BMP UNIT PROCESS DESIGN, MONITORING, AND PERFORMANCE

M. Borst, S. Struck, C. Nietch, and T. O'Connor
National Risk Management Research Laboratory

BOSC WATER QUALITY REVIEW
CINCINNATI, OHIO JANUARY 2006

LTG 3 Poster 05

Science Questions

Multi-Year Plan Science Question:
What Best Management Practice treatment systems and restoration technologies are the most effective options in watershed management when considering treatment of priority stressors in runoff from single and mixed land uses and habitat alterations?

Research Question: How can best management practices be effectively designed and monitored to assess and improve their performance and control priority pollutant loads to receiving waters?

How Research Addresses the Water Quality MYP Goals

This research provides systematic and statistically-robust evidence that BMPs reduce the non-point source load associated with stormwater runoff discharged to receiving waters.

Documenting BMP performance and developing techniques to reliably predict effluent volumes and concentrations is critical to supporting TMDL applications.

Research Objectives

This research determines how Best Management Practices (BMPs) can be designed and monitored to predict and document their performance in reducing priority stressors discharged to receiving waters with known uncertainty.

Structural BMPs are devices routinely installed throughout watersheds to intercept runoff before it drains into receiving waters. Watershed managers install these devices to attenuate flow and other stressors.

Flow attenuation has historically emphasized flood prevention. More recent BMP designs attempt to match post-development hydrographs to the undeveloped condition using combinations of infiltration, evapotranspiration, and discharge structure design. Models, such as SWMM, can effectively predict the BMP hydrology.

The effluent stressor concentration uncertainty is much greater than hydrologic uncertainty. The literature-reported experimental results vary greatly. It is not uncommon for one source to report significant removal while a second reports the BMP serves as a stressor source. Uncertainties of this magnitude make the reported results unsuitable for watershed modeling or TMDL applications.

This research views the BMP as a traditional unit operation and approaches the expected stressor reduction as a predictable quantity based on BMP design and physio-chemical conditions, influent rates, and stressor concentrations.

Mesocosm-scale stormwater Best Management Practices (Edison, NJ)

Instrumented effluent at field BMP (Staten Island, NY)

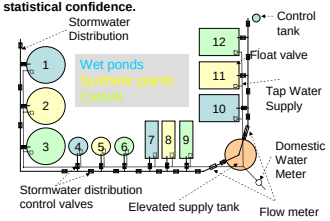
Research Methods & Collaboration

This research hypothesized that much of the variability in the literature-reported BMP evaluations resulted from scale issues. Nearly all researchers evaluated the stormwater controls at either the beaker scale, which fails to incorporate the inherent process heterogeneity, or at full-scale, which is difficult to accurately measure, sample, and monitor and lacks the significant degree of experimental control needed for replication. EPA's research is designed to compliment concurrent WERF-sponsored research.

NRMRL constructed a set of pilot-scale systems believed to balance this scale issue. The devices are large enough to mimic the extraneous watershed influences, but small enough to affordably provide experimental control and enable controlled replication necessary for statistical confidence.

The stormwater at the research facility was characterized to assure that it represented runoff characteristics compiled in national databases (e.g., NURP and NSQD). Methods were developed to homogenize and sample the associated volumes with known statistical certainty. Metered volumes of the collected water were used as system feed. Detailed monitoring of the internal conditions showed diurnal fluctuations typical of full-scale BMP conditions. The entire effluent was collected to assure a perfectly flow-weighted sample.

Concurrent field monitoring at a full-scale structure with similar design in Staten Island, NY helps assure scalability.



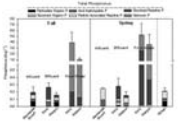
Schematic of pilot-scale stormwater BMP research facility layout.

