New York State Water Resources Institute
Annual Technical Report
FY 2003

Introduction

Research Program

The New York State Water Resources Institute's (NYS WRI) FY2003 activity under the Federal Water Resources Research Act consisted largely of research and information transfer projects funded during FY2000 through FY2003. The FY2003 report covers: one FY2000, one FY2001, and one FY2003 project from national 104G competitions; three multiyear projects from the FY2002 New York competition; five projects from the FY2003 New York competition; and information transfer and student service support by the NYS WRI Director's Office.

The FY2000 104G project, covering large watershed nutrient modeling, began in late 2000 and was completed during FY2003. The model predicts nutrient loadings to coastal and inland ecosystems with a special emphasis on atmospheric deposition of nitrogen. The FY2001 104G project conducted field and lab experiments and refined simulation models of phosphorus in agricultural settings. The FY2003 104G project, which began in late 2003, will examine statistical patterns in low streamflows.

In FY2003, USGS WRD extended its sponsorship of one internship that supported a student from Cornell's School of Civil and Environmental Engineering.

Five FY2003 104B projects and three carry-over FY2002 104B projects reesulted from in-NY competitions whose topic focus reflected NYS WRI's long-term priority on nonpoint source pollutant management. FY 2003 projects covered: interpretive precipitation maps and tables for use in stormwater management; validation of methods for discriminating between ruminants and humans as sources of fecal bacteria; metals retention in sediments of stormwater infiltration basins; stormwater BMPs from a larger basin perspective; and biosensors for tracking *enterococcus fecalis*. FY2002 carry-over projects covered: a precursor to the ruminant/human discrmination methods project in FY2003; septic system management via community outreach; and site identification for constructed wetlands in a small watershed.

Two FY2003 projects will carry over to FY2004. The FY2000 104G project has received a no-cost extension for administrative reasons into the FY2004 period but has completed its work. The new FY2003 104G project extends until FY2006. All other FY2001, FY2002, and FY2003 projects were completed.

Validity Assessment of Methods to Distinguish Between Ruminant and Human Sources of Fecal Contamination in Watersheds

Basic Information

Title:	Validity Assessment of Methods to Distinguish Between Ruminant and Human Sources of Fecal Contamination in Watersheds
Project Number:	2003NY21B
Start Date:	3/1/2003
End Date:	2/28/2004
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Congressional District:	21
Research Category:	Biological Sciences
Focus Category:	Non Point Pollution, Water Quality, Waste Water
Descriptors:	nonpoint source pollution, fecal contamination, water quality, pathogens
Principal Investigators:	Ellen Braun-Howland

Publication

Validity Assessment of Methods to Distinguish Between Ruminant and Human Sources of Fecal Contamination in Watersheds

Problem & Research Objectives:

Nonpoint source (NPS) pollution, including runoff from agricultural operations and failing or improperly sited septic systems can have a substantial detrimental impact on source water quality. In addition to environmental concerns, significant public health effects have been attributed to NPS fecal contamination of both drinking and recreational waters. Pathogens of concern include *Giardia* and *Cryptosporidium*, pathogenic strains of *Escherichia coli*, *Salmonella* sp., and *Listeria monocytogenes*. As indicator organisms are commonly used to ascertain the safety of a water supply, it is important to understand the behavior of these organisms under varying environmental conditions. The proposed studies will examine fecal suspensions in situ to concomitantly measure seasonal and temporal effects on the survival of organisms indicative of fecal contamination. Numbers of traditional indicator organisms, including total coliforms, *E. coli* and *enterococci* will be monitored over time using approved culture techniques. The results of these studies will be compared with the survival of *Bacteroides*, using the PCR-based technique developed by Bernhard and Field. In contrast to detection methods based on culturing, this new technique identifies fecal contamination through the amplification of *Bacteroides* DNA. Additionally, molecular-based in situ hybridizations for the identification of *Bacteroides* will permit the detection of viable organisms, rather than dead cells. The proposed studies are important because they will determine whether the *Bacteroides* method detects recent fecal contamination, or whether the organisms detected could have originated at a spatially or temporally distant site. These results are critical to the validation of the *Bacteroides* method as an appropriate technique for unambiguously discriminating between human and agricultural sources of fecal pollution.

The objectives of the project are:

- To measure the die-off kinetics of fecally-derived indicator bacteria including: *Bacteroides*, *E.coli*, total coliforms, and enterococci *in situ* under varying environmental conditions;
- To determine the effects of fecally-impacted and non-impacted stream conditions on the in situ survival of the various indicator organisms; and

- To confirm that the molecular-based method for the identification of *Bacteroides* results in the detection of DNA from viable organisms, rather than dead cells, using whole cell, *in situ* hybridizations.

Methodology:
Diffusion chambers containing 30 ml of bovine fecal suspensions at two concentrations are incubated, in triplicate, in a "pristine" (minimally impacted by fecal contamination) pond environment and in a separate, fecally-impacted pond environment. The diffusion chambers will be sampled once a week for three weeks, followed by bi-weekly sampling for no more than 16 weeks. Samples are analyzed for total coliforms, *E.coli*, and enterococci using EPA-approved Colilert/Enterolert methodologies. Whole cell *in situ* hybridizations using fluorescently tagged rRNA-targeted probes for *E.coli*, enterococci, and *Bacteroides* will be performed as a measure of cell viability. Also, polymerase chain reaction (PCR) amplifications for detection of *E.coli*, enterococci, and *Bacteroides* will be used to assess the presence of specific DNA sequences over time. Water quality parameters including water temperature, pH, dissolved oxygen, and conductivity will be measured in both pond locations at the time of sampling. Nutrient samples including total phosphorus, TKN, nitrate, ammonia and TOC for both pond environments is collected at the onset of the experiments followed, as time progresses, by bi-weekly and monthly follow-up samples.

Principal Findings & Significance:
We are thoroughly testing the specificity of the whole cell *in situ* hybridization probes and PCR primers to be utilized in this project. To date, the *Enterococcus, E.coli,* and *Bacteroides* primer sets have proven to be highly specific. Also, the *E. coli* and *Bacteroides* probes have been demonstrated to identify viable organisms in fecal samples using fluorescence-based in situ hybridization techniques. Testing of the enterococcus-specific probe is in progress.
Preliminary results, performed using refrigerated calf fecal suspensions, demonstrated that bacterial indicators *(E. coli, Bacteroides* and *Enterococcus)* and *Cryptosporidium*, all remained detectable using PCR amplifications for at least three months. *Cryptosporidiuim* oocysts were additionally visualized using fluorescence-based microscopic techniques. The spring incubations are currently underway. Samples are being analyzed using the methods described and results will be available in the coming weeks.

Project Adjustments:
The investigators intended for the first sampling event to be summer 2003. Due to funding delays, the ironing out of contracts, and the amount of time needed to identify good PCR primer and *in situ* probe sequences, the first sampling event occurred, instead, in spring of 2004. As a result, additional seasonal sampling will take place late in 2004. Due to public health concerns resulting from potential breakage of diffusion chambers in surface water supplies, the diffusion chambers are incubated in ponds on private property, rather than streams. Lastly, fecal suspensions from calves infected with *Cryptosporidium parvum* are being used in these studies, in order to permit the evaluation of relative

survival of bacterial indicators of fecal pollution relative to *Cryptosporidiuim* oocysts, using PCR and fluorescent antibody staining techniques. **Expected Results:** Combating fecal contamination in water supplies requires consideration of the inherent differences between present and proposed indicator organisms in comparison to real protozoan pathogens like *Cryptosporidium*. The results of these studies will determine whether bacteria can be used as indicator organisms for *Cryptosporidium* in water supplies. Overall, we expect that detection of different bacterial species will be method-dependent, and that nutrient concentration, temperature, oxygen saturation, and sunlight exposure will correlate with die-off rates of the organisms.

Current and Future Work:
Diffusion chambers will be deployed during the summer and fall in order to determine the seasonal influence on the detection and survival of organisms.

Extreme Precipitation and Consecutive Dry-day Climatology for New York State Applied to Water Resource Management

Basic Information

Title:	Extreme Precipitation and Consecutive Dry-day Climatology for New York State Applied to Water Resource Management
Project Number:	2003NY22B
Start Date:	3/1/2003
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	22
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Floods, Water Quality
Descriptors:	stormwater, flooding, climatological data, water quality
Principal Investigators:	Arthur T. DeGaetano

Publication

Extreme Precipitation and Consecutive Dry-day Climatology for New York State Applied to Water Resource Management Basic Information

Problem and Research Objectives

Stormwater, particularly from urban areas is also a growing source of pollution in New Yorks waterways. The effective management of this pollution source and the implementation of policies focused on best management practices require knowledge of the meteorological conditions that lead to these runoff events. Climatological information describing peak rainfall and snowmelt volumes as well as the length of time over which pollutants can accumulate on impervious surfaces (consecutive rain-free days) is critical for modeling, designing and managing stormwater discharges and pollutant loads. Enforcement of stormwater regulations will require information on expected storm magnitudes, in particular to identify events that may exceed current design specifications. Climatological data currently used are either outdated or unavailable in a succinct summarized format. The aim of this proposal is to develop and update these climatologies and to disseminate this information through an electronic atlas to assist stormwater management.

Objectives:

To develop and make available sound data that will assist in estimating expected volumes of stormwater under varying climatological conditions. To meet this goal there are seven primary objectives:

1) A revised set of isohyetal maps for New York depicting the spatial distribution of 24-, 12-, 6-, and 1-hour precipitation accumulations for return periods of 2,5,10,25,50,and 100 years.
2) 2) The creation of a set of homogeneous extreme precipitation subregions for New York. Within each subregion, the partial duration extreme rainfall distributions of all stations will be statistically equivalent. This will allow the results of the subsequent analyses to be presented by subregion.
3) 3) A composite set of extreme rainfall intensity-duration curves will be computed for each subregion.
4) 4) On a subregional basis, weekly extreme rainfall probability plots will be compiled. These graphs will identify the probability of receiving a storm of a given magnitude during each week of the year.
5) 5) The analyses in Objectives 3 and 4 will be repeated to account for the combined volume of snow melt and rainfall.
6) 6) Daily probability graphs for the occurrence of consecutive dry days will be computed for each extreme precipitation subregion.
7) 7) This suite of climatological products will be disseminated in the form of an electronic (Worldwide Web) atlas.

Methodology

Daily data from over 210 stations across New York, as well as, additional stations from adjacent portions of neighboring states will be used to develop a set of isohyetal maps. These maps will depict the spatial distribution of 24-, 12-, 6-, and 1-hour precipitation accumulations corresponding to return periods of 2, 5, 10, 25, 50 and 100 years. Partial-duration precipitation data (i.e. the n largest daily precipitation values in n years of record) will be used to the compute return periods. Based on these station data, the state will be divided in extreme precipitation subregions such that no statistical differences will exist between the empirical partial duration extreme rainfall series of each station within a subregion. For each of these subregions extreme rainfall intensity-duration curves and weekly extreme rainfall occurrence probability plots will be computed. These analyses will be conducted for rainfall alone and at selected stations reflects the combined volumes of rainfall and snowmelt. Daily probability graphs for the occurrence of consecutive dry days will be also constructed. These graphs will be based on daily counts of the number of times that a precipitation event of 0.10 inches or more was preceded by dry periods ranging from 1 to 30 days in length.

We have completed each of the proposed project tasks over the last year. In particular our work has led to:

1. A revised set of isohyetal maps for New York depicting the spatial distribution of 24-, 12-, 6-, and 1-hour precipitation accumulations for return periods of 2,5,10,25,50,and 100 years. At the request of the NY State DEC we have also included 1-year return period maps which were originally not proposed.

2. The creation of a set of homogeneous extreme precipitation subregions for New York. Within each subregion, the partial duration extreme rainfall distributions of all stations are statistically equivalent. This allows the results the analyses to be presented by subregion, rather than station.

3. A composite set of extreme rainfall intensity-duration curves for each subregion.

4. Weekly extreme rainfall probability plots, on a subregional basis,. These graphs identify the probability of receiving a storm of a given magnitude during each week of the year.

5. Items 3 and 4, above were repeated to account for the combined volume of snow melt and rainfall. These analyses revealed only subtle changes in the extreme precipitation statistics.

6. Daily probability graphs for the occurrence of consecutive dry days for each extreme precipitation subregion.

7. This suite of climatological products is available in an electronic atlas which can we accessed via the Internet at <http://www.nrcc.cornell.edu/pptext/>

Evaluating the Flow and Treatment of Contaminants in Urban Storm Water Infiltration Basins

Basic Information

Title:	Evaluating the Flow and Treatment of Contaminants in Urban Storm Water Infiltration Basins
Project Number:	2003NY23B
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Funding Source:	104B
Congressional District:	22
Research Category:	Water Quality
Focus Category:	Hydrology, Water Quality, Floods
Descriptors:	stormwater, runoff, infiltration
Principal Investigators:	Tammo Steenhuis, Michael Todd Walter

Publication

Evaluating the Flow and Treatment of Contaminants in Urban Storm Water Infiltration Basins

Abstract: A critical issue in designing infiltration basins is to maintain high hydraulic conductivities but to also incorporate effective pollutant removal to minimize contamination of groundwater. At an infiltration basin constructed in East New York, Brooklyn, New York, a 0.6 meter organic matter layer overlays a high-permability rubble substrate. This research assesses the ability of the organic matter layer to remove dissolved copper (Cu), zinc (Zn), and lead (Pb)in a synthetic urban stormwater mixture applied at hydraulic application rates of 8 cm/hr to 247 cm/hr. Influent concentrations of 0.021 ppm, 0.059 ppm, and 0.28 ppm were used for Cu, Pb, and Zn, respectively. Application rates and metal concentrations are representative of actual field operating conditions. Experiments were run in replicate on three undisturbed soil columns excavated from the East New York Site. Few other studies have used undisturbed soil columns.

For all three metals, no trend was observed between removal efficiency and hydraulic application rate. The breakthrough of a chloride tracer indicates that approximately 10% of downward flow, even at low hydraulic application rates, is preferential flow. Lead was reduced to below detectable limits while Zn was consistently reduced by 70 to 80%. Cu removal rates varied more widely but were generally above 50%.

1. Introduction

Infiltration Basin History

Since the 1970's, two changes in federal regulations have placed heightened emphasis on managing and treating storm water runoff. First, in cities with combined stormwater and sanitary sewers, measures to treat the combined sewage outflow have been required. These measures can take the form of increased treatment plant capacity, expanded stormwater storage, or reductions in stormwater ever reaching the sewers. Secondly, as point source polluters of waters have decreased, an increased emphasis has been placed on controlling non-point source pollution, particularly in areas without stormwater sewers. These regulatory requirements have led to the development, design, and implementation of stormwater management practices such as detention basins, constructed wetlands, and infiltration basins. With an infiltration basin, water is collected from impervious areas and directed to the groundwater instead of readily conveyed to surface waters.

A distinct feature of infiltration basins is the high hydraulic loading rate to groundwater at the infiltration basin site due to accumulation and concentration of water. For the site in Brooklyn, the intent was to infiltrate water collected from an 8-hectare (20 acre) drainage area on a 0.4-hectare (1-acre) parcel. A one-inch storm event (return period of less than a year) would require that 20 inches be infiltrated in the basin. Measurements of infiltration rates at three typical basins on Long Island at Westbury, Syosset, and Deer Park found average infiltration rates of 27 cm/hr, 24 cm/hr, and 6 cm/hr, respectively (Seaburn and Aronson, 1974).

Due to the necessary high infiltration rates and required, sustained high hydraulic conductivities, infiltration basins have traditionally been used in areas with sandy soils. While stormwater is quickly passed to the subsurface, the rapid movement of the pollutant-laden water may result in little pollutant removal. While the use of infiltration basins in places such as Long Island, New York has not been directly linked to the deterioration of groundwater quality in the region, the presence of urban land is clearly related to the frequency of detection and concentration of compounds such as nitrate, pesticides, and volatile organic compounds (Ayers et al.,2000). A critical issue in designing infiltration basins is to maintain high hydraulic conductivities, but to also incorporate effective pollutant removal.

