Science Summary—Water-Quality Improvements Resulting from Suburban Stormwater Management Practices in the Chesapeake Bay Watershed

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Overview of Stormwater Practices to Improve Water Quality in Chesapeake Bay

As the largest and most productive estuary in North America, Chesapeake Bay is a vital ecological and economic resource. In recent decades, however, the bay and its tributaries have been degraded by excessive inputs of nutrients (nitrogen and phosphorus) and sediment from contributing watersheds, and in 1998, the bay was listed as "impaired" under the Clean Water Act. Consequently, a Total Maximum Daily Load (TMDL) was established for nitrogen, phosphorus, and sediment in 2010 (U.S. Environmental Protection Agency, 2010). The TMDL requires that the seven watershed jurisdictions implement management practices to reduce inputs of nutrients and sediment to meet water-quality standards for dissolved oxygen, chlorophyll, and water clarity in the bay. All practices needed to improve water-quality conditions in the bay must be implemented by 2025. The States in the watershed and the District of Columbia have prepared Watershed Implementation Plans (WIPs) to provide details on the types of management practices that will be used to meet the TMDL. Additional information on the TMDL can be found at *http://www.epa.gov/chesapeakebaytmdl/*.

An excess of nutrients and sediment decreases water clarity and fuels algae blooms in the bay, causing adverse effects on water quality, aquatic life, and the appeal of the bay for recreation. Approximately 16 percent of the nitrogen, 32 percent of the phosphorus, and 28 percent of the sediment that reaches Chesapeake Bay is derived from urban and suburban areas in the watershed (U.S. Environmental Protection Agency, 2008). Projections indicate that the suburban population and the associated conversion of agricultural and forested land to development will continue to increase, further increasing the contribution of nutrients and sediment from suburban areas to the bay (Boesch and Greer, 2003; Jantz and others, 2005).

The sources of nitrogen, phosphorus, and sediment from urban and suburban areas include lawn and garden fertilizers, leaky sanitary sewer or septic systems, pet waste, deposition of airborne nitrogen byproducts from automobiles and gas-powered lawn tools, construction activities, and eroding streambanks. Urban and suburban areas are characterized by a large amount of impervious surface cover such as buildings, sidewalks, driveways, and streets, which causes much of the precipitation to run off rather than infiltrate into the ground. Road culverts and curb and gutter systems collect the stormwater and quickly deliver it to area streams, causing high streamflows and resulting in streambank erosion and degradation of stream habitat. Essentially, precipitation washes stormwater contaminants, including nutrients and sediment, from the urban landscape and carries them to area streams that ultimately drain to Chesapeake Bay.

Suburban resource managers use stormwater management facilities—commonly called Best Management Practices (BMPs)—to slow down and treat stormwater runoff in an effort to prevent streambank erosion and remove some of the excess nitrogen, phosphorus, and sediment before the stormwater can reach the streams and be transported to Chesapeake Bay. Some examples of the many types of BMPs used in suburban environments are shown in figure 1.

A

B

C

D

E

Figure 1. Examples of the many types of urban and suburban stormwater management facilities, commonly called Best Management Practices (BMPs): *(A)* above-ground retention pond, *(B)* rain garden, *(C)* rain barrel, *(D)* sand filter, and *(E)* sand filter and detention pond in series. BMPs help to slow the flow of stormwater from the landscape to streams to mitigate streambank erosion, prevent degradation of stream habitat, and reduce the load of contaminants, including nutrients and sediment, tranported in stormwater runoff to local streams and then downstream to Chesapeake Bay.

U.S. Geological Survey Research on Stormwater Practices

The U.S. Geological Survey (USGS) and its partners have been studying the effectiveness of suburban stormwater management practices (BMPs) in moderating the volume of stormwater that runs off to streams, removing contaminants (including excess nutrients and sediment) from the stormflow, and even, in the case of stormwater wetlands (a type of BMP), also providing wildlife habitat. This Science Summary is one in a series that is designed to facilitate the understanding and application of results of relevant studies by Chesapeake Bay resource managers and policy makers. It provides a brief overview of the most recent published work by the USGS and collaborators on suburban stormwater management practices in the Chesapeake Bay watershed, an understanding of how this information can be used to develop effective management policies and practices, and a list of references for additional information. The USGS studies of stormwater practices include:

• Investigating the effect of simple design changes on the ability of stormwater detention basins (another BMP type) to control flooding while also promoting the removal of nutrients and sediment,

• Investigating the effects of the unintended use of stormwater wetlands by wildlife as habitat, and

• Developing tools and methods to examine the effectiveness of different types of stormwater management programs in controlling stormwater flow and the concentrations of the nutrients and sediment it contains.

These USGS studies typically focus on small watersheds, and sometimes even on an individual BMP, and help to gain a detailed understanding that can then be applied to describe the cumulative effect of BMPs at the scale of larger watersheds like the Chesapeake Bay watershed. Management decisions and actions, including choosing which type(s) of BMPs to use, how many BMPs to construct, and whether to use individual BMPs or multiple, different BMPs in series are implemented at the local level. The cumulative effect of many local decisions on BMP use in the bay watershed ultimately has a major impact on the restoration of the bay.

