Deleware Water Resources Center
Annual Technical Report
FY 2003

Introduction

Delaware Water Resources Center Annual Technical Report FY 2003 (3/1/03 - 2/29/04) June 30, 2004

The Water Resources Center receives an annual Federal matching grant as authorized by section 104 of the Water Resources Research Act of 1984 (Public Law 98-242) as amended by Public Law 101-397, Public Law 104-147, and Public Law 106-374. The U.S. Geological Survey (USGS), Department of the Interior, administers the provisions of the Act. This annual evaluation report describes, in the format prescribed by the USGS, the research, training, and information transfer activities supported by the section 104 grants and required matching funds during fiscal year 2003.

Introduction

Understanding the nature of the water quality and water supply problems faced in Delaware, historically and today, requires knowledge of the physiographic nature of the state, its climate, and major land uses. Geologically, Delaware is comprised of the Piedmont and Atlantic Coastal Plain Provinces. Only the northernmost 6% of the state is within the Piedmont, a region created of very old igneous and metamorphic rock. Soils range from well-drained, highly productive silt loams in the Piedmont to well- and excessively well-drained sandy loams and loamy sands in the Coastal Plain. Significant areas of poorly drained soils are also present, particularly in southeastern Delaware. Erosion and surface runoff are the main concerns in the Piedmont, while leaching of contaminants to shallow ground waters is the main water quality problem in the Coastal Plain. Rainfall is plentiful (45 in/yr) and rather constant, averaging 3 to 4 in/month in winter and spring and 4 to 5 in/month in summer. Precipitation typically exceeds evapotranspiration by 12 to 18 in/yr, providing 10 to 12 in/yr of groundwater infiltration. Surface water is the main water supply source in the Piedmont, although the Cockeysville Formation is an important local aquifer of fractured marble and dolomite. This province is dominated by the Christina River Basin, fed by rivers that first flow extensively through Pennsylvania and Maryland. Water quality of the White Clay and Red Clay Creeks and Brandywine River are strongly affected by land use and point sources of pollution in neighboring states. Those rivers flow into the Christina River which, in turn, flows into the Delaware River. Ground water is the major water supply source for the Atlantic Coastal Plain, a province of southeastwardly thickening unconsolidated and semi-consolidated sediments over crystalline basement rock. A primary aquifer in this province for water supply, stream base flow, and confined aquifer recharge is the unconfined Columbia aquifer. In a southwardly expanding wedge, the western portion of this area flows to the Chesapeake Bay through headwaters of the rivers and creeks of the Delmarva Peninsula's eastern shore. The mideast section of the province flows to the Delaware Estuary, fed by the watersheds of 15 creek and river systems. The southwest portion of the state flows into the Inland Bays of Delaware and Maryland and the Atlantic Ocean. The major land use in Delaware today, as in the past, is agriculture (526,070 acres; 41% of the 1.28 million acres in the state), which is dominated by a large, geographically concentrated poultry industry. Other main land uses are urban (19%), wetlands (19%), forests (15%), open water (4%), and barren land (1%). Delaware has 2506 miles of streams and rivers, 2954 acres of lakes/reservoirs/ponds, 841 square miles of estuarine waters, and 25 miles of ocean coastline.

Approximately 2/3 of the state's wetlands are freshwater, and 1/3 is tidal. Protection of the quality and quantity of the State's surface waters and aquifers is a major concern to all agencies and individuals responsible for water resource management in Delaware. Groundwater protection is particularly important given the increasing reliance on this resource for drinking water. In general, the key priority water resource issues today are (not prioritized): (1) enhanced management and control of stormwater runoff, erosion and sediment; (2) improved understanding of sources, transport, fate, and remediation of toxic organics and trace elements; (3) comprehensive management of agricultural nutrients; (4) identifying sources of pathogenic organisms and preventing human health impacts; (5) increased understanding of the response of aquatic systems to pollutants; (6) identification and protection of wellheads and aquifer recharge areas; (7) better management of water supply and demand and development of a systematic means to deal with droughts; (8) treatment and disposal of on-site sewage; (9) protection and restoration of wetlands; and (10) prevention of saltwater intrusion to potable water supplies.

The Water Resource Problems of Delaware

Surface Water Quality: Delaware has a number of serious, documented surface water quality problems. Many can be traced back to point source pollution problems in past decades; others reflect ongoing anthropogenic activities that degrade surface water quality. Water quality is a major state environmental priority and improvements have occurred, particularly since the 1970's, due to the use of state and federal regulatory and funding means to address "end-of-pipe" point sources of surface water pollution. Much of this improvement was due to aggressive use of federal funding, available in the late 1970's and early 1980's under the Clean Water Act and combined with local funding, to expand and improve municipal wastewater treatment systems.

The National Pollution Discharge and Elimination System (NPDES) Program in Delaware has reduced the number of "point sources" from over 200 in the 1970's to 59 today. Major reductions in oxygen demanding materials and toxics in surface waters were achieved. Today, however, large federal investments in the infrastructure needed to reduce point source pollution are more difficult to obtain. This raises the question of whether or not it is reasonable to expect additional major improvements in water quality due to increased control of point source pollution. Reductions in point source pollution of surface waters have drawn attention to the need to control nonpoint pollution. The consensus among state and federal agencies is that Delaware's main water quality challenge today is to manage diffuse sources of pollution from urban, suburban, and rural landscapes.

The major surface water quality problems in Delaware include:

Urbanization: A rapidly expanding urban population is increasing pressures on Delaware's surface waters. Rivers and streams are being affected by elevated temperature and low dissolved oxygen levels that can result from degradation of streambanks and stream channels. In residential and urban areas, increases in impervious surface have resulted in greater and flashier stormwater runoff, leading, in turn, to erosion, sedimentation, shallower water levels and destabilization of stream channels. Biological and habitat quality are also being affected by removal of stream buffers and stream bank "hardening" through use of riprap and concrete.

Drainage: Extensive drainage systems have been installed throughout the state, especially in coastal plain areas. Most were constructed in the 1930's and 1940's by the Civilian Conservation Corps and the Works Progress Administration. At that time, building a drainage ditch system involved channelizing and straightening headwaters of existing natural streams, then constructing ditches out and back from the

channelized stream. Upland wetlands were often drained to reduce mosquito populations. A state "tax ditch program" is re-constructing ditches and in doing so wetlands are protected or augmented and management practices are used to minimize impacts to habitat. The effects on the biological and habitat quality of the waterway once it is stabilized are unknown. Another trend today, is the proliferation of public ditch projects instead of tax ditches. Public funding makes the choice by landowners to tax themselves for reconstruction and maintenance of ditches less compelling. Public ditch projects are typically smaller (a few hundred feet) in scope and take place in the upper reaches of streams (typical bottom width is 3 feet) to augment mostly residential and some agricultural drainage. These projects are often carried out by the Conservation Districts. Nothing is known about the impacts to water quality or ecology from such projects. This lack of information may be important since protection of small headwater streams is critical to watershed health. Few streams in Delaware are unaffected by current or historic drainage projects that modify watershed drainage, natural stream channel configuration, buffers, and nutrient transport.