Characterization of Stormwater Pollutant Loading

The National Urban Runoff Program (NURP) was one of the first studies to quantify a wide range of organic and metallic toxicants in urban storm water runoff although it primarily focused on residential areas and not commercial land use (EPA, 1983). More recent work has quantified 39 different pollutants grouped in the general categories of pesticides, phthalate esters, polynuclear aromatic hydrocarbons, and metals for 9 different land use types (Pitt et al., 1995). Of approximately 50 samples, metals were detected in greater than 90% of the samples while other pollutant types were detected in less than 20% of the samples. Judging from the relative ubiquity of metals in stormwater in comparison to other pollutants, these will be the primary pollutant of interest in these experiments. Other experiments assessing the effectiveness of infiltration practices to remove pollutants have also focused on metals, primarily copper, (Cu), lead (Pb), and zinc (Zn) (Sansalone, 1999, Davis et al., 2001, Farm, 2002,). Metal concentrations are detailed in the methodology section. The synthetic stormwater mix was prepared following the guidance of Davis et al (2001). Metal concentrations are of the same order of magnitude as reported in other studies.

Existing Studies on Pollutant Removal in Infiltration Basins

Davis et al. (2001) constructed a laboratory scale bioretention basin and measured the degree of nutrient and metal removal at different depths within the system. A synthetic runoff solution was applied at a rate of 4.1 cm/hr for 6 hours. Ponding reached a maximum of 12 to 18 inches and water remained ponded for approximately two days, thus suggesting soil hydraulic conductivity was much less than the hydraulic application rate. Percent reduction of Cu, Pb, and Zn was greater than 97%.

Sansalone (1999) conducted column experiments to assess the metal removal efficiency of oxide coated sands. Influent was applied at a rate of 263 cm/hr until breakthrough occurred. For a column incorporating 90-mm of porous pavement aggregate and 522-mm of oxide coated sand, no Pb or Cu breakthrough was observed for >1000 pore volumes while Zn breakthrough was observed after 200 pore volumes. To facilitate more rapid breakthrough, influent Cu and Pb concentrations were approximately 100 times concentrations found in actual stormwater while the influent Zn concentration was approximately 10 times typical concentrations.

Farm (2002) assessed the capacity of peat, zeolite, and calcium silicate rock (opoka) to remove metals. Using metal salt concentrations of between 0.5 and 0.1 mg/L (same order of magnitude as Davis et al.), Farm(2002) considered metal removal capacity at application rates varying from 100 cm/hr to 500 cm/hr. For a 28-mm column consisting of a mixture of peat and opoka, nearly 100% of Zn was removed for hydraulic loads up to 500 cm/hr while upwards of 80% of Cu was removed at similar hydraulic loads. Assessing other substrate materials, Farm found that metal removal efficiency generally declined with increasing flow rate although this was not observed for the opoka/peat mixture. However, Farm reported that clogging of the column bottom occurred suggesting that flow rates through the column may not have been proportional to apparent application rates.

While most studies have suggested that the Cu removal efficiency is relatively similar to that of Zn and Pb, there is one case of where very low Cu removal has been reported. A composted-leaf filter developed as a compact, manufactured treatment device had reported removal efficiencies of 83% for zinc and lead but only 7% for copper (CSF Treatment Systems).

Based on these previous studies, high metal removal efficiencies are expected at the highest hydraulic loading rates anticipated in real world infiltration basins. However, as these experiments all made use of disturbed columns packed within a laboratory setting, no previous work has made use of undisturbed soil columns to study the impact of preferential flow on removal efficiencies.

2. Methodology

Site Background

The Gaia Institute in cooperation with the New York City Department of Parks and Department of Environmental Protection initiated constructed of an infiltration gallery/ wetland in a vacant plot of land in East New York, Borough of Brooklyn, New York in 2001. The infiltration gallery/ wetland was intended to demonstrate the feasibility of employing underused parcels of land for managing storm water runoff and providing urban green space.

The site is located on a filled wetland, formerly part of the Jamaica Bay estuary. While the exact subsurface characteristics of this site are not known, approximately 3 to 5 meters (10 to 15 feet) of construction debris, rubble, and other landfill material were used to raise the ground surface elevation above its original wetland level sometime in the early 20th century. To construct the infiltration gallery/wetland, approximately 0.6 meters (2 feet) of the fill material was removed and replaced with an organic compost layer. Additionally, two depressions were excavated, lined with clay to form permanent pools, and planted with native vegetation. Eventually, the intent is to divert storm water to the site from an adjoining bus garage parking lot and nearby roadways. During a storm, diverted rainfall will temporarily pool on the site and infiltrate to the subsurface through the non-clay lined portions of the green space. Figure 1 shows the approximate location of the site on western Long Island.

Experimental Methods
Three undisturbed soil columns were excavated by hand from the site in East New York, Brooklyn. An approximately 35 cm length of black polyethylene culvert was placed over the column and minimal expansion foam (commercially available "Great Stuff" polyurethane) was injected into the gap between the soil and culvert. The soil columns were of varying depth, 0.33 meters in diameter, and only comprised the organic peat layer. The columns were transported to Ithaca, New York to conduct the laboratory experiments. Column dimensions and soil characteristics are detailed in Table 1. More detailed soil property information will be determined for each individual column when all experiments have been completed and the columns can be dismantled.

Table 1: Soil Column Properties

	Column A	**Column B**	**Column C**
Depth, cm	33	30.5	38
Infiltration Capacity, cm/hr	230	230	134
Soil Texture	54% coarse sand, 30% fine sand, 16% silt & clay		

A schematic of the experimental set-up is shown in Figure 2. For most of the trials, peristaltic pumps were used to deliver water to each column at a controlled rate. However, as the pumps had a maximum capacity of approximately 1 L/ min (82 cm/hr), a rate less than the maximum infiltration capacity, water was poured directly onto the columns for trials in which surface ponding was desired (Trial 4). Percolate was collected using a passive lysimeter consisting of fiberglass wicks (Boll et al., 1992). The lysimeter has 21 separate collections wicks evenly spaced in a grid pattern across the column bottom, thus allowing sampling from specific regions of the column. To limit the influence of preferential edge flow effects, samples were collected as a composite from the 9 inner wicks.

A synthetic stormwater solution intended to replicate average concentrations of metals and nutrients found in urban stormwater was prepared as detailed in Davis et al. (2001) and shown in Table 2.

Table 2: Chemical Make-up of Synthetic Stormwater Solution

Pollutant	Chemical	Chemical Conc. (mg/L)	Metal Conc. (mg/L)
Copper	$CuSO_4$	0.08	0.021
Lead	$PbCl_2$	0.08	0.059
Zinc	$ZnCl_2$	0.6	0.28

Four trials were carried out on each of the three columns. Hydraulic application rate, duration, and constituents of interest for each trial are summarized in Table 3.

Table 3: – Summary of Trial Set-ups

Trial	Hydraulic Application Rate, cm/hr	Duration, min.	Constituents of Interest
1	8	720	Cl^-, Cu, Pb, Zn
2	82	60	Cu, Pb, Zn
3	41	60	Cu, Pb, Zn
4	~247	7-10	Cu, Pb, Zn

Trial 1 applied a synthetic stormwater solution as well as a chloride tracer at a concentration of approximately 16 ppm (including Cl^- from metal salts). For the first two hours, samples were taken every 5 minutes. Sampling decreased to an interval of 30 minutes for the remaining time. Chloride concentrations were measured using a digital chloridometer (Buchler Instruments). Chloride was assessed in order to establish representative Breakthrough Curves (BTCs) for a conserved, non-reactive substance passing through each column. A breakthrough curve plots the concentration of a selected parameter (in this case, chloride) at the column bottom. BTCs for chloride in which transport is wholly dependent on matrix flow closely follow the advective-dispersion equation. In contrast, the presence of preferential flow results in an instantaneous initial jump in percolate chloride concentration.

Additional trials only applied the synthetic stormwater solution. For all trials, the columns were initially wetted with distilled water until all collection wicks drained at an approximately uniform rate. Once the columns were wetted through, the application rate of distilled water was sustained at the respective steady state rate of the trial for approximately 15 minutes before seamlessly transitioning to the application of the synthetic stormwater solution. In trials 2 and 3, samples were taken during the steady state application of distilled water and 5, 15, 30, 45, and 60 minutes after the synthetic stormwater solution application was initiated. In Trial 4, water was only applied for approximately 7 minutes (Column C required approximately 10 minutes due to a lower hydraulic conductivity). Samples were taken 2 and 5 minutes after the sythetic stormwater solution was initiated and approximately 1 minutes after the application was stopped.

Before running any trials with the synthetic stormwater solution, an approximately 4 pH synthetic rain water solution intended to replicate acid rain was applied to the columns (Richards et al., 2000). Percolate was collected and analyzed to determine background levels of Cu, Pb, Zn, phosphorus, and nitrate. Background levels for the metals are shown in Table 4. The pH=4 results are based on an average of two samples apiece taken from columns A and C. The pH=7 results are based on a sample taken during Trial 3 as the columns were being wetted prior to the addition of the synthetic stormwater solution.

Table 4: Background Metal Concentrations in Soil Percolate

	Column A		Column B		Column C	
	PH=4	pH=7	pH=4	pH=7	pH=4	pH=7
Cu	0.038	0.0049	---	0.0089	0.0295	0.0073
Pb	ND	ND	---	ND	ND	ND
Zn	0.052	0.0538	---	0.0126	0.0397	0.0044

Background metal concentrations at a pH of 4 are approximately an order of magnitude higher than background levels at a pH of 7. This finding is generally consistent with research indicating that metals tend to be more mobile under acidic soil conditions (McBride, 1994).

There is some cause for concern that the determination of copper removal efficiencies may be confounded by the fact that at pH=4 background copper concentrations shown in Table 4 were the same order of magnitude as the synthetic stormwater solution as shown in Table 2. However background levels were an order of magnitude less at a pH of 7, the neutral condition at which the actual removal efficiencies were assessed.

Cu, Pb, and Zn concentrations were measured at the Cornell Fruit and Vegetable Lab using an Inductively Couple Plasma Spectrophotometer.

3. Results and Discussion

Consideration of Cu Data Reliability

Figure 3 presents Cu and Zn concentrations for each of the four trials for the three columns. Pb is not included as the percolate Pb concentration was always below the detectable limit.

Particularly for Cu, percolate concentrations varied throughout the trial, generally starting high and diminishing through the trial. Rather surprisingly, in Figure 3a., at a time of zero (prior to the application of the synthetic stormwater solution) the observed copper concentration was higher than any other point during the run.

A comparison of metal concentrations measured in the influent synthetic stormwater solution indicates a large degree of variability in Cu concentrations when the Cu should be nearly constant. The influent metal concentrations should be nearly uniform as the influent, while made in batches, is based on the dilution of the same standardized high concentration metal solution. Table 5 summarizes the apparent Cu concentrations in the influent synthetic stormwater solution. For both Cu and Pb, the standard deviation between influent concentrations for the four trails is nearly equivalent to the mean values. The variability is potentially due to inconsistencies in the chemical analysis.

Table 5: Comparison of Measured Influent Metal Concentrations

	Metal Salt Conc.	Intended Metal Conc.	Used in Summary Analysis	8 (cm/hr)	41 (cm/hr)	82 (cm/hr)	247 (cm/hr)	Trials 1 to 4 Mean	Trials 1 to 4 St. Dev.
Cu (ppm)	0.08	0.021	0.02	0.1118	0.0019	0.0133	0.02	0.0368	0.0506
Pb (ppm)	0.08	0.059	0.03	0.0219	0.0052	0	0.0099	0.0093	0.0094
Zn (ppm)	0.6	0.28	0.3	0.2166	0.2171	0.3546	0.1279	0.2291	0.0936

Relationship of Removal Efficiency to Flow Rate

As the primary objective of these experiments, Figure 4 shows removal efficiencies as compared to flow rate. As noted in the discussion of Figure 3a through 3h, apparent removal efficiency fluctuates throughout certain trials, particularly for Cu. Thus, the removal efficiencies expressed in the figures are the mean of efficiencies observed across the trial.

Pb is not shown since in all trials, the effluent concentration was below the detectable limit. Apparent within Figure 4, the removal of zinc remains relatively constant at approximately 90% for all columns and all flow rates. The removal efficiency of copper is much more variable, both among columns and at different flow rates. To see if another method of quantifying removal within a trial would more successfully explain the relation between flow and removal, flow rate was compared to removal efficiency after 18 L of cumulative flow had been applied during each trial. This alternate method did not reveal any improved relationship. No definite statement regarding the relationship between Cu and flow rate can be made based on the data. This lack of conclusive results is not surprising given the unusual and inconsistent variability in the Cu data.

Determination of Preferential Flow

Figure 5-a, b & c shows the BTCs for each of the three columns as well as a best-fit of the one-dimensional advective-dispersion equation solved for a semi-infinite boundary condition. For each of the three BTCs, a plateau forms at a concentration of approximately 0.8 mg/L almost instantaneously. After the plateau forms, the breakthrough curves closely follow the advective-dispersion equation. The magnitude in the initial instantaneous jump can be used to quantify the fraction of preferential flow in relation to the fraction of matrix flow.

The advective-dispersion was fit to the data by adjusting the average matrix velocity and the diffusivity. Despite being based on a best-fit, these adjusted values are physically realistic. The values for each column are listed in Table 6.

Table 6: Advective-Dispersion Equation Fitting Parameters

	Column A	Column B	Column C
Pore Velocity, cm/min	0.9	0.9	1
Diffusivity, cm^2/min	8	10	7

If downward flow was uniform across the column cross-section and no preferential flow occurred, the expected velocity would be 0.28 cm/min. The diffusivities (D) are two orders of magnitude less than that determined for a soil column composed of 95% sand in which D equaled 0.076 cm^2/min and V equaled 0.18 cm/min (Zurmuhl, 1998). However, D values are typically approximately proportional to the vertical pore velocity, placing the observed Ds in a reasonable range.

There is the possibility that the travel time of solute through the wick may influence the apparent breakthrough curve. A previous investigation into travel time through the fiberglass wick found that a chloride pulse moved at approximately 20.7 cm/min at a hydraulic application rate equivalent to approximately 9 cm/hr (Rimmer et al., 1994). Given that the wicks in our experiment are approximately 35 cm and the hydraulic loading rate is the same order of magnitude, the solute pulse should only be delayed approximately 100 seconds, relatively small compared to the sampling intervals we used.

In general, the presence of preferential flow indicates that 100% pollutant removal will not be possible as a certain fraction of inflow always bypasses the soil matrix structure. Based on the immediate measurement of approximately 1 mg/L chloride of a 15 mg/L influent solution, approximately 7% of the influent moves through the column by way of preferential flow. Thus, the presence of preferential flow provides some explanation of why removal efficiency is not strongly related to flow rate.

Variability Between Columns

Despite being a constructed system, the infiltration basin still makes use of natural materials that grow and are modified over time. Therefore due to the lack of homogeneity in root densities, earthworm activity, frost heave, etc. one would expect inherent spatial variability within the natural system. Three soil columns were used in order to try to capture some of this potential variability. Table 7 ranks columns within each trial based on the average observed metal concentration in the percolate. Again, Pb was not included as all Pb concentrations in the percolate were below the detectable limit.

