; increasing the duration of flood peaks (as a result of detention systems); concentrating runoff at unprotected points along the bank; and creating obstruction to the flow channel.
Off-stream impacts Increased flood damages	Sediment pollution can increase flood damages in at least three ways. First, aggrading stream and lake beds may increase the frequency and magnitude of flood events. Second, the effectiveness of structural flood control devices maybe reduced due to loss of flood storage or siltation in structures. Third, sediment may directly damage agricultural and urban areas when it is deposited by flood waters in structures or on productive lands (Simmons 1987, Clark and others 1985).
Increased strormwater drainage system maintenance needs	Sedimentation in storm water drainage systems and irrigation canals may increase localized flooding problems and require more frequent maintenance of such facilities (e.g., hydro-flushing) (Porter 1976).
Reduced Infiltration	Suspended sediment in runoff and irrigation water sources can seal land surfaces, thereby reducing the infiltration rates. The surface sealant effect and reduced infiltration rates may have adverse impacts of surrounding vegetation by leaving the soil too dry, and increase the rate of runoff which in turn accelerates erosion potential, and reduces aquifer recharge (Guy 1972, Clark and others 1985).
Increased water-treatment costs	Water treatment costs for municipalities and certain industries may be significantly increased by higher concentrations of suspended sediments. Water treatment operations may require greater use of chemical coagulants, greater maintenance filters, and increased chlorination to purify the water (Mason 1981).
Sedimentation damage due to adjacent properties	Property owners downhill of locations undergoing extensive erosion may be adversely affected by the deposition of alluvium from runoff moving across their property. Such deposits may damage existing vegetation, soil characteristics, private drainage works, or structures (Guy 1972).

Source: Paterson et al. (1993). Reproduced with permission.

are filter feeders and sedimentation can interfere with their ability to feed. Lemly (1982) examined the effects of sedimentation on benthic insect communities in an Appalachian trout stream. Results of the study show that sediments covered insect body surfaces and respiratory structures, particularly affecting filter feeding species. Lemly also found a reduction in the range of the size of benthic matter. Further, Lemly found a decrease of available living space due to accumulation of sand and silt. Although not established as general water quality standards for estuaries, biologically based recommendations for maximum total suspended sediment levels have been made for the Chesapeake Bay (Chesapeake Bay Program, 1991). For example, the recommendation for the health of the eastern oyster is 250 mg/L.

Decrease in photosynthetic activity. Increases in turbidity levels not only cloud water, making it visibly unattractive, but turbidity also decreases light penetration, impairing photosynthesis. If photosynthesis is impaired, then the quantity of plankton, a primary food source, is reduced. In Oklahoma farm ponds, clear ponds (< 25 parts per million [ppm] of suspended sediment) produced eight times as much plankton as did ponds with intermediate suspended sediment levels (25–100 ppm) and 12.8 times as much plankton as did ponds with high suspended sediment levels (>100 ppm) (Clark, et al., 1985). The recommended maximum total suspended sediment level to protect submerged aquatic vegetation in the Chesapeake Bay is 15 ppm (Chesapeake Bay Program, 1991).

Adverse effects on aquatic organisms. As part of an extensive literature review, Makepeace et al. (1995) found that turbid water can be detrimental to aquatic biota. The authors found that total suspended solid (TSS) concentration between 25 and 100 mg/L "could reduce a river's primary biological productivity by 13% to 50%. Turbidity has also been found to affect the ability of organisms dependent on vision to feed. For example, in a controlled experiment, Gardner (1981) found that increases in turbidity (60 to 150 nephelometric turbidity units [NTU]) reduced feeding rates of bluegills by 50%. The range in turbidity studied encompasses that typical of North Carolina waters. However, stream turbidity in disturbed watersheds could likely exceed these levels (Gardner, 1981). Organisms that rely on vision for courtship may also be affected (Clark, et al., 1985). Additionally, turbidity can be abrasive to fish and clog gills, affecting mortality (Marsh, 1993).

Pollutants

Storm water contains a multitude of pollutants including metals, organics, pesticides, inorganic pollutants, and oil and grease. These pollutants may have chronic or acute affects on aquatic organisms. Furthermore, these pollutants can be bound to sediment and accumulate on streambeds, leading to bioaccumulation. Field and Pitt (1990) reviewed a three-year monitoring study of a creek in San Jose, California and found that organics and heavy metals in the water column and sediments were likely responsible for the adverse biological conditions. For example, they found four to 60 times greater concentrations of sulfur, lead, and arsenic in urban sediments than in nonurban sediments. In addition, Field and Pitt found evidence of bioaccumulation of lead and zinc in many samples of algae, crayfish, and cattails. The biological conditions of the urban creek included a reduction in native fish species, decreased diversity and abundance of aquatic taxa, and an abundance of pollutant tolerant species of fish and benthic organisms. Finally, Field and Pitt indicate that the long term impacts of such pollutants may be more important than the short term impacts. They attribute the long term impacts to toxic sediments and the inability of organisms to tolerate repeated exposure to toxic contaminants and high flow rates.

Excessive Nutrients

Nutrients such as phosphorous and nitrogen are often used as fertilizer and can be contained in storm water runoff from urban areas and construction sites. When a water body receives an excessive amount of these nutrients, growth of algae and aquatic plants is stimulated. Like all plants, algae require oxygen and when abundant, can decrease the dissolved oxygen available for other organisms. In addition, when algae die they sink to the bottom of water bodies, where bacteria decompose the algae, depleting dissolved oxygen supplies (US EPA, 1995b). The overabundance of nutrients and resulting loss of oxygen, a condition known as eutrophication, leads to fish kills and mass mortality of benthic organisms (Water Environment Federation and the American Society of Civil Engineers, 1992).

2.2.3 Small Stream Impacts

Natural stream channel morphology is based largely on the quantity of water and sediment delivered to the streams (Toy and Hadley, 1987). Sediment loads can reduce stream depths, decreasing their retention and conveyance capacity, which can increase flooding (Water Environment Federation et al., 1992). Because these changes in morphology increase as development of a watershed increases, small streams are more susceptible to the adverse impacts of increased sediments. This is because a given amount of urbanization will affect a greater portion of small watersheds than large and thus have a greater impact.

Alterations in small stream channel morphology are of concern because they can pose significant threats to human health and safety, and can also threaten property (Toy and Hadley, 1987). Furthermore, the habitat provided by small streams can be critical to certain aquatic species. For example, small streams provide spawning and rearing habitats for several species of salmon (Sovern and Washington, 1997). Because of their size, small stream habitats are especially sensitive to excessive flows, sediment, and pollution resulting from construction activities and urban areas. Indeed, Sovern and Washington state that the destruction of small streams caused by urbanization is one significant reason for the decline in salmon populations.

2.3 Summary

The literature provides substantial evidence that storm water runoff from construction sites and urban areas can adversely affect aquatic systems. Runoff from these areas can include litter, chemicals, metals, nutrients, pesticides, bacteria, and sediment. In addition to contributing pollutants, construction sites and urban areas contribute to increased flows to receiving water bodies. The effects of pollutants and increased flows can be detrimental to aquatic organisms and habitat as well as to human health. The costs and benefits associated with controlling runoff from these areas are discussed in greater detail in Chapters 4 and 5, respectively. The resulting benefits are monetized in Chapter 6.