Nutrients are a leading cause of water quality degradation in Delaware. Nutrient effects can be seen especially in lakes, ponds, bays, and estuaries that receive nutrients conveyed by rivers, streams, and ground water. According the State of Delaware's 305(b) report, most estuaries suffer from eutrophication and low dissolved oxygen related to nutrient enrichment. Excessive macroalgae production in the inland bays strongly affects dissolved oxygen levels. In localized areas, large mats of algae accumulate and rot creating "hypoxic and anoxic death zones" as noted in the state Division of Water Resource's 2000 Annual Report. Aquatic life such as oyster beds that cannot move can be destroyed by these conditions. In 2000, plantings for a seagrass re-establishment project were not implemented due to extensive macroalgae growth in the Indian River system. Thirty-four fishkills were investigated in 2000 and 23 in 2001 by the state Division of Fish and Wildlife, some in dead-end lagoons and some in open waters. Many of the incidences are thought to be related to low dissolved oxygen. Though toxic organisms including Pfiesteria have been present in some cases those organisms cannot be directly linked as a cause of any kills. There were 17 fish kills each in 2002 and 2003. Of the fishkills in 2003, 4 were from natural causes, 4 of unknown cause, and 9 were from low dissolved oxygen. Two of those kills were compounded by large phytoplankton blooms. Primary land-based sources of nutrients in Delaware are agricultural practices, septic systems, and urban runoff. About 41% of Delaware's land area is devoted to agricultural activities and 19% to urbanized uses. Delaware's agricultural industry has a strong broiler industry component that heavily influences the state's overall agricultural nutrient balance and has long created nutrient management problems because of the large amount of manure that must be land applied. About 70% of Delaware's cash farm income was from broilers in 2001, with production of 257,700,000 broilers. Delaware's southern most county ranked first among counties nationally in broiler production.

On-Site Wastewater Disposal: DNREC staff has estimated, based on aerial photos, that there are 78,600 septic tanks statewide. Based on a recent inspection program, an estimated 15% of septic systems are considered "unsatisfactory". Eight to 10% are totally unsatisfactory because they are substandard systems such as cesspools, or because the system is failing. The remaining 5 - 7% are unsatisfactory due to a need for minor repairs.

Other problems: Atmospheric deposition is also a concern because research has shown that about 15% of the inorganic nitrogen loading in the Delaware Bay annually and 25% in the summer comes via deposition. Toxics have also affected Delaware waters resulting in fish consumption advisories for 5 lakes/ponds and portions of 12 rivers in 2002. The primary pollutant is polychlorinated biphenyl (PCB). Chlorinated pesticides, dioxins, and mercury have also been identified. Though PCB's have long been

banned, they are persistent in the environment and are transported from land to waters through runoff to settle in waterbody sediments, where they enter the aquatic food chain. Pathogenic organisms in surface waters have caused over 99% of state waters to not be fully supported for primary contact (swimming, for instance) and have negatively affected shellfish harvesting.

Groundwater Quality: A shallow water table and high permeability soils make Delaware's ground water vulnerable to pollution. Shallow unconfined aquifers are especially vulnerable, though deeper confined aquifers are susceptible as well because they subcrop beneath and are recharged by unconfined aquifers.

Major groundwater quality problems in Delaware today are:

Nutrients: Nitrates from agriculture and septic systems are, by far, the major contaminant in Delaware's ground water. There are also some concerns about dissolved phosphorus transport to surface waters by shallow ground water flow in parts of the state where shallow water tables are interconnected with surface waters by ditches and/or tiles.

Organics: Hydrocarbons have also been found as have pesticides, though not at levels which cause alarm. A major source of hydrocarbons, such as MBTE, is leaking underground storage tanks while agricultural activities are the source of pesticides. There are 12,050 regulated underground storage tanks in the State; 9,651 have been properly abandoned and 2,399 are still in use. 3,095 releases to ground water have been confirmed and 2,643 of those have been closed.

Salt water intrusion: Problems with private wells occur sporadically from seasonal salt water intrusion along the Delaware River and the Inland Bays/Atlantic Ocean coastal areas. No major problems have occurred and only one public well in Lewes required abandonment.

Trace elements: Though not considered a health threat, iron concentrations are a widespread problem in Delaware for cosmetic reasons. Many public water supplies have treatment systems to remove iron. Thirty-four percent of 561 raw groundwater samples analyzed by Delaware's Office of Drinking Water exceeded the secondary contaminant level standard of 0.3 mg/L. Concerns are emerging about arsenic in ground waters because of the long-term application of this element in poultry manure to soils overlying shallow drinking water aquifers, and the lowered drinking water standard for As.

Wetlands Quality: A watershed study of nontidal wetlands is currently under way that will provide information regarding overall condition of wetlands and identify major stressors affecting wetland function. For now, the primary evaluation of wetlands lies in determining trends, primarily rate of loss. About 2000 acres of vegetated wetlands were lost statewide between 1981/2 and 1992, predominantly palustrine vegetated wetlands (1890 acres). Of the palustrine vegetated wetlands, the greatest loss was of palustrine forested wetlands (1505 acres). Agricultural activities are considered the primary cause of loss (954 acres) and residential activities had the second greatest impact (436 acres). Estuarine wetlands were destroyed to a much smaller extent (106 acres), mainly due to saltwater impoundments and filling.

Water Supply: Half of Delaware's population is located in the Piedmont (6% of land area) and uses surface water for drinking water. The other 50% of the population relies on ground water and is spread throughout the remaining 94% of the State. With regard to the amount of water used, ground and surface water are of equal importance; with regard to area served, ground water is overwhelmingly dominant. Capacity concerns are important north of the Christina River due to population concentration and the reliance on surface water. For the rest of the state, the reliance on abundant ground water and a diffuse

pattern of development suggest that the supply of potable water is not currently a problem. Recent drought emergencies have brought water supply demand in northern Delaware into conflict with the need to maintain minimum pass-through flows in streams for protection of aquatic resources. Benthic organisms, the foundation of the aquatic food chain, cannot move to avoid dry stream bed conditions. This suggests that not maintaining pass-through flows at all times would be detrimental to stream aquatic life. Required pass-through flows can be high; the need to ensure those flows can result in practices or structures such as reservoirs that are economically inhibitory or may cause as much or greater environmental degradation as occasional dry stream bed periods.

Water Resources Center: An Overview

The Delaware Water Resources Center (DWRC) has been a part of the University of Delaware since 1965. From 1965 until 1993 the DWRC was located in the University of Delaware's Research Office. In 1993, the DWRC was moved to the College of Agriculture and Natural Resource (CANR) where, since 1997, Dr. Tom Sims, Associate Dean for Academic Programs and Research, has served as DWRC Director. The DWRC works with all organizations and agencies in Delaware with an interest or responsibility in water resources. We have a 16 member Advisory Panel representing a wide variety of water resource backgrounds. We regularly cooperate with the Delaware Water Resources Agency, Delaware Geological Survey, Delaware Department of Natural Resources and Environmental Control, Center for the Inland Bays, the Delaware Nutrient Management Commission, Delaware State University, USDA Natural Resources Conservation Service, Delaware Nature Society, and Sierra Club, to name but a few. The DWRC has always supported a wide range of water resource related research, education, and information transfer programs. We cooperate with many academic departments and units that conduct water-related research at the University of Delaware, including the Water Resources Agency in the Institute for Public Administration, the Departments of Biology, Bioresources Engineering, Chemistry, Civil Engineering, Geography, Geology, and Plant and Soil Sciences, as well as the College of Marine Studies and the College of Human Services, Education and Public Policy.

Close communication is maintained between the DWRC and State natural resource agency representatives and water officials to address priority water quality and water quantity concerns in the State. Through efforts such as these, the DWRC has provided key stakeholders a forum for discussion and an opportunity for education regarding water resources.