The type and physical design of stormwater management facilities (or BMPs) affect their ability to control flow and retain nutrients and sediment (Hogan and Walbridge, 2007); however, understanding the use of BMPs in series on the landscape is essential for achieving watershed-scale stormflow and contaminant reduction in support of Chesapeake Bay restoration. Traditionally, stormwater BMPs have been used in a centralized manner (a small number of BMPs is located in a given area and the surrounding urban areas drain to them). Recently (since about the 1990s), stormwater managers and land-use planners have begun to integrate BMPs into the urban landscape and use them in a distributed way (multiple, different BMPs, sometimes connected in a series and used to detain stormwater; increase infiltration to groundwater; and increase the removal of nutrients, sediment, and other contaminants).

The USGS, the U.S. Environmental Protection Agency (USEPA), and local county partners are examining the use of BMPs in a distributed manner both during development (sediment- and erosion-control phase) and after development (stormwater management phase) in urbanizing areas in Maryland (Hogan, 2008; Loperfido and Hogan, 2012; see Jarnagin (2009) for additional information on study sites). This research documents patterns of BMP use and connectivity (fig. 2) to determine the location of a watershed on the gradient from centralized to distributed stormwater management, and monitors and quantifies BMP effectiveness by linking landscape changes to changes in stream hydrology, water quality, stream channel morphology, and biology (Hogan, 2008; Loperfido and Hogan, 2012; Jarnagin, 2009; Montgomery County Department of Environmental Protection, 2010). The results of this study will help identify which BMP types and spatial patterns (centralized, distributed, or a combination) are most effective for reducing stormwater runoff from suburban areas, and the contaminants it contains, both during and after construction.

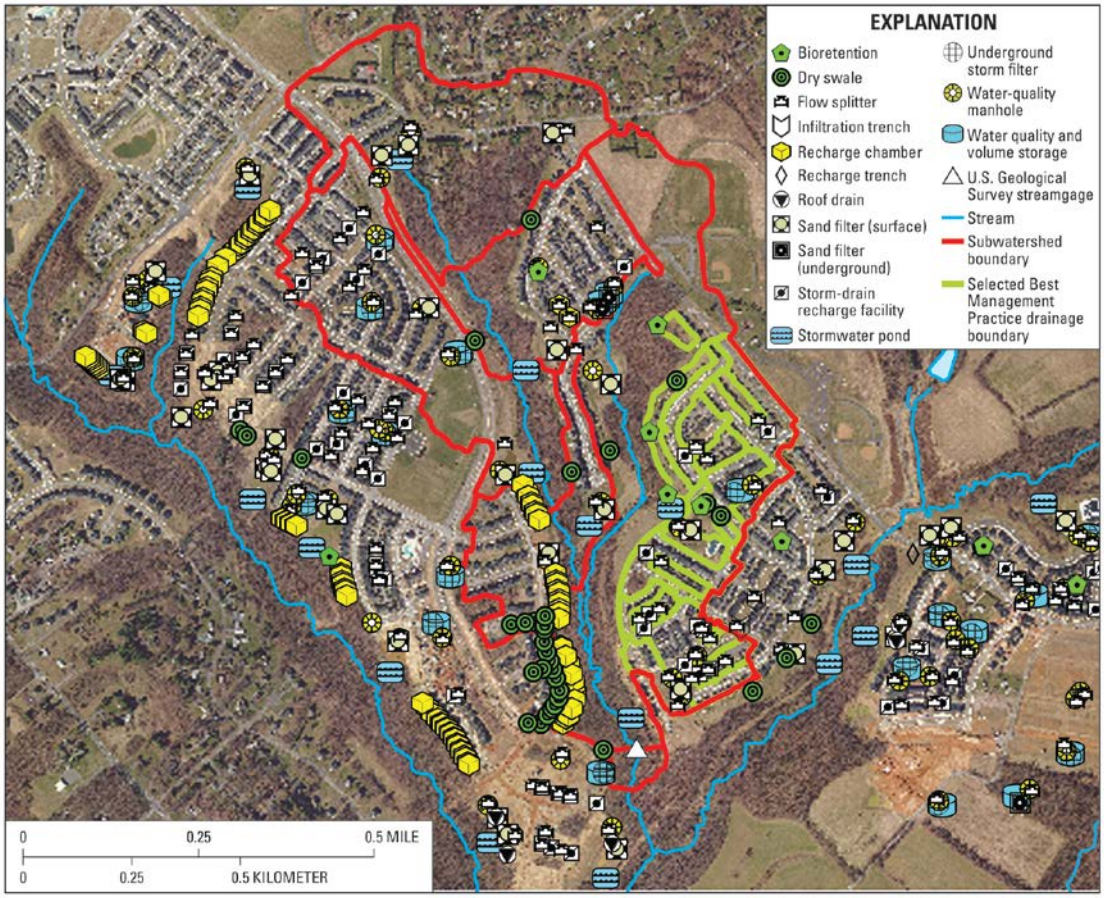

Figure 2. An example of the database of stormwater management facility (or Best Management Practice) use and connectivity at one of the Maryland study sites. (See Jarnagin (2009) (*http://www.epa.gov/esd/land-sci/clarksburg01-05.htm*) for additional information on study sites.)

