Rainy-Day Research

Stormwater management study facilitates understanding of solutions and costs.

By Les Lampe, Howard Andrews, Michael Barrett, and Peter Martin

Changes in land use associated with urbanization can cause major changes in the volume and quality of stormwater runoff. These changes include an increase in concentration of many stormwater pollutants, some of which may be toxic to sensitive aquatic species. In addition, the volume of runoff generated by impervious surfaces, which may be as much as 20 times the volume observed in undisturbed watersheds, may exacerbate flooding downstream—resulting in loss of riparian habitat through erosion of stream beds and banks.

Best Management Practices (BMPs) in the United States and Sustainable Urban Drainage Systems (SUDS) in the United Kingdom are measures that are being used to reduce these impacts to receiving waters. There is strong interest in both countries in determining costs associated with BMPs/SUDS construction and maintenance. Developing funding sources to provide perpetual maintenance of these systems is a critical need, since stormwater authorities are often responsible for maintaining these facilities as part of their "asset base."

A recently completed, three-year research study was designed to gain a better understanding of these stormwater management systems. Launched to document the performance and whole-life costs of BMPs/SUDS, the research focused on understanding the future financial liabilities associated with the widespread implementation of BMPs/SUDS.

Study Funding

The study was funded by the Water Environment Research Foundation (WERF, www.werf.org), United Kingdom Water Industry Research (UKWIR, www.ukwir.org), and the American Water Works Association Research Foundation (AwwaRF, www.awwarf.org). The project team was directed by Black & Veatch (www.bvcom) offices in the United States and United Kingdom. Project team members also included H.R. Wallingford, UK (www.hrwallingford.co.uk); the Urban Water Technology Centre, Abertay University, Dundee, Scotland (www.uwtc.tay.ac.uk); Center for Research in Water Resources, University of Texas at Austin (www.crwr.utexas.edu); and Glenrose Engineering, Inc. (www.glenrose.com). The project was managed by WERF as project 01-CTS-21T.

"The challenges faced by municipalities, stormwater agencies, and others in controlling pollution from stormwater runoff are immense," said WERF Research Program Director Jeff Moeller. "Information developed though this study provides guidance that will help organizations cost-effectively achieve water quality goals."

The first phase of the study consisted of an extensive review of scientific literature and survey of existing information on BMPs and SUDS. The second phase consisted of an in-depth evaluation to assess performance maintenance requirements and whole-life costs of selected BMPs/SUDS, including retention ponds, extended detention basins, vegetated swales, bioretention systems, porous pavement, and various infiltration facilities.

Performance of these systems, determined through evaluation of material contained in the International BMP Database (www.bmpdatabase.org), was related to critical design factors such as pool volume, residence time, and climatic variables. Based on information contained in the International BMP Database, Figure 1 shows the relative capabilities of retention ponds, extended detention basins, and vegetative swales for removing total suspended solids. With limited data available for some types of facilities, engineers are restricted in their ability to design these systems to achieve specific water quality objectives.

Frequently used in parking lots, bioretention systems such as this one in Maryland consist of a grass buffer strip, a sand bed, a ponding area, an organic or mulch layer, planting soil, and plants.

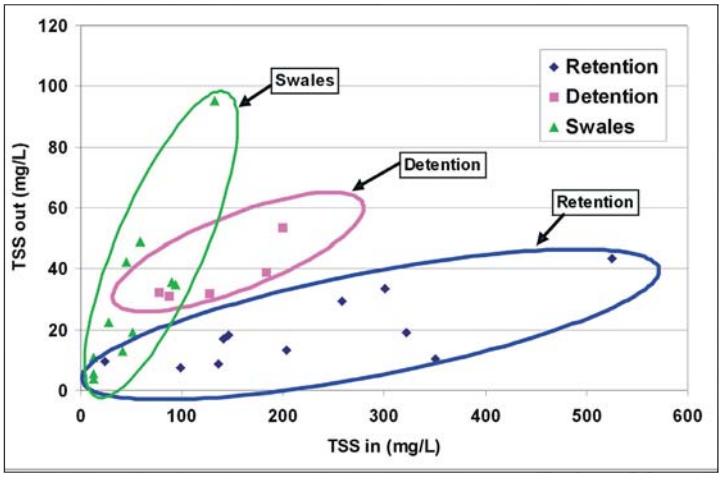

Figure 1. This figure show the relative capabilities of retention ponds, extended detention basins, and vegetative swales for removing total suspended solids. The source of this data is the International BMP Database.