Section 104 Objectives

The DWRC has defined a two-fold mission to meet the goals of the Water Resources Research Act: (1) To support research, education, and public outreach programs on water supply, water quality, and water management, issues of major importance to Delaware citizens; (2) To support training and education programs for future water scientists, engineers, managers, and policymakers who will lead water resources research, planning, and management efforts in the future.

To meet these goals we have focused our efforts during 2003 into three major areas:

(1) Graduate Fellowship Program: A competitive graduate fellowship program supports graduate fellows on a 3-year cycle. The four Ph.D. and one M.S. graduate fellows supported during the period of this report were in the College of Agriculture &Natural Resources, College of Marine Studies, and the Center for Energy and Environmental Policy. Three conducted research in support of efforts by the Delaware Nutrient Management Commission to develop a state-wide nutrient management program that protects

and improves water quality, and the other two are researching water quality topics of virus deactivation/removal and arsenic transport / fate;

(2) Undergraduate Internship Program: We initiated a highly successful undergraduate internship program in 2000. In the first 4 years we funded 32 undergraduate interns from four Colleges within the University of Delaware. Interns work with faculty to conduct research, prepare a written project report, and present their findings at an annual conference;

(3) Information Transfer: The DWRC web site and newsletters (print and electronic) are sources of up-to-date information on DWRC activities and water-related issues of importance to Delaware and the region. Our web site provides information on water resources problems, links to water-related organizations, internship and job opportunities in the water resources, a calendar of upcoming events, and a Kids Zone for teachers and parents. We also co-sponsor an annual state-wide conference on water resource topics of current interest.

Delaware Water Resources Center Program Goals and Priorities

The primary goal of the Delaware Water Resources Center is to support research that will provide solutions to the State's priority water problems. A secondary goal is to promote the training and education of future water scientists and engineers. A third goal is to serve as a source of information to water researchers, decision makers, natural resource protection agency personnel and to the public through technology transfer projects.

Description of Delaware Water Resources Center Program Management and Administration March 1, 2003 through February 29, 2004 (FY03)

1. Institute Director Dr. J. Thomas Sims T. A. Baker Professor of Soil and Environmental Chemistry Associate Dean for Academic Programs & Research Director, Institute of Soil & Environmental Quality and Delaware Water Resources Center College of Agriculture and Natural Resources

113 Townsend Hall University of Delaware Newark, DE 19716-2103 e-mail: jtsims@udel.edu Phone: 302-831-6757 FAX: 302-831-6758

2. Administrative Personnel: Amy Boyd Program Coordinator, Delaware Water Resources Center

113 Townsend Hall University of Delaware Newark, DE 19716-2103 e-mail: aboyd@udel.edu Phone: 302-831-6757, 302-738-6779 FAX: 302-831-6758

3. Abstract of Program and Management Overview: The Delaware Water Resources Center (DWRC) research, education and information transfer programs focus on issues of state and regional importance to both water quality and water quantity. Long-term priority areas of the DWRC have included nonpoint source pollution of ground and surface waters, development of ground water supplies, the impact of hydrologic extremes on water supply, and socio-economic factors affecting water supply and water quality. In 2000, the 16-member DWRC Advisory Panel identified five specific areas for near-term DWRC efforts: (1) Research on agricultural nutrient management and water quality; (2) Basic and applied research on sources, fate, and transport of water pollutants; (3) Quantification of the response of aquatic ecosystems to pollutant inputs; (4) Water supply, demand, and conservation, as affected by changing land uses in Delaware and the mid-Atlantic states; and (5) Management and control of stormwater runoff. The

FY2003 DWRC research program addressed these issues by supporting graduate fellowships, an undergraduate student internship program, and statewide presentations including an intern research poster session, a land use change impact water resources conference, a drought gardening symposium, and Boy Scout youth and public water conservation training.

Research Program

The Delaware Water Resources Center funded four graduate fellowship research projects and ten undergraduate internship research projects during 2003. Two graduate fellowships were granted in December 1999 and spanned a three-year period ending May 2003. The other two were granted in July 2003 and are renewable through 2006. The ten DWRC undergraduate internship projects were for the period of one year, bringing to 32 the total number of internships funded by the DWRC since the program's 2000 inception.

Graduate Fellowship in Water Quality: Baseflow and Storm Discharge of Nutrients to Delaware's Inland Bays

Basic Information

Title:	Graduate Fellowship in Water Quality: Baseflow and Storm Discharge of Nutrients to Delaware's Inland Bays
Project Number:	2002DE1B
Start Date:	3/1/2000
End Date:	5/31/2003
Funding Source:	104B
Congressional District:	At-large
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Geochemical Processes
Descriptors:	Eutrophication, Land Use, Nitrogen, Nutrients, Rainfall-Runoff Models, Rainfall-Runoff Processes, Water Quality, Water Quality Monitoring
Principal Investigators:	Jennifer Jennings, Joseph R. Scudlark, William J. Ullman

Publication

1. Jennings, Jennifer, William Ullman, and Joseph Scudlark, March 2002, The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 12 pages.
2. Jennings, Jennifer, William Ullman, and Joseph Scudlark, June 2002, The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 3 pages.
3. Boyd, Amy, and J. Thomas Sims, editors, 2002, The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays. Delaware Water Resources Center WATER NEWS V3 No1 Spring 2002, pp5-6. http://ag.udel.edu/dwrc/newsletters/JenningsSpr2002.pdf
4. Jennings, Jennifer, 2003, The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays, "M.S. Dissertation", University of Delaware, Newark, Delaware, 163 pages.
5. Ullman, William J, Joseph Scudlark and Jennifer Jennings, 2003, Base Flow and Storm Discharge of Nutrients to Delaware's Inland Bays, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 8 pages.
6. Jennings, J.A., J.R. Scudlark, K.B. Savidge, and W.J. Ullman, 2003, Estuarine eutrophication by

atmospheric phosphorus, in National Atmospheric Deposition Program 2003 Ammonia Workshop proceedings, Washington, D.C. 20-22 October 2003.

7. Jennings, J.A., K.B. Savidge, J.R. Scudlark, A.S. Andres, and W.J. Ullman, in press 2004, Nitrogen Loads Through Baseflow, Stormflow, And Underflow From The Watershed To Rehoboth Bay, Delaware. Estuaries (submitted).
8. Scudlark, J.R., J.A. Jennings, M.J. Roadman, K.B. Savidge, and W.J. Ullman, in press 2004, Atmospheric Nitrogen Inputs To The Delaware Inland Bays: The Role Of Ammonia. Environmental Pollution (submitted).

Previous Project Numbers: DWRC G-03 (FY00); NIWR 2000DE3G (FY00), 2001DE3681B (FY01), and 2002DE1B (FY02 and FY03).

Names and degree level (highest level during the reporting period) of all students who worked on the research project: Jennifer A. Jennings, M.S. recipient April, 2003.

Abstract (of M.S. thesis based on this fellowship's research)

In this research, the discharge of water and associated nutrients from one sub-watershed of Delaware's Inland Bays (Bundicks Branch) was studied in detail so that total nitrogen and phosphorus loads from this tributary, and potentially others with similar geological, hydrological, and land use characteristics could be determined. The calculated loads, based on measured data were compared to previous model estimates, which have been and continue to be used by managers, for the establishment of nutrient loading targets and land use management practices within the watershed.

In order to accurately determine storm loads at Bundicks Branch, an alternative baseflow minimization separation technique, which reduced and ultimately shut off groundwater inputs under the peaks of storm events, was developed. This model yields more reliable estimates of baseflow and storm loads at this tributary. Samples collected during both the hourly and daily sampling experiments revealed that dissolved nutrient concentrations fluctuated little (<12%) within a day and between sampling dates, while particulate constituents were more variable on both time scales and calculated loads can carry a greater degree of uncertainty (>40%).