Research Results

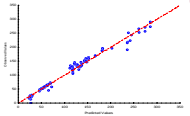
Existing pilot-scale results from NRMRL's research facility document the ability of wet ponds and constructed wetlands to alter the load discharged to receiving waters from wet ponds and constructed wetlands. Storms are treated as batch operations resulting from short-duration, high-intensity rain events. Current stressors of interest include sediment, identified heavy metals, indicator bacteria, and nutrient species.

Changes in nutrient concentration vary seasonally. Bacterial indicators decrease with time but do not strictly follow the temperature-dependent first-order decay models commonly assumed in current models. Sediment reduction is highly predictable based on influent concentration and hydraulic loading (ratio of runoff volume to BMP surface area).

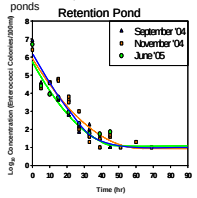
The effluent water temperature and other water quality descriptors from open-water ponds and wetlands are measurably different. These differences may be important in selected applications (e.g., temperature or dissolved oxygen TMDLs).



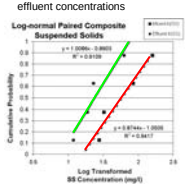
Seasonal comparison of phosphorous in effluent from pilot-scale wetlands and wet ponds



Comparison of model-predicted effluent TSS concentration with measured effluent concentrations



Time-dependent effluent enterococci concentration from retention ponds measured in pilot-scale BMPs



Comparison of field measured influent and effluent concentrations at operating control in Staten Island, NY

Research Conclusions & Future Directions

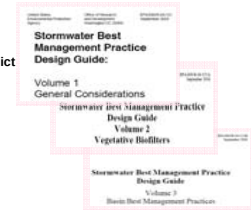
Preliminary analysis suggests that discharged stressor concentrations and loads can be effectively modeled. After verification, these BMP models will be incorporated into watershed models to better predict the ability of these controls to lower receiving water stressor concentrations throughout the watershed. With this capability, watershed managers can better predict the water quality changes achievable by introducing the BMPs at given positions throughout the watershed.

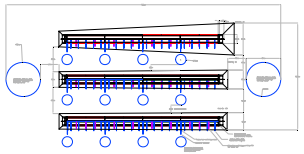
Future work must expand the existing data set to consider potential effects of runoff timing (influent hydrograph) on BMP performance.

NRMRL will combine BMP performance models with recently-released whole-life cost estimating tools to evaluate the comparative cost effectiveness of alternate designs and approaches including sequential BMPs.

Pilot-scale results must be demonstrated to effectively scale to field (full) scale conditions. These pilot scale results and the current field monitoring program provide a framework for the evaluations and monitoring.

Swales are an integral part of many BMP systems, the primary drainage tool for the national highway system, and part of the Low Impact Development planning. Little monitoring data exist that enable EPA to document the stressor or volume reductions achieved by swales. Pilot-scale swales are currently under construction at the NRMRL Edison facility to evaluate a swale's ability to reduce stressor loads alone and in combination with other structure practices.





Pilot-scale experimental swales (under construction) in Edison, NJ. Research plans under development with external collaborators.

Interactions with Customers

Interactions include routine updates of products with EPA Office of Water (including OWOW, OWM). Presentations in August of 2005 at the national state stormwater coordinators meeting allowed direct interaction with state stormwater representatives. Teaming with New York City DEP, VA DEQ, SC DEP, and university researchers occurred throughout the process as well as collaborative work with EPA Regions 2, 3, and 4. Collaboration with other modeling projects will involve other customers and clients.

How Research Contributes to Outcomes

BMPs are the fundamental tool in addressing runoff to meet TMDLs, water quality standards, and designated uses. This research provides an efficient, cost-effective approach to developing effective BMP design procedures, predicting the reduced stressor loads to receiving waters, and understanding the uncertainties associated with the devices. The approach enables application to local conditions and enables efficient use of limited water quality restoration funds in communities to effectively improve water quality. The results will be incorporated into subroutines in BMP placement model and cost estimating tools.