New York State Water Resources Institute
Annual Technical Report
FY 2004

Introduction

NYS WRI devotes most of its resources to research and outreach to assist in state and local government problem solving and demonstration projects. Staff and many cooperating Cornell faculty have been enmeshed in New York States (and more recently New York City) water resources management processes, focusing on the most scientifically demanding water problems.

NYS WRIs FY2004 competitive grants program was operated jointly with the New York State Department of Environmental Conservations (NYS DEC) Division of Water, with the assistance of other NY State Departments. NYS DEC contributed $50,000 of Clean Water Act section 319 funds to support additional projects by higher education. Projects were solicited competitively from about 50 academic entities in NY. Projects were evaluated and selected for funding by a panel consisting of representatives of agencies on the New York State Nonpoint Source steering committee, and a SUNY academic representative.

Project oversight is primarily through project principals submission of annual synoptic and statistical information for including in NYS WRIs reports to USGS and NIWR. Feedback from project clintele to NYS WRI is an additional factor in evaluating project principals requests for later funding.

Research Program

The New York State Water Resources Institutes (NYS WRI) FY2004 activity under the Federal Water Resources Research Act consisted largely of research and information transfer projects funded during FY2000 through FY2004. Three national 104G projects, eight state 104B projects, and the NYS WRI Directors Office information and transfer projects are included in this report.

National Projects: The FY2000 104G project, covering large watershed nutrient modeling, began in late 2000 and was largely 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 did not begin until May 2005, examines statistical patterns in low streamflows

State Projects: Four FY2004 104B projects resulted from NY competitions whose topic focus reflected NYS WRIs long-term priority on nonpoint source pollutant management. Urban stormwater management, development of water quality tools to identify high runoff risk areas, assessing nitrate-nitrogen in surface and groundwater, and measuring the effects of wetland and riparian zones on water quality, were the focus of the four projects.

Four FY2003 projects continued to FY2004. The FY2000 104G project has received a no-cost extension for administrative reasons into the FY2004 period and has now completed its work. The new FY2003 104G project extends until FY2006.

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
Principal Investigators:	Chuck Kroll

Publication

1. Zhang, Z, and C N Kroll, 2005, Estimation of low streamflow statistics at ungauged sites using baseflow correlation, American Geophysical Union conference, New Orleans, LA; Spring 2005.
2. Hirabayashi, S, C N Kroll, 2005, Developing a geospatial data model to derive watershed characteristics for low streamflow prediction, American Geophysical Union conference, New Orleans, LA, Spring 2005.

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

Principal findings or significant results:
Research on this project began in May 2005. During the last year we have been working primarily on three issues:

- validity of the assumptions of the baseflow correlation technique (bfc),
- experimental design of a jackknife simulation used to assess the bfc, and
- development of GIS tools to automate the generation of regional watershed characteristics from digital information.

The bfc is an information transfer technique, where a nominal number of baseflow measurements are obtained at an ungauged river site, and then correlated with flows from a nearby gauged site. Using this information, low streamflow statistics can be estimated. We have develop new results which allow the user to understand the impact of gathering more streamflow measurements as well as the strength of the correlation between the flows. This information is crucial to users, as it provides a set of guidelines to understand how to employ the bfc in practice. We have also developed a better understanding of the impact of performance metrics on the assessment of the bfc.

Notable Achievements:
A extremely notable achievement is the development of a GIS tool to automate the regional development of watershed characteristics. Currently there is an abundance of meteorologic, geologic, topographic, and land use information available in digital formats. When one has only a small number of grids, calculating characteristics at numerous watershed in a region is a time consuming but obtainable task. When the number of grids is in the thousands, the time and effort required to process this information on a regional level is tremendous. Within an ArcGIS environment, we have develop new GIS tools to completely automate this procedure. Not only does this reduce the time to process this information, but it also helps avoid human error that can occur from manually processing this information. The information derived will be employed in regional regression models of low streamflow statistics within our study regions. As many researchers throughout the world require the development of databases of environmental information on a watershed scale, we envision a wide audience that will benefit from the availability of this new GIS tool.

Students supported:
During the last year, 1 PhD student has been supported full-time on this project. In addition, 1 PhD student and 1 MS student have received summer support from this project.

Innovative management of stormwater on under-utilized urban surfaces

Basic Information

Title:	Innovative management of stormwater on under-utilized urban surfaces
Project Number:	2004NY47B
Start Date:	3/1/2004
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	26
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Treatment, None
Descriptors:	Urban stormwater, Combined sewer systems, Impermeable surfaces, Storage
Principal Investigators:	Tammo Steenhuis, Jackie Brookner, Franco Montalo, Eric Rothstein, Michael Todd Walter

Publication

1. Jawlik, P, 2004, Suspended solid removal from urban stormwater runoff, NSF-REU project report, Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY.

TITLE: Innovative Management of Stormwater on Underutilized Urban Surfaces

Problem and Research Objectives

The 1972 amendments to the Federal Water Pollution Control Act (also known as the Clean Water Act) prohibit the discharge of any pollutant to waters of the United States from a point source unless the discharge is authorized by a National Pollutant Discharge Elimination System (NPDES) permit. Despite the progress made by these amendments, degraded water bodies still exist. According to the 1996 National Water Quality Inventory, a biennial summary of state surveys of water quality, approximately 40 percent of surveyed U.S. water bodies are still impaired by pollution and do not meet water quality standards. A leading source of this impairment is polluted nonpoint source pollution. In fact, according to the Inventory, 13 percent of impaired rivers, 21 percent of impaired lake acres, and 45 percent of impaired estuaries are affected by nonpoint source urban/suburban stormwater. In New York City wastewater, stormwater, and combined sewer overflows (CSO's) are considered the largest single source of pathogens in the New York Harbor region

The management of stormwater runoff in densely urbanized areas with substantial impermeable surfaces presents a major design challenge. Large volumes of runoff are generated from extensive impermeable surfaces, yet few locations exist within the urban watershed for its storage and treatment using conventional stormwater best management practices (BMP's). The large land areas typically required to construct detention basins, and wet and dry ponds prohibit their use in most urban areas. A further limitation of these conventional BMP approaches is their mixed track record in treating the suite of contaminants (i.e., pathogens, metals, nutrients, DOC, etc.) found in urban stormwater. End of pipe solutions, on the other hand, are costly.

A more viable option for urban stormwater management may be a pollution prevention approach whereby runoff is intercepted high in the urban watershed in or on small, underutilized areas and surfaces before it reaches catchbasins and sewers. These urban stormwater "resisters" can then be used to facilitate evapotranspiration and infiltration vis-à-vis vegetation. Our goal is to design these systems to aesthetically improve the urban experience. This is the biosculpture™ concept developed by the designer, Jackie Brookner. The challenge of using such systems in temperate urban climates is to develop a substrate that is both porous, yet has enough structural integrity to withstand disintegration from freeze/thaw cycles, corrosion, sunlight, pH and other chemical interactions. In addition, the substrate would preferably be made from abundant, locally available materials, and must be economical and sustainable in terms of total life cycle analysis from origin to future uses.

The overall goal of the project is to create prototype structures that function ecologically and hydrologically in a stormwater treatment context, but that also aesthetically enhance urban environments.

Methodology:

Due to a delay in funding arrangements the project started late and is continuing with a no-cost extension. One study that was carried out by Paul Jawlik with the objective to test numerous materials for suspended solid removal ability. The materials were tested for clogging, particulate removal capacity, and hydraulic conductivity with 20 μm particles and where applicable 200 μm particles.

Hydraulic Conductivity Measurement: The materials in Table 1, excluding the volcanic rock, were placed in the base of separate 2.5 inch diameter, open-ended columns. For the rockwool and plastics, silicon glue was applied to the material-column interface to

Table 1: Materials and Properties

Material	Relevant Information
Sand	800-1000 μm Grains
Porex Porous Plastic (Fine)	10-20 μm Pores
Porex Porous Plastic (Medium)	20-30 μm Pores
Porex Porous Plastic (Coarse)	90-130 μm Pores
Grodan Rockwool	Water Flow – Along Grain
Grodan Rockwool	Water Flow – Against Grain
Mirafi Geotextile	1120S
Volcanic Rock	Whole
Volcanic Rock	1000-1500 μm Grains

ensure stability and create a watertight seal. For the sand, a mesh of slightly finer size than the sand was placed on the bottom of the column. The Mirafi Geotextile was simply strapped around the bottom of the column. In the case of the whole volcanic rock, expandable foam was applied to the edges so as to make the irregular shape fit snuggly into a 6-inch diameter column. The particulate volcanic rock was placed in a 0.75-inch diameter column with wire mesh attached to the bottom. Water was pumped into the column at a given rate until ponding started. The hydraulic conductivity was then calculated with Darcy's Law.

Clogging: Each material was fitted into a column in the same manner as the samples in the hydraulic test. Approximately 1 gram of 20 μm (mean diameter) Agsco glass microspheres were added to one liter of water. The solution was thoroughly stirred and poured into the test column with the outflow collected. The time for the solution to pass through the material was noted. The concentration of the initial solution and the outflow solution was determined using a Spectronic 501 spectrophotometer. This process was repeated once a day, with the exception of several gaps, for each material until a trend became discernable. For rockwool, an additional test was conducted. One liter of microsphere solution was applied consecutively to the rockwool in one day. A thinner slice of rockwool was also used. Excluding these changes, the same procedures outlined previously were applied.

Larger Particle Filtration: The sand and crushed volcanic rock had void spaces much larger in magnitude than the 20 μm microspheres. These two materials were therefore tested with 200 μm spheres in addition to 20 μm spheres.

Principal Findings and Significance:

Hydraulic Conductivity Phase: Results of the conductivity test are displayed in Table 2. The rockwool had the highest conductivity; water flowed through it quickest. Hydraulic conductivity was dependant on material orientations, with the perpendicular sample having a noticeably higher conductivity. This may be due to non-homogenous qualities of the rockwool. There is going to be a difference in conductivities because the water is not seeing the same both for both orientations. The sand had a slightly lower conductivity than the rockwool and the crushed volcanic rock lower than the sand. The solid volcanic rock was completely impermeable at the time scale considered. The coarse porous plastic, with an average pore size of 90-130 μm, had a hydraulic conductivity five times higher than the medium plastic (20-30 μm) and more than ten times higher than the fine plastic (10-20 μm). .

Table 2: Hydraulic Conductivity Values

Material	Conductivity (m/day)
Mirafi Film	~141
Rock Wool:	
Cut Perpendicular to Grain	596
Cut Parallel to Grain	363
Volcanic Rock - whole	0
Volcanic Rock - crushed	262
Porous Plastic:	
Fine	10.9
Medium	22.6
Coarse	115
Sand:	333

Clogging: The fine and medium plastics removed on the average 10-25% of the 20 μm microspheres while rockwools were able to remove 20-50% on the average depending on the material orientation . The sand, volcanic rock, geotextile, and coarse plastic, however, were poor at removal. The medium and fine plastics displayed very similar behavior. They had high initial removal percentages (up to 90%) followed by steep drop-offs. Also, as their conductivity decreased, they became worse at removing suspended solids. The existence of these similarities is indicative of the plastics' similar pore size relative to each other and to the microspheres. Removing less pollutant as the conductivity decreases is counter-intuitive. The longer water takes to pass through each plastic, the more pollutant the plastic should remove. The plastic having a range of pore sizes, however, creates a range of paths that water can flow through. As solution is added, the smallest paths become clogged while the largest ones do not. Eventually, the solution travels preferentially by wide paths. This not only increases the time for a given amount of solution to pass through the plastic as there is less cross sectional area the water flows through, but it also reduces the solute that can be trapped inside the plastic. The result is a longer passing time with poor removal percentages.

Material orientation was important, especially for the rockwool. The parallel orientation's removal percentage decreased linearly before flattening out with minor oscillations around 10%. The perpendicular orientation on the other hand, displayed different behavior. For the first four days it removed over 50% of the particulates. After its fourth day of being treated, however, the removal percentage changed significantly; large fluctuations in the removal occurred, sometimes with negative removal. This possibly is due to the rockwool having reached a threshold and upon reaching this load, the solids become more susceptible to washing out. This is what appears to be happening from Days 7-11..

The results for the sand, volcanic rock, geotextile, and coarse plastic were all sporadic. Data fluctuated above and below zero removal for all materials except for the sand, which stayed consistently below zero. The materials all have void spaces larger than the microspheres. As a result, they materials do not function well as filters. The coarse plastic, even though it was a poor filtering media, over time restricted water flow.

Larger Particle Filtration: The volcanic rock and sand where efficient at removing the 200 μm microspheres; displaying consistent removal percentages in excess of 80%. There was minor clogging in the sand and major clogging in the volcanic rock. Although the volcanic rock consistently removed around 98% of the micropheres, it also clogged at an exponential rate. The sand was also an excellent filter, removing in excess of 80% in all samples with minor reductions one liter to the next. Although its removal was less than the volcanic rock, it showed no clogging. The high removal percentages and resistance to clogging make the sand a better choice of filtering media for this particle size.

Achievements

The building block for the bio sculptures have been constructed and will be tested starting in July.

Regional water quality tools for identifying high runoff risk areas in watersheds.

Basic Information

Title:	Regional water quality tools for identifying high runoff risk areas in watersheds.
Project Number:	2004NY48B
Start Date:	3/1/2004
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	22
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Agriculture, Nutrients
Descriptors:	Nonpoint pollution; Agriculture; Nutrients; Transport processes; GIS
Principal Investigators:	Todd Walter, Michael Todd Walter

Publication

1. Agnew, L.J., A. Lembo, V. Collins, P. Gerard-Marchant, T.S. Steenhuis, M.T. Walter, 2005, Identifying hydrologically sensitive areas: Bridging science and application, Journal of Environmental Management, In press. Lyon, S.W., A.J. Lembo, M.T. Walter, T.S. Steenhuis, 2005, Defining probability of saturation with indicator kriging on hard and soft data, Advances in Water Resources, In press.
2. Agnew, Laura J., 2004, Identifying hydrologically sensitive areas: Bridging science and application, MS Dissertation, Department of Biological and Environmental Engineering, CALS, Cornell University, Ithaca, NY. Collins, Virginia, 2004, A regional tool for hydrologically sensitive area identification in the northeastern United States, Masters of Engineering, Department of Biological and Environmental Engineering, CALS, Cornell University, Ithaca, NY.
3. Agnew, L., M.T. Walter, P. Gerard-Marchant, A. Lembo, Jr., S. Lyon, L.D. Goehring, T.S. Steenhuis, 2004,Variable source area hydrology applications to water quality rrotection and risk assessment: Bridging science and practice (04-00XX), NABEC 2004, Northeast Agricultural and Biological Engineering Conference, University Park, PA, June 27-30, 2004.
4. Collins, Virginia, 2004, A regional tool for hydrologically sensitive area identification in the northeastern United States, Masters of Engineering, Department of Biological and Environmental Engineering, CALS, Cornell University, Ithaca, NY.
5. Lyon, S.W., A.J. Lembo, M.T. Walter, T.S. Steenhuis, 2005, Defining probability of saturation with

indicator kriging on hard and soft data, Advances in Water Resources, In press.

Title: **Regional Water Quality Tools for Identifying High Runoff Risk Areas in Watersheds**

Introduction

Despite several decades of attention to the problem, nonpoint source (NPS) pollution from agricultural land continues to be an acute regional problem. The pollutant transport components of most water quality management strategies continue to lag several decades behind current scientific understanding of the relevant hydrological and transport processes. Runoff is perhaps the most substantial NPS pollutant transport mechanism. Recently the research group in Cornell University's Soil and Water Lab (SWL) has proposed water quality protection strategies based on saturation excess and variable source area (VSA) hydrology, hydrological concepts that have been well established since the in the 1960's but not been incorporated into the water quality dogma. SWL, a national leader in developing new NPS pollution control strategies based on the most current hydrological science, has developed the concept of hydrologically sensitive areas (HSAs), which are those areas in a watershed most prone to saturate and generate runoff (overland flow). The focus of this project is to develop user-friendly ways to identify where and when HSAs will occur in landscapes of the Northeastern U.S.

Project Description

The ultimate goal of this project was to develop tools to "increase the capability of … county or municpal governments to… protect their water resources, especially… methods which provide quantified bases for decision-making (FY2004 RFP)." The primary specific goal of this project is to develop and evaluate new GIS-based, computational tools for identifying HSAs in Northeastern US landscapes, i.e., areas that are especially prone to generating runoff. This project has four distinct tasks: 1) determine monthly probabilities of generating runoff using a physically-based, fully distributed hydrological model applied to 6 to 12 twelve watersheds; 2) Overlay "proxy parameters" (based on topography or stream proximity) on maps of runoff probability developed task (1) and evaluate the statistical agreement between the runoff probability and the "proxy parameters;" 3) Evaluate the degree of similarity in the relationships among different watersheds to determine how regionally consistent proposed tools are 4) Determine which months are statistically different from each other in order to ascertain whether monthly, seasonal, or some other distribution of hydrological sensitivity is warranted. As part of this project we would also like to launch a usable Internet-based tool.

Principal findings and Notable achievements

The primary accomplishment of this project is the establishment of a simple relationship between landscape topography and risk of runoff generation. The relationships change throughout the year, but in a consistent and predictable way. As part of task (2) we also investigated relationship between runoff risk and proximity to stream and found that the relationships were substantially more inconsistent, although the relationships we found could be used if no reliable topographic data were available or if one needs a quick field-tool.

We determined runoff risks for eight basins from Connecticut, Pennsylvania, and New York (Task 1). In accordance with task (3), we found that the topography-runoff risk relationships are relatively similar among different watersheds and agreed well with our small duration (~ 8 months) of field measurements.

We are currently developing a point-and-click, interactive Internet-mapping tool for identifying HSAs in upstate New York. This activity has been unexpectedly difficult because Internet-mapping software is still rapidly developing and we have had to try several different platforms. We have decided on Manifold (GIS) and we will be launching tools for Delaware and Tompkins County this summer. Although we initiated this project on schedule, funding was substantially delayed and we anticipate using the remaining funds to complete this final phase, i.e., launching prototype Internet tools.

New External Proposal (these build substantially on this project)

Title: Integrating data and models from the Cannonsville, NY watershed to assess short- and long-term effects of phosphorus BMPs in the Northeast
Agency: USDA – CEAP
Request: $659,995 (in review)
Duration: 2005 to 2008 (3 yrs)
Cooperators/Affiliations: Steenhuis*, Shoemaker*, Walter*, Stedinger*, Richards, Geohring, (Cornell Univ.), Qui* (NJIT), Gburek, (USDA-ARS, Penn State University), Schneiderman, Thongs, Zion (NYC-DEP), McHale (USGS).

Other related proposals are currently in development with primary cooperators from Cornell Univ. (M.T. Walter, Art Lembo, the Biological and Environmental Engineering Soil and Water Lab and other faculty), Pennsylvania State University (Dr. Gburek), the NYC-DEP (Drs. Schneiderman, Zion, Thongs), Walton NRCS office (Gary Lemon), and environmental planners in Tompkins County (Kate Hacket and Deborah Gross). We anticipate that continued enthusiastic working relationships with the primary investigators noted above will continue for many years.

Assessing nitrate-nitrogen in surface and groundwater in eastern Wyoming County, NY

Basic Information

Title:	Assessing nitrate-nitrogen in surface and groundwater in eastern Wyoming County, NY
Project Number:	2004NY51B
Start Date:	3/1/2004
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	26
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Groundwater, Nitrate Contamination
Descriptors:	Nonpoint pollution; Groundwater; Drinking water; Nitrate-nitrogen;
Principal Investigators:	Larry D Geohring, Karl J. Czymmek

Publication

Title: Assessing Nitrate-Nitrogen in Surface and Groundwater in Eastern Wyoming County New York

Problem & Research Objectives:

High nitrate-nitrogen (NO_3-N) concentrations in groundwater supplying private drinking water supplies are a concern to Wyoming County residents. A county-wide sampling of private drinking water supplies carried out in 1988-1989 found NO_3-N concentrations ranging from <0.1 to 40 mg L^{-1}, with 23 of 206 samples exceeding the 10 mg L^{-1} maximum contaminant level (MCL) established by the Safe Drinking Water Act (Hurd, 1989). The majority of samples exceeding the MCL occurred at or near farm sites in Eastern Wyoming County where intensive agriculture (dairy farming) is the major land use. Farmers and other rural residents in the area remain concerned about nitrates, and are interested in determining whether the implementation of nutrient management plans (NMP) is having an effect on reducing or curtailing nitrate levels. This information will also help in the development of a revised Nitrogen Leaching Index (NLI) for New York state. A recently formed state-wide groundwater working group is also interested in this study to address groundwater contamination concerns from agriculture.

The goal of this case study project is to determine the trend in NO_3-N concentrations in groundwater and to utilize the information in state/regional nutrient management/water quality educational programs. Approximately fifteen groundwater sites are being monitored in Eastern Wyoming County, near locations where a significant number of sites exceeded the MCL for NO_3-N during previous testing. A similar number of surface water sites are also being monitored. Specific project objectives are: 1) To monitor surface and groundwater supplies for NO_3-N concentrations, 2) To collate and compare new sample data with previous sampling results, 3) To conduct detailed site evaluations and well pump tests, and 4) To develop and carry out educational sessions to disseminate the information.

Methodology and Progress:

Project Objective 1: In cooperation with Wyoming County collaborators, surface and groundwater supplies have been identified for further testing. Approximately fifteen sites have been selected for routine surface water sampling (small streams and drain tile outlets). Also, about fifteen groundwater supplies used for drinking water (wells and springs) were selected for follow-up sampling, based on the previous 1988-1989 study. The surface water is being grab sampled at about four week intervals. Some of the groundwater supplies are also being sampled at four week intervals, and others are being sampled at times coinciding with the time of the year the previous groundwater sampling had been done. Water samples are transported in coolers to the Cornell Nutrient Analysis Laboratory for analysis. The water samples are routinely analyzed for NO_3+NO_2–N, NH_4-N and PO_4-P. Some of the surface and groundwater samples are also being analyzed for other major cations and anions (Al, C, Ca, Cl, Fe, K, Mg, Mn, Na, and SO_4-S). Any other information which can be obtained, such as previous sampling data, well and water-level depths, surface flows and pumping rates, well driller logs, adjacent land use, and near-by on-site waste management systems, is also being documented.

Project Objective 2: Water sampling data from previous studies and other monitoring is being identified and collected for review. This has included any other private sampling results made available, other Wyoming County DOH test results, and the Letchworth State Park Water Quality Monitoring Program (Rabideau, 2003). These data are being used along with the sampling data being collected under Objective 1 for comparative and trend analysis purposes.

Project Objective 3: Ground elevations and equilibrium water levels for many of the wells have been determined to establish the potentiometric surface and direction of groundwater flow. Elevations and distances along the watercourses being surface sampled have also been obtained. There has been difficulty obtaining landowner cooperation to conduct well pumping tests and obtain more intensive data. Many of the wells are in constant use and have chlorine injected directly into the well, so physical and temporal access to wells is extremely limited

Project Objective 4: Several meetings have been held with Wyoming County collaborators and with a local group of producers and their certified crop advisors. Two educational meetings were specifically targeted to farmers in the sampling study area. Due to the locally complicated and contentious nature of producer/community relations in terms of groundwater in the past, producers participation has not been uniform and it is difficult to obtain wide-spread cooperation and consensus from the case study participants if and how to share project results. Some educational resource materials were prepared for the meetings and shared with project participants to illustrate the nature of the groundwater problem, how dairy activities could potentially be contributing and to discuss some potential courses of action for addressing the problem of nitrate contamination of groundwater.

Principal Findings & Significance: The groundwater pattern(s) in the area appear to be complex and follow a more regional influence, rather than being associated with the more identifiable boundaries of the surface watersheds. Sampling of tile drained fields and many of the surface watercourses have found nitrate-N concentrations which exceed the drinking water standard of 10 mg L^{-1} though such discharges do not directly violate any laws. The predominant discharge in several of these small surface watersheds appears to be tile drain discharges. A few of the groundwater wells that are being sampled have consistently high nitrate-N values, but other nearby wells have very low nitrate levels.

References:

Hurd, T.M., 1989. Nitrate levels in private drinking water supplies of Wyoming County, unpublished report of Wyoming County Department of Environmental Health, August, 23, 1989, 12 pp.

Rabideau, A.J., 2003. Letchworth State Park Water Quality Monitoring Program. See: (http://www.eng.buffalo.edu/ees/research/water_quality.htm).

Student Support:

To be identified for fall semester (2005)

Notable Achievements: (if any)

The preliminary project efforts and water sampling data have been of great interest to the Wyoming County collaborators and some farmer participants, who have used the information to secure additional NY state environmental bond act funds to address pollution concerns on the dairy farms.