Storm loads of 17 monitored events at Bundicks Branch were evaluated for seasonal trends and used to project annual storm loads. Normalization of storm loads by precipitation amount (P) and integrated storm discharge (Q) revealed that the loads per unit P or Q of sequential monitored events were fairly similar. The loads of unsampled storms between monitored events were therefore determined using the average "per unit" loads of the previous and following sampled storms.

These same, and similar, flow based calculations were applied to less studied sub-watersheds. As a result of the detailed study conducted at Bundicks Branch, annual nutrient loads in both the baseflow and stormflow discharge components could be estimated at two similar sites using the Bundicks Branch model calibrated with data from these sites. Using this approach, total, baseflow, and storm loads may be determined with substantially less discharge and water quality data.

The loads computed in previous chapters using flow-based calculations were used to evaluate loading estimates produced by land use-based nitrogen and phosphorus models. The estimated loads from the Ritter (1986a), Horsley & Witten (1998), and USDA (Cassell and Meals, 1999) models appear to represent an upper bound to the actual nutrient loadings. The Ritter (1986a) approach gave very good estimates of N when applied to Bundicks, while the Horsley & Witten (1998) approach produced a value approximately 30% greater then the measured loads. Both the Ritter (1986a) and USDA (Cassell and Meals, 1999) P models overestimated measured P loads at Bundicks Branch by 400%. These results indicate that existing non-point discharge targets should be revised in light of recent observations.

It was also determined, after analysis of atmospheric N and P deposition rates to the watershed, that the land uses of Bundicks Branch attenuated both N and P on a seasonal basis with peaks in attenuation occurring during the peak-growing season. Thus, the land uses and land covers of the

studied sub-watersheds were found to take on both the role of net nutrient source and the role of net nutrient sink at different times of the year. Future management practices that take into account the seasonality of nutrient attenuation in the watershed, may better achieve management goals.

Finally, the nutrient loadings determined at Bundicks Branch during this study were extrapolated to represent the non-point source load from the entire Rehoboth Bay sub-basin and were compared to the loading contributions from direct atmospheric deposition and the Rehoboth Wastewater Treatment Plant. This analysis revealed that prior nitrogen budgets were sound, with the watershed contributing close to 80% of the annual N load to the bay, 17% from direct atmospheric deposition, and 4% from the WTP, but suggested that the actual phosphorus budget is substantially different then previously believed. On an annual average basis, this approach estimates that the watershed and Rehoboth WTP contribute relatively equal proportions of the P load to Rehoboth Bay at 41 and 45% respectively. In addition, it appears that the loading proportion from the WTP can be even greater during summer months, especially those that are dry, suggesting that focus should also be paid to the management of point sources in regard to nutrient pollution.

Information Transfer

1. Jennings, Jennifer. "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays", Delaware Nutrient Management Commission (DNMC) meetings of the "Technology" and "Program and Education" committees, Dover, DE. May 20, 2003.

    The DNMC-developed statewide plan implements best management practices (BMPs) to reduce nutrient loading to surface and groundwaters. Jennings' research provided a quantitative estimate of relative nutrient loading to Delaware's Inland Bays by base flow and storm flow vital to the DNMC efforts to identify the most effective BMPs for water quality protection.

2. Jennings, Jennifer. "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays", Meeting of the Delaware Department of Natural Resources and Environmental Control (DNREC), Watershed Assessment Branch, Dover, DE. June 4, 2003.

3. Jennings, Jennifer. "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays", Meeting of the Center for the Inland Bays (CIB) "Scientific and Technical Advisory" committees, Lewes, DE. June 20, 2003.

4. Jennings, J.A., J.R. Scudlark, K.B. Savidge, and W.J. Ullman, 2003, Estuarine eutrophication by atmospheric phosphorus, in National Atmospheric Deposition Program 2003 Ammonia Workshop proceedings, Washington, D.C. 20-22 October 2003.

Presentation Abstract

Annual total nitrogen and phosphorus loads have been determined at one sub-watershed of Delaware's Inland Bays (Bundicks Branch) using an extensive water quality data set and flow-based loading calculations, where load is determined as the product of concentration and discharge. The total discharge, which was measured, was separated into the baseflow and stormflow components using a baseflow minimization separation technique that reduces the

baseflow component of discharge during storm periods in proportion to storm-related stage height increases. High frequency sampling experiments were conducted to determine the uncertainty associated with estimated baseflow loads. Dissolved constituent concentrations appear to be less variable then the particulate counterparts and as such, the dissolved baseflow loads have less uncertainty (<12% compared to >40% for particulate loads). Storm loads can be estimated for unsampled rain events by normalizing loads to storm discharge, which produces annual storm loads with uncertainties less then 10% during monitored periods of time. Based on an analysis of water budgets, a considerable amount of water and nutrients appear to bypass the Bundicks Branch gauging station and discharge further downstream or directly into Rehoboth Bay. This underflow component can be estimated using a water budget at Millsboro Pond to calculate average monthly evapotranspiration. The loading rates utilized in several land use loading models were applied to Bundicks Branch. The annual nitrogen loads determined at Bundicks Branch during this study (28,000-34,000kg/yr) are within 30% of the annual average load estimated by the Horsley & Witten (1998) N-model (40,000kg/yr). The annual phosphorus loads determined during this study (170-290kg/yr), however, are substantially less then the annual average load estimated by the USDA P-model (1,365kg/yr) (Cassell and Meals, 1999). This implies that the non-point source P load from the entire Rehoboth Bay sub-basin is also likely less then previously believed. As a result, P contributions to Rehoboth Bay from the Rehoboth Wastewater Treatment Plant (RBWTP) and direct atmospheric deposition are both relatively greater than anticipated. Atmospheric deposition of P, which has been assumed to be negligible, actually contributes 14% of the annual P load, while the RBWTP may contribute anywhere from 50-75% of the P load, depending on the season.

Graduate Fellowship in Water Quality: Environmental Policies for a Sustainable Poultry Industry in Sussex County, Delaware

Basic Information

Title:	Graduate Fellowship in Water Quality: Environmental Policies for a Sustainable Poultry Industry in Sussex County, Delaware
Project Number:	2002DE3B
Start Date:	3/1/2001
End Date:	5/31/2003
Funding Source:	104B
Congressional District:	At-Large
Research Category:	Water Quality
Focus Category:	Law, Institutions, and Policy, Water Quality, Nutrients
Descriptors:	Agriculture, Economics, Policy, Non Point Pollution, Nutrients, Water Quality
Principal Investigators:	Lynette Ward, John M. Byrne, William Frederick Ritter, Young-Doo Wang

Publication

1. Ward, Lynette, William Ritter, John Byrne, and Young-Doo Wang, 2001, Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 30 pages.
2. Ward, Lynette, William Ritter, John Byrne, and Young-Doo Wang, 2002, Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 5 pages.
3. Ward, Lynette, 2002, Poster presentation: Market and Technical Barriers to Alternative Uses for Poultry Litter, in Air and Waste Management Association Conference proceedings, Baltimore, MD.
4. Ward, Lynette, 2003, Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware, "Ph.D. Dissertation", University of Delaware, Newark, DE, 348 pages.
5. Ward, Lynette, William Ritter, John Byrne, and Young-Doo Wang, 2003, Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 21 pages.
6. Ward, Lynette, 2003, Phosphorus Management Options for the Delmarva Poultry Industry, in World Water and Environmental Resources Congress proceedings, Philadelphia, PA.
7. Ward, Lynette, 2003, A Characterization of Delaware's Agricultural Industry, in New Opportunities for Delmarva Agriculture proceedings, Dover, DE.