Table 7. Ranking of Columns by Observed Metal Percolate Concentration

	8 (cm/hr)		**41 (cm/hr)**		**82 (cm/hr)**		**247 (cm/hr)**	
	Cu	Zn	Cu	Zn	Cu	Zn	Cu	Zn
Column A	Lo	Hi	Med	Med	Lo	Med	Med	Med
Column B	Hi	Med	Hi	Med	Hi	Med	Hi	Hi
Column C	Med	Lo	Lo	Lo	Med	Lo	Lo	Lo

Column B consistently had the highest percolate copper concentrations and alternated with Column A in having the highest zinc percolate concentrations. Column C consistently had the lowest observed percolate metal concentrations. This suggests that there are fundamental properties within the columns that affect the metal removal efficiency. As the most obvious factor, Column C was found to have the lowest hydraulic conductivity as assessed during Trial 4.

4. Conclusions and Recommendations

A series of laboratory experiments were conducted to evaluate the pollutant removal capacity of an organic matter layer overlaying a highly conductive sublayer. Of primary interest was to assess whether the organic matter layer can remove pollutants at the high hydraulic loading rates permitted by the relatively high conductivity of the substrate. Experiments showed that the removal efficiencies of Pb, Cu, and Zn were independent of hydraulic application rate. Removal of Pb and Zn was consistently above 90% while removal of Cu was more variable but was generally near 50%.

Breakthrough curves illustrated that approximately 10% of the flow through the columns travels through macropores, not matrix flow. Due to the rapid transport through macropores, little pollutant removal is likely to occur. Thus, any organic matter layer applied under natural conditions, will be unlikely to achieve a removal efficiency much greater than 90%.

Several recommendations can be made for future experiments. First, the experiments could be repeated using higher metal concentrations in the synthetic stormwater solution, even if these concentrations do not match levels routinely observed in actual stormwater. Primarily, these higher levels would minimize the significance of background metal levels. Additionally, the experiments could be repeated using a synthetic stormwater solution decreased to a pH typical of acid rain. One presumes that metals would be more mobile at lower pH levels.

A more extensive series of experiments could consider long-term removal for a more complete hydrologic cycle in which there are periods of wetting and drying. In particular, metal concentrations would be measured as the columns are wetted with pure distilled water void of any metals. During this wetting, one would anticipate desorption of metals since influent concentrations would not be in equilibrium with soil metal levels in the column.
A final suggestion is to run the experiments using pesticides and organic compounds instead of metals, as these compounds are more commonly found in groundwater than trace metals.

[Begin pdf]

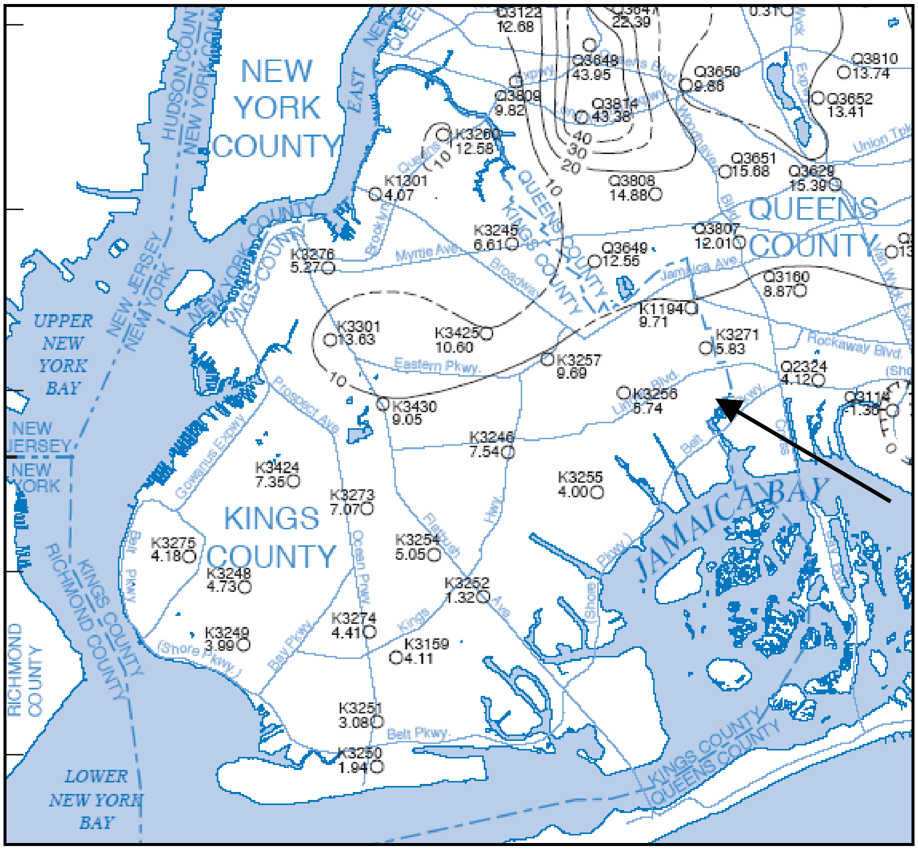


Figure 1. Site location shown on USGS map of the Upper Glacial Aquifer on Western Long Island, March-April 2000 (source: Ron Busciolano, USGS WRIR 01-4165)

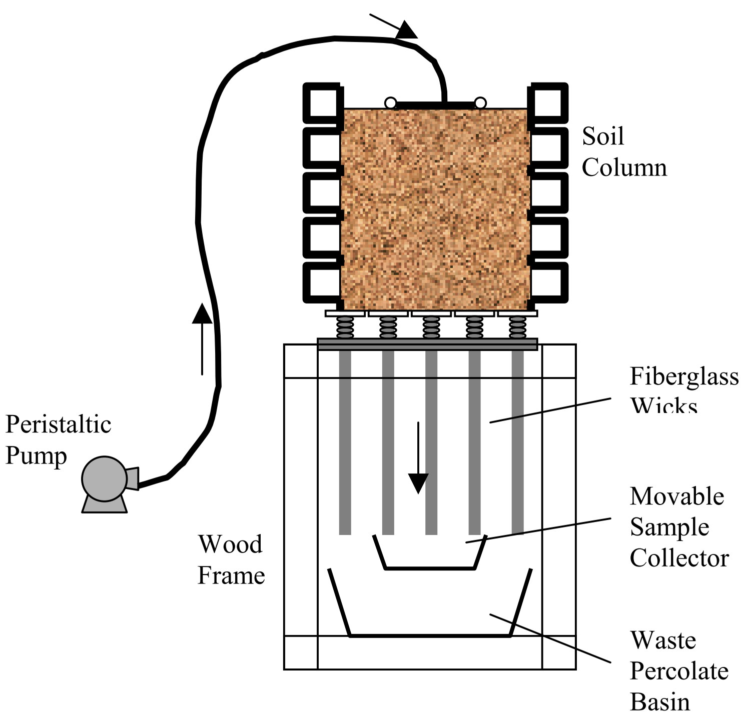


Figure 2. Schematic of experiment set-up.

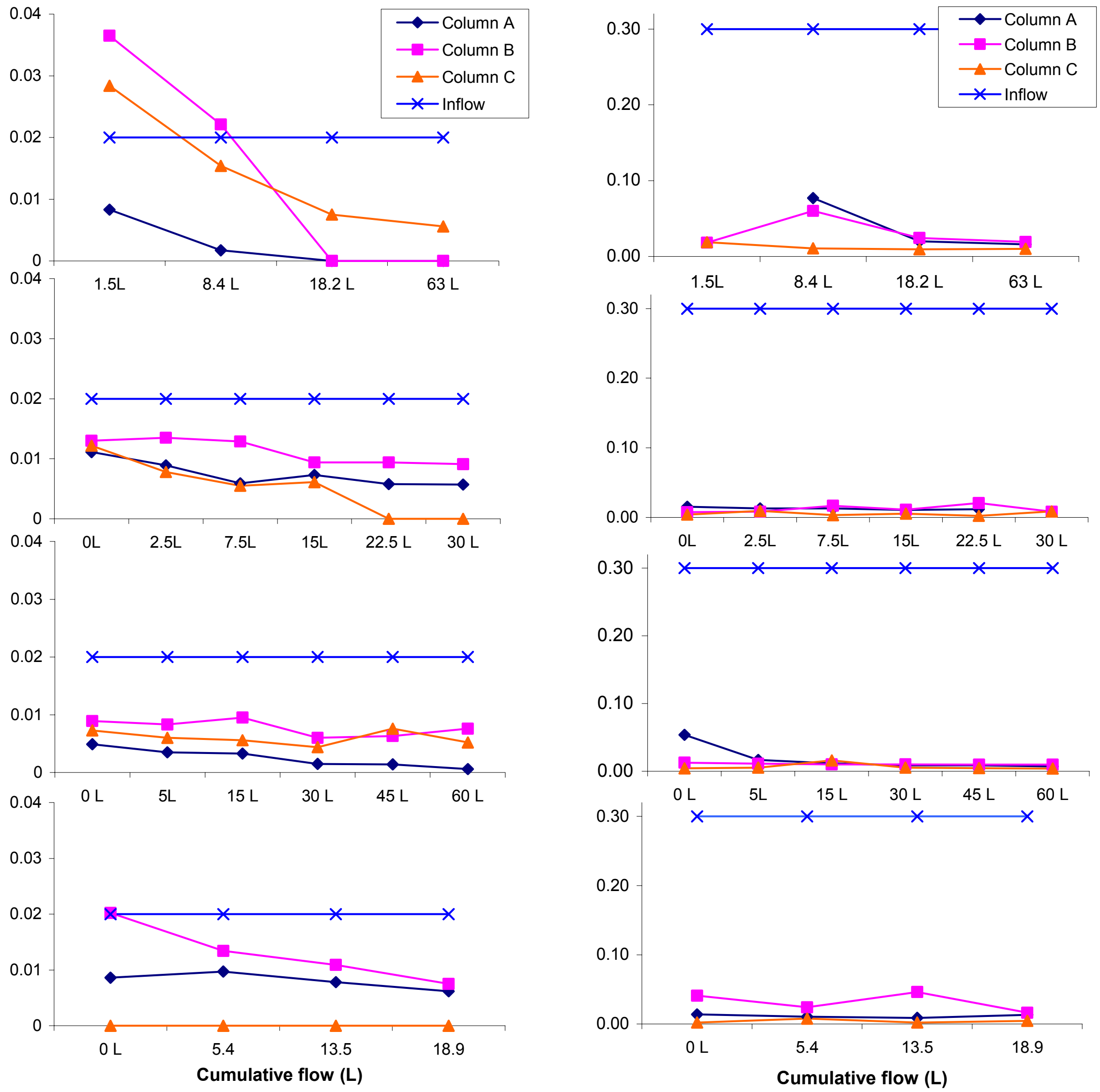
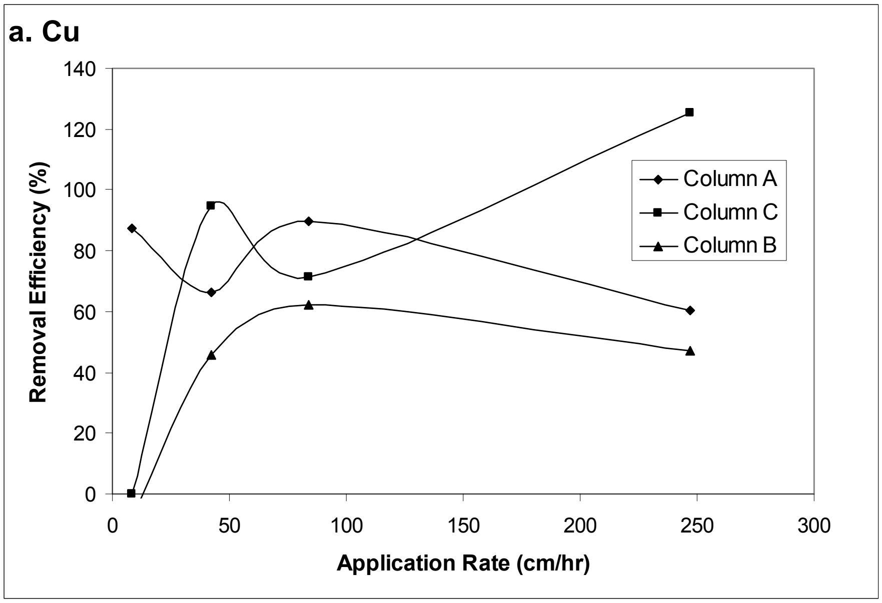


Figure 3: Column Percolate Concentrations of Copper and Zinc at cumulative flows. Graphs A through D represent Copper concentrations at 8 cm/hr, 42 cm/hr, 84 cm/hr and 247 cm/hr respectively. Graphs E through H represent Zinc concentrations at 8 cm/hr, 42 cm/hr, 84 cm/hr and 247 cm/hr respectively. Data included for the three different soil columns: diamond – column A, square – column B, triangle – column C, and x – inflow concentration.



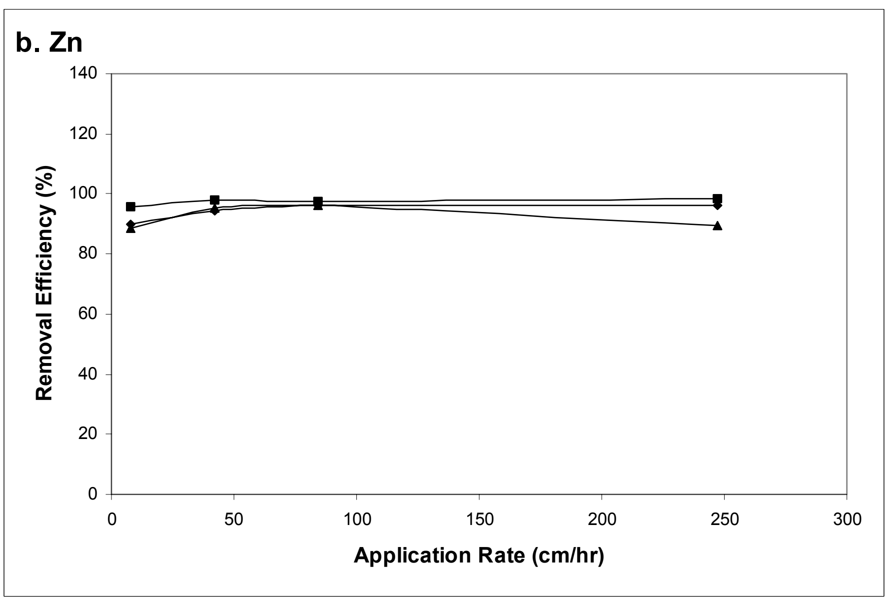


Figure 4. Metal removal efficiencies for varying hydraulic application rates on three different soil columns: Diamond - Column A, Triangle - Column B, Square - Column C. Pb is not shown as removal was consistently below detection limit.