This Science Summary focuses on findings from the Maryland sites but also includes key findings from research on stormwater practices in Fairfax County, Virginia. The **KEY FINDINGS** and **IMPLICATIONS FOR MANAGEMENT POLICIES AND PRACTICES and NEXT STEPS** listed below are from Karouna-Renier and Sparling (2001); Sparling and others (2004); Hogan and Walbridge (2007); U.S. Environmental Protection Agency (2008); Montgomery County Department of Environmental Protection (2010); and U.S. Environmental Protection Agency (2010).

KEY FINDINGS

•The physical design of stormwater detention basins affects their ability not only to capture or slow down the flow of stormwater runoff but also to reduce the load of nutrient and sediment contaminants it transports to streams. Simple changes in basin topography and the use of wetland vegetation can help to improve water quality by removing and retaining nutrients and sediment as well as increase the detention of peak stormwater flows (fig. 3; Hogan and Walbridge, 2007).

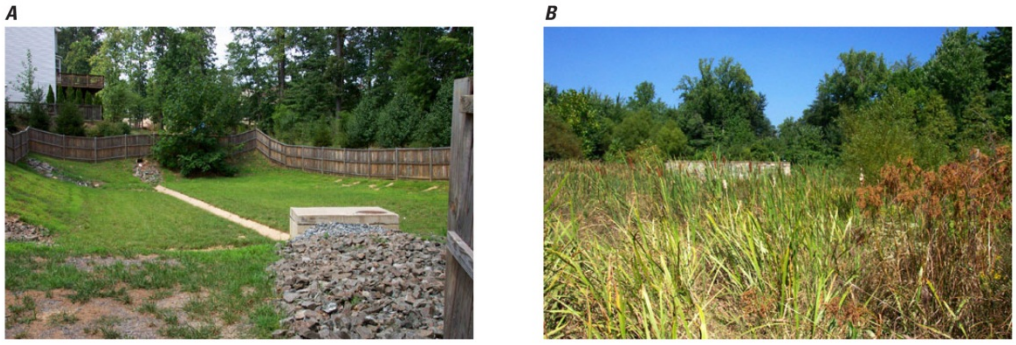

Figure 3. Stormwater detention basins (a type of Best Management Practice (BMP)) designed for *(A)* flood control only (detention of stormwater), and *(B)* flood control and water quality (detention of stormwater and removal of nutrients and sediment).

•At the Maryland study sites, the construction phase of the study resulted in changes in stream biota and changes in stream hydrology despite the sediment- and erosion-control BMPs that were in place during development (Montgomery County Department of Environmental Protection, 2010).

•Because stormwater wetlands can be attractive to wildlife and may be the only wetland habitat in some urban areas, they provide not only stormwater management but also important habitat ecosystem services (Sparling and others, 2004).

•Invertebrates living in stormwater treatment ponds were found to contain high levels of copper and zinc (Karouna-Renier and Sparling, 2001).

•Elevated concentrations of copper and zinc were found in stormwater wetland sediment and in carcasses of 8-day-old red-winged blackbird (*Agelaius phoeniceus*) nestlings inhabiting stormwater sites. These results suggest that the nestlings were either directly or indirectly impaired by the elevated zinc levels (Sparling and others, 2004).

IMPLICATIONS FOR MANAGEMENT POLICIES AND PRACTICES AND NEXT STEPS

• As population and suburban land use in the Chesapeake Bay watershed increase, the importance of using stormwater BMPs that provide multiple functions and services (such as flow, nutrient, and sediment retention), and of using BMPs on the landscape in a manner that maximizes their efficiency, will increase. This research helps USEPA and Chesapeake Bay jurisdictions plan and implement stormwater practices to reduce nitrogen, phosphorus, and sediment in stormflow to help achieve the bay TMDL.

•Stormwater management practices continue to evolve as we learn more about their effectiveness in controlling stormwater runoff and the loads of contaminants (including nitrogen, phosphorus, and sediment) runoff transports from the landscape to streams. Current trends indicate that BMP use is tending toward a more distributed approach with an emphasis on stormwater infiltration and individual property-management techniques (for example, rain gardens, rain barrels, individual property dry wells, infiltration systems, and reuse systems).

As monitoring results for nutrient and sediment from these studies become available, the findings can be used to update estimates of stormwater practice efficiencies used in the USEPA Chesapeake Bay watershed model. The results will also help CBP partners employ adaptive management to more strategically design and implement stormwater BMPs.

•The USGS will be summarizing results of research being conducted in Fairfax County, Virginia, and Montgomery County, Maryland, to add to available information about the effect of stormwater practices on the transport of nutrients and sediment by stormflow. The USGS also plans to summarize research on agricultural practices in several small watersheds in the Chesapeake Bay Basin.

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