8. Ward, Lynette. 2003. Overcoming Market and Technical Barriers to Poultry Litter Compost, in International Solid Waste Management and Technology Conference proceedings, Philadelphia, PA.
9. Boyd, Amy, and J. Thomas Sims, editors, 2003, Environmental Policies for a Sustainable Poultry Industry in Sussex County, Delaware, Delaware Water Resources Center WATER NEWS V4 No1 p4. http://ag.udel.edu/dwrc/newsletters/Spring2003p4.pdf

Previous Project Numbers: DWRC G-02 (FY00); NIWR 2001DE4301B(FY01) and 2002DE03B (FY02 and FY03).

Information Transfer

1. Ward, Lynette. March 25, 2003. Paper: Overcoming Market and Technical Barriers to Poultry Litter Compost. International Solid Waste Management and Technology Conference, Philadelphia, PA.

2. Ward, Lynette. June 26, 2003. Paper: Phosphorus Management Options for the Delmarva Poultry Industry. World Water and Environmental Resources Congress, Philadelphia, PA.

The names and degree level (highest level during the reporting period) of all students who worked on the research project is: Lynette Ward, PhD recipient May 6, 2003.

Abstract:

Sussex County, Delaware produces more broilers than any other county in the United States, producing 247.4 million broilers in 2001. While poultry production is the primary economic activity in the county, it is also the primary source of nutrient pollution. Poultry litter is applied to the county's cropland at rates that exceed the crop's agronomic needs. As a result, phosphorus levels have built up in the soils and nutrients now enter the county's waterways causing water quality problems. Consequently, land application can no longer be the sole disposal method for poultry litter in Sussex County.

The intent of this research was to develop environmental policies that promote the creation of a sustainable poultry industry in Sussex County, Delaware. Sustainable poultry industry practices meet the triumvirate goals of being environmentally sound; economically viable in both the short-term and long-term; and socially responsible in the sense of promoting equity, and preserving rural communities and quality of life. This research evaluated the economic feasibility of methods to reduce the phosphorus content of poultry litter, bind soluble phosphorus to soils, or to find beneficial uses other than direct land application.

The following nutrient management strategies were evaluated in terms of their technical and economic feasibility:
1.) the use of high availability phosphorus corn in poultry rations,
2.) the addition of the enzyme phytase in poultry rations,
3.) biogas production,
4.) energy generation,
5.) composting,
6.) use as a cattle feed supplement, and
7.) pelletizing.

The economic analysis of nutrient management strategies was conducted using Implan Professional 2.0, a PC based economic analysis software system that uses both data files and software to create regional models. Implan was used to do an economic analysis of not only the alternative uses for poultry litter, but to measure the economic and social impacts of developing a sustainable poultry industry in Sussex County in terms of factors such as dollars of sales, local taxes received, impact on tourism revenues, and jobs created.

The results of this research indicated that a combination of pelletizing and composting poultry litter to create value-added products and the use of the enzyme phytase to lower the concentration of phosphorus in the litter were the optimal nutrient management strategies for the study area. The adoption of these strategies would enable the study area to achieve nutrient management sustainability, which results in improved economic viability of the region, enhanced water quality and preservation of rural community structure and values.

Undergraduate Internship: Breeding Of Potential West Nile Virus Vectors In Stormwater Ponds And Constructed Wetlands

Basic Information

Title:	Undergraduate Internship: Breeding Of Potential West Nile Virus Vectors In Stormwater Ponds And Constructed Wetlands
Project Number:	2003DE19B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At Large
Research Category:	Biological Sciences
Focus Category:	Wetlands, Surface Water, None
Descriptors:	Wetlands, Surface Water
Principal Investigators:	Megan Bielawa, John Gingrich

Publication

1. Bielawa, Megan, Jack Gingrich, 2004, Breeding Of Potential West Nile Virus Vectors In Stormwater Ponds And Constructed Wetlands, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 19 pages.

Undergraduate Internship Project #1 of 10 for FY03

The project is co-sponsored by the ***UD College of Agriculture and Natural Resources (CANR)*** and the ***DWRC***.

"My DWRC project allows me to build on my existing interest in infectious diseases. Factors surrounding the spread of West Nile virus is a timely topic in our community, and I hope to investigate and better understand the role of agents found in new water impoundments at construction sites as predictors of the disease."
– Megan Bielawa, University of Delaware undergraduate senior, Biology major.

Abstract:

The objectives considered in this study included: 1) characterization of mosquito production in four different types of wetlands; 2) determine what constituted good and poor mosquito habitats; 3) determine what species of vectors may increase or decrease virus activity; and 4) determine during which parts of the season these mosquitoes breed most actively.

Sites were selected throughout Delaware and divided into retention, detention, constructed wetlands, and CREP ponds with a total of 53 sites selected. Collections were standardized throughout the season. Each site was sampled using a 350-ml dipper at 5 sub-sites per site, which were marked with plastic marking flags. Mosquitoes found at each site were returned to the lab for species identification. Water quality measurements including water temperature, pH, conductivity, and total dissolved solvents were taken at each site along with water appearance, pollution, dominant vegetation, depth, amount of shade, and predation levels. Large constructed wetlands were divided into zones and then sub-sites and sampled as described for the smaller sites.

Data were collected at bi-weekly intervals throughout the season, returned to the lab, and entered into a Microsoft Access database. Mosquitoes brought back to the lab were maintained at a 26.5^{o}C environment until species identification. Once the data from all of the sites was entered into the database, analysis and comparisons of the data were made.

Distribution of mosquitoes peaked in abundance twice during the season, once in June and again in August. These peaks in abundance occurred mostly in retention and detention ponds, and to a lesser degree in CREP ponds, which only peaked once in late June. Retention and CREP ponds were further classified into shallow and steep-sided. In both cases, shallow ponds produce more mosquitoes than steep sided ponds. Heavily shaded ponds were associated with a higher number of mosquitoes than partially or un-shaded ponds. According to the predator index, an increase in predators lagged an increase in mosquitoes by approximately two weeks. In detention ponds, *Aedes vexans*, an important WNV vector, was the principle species seen. In retention ponds, *Culex salinarius* and *Culex territans* were more abundant, both being important WNV vectors. Cattails and sedges were associated more with *Ae. vexans* and *Oc. sollicitans* while *Cx.* species closely associated with cattails, phragmites, and willows. Mosquitoes were more abundant in turbid water than in clear, colored, or polluted water. Larval mosquito levels were also low at very acidic or basic pH levels and peaked in abundance at levels of pH=6 and pH=9, with the higher peak at six.

Mosquito production was highest in retention and detention ponds. *Culex* species, particularly *Cx. salinarius* and *Cx. territans*, and *Ae vexans* were important WNV vectors that may increase virus

activity where these species were most prominent. Retention ponds were good habitats for *Cx.* species, while detention ponds, due to continual drying out and flooding, made good habitats for *Ae. vexans*. Breeding of these species was most active in mid-June and late August.