Measuring the effects of wetland and riparian zones on water quality in the urban Patroon Creek Watershed, Albany County, NY.

Basic Information

Title:	Measuring the effects of wetland and riparian zones on water quality in the urban Patroon Creek Watershed, Albany County, NY.
Project Number:	2004NY52B
Start Date:	3/1/2004
End Date:	2/28/2006
Funding Source:	104B
Congressional District:	21
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Wetlands, Water Quality
Descriptors:	Nonpoint pollution; Stormwater; Wetlands; Urban and suburban land use;
Principal Investigators:	John G. Arnason, George Robinson

Publication

1. Arnason, J G, 2004, Conference on rising salt concentrations in tribuatries of the Hudson River Estuary, presentation and abstract, Hudson Eiver Environmental Society, Kingston, NY, December 6, 2004.
2. Robinson, G R, 2004, Environmental restoration within the Hudson River Basin, presentation and abstract, Hudson River Environmental Socienty, Hudson, NY, March 22, 2005.
3. Erickson, Elazabeth K, 2004, Road salt application ad its effects on sodium and chloride ion concentrations in an urban stream: Patroon Creek, Albany, NY, MS Thesis, Department of Earth and Atmospheric Sciences, University at Albany, State University of New York, Albany, NY.

Title: Measuring the effects of wetland and riparian zones on water quality in the urban Patroon Creek Watershed, Albany County, NY

Note: Due to administrative delays, grant funds were not received at the University until February 2005, the end of the original project period. In order to expedite the project, work was carried out during 2004 and early 2005 using a funding advance from the University through an "at-risk" account. The P.I.'s have requested and received a 1-year, no-cost extension on the project and expect to complete it by February 2006. Below, we report preliminary findings and results. We will present a complete report at the termination of the extended project period.

Site description and preliminary survey data

At its western edge, the main body of Six Mile Reservoir (south of the CSXRR line) is fed by two inlet streams (Figure 1). The northern fork begins W of Rapp Rd just south of the tracks and meanders through the Pine Bush Preserve. We believe the source is primarily ground water, with some surface drainage. We have a three year record of water samples from the upstream part of this creek (Site 1, Figure 1), and a shorter record for several sites downstream and along the banks of the northern fork as it widens into the reservoir (sites in yellow, Figure 1).

We have so far traced the southern fork to a culvert that passes under Rapp Rd., across from the entrance to the Albany Sanitary Landfill, adjacent to I-90 (NYS Thruway). This south fork begins to widen approx. 350 m (1100 ft) northeast of the culvert, eventually mixing with the north fork about 700 m further east. USGS maps do not show any inlet, with the south fork drawn as a backwater without any feeding streams. We first followed this southern fork inlet in June 2004, as part of a study of potential road salt accumulation in the Patroon Creek watershed. We have since taken samples every 1-2 months below the culvert and further downstream along the shores of the widening southern fork.

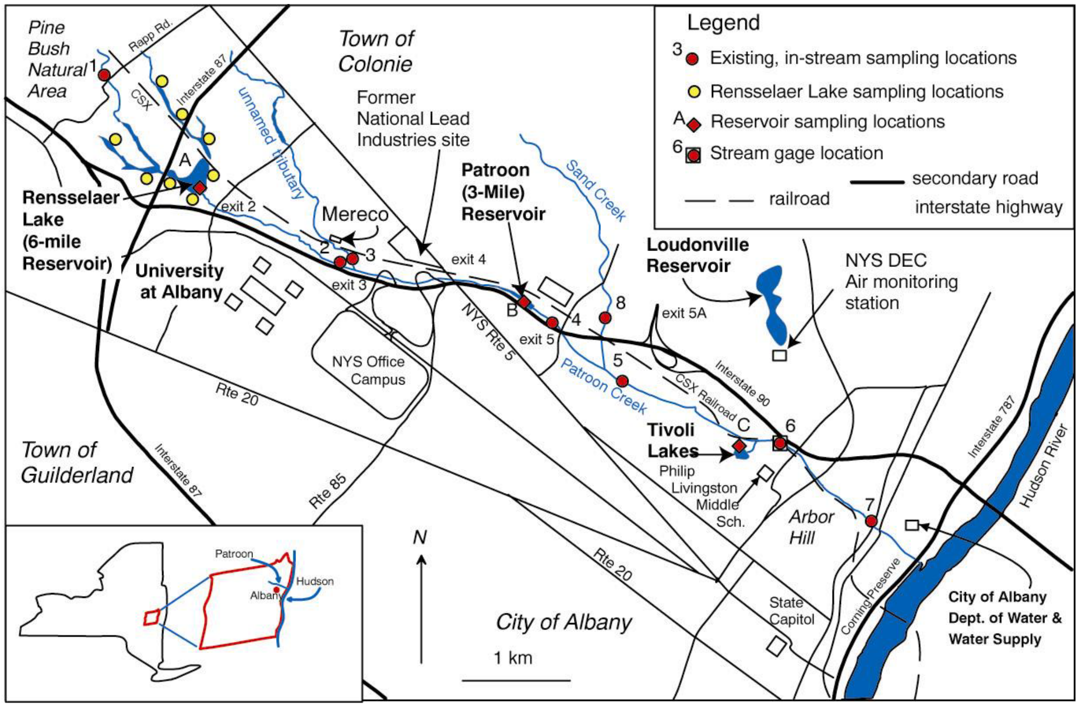

Figure 1. Map of Patroon Creek and Rensselaer Lake showing sampling locations and major features.

Water chemistry

From June 2002 to June 2004, we conducted weekly sampling of Patroon Creek at seven sites for temperature, pH, dissolved oxygen (D.O.), major anion and cation concentrations, and alkalinity under an EPA grant funded through the EMPACT program. We have also developed a high-resolution (2 m) GIS for the reservoir basin, including land cover classes, riparian buffer widths.

In order to develop a longer term water chemistry record, we have continued to collect grab samples on a monthly basis at the same seven sites from July 2004 to the present as part of the current project. In addition to the above parameters, we are now also measuring specific conductivity. Beginning in April 2005, we added an additional sampling site for a total of eight sites. In addition to the periodic sampling, we collected water samples during storm events in January and March 2005. The date, type and number of samples collected from Patroon Creek as part of this project are summarized in Table 1. We are in the process of completing the analysis of existing water samples and compiling the data.

From June 2004 to May 2005, we have been collecting water grab samples and measuring T, pH, D.O., and conductivity periodically at several of 15 different sites in Rensselaer Lake. The date, type and number of samples are summarized in Table 2. We also measured water quality parameters (T, D.O., and pH) and collected samples for major ion chemistry from the water column in the deepest part of the lake (~7.0 m depth). Water column measurements were made in July and December of 2004. These measurements will be compiled together with measurements from April, May, September, and October, taken in previous years in order to more fully characterize the stratification of the reservoir.

Table 1. Summary of measurements and water samples collected along Patroon Creek (sites in red, Figure 1) , July 2004 to May 2005.

Date	*# Anion/Cation samples*	*# Bacteria Samples*	*# Temp, pH, & D.O. measurements*	*# Conductivity measurements*
7/13/04	7	7	7	0
8/10/04	7	7	7	0
10/12/04	7	7	7	0
11/3/04	7	0	7	7
11/9/04	7	7	7	7
12/14/04	7	7	7	7
1/11/05	7	7	7	7
1/26/05*	3	0	3	3
2/8/05	7	7	7	7
3/8/05*	1	0	1	1
3/11/05	7	0	7	7
3/21/05*	3	0	3	3
3/28/05*	5	0	5	5
4/12/05	8	7	8	8
5/10/05	8	7	8	8
Total	91	63	91	70

* Storm Events

Table 2. Summary of measurements and water samples collected at sites along Rensselaer Reservoir (sites in yellow, Figure 1), June 2004 to May 2005.

Date	*# Anion/Cation samples*	*# Bacteria Samples*	*# Temp, pH, & D.O. measurements*	*# Conductivity measurements*
6/3/04	6	0	6	6
6/8/04	3	0	3	3
6/21/04	4	0	4	4
7/14/04	9	0	9	9
7/15/04	5	0	5	5
8/9/04	13	0	13	13
11/18/04	12	0	12	12
2/8/05	13	0	13	13
3/24/05	9	0	9	9
5/19/05	8	0	8	8
total	83	0	83	83

Soil Chemistry

We have collected several dozen soil samples from around the reservoir. These will be characterized through grains size analysis, total carbon content, mineralogy by XRD, and cation/anion exchange capacity.

Principal findings or significant results

In June 2004, we began systematic and periodic water sampling in and around Rensselaer (a.k.a. "6-mile") Reservoir in order to characterize spatial and seasonal variations in water quality as well as to identify point sources of contaminants. We also collected a suite of soil samples around the reservoir in order to determine soil properties that might influence water quality, such as anion and cation exchange capacity.

Our principal findings to date are as follows:

1. Rensselaer Lake is a eutrophic reservoir with an area of 14.3 ha and a mean depth of 3.35 m. The greatest depth (7.0 m) occurs near the dam at the southeastern corner of the lake (Figure 1). A smaller basin about 4.5 m deep occurs just upstream of the I-87 bridge. During the summer months, the lake is stratified with an oxic epilimnion and anoxic hypolimnion. Chloride ion concentrations are elevated (~250 ppm) in the hypolimnion relative to the epiliminion (~150 ppm). Fall turnover occurs in late September to early October. Following turnover, the bottom waters remain enriched in chloride relative to surface waters, although the gradient is decreased relative to that present during summer stratification. Due to dangerous ice conditions, we were unable to observe winter stratification or spring turnover, if present. Therefore it is unknown if the reservoir is monomictic or dimictic.
2. The source of chloride ion is likely to be from road de-icing salts. Major sources include interstate highways 87 and 90 maintained by the NYS DOT; the Exit -24 toll plaza maintained by the NYS Thruway Authority, and numerous secondary roads and parking lots maintained by the City of Albany, Town of Colonie, and private agencies. Continued application to the watershed could lead to permanent stratification of the reservoir.

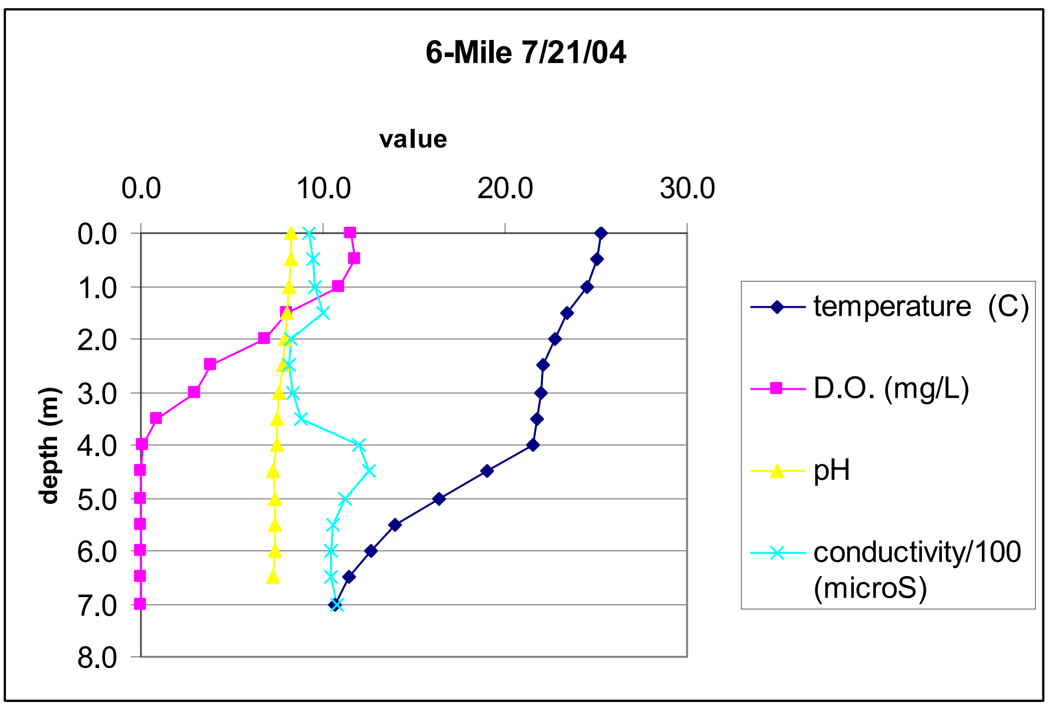

Figure 2. Profile of Rensselaer Lake water column during summer stratification. The thermocline occurs between 4-5.5 m depth. Below 4.0 m, lake waters are anoxic and have higher average conductivity than surface waters.

3. Rensselaer Lake waters are derived from both ground and surface water sources. We have identified three sources in the proximity of the first culvert, (1) apparent groundwater seepage that joins the flow below the culvert, (2) a second large culvert just downstream that appears to run under the north bank, either draining I-90 or

passing under it, and (3) a small culvert (black corrugated drain pipe) that carries water under Rapp Rd. from the vicinity of a trailer park entrance to the south of the main culvert. All four inlets join to feed the 350 m-long creek that leads to the southern reservoir fork. Most of our samples have been taken from a single site that contains a mix from all four water sources. On Feb. 20, 2005, we took separate water samples and field measurements of all four sources. We have not yet analyzed the samples, but field readings are given in Table 3.

Table 3. Field readings from Feb. 20 field sampling. Air temp. was approx. -3 C (27 F). Site numbers are for yellow sites on Figure 1 (not labeled).

Site	Possible source	Water Temp	DO[1]	SC[2]
1.Culvert under Rapp Rd.	groundwater	10.2 C (50.4 F)	0.70	3508
2. Seepage around culvert.	groundwater	10.2 C (50.4 F)	3.8	3629
3. Culvert under I-90	?	6.5 C (43.7 F)	10.6	2427
4. Corrugated pipe	road drainage?	1.4 C (34.5 F)[3]	3.0	1193
5. N fork (APB Preserve)	groundwater	3.9 C (39.0 F)	10.4	570

[1]Dissolved oxygen in mg/l;
[2]specific conductance in µS /cm, adjusted for 25 C.
[3]Surface frozen, water not moving, pipe empty.

Clearly different water sources are contributing. For comparison, site #5 consistently tests out as our cleanest water, with the lowest major ion concentrations, so we use it as a reference site for Pine Bush groundwater. Sites 1 and 2 appear to flow from a very different source, with the warmest water and the highest conductivity. Mean conductivity (SC) for the south fork stream (Site 1) over six months was 1650 µS, and 508 µS for the north fork stream (Site 5). Differences in major ion concentrations are even stronger (Table 4).

Table 4. Major cations (A) and anions (B) comparing upstream sites of the north and south forks of the western part of Six Mile reservoir. All values are in mg/l (approx. ppm). Data are from a single sample, 6/04.

A. Cations

Stream	Sodium	Ammonium	Potassium	Magnesium	Calcium
South fork (Site 1)	384.3	56.9	22.5	29.6	124.3
North fork (Site 5)	41.1	0.7	1.4	11.9	65.2

B. Anions

Stream	Chloride	Nitrate	Phosphate	Sulfate

South fork (Site 1)	649.5	0.1	0.23	25.19
North fork (Site 5)	70.0	1.65	0.27	31.32

The South Fork sample was tested twice in one run of the ion chromatograph, and we took a second sample and tested that on a later run. All three tests gave similar results. North fork values are consistent with a two-year dataset of weekly tests. Therefore, although we need to test our backlog of South Fork water samples from later months (7/04 to current), we do not believe that sample error or technical errors are responsible for the large differences seen in Table 2. In addition, the large discrepancies in field conductivity (Table 1) are borne out by other data and are consistent with the ion concentration differences.

Preliminary interpretation

A preliminary hypothesis is that much of the South Fork inlet derives from groundwater fed by landfill leachate. This will require much more testing, but we have several clues. First, we observed warm water low in oxygen. Second, the extremely high ammonium values (higher than typically reported even for watersheds with heavy agricultural inputs) are very unusual. This together with the near-zero nitrate values indicate an N-rich, anoxic source. A third piece of preliminary evidence is visual. The water is oily and very reddish/orange. Photographs from July 2004 are pasted in the next page.

We plan to continue monitoring and sampling through next summer with support from NYS WRI and USGS, and we have no plans to release data until all tests are run and analyses are thoroughly checked.

Students supported:

A total of three graduate students will be supported during this project. Sean Madden (M.S. Biological Sciences, 2004) was supported during summer 2004. His duties included sampling and laboratory analysis. Chuck Begeal (M.S. student, DEAS) and Dan Capuano (Ph.D student in Biological Sciences) will be supported during summer 2005. Their duties will include water and soil sampling, laboratory analysis, data analysis, and GIS analysis of data.

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:	Models, Nutrients, Surface Water
Descriptors:	dissolved phosphorus, water quality modeling, best management practices,
Principal Investigators:	Tammo Steenhuis

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

Problem and Research Objectives:

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

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

Methodology:

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

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

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

Principal Findings and Significance:

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

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

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

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

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

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

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, 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 pulldownmenu (GWLFXL) which appears when the workbook is loaded.
- Model parameters can now be read either from existing GWLF input files (ie textfiles) 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://www.eeb.cornell.edu/biogeo/usgswri/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.

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.

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:	12/31/2004
Funding Source:	104B
Congressional District:	21
Research Category:	Not Applicable
Focus Category:	Non Point Pollution, Water Quality, Waste Water
Descriptors:	nonpoint source pollution, fecal contamination, water quality, pathogens
Principal Investigators:	Ellen Braun-Howland

Publication

1. Braun-Howland, E, 2005, Assessment of methods to distinguish between human and ruminant sources of fecal polution, 29th Annual meeting of the New England Association of Environmental Biologists, Fort William Henry, Resorts & Conference Center, Lake Geoge, NY, March 2005.
2. Lendrum, Jacqueline, E Braun-Howland, 2005, Assessment of methods to distinguish between human and ruminant sources of fecal pollution, State University of New York, School of Public Health, Student Poster Day, April 2005.

Title: 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*.

Because 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 studies presented herein examined 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 were monitored over time using approved culture techniques. These results are compared with the survival of *Bacteroides,* determined using the PCR-based method developed by Bernhard and Field (2000). In contrast to detection methods based on culturing, this alternative technique identifies fecal contamination through the amplification of *Bacteroides* DNA. Previous studies in our laboratory have shown that the *Bacteroides* test is able to detect species-specific markers of fecal pollution in surface waters impacted by CAFO operations and in septage samples. Finally, the use of rRNA-based *in situ* hybridizations for the identification of *Bacteroides,* would permit the detection of potentially 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 recent human and agricultural sources of fecal pollution.

The original objectives of the project were:

- 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.

Four significant project adjustments were made. The first is that the studies were carried out in surface water environments on private property, rather than streams, due to potential public health consequences associated with breakage of the chamber membranes during incubation. Secondly, *in situ* incubations were carried out cross-seasonally due to the unexpected duration of survival of the test organisms. Thirdly, the calf feces used in these studies were naturally infected with *Cryptosporidium parvum* oocysts, permitting concomitant evaluation of the detection of this important protozoan pathogen over the course of these studies. Lastly, detection of *Bacteroides* using *in situ* hybridizations was unsuccessful due to an unacceptable amount of autofluorescence associated with the fecal samples.

Methodology:

Fecal samples obtained as a composite mixture from several calves were a kind gift from Dr. Dwight Bowman, Cornell University. Diffusion chambers (McFeters and Stuart, 1972) containing 30 ml of bovine fecal suspensions at two concentrations were incubated, in triplicate, in a pond environment minimally impacted by fecal contamination and in a separate, fecally-impacted pond. The diffusion chambers were sampled over a period of 223 days, beginning with weekly sampling during the month of May, then biweekly sampling during June and July, followed by monthly sampling from August to December. Diffusion chambers were removed from the environment in December, prior to deep-freezing of the ponds. Diffusion of molecules through chamber membranes was ascertained after their removal from the environment by spectrophotometrically demonstrating the transfer of FITC dissolved in an outside aqueous environment to the inside of the chambers. Also, the extent of biofilm formation on chamber membranes was assessed using scanning confocal laser microscopy.

Samples were analyzed for total coliforms, *E.coli*, and enterococci using EPA-approved Colilert/Enterolert methodologies until the October sampling date, when limits of detection for organisms remaining in some of the test chambers required the addition of a membrane filtration format. For detection of *E. coli* SM 9222D (APHA) was used, followed by incubation on NA-MUG medium. Enterococci were detected using mE agar and confirmed on EIA agar according to EPA Method 1106.1.

Polymerase chain reaction (PCR) amplifications for detection of *E.coli*, enterococci, *Bacteroides* and *Cryptosporidium* were used to evaluate the presence of specific DNA sequences during the sampling period. Because *E. coli*, enterococci and, in many cases, *Cryptosporidium* oocysts were detectable using standard techniques after 223 days incubation, amplifications were performed on samples from selected, rather than each, sampling date. Amplification conditions and primers used were based on the following protocols: *Cryptosporidium* (LeChevallier et al., 2003); enterococci (Haugland et al., 2005); *E. coli* (Williams and Braun-Howland, 2003, Lane et al., 1985) and *Bacteroides* (Bernhard and Field, 2000).

Cryptosporidium oocysts were microscopically detected and enumerated, in duplicate, at each time point using standard immunofluorescence staining techniques on 10-50 µl aliquots of sample (or dilution thereof) that had been spotted and dried on a multiwell slide coated with poly-L-lysine. Inclusion of the fluorochrome, DAPI, aided in the identification of oocysts containing sporozoite nuclei. Because the results of previous studies indicated that sample drying temperature affects the percentage of oocysts that are DAPI positive, detection of *Cryptosporidium* oocysts was carried out using drying temperatures of both 41 ^{o}C and 65 ^{o}C.

Water quality parameters including water temperature, pH, dissolved oxygen, and conductivity were measured in both pond locations at the time of sampling. Nutrient samples including total phosphorus, TKN, nitrate, ammonia and TOC for both pond environments were collected.

Principal Findings & Significance:

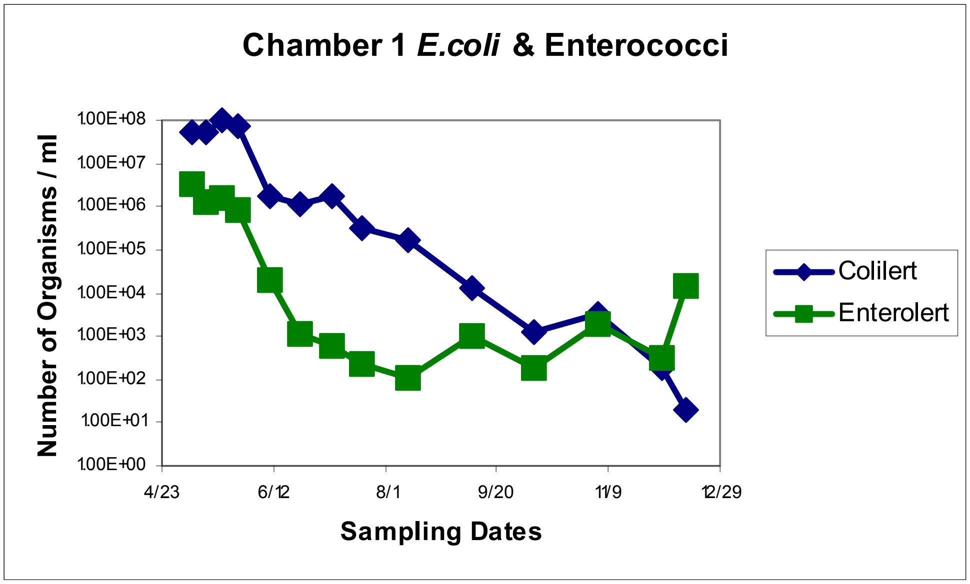
To our knowledge, this is the first study to concomitantly examine *in situ* survival rates of *E. coli*, enterococci, *Bacteroides* and *Cryptosporidium parvum* in unadulterated calf feces. All organisms were detectable in at least one of the triplicate diffusion chambers examined over a 223 day incubation period. Therefore, under the conditions employed, none of the organisms evaluated was a good indicator of recent fecal pollution. These results do, however, suggest that *E. coli* may be an appropriate indicator for the presence of agriculturally-derived *C. parvum*.