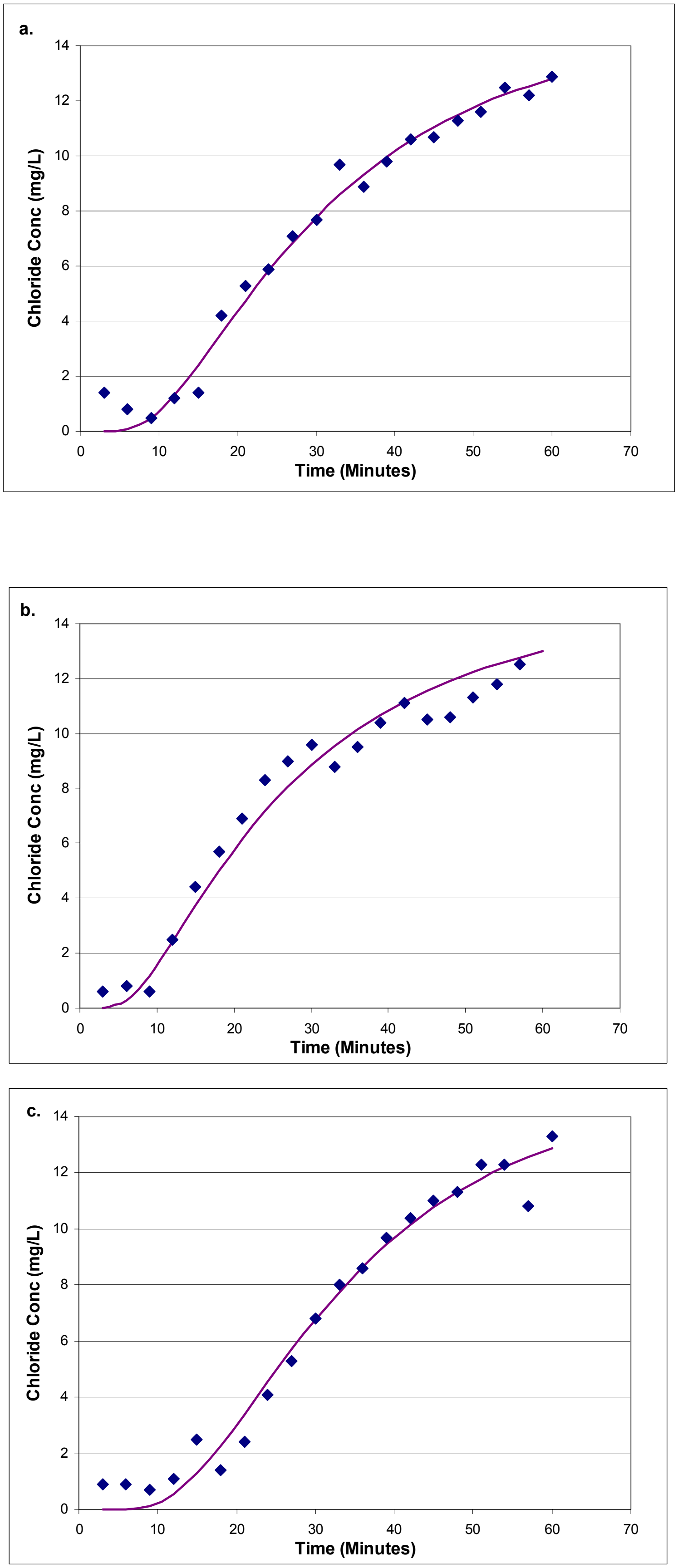

a.
b.
c.
Chloride Conc (mg/L)
Time (Minutes)
0
2
4
6
8
10
12
14
0
10
20
30
40
50
60
70

Figure 5. Observed chloride concentrations (points) versus chloride concentrations predicted using the advective-dispersion equation for columns am b, and c. The plateau in the observed data in the first several minutes is indicative of preferential flow.

[End pdf]

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GIS Based Spatial Modeling and Analyses of Urban Stormwater Size and Stormwater Management Practice (SMP) Feasibility in the Lower Buffalo River Watershed.

Basic Information

Title:	GIS Based Spatial Modeling and Analyses of Urban Stormwater Size and Stormwater Management Practice (SMP) Feasibility in the Lower Buffalo River Watershed.
Project Number:	2003NY24B
Start Date:	3/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	27
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Hydrology
Descriptors:	stormwater, runoff, urban stormwater
Principal Investigators:	Tao Tang

Publication

Title: GIS Based Spatial Modeling and Analyses of Urban Stormwater Size and Stormwater Management Practice (SMP) Feasibility in the Lower Buffalo River Watershed.

Introduction

This project aims to identify the size (acre-feet) of storm runoff in each of Storm Water Catchments (SWC) in the Lower Buffalo River watershed. Then, the suggestions of suitable Stormwater Management Practice (SMP) tool or tools will be proposed through the spatial analysis of five screening factors. The suggestions for the choice of five SMP tools for each of the SWCs will be proposed by mapping and analyzing the major parameters of five screening (feasibility) factors, namely Land Use, Physical Feasibility, Watershed/Regional Factors, Storm Management Capability, and Community and Environmental Factors.

Work Accomplished

Stormwater catchments of the lower Buffalo River watershed were delineated using USGS DEM with 10 meter resolution and the ArcHydro extension in ArcGIS. A total of 86 catchments were delineated for the entire Buffalo River Drainage Basin. Among them, 26 fall into the area of the lower Buffalo River watershed (Figure 1.). The delineated catchments are topologically connected in terms of river drainage network.

Land use map apply the modified American Planning Association (APA) land use scheme with structure and function dimensions is accomplished. The map was compiled using New York State 2002 true color aerial photographs with wither 1 foot or two feet spatial resolution. A total of 8,640 land use polygons were generated for the entire Buffalo River drainage basin (Figure 2).

Figure 1. Catchments delineation in the lower Buffalo River watershed in Comparison with Entire Drainage Basin

Slope and flow direction map layers in the raster format were generated from the USGS DEM with 10 meter resolution. Currently, it is being converted into vector format and it is in the process of merging polygons with slope degree ranges. The objective is to combine them into 60 to 70 slope range categories (Figure 3). Since the distribution of the slopes is mainly cluster in the lower degree angles, the categories of the ranges will be arranged by statistical classification method in ArcGIS.

Soil distribution map was compiled for the entire Buffalo River Drainage Basin. However, detailed soil classifications (SSURAGO) are only available in the lower and middle watershed areas that fall into the Erie County. Therefore, the detail soil map in the Erie County was merged with less detail soil classification map (STATSGO) in other counties in the upper watershed (Figure 4.)

. Field sampling and measurement sites were selected from the drainage points of the catchments. Eight sampling sites were selected through field investigations of 20 confluences and drainage outlet sites. Differential GPS survey of these sites was conducted. The sediment discharge and major pollutant loadings of TSS, TP, TN, Cu, Pb, Zn, and F. Coli will be interpolated using these eight sample points. (Figure 5).

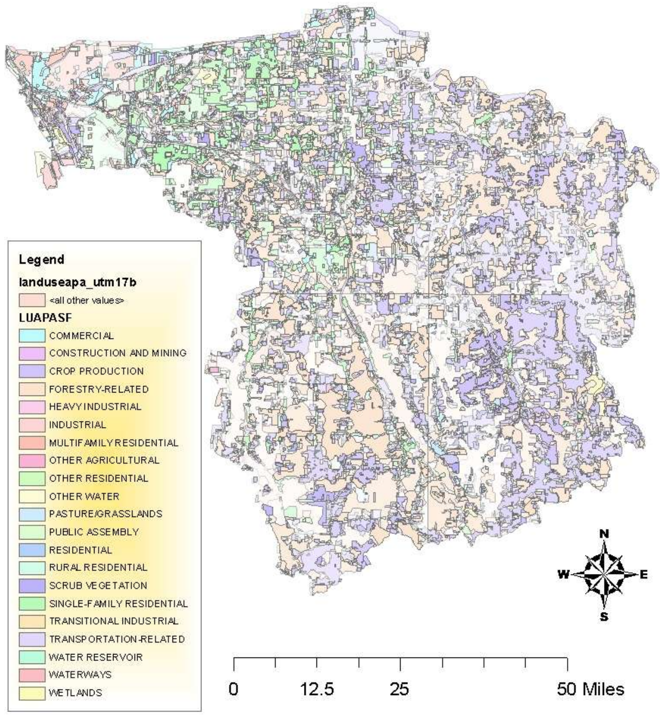

Figure 2. Land Use Classification Using APA Land Based Classification System

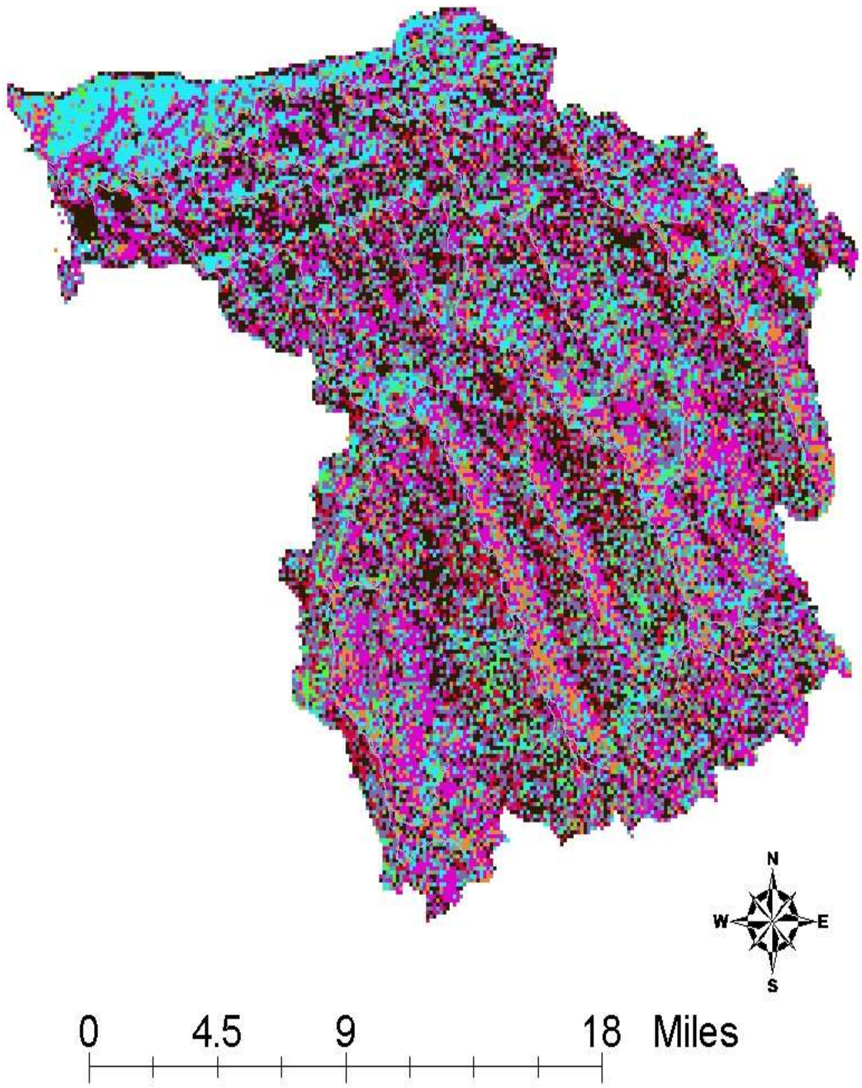

Figure 3. Flow Direction and Slope in the Buffalo River Watershed in Vector Format

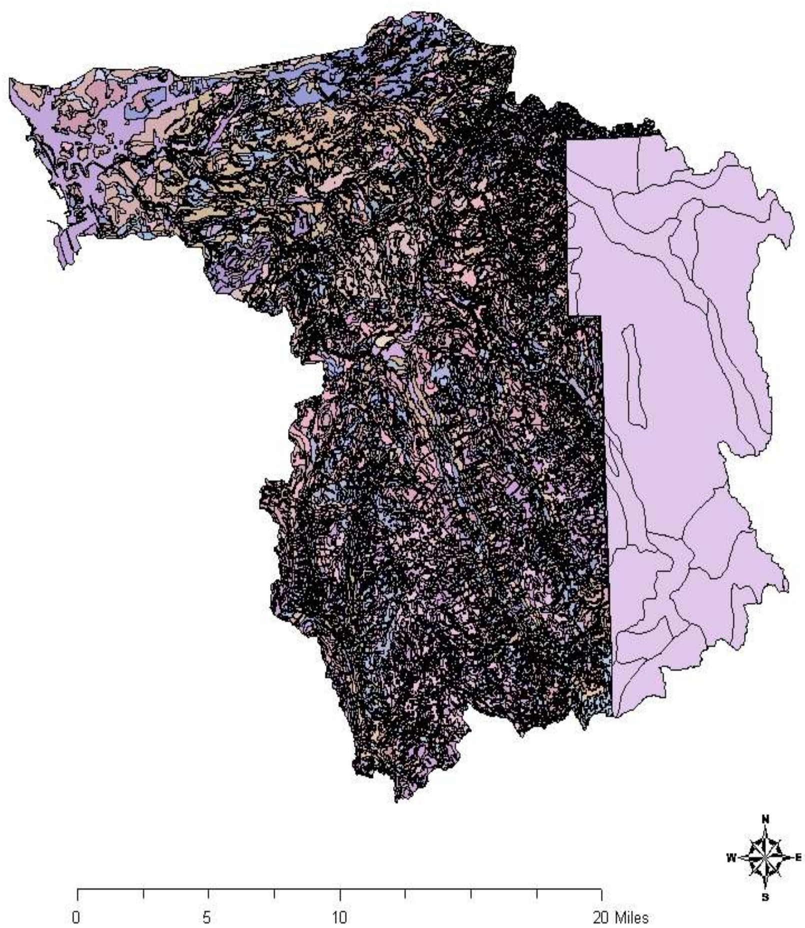

Figure 4. Soil Map in the Buffalo River Watershed (compiled with different levels of classifications, classified using SSURAGO).

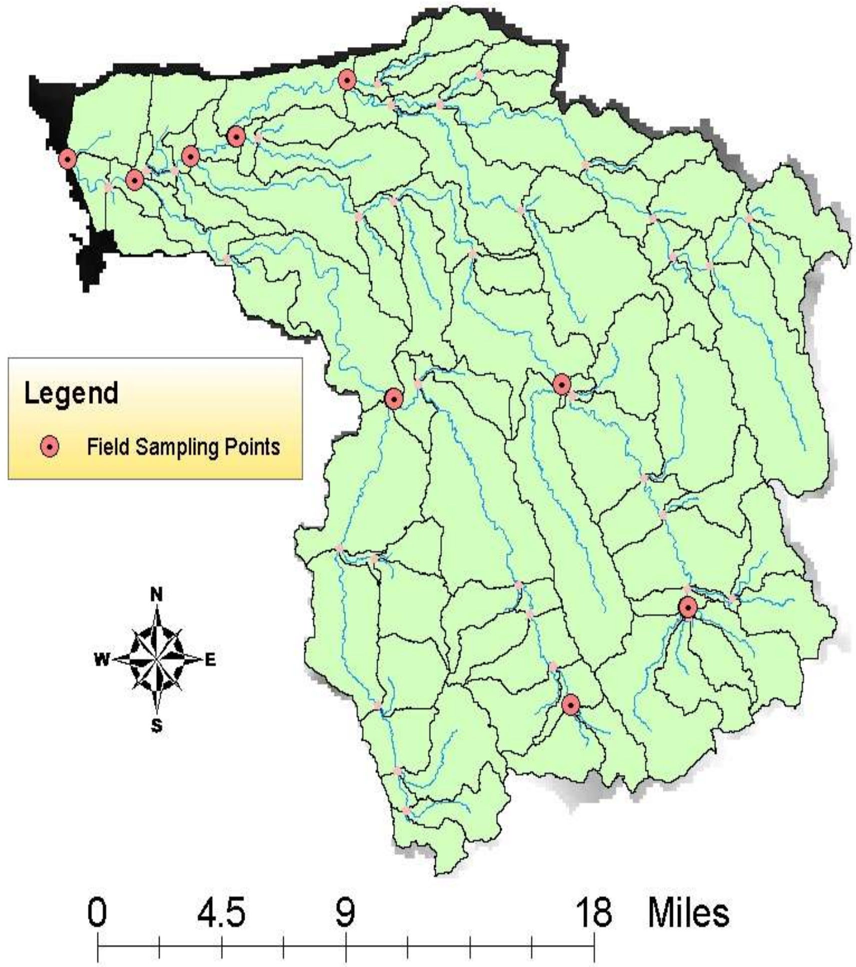

Figure 5. Field Sampling Sites (Nine sites are shown on this map. One of the two upper reach or head water sites will be sampled in each of the field samplings.)

Work in Progress

Field sampling and analyses are currently conducted for two rainfall storm events and one dry weather environment. The purpose of these field samplings is to incorporate field data into the GIS based mapping and spatial analysis. Mapping of slope and vegetation covers are in the progress. The average household income and population of age under 18 or younger in the lower Buffalo River watershed still need to be accomplished in GIS to fulfill the requirement of community and environmental factors.

