Report for 2001NY921G: Modeling phosphorus control best management practices on a watershed scale to improve surface drinking water quality

- Other Publications:
    - Gerard-Marchant, P, T S Steenhuis, M T Walter, V T Mehta, M S Johnson, and S Lyon, 2002, Saturated Excess runoff modeling in undulating and mountainous watersheds, Poster EGS02-A-00665, EGS XXVII General Assembly, Nice, France, April 2002.
    - Gerard-Marchant, P, 2002, The soil moisture routing model: A user manual, version 1.0, Soil and Water Laboratory, Biological and Environmental Engineering Department, Cornell University, Ithaca, NY.
    - Mehta, V K, M S Johnson, P Gerard-Marchant, M T Walter, and T S Steenhuis, 2001, Testing a varible source GIS-based hydrology model for watersheds in the northeastern US, the Soil Moisture Routing Model, Eos Trans. AGU 82(47), Fall Meeting Suppl., Abstrats H22I-05, 2001.
- Articles in Refereed Scientific Journals:
    - Gao, B, M T Walter, T S Steenhuis, W L Hogarth, J-Y Parlange, 2004, Rainfall induced chemical transport from soil to runoff: Theory and experiments, Journal of Hydrology, 294(2004): 291-204.
    - Gerard-Marchant, P, M T Walter, T S Steenhuis, 2005, Two simple models of phosphorus release during simulated rainfall, Journal of Environmental Quality (in press)
    - Johnson, M S, W F Coon, V K Mehta, T S Steenhuis, E S Brooks, and J Boll, 2003, Applicaiton of two hydrologic models with different runoff mechanisms to a hillslope dominated watershed in the northeastern US: A Comparison of HSPF and SMR, Journal of Hydrology, 284:57-78.
    - Kim, Y-J, C J G Darnault, N O Bailey, J-Y Parlange, and T S Steenhuis, 2005, Equation for describing solute transport in field soils with preferential flow paths, Journal of Soil Science Society of America, 69(2):291-300.
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    - Lyon, S W, A J Lembo, M T Walter, T S Steenhuis, 2005, Defining probability of saturation with indicator kriging on hard and soft data, Advances in Water Resources (in press).
    - Lyon, S W, M McHale, M T Walter, T S Steenhuis, 2005, Effect of runoff generation mechanism on estimating land use control of P concentrations, Journal of American Water Resources Association (JAWRA), (accepted).
    - Mehta, V, M T Walter, E S Brooks, T S Steenhuis, M F Walter, M Johnson, J Boll and D Thongs, 2005, Application of SMR to modeling watersheds in the Catskill Mountains, Environmental Modeling an Assessment, (in press).
    - Srinivasan, M S, P Gerard-Marchant, T L. Veith, B Gburek and T S Steenhuis, 2005, Watershed scale modeling of critical source areas of runoff generation and

phosphorus transport, Journal of the American Water Resources Association, 41(2):361-375 APR 2005.
    - Walter, M T, T S Steenhuis, V K Mehta, D Thongs, M Zion and E Schneiderman, 2002, Refined conceptualization of TOPMODEL for shallow subsurface flows, Hydrological Processes, 16:2041-2046.
    - Walter, M T, V K Mehta, A M Marrone, J Boll, T S Steenhis and M F Walter, 2003, A simple estimation of the prevalence of hortonian flow in the New York City watersheds, ASCE Journal of Hyudrological Engineering, 8:214-218.
    - Walter, M T, P Gerard-Marchant, T S Steenhuis, M F Walter, 2005 Closure: A simple estimation of the prevalence of Hortonian flow in the New York City watersheds, ASCE Journal of Hydrological Engineering, 10(2):169-170
- Dissertations:
    - Johnson, M S, 2001 Comparative analysis of two watershed hydrologic simulations program - Fortran (HSPF) and the soil moisture routing model (SMR), MS Thesis, Department of Biological and Environmental Engineering, CALS, Cornell University, Ithaca, NY
    - Mehta, V K, 2001, A multi-layered soil moisture routing (SMR) model applied to distributed hydrological modeling in the Catskills, MS Thesis, Department of Biological and Environmental Engineering, CALS, Cornell University, Ithaca, NY.

Report Follows

Title: Modeling phosphorus control best management practices on a watershed scale to improve surface drinking water quality.

Problem and Research Objectives:
Non-point sources –agriculture is no exception – are one of the largest contributions of phosphorus (P) to surface waters, where excess P typically results in eutrophication. The Environmental Protection Agency (EPA) generally requires filtration for surface water supplies. New York City (NYC) was granted an exemption from filtration for surface drinking water supplies provided that an acceptable watershed program plan and protective measures can be achieved, with significant emphasis on P control. A high priority has been placed on the development and implementation of effective best management practices (BMPs) for P control. However, no effective modeling tool is available to evaluate the potential impacts of BMPs on P transport in shallow, sloping soils such as occurring in the northeastern US.