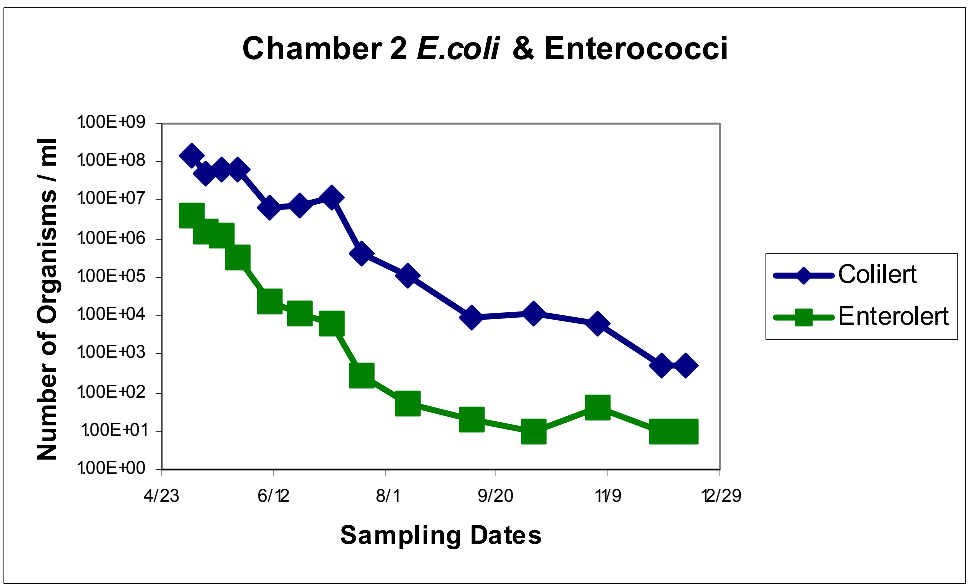
One original premise of these studies was that bacteriological indicators of fecal pollution would become undetectable during the incubation period using growth on bacteriological medium as the criterion. At that point, molecular techniques would be used to ascertain the presence of the various indicator organisms. Therefore, PCR amplification-based detection of *E. coli* and enterococci could be compared to the PCR-based detection of *Bacteroides*. However, the results of these studies demonstrated that, using standard techniques, measurable amounts of *E. coli* and enterococci remained in diffusion chambers after 223 days incubation in the environment

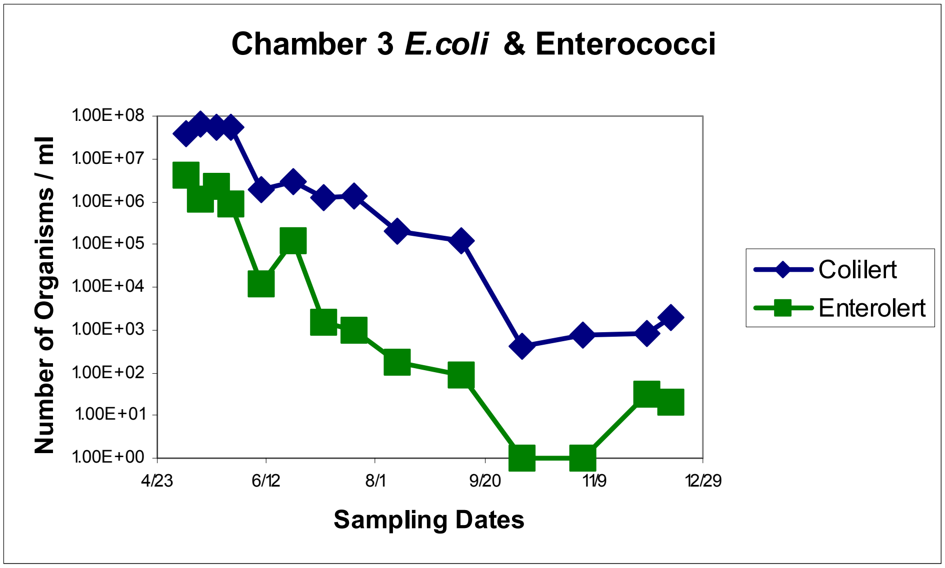
Numbers of *E.coli* and enterococci detected in diffusion chamber samples over time are presented in Figure 1. Chambers 1-6 were incubated in the low nutrient environment, where as 7-12 were incubated in a pond moderately impacted by farming activities. Membranes on two of the three chambers containing undiluted sample (chambers 7,9) were compromised during the study due to parasite infestation.

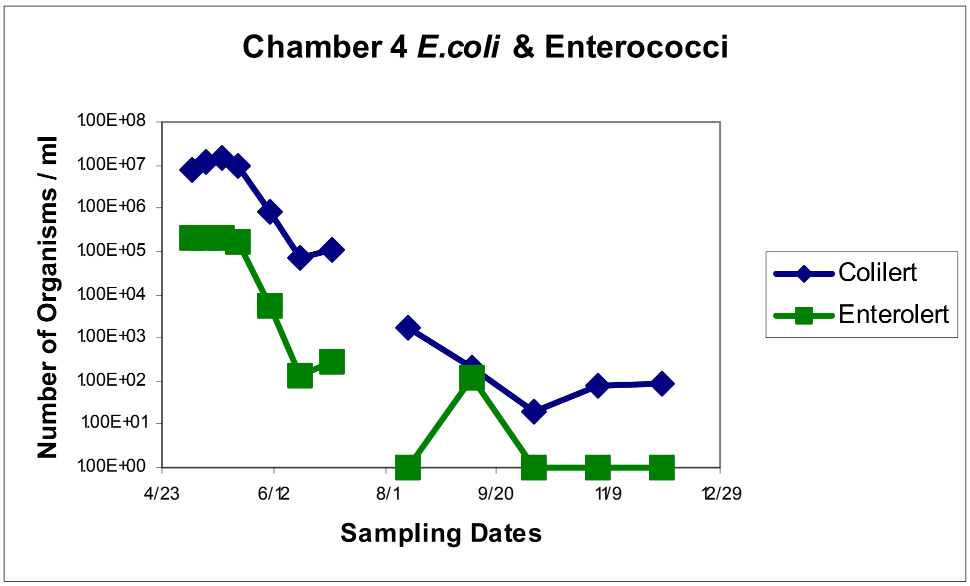
Relative survival of organisms was apparently unimpacted by incubation conditions (chambers 1-3 versus 8; 4-6 versus 10-12). Numbers of *E. coli*, approximating 10^8 organisms/ml in undiluted chambers, were stable for about one month in both pond environments; low numbers of *E. coli* (10^0-10^1 organisms/ml) were still detectable on bacteriological media at the end of the incubation period. Survival of *E. coli* and enterococci was apparently affected by initial concentration of organisms (chambers 1-3 vs. 4-6; 8 versus 10-12): a more rapid reduction in bacterial numbers was observed in diluted samples. Similar results were observed for numbers of enterococci in the twelve chambers, although the numbers were much more variable between the triplicate chambers.

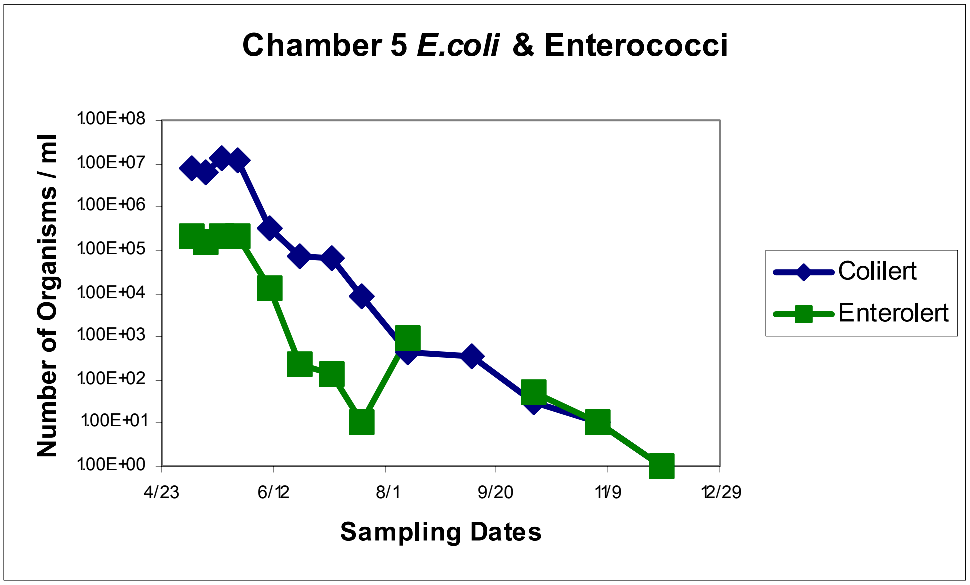
Figure 1. Detection of E. coli and enterococci over time in diffusion chambers. Chambers 1-3 and 7-9 contained undiluted calf feces; contents of chambers 4-6 and 10-12 were diluted ten-fold. Chambers 1-6 were incubated in a pond relatively unimpacted by human or agricultural waste, whereas chambers 7-12 were incubated in a pond moderately impacted by farming activities.

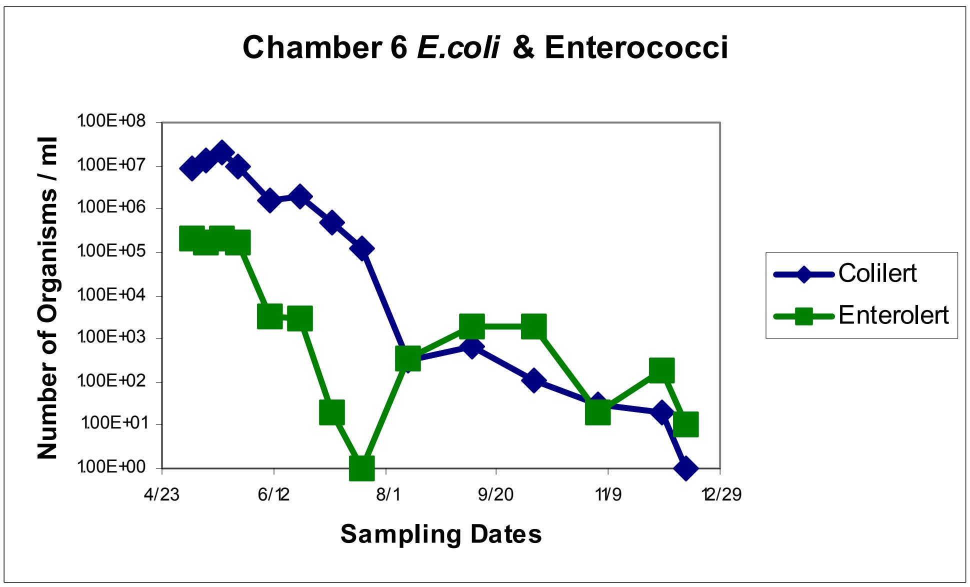


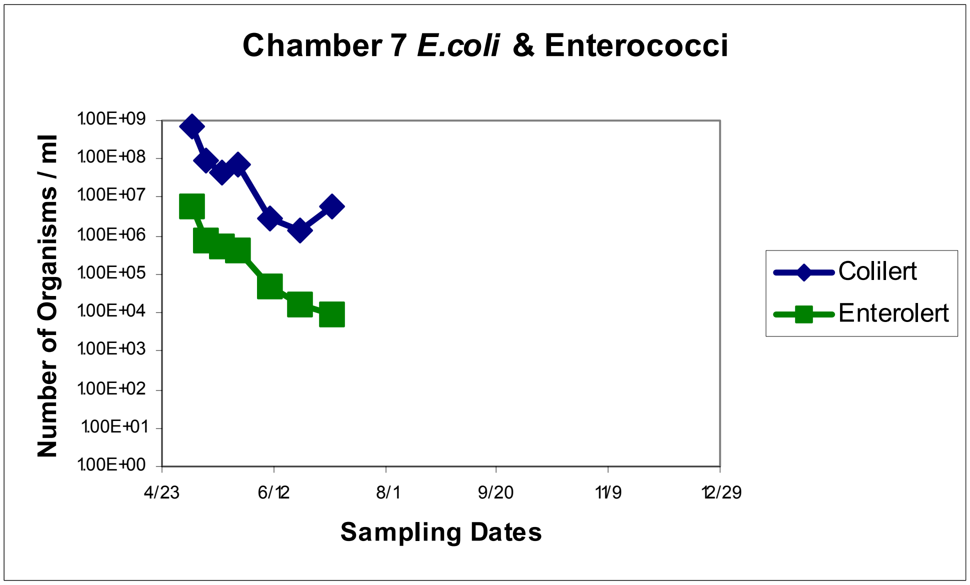


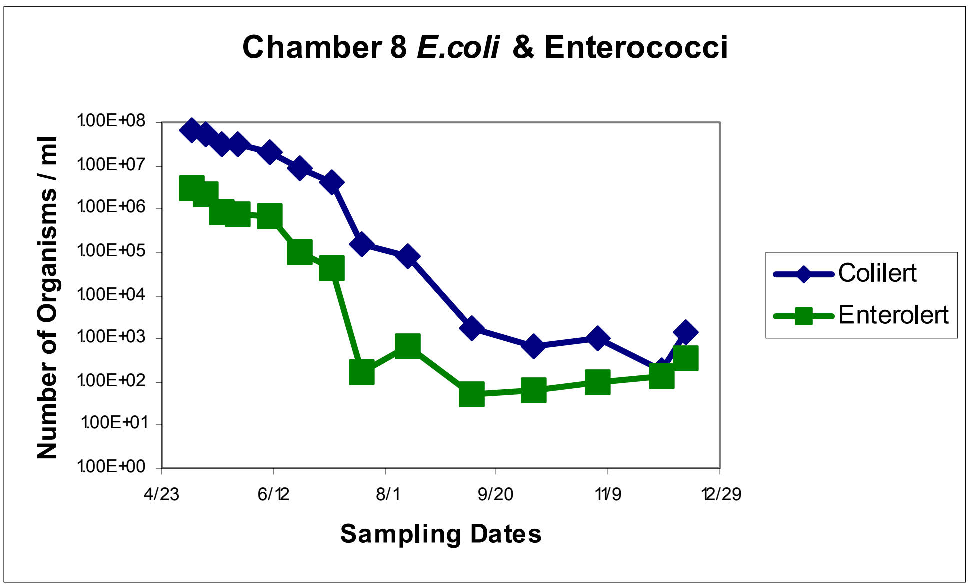

Chamber 3 E.coli & Enterococci
Number of Organisms / ml
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
4/23
6/12
8/1
9/20
11/9
12/29
Sampling Dates
Colilert
Enterolert

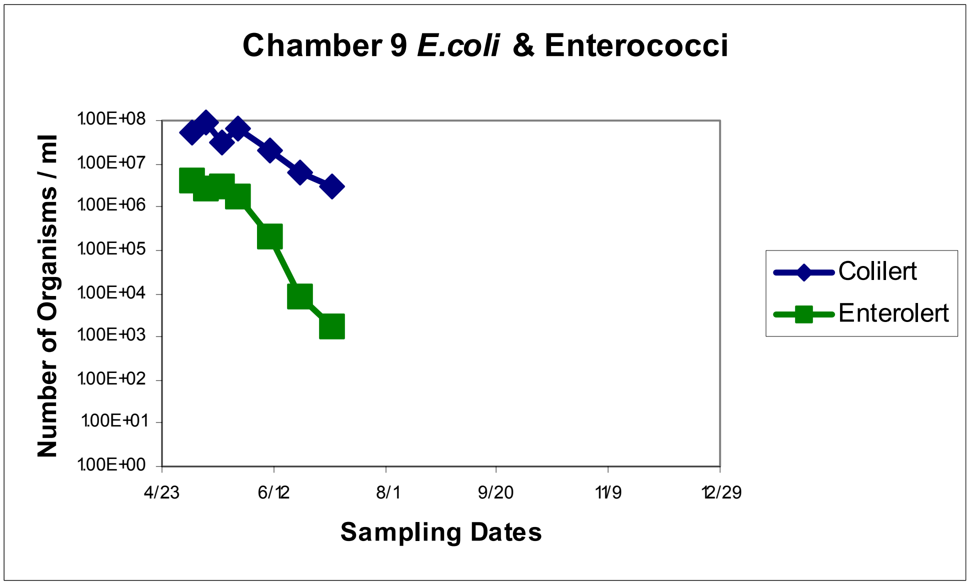

Chamber 4 E.coli & Enterococci
Number of Organisms / ml
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
4/23
6/12
8/1
9/20
11/9
12/29
Sampling Dates
Colilert
Enterolert

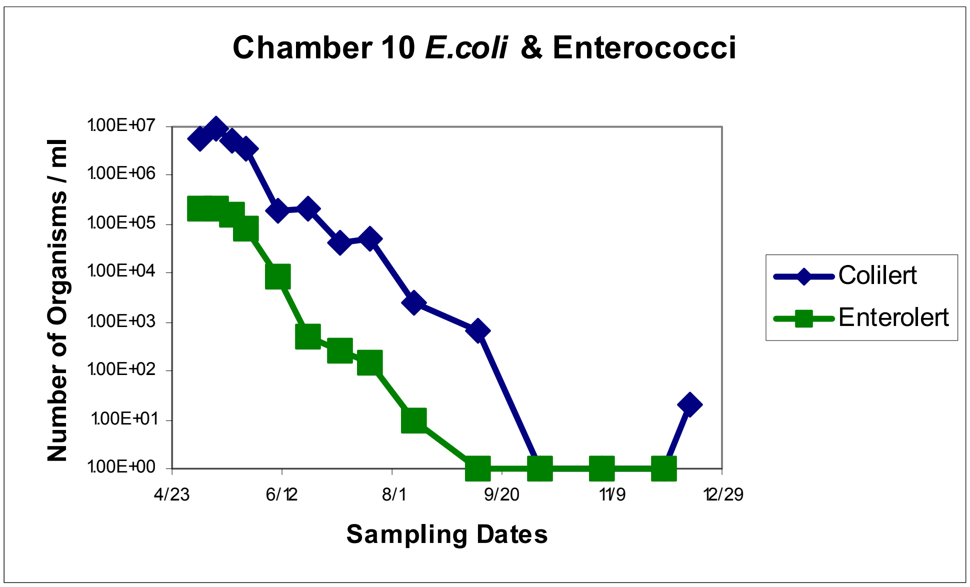

Chamber 5 E.coli & Enterococci
Number of Organisms / ml
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
4/23
6/12
8/1
9/20
11/9
12/29
Sampling Dates
Colilert
Enterolert

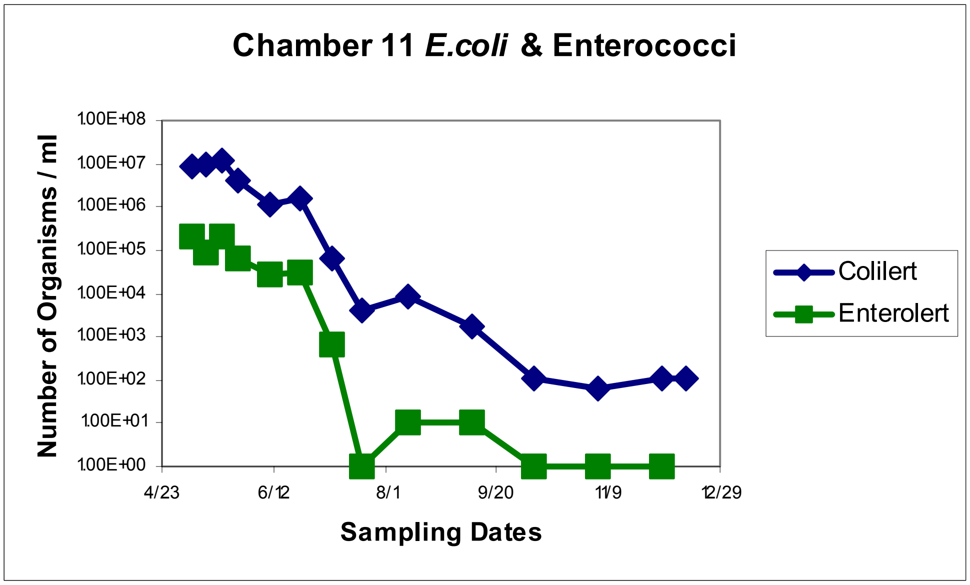

Chamber 6 E.coli & Enterococci
Number of Organisms / ml
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
4/23
6/12
8/1
9/20
11/9
12/29
Sampling Dates
Colilert
Enterolert

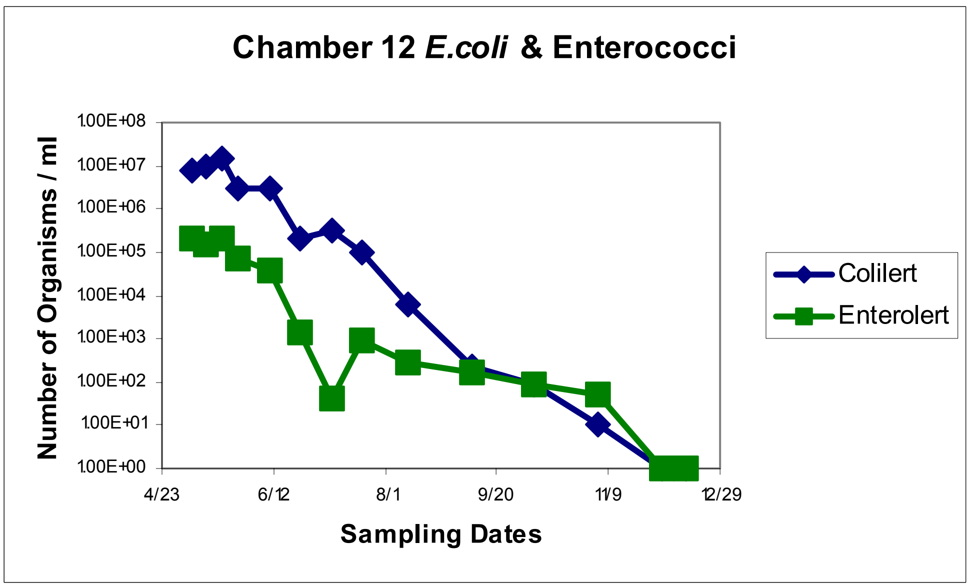

Chamber 7 *E.coli* & Enterococci
Number of Organisms / ml
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
4/23
6/12
8/1
9/20
11/9
12/29
Sampling Dates
Colilert
Enterolert


Chamber 8 *E.coli* & Enterococci
Number of Organisms / ml
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
4/23
6/12
8/1
9/20
11/9
12/29
Sampling Dates
Colilert
Enterolert


Chamber 9 *E.coli* & Enterococci
Number of Organisms / ml
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
4/23
6/12
8/1
9/20
11/9
12/29
Sampling Dates
Colilert
Enterolert


Chamber 10 *E.coli* & Enterococci
Number of Organisms / ml
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
4/23
6/12
8/1
9/20
11/9
12/29
Sampling Dates
Colilert
Enterolert

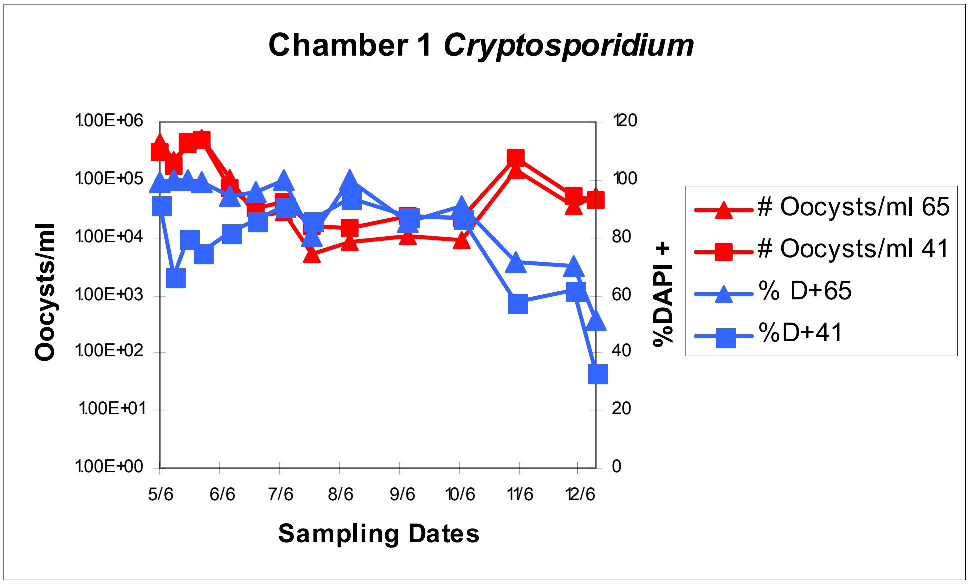


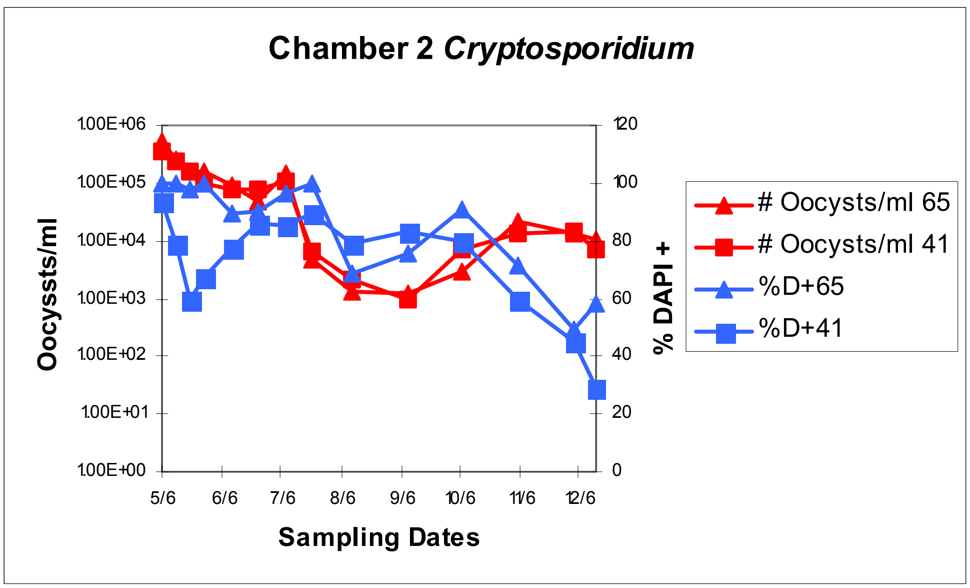


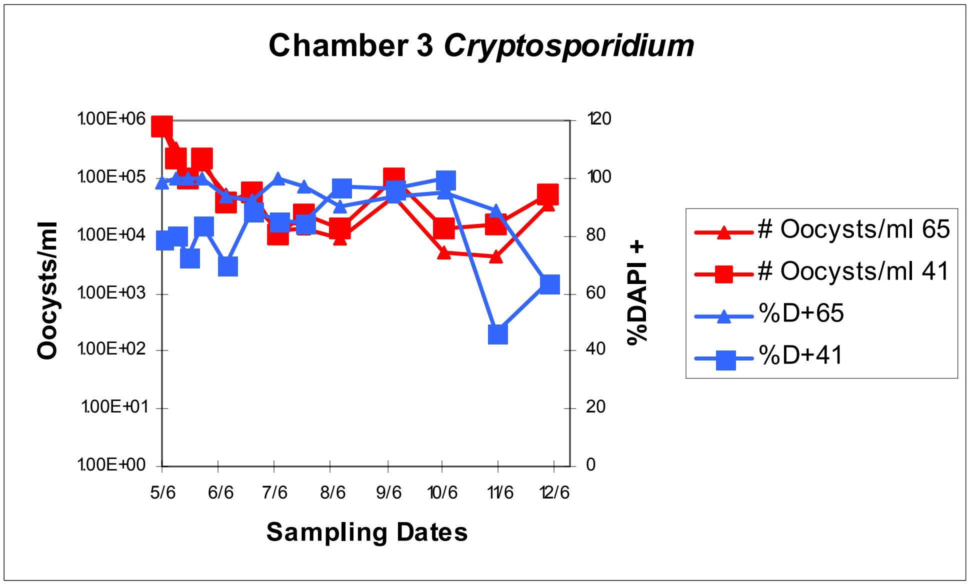
Numbers of *Cryptosporidium parvum* oocysts detected at 41 ^{o}C and 65 ^{o}C, and the relative percentages of DAPI positive oocysts, are presented in Figure 2. Numbers of DAPI positive oocysts were low, but detectable, at the end of the incubation period. Excystation assays performed on a sample removed in December, 2004 demonstrated the presence of oocysts capable of excystation. However, limited infectivity assays performed using the cell culture-focus detection method (DiGiovanni et al., 1999) indicated that few, if any, of the oocysts were infectious.