After the field samplings were accomplished, percent contaminate loading maps will be compiled. Modification of field sampling was made from the catchments to the confluences or drainage points of the stormwater catchments because the difficulties encountered for entering private properties and obtain permissions. Basic topology of river network and connectivity of catchments in the lower Buffalo River watershed will be used to interpolate and map the percent contaminate loadings based on field data.

The map layers will be overlayed and the WQv (water quality volume) will be calculated using the 90% rainfall. Loading of each of seven contaminates will be calculated according the NY DEC "simple method" model. The SMP selection factors will be evaluated visually from digital maps for the location selections of the Stormwater Management Practice tool selections for each of the catchments.

Preliminary Discussions

One full time graduate student and one part time graduate student are working on this project. Since both my research and their research interests are on Geographic Information Systems (GIS) and computer mapping, the theoretical approach of this project is focused on the inter-map layer connectivity and topological interpolations. ArcHydro extension of ArcGIS was applied in this approach. Mapping part of the project encountered some difficulties. For instance, the USGS DEM (digital elevation model) with 10 meter resolution can generate slope, flow direction, etc in raster GIS data format. However, the conversion from raster to vector data structure produced four million small polygons that take very long computing time to be merged in certain slope degree groups.

Owing to the limited funding form the grant, the field sampling is not extensive. Eight sites were selected for collecting water samples based on the confluence locations and field accessibility. More field sampling sites would yield more reliable and accurate estimation. In general, this project was mainly designed for Stormwater influence factor mapping and interpolation, other than extensive sampling. Estimations will be made for the spatial distributions of contaminate loadings from the comparison of the field sample of loadings in the lower, middle, and upper reaches of the Buffalo River watershed. The mapping and modeling work using topology in this project was presented in the New York State GIS Conference in Albany.

Combining an Optical Strip-Assay Biosensor with Ribotyping for Bacterial Source Tracking of Enterococcus faecalis in the Lower Hudson River Basin

Basic Information

Title:	Combining an Optical Strip-Assay Biosensor with Ribotyping for Bacterial Source Tracking of Enterococcus faecalis in the Lower Hudson River Basin
Project Number:	2003NY25B
Start Date:	3/1/2003
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	22
Research Category:	Biological Sciences
Focus Category:	Non Point Pollution, Water Quality, Waste Water
Descriptors:	non-point source pollution, fecal contamination, water quality, pathogens, wastewater
Principal Investigators:	Janice E. Thies

Publication

1. Reilly, J P, J E Thies and A. Baeumner, 2003, Development of an Optical Strip-assay Biosensor for Enterococcus faecalis. American Society for Microbiology Annual Meeting, Washington, DC
2. Reilly, J P and J E Thies, 2003, Emerging Water Contaminants: Preliminary findings from Ribotyping of Enterococci Isolated from Wappinger and Stony Creek Catchments. Invited talk at the Dutchess Environment Council meeting.
3. Hartel, PG, S Myoda, RL Kuntz, K Rodgers, J Entry, S Ver Wey, E Schroder, J Calle, M Lacourt, JE Thies, JP Reilly and JJ Fuhrmann, 2004, Geographic and Temporal Changes of Enterococcus faecalis Ribotypes for Bacterial Source Tracking, Journal of Environmental Quality, submitted for publication 6/04.

Combining an Optical Strip-Assay Biosensor with Ribotyping for Bacterial Source Tracking of Enterococcus faecalis in the Lower Hudson River Basin

Problem and Research Objectives:

The second most reported impairment affecting tributary waters in the southern portion of the Lower Hudson River basin is runoff from urban and extensively developed suburban areas (NYSDEC 1999). Runoff can be directly attributed to the rapid population growth in the region, which in turn has caused many wastewater treatment plants to be overloaded with volumes far beyond the limits of their initial design capacities. Pathogen impairment of receiving water may then ensue. Despite convincing scientific data, only about 1/3 of all states have adopted either *E. coli* or enterococci counts as indicators of fecal pollution for monitoring fresh and marine waters (EPA 1999). Clearly, there is still a need for coordinated scientific studies to foster consistent use of indicator species of fecal contamination to determine potential health risks in tributary waters.

The specific goals of this proposed project in the Wappinger and Stony Creek tributaries were to:

- ribotype isolates of *Enterococcus faecalis* from water and suspected sources of contamination in order to develop a pathogen tracker database.
- use the database to identify the source(s) of fecal contamination in the Wappinger and Stony Creek tributaries.
- develop a species-specific ribosomal DNA gene biosensor for rapid detection of *Enterococcus faecalis* from environmental samples (water and human feces).

Methodology:

Ribotyping and database development: A transect was followed to collect both water and fecal samples at four time points: Oct., 2002 and April, June and August, 2003. To the degree possible, samples were collected during base flow conditions. Sampling was every 100-500 meters along the creek side immediately downstream and upstream of the suspected source of contamination (wastewater treatment facility). At each of the two sites 2 upstream and 3 downstream grab samples (10 cm below the water surface) were collected in 12 oz. Nalgene bottles that had been rinsed three times with stream water prior to final collection. Samples were returned to the Thies Laboratory at Cornell University and immediately processed using the IDEXX Enterolert™ system. This system has been used successfully in previous ribotyping studies (Hartel et al., 2001) to enumerate enterococci in freshwater samples. An isolation protocol for speciation of *Enterococcus faecalis* was followed (P. Hartel pers. comm.). Isolates from October 2002 and April 2003 were overnight shipped to University of Georgia for ribotyping. Isolates from the June and August sampling in 2003 were ribotyped in the Laboratory of Molecular Typing facility (M. Wiedmann, Director), Stocking Hall, Ithaca, NY. Ribotype patterns generated from this study were deposited into the Pathogen Tracker 2.0 database currently being developed by Dr. Martin Wiedmann. Riboprint .txt files were imported into Bionumerics V. 3.0 statistical software package (Applied Maths, Kortrijk, Belgium). Similarity indices were determined using Dice's Coincidence Index and the distance among clusters calculated using the unweighted pair-group method using arithmetic averages (UPMGA).

Biosensor design: The following outlines the major steps in the protocol that was followed to detect *Ent. faecalis* using oligonucleotide-tagged liposomes in a competitive assay format per Esch et al. (2001) and Baeumner et al. (2002). Briefly, the assay principle is as follows: A DNA capture probe is immobilized on a polyethersulfone (Pall/Gelman Company, Port Washington, NY) strip via streptavidin/biotin binding. A DNA reporter probe is coupled to the surface of a liposome. When an rRNA gene sequence unique to *Ent. faecalis* is present, a sandwich is formed between the ssDNA capture probe, rRNA gene target, and the reporter probe. When the target sequence is present, liposomes are captured in the capture and detection zone (Figure 1).The number of liposomes present is directly proportional to the copy number of *Enterococcous faecalis* 16S rRNA genes present.

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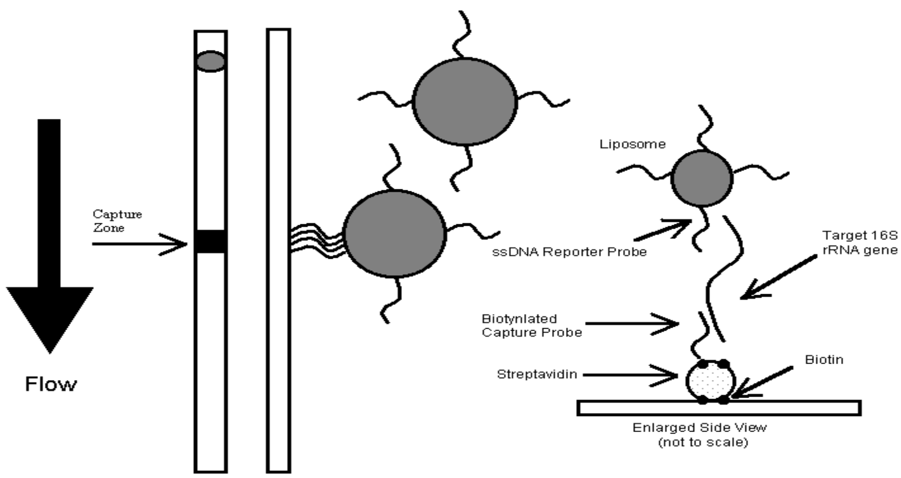

Figure 1. Competitive assay format.

Principal Findings & Significance:

- Ribotypes with >90% similarity to those from the Tivoli wastewater treatment facility were found downstream from the facility, suggesting that the plant is a source of contamination. However, very dissimilar ribotypes patterns were also found downstream at the Tivoli Mouth of Bay (to Hudson River) site. This suggests that other human/non-human sources might also be contributing to the contamination.
- The biosensor employs sulforhodamine B (SRB) dye-encapsulated liposome technology in a competitive assay format to detect the presence of a synthetic 16S rRNA gene sequence specific to *Ent. faecalis*. Two different target analyte sequences were hybridized with liposomes that had reporter probes (ssDNA oligonucleotides) attached to them. The bioassay strip was very sensitive when used with synthetic target sequences. The lowest level of detection of 16S rRNA synthetic gene sequences for Analytes 1 and 2 was 14 fmol/µL and 19 fmol/µL,

respectively. A dynamic range up to 5000 fmol/µL for both sequences was obtained. The assay can be run in under 20 minutes. Hence, the technology has promise.

- To date, the biosensor has not been able to detect the target sequence amplified from *environmental* isolates or ATCC strains of the *Ent. faecalis* 16S rRNA gene. The positive signal generated with the control *synthetic* sequence suggests that perhaps secondary structures (e.g. hairpins) may be inhibiting the hybridization of the target analyte with the capture and reporter probes. More work is needed to determine what is hindering detection of target sequences from bacterial isolates.

- The study confirms that ribotyping of indicator bacteria is a useful and highly discriminatory approach to BST, but that it must be combined with a targeted sampling protocol in order to be a cost-effective alternative for BST efforts.
- The development of a species-specific primer that works in a biosensor to detect synthetic sequences of *Enterococcus faecalis* is a positive first step in the development of an inexpensive new technique to detect pathogens from the environment.
- The study has brought to light that failing wastewater treatment facilities in the Tivoli township are likely contributing to elevated levels of total coliforms and enterococci.

Development of Methods to Distinguish Between Ruminant and Human Sources of Fecal Contamination in Watersheds

Basic Information

Title:	Development of Methods to Distinguish Between Ruminant and Human Sources of Fecal Contamination in Watersheds
Project Number:	2002NY7B
Start Date:	3/1/2002
End Date:	8/31/2003
Funding Source:	104B
Congressional District:	NY 21, NY 22
Research Category:	Biological Sciences
Focus Category:	Non Point Pollution, Waste Water, Water Quality
Descriptors:	non-point source pollution, fecal contamination, water quality, pathogens
Principal Investigators:	Karen Sklenar, Ellen Braun-Howland

Publication

Development of Methods to Distinguish Between Ruminant and Human Sources of Fecal Contamination in Watersheds

Problem & Research Objectives:
In order to reduce fecal contamination of water bodies, watershed managers first need to identify the sources of contamination. Traditionally, results of fecal coliform and fecal streptococcus testing have been used. Since these bacteria are found in both humans and other mammals, watershed managers look to the ratio of fecal coliform to fecal streptococcus as a possible indicator of the source of contamination. However, this method is unreliable.

For this project, we proposed to assess the ability of a molecular-based PCR method to identify sources of fecal contamination in watersheds. This method identifies fecal contamination through the amplification of *Bacteroides* DNA using the polymerase chain reaction. In addition to permitting the identification of fecal contamination, the method is exceptional due to its potential ability to identify quickly and efficiently the source of contamination as being of human or ruminant origin.

The objectives of the project were:

1. To assess the effectiveness of the *Bacteroides* PCR test, coprostanol, and caffeine at identifying sources of fecal contamination in watersheds;

2. To compare the sensitivity of the *Bacteroides* PCR test, coprostanol, and caffeine with more established indicators of fecal contamination (total coliforms, fecal coliforms, *E. coli*, fecal streptococcus, enterococcus) under different seasonal and land use conditions;

3. To conduct a preliminary evaluation of the effect of agricultural best management practices (BMPs) on water quality downstream of farms in Albany and Rensselaer Counties.

The project focused on the analysis of samples collected from several stream stations in Albany and Rensselaer Counties. Samples were collected in triplicate from four sites on four sampling dates.

Methodology:
Investigators worked closely with representatives from the Albany and Rensselaer County Soil and Water Conservation Districts to identify stream stations that would be used for the study. In the cases where streams were located downstream of farms, the farmers were consulted and their approval was obtained before a station was selected for the study.

The specific locations of the stations that were used for this study are blind, both in terms of when results were reported, and for the investigators when they performed the laboratory analyses. Instead of a specific identity, stations were assigned alpha-numeric labels and categorized by their upstream land use.

The first round of sampling was conducted in July 2002 over four days. The samples collected were considered representative of summer, low flow conditions. Samples from the second sampling, conducted in November, were considered representative of moderate flow conditions. High flow conditions were encountered during the March 2003 spring-thaw sampling event, while moderate flow conditions were again encountered during the final sampling event in May of 2003. Twelve stations were sampled at each event, with triplicate samples collected at each station. The breakdown of sampling stations is as follows:

- Three stations downstream of CAFOs with no BMPs in place;
- Two stations downstream of CAFOs with BMPs in place;
- Three stations draining a combination of farms and residential areas with septic systems;
- Three stations downstream of septic systems considered failing or poorly sited; and
- One station downstream of forested land with neither farms nor residences upstream.

All samples were evaluated for the presence of fecal coliforms, fecal streptococcus, total coliforms, *E.coli*, enterococci, and *Bacteroides*. Samples were also collected for measurement of caffeine and coprostanol, potential indicators of human fecal pollution. Temperature, dissolved oxygen, pH and conductivity were measured at each sampling point.

Project Adjustments:

Because total coliform and *E. coli* numbers were very high in many of the July samples, subsequent samples were diluted prior to analysis.

Stream measurements, including temperature, pH dissolved oxygen and conductivity, were made using a Hydrolab multiprobe unit. The pH measurements taken during July's sampling were unreliable due to equipment malfunction. In November, pH measurements were made with another field meter. The Hydrolab multiprobe unit was serviced and calibrated for pH prior to March and May sampling events. The July pH measurements will not be included with the study's other results.

The investigators intended for the first sampling event to be Spring 2002. Due to funding delays, the ironing out of contracts, and the amount of time needed to identify good sampling locations, the first sampling event occurred, instead, in Summer of 2002. As a result, Late Winter and Spring sampling took place in 2003.

Principal Findings & Significance:

Seasonal samples were collected based on the premise that, conditions of higher water flow create an initial first flush of contaminants, followed by a dilution effect on the total mass of contaminants within a watershed, while under conditions of low water mass, the contaminant levels per quantity of water will be higher. All sample data from this project reflect a lower bacterial load in waters at the March, high-flow sampling event, and higher bacterial loads in waters during the July, low-flow sampling event.

The major focus of this research project was to validate molecular methods for water quality assessment and source identification. Methods published by Bernhard and Field were preliminarily tested on human septic samples, bovine manure samples, and various wild and domestic animal manure samples. Preliminary results predicted a quality assay for use in water pollution control applications. However, this research project identified several problem areas in the published protocol. Major adaptations were required, in order to identify successfully *Bacteroides* DNA in turbid water samples containing high levels of molecular inhibitors. Overall, an enrichment step, designed to increase numbers of *Bacteroides* was routinely performed to increase the assay sensitivity; more stringent DNA isolation techniques were employed to reduce inhibitors of the PCR reactions; and parameters used in PCR amplification reactions were significantly modified. Lastly, we found that the detection of species-specific *Bacteroides* DNA was dependent upon the source/type of *Taq* polymerase used.

