Urban Storm-Water Regulations—Are Impervious Area Limits a Good Idea?

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Introduction

With the implementation of Phase II of the National Pollutant Discharge Elimination System (NPDES) Stormwater regulations, many municipalities are now developing new or updated regulations to address water quality and receiving water protection. Among the many strategies that communities can consider are watershed-wide impervious area limits on new development. This is a concept that has arisen for several reasons: (1) The noting by various authors of correlations between increases in impervious area and the degradation of receiving waters; (2) the perceived ease of application of such regulations from a planning perspective; and (3) the desire of communities to minimize the impacts of development. While the authors of this editorial agree that impervious area is a useful indicator of the degree of urbanization in a watershed, we believe that the application of an impervious area limitation as a *regulatory* measure is poor public policy that fails to address the basic objective of using sound science and engineering to identify and mitigate the impacts of urbanization and storm-water runoff on receiving waters and the environment.

This editorial summarizes representative impacts of urbanization on receiving waters, provides a brief history of the use of imperviousness as an indicator, reviews some of the factors influencing water quality in addition to imperviousness, identifies some of the unintended consequences of impervious area limits, and suggests an integrated and comprehensive approach to storm-water management and regulation.

Effects of Urbanization on Receiving Waters

Traditional storm-water management focused on moving water away from people, structures, and transportation systems as quickly and efficiently as feasible. This was accomplished by creating conveyance networks of storm sewers, roof drains, and lined channels that concentrated runoff flows for discharge to receiving waters. Representative consequences of this traditional approach to drainage include

- Increased runoff frequency, volume, and duration (i.e., increased "work" to reshape streams)
- Larger peak discharges and flow velocities (i.e., increased stream-shaping energy)
- Change in base flow (dry weather) regime
- Increased flooding risk
- Increased runoff temperature
- Loss of riparian zones and wetlands, with associated loss of terrestrial and avian habitat
- Habitat damage and ecosystem disruption associated with streambed and bank erosion leading to sediment and pollutant transport, channel widening and instability, and destruction of both aquatic and terrestrial physical habitats
- Introduction of new pollutant sources and types
- Increased contaminant transport and water quality degradation
- Production of potentially toxic concentrations of contaminants in receiving waters and their long-term accumulation

These effects are highly site-specific and can vary substantially from one watershed to another. With increasing frequency, these adverse effects are being addressed by communities around the United States by implementing various structural and nonstructural best management practices (BMPs).

History of Impervious Area as an Indicator

In the late 1970s and early 1980s, the National Urban Runoff Program (NURP), conducted by the United States Environmental Protection Agency (USEPA) and the U.S. Geological Survey (USGS), collected extensive hydrologic and water quality data from over two dozen cities around the United States (USEPA 1983). A common finding of the NURP analyses and related storm-water model development was the identification of "directly connected impervious area" as a major factor in determining effects of storm-water runoff. It was clear that impervious area could be related to changes in hydrology (e.g., increases in peak flows, increases in duration and frequency of floods, changes in base flow) and increases in contaminant concentrations and loads. As regulatory programs developed to address urban runoff, such as the storm-water National Pollutant Discharge Elimination System (NPDES) regulations under the Federal Clean Water Act, there was a shift in management emphasis from storm-water conveyance to protection of receiving water ecosystems. At the same time, there was a new emphasis on watershed management (USEPA 1996), which requires a better sense of how physical, chemical, and ecological processes are integrated and how these processes can be altered by land use change, such as urbanization effects on habitat (USGS 2001).

As watershed management programs developed, there was also a need to identify indicators that would simplify the analysis of complex interactions (USEPA 2001). A wide range of indicators has been identified, some applicable to aquatic ecosystems, some specific to water quality, and others specific to types of land use change (USEPA 2003; Niemi and McDonald 2004). Impervious area has become one of the most commonly used indicators of land use change and urbanization. The utility of impervious area as an indicator and as a tool for storm-water management has been the focus of numerous studies (Horner et al. 2002; Schueler 2000; USGS 2001; Weber and Bannerman 2004). It is clear from the history and present status of the investigations of impervious area that this parameter is an important indicator of land use changes and a key factor in how watersheds respond to rainfall (Hatt et al. 2004).

Although impervious area is a technically sound and easy-to-use *indicator* of the degree of urbanization, the present state of science finds substantial variability in the effects of impervious area on receiving water quality and integrity. Impacts are highly location-specific and can differ significantly by region and even discrete stream channel reaches. This issue leaves much to be resolved before impervious area can routinely be used as a *management or regulatory tool*; one resolution might involve imposing a percent impervious area limit in a watershed via a drainage ordinance and/or regulation.

Other Factors Influencing Water Quality and Receiving Water Protection

The simplicity of an impervious area limit approach does not account for the many complex factors that can have significant water quality and receiving water implications regardless of the amount of impervious area on a site (Allan 2004; Hatt et al. 2004). Representative factors related to a proposed development site include

- The nature of proposed impervious areas and the extent to which runoff from these areas is managed and "disconnected" from other impervious areas; it is important to recognize that "not all impervious areas are created equal" (Bledsoe 2002; Hatt et al. 2004)
- Runoff characteristics (frequency, magnitude, duration, volume, timing, etc.)
- Soil characteristics to include permeability, hydrologic soil group, erodibility, and runoff characteristics
- Slopes and site topography
- Wetland and water body buffer zone protection and preservation measures
- Storm-water management strategy for development, including structural and nonstructural best management practices (BMPs) and extent to which "low impact development" (LID) practices are used
- Natural water quality features of the site, including wetlands, riparian areas, and lakes
- Proposed land use and potential pollutant sources
- Historic land use and its impact on water quality (mining, agriculture, forestry, etc.)
- Site development plan