Relative numbers of *E. coli* observed inside and outside of the incubation chambers, together with microscopic data showing the presence of unique algal genera inside, versus outside, of the chambers (data not shown), indicated that the chamber membranes remained intact throughout the sampling period.

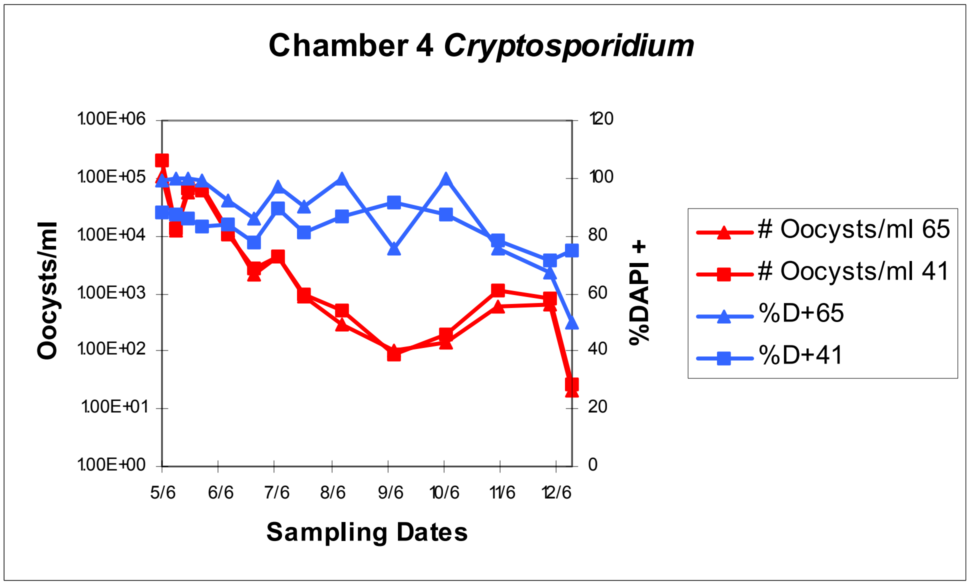
Figure 2. Detection of Cryptosporidium parvum oocysts over time in diffusion chambers using immunofluorescent staining. Sporozoite nuclei were visualized using DAPI (D+). Samples were dried at either 65 or 41°C.



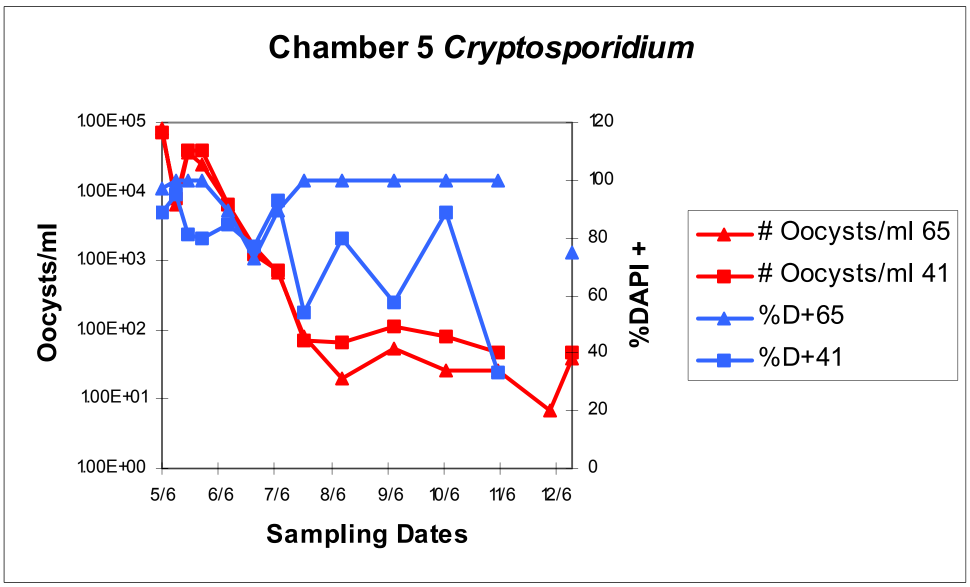




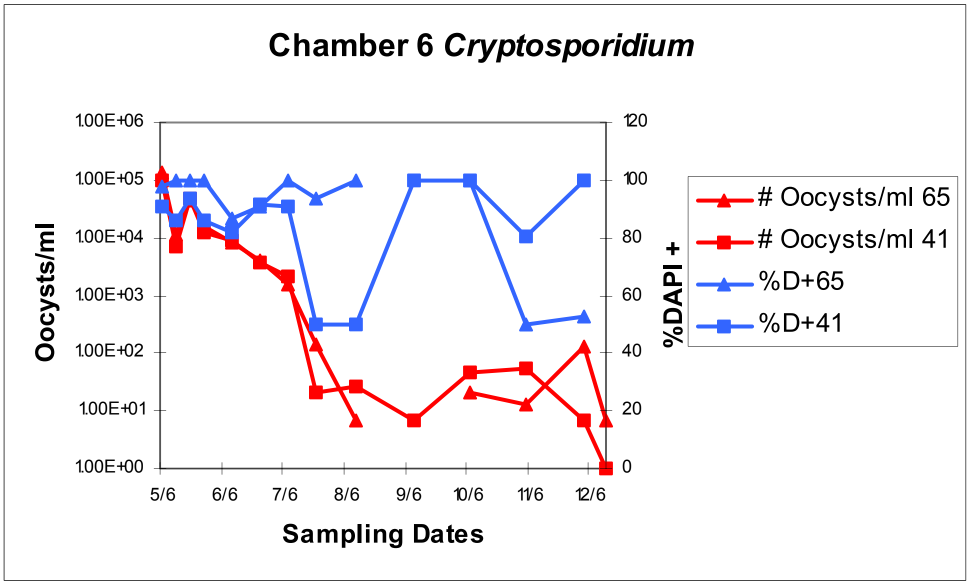
Chamber 3 *Cryptosporidium*
Oocysts/ml
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
%DAPI +
120
100
80
60
40
20
0
5/6
6/6
7/6
8/6
9/6
10/6
11/6
12/6
Sampling Dates
Oocysts/ml 65
Oocysts/ml 41
%D+65
%D+41

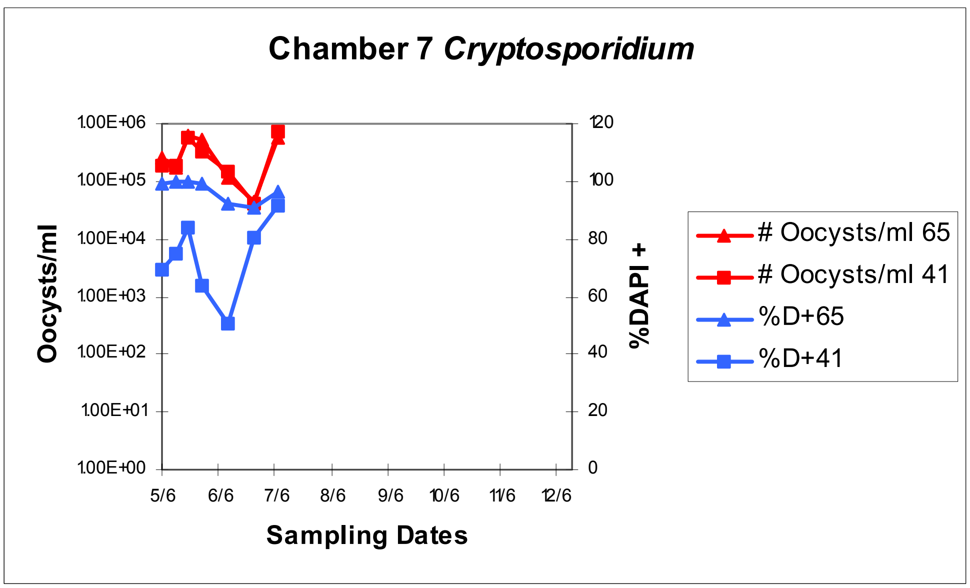


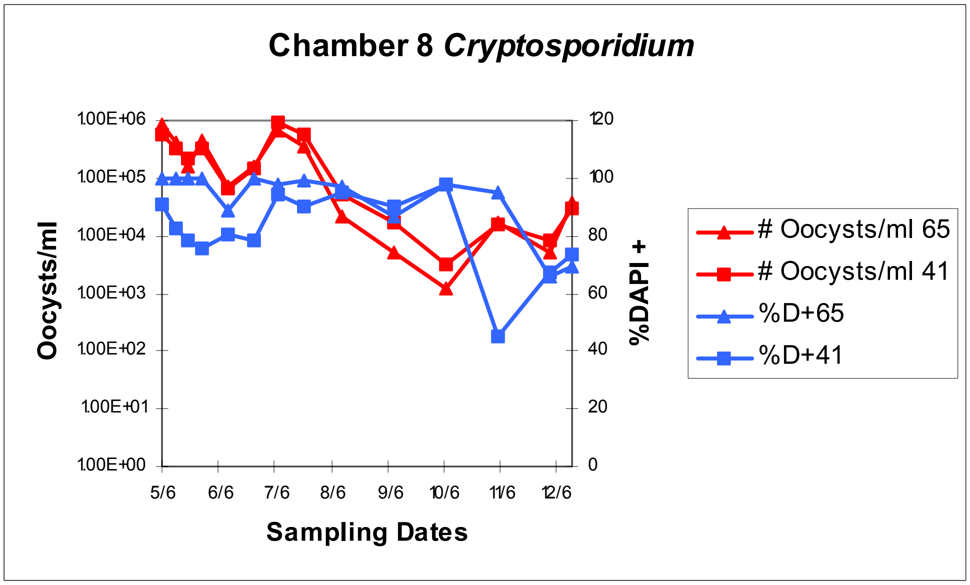
Chamber 4 Cryptosporidium
Oocysts/ml
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
%DAPI +
120
100
80
60
40
20
0
5/6
6/6
7/6
8/6
9/6
10/6
11/6
12/6
Sampling Dates
Oocysts/ml 65
Oocysts/ml 41
%D+65
%D+41

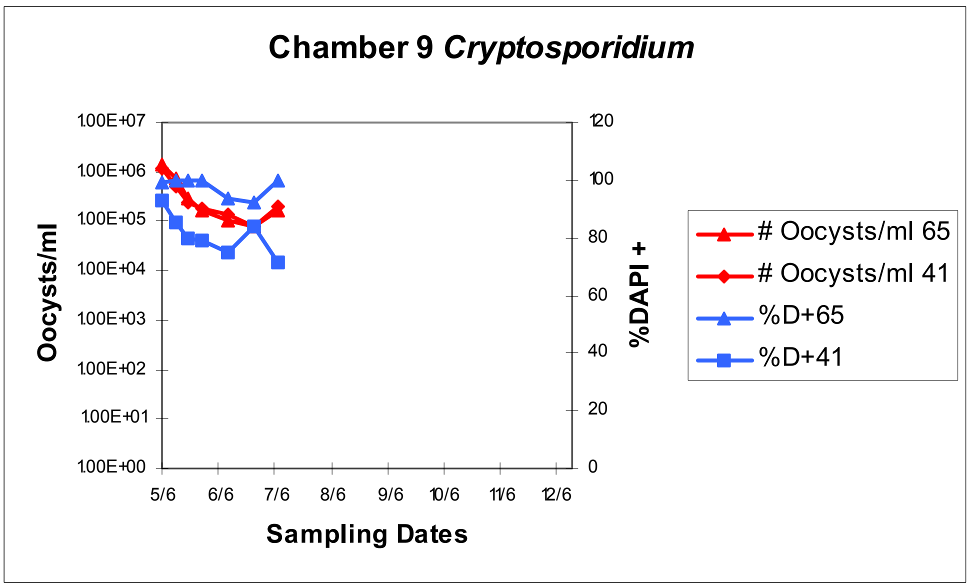


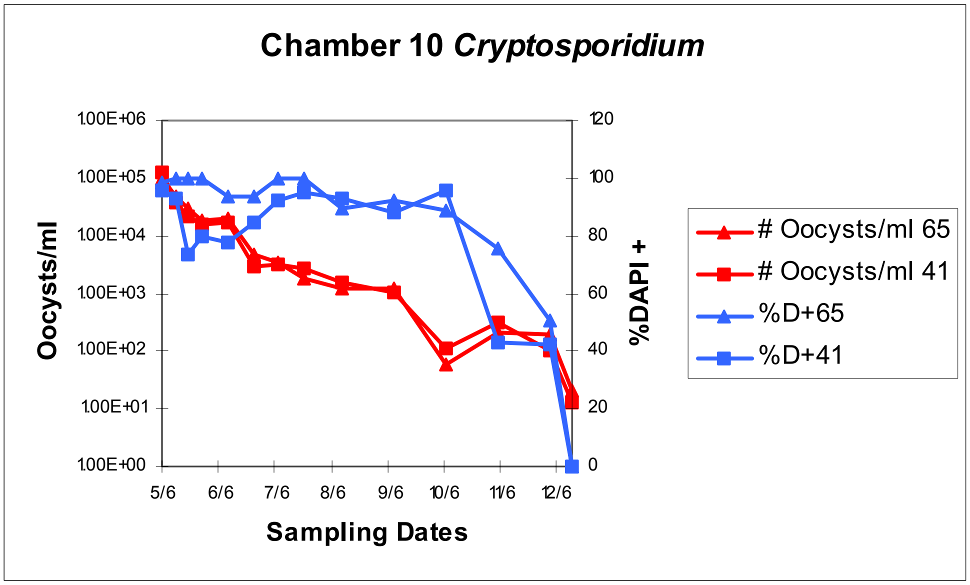
Chamber 5 Cryptosporidium
Oocysts/ml
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
%DAPI +
120
100
80
60
40
20
0
5/6
6/6
7/6
8/6
9/6
10/6
11/6
12/6
Sampling Dates
Oocysts/ml 65
Oocysts/ml 41
%D+65
%D+41

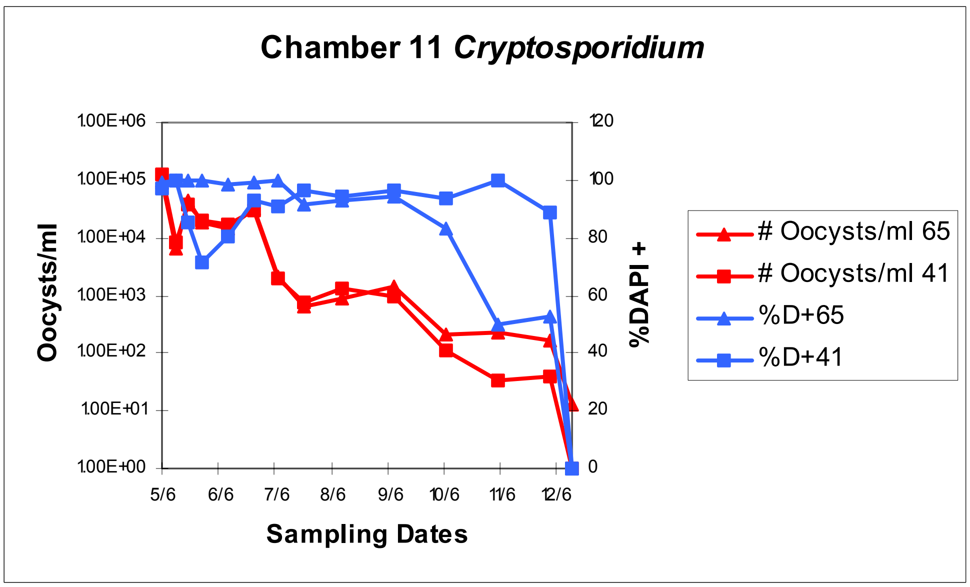

Chamber 6 Cryptosporidium
Oocysts/ml
%DAPI +
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
120
100
80
60
40
20
0
5/6
6/6
7/6
8/6
9/6
10/6
11/6
12/6
Sampling Dates
Oocysts/ml 65
Oocysts/ml 41
%D+65
%D+41

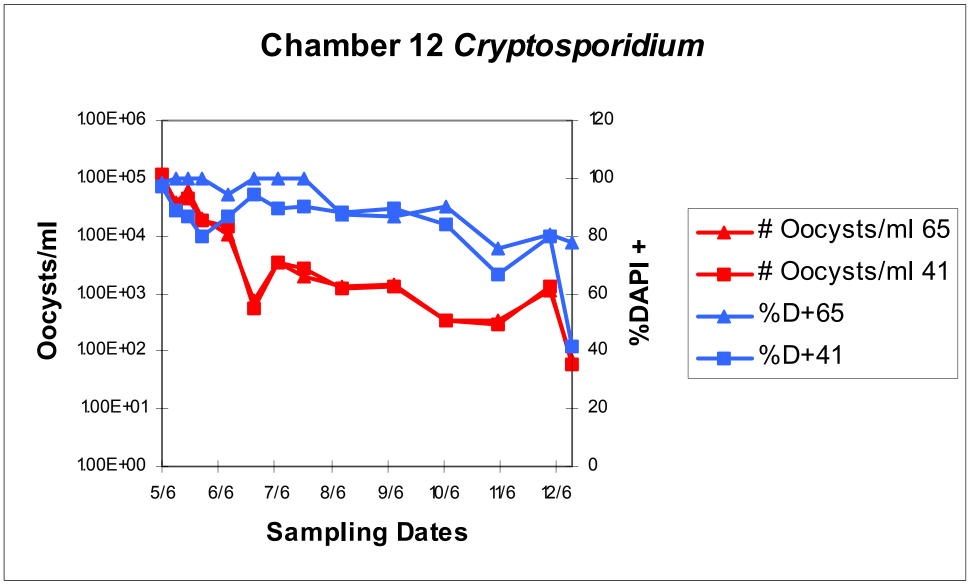

Chamber 7 Cryptosporidium
Oocysts/ml
%DAPI +
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
120
100
80
60
40
20
0
5/6
6/6
7/6
8/6
9/6
10/6
11/6
12/6
Sampling Dates
Oocysts/ml 65
Oocysts/ml 41
%D+65
%D+41


Chamber 8 *Cryptosporidium*
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
Oocysts/ml
120
100
80
60
40
20
0
%DAPI +
5/6
6/6
7/6
8/6
9/6
10/6
11/6
12/6
Sampling Dates
Oocysts/ml 65
Oocysts/ml 41
%D+65
%D+41


Chamber 9 *Cryptosporidium*
1.00E+07
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
Oocysts/ml
120
100
80
60
40
20
0
%DAPI +
5/6
6/6
7/6
8/6
9/6
10/6
11/6
12/6
Sampling Dates
Oocysts/ml 65
Oocysts/ml 41
%D+65
%D+41


Chamber 10 *Cryptosporidium*
Oocysts/ml
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
%DAPI +
120
100
80
60
40
20
0
5/6
6/6
7/6
8/6
9/6
10/6
11/6
12/6
Sampling Dates
Oocysts/ml 65
Oocysts/ml 41
%D+65
%D+41


Chamber 11 *Cryptosporidium*
Oocysts/ml
1.00E+06
1.00E+05
1.00E+04
1.00E+03
1.00E+02
1.00E+01
1.00E+00
%DAPI +
120
100
80
60
40
20
0
5/6
6/6
7/6
8/6
9/6
10/6
11/6
12/6
Sampling Dates
Oocysts/ml 65
Oocysts/ml 41
%D+65
%D+41



The results of PCR amplifications performed on samples obtained during May, July and December are presented in Table 1. At study onset in May, all samples in all chambers were PCR-positive for *E.coli*, enterococci, *Bacteroides* and *Cryptosporidium parvum*, except one repeatedly negative *Cryptosporidium* result in chamber 6. In July, PCR amplifications performed on diluted fecal samples incubated in the unimpacted pond (chambers 4-6) were repeatedly negative for Cry*ptosporidium* and *Bacteroides.* However, *Bacteroides* DNA was detected in two of these three chambers in December. *Cryptosporidium* was not detected using PCR amplification results in chambers 4,5, and 6 during the December sampling. By the final sampling date in December, *E. coli* was no longer detectable using the PCR in any of the chambers containing diluted sample (4-6, 10-12), as well as chamber 8. Chambers 10-12 and 6 were additionally PCR-negative for enterococci. It should be noted, however, that negative PCR amplification results are commonly attributable to the presence of inhibitors in DNA preparations. Alternatively, the assay may have reached its limit of detection under the conditions used.

Table 1. Detection of indicator organisms and *Cryptosporidium parvum* over time using polymerase chain reaction amplifications. Negative results were subjected to additional DNA purification steps, as well as alternate DNA concentrations and sources of polymerase.