Undergraduate Internship: Enhanced Pollutant Biodegradation by Electrode Use

Basic Information

Title:	Undergraduate Internship: Enhanced Pollutant Biodegradation by Electrode Use
Project Number:	2003DE21B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Engineering
Focus Category:	Waste Water, Treatment, Water Quality
Descriptors:	Water Quality, Waste Water, Treatment, Surface Water
Principal Investigators:	Kate Schutte, Steven K Dentel

Publication

Undergraduate Internship Project #2 of 10 for FY03

The project is co-sponsored by the ***UD College of Engineering*** and the ***DWRC.*** Ms. Schutte will utilize and improve a newly discovered microbial process that can biodegrade water pollutants without aeration and that can generate electrical energy as a direct by-product. This project is co-investigated by Andrew Joslyn (project **2003DE24B,** intern project #27 of 32 to date**)** and extends the work of 2002 ***DWRC*** interns Aditya Sharma and Bret Strogen (project **2002DE40B,** intern project #22 of 32 to date).

"I am growing bacteria on electrodes under optimal conditions and attempting to transplant these electrodes into sludge [wastewater] *material. I will explore whether the bacteria or some other source is producing current. I am looking forward to the impact my work will have on future experiments."*
--Kate Schutte, University of Delaware undergraduate senior, Environmental Engineering major.

Abstract:

This research explored the use of graphite electrodes added to a zoned aerobic/anaerobic reactor, in order to speed the degradation of organic pollutants in water or wastewater. The lower electrode, located in the anaerobic section, provided a fairly simple method of supplying an electron acceptor through half-reactions occurring at or near this surface. It is believed that this can not only accelerate the degradation process, but also generate electricity as an additional benefit.

The research focused on culturing a specific microorganism, Geobacter metallireducens, to facilitate this process. This bacterium has been shown capable of direct colonization of electrode surfaces, with mitochondrial membrane surfaces available to the outer cell membrane to facilitate electron transport. The research hypothesis was that enrichment of the process with this microorganism would increase the current flow.

Our plan was to culture Geobacter on the enrichment media and, from there, directly onto the electrode surfaces, which would then be transferred to the reactor for use as a Geobacter-enhanced anode. The material selected for the electrode is key to maximize the conductivity of electrons and the sustainability of the stationary growth. This technique proved unsuccessful, probably due to the difficulty of culturing Geobacter, and especially in attempting to develop a viable population directly on the electrode surface.

Suggestions for future research include (1) avoid culturing directly in the presence of the electrode surface, and (2) identify more favorable growth conditions to increase the growth rate of the Geobacter, since the slow growth rate led to both maintenance difficulties, and less time to alter the experimental approach.

Undergraduate Internship: Fairfield Run: An Evaluation of Stream Habitat Restoration at the UD Experimental Watershed

Basic Information

Title:	Undergraduate Internship: Fairfield Run: An Evaluation of Stream Habitat Restoration at the UD Experimental Watershed
Project Number:	2003DE22B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Not Applicable
Focus Category:	Surface Water, Ecology, Management and Planning
Descriptors:	Surface Water, Ecology, Management and Planning, Conservation, Geomorphological Processes, Education, Methods
Principal Investigators:	Kristen Sentoff, Gerald Kauffman

Publication

1. Sentoff, Kristen, Gerald J. Kauffman, 2004, Fairfield Run: An Evaluation of Stream Habitat Restoration at the UD Experimental Watershed, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 56 pages.

Undergraduate Internship Project #3 of 10 for FY03

Ms. Sentoff's project is funded by the ***DWRC***. She will recommend habitat restoration techniques for areas along Fairfield Run, a tributary of the White Clay Creek. Fairfield Run was classified by previous ***DWRC*** interns (Jennifer Campagnini in FY00 DWRC project G-04, continued by Tara Harrell in FY01 as DWRC project G-14) as impaired by bank erosion due to watershed urbanization. A related project, investigated by Judith Walker and also advised by Gerald Kauffman, is "Blue Hen Creek: An Evaluation of Stream Habitat Restoration at the UD Experimental Watershed", project **2003DE26B** (intern project #29 of 32 to date).

"Many students do not realize what wonderful natural resources we have right here in Newark. I am excited to have the opportunity not only to learn about water resources management in the UD Experimental Watershed, but also to help improve the watershed for future education and enjoyment."
-- Kristen Sentoff, University of Delaware undergraduate senior, Natural Resource Management major.

Abstract:

Previous research has delineated the UD Experimental Watershed for educational purposes and has determined that surrounding land use negatively impacts the streams in it. The purpose of this project is to conduct research into stream restoration techniques and collect the necessary data for restoration implementation on Fairfield Run in the UD Experimental Watershed. The researchers chose a reference stream reach and candidate sites for restoration. They then conducted water quality, habitat, and stream geomorphology surveys. This data was incorporated into stream restoration designs. The candidate restoration sites were found to be impaired in comparison to the reference condition in terms of both water quality and habitat. The restoration and reference stream reaches had similar geomorphology classifications. The researchers selected vortex rock weirs, branch packing, single vanes, tree revetments, stone toe protection, live stakes, and cross vanes from the restoration techniques for use on Fairfield Run. Many viable restoration techniques are available that utilize natural materials already found in the UD Experimental Watershed. Fairfield Run is impaired and could be improved through use of some of these restoration techniques. Furthermore, its geomorphology classification suggests that it is a good candidate for restoration. The restoration project can be used to further the educational mission of the UD Experimental Watershed by involving students and the public in an effort to improve stream quality and watershed health.

Undergraduate Internship: Biological and Enzymatic Treatment of a Food Processing Wastewater

Basic Information

Title:	Undergraduate Internship: Biological and Enzymatic Treatment of a Food Processing Wastewater
Project Number:	2003DE23B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Waste Water, Treatment, Water Quality
Descriptors:	Waste Water, Treatment, Water Quality
Principal Investigators:	Alice McDermott, Anastasia Chirnside

Publication

1. McDermott, Alice, Anastasia Chirnside, 2004, Biological and Enzymatic Treatment of a Food Processing Wastewater, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 8 pages.

Undergraduate Internship Project #4 of 10 for FY03

This project is co-sponsored by the ***University of Delaware College of Agricuture (CANR) and DWRC***. Ms. McDermott is investigating both the effectiveness of adjusting pH and of using an enzyme culture in wastewater treatment.

"I want to understand how excess nutrients like nitrogen can be successfully removed from wastewater discharges from industry. It's important that we know and apply the best available technology for clean surface water quality."
-- Alice McDermott, University of Delaware undergraduate freshman, Art History major.

Abstract:

Soy flour is an excellent low-fat source of isoflavones and protein, providing eight amino acids necessary for human health. However, the processing of soy flour is not environmentally friendly. The soy processing wastewater has extremely high amounts of Total Kjeldahl Nitrogen (TKN), Chemical Oxygen Demand (COD) and a high pH. We have developed an attached growth, packed-bed bioreactor (PBR) containing the white rot fungus (WRF), *Phanerochaete chrysosporium*. This fungus secretes enzymes that catalyze oxidation reactions resulting in degradation of recalcitrant compounds. Previous studies utilizing the fungus in the bioreactor found that the high pH of the wastewater caused inhibition of TKN and COD degradation. We hypothesize that adjustment of the wastewater pH before introduction into the bioreactor would overcome this inhibition and result in a greater reduction of the TKN and COD.

The first objective was to investigate the effectiveness of pH adjustment of the wastewater before treatment in the bioreactor and to evaluate the continuous recycling of the pH adjusted effluent throughout the experiment.

The second objective was to investigate the effectiveness of treating the wastewater with the enzyme culture solution obtained from the reactor in order to overcome the inhibitory effect of high pH on fungal activity within the reactor.

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Objective 1: The pH of the wastewater was adjusted to 7.52. It was then fed to the PBR at a pumping rate of 0.7 ml min^{-1} with the recycle flow (2:1). The effluent was sampled daily and measure for TKN, COD and pH. The overflow effluent was collected, the pH was readjusted to 7.0 and then pumped into the PBR.

