Report as of FY2006 for 2006IL134G: "Evaluating Alternatives for Watershed-Scale Design of BMPs"

Publications

- Conference Proceedings:
  - Kaini, P., K. Artita, J. Nicklow, 2007, Evaluating optimal detention pond locations at a watershed scale, in Proceedings of the 2007 World Environmental and Water Resources Congress, American Society of Civil Engineers, Reston, VA, CD-ROM.

Report Follows

National Institutes of Water Resources/
Illinois Water Resources Center
Annual Report

1. **Project Number:** 2006IL134G

2. **Project Title and PIs:** Evaluating Alternatives for Watershed-Scale Design of BMPs; Dr. John W. Nicklow, P.E., P.H., D.WRE, Professor, Department of Civil and Environmental Engineering, Southern Illinois University at Carbondale (SIUC)

3. **Research Category:** Best Management Practices, Decision Support Modeling

4. **Problem and Research Objectives:** In recent years, stormwater runoff has received significant attention in the U.S. due to an improved understanding and increased public awareness of it potential impacts. One of the most significant outcomes of this attention has been an increased emphasis on the application of Best Management Practices (BMPs) as runoff controls. Too often, however, the overall layout of BMPs throughout a watershed is a patchwork of individually-designed structures and devices. Recent literature suggests that such fragmented layouts may actually worsen storm water impacts in a watershed, thus negating the intended purpose of runoff controls. Detention-based systems and other structural BMPs are instead most cost-effective when designed and implemented in regionally-strategic combinations to meet related stormwater treatment goals. This concept is consistent with recent emphasis on comprehensive, holistic watershed-scale management, an idea strongly promoted by the U.S. EPA since the early 1990s. Unfortunately, there exists neither a methodology, nor a generalizable model, for selecting, placing, and sizing BMP combinations that cost-effectively achieve treatment goals at the larger spatial scale of an entire watershed.

   The objectives of this research include development of a new, publicly-available decision-support framework and corresponding software model that bridges the gap between individual BMP design and the implementation of watershed-scale runoff controls. This decision-making framework and corresponding computational model will assist in determination of the most cost-effective combination, including types, sizes, and locations, of BMPs and a set of near-optimal alternatives for the control of storm water impacts. The benefit of such an approach is straightforward: implementation of the optimal design or near-optimal alternatives will likely result in a more effective reduction of stormwater impacts at lower stakeholder cost. Although the decision-support model is designed to be transferable to other basins, it is being developed and tested using a portion of the Lower Kaskaskia watershed in southwestern Illinois. Eastward expansion of the city of St. Louis and the Metro East region will require construction of structural BMPs, especially detention and retention ponds, to limit adverse affects of this future growth. To promote the realization of benefits of watershed-scale design in professional practice, the methodology and application results will be disseminated to federal and state agency personnel, concerned local stakeholders, and the wider water resources community through

regional meetings and workshops, an outreach bulletin, nationally-organized conferences, and peer-reviewed journals.

5. **Methodology:** A decision support model has been created by linking an evolutionary optimization algorithm (genetic algorithm) with the U.S. Department of Agriculture's Soil and Water Assessment Tool (SWAT) for comprehensive hydrologic simulation. The initial model is currently undergoing testing, evaluation, and refinement to improve predictive capacity and computational performance. The resulting modeling framework is capable of determining watershed-scale detention pond design parameters that:

   Minimize → total cost of detention facilities
   Subject to → (i) governing physical laws of watershed hydrology and water quality, (ii) maximum allowable peak flow rates, maximum detention pond sizes)

   Constraints on water quality/quantity (e.g., maximum nutrient concentrations) will be added in the coming months. Furthermore, additional BMPs (e.g., swales, filter strips, and wetlands) will be added to the decision support framework.

   Within the new model, SWAT is used to solve constraints that govern watershed hydrology such that the complex interactions between water quantity and quality are fully captured. In addition, SWAT is capable of simulating several standard structural BMPs, including detention ponds, constructed wetlands, filter strips, and swales. Meanwhile, the evolutionary algorithm identifies optimal BMP designs. Two types of evolutionary algorithms, a genetic algorithm (GA) and a species conserving genetic algorithm (SCGA), are being investigated for solution to this problem. The GA solves the problem by finding a single near-optimal solution while the SCGA produces multiple alternative designs that vary minimally in cost from that of the optimum, but are different with respect to design parameters (i.e., BMP type, size, and/or location) and unmodeled objectives (e.g., stakeholder preferences). Originally, another evolutionary algorithm known as the artificial life algorithm was to be used for alternatives generation; however, the SCGA was found to be less computationally demanding and better suited for the distributed nature of the problem.

   To meet outreach objectives, an educational brochure aimed at local stakeholders was assembled to introduce and explain important concepts in watershed-scale BMP design such as "What is a watershed?", "What is a BMP?", and "Why is watershed-scale design important?" Currently, these brochures are in final printing and awaiting distribution. Additional outreach will involve demonstration and visualization of the decision-support model on the entire Lower Kaskaskia basin and a roundtable discussion on future model improvements with local stakeholders that include the Southwest Illinois Resource Conservation and Development Council (SWILRC&D), National Resource Conservation Service, Illinois Dept. of Agriculture,

Illinois Dept. of Natural Resources, U.S. Fish and Wildlife Service, Farm Bureau, Soil and Water Conservation Districts, county board members, and others.

6. Principal Findings to Date and Significance:

- Collection and review of pertinent scientific literature demonstrates increasing emphasis on watershed-scale design of BMPs;
- A digital elevation model and related thematic GIS data for the Lower Kaskaskia basin have been collected and evaluated;
- Development and testing of a GA, artificial life algorithm, and SCGA software modules for various benchmark test problems demonstrated the strength and flexibility of these algorithms and have revealed that the GA and SCGA are appropriate for integration into the decision support model;
- The SWAT source code was modified to facilitate a seemless link to the optimization algorithms and the SWAT-GA interface was created;
- Initial testing and application of the SWAT-GA model on Silver Creek basin demonstrates a capability to identify least-cost detention pond design;
- The educational outreach brochure has been created for stakeholders and decision-makers in the Lower Kaskaskia basin;
- Positive feedback received at a recent peer-reviewed national conference (see Section 8) has reaffirmed the importance of the current problem and the approach being applied.