Chamber number	1	2	3	4	5	6	7	8	9	10	11	12
Date	May	May	May	May	May	May	May	May	May	May	May	May
Cryptosporidium	+	+	+	+	+	neg	+	+	+	+	+	+
E. coli	+	+	+	+	+	+	+	+	+	+	+	+
Enterococcus	+	+	+	+	+	+	+	+	+	+	+	+
Bacteroides	+	+	+	+	+	+	+	+	+	+	+	+
	July	July	July	July	July	July	July	July	July	July	July	July
Cryptosporidium	+	+	+	+	neg	neg		+		+	+	+
E. coli	+	+	+	+	+	+		+		+	+	+
Enterococcus	+	+	+	+	+	+		+		+	+	+
Bacteroides	+	+	+	neg	neg	neg		+		+	+	+
	Dec	Dec	Dec	Dec	Dec	Dec	Dec	Dec	Dec	Dec	Dec	Dec
Cryptosporidium	+	+	+	neg	neg	neg		+		+	+	+
E. coli	+	+	+	neg	neg	neg		neg		neg	neg	neg
Enterococcus	+	+	+	+	+	neg		+		neg	neg	neg
Bacteroides	+	+	+	+	neg	+		+		+	+	neg

A variety of statistical measures will be used to assess the significance of these findings. Cross correlation plots are being utilized to determine “differences” in microbiological data between incubation locations, chamber triplicates and the two fecal sample concentrations. A linear regression model is being developed to better understand the impact of incubation temperature, algal numbers and dissolved oxygen on organism detection. A mass balance must also be examined to explore the potential effect of dilution due to sample removal on experimental results.

Notable achievements:

2004. Excellence in Research Award presented to Jacqueline Lendrum, University at Albany, School of Public Health for a poster describing this work.

Poster presentations:

“Assessment of Methods to Distinguish Between Human and Ruminant Sources of Fecal Pollution.” 29th Annual Meeting of the New England Association of Environmental Biologists. Fort William Henry, Resorts & Conference Center, Lake George, NY. March, 2005.

“Assessment of Methods to Distinguish Between Human and Ruminant Sources of Fecal Pollution.” State University of New York, School of Public Health, Student Poster Day. April, 2005.

Student support: Jacqueline Lendrum, University at Albany, School of Public Health, Department of Environmental Health and Toxicology. Ph.D. expected December, 2005.

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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:	2/28/2004
Funding Source:	104B
Congressional District:	22
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Floods, Water Quality
Descriptors:	stormwater, flooding, water quality, climatological data
Principal Investigators:	Arthur T. DeGaetano

Publication

1. DeGaetano, A, 2004, Web site: Suite of climatological products is available in an electronic atlas. Access via the Internet at

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

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) 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) A composite set of extreme rainfall intensity-duration curves will be computed for each subregion.

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) The analyses in Objectives 3 and 4 will be repeated to account for the combined volume of snow melt and rainfall.

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

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. Partial2 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 is 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/>

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:	9/30/2004
Funding Source:	104B
Congressional District:	27
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Hydrology
Descriptors:	Non Point Pollution, Water Quality, Hydrology
Principal Investigators:	Tao Tang

Publication

1. Bruce, Ian, 2005, GIS based spatial analysis of antibiotics contamination in the surface waters, MS Thesis, Department of Geography and Planning, Buffalo State College, Buffalo, NY
2. Tang, Tao, I Bruce, and M Dolce, 2004, GIS based topological analysis of pollution contributing factors in the Buffalo River drainage Basin, Presentation, NYS GIS Conference, Rochester, NY.

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

1. Introduction

The objective of this research is to provide local government officials with two kinds of information based on GIS mapping, modeling, and analyses in combination with field observations for urban storm water management. These are:

a. Where and how much urban storm water runoff is generated during the urban storm runoff events?
b. Which of the five SMP (Storm water Management Practice) tools provided by EPA and New York State DEC would be most suitable for the storm water detention and clean up in a particular storm water catchment (SWC) with respect to the five feasibility criteria?

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, suitable storm water management practice (SMP) tools will be proposed through the spatial analysis of five screening factors. These suggestions for each of the SWCs will be proposed by mapping and analyzing the major parameters of five screening (feasibility) factors: Land Use, Physical Feasibility, Watershed/Regional Factors, Storm Management Capability, and Community and Environmental Factors.

2. Methods and Approaches

2.1 Delineation of storm water catchments in the Buffalo River Drainage Basin

Storm water catchments of the lower Buffalo River watershed were delineated using original Digital Elevation Models (DEM) from the US Geological Survey (USGS) with 10 meter resolution. The merged DEM quadrangles were trimmed by drainage divide polygon using map algebra in the ArcGIS Spatial Analyst. Merged DEM model in the drainage basin was used to generate flow accumulations and river network. The ArcHydro extension in ArcGIS was applied for the delineation of the river network, storm water catchments, and topology of runoff flow directions using the DEM model.

DEM cells were reconditioned to incorporate the previously identified river drainage system from aerial photographs and hydrological base maps. Threshold of 0.5% grid cells was adopted in this study for river flow generation. Entire drainage network is connected topologically with from-node and to-node that designate the drainage direction. Outlet points for each of the catchments were also identified in the ArcHydro model, called drainage points. 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 and 2). The delineated catchments are topologically connected in terms of river drainage network.

2.2 Compiling of land use map

The detail land use classification and mapping in the Buffalo River drainage basin were conducted using true color digital orthographic air-photographs taken in 2002. The orthographic air-photos were obtained from the office of New York State GIS clearing house. A variety of land use or land cover classification schemes were published. In general, these can be classified into two categories: (1) land use planning and human activity related systems, such as real property classification for tax assessment (Erie County of Environment and Planning, 1997); (2) natural resource inventory and land cover identification system, such as LUNR-New York State Land Use and Natural Resource Inventory (Hardy et al., 1971).

The land use classification scheme in this research was developed using Land-Based Classification Standards (LBCS) established by American Planning Association (APA) and American Institute of Certified Planners (AICP) (APA, 1999). Land-Based Classification Standards provide a consistent model for classifying land uses based on their characteristics. The standards are based on a multi-dimensional land-use classification model. The LBCS provides comprehensive schemes and flexibility of sharing information across different disciplines. There are five dimensions in this system. These are: activity, function, structure, site development characteristics, and ownership. Land use types are organized in a set of criteria in each of the dimensions.

The land use classification scheme in this study was established from structure and function dimensions of LBCS system. Structure refers to the type of structure or building on the land. Land-use terms embody a structural or building characteristic, which suggests the utility of the space (in a building) or land (when there is no building), such as single-family house, office building, warehouse, hospital building, or highway etc. Function refers to the economic function or type of establishment using the land. Every land use can be characterized by the type of establishment it serves, such as agricultural, commercial, industrial, relate to enterprises (LBCS research group, 2003). The land use classification scheme is shown in Table 1.

2.3. Impervious surface cover delineation from land use classification and mapping

The mean impervious surface covers in each of the catchments were calculated for each of the land use types using the percentage index developed by Cappiella and Brown (2001). The percentage index scheme is shown in Table 2.

Impervious land cover scheme for the Buffalo River watershed was calculated by relating land use categories to the impervious cover scheme from the Center for Watershed Protection (Cappiella and Brown, 2001). The relations are shown in Table 3. Mean impervious cover values that were listed as a range were averaged. Many of the values were combined and averaged to account for land-use categories that were not explicitly listed in the table. Table 3 details the revised impervious cover estimates for the land-use classification system used in our study.

Land Use Classification Scheme: STRUCTURE/FUNCTION Dimensions	
Structure 1000: Residential buildings	
Structure 1100:	Single-family buildings
Structure 1200:	Multifamily structures
Structure 1300:	Other specialized residential structures
Structure 2000: Commercial buildings and other specialized structures	
Structure 2100:	Office or bank building
Structure 2200:	Store or shop building
Structure 2210:	Shop or store building with drive-through facility
Structure 2220:	Restaurant building
Structure 2230:	Standalone store or shop building
Structure 2240:	Department store building
Structure 2270:	Gasoline station
Structure 2280:	Automobile repair and service structures
Structure 2500:	Malls, shopping centers, or collection of shops
Structure 2600:	Industrial buildings and structures
Structure 2610:	Light industrial structures and facilities
Structure 2615:	Laboratory or specialized industrial facility
Structure 2620:	Heavy industrial structures and facilities
Structure 2621:	Assembly and construction-type plants
Structure 2622:	Process plants (metals, chemicals, etc.)
Structure 2630:	Oil refinery facility
Structure 2700:	Warehouse or storage facility
Structure 3000: Public assembly structures	
Structure 3300:	Sports stadium or arena
Structure 3400:	Exhibition, convention, or conference structure
Structure 3900:	Passenger assembly
Structure 3920:	Airport terminal
Structure 3930:	Bus terminal
Structure 3940:	Train station
Structure 3950:	Harbor or port terminal
Structure 4000: Institutional or community facilities	
Structure 4100:	Medical facility
Structure 4200:	School or university buildings
Structure 4500:	Public safety-related facility
Structure 4700:	Cemetery, monument, tombstone, or mausoleum
Structure 5000: Transportation-related facilities	
Structure 5100:	Linear or network feature
Structure 5130:	Highways and roads
Structure 5131:	Principal arterial--interstate
Structure 5132:	Principal arterial--freeway and expressway
Structure 5150:	Railroads, including monorails, etc.

Structure 5160:	Waterways
Structure 5500:	Water transportation or marine related
Structure 5600:	Air and space transportation facility
Structure 5610:	Runway
Structure 5700:	Railroad facility
Structure 6000: Utility and other non-building structures	
Structure 6200:	Water-supply-related facility
Structure 6270:	Water treatment and purification (WTP) facility
Structure 6300:	Sewer and waste-related facility
Structure 6320:	Landfill facility
Structure 6340:	Hazardous waste storage facility
Structure 6350:	Sewer treatment plant
Structure 6400:	Gas or electric power generation facility
Structure 6430:	Power generation plants
Structure 6450:	Geothermal facility
Structure 8000: Sheds, farm buildings, or agricultural facilities	
Structure 8100:	Grain silos/storage structures for grains and agricultural products
Structure 8200:	Livestock facility
Structure 8210:	Dairy facility
Structure 8220:	Poultry facility
Structure 8230:	Cattle facility
Structure 8500:	Greenhouses
Structure 8900:	Other farm and farming-related structures
Function 9000: Agriculture, forestry, fishing and hunting	
Function 9100:	Crop production
Function 9110:	Grain and oilseed
Function 9120:	Vegetable farming or growing services
Function 9130:	Fruits and trees
Function 9400:	Forestry and Logging
Function 9410:	Logging
Function 9420:	Forest nurseries
Function 9500:	Pasture/Grasslands
Function 9600:	Wetlands
Function 9900:	Unclassifiable function
Function 9910:	Not applicable to this dimension
Function 9990:	To be determined
Function 9999:	To be determined

Table 1. Land Use Classification.

Land Use Category	**Mean Impervious Cover (%)**
Agriculture	2%
Open Urban Land	9%
2 Acre Lot Residential	11%
1 Acre Lot Residential	14%
½ Acre Lot Residential	21%
¼ Acre Lot Residential	28%
1/8 Acre Lot Residential	33%
Town-home Residential	41%
Multifamily Residential	44%
Institutional	31-38%
Light Industrial	50-56%

Commercial	70-74%

Table 2. Impervious land cover index (after Cappiella and Brown, 2001).

Table 3 Revised Mean Impervious Cover Percentage relating to Land Use		
Land-Use Code (APA)	**Analogous Land-Use Code(s) (Table A.3)**	**Mean Impervious Cover**
1000	[0.5 Acre, 0.25 Acre, 0.125 Acre] (*Average*)	0.273
1100	[0.5 Acre, 0.25 Acre, 0.125 Acre] (*Average*)	0.273
1160	[2 Acre, 1 Acre] (*Average*)	0.125
1200	Multifamily Residential	0.44
1300	Town-home Residential	0.41
2000	Commercial	0.72
2600	Light Industrial (*Low Value*)	0.48
2620	Light Industrial (*High Value*)	0.59
2621	* Estimation	0.7
2622	Light Industrial (*Average*)	0.535
3000	Open Urban Land	0.09
5000	* Estimation	0.9
5160	NONE	0
6280	NONE	0
6299	NONE	0
8900	Agriculture	0.2
9100	Agriculture	0.2
9400	* Estimation	0.01
9500	Agriculture	0.02
9510	[Agriculture, Open Urban Land] (*Average*)	0.055
9600	NONE	0

2.4. Water quality volume (WQv) calculation and mapping

Water quality volume (WQv) is the volume (acre-feet) of accumulated storm water runoff in an area. The WQv for each of the storm water catchments (SWCs) was computed by applying the New York State DEC storm water runoff size prediction model. The model is as follows.

$WQv = [(P)\ (Rv)\ (A)]/12.$

P is 90% rainfall event number as showing on the New York State Department of Environmental Conservation (NYSDEC – New York State Storm water Management Design Manual, 2002). $Rv = 0.05 + 0.009(I)$, where I is the percentage of impervious land cover. A is the calculated area in acres.

The Rv was calculated for each of the land use type identified in the entire Buffalo River watershed using the impervious land cover values – I. Then, it was aggregated by each of the catchments. Areas (A) of each of the catchments were computed using GIS database. WQvs were mapped for the 26 storm water catchments in the lower Buffalo River watershed.

2.5. Field sampling and water sample analyses

Field sampling and analyses were conducted for two rainfall storm events and one base flow environment (dry weather) during the summer of 2004. The purpose of these field samplings is to incorporate field data into the GIS based mapping and spatial analysis. Modification of field sampling was made from the catchments to the confluences or drainage points, because there were difficulties encountered for entering private properties and obtaining permissions for sampling during the storm event. Basic topology of the river network and connectivity of the catchments in the lower Buffalo River watershed were used to interpolate and map the percent contaminate loadings based on field data.

A total of seven sampling sites were selected in the lower and mid-reach of Buffalo Rivers. Five of them are located in the lower Buffalo River watershed, and two are located in the mid-reach area. These two sample sites serve as control points of baseline pollutant loadings from upper and middle areas of the watershed. The sampling sites and their locations are shown in Table 4.

Field Sampling Records		**GPS Location**		**Sampling Date**	**5/24/2004**	**5/27/2004**	**6/15/2004**
	Street Location	**UTM-WGS84**		**Catchment Unit Location**	**High Storm Event**	**Low Storm Event**	**Dry Weather Flow**
		Easting	**Northing**				
Site # 1	Erie Basin Marina	672945.04	4749477.60	Drain of Buffalo River to Lake Erie	101	201	301
Site #2	Bailey Ave.	677540.68	4747690.21	Cazenovia/Buffalo River Confluence	102	202	302
Site #3	Harlem/ Clinton Rd.	677985.16	4747981.59	Buffalo Creek/Buffalo River Confluence	103	203	303
Site #4	Bowen St.	680740.93	4748781.65	Cayuga / Buffalo River Confluence	104	204	304
Site #5	Union Rd.	679533.93	4748159.38	Bottom Creek/Buffalo River	105	205	305

				Confluence			
Site #6	Highway 20A	692692.22	4737043.14	Cazenovia E/ Cazenovia W Confluence	106	206	306
Site #7	Back of Yoga Club Hunters Creek Rd.	702026.22	4738019.55	Hunters / Buffalo River Confluence	107	207	307

Table 4. Field sampling sites information

Water sample analyses were performed by the Erie County Health Laboratory. The water samples were delivered to the laboratory within a six-hour period after the field sampling. Seven major pollutant elements were analyzed for each of the seven sites and for each of the three field sample runs. These are:

1. Total Suspended Solids (TS)
2. Total Phosphorus (TP)
3. Total Nitrogen (TN)
4. Fecal Coliform (FC)
5. Copper (Cu)
6. Lead (Pb)
7. Zinc (Zn)

All of the samples were analyzed using the standard analytical methods from the US Environmental Protection Agency (EPA). All the pollutants were measured by mg/L except the Fecal Coliform (FC). Fecal Coliform was measured by numbers/L.

Annual storm water contaminate loads were calculated using the laboratory analytical results for each of the 26 lower Buffalo River catchments. The general hypothesis for load computation is that the pollutant concentration at a drainage outlet or drainage point along the Buffalo River should be contributed to by all the catchments above it, subtracted by dilutions or temporal detentions. Therefore, the loads can be estimated using the topologically connected spatial model generated from the ArcHydro extension in ArcGIS.

2.6. Delineation and mapping of physical feasibility factors

Physical feasibilities of five storm water management practice tools were analyzed: pond, wetland, infiltration facility, filtering facility, and open channel. The major factors considered are soil texture, water table, the drainage area in acres, and the slope within the quarter mile radius surrounding the drainage outlets of the 26 catchments in the lower Buffalo River watershed. Each of the above factors is ranked against a standard scheme of scores from 0 to 20. A score of 20 represents the most favorable feasibility, and a score of 0 represents the least favorable. The New York State Stormwater Management Design Manual (2003) was consulted for the ranking of the feasibility scores. The soil texture types are: very fine sandy loam (VFSL), silt loam (SIL), silty clay loam (SICL), mucky silt loam (MK-SIL) or mucky very fine sandy loam (MK-VFSL), loamy fine sandy loam (LFSL), gravel loam (GRL) or loam (L) , and urban land. The scores of the five storm water management tools are shown in Table 5.

SMP Group	VFSL (Very fine sandy soil)	SIL	SICL	MK-SIL or MK-VFSL	LFSL	Urban land (Empty, classified in urban	GRL or L
Pond	10	10	20	0	0	0	0
Wetland	10	10	20	10	10	0	0
Infiltration	20	20	0	0	20	10	0
Filters	20	10	0	0	20	10	10
Open Channels	10	0	0	0	10	0	0

Table 5. Soil texture feasibility score of five storm water management tools

The physical feasibility factor of water table was also derived from soil survey database. The lower the water table from the ground, the higher the score of a storm water management tool. Strom water management tools that have less impact to the ground water obtain relative higher scores given the presence of a shallow water table. In general, it is considered that if the water table is more than 3 feet deep, there is no impact of SWMP tools to the ground water (Table 6).

SMP Group	Less than 2 feet	2 – 2.5 feet	2.5 – 3 feet	More than 3 feet or Empty
Pond	0	10	20	20
Wetland	0	10	20	20
Infiltration	0	0	10	20
Filters	0	10	10	20
OpenChannels	0	10	20	20

Table 6. Ground water feasibility score

Physical feasibility of drainage areas in acres were derived from GIS spatial database of the Buffalo River watershed. According to the New York Storm Water Management Design Manual, different management facilities have different requirements for the drainage collection area. The scores are shown in Table 7.

SMP Group	20 acres or higher	10 – 20 Acres	5-10 Acres	Less than 5 Acres
Pond	20	20	10	0
Wetland	20	20	10	0
Infiltration	0	10	10	10
Filters	0	10	20	10
Open Channels	0	0	0	20

Table. 7. Drainage areas feasibility score.

Slope physical feasibility was derived from the slope map that was computed from digital elevation models (DEM). Only the slopes around the drainage outlets of the catchments were considered. Both the percentage of the slope and the slope angles were considered. Mean percent slope values were used when assigning scores. Any value not listed (ie; 5.5%) was assigned to the closest value. The feasibility scores are shown in Table 8.

SMP Group	15% (3 degrees) or higher	6-10% (1.5 - 2 degrees)	4% or less (1 degree or less)
Pond	0	10	20
Wetland	0	20	20
Infiltration	0	10	20
Filters	0	0	20
Open Channels	0	0	20

Table 8. Feasibility score of slope.

2.7. Delineation and mapping of watershed/regional factors

According to the New York State Storm Water Management Design Manual (2003), surface fresh water bodies, such as rivers, lakes, and ground water aquifers, must be protected from urban storm water contamination. Buffer zones were created along all the river channels and along the lake shore in this study to identify protection zones. The buffer distance on each side of the rivers, and surrounding the lake shores and sites of ground water aquifers, was selected as 250 feet or about 80 meters. There will be no storm water management tools or facilities built within these protection zones. Therefore, the scores of all of the five SWM tools were set to 0 within the buffer zone. The feasibility scores are shown in the Table 9.

SMP Group	Within 250 feet buffer zone	Out of the 250 feet buffer zone
Pond	0	20
Wetland	0	20
Infiltration	0	20
Filters	0	20
Open Channels	0	20

Table 9. Feasibility score of protection buffer zone with regional concerns

2.8. Delineation and mapping of storm water pollutant load and management capabilities

The annual stormwater pollutant loads of the seven major pollutants were calculated for the 26 catchments in the lower Buffalo River watershed using the "Simple Method" model (Schueler, 1987). The "Simple Method" model estimates pollutant loadings of a drainage area as a product of annual runoff volume and pollutant concentration of each of the chemical constituents. The model equation is as follows:

L = 0.226 * R * C * A (for TS, TP, TN, Cu, Pb, Zn). --------- 1A

Where: L = Annual Load (lbs)
R = Annual Runoff (inches)
C = Pollutant Concentration (mg/l)
A = Area (acres)

L = 103 * R * C * A (for bacteria, such as Fecal Coliform - FC) ----- 1B
Where: L = Annual Load (Billion Colonies)
R = Annual Runoff (inches)
C = Bacteria Concentration (1,000/ml)
A = Area (acres)

Where constant numbers of 0.226 and 103 are unit conversion factors. The annual runoff values (R) of the catchments can be calculated by following equation.

R = P * Pj * Rv --------------- 2

Where: R = Annual Runoff (inches)
P = Annual Rainfall (inches)

Pj = Fraction of Annual Rainfall Events that Produce Runoff (~0.9)
Rv = Runoff Coefficient

The runoff coefficient Rv can be estimated using the following equation. Where percentage impervious land cover (or impervious fraction – Ia) can be calculated with detailed land use mapping as indicated in the previous section.

$Rv = 0.05 + 0.9(Ia)$ ------------- 3

Where: Rv = Runoff Coefficient
Ia = Impervious Fraction (as decimal, between 0.0 and 1.0)

The annual loads calculations were based on the detail land use mapping applying LBCS system. The impervious fraction (Ia) was calculated for each of the land use polygons based on the established relationships of land use and impervious cover (Table 3) of this report. The distribution of average annual precipitation in the Buffalo River drainage basin was obtained from Cornell University Geospatial Information Repository (CUGIR). The dataset was originally collected by the New York State weather forecasting network, and it is a 20 year average. Two separate computations of loadings were conducted. One is called theoretical loadings that were calculated from average values of previously measured concentrations across the United States (Bannerman, 1993; Claytor and Schueler, 1996; Steuer et al., 1997; Waschbusch, 2000). The average pollutant concentrations for different urban land use types are listed in Table A.2 within the New York State Storm Water Management Design Manual (2003). The other computation of loadings is based on the results of field sample analyses, and it is simply called the calculated loadings.

Annual rainfall distribution map layer in GIS was overlaid on to the land use polygons to calculate the annual runoff using the equation (2) of the "Simple Method" model. The areas of the land use polygons were calculated in GIS. Knowing area calculations were in square meters because the map layer is in UTM projection, acreage was derived by dividing the area values by 4,047 (converting factor) for each of the polygons. The load of each of the land use polygons was calculated then using the equations 1A or 1B of the "Simple Method" model. Concentrations of total nitrogen, total phosphorus, and total suspended solids for agricultural and forested land uses were decided based on the average values from previously published literatures (Kelly et all, 1991; Moore and Truesdale, 1995; Muhammetoglu and Van den Brink, 1997). The eighty-six catchments were overlaid onto the land use layer to aggregate the average percentage of impervious land covers (Ia) and pollutant concentrations to the catchment level.

The values within each catchment were either summed or averaged depending on its type; all load values were summed, acreage and area were summed, runoff coefficient was summed, water quality volume was summed, percent impervious was averaged, and annual rainfall was averaged. The result was a single shapefile of the Buffalo River watershed in GIS showing eighty-six catchment polygons. Each of these catchments have theoretical pollutant loadings, annual runoff, runoff coefficient, average annual rainfall, mean impervious fraction, and water quality volume data.

Since seven sites were sampled in the lower Buffalo River watershed instead of sampling from each of the eighty-six individual catchments, pollutant loads values were computed for the drainage areas of these seven sites for both theoretical concentrations from previous studies across the nation, and the field measured concentrations from the Buffalo River. Two assumptions were made to support this approach. First, the chemical concentrations at seven drainage outlet points are the collected effect of the drainage area above the points. Therefore, it can be used to estimate the annual storm water pollutant loads from the drainage areas. Secondly, the storm water pollutant loadings from the catchments can be calculated by subtracting the storm event loads by the baseline loads (non-event or dry weather).

Measured concentrations were used to calculate loadings for all seven locations and for all three days of sampling. Each day of sampling represented different flow situations; high flow, low flow, or baseline flow. The net high storm event was represented by subtracting the baseline flow calculated loadings from the high flow calculated loadings. The net low storm event was represented by subtracting the baseline flow calculated loadings from the low flow calculated loadings. The mean of the two, the net low storm event and the net high storm event, was then calculated.

Regression Analysis was used in the Microsoft – Excel to correlate the calculated values from field sampling with the theoretical values. The theoretical values served as the independent variable, and the mean of the net high storm event and net low storm event values served as the dependent variable. The resulting slope of the regression line was used to adjust the calculated loadings to values that are more representative of real-world measured data. In terms of scoring the storm water management capability, it was assumed that every catchment less than the mean annual load of all 26 lower Buffalo River catchments (L) or WQv will obtain 100% effective removal (20 score). The scores for those catchments that have higher than the mean load or WQv are shown in Table 10.