Representative factors related to the receiving water include

- Upstream watershed characteristics, including size, slope, geology, soils, land uses, sediment yield, vegetation, runoff characteristics, pollutant sources, and influences on physical, chemical, and biological conditions
- Hydrology, local climate, and meteorology
- Water chemistry
- Geomorphology
- Aquatic life
- Stream order

Applying "one size fits all" impervious area limits to proposed land developments does not properly account for these and other factors. Considering the above, a site with low imperviousness could have poor water quality and significant receiving water impacts (e.g., a farm stream through a cow pasture with highly erosive Type C and D soils and upgradient feed lots). Conversely, a site with relatively high impervious area could have good water quality and provide a high degree of receiving water protection (e.g., a development using a wide array of structural and nonstructural BMPs, LID, and detention and runoff reduction practices that are properly designed and maintained).

Unintended Consequences of Impervious Area Limits

A direct connection can be made between impervious area limitations and urban sprawl (Field et al. 2000; Schueler 2000). Areas subject to urban sprawl typically suffer from a lack of integrated transportation and land-use planning, which leads to inefficient systems (in terms of cost and functionality) and elevated pollutant loadings (National Commission on the Environment 1993; Tetra Tech 1996; USEPA 1997). The Chesapeake Bay Foundation (1997) identified the impacts of urban sprawl:

- Five to seven times more sediment and phosphorus than a forest
- Nearly twice as much sediment and nitrogen as compact development
- Four to five times as much land used per person compared with 40 years ago
- Twice as much road building as compact development
- Three to four times as many automobile trips per day
- Much more air pollution than compact development
- Lower tax revenues in relation to the cost of providing infrastructure
- Induced relocation of people from central cities and inner suburbs

A developer faced with an impervious area limitation may simply purchase more land, especially in newly developing areas where land is readily available. Such an approach enables compliance with the regulation but may do nothing to reduce receiving water effects and the array of other environmental impacts. Although the public benefits of dedicated open space in urban areas are substantial, simply setting aside open space through low development densities and checked urban sprawl will fail to accomplish storm-water management objectives in the absence of a comprehensive management plan.

Impervious area limits result in the distribution of impervious area and associated effects throughout the watershed, with increased connectivity of roads and other transportation systems, and in the end may actually lead to increases in directly connected impervious area.

Comprehensive Storm-Water Management

Protection of a receiving stream requires a comprehensive approach to storm-water management that directly addresses the causes of watershed impairment. The first step in an effective management strategy is to clearly define goals of the program. This step is crucial in garnering public support, and it provides the basis for developing technological answers based on defensible scientific principles. Storm-water management programs that fail to clearly define objectives and/or develop approaches based on sound science are recipes for failure and litigation (Debo and Reese 2003; Field et al. 2000; USEPA 1997).

According to Richards (1995), "once ecosystem stresses are understood, the impacts of alternative management scenarios can be assessed and the design of engineering measures that complement or enhance ecosystem characteristics can then proceed." Impervious area limits will not address actual stressor reduction and may lead to addition of new, more severe stressors in a watershed. Effective watershed management and site-planning strategies take advantage of a broad mixture of structural and nonstructural control methods which are implemented in accordance with sound engineering and scientific guidance and criteria, and which are regularly maintained, monitored and adjusted, as necessary. Common elements of a comprehensive approach identified by many experts (ASCE/WEF 1998; Debo and Reese 2003; Prince George's County, Maryland 1999; Shaver 1998; Stahre and Urbonas 1990; Tetra Tech 1996; Denver Urban Drainage and Flood Control District 1992; Urbonas and Roesner 1993; USEPA 1997; Hatt et al. 2004; Allan 2004) include the following:

- Source control of pollutants
- Utilizing runoff reduction and LID techniques
- Minimizing directly connected impervious area
- Designing detention and retention facilities for small, frequently occurring events (in addition to larger storms) to address adverse physical impacts to receiving streams
- Using a "treatment train" approach (multiple BMPs, in succession)
- Incorporating channel stabilization methods

It is interesting to note that the NPDES Phase II permit requirements set up the framework for comprehensive storm-water management by addressing many of the issues discussed herein, yet do not require an impervious area limit. Indeed, at this time, few communities have adopted impervious area limits. This approach would certainly not currently be considered a standard of practice for American municipalities.

Conclusions

Increased impervious area is a symptom of urbanization, not necessarily the sole cause of receiving water and overall environmental degradation. The issue is not that impervious area exists; rather, the issue is the arrangement of impervious area within a landscape and the potential for directly connected imperious area to modify flow and enhance the transport of contaminants to the receiving stream. Furthermore, by causing urban sprawl and diverting attention from needed source controls and treatment BMPs, an impervious area limit may actually create additional and possibly more significant environmental problems.

If municipalities are compelled to impose or consider imposing impervious area limits, the writers then urge to first conduct comprehensive, watershed-specific receiving water and other environmental impact assessments. These types of assessments help to define the total environmental and urban infrastructure consequences and costs in order to provide at least some basis for the proposed limits on imperviousness.

Appropriate site planning and design can mitigate many of the impacts of urbanization. Protection or recovery of a receiving water is dependent on developing a comprehensive approach that addresses the causal relationships between urban development and environmental impacts. Effective management and regulation requires careful planning, application of advanced control measures, and continued vigilance in terms of maintenance and monitoring, and a willingness to adapt and improve technology and management programs.

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