With respect to objective 1, all CAFO-designated sites, with and without BMPs, were identified as having fecal pollution from ruminant sources at least once during the sampling period. Likewise, all sites suspected of having leaking or poorly sited septic systems were positive for human-specific fecal pollution, and all sites thought to have mixed sources were positive for both ruminant and human-specific *Bacteroides* at least once during the year. Although this study encompassed only a single sampling day during four seasons, our results suggested that the likelihood of detecting *Bacteroides* DNA was seasonal. During a period of high flow in March 2003, water samples were negative for both human and ruminant-specific *Bacteroides*, with the exception of a single site designated as likely to be contaminated with septage. Also, during the period of low flow in July, 2002, triplicate samples of one of each of the three CAFO and three septic-contaminated sites failed to appropriately identify the pollution source using PCR. These results were likely due to significant water turbidity, and concomitant inhibition, of molecular-based tests. The vast majority of samples (15/18) were correctly identified with respect to likely contamination source in November. During May, several of the sites designated as being contaminated with septage were also positive for ruminant-specific *Bacteroides*; this may have resulted from seasonal land application of manure. Overall, our results indicate that the detection of, and discrimination between, human and ruminant sources of fecal pollution is affected by ambient environmental conditions, and may require several sampling events.

Technical difficulties with the caffeine and coprostanol analyses precluded conclusions regarding the appropriateness of using these compounds as indicators of human fecal pollution. The results of this testing were ambiguous, apparently because environmental levels of these compounds were at concentrations similar to, or lower than, background levels detected in analytical reagents.

With respect to sensitivity of the test, all samples that were positive for *Bacteroides* using PCR amplifications were also positive for total colifoms, *E. coli*, enterococcus and fecal streptococcus, with the exception of the "unimpacted" site. In that case, while low numbers of *E. coli* (4.2/100 mls) or enterococci (<10/100 mls) were sporadically observed, *Bacteroides* DNA was only detected on one occasion, *viz.,* the May sampling event. The PCR test did not identify the *Bacteroides* DNA as either of human or ruminant origin, suggesting an alternate mammalian source of fecal pollution. On occasions when *E. coli*/enterococci, but not *Bacteroides*, were detected, it seems likely that the *E. coli* was from a source lacking *Bacteroides* DNA that could be amplified under the test conditions employed, e.g., birds.

In general, total coliform numbers were high in all samples, regardless of station location, including the unimpacted control samples; fairly high numbers of *E. coli*, fecal streptococci, enterococci, and fecal coliforms were found in all but the control site samples; and there was no apparent relationship between land use upstream and the fecal coliform/fecal streptococcus ratio. While triplicate results were largely within appropriate variability ranges for numerical evaluations of numbers of total coliforms, *E.coli*, and enterococci, the FC/FS ratio identified variable sources of contamination in many instances.

Objective 3 of the proposal addressed evaluation of BMPs with respect to water quality parameters. As noted above, all CAFO-designated sites were positive for ruminant-derived *Bacteroides* at least once during the sampling period. Only two sites employing BMPs were examined. While the detection of ruminant-specific pollution was decreased at one of the sites, the small size of the sample number and limited sampling dates precludes any conclusions regarding the efficacy of BMPs.

Notable Achievements:
Excellence in Research Award, University at Albany, School of Public Health, for poster describing this research.

Initiatives for Women Grant Awarded to Jacqueline Lendrum in recognition of academic merit and research conducted and support for research continuation through the summer of 2003

Current and Future Work:
Research related to this grant has continued well beyond the close of the funding period due to difficulties encountered with the PCR assay. In the near future, all data will be subjected to statistical analysis and a journal article will be written and submitted for publication.

The current research project, also funded by the Water Resources Institute, further examines the bacteria identified in the first research project in recognition that more extensive data regarding die-off kinetics and viability assessments is needed.

A Watershed-Scale Biogeochemical Loading Model for Nitrogen and Phosphorus

Basic Information

Title:	A Watershed-Scale Biogeochemical Loading Model for Nitrogen and Phosphorus
Project Number:	2000NY5G
Start Date:	9/1/2000
End Date:	6/30/2004
Funding Source:	104G
Congressional District:	NY26
Research Category:	Water Quality
Focus Category:	Hydrology, Models, Nutrients
Descriptors:	denitrification, ecosystems, hydrologic models, geographic information systems, land-water interactions, land use, mathematical models, rainfall-runoff processes, watershed management
Principal Investigators:	Robert W Howarth, Elizabeth W. Boyer, Dennis Swaney

Publication

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A Watershed-Scale Biogeochemical Loading Model for Nitrogen and Phosphorus

Problem and Research Objectives

Two recent reports from the National Academy of Sciences have concluded that eutrophication is the biggest pollution problem in the coastal marine waters of the United States (NRC 1993, NRC 2000). Eutrophication lowers biotic diversity, leads to hypoxic and anoxic conditions, facilitates harmful algal blooms, causes dieback of seagrass beds, and can lead to changes in ecological food webs that lower fishery production (NRC 2000). Over 40% of the estuaries in the country are degraded from eutrophication, with the problem being particularly severe in the northeastern and mid-Atlantic regions (Bricker 1999). For most estuaries in these regions, eutrophication is caused primarily from over-enrichment with nitrogen; phosphorus is a secondary contributor (Howarth 1988; Nixon 1995; NRC 2000). Most of the nitrogen delivered to coastal waters in the US, including the northeastern and mid-Atlantic regions, comes from non-point sources in the watershed (Howarth et al. 1996). Agricultural sources are important in some watersheds, dominating the flux in the Mississippi River basin and contributing to the flux of some estuaries in the mid-Atlantic region, but atmospheric deposition of nitrogen from fossil-fuel combustion is an even greater source of nitrogen to estuaries for most of the mid-Atlantic region and for the northeastern US (Howarth et al. 1996; Smith et al. 1997; Jaworski et al. 1997; Goolsby et al. 1999; NRC 2000).

In regions subject to changes in land use and in atmospheric deposition of nitrogen, the processes that control nutrient loads to the coastal zone are complex. Variability of these hydrological and biogeochemical processes is increasing as weather and climate change. Understanding how these processes affect the magnitude and transformations of the nutrient loads is necessary in order to manage the environmental resources of the coastal zone. Further, it is important for those living in and managing coastal watersheds to understand the impacts of their activities and policies on these nutrient loads. A relatively
simple modeling tool that can estimate the impacts of various activities in the watersheds can greatly enhance, at low cost, our ability to manage these regions effectively and to communicate the effects of human activities and environmental processes on nutrient loads. The report of the National Academy of Science s Committee on Causes and Management of Coastal Eutrophication concluded that no model currently available to managers fulfills this need for estimating the controls on nitrogen loads (NRC 2000).

They noted in particular that most models used by watershed and estuarine managers fail to deal adequately with nitrogen deposition onto the landscape with subsequent export downstream, even though this is the number one input of nitrogen to many estuaries. The Committee further concluded that the development of such a model particularly one that deals with atmospheric deposition -- is one of the most pressing priorities for solving the problem of coastal eutrophication (NRC 2000). Our aim has been to develop such a model.

To mitigate the effects of human activities on the supply of nutrients to surface waters, managers are tasked with gaining an understanding of the landscape source areas delivering nutrients to receiving waters. We have developed an easy-to-use model for calculating loads of N and P to coastal watersheds, targeted toward management applications. The model describes transport of water, sediment and nutrients from the landscape to receiving waters. Our goal has been to create a model structure that will be used widely; thus we have developed the model in a commonplace platform: the Excel workbook. This version of the model, GWLFXL1.0, runs as a Visual Basic for Applications (VBA) program with an Excel interface.

Model Summary

In its current form, the model uses the event-based dynamics of a simple, lumped hydrologic model (Generalized Watershed Loading Function (GWLF) (Haith and Shoemaker, 1987) GWLF is a parsimonious, event-based model that has been used successfully to analyze the hydrology, sediment, and nutrient loads of several mixed watersheds in the United States, including the New York City reservoir system, the Hudson River (Howarth et al., 1991; Swaney et al., 1996), the Tar-Pamlico (Dodd and Tippett, 1994), and the Choptank River drainage of the Chesapeake Bay (Lee et al., 2000). We have added additional functionality to handle atmospheric deposition of nutrients, simple estimates of denitrification rate, and changes over time of the areas of different landuse/land cover categories. The original model used daily historic or synthetic temperature and precipitation data to simulate monthly discharge, sediment load, and nutrient transport. We have developed a separate stand-alone weather generation package (also Excel/VBA based) to allow the user to generate alternate climate scenarios in a format compatible with the model.

New Features

Model Input/Output After the "port" of GWLF code to Excel was achieved, several features of i/o were radically redesigned in the interest of flexibility:

- Model simulation options are now controlled primarily from an Excel pulldown menu (GWLFXL) which appears when the workbook is loaded.
- Model parameters can now be read either from existing GWLF input files (ie text files) or from parameter worksheets embedded within the workbook.
- Model output is now organized into several output worksheets, depending upon the time scale desired (ie annual, monthly, or daily). Worksheets that group the output by land use category are also generated at the option of the user. An advantage of organizing model output by worksheet is the ready creation of graphics within Excel from the tabulated values, or further user-generated statistical analyses of model scenarios.

Model Calibration Mode. A major addition to the package is the model calibration mode which utilizes the Solver addin feature of Excel to obtain a least-squares fit of a selection of model parameters to monthly streamflow, sediment flux, or nitrogen flux data. Model parameters are selected and calibration datasets are entered in the calibrate worksheet. The desired calibration mode is chosen from the pulldown menu. Solver then drives the model, iteratively changing the selected parameters, until model best matches the data in a least-squares sense. Up to 5 parameters may be selected, though as of this writing, the procedure appears to work best with one or 2 parameters at a time.

Parameter Uncertainty Analysis. Another new mode of using the model is parameter uncertainty analysis, in which the effect of uncertainty about parameter values on model output is estimated quantitatively. The process occurs in 3 steps:

- In the "stochastic" worksheet, the model parameters to be investigated are assigned probability distributions, together with estimates of their mean and variance, etc
- The user chooses the number of replicate runs desired for the analysis, and then draws the corresponding parameter values from their individual distributions; this option is selected from the pulldown menu
- The user runs the model in uncertainty mode, repeating the simulation for each realization of the parameter values, and the mean and standard deviation of the model outputs are stored in the "uncertainty" worksheet.

When the runs are complete, the user can plot the time series of means and confidence intervals for any model variable corresponding to the selection of parameters evaluated.

Project updates and website

The current version of the model and associated documentation and tutorials can be downloaded from the project website: http://cfe.cornell.edu/biogeo/USGSWRI.htm. Model updates, fixes, and future documentation will be made available here as well. While the VBA module containing the code is currently password protected to prevent tampering, the code is provided in Appendix 1 of the project report at the above website. Interested researchers can obtain the password by contacting Dennis Swaney at dps1@cornell.edu.

Current and future research directions in follow-on projects

Although the USGS/WRRI funded phase of the project has ended, we have obtained additional funding from an EPA star grant to pursue model development. We are currently engaged in adding more functionality to the model, aiming in particular at refining the descriptions of watershed biogeochemistry and hydrology, writing a model description for publication in a peer-reviewed journal, and beginning to evaluate the model against estimates of nitrogen load for 16 northeast US watersheds (Boyer et al., 2002). Links to further progress with the model development will be reported at the above website.

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

Basic Information

Title:	Modeling phosphorus control best management practices on a watershed scale to improve surface drinking water quality
Project Number:	2001NY921G
Start Date:	9/1/2001
End Date:	8/31/2004
Funding Source:	104G
Congressional District:	26
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Agriculture, Water Quality
Descriptors:	dissolved phosphorus, water quality modeling, best management practices, watershed management, hydrology
Principal Investigators:	Tammo Steenhuis

Publication

1. Gérard-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.
2. Gérard-Marchant, P., 2002, The Soil Moisture Routing Model: A User Manual, Version 1.0, Soil and Water Laboratory, Biological and Environmental Engineering Dept., Cornell University, Ithaca, NY, USA.
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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 was returned for revisions to us.

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.

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 has been submitted for publication.

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 will be presented at the international AWRA meeting in New York City this summer

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.

An Assessment of New Advances in Low Streamflow Estimation and Characterization

Basic Information

Title:	An Assessment of New Advances in Low Streamflow Estimation and Characterization
Project Number:	2003NY33G
Start Date:	8/1/2003
End Date:	7/31/2006
Funding Source:	104G
Congressional District:	25
Research Category:	Climate and Hydrologic Processes
Focus Category:	Drought, Water Use, Non Point Pollution
Descriptors:	risk assessment, geographic information system, watershed hydrology, statistical hydrology, regional hydrology
Principal Investigators:	Chuck Kroll

Publication

Title: An Assessment of New Advances in Low Streamflow Estimation and Characterization

Primary PI.: Chuck Kroll

Problem and Research Objectives:

Understanding the frequency and duration of low stream flow events is critical to the efficient management of water resources throughout the Northeastern United States. Low stream flow statistics are used to determine waste allocations, plan water supply, irrigation systems, and hydropower, site treatment plants and landfills, and determine inter-basin withdrawals and transfers. In addition, low stream flow events are often critical periods for aquatic habitats. Usually low stream flow statistics are required at river sites where no record of past stream flows is present. Using regionalization approaches, the proposed research will investigate estimating low stream flow statistics at such ungauged river sites by comparing four estimation methods: regional regression, base flow correlation, combined regional regression/base flow correlation, and an index drought procedure.

Methodology and Intended Results:

The thirteen states comprising the Northeastern United States will be divided into five geopolitical study sub-regions. In each of these sub-regions the four methods will be developed and compared using a rigorous statistical comparison via a delete-one jackknife re-sampling procedure. Stream flow records from over 300 gauged river sites throughout the Northeast will be used to perform this analysis. The outcome from this research will be a recommendation for each sub-region as to the best available methodology for estimating low stream flow statistics at ungauged river sites. This process will also involve evaluating low stream flow series for the possible impact of changing climate, an important issue that is of concern to many water managers.

Principal Findings and Significance

Progress report:
This work investigated the ability of various probability distributions to describe low streamflow series in various geographical regions, including the Northeastern United States. L-moment diagrams were used in this experiment, where the weighted distance between a LOWESS fit to the data and the L-moment relationship for a specific probability distribution was used as a performance measure. It was found that 2-parameter distributions do not provide an adequate fit, and of the 3-parameter distributions investigated, the 3-Parameter Log-Pearson (LP3) and the Generalized Extreme Value (GEV) provide the best fits.

Interestingly, at sites where some annual minimum low stream flows are reported as zero (i.e. intermittent river sites), a marked shift in the L-moment diagrams were observed. Such sites are said to contain "censored data", since all values below a measurement threshold (usually 0.01 cfs), are reported as zero. A Monte Carlo experiment was performed to investigate this phenomenon. The observed shift appeared more consistent with censoring of a real-spaced probability distribution, as opposed to censoring of log-spaced distribution. This finding may suggest that use of the GEV distribution may be better than using the LP3 distribution, which is the common probability distribution used to model low stream flow frequency in the United States.

A Masters student investigated various regionalization techniques for grouping river sites (Ko, 1999). The largest contribution of this work was how clearly it showed the importance of watershed hydrogeology in describing low streamflow frequency. Both the baseflow recession constant and the baseflow index were used to represent hydrogeology. An investigation of how best to estimate these quantities at ungauged river sites is presently being done.

Investigators associated with the project have developed a GIS approach to estimating various watershed characteristics. This methodology allows us to take advantage of new digital grids of climatic, topographic, and geologic parameters which impact watershed hydrology. A conference paper (forthcoming) analyzed scale issues by comparing output from both a 10 meter and 1 kilometer DEM, using various flow routing techniques. Output was used to model low streamflows in New York State. In this exploratory work, little improvement in these models was obtained when a finer scale grid or a more complex flow routing algorithm was employed.