SMP Group	TSS Removal >= Mean L (lb) of all the 26 catchments [<Mean L]	TP Removal >= Mean L (lb) of all the 26 catchments [<Mean L]	TN Removal >= Mean L (lb) of all the 26 catchments [<Mean L]	Bacteria Removal >= Mean L (lb) of all the 26 catchments [<Mean L]	Metals Removal >= Mean L (lb) of all the 26 catchments [<Mean L]	Large WQv >= Mean – (Acre-feet) [<Mean L]
Pond	10 [20]	10 [20]	10 [20]	10 [20]	10 [20]	10 [20]
Wetland	10 [20]	10 [20]	10 [20]	10 [20]	0 [10]	10 [20]
Infiltration	0 [5]	10 [20]	10 [20]	10 [20]	10 [20]	0 [5]

Filters	0 [5]	10 [20]	10 [20]	0 [10]	10 [20]	0 [5]
Open Channels	0 [5]	10 [20]	0 [10]	0 [0]	10 [20]	0 [5]

Table 10. Feasibility scores of pollutant loadings and storm water volume - WQv.

2.9. Delineation and mapping of community and human activity related factors

The community and environmental factor was divided into three sub-factors. These are affordability, safety, and community acceptance. The affordability was derived from average household income. Safety was derived from the demographic data from population of age 18 or younger. Both of them were aggregated from the US Census Bureau Tiger files at block group level. Community acceptance was designed by a mail survey to six households in each of the lower Buffalo River watersheds. However, only 15 of the 156 surveys were responded, and only six of the 15 responded surveys were address identified. After evaluating the survey results of the questionnaires, it was reorganized that the survey does not represent the public opinions of the strom water management tools. Therefore, it was decided to omit the survey result in the final evaluations.

The feasibility scores of the sub-factors are shown in Table 11. Those catchments where the household incomes are lower than mean value of the 26 lower Buffalo River catchments were given the scores listed in the table, and those of them higher than the mean value were given the scores in the brackets. With respect to safety, those catchments with populations of age 18 or under greater than the mean value of the 26 lower Buffalo River catchments were assigned the scores listed. Those with lower than the mean of the 26 lower Buffalo River catchments were assigned the scores in the brackets.

SMP Group	Affordability < Mean house hold annual income of all 26 catchments	Safety > Greater than the mean age 18 or under
Pond	20 [20]	0 [10]
Wetland	10 [20]	0 [10]
Infiltration	10 [20]	20 [20]

Filters	0 [10]	10 [20]
Open Channels	10 [20]	20 [20]

Table 11. Sub-factors of community concerns

2.10. Suitability score assignment and total suitability score calculation for five SWM tools

The total suitability score for each of the storm water management practice (SMP) tools were calculated for each of the 26 lower Buffalo River catchments. The total suitability score was summarized from the scores of five feasibility factors using the following model:

$$Ssmpi = LU + PF + WR + SWMC + CE \quad \text{--------------} \; 4$$

Where: the Ssmpi is the total score for a particular SMP tool i; LU is the land use; PF is the physical feasibility, WR is the watershed and regional concerns; SWMC is the storm water management capability; and the CE is the community and environmental concerns.

Each of the feasibility factors was assigned a maximum score of 20. Therefore, the maximum score for Ssmpi is 100. The scores of sub-factors were averaged with equal weight for each of the feasibility factors. Then, the scores were added using the equation 4, and joined with the attribute table of the GIS map of the lower 26 catchments of the Buffalo River watershed.

2.11. Spatial location identifications of possible SWM tools in the lower Buffalo River watershed

Possible locations of storm water management tools in the 26 lower Buffalo River catchments were identified by overlaying map layers of land use, buffer of streams and lake shores, and slope on to the catchments map. The principal guidelines are as follows:

1. The sites of SWM tool must be close to the drainage outlet of the catchment in the drainage collection area.
2. The sites of SWM tool must be located on vacant land, natural vegetation covered land, or agricultural land use unless it is impossible to select these land uses.
3. The sites of SWM tool must be more than 250 feet away from the rivers and lake shores.
4. The sites of SWM tool must be located in gentle slope areas with favorable soil type.

3. **Results**

Stream network hydro-edges were generated with unique stream reach ID code using US Geological Survey 10 meter resolution digital elevation model (DEM) and the ArcHydro GIS extension. Stream flow directions and drainage outlet points for the catchments ware delineated on the drainage network map layer (Figure 1.). Each of the 86 catchments was delineated with the ArcHydro model, and 26 of them were identified as lower Buffalo River watershed catchments (Figure 2). The unique characteristic of this spatial model is the topological connections of the catchments and river network (Figure 3 and 4). The spatial model is ready to incorporate the map layers of five major feasibility factors to conduct forward and backward tracing.

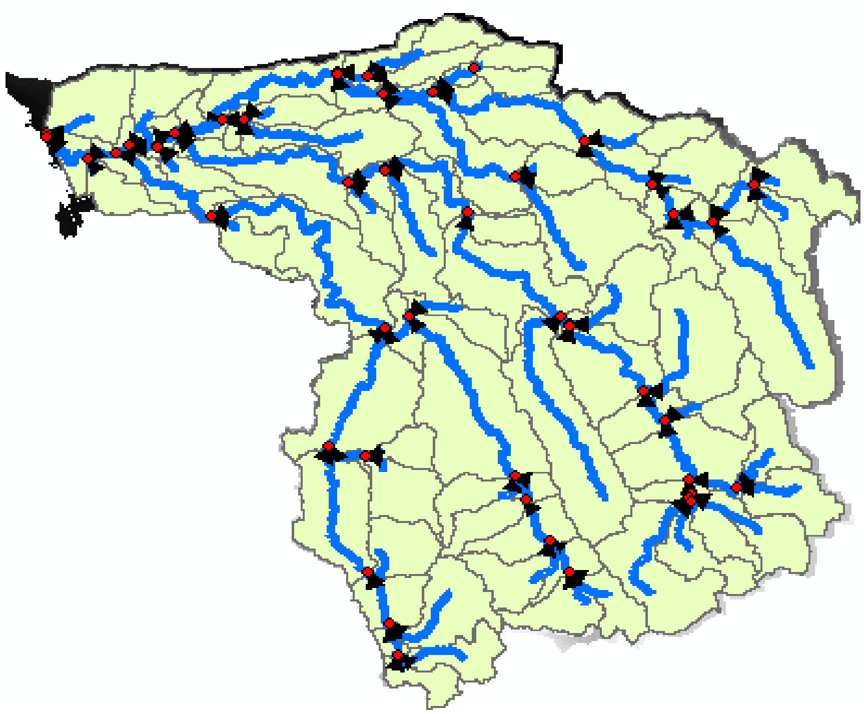


Figure 1. Stream flow direction and drainage outlet points of the Buffalo River catchments

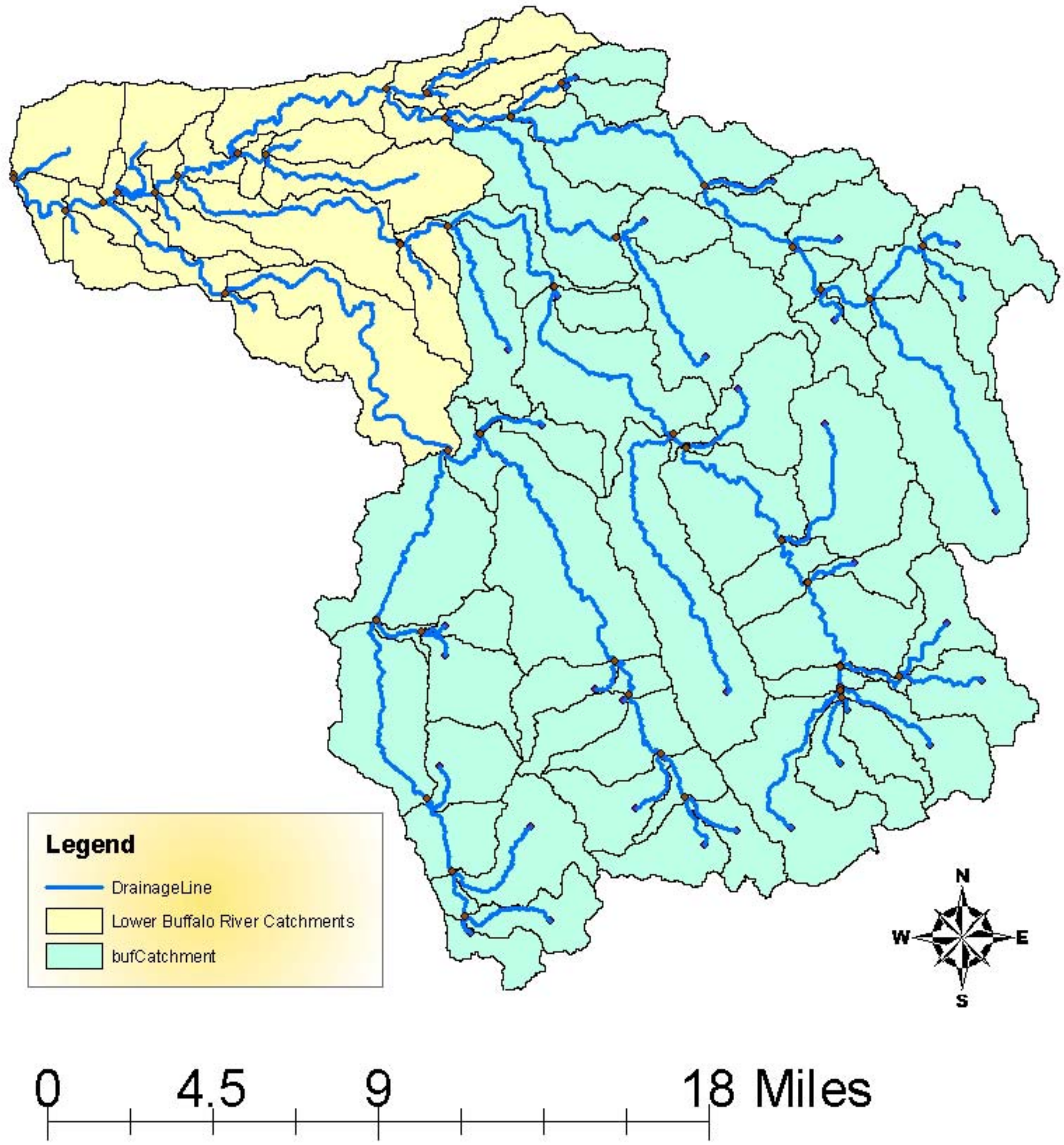


Figure 2. Catchment delineation in the lower Buffalo River watershed in comparison with entire drainage basin

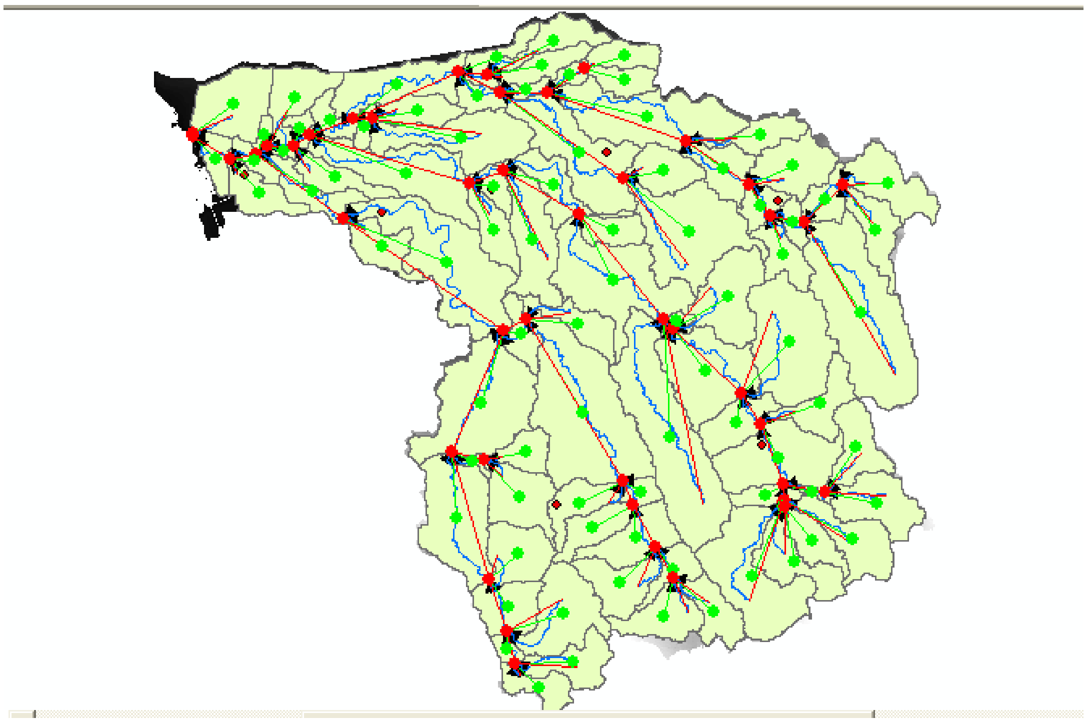


Figure 3. Schema links and schema nodes of the drainage network in the spatial model of Buffalo River watershed.

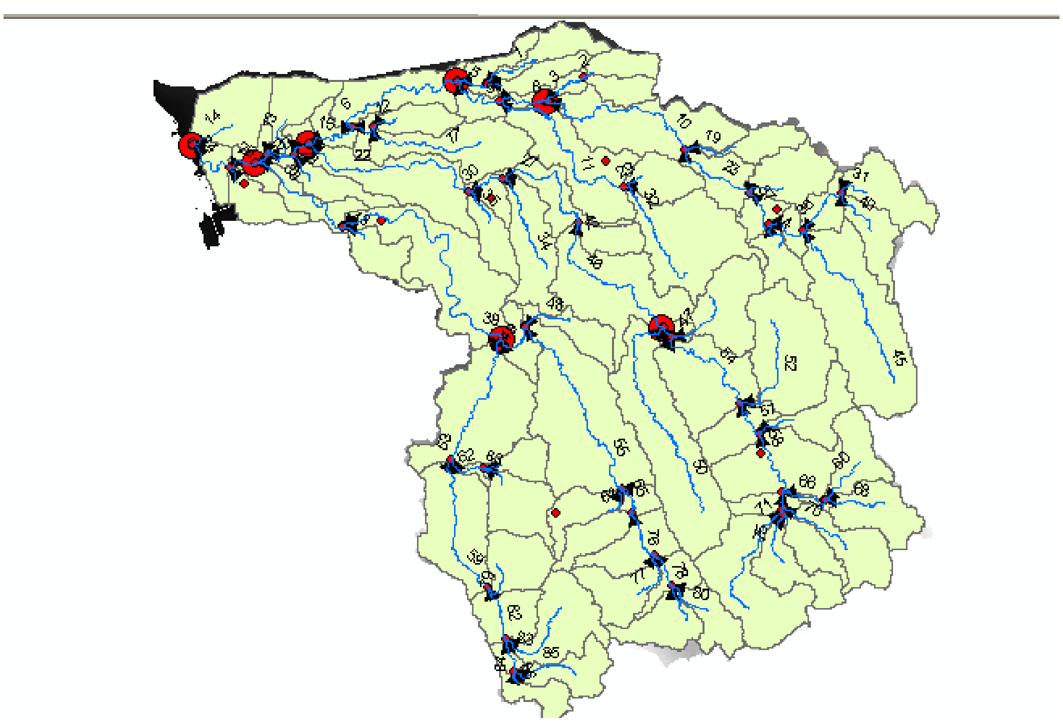


Figure 4. Nested catchments with drainage ID number. Sample sites are shown with large red dots.

Map layers of slope, flow direction, and flow accumulation in the raster format were generated from the USGS DEM with 10 meter resolution (Figure 5). Flow direction and accumulation were converted into vector format using the ArcHydro ArcGIS extension. However, the raster to vector conversion of the slope map layer and the process of merging polygons occupied very long computing time and very large computer hard drive space. Therefore, the conversion process was stopped until the faster and more efficient technology is available. Land use map applied the modified American Planning Association (APA) land based classification systems (LBCS) scheme with structure and function dimensions. The map was compiled using New York State 2002 true color digital orthographic aerial photographs with either one foot or two feet spatial resolution. A total of 8,640 land use polygons were generated for the entire Buffalo River drainage basin (Figure 6).

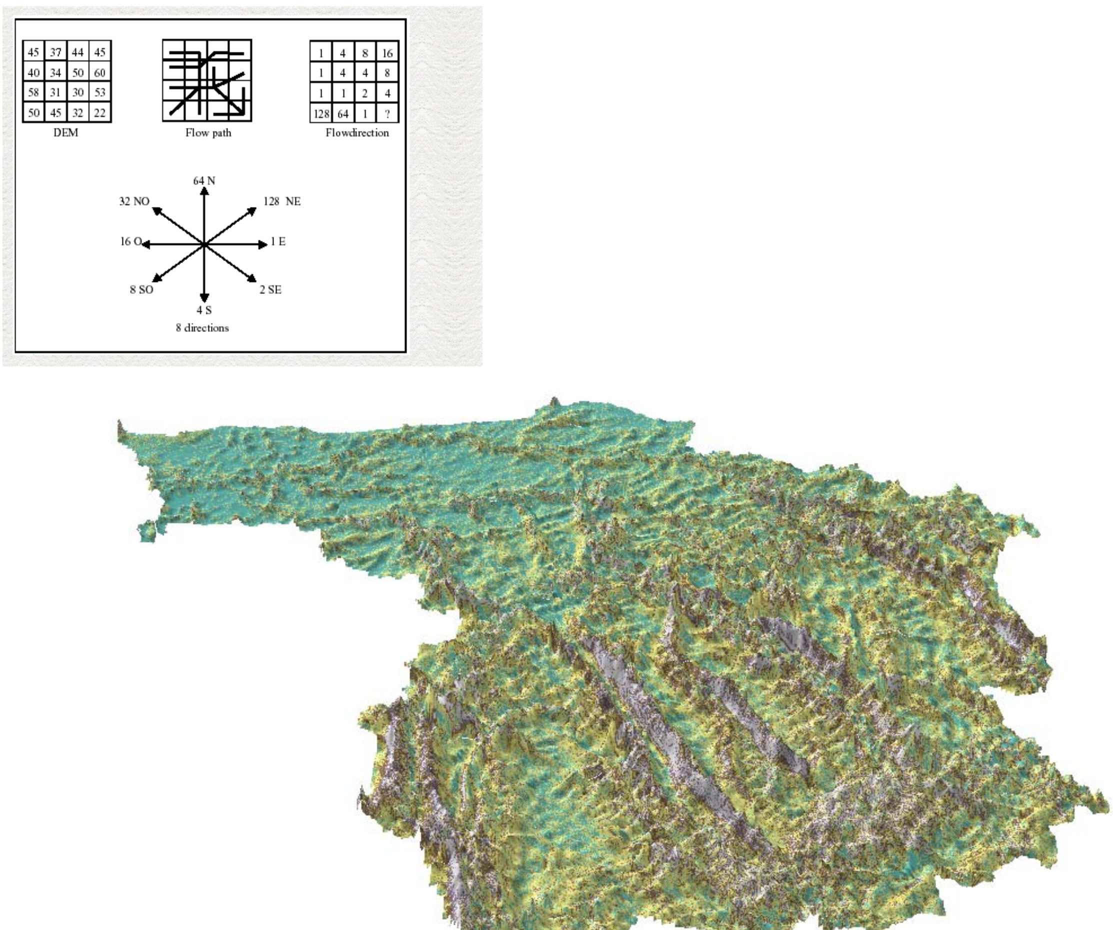


Figure 5. Raster flow directions and three dimensional view of slopes in the Buffalo River watershed.

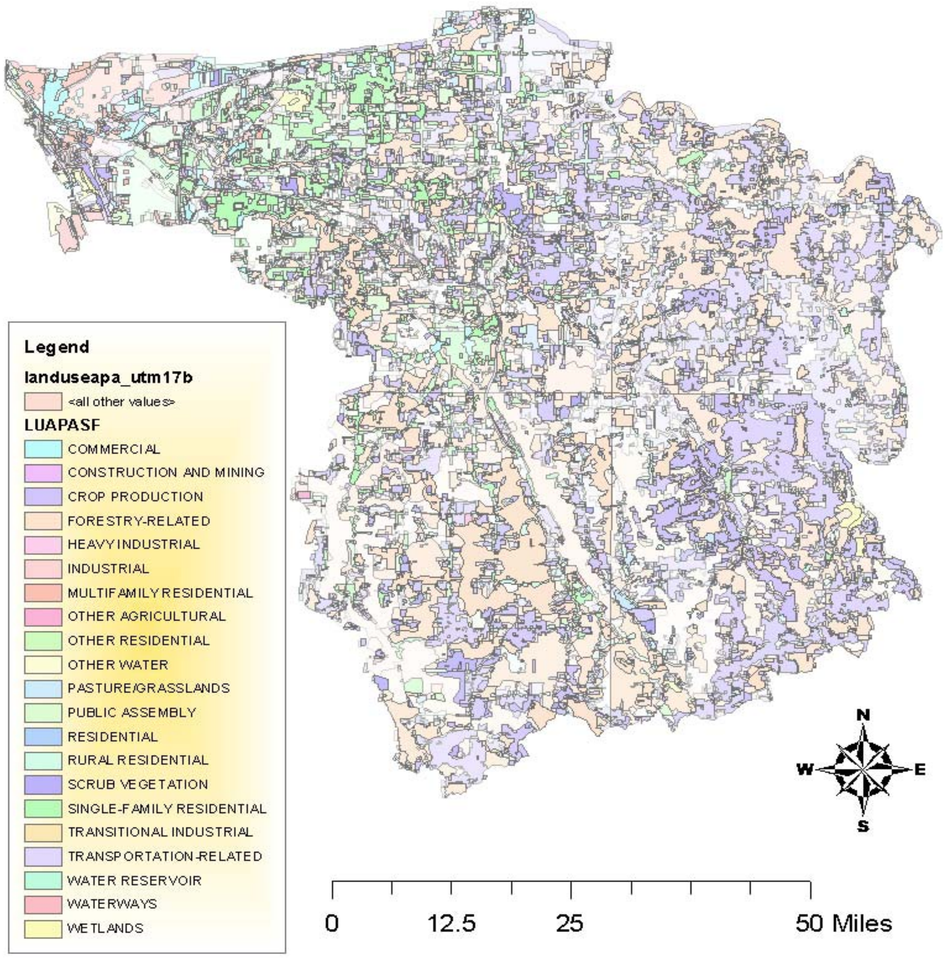


Figure 6a. Land use classification using APA Land Based Classification System (LBCS)

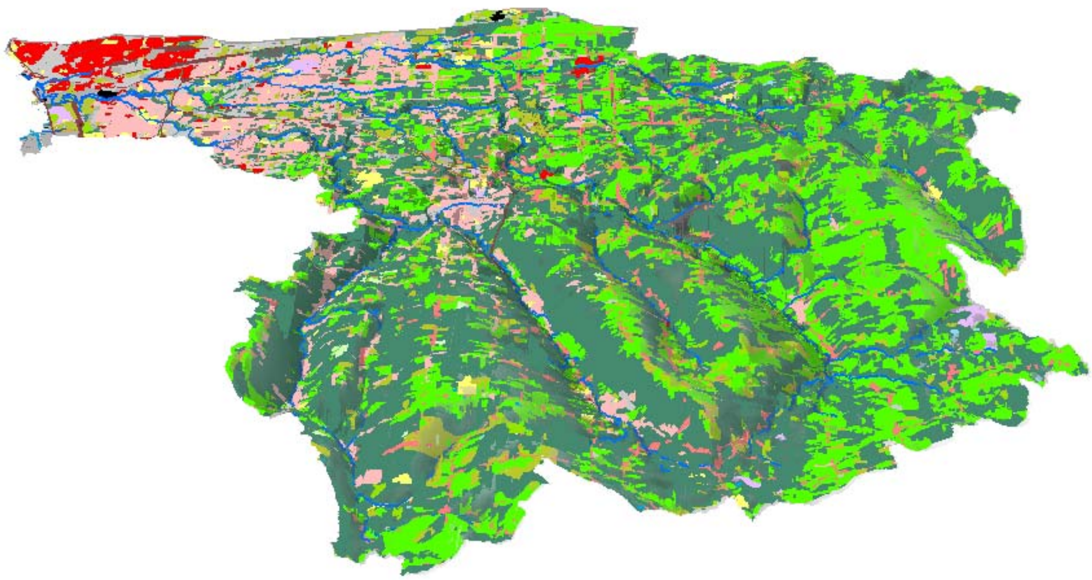


Figure 6b. Land use overlay on the digital elevation model (DEM) – red and pink colors indicate urban, commercial, and industrial land uses; - green and dark green indicate agricultural and natural vegetation.