The overall goal of this study is to develop and test a model that can predict, on the watershed scale, the transport of P from agricultural and forest lands on shallow sloping soils. This will be accomplished by: 1) performing laboratory and field experiments to understand P movement on shallow soils, 2) improving the spatially distributed Soil Moisture and Distribution model (SMDR) that includes P fate and routing routines, and 3) validating the model with data collected from Town Brook and other watersheds in the Catskills.

Methodology:
In order to understand P movement on shallow soils, we decided to put more emphasis on P loss from manure and fertilizers than was originally described in the proposal. A set of experiments will be carried out on sloping artificial runoff plots in the laboratory with a rainulator. Manure and/or fertilizers will be added on the top of the slope and the P concentration will be measured as a function of time and distance along the slope.

Another set of experiments will be carried out in the field with milk house wastewater strips. The advantage of these strips is that daily P is added and, therefore, ideal to study the movement of P. Phosphorus losses are highly dependent on the distance to streams. Therefore, P transport should be simulated with a model that conserves the spatial information. Spatially distributed models are ideal for this purpose. For this project, we will adapt the spatially distributed SMDR model by incorporating P generation and transport mechanisms (SMDR has been proven suitable for the hydrologic and geologic characteristics of the Northeast).

Validation will occur in two steps. First, the simple analytical relationships between soil P content and P concentration in surface and groundwater will be validated with simple laboratory experiments described above. Then, the SMDR model with the laboratory validated P routines will be tested on a watershed scale.

Principal Findings and Significance:

The project was funded in November 2001 and, consequently, the principal findings relate to the first one and a half-year of the study. The field laboratory studies with the milk house wastewater filter have been completed and showed that dissolved P can move over the same distance as a chloride tracer. The data have been analyzed and are currently written up. One publication has been submitted and two more are nearly finished. During the first year of the project we prepared two publications concerning the validation of the previous version of SMDR (called Soil Moisture Routing Model or SMR). The paper by Metha et al. (2003) is now in press. We also compared the model with the Hydrological Simulation Program -- Fortran (HSPF). Discharges were simulated equally well with both models, but only SMR was able to accurately predict the spatial distribution of water and locations of runoff-generating zones in the watershed. This paper has been published (Johnson et al. 2004)

The new SMDR code is now stabilized and is being rewritten in C so that it can be executed as part of the ARC. In this new code, infiltration and drainage are simulated more realistically. This was necessary in order to implement routines for P leaching in the soil. Evaporation calculation algorithms were also modified to take better into account the development stages of different vegetation covers. Additional routines were developed to simplify the generic use of the program and to streamline the importation of input maps or the creation of input look-up tables. A user manual, incorporating a fully commented code, has been released. Mauscripts concerning this model and its validation have been prepared and will be submitted shortly.

We also showed that TOPMODEL could be used on shallow soils without a ground water table by simply transforming the depth of the groundwater to moisture content in the soil above the impermeable layer. More details are given in Walter *et al.* (2002).

In addition, a simple model has been developed for the release of P from spread manure. This model links cumulative P load released to cumulative runoff, through a simple relationship requiring the knowledge of only two parameters: percentage of water-extractable P in the manure and the volume required to wash half the P out of the manure. This paper is in press in the Journal of Environmental Quality.

Finally, we have developed a routine that allows us to calculate the loss of land-applied manure. A fully distributed modeling of manure P leaching requires the knowledge of the actual location of the land-applied manure, as well as the quantities involved. Unfortunately, such data is not available. Therefore, a semi-distributed approach is followed. The watershed is divided in a number of geographical units. Each unit corresponds to the smallest area for which some information about manure application is available: for example, a farm, or a particular field in a farm, depending on the scale of the watershed. Each of these "manure application units" is then subdivided into elementary "spreading plots". The size of each plot is defined as the area covered during a single manure spreading. For example, when manure application units are identified with fields, the plot size will correspond to the area covered by a single spreader, that is, a stripe of approximately 2000 m2 (723 x 33 with a 4overlap). This model has been tested

on a farm in the Catskill Mountains and gave reasonable results. This paper has been presented at the international AWRA meeting in New York City .

Notable Achievements:
We have been able to modify the SCS curve number approach so that it can be used with the topographic index to predict the saturated areas in undulating landscapes with relatively shallow soils. Recently we have incorporated this procedure in the General Watershed Loading Function. that is now called VS-LF (Variable Source Loading Function). It is being recognized as of the best ways to model pollutant loading in a recent issue of the *Journal of American Water Resources Association.* A publication in cooperation with the NUCDEP concerning this approach almost fished and will be submitted before the end of the summer. Finally, we have validated the distributed output of SMDR and developed a distributed phosphorus model. The manuscripts are currently under review by the cooperators in the NYC source watershed and will be submitted for publication this summer