This project investigated the use of various techniques for performing log-linear regression when the dependent variable is sometimes reported as zero (Kroll and Stedinger, 1999). Techniques included dropping these sites, adding a constant to all at-site quantiles, and the use of an ordinary and weighted Tobit models. A Tobit model was shown to be a much better technique than dropping sites or adding a constant. Use of a weighted Tobit model, which accounts for the heteroscedasticity of the regression model, did not produce much improvement over the use of an ordinary Tobit model.

The project has also completed the code to investigate the use of baseflow correlation techniques to estimate low streamflow statistics. Output from this code is presently being compiled. An experiment with Dr. Richard Vogel of Tufts University is examining trends in low streamflows over the last 50 years. This work is crucially important for the investigation of climate change on hydrologic processes.

Septic System Pollution Prevention BMPs: Development of Public Outreach Approaches, Assessment, and Decision-Making Tools for Local Government

Basic Information

Title:	Septic System Pollution Prevention BMPs: Development of Public Outreach Approaches, Assessment, and Decision-Making Tools for Local Government
Project Number:	2002NY3B
Start Date:	3/1/2002
End Date:	8/31/2003
Funding Source:	104B
Congressional District:	NY 29
Research Category:	Water Quality
Focus Category:	Waste Water, Treatment, Water Quality
Descriptors:	septic systems, water quality, pathogens
Principal Investigators:	Kim Irvine, Sherry Fontaine

Publication

1. Irvine, K.N., Brown, N., and Perrelli, M.F. 2003. Septic system pollution prevention BMPs: Development of public outreach approaches, assessment, and decision-making tools for local government. Great Lakes Pollution Prevention Roundtable, Summer Conference, Erie, PA.
2. Irvine, K.N., Perrelli, M.F., and Brown, N. 2003. Development of a GIS-based watershed modeling tool to assess septic system impacts on water quality. Middle States Division, Association of American Geographers Annual Meeting, Albany, NY.
3. Irvine, K.,Fontaine, S. Septic System Pollution Prevention. [on web, 2004]http://www.erie.gov/environment/compliance/pollution_prevention.asp#SepticSystem

Title: Septic system pollution prevention BMPs: development of public outreach approaches, assessment and decision-making tools for local government.

Problem & Research Objectives:
Irvine and Pettibone (1993) found that bacteria sources in the upper Buffalo River watershed (a mix of forest, agriculture, rural residential, and small town land uses) potentially had a greater impact on water quality in the lower Buffalo River than the CSOs that discharge to the lower river. Subsequent projects (Irvine and Pettibone, 1996; Wills and Irvine, 1996) confirmed that upper watershed sources, particularly in association with storm events, produced high levels of fecal coliforms in the three major tributaries to the Buffalo River (often in the range of 10,000-30,000 cfu/100 mL). One of the principal bacteria sources in the upper watershed appears to be failing septic systems.

Although septic systems appear to be an important bacteria source within the upper watershed, tools/approaches have not been developed to assess problems within specific reaches or the potential effects of improved septic practices on water quality. The objective of the research is to develop a program that optimizes public outreach and decision-making on a watershed basis and thereby maximizes water quality benefits from implementation of septic system BMPs. The research will focus on two areas, one being the delivery and assessment of a county level outreach program related to appropriate septic construction and maintenance; and the other being application of computer-oriented tools (GIS, remote sensing, water quality modeling) to help Erie County Department of Environment and Planning (DEP) personnel identify problem source-areas and evaluate the potential impact of septic remediation on receiving water quality.

Methodology:
Outreach. Two workshops on proper septic system construction and maintenance already were sponsored by the Erie County Water Quality Coordinating Committee and its member agencies. These workshops were delivered in the Towns of Grand Island and Clarence. Two additional workshops were offered, one in the Town of Sardinia and the other in the Town of Eden. A short video produced by Cornell University started the program and provided the participants with a basic understanding of their system. The information was augmented with three short presentations addressing soil considerations, septic system design and standards, health implications of failing systems, causes of septic failure and how to recognize problems, and the costs associated with installation, replacement and repair.

A survey instrument was developed to identify current community septic system characteristics and practices and to assess the effectiveness of the workshop approach in disseminating information on appropriate septic system practices. The survey was mailed to participants of the Grand Island and Clarence workshops, while participants of the Sardinia and Eden workshops completed the survey the evening of the workshop.

A web page was added to the Erie County DEP home site that provides general information about septic systems as well as the literature distributed at the workshops in an Adobe Acrobat readable format. The URL of the web page is:

http://www.erie.gov/environment/compliance/pollution_prevention.asp#SepticSystem

Bacteria Source Assessment Tools. As a first step in identifying potential source-areas of septic system discharge, ArcView GIS was used to identify areas within the Buffalo River watershed that are serviced by municipal/county treatment plants and those that are not. All homes, commercial, industrial, and institutional facilities that are outside of sewered areas and within 300 ft. of a waterway in the Buffalo River watershed were identified using available GIS layers and digital orthoquads. Bacteria loadings from these structures were estimated using typical septic system flow rates and bacteria levels determined from a literature review. The Buffalo River watershed was divided into 101 sub-basins and stream flow within each sub-basin was modeled using the U.S. EPA's BASINS (Better Assessment Science Integrating point and Non-point Sources, Release 3) version of HSP-F (Hydrologic Simulation Program-Fortran, also referred to as winHSP-F). Fecal coliform levels in the stream of each sub-basin were estimated using the total fecal coliform load divided by the modeled stream flow volume for the day.

Principal Findings & Significance:
The questionnaire revealed some positive aspects of public understanding, as well as some areas of concern regarding proper septic system practices. For example, while most people conducted or were aware of at least some of the BMPs, and the majority of respondents pumped their septic system every 3-5 years, approximately one-third of the homes had a septic system that was more than 30 years old. The average lifespan of a properly designed, installed, and maintained septic system is 20-30 years (Cornell Cooperative Extension, Fact Sheet SS-4), so the relatively large proportion of older systems in rural Erie County represents a higher risk for failure. There also was a relatively high percentage of septic systems in the 1-9 year age category, in part reflecting the current trend of out-migration from the city of Buffalo. Our questionnaire showed that the percentage of respondents pumping their septic system every 3-5 years ranged from 54-85% for the different workshop locations, with an average of 62%. By comparison, Schwartz et al. (1998) reported 35-73% (average of 53%) of respondents pumped their systems every 3-5 years in three upstate New York counties.

A great deal of discussion at each workshop focused on not using additives to accelerate settling or decomposition. Workshop attendees frequently asked about the use of additives, but such use was not recommended by the presenting team and this position also is supported in the literature (e.g. Cornell Cooperative Extension, Publication FS-1, *Your Septic System*). A good summary of this issue is provided at the website, www.inspect-ny.com/septic/septadds.htm. The North Carolina Cooperative Extension (Soil Facts publication AG-439-13) noted that additives can include biologically based material (bacteria, enzymes, and yeast), inorganic chemicals (acids and bases), or organic chemicals (including solvents), but there is no evidence that these products reduce the need for pumping and may even contain organic chemicals that can damage the drainfield or contaminate groundwater.

Workshop attendees were asked about their use of water softeners and several people had follow-up questions of their own. Sardinia had the largest proportion of respondents with water softeners, at about one-third, while the mailings and Eden respondents had around 10 per cent each. Based on these results, it appears that the practice of water softening is not particularly wide-spread. The website http://swopnet.com/geo_wastewater_2000/machmeier/Machmeier_Get_To_Know.html noted that water softeners often are blamed for the malfunction of a septic tank. The softener adds sodium chloride to the water. As the softener ages, and if the resin beads are not kept clean (particularly if they become fouled by iron), they cannot take on the same amount of salt and the unused salt goes into the waste water. If the salt dose becomes too high, it can inhibit the growth of the digestive bacteria in the septic system. Proper maintenance of the water softener should avoid this problem.

Based on the response to Question 15 of the questionnaire it can be concluded, with some caution, that the frequency of septic system failure ranged between 10 and 42%, with an average of 27%. The U.S. EPA (2002) found that comprehensive data to measure the true extent of septic system failure are not currently collected. Although failure rate estimates have been made for 28 different states, no state directly measured its own failure rate and the conditions used to define a failure varied from state to state. The failure rates, as reported by the U.S. EPA (2002), ranged from low values of 0.4-0.5% (Arizona, Utah, Wyoming) to high values of 50-75% (Louisiana, Minnesota, Missouri). The failure rate for New York was listed as 4%, which clearly is less than the rate calculated for this study. Part of the reason for the lower rate as reported by the U.S. EPA (2002) may be related to the fact that failure in New York is only reported when a home sale occurs, or when a local health department is called. The response pattern for Question 16 matched well with that of Question 15. The lowest rate of reported problems with system failure was recorded for the mailings (10%), which also had the highest percentage of people indicating that they did not have plans to replace their septic system (83%). The Eden survey had the highest rate of reported problems with system failure (42%) and the lowest percentage of people indicating that they did not have plans to replace their septic system (54%).

The cost of replacing a septic system clearly was an important consideration for workshop attendees, as 47-59% (average of 51%) indicated cost was at least in part a deciding factor in replacement. For those who responded to the question, it seems that a subsidy in the range of 75% of the cost, or $2,700, would be needed to encourage people to replace their system. The U.S. EPA (2002) provided some useful information on sources of subsidies and loans for septic system replacement, but unfortunately we did not have this information when the workshops were run. This information would be a useful addition to future workshops.

Unanimously, people found information on the operation and maintenance of a septic system as being most valuable, while the soils information was seen as least valuable, except to a couple of respondents who were looking to build a new home and septic system. This result suggests that we might reduce the length and detail included in the soils part of the workshop.

The visualization of potential fecal coliform loadings, on a sub-basin scale, provides a good outreach tool. Development of these loading estimates is not complicated and most county agencies would have personnel skilled enough in GIS and spreadsheet applications to conduct such analyses. However, time and funding considerations may be such that this type of evaluation would not be possible. The spatial pattern of loading estimates matched well with historical fecal coliform data for the watershed. Results of the BASINS winHSP-F modeling indicated that septic systems may be the source of 20-50% of the fecal coliform concentration in downstream sub-basins during dry weather. The BASINS winHSP-F model provides the capability of exploring "what if" scenarios to examine the impacts of different levels of septic system treatment efficiency and also can be used in TMDL development. Although BASINS version 3.0 is easier to work with than its predecessors, the model still requires considerable time and experience in both GIS and water quality modeling and a training session with Erie County DEP personnel indicated that it was unlikely that most county agencies would have the resources available to operate the model in-house.

Several specific questions arose in relation to the modeling effort, including the fact that fecal coliform may be preferentially attached to sediment, rather than present in free form (i.e. dissolved phase as assumed in the model) which can affect transport and fate estimates. The influence of storms on bacteria characteristics also needs to be clarified, for example in the areas of resuspension of inoculated sediment, possible dilution effects, and the relative importance of different source-inputs.

It would be useful to continue the septic system workshops in Erie County and the western New York region, as well as maintain the outreach page on the Erie County Department of Environment and Planning website. To further clarify the impact of septic systems on bacterial contamination, it would be useful to conduct an intensive sub-basin scale study in which contributions from different sources are identified through newer "fingerprinting" technologies such as ribotyping (e.g. Virginia Department of Environmental Quality 2002a, b). The effect of septic system remediation also should be demonstrated at the sub-basin scale through pre- and post-abatement monitoring. Under this scenario, a sub-basin with failing septic systems would be identified, homeowners would be provided a subsidy to improve their systems, and the impact would be monitored. This type of approach would be necessary on a sub-basin scale because often at a larger spatial scale the "intervention effect" of abatement can be masked (Wolf, 1995).

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Supporting Community Watershed Restoration Efforts in Catatonk Creek

Basic Information

Title:	Supporting Community Watershed Restoration Efforts in Catatonk Creek
Project Number:	2002NY4B
Start Date:	3/1/2002
End Date:	8/31/2003
Funding Source:	104B
Congressional District:	NY 26
Research Category:	Water Quality
Focus Category:	Hydrology, Water Quantity, Water Quality
Descriptors:	flooding, water quality, streambank erosion, hydrology, education
Principal Investigators:	Joseph Graney, James Curatolo, Karen Maria Salvage

Publication

1. Wood, E, 2004, A Comparison of Physical and Chemical Hydrogeology in Catatonk Creek Watersheds, Great Lakes Research Consortium Comference, March 2004, Syracuse NY.
2. Hubbard, K, 2004, Hydrologic Response of Miller Creek to Reservoir Releases, Great Lakes Research Consortium Conference, March 2004, Syracuse, NY.
3. Hunsinger, G, 2004, Hydrological and Numerical Assessment of Rainfall-Runoff Response for the Headwaters of Catatonk Creek, American Geophysical Union meting, May 2004, Washington, DC

Title: Supporting community watershed restoration efforts in Catatonk Creek.

Problem and Project Goals:
The headwaters of the Susquehanna River within New York State are characterized by excessive flooding during major storm events and spring snowmelt. The terrain within the Upper Susquehanna River sub-basins includes rolling hills with steep walled side valleys that focus runoff to feed the main river flows. Readily erodible glacial deposits are present along streambanks and blanket the shale bedrock in upland areas. Because of the steep gradients and glacial till deposits, the feeder streams can carry large sediment and gravel loads resulting in streambank erosion, gravel and sediment deposition, and flooding, all issues of concern for local stakeholders. The Upper Susquehanna Coalition is a grass roots based organization of county natural resource professionals that provide technical support to local stakeholders. The USC is constructing wetlands within Catatonk Creek watersheds in Tioga and Tompkins County, New York as a means to alleviate problems associated with storm runoff. This project was designed to collect baseline data prior to wetland construction, and to predict where wetland construction would be most beneficial. This project also provided a mechanism to educate local citizens about processes within watersheds and provided training to university students in watershed assessments.

Project Objectives:

- Continue assessments of the Catatonk Watershed to locate sites for wetlands construction
- Compare physical and chemical hydrology within two adjacent Catatonk watersheds (Miller Creek and Sulfur Springs) that experience differences in sediment loading and stream flow on a storm event and seasonal basis.
- Provide baseline data for a watershed hydrological model to aid in selecting effective implementation projects to determine how effectively they might modify flows associated with flooding
- Use the information gathered to develop future collaborative proposal submissions between USC and BU personnel

Methodology:
Comparative hydrology within the Miller Creek and Sulphur Springs sub-basins within the Catatonk Watershed was assessed using GIS based tools in conjunction with measurement of water quantity and quality parameters.

The USC and Penn State University have developed an ArcView GIS-based assessment tool for stream corridor problems and wetland development potential. The tool manages data, maps and photographs in an interactive format. The USC and Binghamton University students used this tool to continue assessments within the Catatonk Creek Watershed.

The USC and BU deployed a continuous rainfall gage and flow meter network (automated stream height gages) in high priority tributaries to collect pre-wetland construction flow information. The stream height and gages in conjunction with manual flow velocity and volume measurements were used to construct stream rating curves. Water and suspended sediment samples were collected on a "significant event basis" schedule using automated stormwater runoff samplers at two of the flow measurement sites near the mouth of the Miller Creek and Sulfur Springs sub-watersheds. Base flow sampling was also conducted in these watersheds on a once per week basis. Data collection for the project occurred over a one year period of time, from

June 2002 and through May 2003. Water chemistry parameters including temperature, pH, and conductivity were measured, and dissolved and particulate-bound metal concentrations were assessed through use of ICP-MS technology. All of this information on physical and chemical parameters is being used for input and calibration within hydrological models based on Watershed Modeling Systems (WMS) interfaces.