Soil distribution map was compiled for the entire Buffalo River Drainage Basin. However, detailed soil classification and mapping (SSURGO) are only available in the lower and middle watershed areas that fall into the Erie County at this time. 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 7). Field sampling and measurement sites were selected from the drainage points or drainage outlets of the catchments. Seven sampling sites were selected in the lower Buffalo River watershed. Differential GPS surveys of these sites were conducted. The major pollutant loadings of TSS, TP, TN, Cu, Pb, Zn, and F. Coli were analyzed and interpolated using these seven sample points. (Figure 8).

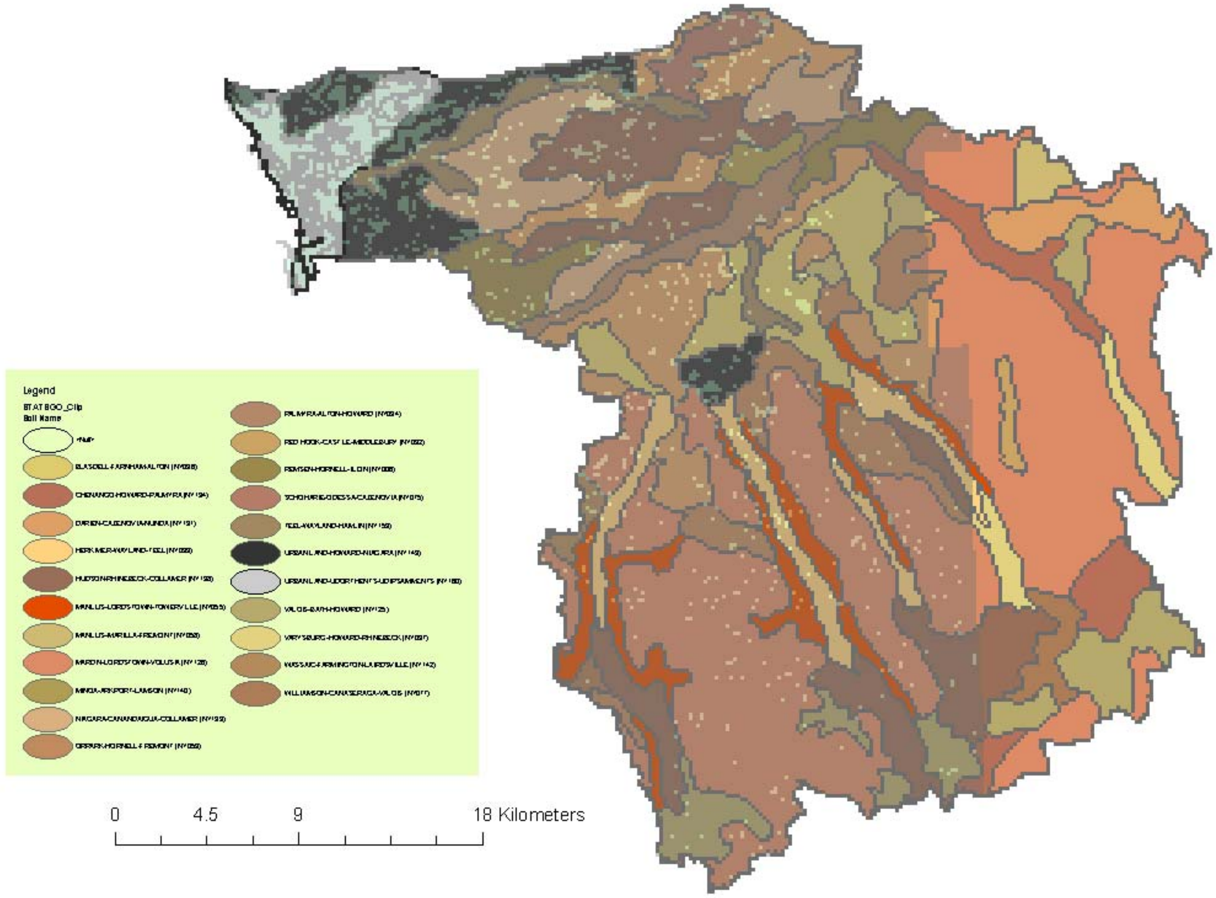


Figure 7. Soil Map in the Buffalo River Watershed (compiled with different levels of classifications SSURGO and STATSGO).

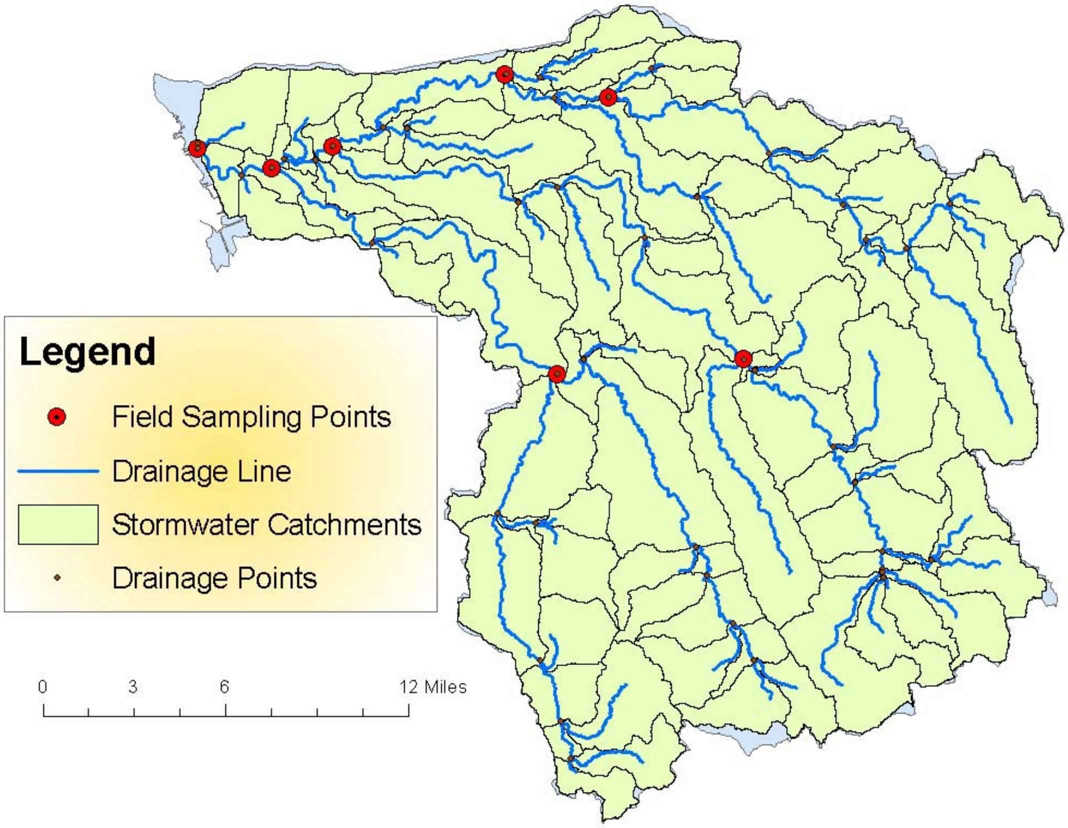


Figure 8. Field sampling sites in the lower Buffalo River watershed.

The analytical results of the seven pollutants sampled in the seven sites in the lower Buffalo River watershed are shown in the Table 1-3 in the Appendices. All the pollutant concentrations are in milligram or microgram per liter (mg/L or µg/L) except the bacteria of fecal coliform (FC) which is measured by numbers per liter. The results of high storm event are listed in the Table 1, that of the low storm event are listed in the Table 2, and the concentrations of base-line environment (dry weather) are listed in the Table 3.

The annual loads of the seven major pollutants for the seven sampled sites were calculated from two independent sets of concentrations (Table 4-6 in the Appendices). One is the average concentrations computed from the detailed land use map using the source and concentration table for different land uses from the New York State Stormwater Management Design Manual. The other is calculated from the field sample concentrations. Both of them were calculated using the "Simple Method" model equation 1A and 1B. The basic assumptions applied in these calculations are: 1) the annual loads of the pollutants at a drainage point should be the collection of loads of all the drainage catchments above that drainage point; 2) the net annual loads of storm water events from the catchments areas should be the results of annual storm water event loads subtracted by the annual base-line (dry weather) loads. The "theoretical loading" in the tables is the calculated annual loadings (lbs) from the average concentrations of previous studies (Bannerman, 1993; Claytor and Schueler, 1996; Steuer et al., 1997; Waschbusch, 2000) provided in the New York State Storm water Management Design Manual. The "calculated loading" (lbs) was directly calculated from the field sample concentrations. Total contributing areas were also calculated for these seven points using catchments base map in GIS.

Calculations of net high storm event and net low storm event are shown in Table 7 in the Appendices. The net mean of the storm event is the average of net high storm and net low storm events. Base-line or dry weather concentrations were applied to filter out the non-stormwater runoff loadings. However, the negative values of mean net storm event loadings were generated for total nitrate (TN); simply the measured concentration in the dry weather was higher than both high and low storm events. In response to thios discrepancy, an adjustment was made for TN. The original loadings of high storm and low storm were used to calculate the mean storm loads instead.

Regressions of the theoretical dataset and calculated dataset from field sample analysis were conducted for the seven major pollutants. The example of TSS, Cu, and FC are shown in Tables 8-10 in the Appendices. Excel statistical functions were used to perform the analysis and graph the results. The slope coefficient of the regression line was used to adjust the theoretical values of the 26 lower Buffalo River catchments in order to be more representative of the local environment. The annual runoffs of the 26 catchments in the lower Buffalo River watershed were calculated using Equation 2 in the "Simple Method" model (Figure 9). The annual storm water quality volumes (WQv) were calculated for the 26 lower Buffalo River catchments (Figure 10). WQvs are related to the areas of impervious land cover and the drainage area of the catchment. The former factor can be computed using the detailed land use map. The higher the percentage of the impervious land cover, the higher the WQv. In this study, the highest WQv occurs in Catchment 14 located in the downtown area in the City of Buffalo at the mouth of the Buffalo River. In general, the WQv decreases from the catchments in the mouth areas of the Buffalo River towards that of the upper reach, it also decreases as the catchment size decreases.

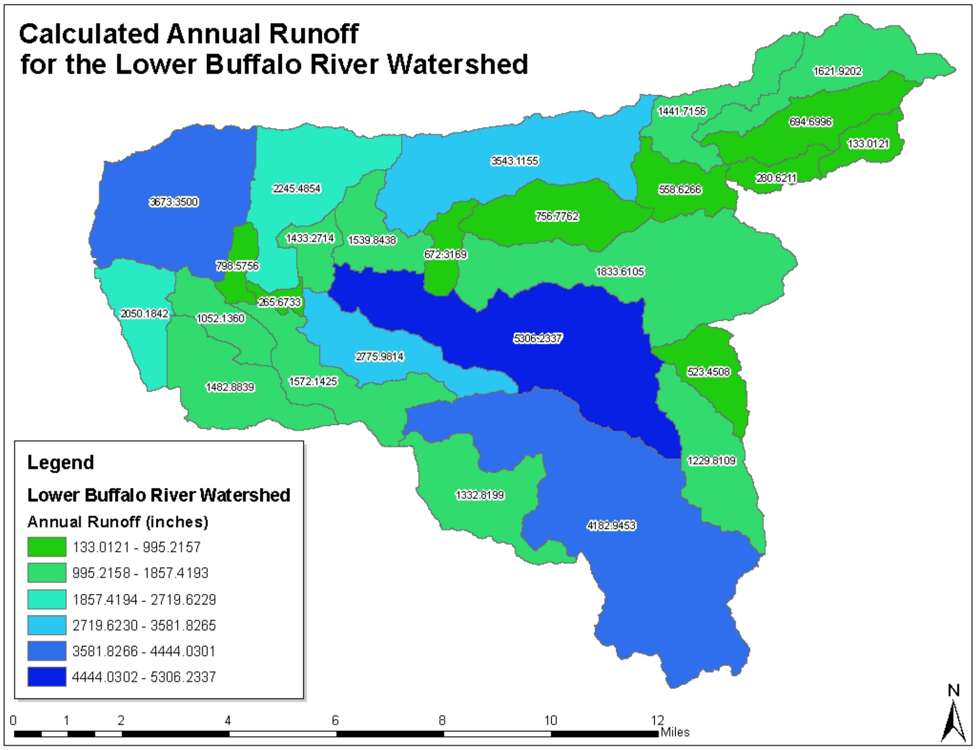


Figure 9. Annual runoff distribution in the 26 lower Buffalo River catchments

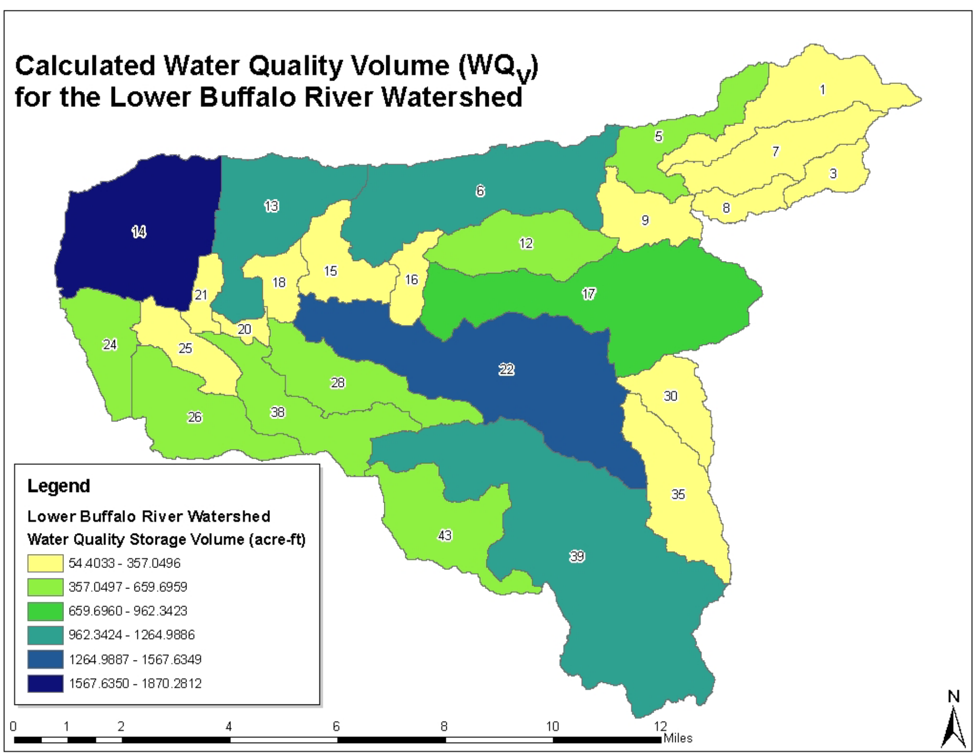


Figure 10. Water Quality Volume (WQv) of the 26 lower Buffalo River catchments in acre-feet

Suitability scores of five screening factors were calculated for each of the five storm water management (SMP) tools. Each of the screening factors was assigned to a maximum of 20 score. Some factors, such as physical feasibility (PF) were also subdivided into several sub-factors. The sub-factors of a particular factor were averaged to obtain the mean score of that factor. The example of the evaluation of five factors to the infiltration facility is shown in the Figure 11 (Others are in the Appendices.). The red color indicates the low suitability to a particular screening factor, and the green color indicates the high suitability to the factor. In general, the infiltration facility is more suitable to most of catchments in terms of land use types, physical feasibility, and watershed concerns. However, it is less suitable to storm water management capability and community concerns, in particular for those catchments with large drainage areas and for those that are located in the downtown low average income areas.

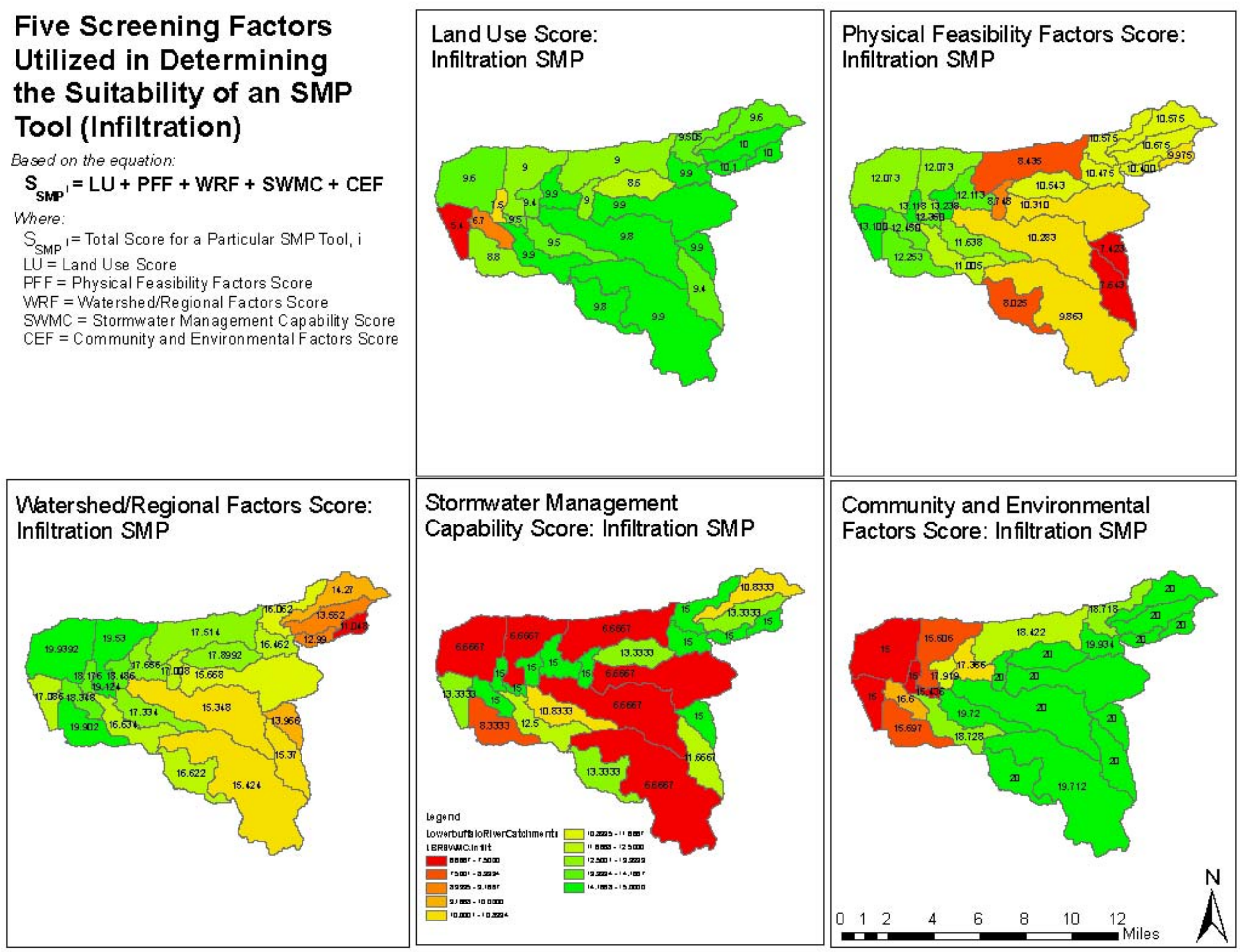


Figure 11. Five screening factors for a particular SMP tool – Infiltration Facility

The final scores of five different storm water management (SMP) tools summarized from five screening factors are shown in the Table 12. The maps of summary scores of the five SMP tools for each of the 26 catchments in the lower Buffalo River watershed are shown in Figure 13. The maximum suitability score is 100. The detention pond among the five SMP tool groups obtained the highest total scores for 25 of the 26 stormwater catchments. The infiltration facility obtained the highest score in catchment 14 (Figure 12). Catchment 14 is located in the downtown area within the City of Buffalo and north at the mouth of the Buffalo River. The most suitable and secondary suitable SMP tools are listed in Table 13.

Catchment ID	SMP_POND	SMP_WETLAND	SMP_INFILT	SMP_FILTERS	SMP_OPENCHAN
1	70.020	67.650	65.278	44.737	61.403
3	73.098	70.528	66.023	42.631	64.148
5	75.597	70.295	69.860	51.003	61.080
6	67.832	62.634	60.038	44.679	46.962
7	73.585	69.022	67.560	44.719	60.735
8	75.215	70.045	68.490	45.973	61.115
9	80.144	71.733	71.771	51.136	57.546
12	77.015	70.101	70.375	52.340	58.399
13	67.438	56.999	62.875	58.471	52.184
14	59.614	51.469	63.278	59.642	48.418
15	83.601	73.622	72.034	59.072	61.342
16	77.358	75.238	69.756	57.559	56.308
17	68.119	61.949	62.545	40.664	54.319
18	79.066	70.415	74.042	69.555	61.085
20	79.147	68.438	71.410	54.066	59.210
21	74.379	65.709	68.794	64.944	56.861
22	68.948	63.703	62.097	44.691	56.061
24	68.419	59.906	63.919	55.778	56.919
25	76.001	66.631	69.098	58.784	55.898
26	73.008	60.713	64.984	50.527	55.554
28	74.752	66.727	69.024	53.506	58.051
30	73.359	72.389	66.289	40.774	60.834
35	70.437	70.345	64.079	40.798	60.187
38	77.682	67.943	68.767	53.226	54.973
39	67.923	63.564	61.565	40.177	58.716
43	78.134	71.396	67.780	49.768	59.385

Table 12. The summary scores of the five storm management (SMP) tools for the 26 catchments in lower Buffalo River watershed.

Storm water management tools were suggested for each of the 26 catchments in the lower Buffalo River watershed. These suggestions are based on the screening scores, the major land use activities, and the natural environments (Table 13). Catchments 1 and 3 are located in the upper reach area of the lower Buffalo River watershed with mixed suburban and agricultural land use activities. Detention ponds or wetlands were suggested to these catchments. Catchments 5, 6, 7, 8, 9 and 12 are also located in the upper reach area with relative larger drainage areas and mixed suburban and agricultural land uses.

Detention ponds were suggested to these catchments. Catchments 13 and 14 are located in the downtown urban and near downtown suburban areas with high population density. The infiltration or filtering facilities were suggested. Catchments 15, 16, 17, 18, 22, 26, 28, 39, and 43 are located in the suburban to the near suburban agricultural areas. Detention ponds were suggested to them. Catchments 20, 21, 24, 25, and 38 are located in the urban and near suburban areas with relatively small drainage areas. Detention pond or infiltration facilities were suggested to theses catchments. Catchments 30 and 35 are located in the upper reach areas of the lower Buffalo River watershed with major agricultural activities mixed with suburban residential. The detention ponds or wetlands were suggested to them.

