Report as of FY2007 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.
  - Artita, K.S., P. Kaini, and J.W. Nicklow, 2008, Generating alternative watershed-scale BMP designs with evolutionary algorithms, in Proceedings of the 2008 World Environmental and Water Resources Congress, American Society of Civil Engineers, Reston, VA, CD-ROM (in press).
  - Kaini, P., K.S. Artita, and J.W. Nicklow, 2008, Designing BMPs at a watershed-scale using SWAT and a genetic algorithm, in Proceedings of the 2008 World Environmental and Water Resources Congress, American Society of Civil Engineers, Reston, VA, CD-ROM (in press).

Report Follows

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

Problem and Research Objectives: Best management practices (BMPs) are widely-used structural or non-structural methods intended to manage and/or improve the quantity and quality of stormwater runoff. BMPs are commonly individually designed and site-specific. Studies (e.g., Ferguson, 1991), however, suggest that such fragmented layouts may actually worsen stormwater impacts at the scale of a watershed, thus negating the intended purpose of runoff controls. Detention systems and other structural BMPs are instead most cost-effective when designed and implemented in regionally-strategic combinations to meet related stormwater treatment goals. Implementation of a watershed-scale BMP design is often challenged by conflicting objectives (e.g., environmental, ecological, economic criteria) as well as unquantifiable (and therefore, unmodeled) objectives. Identifying a least cost BMP design and several alternative, near-optimal combinations allows decision-makers to assess tradeoffs between designs and will likely result in a more effective reduction of stormwater impacts at lower stakeholder cost.

The objective of this research is the development of a new, publicly-available decision-support framework and software model that bridges the gap between individual BMP design and the implementation of watershed-scale runoff controls. The corresponding computational model will be capable of determining the least-cost combination of BMP design (including types, sizes, and locations of BMPs), along with a set of near-optimal alternatives for the control of stormwater impacts. This decision-making framework will be developed and tested on Silver Creek watershed, a portion of the Lower Kaskaskia watershed in southern Illinois. 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 journal articles.

Methodology: A decision support model has been created by linking evolutionary optimization algorithms (EAs) with the U.S. Department of Agriculture's Soil and Water Assessment Tool (SWAT). The initial model has undergone testing, evaluation, and refinement to improve predictive capacity and computational performance. The resulting modeling framework is capable of determining watershed-scale BMP designs that:

Minimize → total cost of BMPs

Subject to →
i. governing physical laws of watershed hydrology and water quality,
ii. BMP size constraints (e.g., maximum detention pond area)
iii. maximum peak flow and sediment load rates (i.e., water quantity and quality constraints),
iv. BMP placement constraints (i.e., no BMPs can be placed in subbasins with wetlands or forests as its dominant land use type).

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. SWAT also simulates several standard structural BMPs, including detention ponds, infiltration ponds, parallel terraces, grade stabilization structures, grassed waterways, and filter strips. Meanwhile, the EA identifies optimal BMP designs and solves the overall optimization problem. Two types of EAs, a genetic algorithm (GA) and a species conserving genetic algorithm (SCGA), are used for solution to this problem. The GA solves the problem by finding a single near-optimal solution; the SCGA produces multiple alternative designs that vary minimally in cost from that of the optimum, but are maximally different with respect to design parameters (i.e., BMP type, size, and/or location) and unmodeled objectives (e.g., stakeholder preferences).

To meet outreach objectives, PIs have discussed work with stakeholders in and near the test watershed, and they have scheduled a workshop for summer 2008, to include a demonstration of the decision-support model for Silver Creek and a roundtable discussion on future model improvements. Anticipated participants include representatives of 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. Additional outreach and dissemination is occurring through University and community meetings and through professional publications.

Principal Findings to Date and Significance:

- Collection and review of pertinent scientific literature demonstrates increasing emphasis on the use of EAs in watershed-scale design of BMPs;
- In addition to detention ponds, other structural BMPs, including infiltration ponds, grassed waterways, parallel terraces, and filter strips, have been included into the model, thus incorporating more options for BMP designs and combinations;
- The SWAT source code has been modified to facilitate a seamless link to the optimization algorithms, thus eliminating the need to continuously modify the original SWAT codes each time a potential BMP design needs to be evaluated;
- An alternative-generation scheme has been developed and coupled with the decision support model; the complete model has been tested and indeed shows that watershed-scale design of BMPs can effectively reduce stormwater impacts at lower stakeholder cost;
- Presentation of preliminary results at recent meetings, including a University-wide research meeting, local community outreach meeting, and the World Environmental and Water Resources Congress, designed to facilitate practical utility and cross-fertilization of concepts and interdisciplinary collaborations;
- Distribution of an educational outreach brochure that included general information about watershed-scale design of BMPs and application-specific results (i.e., proof of concept);
- Preparation of two peer-reviewed journal articles