Principal Findings:
Several coupled processes result in the differences in physical and chemical hydrology in the two watersheds. Surface flow is ephemeral in Sulfur Springs but sustained year round in Miller Creek. Bedload transport is of much greater concern in Sulfur Springs than in Miller Creek. Water levels in Sulfur Springs after storm events respond more quickly and resulting hydrograph response is more flashy than in Miller Creek. The main controls for the hydrologic differences between the adjacent watersheds include differences in topographic gradients, and the presence or absence of wetlands and floodplains near the mouths of the watersheds. The topographic gradient in Sulfur Springs is steeper than in Miller Creek, which resulted in higher velocity, channelized flow. The natural wetlands in Miller Creek decrease peak runoff stage in comparison to Sulfur Springs, where natural wetlands are lacking. The floodplains near the mouth of Miller Creek provides a source of groundwater that sustains baseflow year round. Most of the sediment transport in the watersheds occurred during spring snowmelt, associated with streambank erosion. This natural process and source of material may be difficult to alleviate. However, significant amounts of sediment were also mobilized during summer thunderstorms due to road ditch cleanout activities. Through the education of local stakeholders within the watershed, this anthropogenic process that provides sediment to the streams is being modified.

Based on the results from this project, wetland construction is being planned within the Sulfur Springs sub-watershed. Construction of several types of wetlands has been proposed. Several will be sited to reduce peak flows to help alleviate bank erosion problems, while others will be used as a means to sustain base flow. Conditions within Miller Creek will continue to be monitored in order to provide an unperturbed watershed in order to document hydrologic effects from wetlands construction in the adjacent watershed.

Notable Achievements: Student Support and Follow-on Funding

Student Support:
This project provided training to university students in watershed assessments as well as research opportunities to study processes in watersheds. Portions of two Master's Thesis Projects and one Undergraduate Thesis were supported by this funding.

Student	Degree	Completion Date
Erin Wood	Masters	Spring 2004

Title: A Comparison of Physical and Chemical Hydrogeology in Catatonk Creek Watersheds

Glendon Hunsinger	Masters	Summer 2004

Title: Hydrological and Numerical Assessment of Rainfall-Runoff Response for the Headwaters of Catatonk Creek

Kenneth Hubbard	Bachelors	Fall 2003

Title: Hydrologic Response of Miller Creek to Reservoir Releases

Follow-on Funding:
Collaboration with the USC on this project evolved into several grant application submissions. Most noteworthy was selection of the Upper Susquehanna River Basin for project support through the EPA Watershed Initiative. This support will involve further collaboration of USC and BU personnel in the Catatonk and other watersheds. We will be using some of the funds from this award to continue hydrologic study before, during and after wetlands construction in Catatonk watersheds. We believe this is a notable achievement because we not only met the goal of proposal generation outlined within the project objectives, but used results from this project to obtain monies to continue to fund ongoing and future projects.

Conference Presentations:
Erin Wood and Kenneth Hubbard will present the results of their work at the Great Lakes Research Consortium Conference in March 2004 in Syracuse, NY. Glendon Hunsinger will present the results of his work at the spring 2004 meeting of the American Geophysical Union in May in Washington, DC.

Information Transfer Program

Director’s Office Information Transfer

Basic Information

Title:	Director’s Office Information Transfer
Project Number:	2003NY26B
Start Date:	3/1/2003
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	22
Research Category:	Not Applicable
Focus Category:	Management and Planning, Non Point Pollution, Water Quality
Descriptors:	education, water quality management, nonpoint pollution
Principal Investigators:	Keith S. Porter

Publication

1. Benaman, J.M., 2003, Uncertainty and sensitivity analyses for watershed models : hydrology and sediment transport modeling on the Cannonsville Reservoir system, PhD dissertation, Cornell University, Ithaca, NY.
2. Remnek, A.D., 2003, Modeling, automated parameter calibration and sensitivity analysis of a watershed model of the Shaw Road Basin, MS dissertation, Cornell University, Ithaca, NY
3. Yang, C.-P., 2003, The effects of precipitation measurement technology and distribution methods on runoff/sediment results for soil and water assessment tool (SWAT), MS dissertation, Cornell University, Ithaca, NY.
4. Hively, W.D., 2004, Phosphorus Loading from a Monitored Dairy Farm Landscape, PhD dissertation, Cornell University, Ithaca, NY.

Director's Office Information Transfer

Over the past several years WRI has continued to promote specifically the engagement of the wider academic community in water resource management issues in New York State. As in previous years, opportunities to pursue this aim were sought through the New York State Soil and Water Conservation Committee, the New York State Agricultural Environmental Management Committee, and the New York State Non Point Source Coordinating Committee (NPSCC). NYS WRI also participates in work groups of NPSCC, with an emphasis on stormwater (the highest priority for NPSCC leader NYS Department of Environmental Conservation), agriculture, and information and outreach. Most NYS WRI activity on these groups in FY2002 related to Delaware County phosphorus management projects, drawing in local government partners from that cluster. Principals of several 104(b) projects funded in FY2003 and earlier years participated in NPSCC work groups.

As part of the Delaware County project cluster, Masters of Landscape Architecture student Outi Salminen continued to work with the Village of Stamford and an engineering consultant to devise options for stormwater quality management, flood management, and recreation. The project revolves around a piped stream channel downstream of a wetland that formerly hosted a small impoundment. Restoration of the impoundment and opening up of much of the currently piped stream could improve wildlife habitat, eliminate local flooding, and possibly benefit water quality.

A new topical focus for NYS WRI's outreach work began to emerge in the second half of the FY2003 period. New York has entered into an interstate agreement with all other Chesapeake Bay watershed states to reduce nutrient and sediment loading to the bay. At the requests of New York State DEC and the upper Susquehanna Coalition (a network of county agencies), NYS WRI began to evaluate water quality monitoring and modeling activities by the Chesapeake Bay program and to consider how New York should marshal its own technical resources to evaluate its own options and progress toward the very ambitious nutrient reduction targets assigned to New York. This topic will continue into FY2004, and may result in a new NYS WRI Meta project like the one featuring Delaware County.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	9	0	0	0	9
Ph.D.	3	0	1	0	4
Post-Doc.	0	0	0	0	0
Total	16	0	1	0	17

Notable Awards and Achievements

Project Number 2002NY7B, Principal Investigator Ellen Braun-Howland received an Excellence in Research Award, from the University at Albany, School of Public Health, for a poster describing this research. Also, Jacqueline Lendrum received an Initiatives for Women Grant Award in recognition of academic merit and research and support for research on this project through the summer of 2003.

A specific goal and continuing achievement of the NYS Water Resources Institute (WRI) is the transfer of technical capacities to promote best watershed management at the local level. The twin basis of this transfer is the acquisition of sound data and information and the use and analysis of that data through simple technical methods such as mathematical models. There is a dual aspect of WRI's efforts. First, WRI is facilitating sound scientific research and transfer of knowledge in watershed practice. Second, WRI is fostering a dialog about satisfying elements of the Continuous Planning Process (CPP) as required under the US Clean Water Act - Sect 303.

Two elements of the CPP in particular, Water Quality Planning and Inter-governmental Cooperation, depend upon local responsibilities and actions. WRI has based this dialog in the New York City watershed where the Delaware County Action Plan (DCAP), in which WRI has played a leading role, serves as a highly successful example of what can be achieved a the local level. DCAP is regarded by New York State as an outstanding demonstration for watershed planning and management with potential applicability throughout the State. With extension of DCAP methods in mind, WRI is currently promoting the understanding and application of DCAP methods, including watershed monitoring and modeling, specifically in the Susquehanna River Basin and in the Hudson River Watershed. There is particularly interest in the development of local technical capacities in the former. The Susquehanna River Basin, as part of the Chesapeake Bay Watershed, is challenged to meet very substantial reductions (more than 40%) in loadings of nutrients and sediment to meet water quality objectives in the Chesapeake Bay. These load reductions crucially will depend upon voluntary planning and management by local governments, farmers, businesses, and landowners. Hence local capacity building in the Susquehanna River Basin has become a priority for New York State. WRI is assisting in meeting this critical priority.

Publications from Prior Projects

1. 2000NY8B ("Preferential flow and organic enhancement of metals transport to groundwater from land-applied biosolids in the northeastern U. S.") - Conference Proceedings - Qureshi, S., B.K. Richards, T.S. Steenhuis, M.B. McBride, P. Baveye, and M.S. Aktar, 2001, Biological Release and Leaching of Heavy Metals from Metalliferous Peat Affected by Temperature, ASA-CSSA-SSSA Annual Meetings, Charlote, NC, October 21-25, 2001.
2. 2000NY8B ("Preferential flow and organic enhancement of metals transport to groundwater from land-applied biosolids in the northeastern U. S.") - Articles in Refereed Scientific Journals - Qureshi, S., B.K. Richards, A.G. Hay, C.C. Tsai, M.B. McBride, P. Baveye, and T.S. Steenhuis, 2003, Effect of Microbial Activity on Trace Element Release from Sewage Sludge, Environmental Science and Technology, 37:3361-3366.
3. 2000NY8B ("Preferential flow and organic enhancement of metals transport to groundwater from land-applied biosolids in the northeastern U. S.") - Articles in Refereed Scientific Journals - Qureshi, S., B.K. Richards, M.B. McBride, P. Baveye, and T.S. Steenhuis, 2003, Temperature and Microbial Activity Effects on Trace Element Leaching from Metalliferous Peats, Journal of Environmental Quality, 32:2067-2075.
4. 2000NY8B ("Preferential flow and organic enhancement of metals transport to groundwater from land-applied biosolids in the northeastern U. S.") - Dissertations - Qureshi, S., 2002, Effect of Microbial Activity on Trace Element Release from Digested/Dewatered Sewage Sludge and Metalliferous Peat, Ph.D. Dissertation, Department of Agricultural and Biological Engineering, Cornell University, Ithaca, NY.
5. 2001NY1141B ("Nitrogen, Phosphorus, and Sediment Attenuation Capacities of Wetland Plants within the Nanticoke Creek Corridor") - Dissertations - Kao, J.T., 2002, Differential Nitrogen and Phosphorus Retention by Wetland Plants, MS Thesis, Department of Biological Sciences, SUNY Binghamton, Binghamton, NY.
6. 2001NY1141B ("Nitrogen, Phosphorus, and Sediment Attenuation Capacities of Wetland Plants within the Nanticoke Creek Corridor") - Conference Proceedings - Kao, J,T., J.E. Titus, and C. Graham, 2002,Differential Nitrogen and Phosphorus Accumulation by Five Wetland Plant Species, Annual National Meeting of the Ecological Society of America, Tucson, AZ, August 2002.
7. 2002NY1B ("Evaluation of Vegetated Filter Areas for Phosphorus Removal") - Conference Proceedings - Dittrich, T.M., L.D. Geohring, M.T. Walter, and T.S. Steenhuis, 2003, Revisiting Buffer Strip Design Standards for Removing Dissolved and Particulate Phosphorus, IN: Total Maximum Daily Load Environmental Regulations II Conference Proceedings, November 8-12, 2003, Albuquerque, NM, ASAE Publication 701P1503, ASAE, St. Joseph, MI pp 527-534.
8. 2002NY1B ("Evaluation of Vegetated Filter Areas for Phosphorus Removal") - Dissertations - Dittrich, T.M., 2004, Buffer Zone Form, Function and Design: A Review, MS Thesis, Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY.
9. 2002NY2B ("Predicting Dissolved Phosphorus Losses in Overland Flow in Northeastern U.S.") - Dissertations - Gao, B., 2003, Raindrop Induced Sediment and Solute Transport from Soil to Surface Runoff, Ph.D. Thesis, Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY.
10. 2002NY2B ("Predicting Dissolved Phosphorus Losses in Overland Flow in Northeastern U.S.") - Articles in Refereed Scientific Journals - Aktar, M.S., T.S. Steenhuis, P.A. Medrano, M.deGroot, and B.K. Richards, 2003, Dissolved Phosphorus Losses from Undisturbed Soil Cores: Related to

Adsorption Strength, Flow Rate, or Soil Structure? Soil Science Society of America Journal, 67:458-470.

11. 2002NY8B ("Greenhouse BMPs: Transforming Principles into Practice Year Two ") - Other Publications - CALS Administration, April 2002: Protecting the Environment with Best Management Practices, Poster, NYS IPM Program, Cornell University, Ithaca, NY.
12. 2002NY8B ("Greenhouse BMPs: Transforming Principles into Practice Year Two ") - Other Publications - Weiler, T., 2002, Greenhouse Fertilizers: Best Management Practices for Watershed Protection, Fact Sheet, Department of Horticulture, Cornell University, Ithaca, NY.
13. 2002NY8B ("Greenhouse BMPs: Transforming Principles into Practice Year Two ") - Other Publications - Hall, K, 2002, Improving Pesticide Storage Facilities, Erie County Cooperative Extension, East Aurora, NY.
14. 2002NY8B ("Greenhouse BMPs: Transforming Principles into Practice Year Two ") - Other Publications - Best Management Practices in Greenhouses, 2003, Agricultural Environmental Management Tier II Worksheets Including Glossary and Agricultural Water Quality Principles on: Fertilizer Storage & Handling in the Greenhouse; Pest Management for the Greenhouse; Pesticide Storage in the Greenhouse; Weed Management for the Greenhouse Environment; Greenhouse Maintenance; and Greenhouse Renovation and Construction, NYS IPM Program, Cornell University, Ithaca, NY.
15. 2002NY8B ("Greenhouse BMPs: Transforming Principles into Practice Year Two ") - Other Publications - 2003 New York State Ornamentals Project Reports Relating to IPM, December 2003, Monitoring Nutrient Solutions: Hands-on Training in BMPs for Greenhouse Growers, Cornell University Cooperative Extension, Ithaca, NY.
16. 2002NY8B ("Greenhouse BMPs: Transforming Principles into Practice Year Two ") - Other Publications - 2003 New York State Ornamentals Project Reports Relating to IPM, December 2003, Greenhouse BMPs: Transforming Principles Into Practice Years One and Two, Cornell University Cooperative Extension, Ithaca, NY.
17. 2001NY1081B ("Microbial indicators: new tools for assessing phosphorus eutrophication") - Articles in Refereed Scientific Journals - Chapin C.T. and B.L. Bedford, Heterogeneity in Soil Phosphorus Pools and Plant Species Richness in Calcareous Fens, Submitted to American Midland Naturalist, August 8, 2003.
18. 2001NY1081B ("Microbial indicators: new tools for assessing phosphorus eutrophication") - Articles in Refereed Scientific Journals - Chapin, C.T., B.E. Wolfe, and B.L. Bedford, Responses of Soil Alkaline Phosphatase Activity to Phosphorus Addition in Two Calcareous Fens, Submitted to Biology and Fertility of Soils, August 15, 2003.
19. 2001NY1081B ("Microbial indicators: new tools for assessing phosphorus eutrophication") - Articles in Refereed Scientific Journals - Chapin, C.T. and B.L. Bedford, Short-Term Responses of Soils and Plant Species in Calcareous Fens to Addition of Nitrogen and Different Forms of Phosphorus, Submitted to American Journal of Botany, December 17, 2003.
20. 2001NY1841B ("Epidemiologic Risk Analysis of Cryptosporidium parvum in Watershed: the Role of Genetic Variation Among Isolates") - Articles in Refereed Scientific Journals - Mohammed, H.O., D.V. Nydam, S.E. Water, 2003, The Risk of Contamination of Water Supply Reservoirs From Dairy Farms, Proceedings IIX International Symposium of Veterinary Epidemology Economics, Sant Diego, Chile, November 12-21, 2003.
21. 2000NY1B ("Watershed Management: Optimizing the Location of Riparian Buffers") - Articles in Refereed Scientific Journals - Azzaino, Z, J.M. Conrad and P.J. Ferraro, 2002, Optimizing the Riparian Buffer: Harold Brook in the Skaneatles Lake Watershed, New York, Land Economics 78(4):501-415.
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