Objective 2: Inorganic N was removed from the wastewater. The pH was adjusted to 7.0. Two wastewater dilutions (10% and 20%) and 2 enzyme concentrations (5% and 10%) were examined. The diluted wastewater was treated with the enzyme solutions and monitored for changes in TKN, pH and COD for 24 hours.

Results and conclusions:
Continuous adjustment of pH during recycling of the wastewater within the PBR resulted in an increase in the amount of TKN and COD degraded. Over 90% of the TKN and 33% of the COD were removed during treatment within the PBR. Treatment of the wastewater with the fungal enzyme solution had little effect on TKN concentration. However, there was a 50 to 67% decrease in the total amount of COD found in the wastewater. The pH remained constant.

With the improved pH control in the PBR during recycling events, a greater amount of TKN and COD was removed from the wastewater. Treatment of the wastewater with fungal enzymes resulted in a significant decrease in COD concentration. These positive results indicate that treatment of recalcitrant wastewater with the WRF deserves further investigation. A combination of treatments, inside and outside the PBR, could lead to complete removal of both COD and TKN thus allowing for discharge of the treated wastewater into surface water streams.

Undergraduate Internship: Enhanced Degradation of Benzoate by Electrode-Utilizing Microorganisms

Basic Information

Title:	Undergraduate Internship: Enhanced Degradation of Benzoate by Electrode-Utilizing Microorganisms
Project Number:	2003DE24B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Engineering
Focus Category:	Waste Water, Treatment, Water Quality
Descriptors:	Waste Water, Treatment, Water Quality, Surface Water
Principal Investigators:	Andrew Joslyn, Steven K Dentel

Publication

1. Joslyn, Andrew, Steven Dentel, 2004, Enhanced Degradation of Benzoate by Electrode-Utilizing Microorganisms, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 6 pages.

Undergraduate Internship Project #5 of 10 for FY03

The project is co-sponsored by the ***UD College of Engineering*** and the ***DWRC.*** Mr. Joslyn aims to explore wastewater reactor configurations that will optimize the growth of particular bacterial microorganisms responsible for biodegradation of water pollutants. This project is co-investigated by Kate Schutte (project **2003DE21B,** intern project #24 of 32 to date**)** and extends the work of 2002 ***DWRC*** interns Aditya Sharma and Bret Strogen (project **2002DE40B,** intern project #22 of 32 to date).

"If wastewater treatment plants could use my reactor's technology to more quickly biodegrade pollutants and additionally create a current that could be used to support other treatment activities, the effect on their efficiency would be profound."
-- Andrew Joslyn, University of Delaware undergraduate senior, Environmental Engineering major.

Abstract:

This study of electricity generation by microorganisms was conducted to determine whether or not biodegradation was enhanced by the presence of an electrode system. The results show that a reactor with a closed circuit was able to degrade 60.6% of the organic content, whereas a reactor with an open circuit only degraded 48.7%. In addition, the experiment showed a clear connection between the addition of benzoate and the production of an electric current. In one reactor, with a sodium benzoate concentration of about 3.8 g/L, the current production was much greater (peak at more than 800 microamps) than in another reactor with one-tenth the concentration of benzoate (peak at about 500 microamps). When 1 gram of sodium benzoate was spiked into the reactors after 69 days, the current production increased almost immediately.

Discussion

This experiment showed that current and voltage can be created and maintained by a mixed, anaerobic, sludge culture. The results of this experiment suggest that the degradation of organic materials can be enhanced by connecting a circuit between an anaerobic digestion compartment and an aerated chamber.

The current production seems to be limited by the available surface area of graphite electrode. This was shown when, periodically, one of the two circuits in a reactor was disconnected and the other was measured for current. In these cases, the current production through one electrode increased, but never equaled the sum of currents produced when both circuits were closed. Therefore, one can expect to see a greater rate of degradation of organic material when the surface area of graphite electrode is increased.

Conclusion

The major finding in this research was that the degradation of organic material was enhanced when the graphite electrode circuit was closed. This must mean that at least one organism gained an advantage by having the electrode available for electron shuttling.

The next steps in this research should be to determine the mechanism for electron transport, identify the organism(s) responsible for current production, and test various organic compounds to see if there is potential for enhanced degradation. For example, there are some pollutants common to surface and groundwater, such as TCE. If the degradation of TCE (or other

hazardous organic compounds) could be enhanced using an electrode system like the one designed in this experiment, there could be great implications for remediation projects around the world.

Undergraduate Internship: Enumeration of Aquatic RNA Viruses from a Mixed Viral Sample

Basic Information

Title:	Undergraduate Internship: Enumeration of Aquatic RNA Viruses from a Mixed Viral Sample
Project Number:	2003DE25B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Biological Sciences
Focus Category:	Ecology, Surface Water, None
Descriptors:	Ecology, Surface Water
Principal Investigators:	Matt Simon, Kurt Williamson, Eric Wommack

Publication

1. Simon, Matthew, K. Eric Wommack, Kurt E. Williamson, 2003, Enumeration of Aquatic RNA Viruses from a Mixed Viral Sample, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 11 pages.

Undergraduate Internship Project #6 of 10 for FY03

The project is co-sponsored by the ***University of Delaware College of Marine Studies (CMS) and the DWRC.*** Mr. Simon hopes to better characterize viruses, which are now known to be the most abundant life-form in natural waters and also to be efficient transformers of bacteria and plankton into organic matter.

"I have been using epifluorescence microscopy to detect and quantify viruses. Ultimately, I hope to extract viruses from soils in a number of ways, discovering which are most efficient at helping us understand the biological diversity of viral communities in soils."
– Matt Simon, University of Delaware undergraduate junior, Biology major.

Abstract:

Many studies have demonstrated a high abundance of viruses in aquatic ecosystem and there seems to be a growing interest in viruses. However, methods used to date have focused on dsDNA viruses and little effort has been made to determine the overall abundance of RNA viruses. In this study, we attempted to determine the efficacy of quantifying RNA viruses from a mixed sample using epifluorescence microscopy (EFM). Prior to enumeration of RNA viruses, it was necessary to determine if unencapsidated viral nucleic acids could be visualized using EFM. This was accomplished by using dsDNA bacteriophage T4 as a model system. Viral capsids were lysed using physical (heat) and enzymatic (Proteinase K) treatments. Additionally, attempts were made to visualize naked DNA of λ-HindIII (~23 kb) under EFM. Phage T4 seemed to be resistant to protease treatment since the number of viruses in protease-treated samples did not differ significantly from untreated controls. When phage capsids were denatured by heating, discrete virus particles could not be detected. The λ -HindIII preparations provided further evidence that naked DNA cannot be enumerated using EFM. The inability to resolve un-encapsidated DNA as countable units demonstrated that discrimination of RNA viruses from a mixed sample is not possible using EFM techniques.

Undergraduate Internship: Blue Hen Creek: An Evaluation of Stream Habitat Restoration at the UD Experimental Watershed

Basic Information

Title:	Undergraduate Internship: Blue Hen Creek: An Evaluation of Stream Habitat Restoration at the UD Experimental Watershed
Project Number:	2003DE26B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Not Applicable
Focus Category:	Surface Water, Ecology, Management and Planning
Descriptors:	Surface Water, Ecology, Management and Planning, Conservation, Geomorphological Processes, Education, Methods
Principal Investigators:	Judith Walker, Gerald Kauffman

Publication

1. Walker, Judith, Gerald J. Kauffman, 2004, Blue Hen Creek: An Evaluation of Stream Habitat Restoration at the UD Experimental Watershed, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 61 pages.