The relative hydraulic performance of individual facilities as well as treatment trains (BMP/SUDS components in series) was determined through computer modeling of their behavior for observed events, design storms, and five years of stochastically generated rainfall data for areas with different soil types and rainfall patterns. Most BMPs/SUDS systems provide a high level of peak rate attenuation; however, the modeling showed that they were unable to reduce the volume of runoff to predevelopment levels. This is because the majority of storm events do not generate any runoff at all in the predeveloped condition. In addition, the capabilities of the current generation of models cannot adequately represent the processes employed in many of these systems.

A survey of BMPs in various regions of the United States revealed substantial differences in design. These differences are related to issues of safety, vector control, and receiving water objectives. For example, components such as low-flow channels in extended detention basins are preferred in some areas to facilitate maintenance, but avoided in other areas to minimize warming of runoff discharged to temperature-sensitive receiving waters. The researchers concluded that there is no optimum design for BMPs that is applicable to all areas.

Whole-Life Cost Analysis

Capital costs comprise a significant portion of the expenditures considered in whole-life cost analysis. These costs were compiled from literature sources and through a survey of stormwater management agencies in the United States. The researchers discovered that 1) capital cost information is difficult to obtain, and 2) costs from different regions cannot easily be compared—unless the objective is to simply describe one cost as higher, lower, much higher, etc., than another. The large variation in costs for similarly sized facilities in different regions indicates that the cost of a particular facility should not be expected to be similar to averages reported in national studies.

Maintenance requirements were compiled from surveys of organizations responsible for these activities in the United States and United Kingdom and through detailed monitoring of selected

Retention ponds like this one in Colorado are among the most widely applied stormwater management practices.

Trenches and soakaways, such as this infiltration trench in Wisconsin, are shallow trenches filled with rubble or stone to create temporary subsurface storage for infiltration of stormwater runoff; the runoff gradually exfiltrates through the bottom and/or sides of the trench into the subsoil and eventually reaches the water table.

A porous pavement system, such as this one in Scotland, consists of a load-bearing, durable surface combined with an underlying layered structure that temporarily stores water before infiltration or drainage to a controlled outlet.

sites. Estimates of maintenance costs were developed based on the time and materials required to perform maintenance activities. Maintenance budgets were found to be established largely by the expectations of people living or working near the facilities rather than based on technical requirements. Essentially no public agency interviewed in the United States had the resources to fully maintain BMPs in the agency's jurisdiction to the level expected or hoped for according to its maintenance guidelines.

Whole-life cost models were developed using both construction and maintenance costs. These models were developed in a spreadsheet framework to allow users to calculate the expected cost associated with the various BMPs/SUDS facilities based on drainage area, maintenance expectations, and other factors. The level of maintenance was more important than the capital cost in determining the whole-life costs for many of these facilities.

This study also identified a number of research needs that should be addressed to help those concerned with the design, performance, and maintenance of these facilities. The researchers recommended meeting these needs through field monitoring of BMPs/SUDS performance and better record keeping—a combination of activities that will help more accurately determine expected maintenance costs for various types of facilities.

"This research study greatly enhanced our international understanding of stormwater runoff issues and costs," said Moeller. "But it also revealed how much more we need to learn in order to cost-effectively apply available stormwater management techniques. Recommendations for future action will be carefully considered."

The final report, *Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems,* will be available from the Water Environment Research Foundation (www.werf.org) later this year. For additional information, contact Jeff Moeller at WERF by telephone at 703-684-2461 or by e-mail at jmoeller@werf.org. GE

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