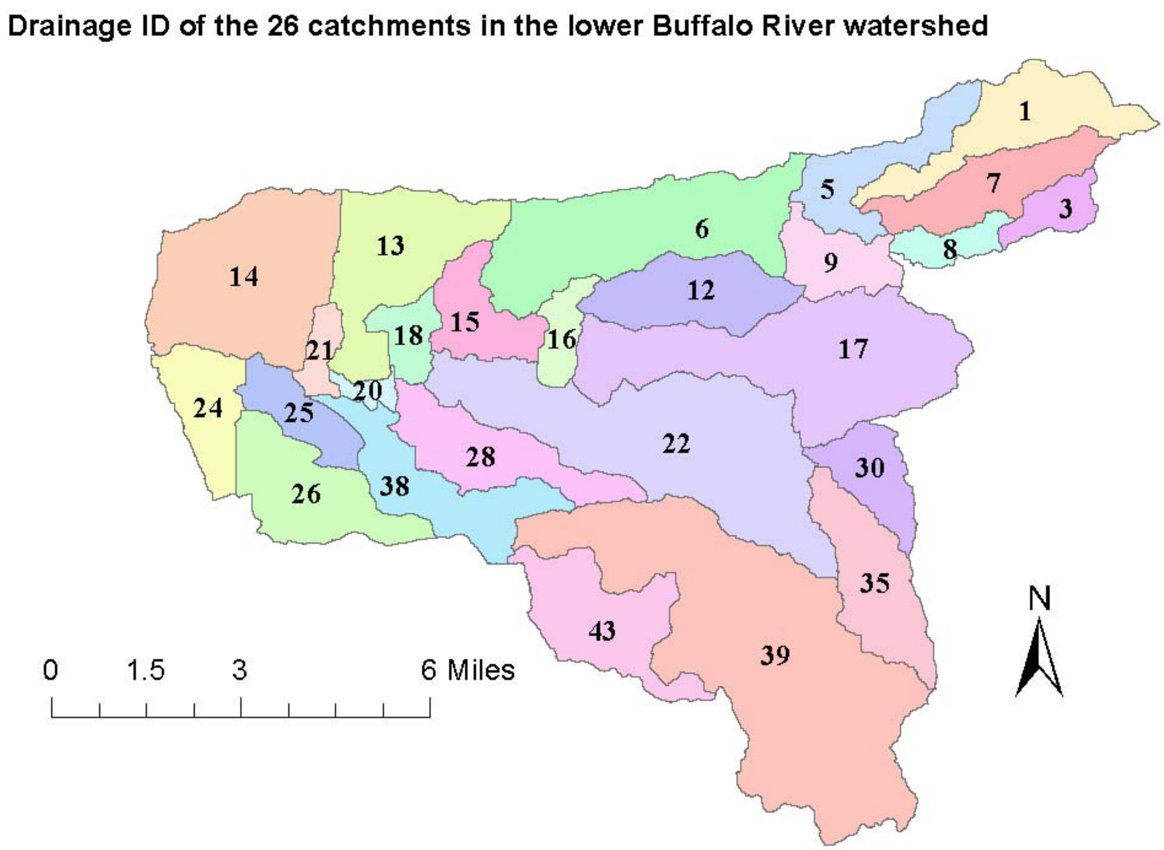
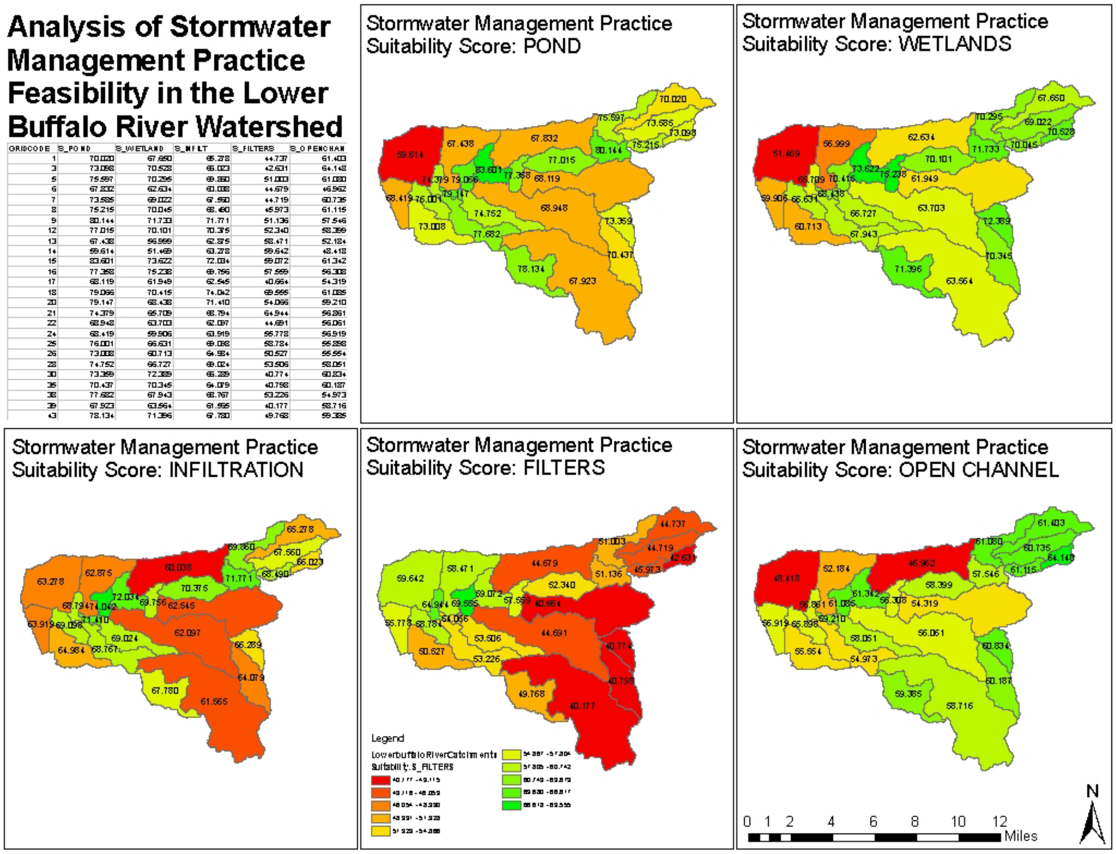


Figure 12. Drainage ID numbers of the storm water catchments model.



Analysis of Stormwater Management Practice Feasibility in the Lower Buffalo River Watershed

GRIDCODE	S_POND	S_WETLAND	S_INFILT	S_FILTERS	S_OPENCHAN
1	70.020	67.650	65.278	44.737	61.403
3	73.098	70.528	66.023	42.631	64.148
5	75.597	70.295	69.880	51.003	61.080
6	67.832	62.634	60.038	44.679	46.962
7	73.585	69.022	67.560	44.719	60.735
8	75.215	70.045	68.490	45.973	61.115
9	80.144	71.733	71.771	51.136	57.546
12	77.015	70.101	70.375	52.340	58.399
13	67.438	56.999	62.875	58.471	52.184
14	59.614	51.469	63.278	59.642	48.418
15	83.601	73.622	72.034	59.072	61.342
16	77.368	75.238	69.756	57.569	56.308
17	68.119	61.949	62.545	40.664	54.319
18	79.066	70.415	74.042	69.555	61.035
20	79.147	68.438	71.410	54.066	59.210
21	74.379	65.709	68.794	64.944	56.861
22	68.948	63.703	62.097	44.691	56.061
24	68.419	59.906	63.919	55.778	56.919
25	76.001	66.631	69.098	58.784	55.898
26	73.008	60.713	64.984	50.527	55.554
28	74.752	66.727	69.024	53.506	58.051
30	73.359	72.389	66.289	40.774	60.834
35	70.437	70.345	64.079	40.798	60.187
38	77.682	67.943	68.767	53.226	54.973
39	67.923	63.564	61.565	40.177	58.716
43	78.134	71.396	67.780	49.768	59.385

Figure 13. Suitability of five stormwater management (SMP) tools to the 26 stormwater catchments in the lower Buffalo River watershed.

CATCHMENT_ID	MOST_SUITABLE_TOOL	SECONDARY_SUITABLE	SUGGESTTED_TOOL
1	Pond	Wetland	Pond/Wetland
3	Pond	Wetland	Pond/Wetland
5	Pond	Wetland	Pond
6	Pond	Wetland	Pond
7	Pond	Wetland	Pond
8	Pond	Wetland	Pond
9	Pond	Infiltration	Pond
12	Pond	Infiltration	Pond
13	Pond	Infiltration	Pond/Infiltration
14	Infiltration	Filters	Infiltration/Filter
15	Pond	Wetland	Pond
16	Pond	Wetland	Pond
17	Pond	Infiltration	Pond
18	Pond	Infiltration	Pond
20	Pond	Infiltration	Pond/Infiltration
21	Pond	Infiltration	Pond/Infiltration
22	Pond	Wetland	Pond
24	Pond	Infiltration	Pond/Infiltration
25	Pond	Infiltration	Pond/Infiltration
26	Pond	Infiltration	Pond
28	Pond	Infiltration	Pond
30	Pond	Wetland	Pond/Wetland
35	Pond	Wetland	Pond/Wetland
38	Pond	Infiltration	Pond/Infiltration
39	Pond	Wetland	Pond
43	Pond	Wetland	Pond

Table 13. Most suitable and secondary suitable stormwater management (SMP) tools for the 26 catchments in the lower Buffalo River watershed.

Suitable storm water management (SMP) tool locations for each of the 26 catchments in the lower Buffalo River watershed were identified and suggested as shown in Figure 14. The major criteria that were used for the selection are land use, buffer zone of the rivers and lake shore, and slope close to the drainage outlet points of the catchments. Each of the selected sites must be close to the drainage outlet points in the catchment area. Each of the selected sites must be at least 250 feet away from the river channel or lake shore. That means the sites must out of the buffer zone of the rivers and lake shores. Regarding land use, the preferred types for the SMP sites are vacant land, agricultural land, and natural vegetation covered land. In situations where these land use types are not available in the designated areas, other land use types, such as residential land, were selected.

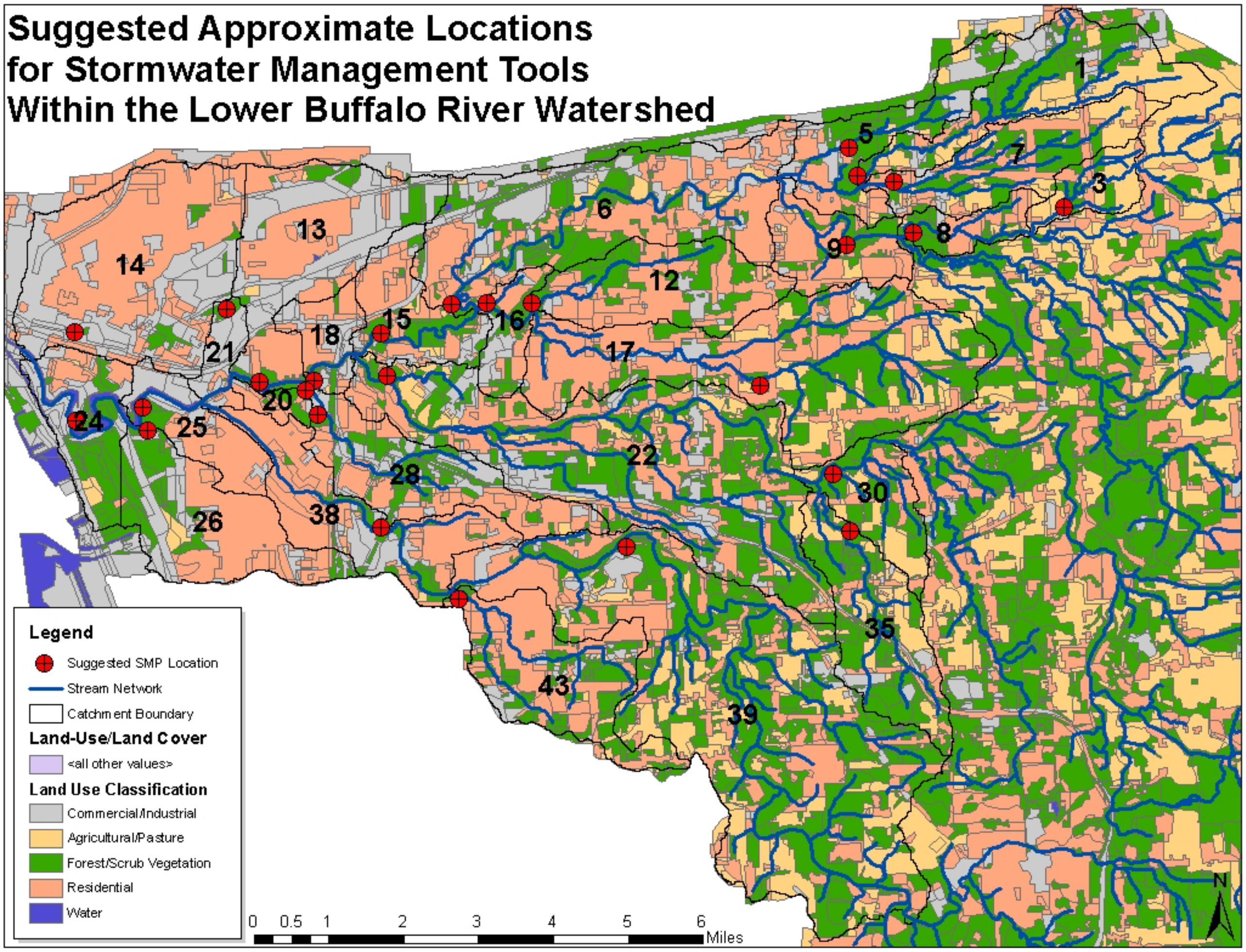


Figure 14. The suggested storm water management (SMP) tool locations for 26 lower Buffalo River watershed catchments.

4. Discussions

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

Owing to the limited funding from the grant, the field sampling was not extensive. Seven 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 particular, field sampling during the rainfall storm event are need in the 26 lower Buffalo River catchments in order to calibrate the "Simple Method" model for more precise prediction. In general, this project was mainly designed for Storm water influential factor mapping and interpolation, other than extensive sampling. Estimations were made for the spatial distributions of contaminate loadings from the comparison of the field sample of loadings in the lower reach of the Buffalo River watershed with that of the mid-reach area. The mapping and modeling work applying topology in this project was presented in the 2003 New York State GIS Conference in Albany. Some results of this study will be presented in the 2004 New York State GIS Conference.

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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,
Principal Investigators:	Janice E. Thies

Publication

1. Reilly, J.P., J.E. Thies, A. Baeumner, 2003, Development of an optical strip-assay biosensor for Enterococcus faecalis, American Society for Microbiology Annual Meeting, Washington, DC.
2. Hartel, P.G., S. Myoda, R.L. Kuntz, K. Rodgers, J. Entry, S. Ver Wey, E. Schroder, C.I. Castro, J.E. Thies, J.P Reilly and J.J. Fuhrmann, 2003, Geographic and temporal variability of Enterococcus faecalis ribotypes for bacterial source tracking, American Society for Microbiology Anual Meeting, Washington, DC.
3. Reilly, J.P., A.J. Baeumner and J.E. Thies, 2005, Detection of synthetic Enterococcus faecalis gene sequence by a strip-based optical biosensor, Journal of Environmental Quality, In press.
4. Hartel, P.G., S. Myoda, R.L. Kuntz, K. Rodgers, J. Entry, S. Ver Wey, E. Schroder, C.I. Castro, J.E. Thies, J.P. Reilly, and J.J. Fuhrmann, 2005, Geographic and temporal variability of Enterococcus faecalis ribotypes for facterial source tracking, Journal of Environmental Quality, In Press.
5. Reilly, Johm, 2005, Combining an optical strip-assay biosensor with ribotyping for microbial source tracking of Enterococcus faecalis in the lower Hudson River Basin, MS Thesis, Department of Crop and Soil Sciences, CALS, Cornell University, Ithaca, NY.

Title: Tracking of *Enterococcus faecalis* in the Lower Hudson River Basin

Overview

Determining the presence/absence of fecal bacteria and their sources continues to be important for water quality managers monitoring bacterial contamination of public water bodies. *Enterococcus faecalis* is a fecal bacterium used to indicate the potential presence of more pathogenic fecal bacteria in contaminated waterways. This bacterium is currently being tested as a means to distinguish contamination arising from humans and birds from that derived from other animals. Two complementary molecular methods for (i) bacterial detection and (ii) source tracking were developed and used in this project. An optical biosensor was developed to detect *Enterococcus faecalis* and ribotyping of isolates was used to fingerprint these bacteria and track their likely source.

Biosensor

The first project aim was to develop an inexpensive, portable, and accurate biosensor that could be used to confirm the presence of *Ent. faecalis* in impaired waterways. The biosensor developed in this project employs sulforhodamine B (SRB) dye-encapsulated liposome technology to generate a positive signal when the target 16S rRNA gene is present.

Experiments were conducted with synthetic sequences and subsequently with 16S rRNA gene sequences from environmental isolates. Two different target analytes were hybridized with liposomes that had single-stranded DNA oligonucleotides (reporter probes) attached to them. The lowest level of detection of 16S rRNA synthetic gene sequences for Analytes 1 and 2 was 14 fmol μL^{-1} and 19 fmol μL^{-1}, respectively. A dynamic range up to 5000 fmol μL^{-1} for both synthetic sequences was obtained. A genus-level primer pair was then designed to amplify a sequence of the 16S rRNA gene of *Enterococcus* spp. and used to test the ability of the biosensor to detect the target sequence in samples mimicking those from the environment.

To date, the biosensor has yet to detect successfully the target 16S rRNA gene sequence amplified from environmental isolates. Trouble-shooting involved testing for and ensuring a sufficient concentration of ssDNA for binding to the capture probe; testing for failure of the reporter probe to successfully bind to the liposome surface; and examining the sequence of the 400 bp amplicon from the environmental isolates for potential hairpins or steric hindrance that might preclude binding of the amplicon to the capture probe.

Perhaps the greatest obstacle to overcome for the practical, field-based application of any strip-based biosensor is the large amount of water that may need to be filtered to obtain sufficient quantities of DNA to detect a signal for the *Ent. faecalis* 16S rRNA gene. Despite protracted efforts to detect the target sequence from environmental samples, this is yet to be accomplished. However, the excellent success of the biosensor to detect synthetic sequences provides 'proof of concept' for the biosensor design. Once problems with detection of amplified *Ent. faecalis* isolate sequences are resolved, the biosensor should provide a powerful new tool for water quality managers to quickly and accurately detect and report water quality impairment in water bodies of interest.

Ribotyping

Ribotyping is a DNA fingerprinting method that is used to compare the genetic similarity between samples of varying origin. Ribotyping of *Ent. faecalis* was employed to determine the similarity between 16S rRNA gene restriction fragment length polymorphism (RFLP) patterns derived from isolates obtained from two wastewater treatment facilities (Tivoli, NY and Wappingers Falls, NY) and those obtained from upstream and downstream grab samples.

Ribotype patterns obtained from *Ent. faecalis* isolates from the two NY sites clustered separately from each other indicating distinct geographic separation. However, within sites, there was evidence of the presence of resident ribotypes within each sampling time, but not between sampling times. These results confirmed the need for intense targeted sampling to track the potential source(s) of fecal contamination at the two NY sites. On the first 3 of 4 sampling dates, *Ent. faecalis* ribotype patterns from the Tivoli wastewater treatment plant matched (>90% similarity) patterns generated from downstream isolates sampled at the mouth of the tributary to the Hudson River. This suggests that the plant may be a point-source of contamination in this tributary. For the Wappingers Falls site, at least one ribotype was observed downstream of the wastewater treatment plant in June, 2003, that matched (>90% similarity) to a ribotype from the plant, however, a similar ribotype pattern was also obtained from the upstream samples. Hence, the wastewater treatment plant was not the only source of human fecal contamination in this tributary.

Future efforts should be directed toward assuring that wastewater treatment plants in the region are designed to manage their current loads. When combined with intense targeted sampling, ribotyping proved to be an effective technique for detecting human fecal contamination in this watershed context.

Study Impact Summary

A prototype, species-specific biosensor that detects synthetic sequences of *Enterococcus faecalis* has been developed, providing proof of concept. Further development of this new technique should lead to production of a valuable tool for water managers that could be used to detect this indicator species in the environment. Isolating and ribotyping *Ent. faecalis* indicated the wastewater treatment plants were one, but not the only, source of these indicator bacteria in the catchments studied. This study confirms that ribotyping must be combined with a targeted sampling protocol in order to more specifically identify persistent and ephemeral sources of water contamination. This approach is a cost-effective alternative for the massive databases required by most other bacterial source tracking approaches.

Information Transfer Program

Director’s Office Information Transfer

Basic Information

Title:	Director’s Office Information Transfer
Project Number:	2004NY56B
Start Date:	3/1/2004
End Date:	2/28/2005
Funding Source:	104B
Congressional District:	26
Research Category:	None
Focus Category:	Management and Planning, Education, Law, Institutions, and Policy
Descriptors:	None
Principal Investigators:	Keith S. Porter

Publication

1. Porter, Keith S, 2004, Does the CAP fit? Rectifying Eutrophication in the Chesapeake Bay. The Journal of Water Law, Vol 15, Issue 5, p188-191.
2. Porter, M J, K, S Porter, H Cook, L Smith, A Bailey, K Hiscock, J Hillman, A Inman, and C Tawney, 2005, Building networks for a RELU capacity building programme: Exploiting options from the Eastern US and nearby European Continent, Proceedings from Workshop held at Imperial College London, Charing Cross Campus, Hammersmith, West London, UK, November 16-17, 2004.
3. Porter, M J, K Porter, and D Frazier, 2004-5, Linking Economic Interests, Water Quality and Sound Science, Progress Report, Delaware County Action Plan (DCAP), Department of Watershed Affairs, Delhi, NY, (in progress).
4. Porter, Keith S., 2004, The New York City Watershed Experience: A compelling example for the restoration and protection of water resources in their watershed context?, Presentation to the Cornell Law School Environmental Law students, Cornell University, Ithaca, NY.
5. Outreach Support Group, Upper Susquehanna Coalition, 2004, New York and the Chesapeake Bay: Should I be concerned? Outreach materials supporting voluntarily reducing nutrients in the headwaters to the Chesapeake Bay, Prepared by the NYS Water Resources Institute, Cornell University, Ithaca, NY.
6. Chenango Water Operators Council, 2004, Do you know where your water comes from?, Outreach material in support of the Council, Prepared by NYS Water Resources Institute and Rogers Environmental Education Center, Norwich, NY.

NY WRI Information Transfer for FY2004

Over the past several years WRI has continued to promote 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 federal, state, regional and local public and private partners. Most NYS WRI activity with these groups in FY2004 related to the New York City Watershed Program (Delaware County phosphorus management projects), the Susquehanna River Basin in the Chesapeake Bay Watershed, and the Hudson River valley.

Continuing Outreach and Information Transfer

As part of the stormwater regulations imposed by the NYS DEC, NYS WRI has been called on to assist in providing water education for municipalities through its NY Project WET (Water Education for Teachers) program. The NY Project WET is developing regional stormwater training sessions with the NYS DEC for municipalities and other educators, such as the Soil and Water Conservation Districts, environmental groups and Cooperative Extension.

A continuing focus for NYS WRI's outreach is in the headwaters of the Chesapeake Bay. 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 the NYS DEC and the Upper Susquehanna Coalition (USC—a network of county agencies), NYS WRI began to evaluate water quality monitoring and modeling activities carried out by the Chesapeake Bay program and to consider how New York should marshal its own technical resources to evaluate its options and progress toward the very ambitious nutrient reduction targets assigned. This work continued through FY2004. Currently a tributary strategy for New York is under development to reduce nutrients and sediments coming from nonpoint sources of pollution. In particular, WRI has assisted in fostering scientific support and the sharing of scientific understanding for the development of the tributary strategy

New Outreach Areas

Two new areas of outreach for NYS WRI were developed in the past year. One occurred with colleagues from Imperial College, the Westcountry Rivers Trust, and the University of East Anglia, United Kingdom, in the last half of FY2004. The focus of the program was building a network for a capacity building program for creating catchment strategies in the UK that exploit successful management options from the eastern US and European continent. Three US watershed programs that were highlighted as successful examples for the UK were the NYC Watershed Program, the Delaware County Action Plan (DCAP), and the upper Susquehanna River Basin that are the headwaters of the Chesapeake Bay. This project has prompted a considerable dialog with watershed groups in the UK. Two workshops were convened of UK/US stakeholders, including representatives from agriculture, academia, local government statutory agencies, and the voluntary sector. A major outcome of this project will be the preparation of a catchment strategy for UK watersheds based on stakeholder inputs.

Providing Environmental Law students with an opportunity to work within the NYS WRI watershed projects with faculty and local government leaders is the second new outreach area currently underway. Objectives for the students are to:

- Learn how real-life governmental agencies, communities, businesses and other public and private constituencies work together to address environmental issues.
- Discover opportunities for practice within the environmental law arena.
- Develop and research one legal issue bearing on the legal effects of the regulations and strategies under the NYC Watershed Agreement.

An over-arching goal for Environmental Law students and the WRI Director in developing this six-credit course is to assist a watershed community create and maintain a comprehensive compliance strategy under the NYC Watershed Agreement

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	0	0	0	0	0
Masters	16	2	0	0	18
Ph.D.	2	2	0	0	4
Post-Doc.	2	0	0	0	2
Total	20	4	0	0	24

Notable Awards and Achievements

2001NY921G: The SCS curve approach has been modified for use with the topographic index in predicting the saturated areas in undulating landscapes with relatively shallow soils. The procedure has been incorporated in the General Watershed Loading Function (GWLF), now called Variable Source Loading Function (VS-LF). This has been recognized by the Journal of American Water Resources Association as one of the best ways to model pollutant loading.

2003NY21B: An Excellence in Research Award was presented to Jacqueline Lendrum in 2004, University at Albany, School of Public Health, Albany, NY, for a poster describing the research under this grant.

2004NY56B: The WRI Directors Information Transfer Project co-convened an International two-day workshop in London, UK, with colleagues from Imperial College, the University of East Anglia, and the Westcountry Rivers Trust. A goal of the workshop was to solicit research questions and issues from invited stakeholders concerning catchment management. Stakeholders discussed priority issues from ongoing successful catchment management programs in the US, the UK and EU. These priority issues will be the basis for a research strategy for catchment management, and will the basis for the second International two-day workshop to be held in May 2005.

Publications from Prior Projects