Undergraduate Internship Project #7 of 10 for FY03

The project is co-sponsored by the ***UD Institute for Public Administration Water Resources Agency (WRA and DWRC.*** Ms. Walker, University of Delaware undergraduate senior, Natural Resource Management major, will recommend habitat restoration techniques for areas along Blue Hen Creek, a tributary of the White Clay Creek. Blue Hen Creek was classified by previous ***DWRC*** interns (Jennifer Campagnini in FY00 project G-04, continued by Tara Harrell in FY01 as project G-14) as impaired by bank erosion due to watershed urbanization. A related project, investigated by Kristen Sentoff and also advised by Gerald Kauffman, is "Fairfield Run: An Evaluation of Stream Habitat Restoration at the UD Experimental Watershed", project **2003DE22B** (intern project #25 of 32 to date).

Abstract:

Previous student researchers have delineated an Experimental Watershed on the University of Delaware campus and further linked how changes in land use affect the health of streams. The purpose of this project is to research various types of stream restoration techniques that are applicable to Mid-Atlantic Piedmont streams and use the research to design a restoration plan for Blue Hen Creek. All of the restoration technique sources found during the research phase of this project were tabulated into a matrix that can be used to determine the appropriate restoration technique based on stream condition and available resources. A reference stream was selected and used throughout the project as a comparison of stream health to Blue Hen Creek. The reference stream was also used as a model for the results desired after the restoration techniques are implemented in later phases of the project. Field stations every 100 feet were set up along the stream to aid in the placement of the restoration designs. Following similar monitoring techniques of previous researchers, stream health grades were given to both Blue Hen Creek and the reference stream. The overall, Blue Hen Creek received a water quality score 3.03 or a B- and the reference stream received 3.56 or an A-. Stream habitat surveys were conducted on both streams as well with Blue Hen Creek only receiving a moderate score while the reference stream received the high rating of Very Good. The Rosgen method of stream classification was also performed on Blue Hen Creek and the reference stream. The streams received very close classifications meaning that the reference stream is a good approximation of what Blue Hen Creek would be without human disturbances. Blue Hen Creek is currently classified as a C5 and the reference stream is a class C3b. All of the results from the data collected indicated that while Blue Hen Creek is in need of restoration, the stream should respond positively to properly applied restoration techniques. Based on the literary research and fieldwork, specific sites ware selected for restoration and paired with appropriate restoration techniques to be implemented in a later phase. Nine restoration techniques are recommended for implementation on either the entire length of the stream or on specific field stations on Blue Hen Creek. Future researchers will be able to implement the restoration designs and monitor their effects on the stream health and overall health of the watershed.

Undergraduate Internship: Influence Of Nitrogen Form On Nickel Accumulation By ALYSSUM MURALE

Basic Information

Title:	Undergraduate Internship: Influence Of Nitrogen Form On Nickel Accumulation By ALYSSUM MURALE
Project Number:	2003DE27B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	at large
Research Category:	Water Quality
Focus Category:	Geochemical Processes, Toxic Substances, Treatment
Descriptors:	Geochemical Processes, Toxic Substances, Treatment, Conservation, Management and Planning, Water Quality
Principal Investigators:	Justin Glier, Donald L. Sparks, Ryan Tappero

Publication

Undergraduate Internship Project #8 of 10 for FY03

The project is co-sponsored by the ***University of Delaware Department of Plant and Soil Sciences (PLSC) and DWRC.*** Mr. Glier will explore the effect of nitrogen as an effective and affordable amendment to enhance plant-based cleanup of nickel-contaminated soils.

"I am thrilled to have the opportunity to study the prospective uses of plants in environmental remediation. We have the potential to undercut the costs of more conventional clean-up techniques by millions of dollars by simply planting and maintaining specialized crops on hazardous areas."
-- Justin Glier, University of Delaware undergraduate senior, Environmental Soil Science major.

Abstract:

Unique metal-accumulating plants (i.e. hyperaccumulators) have the ability to absorb, translocate, and compartmentalize excess quantities of heavy metals. These rare plants can be used to extract metals from contaminated sites (i.e. phytoextraction) or to mine metal-rich soils (i.e. phytomining). Due to electrical neutrality requirements, N form has a profound effect on the cation/ anion balance in plants and controls rhizosphere acidification/ alkalinization. Ammonium sulfate fertilizers are often used to promote rhizosphere acidification for enhanced phytoextraction. However, several researchers have recently reported a counter-intuitive "pH effect" on Ni accumulation, where Ni is extracted more efficiently at higher pH than at lower pH. The effect of nitrogen form (i.e. NO_3^- or NH_4^+) on Ni accumulation by *A. murale* was investigated to evaluate the best type of fertilization for phytoextraction. Plants (propagated from vegetative cuttings) were grown in perlite media and exposed to nutrient solution via an ebb and flow method. The modified 1/3-strength Hoagland's solution contained 25 uM Ni and was buffered at pH 6.2 with 2 mM MES. After four weeks exposure, plants were harvested (root and shoot), weighed, dried, digested (EPA 3050 B), and analyzed for total metal content (and nutrients) by ICP. Alyssum plants supplied with NO_3^- had 3-fold greater biomass and more than a 3-fold higher Ni concentration than did plants treated with NH_4^+. Nitrogen form did not alter the translocation factor (~2.5) for nickel. Plants supplied with NO_3^- accumulated significantly more Mn, Ca, and Mg than did plants supplied with NH_4^+, while the latter accumulated more sulfate and phosphate. The results showed nearly a 10- fold difference in Ni extraction in response to available N form, with the NO_3^- treatment providing the greatest uptake. These studies suggest the form of nitrogen could play a significant role in enhancing the ability of hyperaccumulator plants to remove toxic metals from contaminated soils. Better understanding these effects could significantly improve soil and environmental quality.

Undergraduate Internship: Nanticoke Watershed Total Maximum Daily Load Project

Basic Information

Title:	Undergraduate Internship: Nanticoke Watershed Total Maximum Daily Load Project
Project Number:	2003DE28B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Nutrients
Descriptors:	Water Quality, Non Point Pollution, Nutrients, Groundwater, Nitrate Contamination, Surface Water
Principal Investigators:	Mark Neimeister, Alan Scott Andres

Publication

1. Neimeister, Mark, A. Scott Andres, 2004, Nanticoke Watershed Total Maximum Daily Load Project, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 14 pages.

Undergraduate Internship Project #9 of 10 for FY03

The project is co-sponsored by the ***Delaware Geological Survey (DGS) and DWRC***. Mr. Neimeister is collecting and statistically evaluating water samples with the goal of developing improved methods for computing watershed pollutant loads.

"The Nanticoke River watershed is ranked as one of the top priority Delaware watersheds needing evaluation of the amount of pollution it can handle before significant environmental damage takes place. My analysis of baseflow, stormflow, and ground water samples will help evaluate ways to improve pollution measurements."
-- Mark Neimeister, University of Delaware undergraduate senior, Geography major.

Abstract:

This report included various topics relating to water quality and the Nanticoke drainage basin. In addition to the Nanticoke near Bridgeville, Delaware sub-watershed, four new delineated watersheds were established. Areas of potential recharge conditions such as high runoff were then identified within the five basins.

The major research done in the study concerned the water quality of the Nanticoke River, collected near Bridgeville. Two studies of various lengths were evaluated and processed. In order to complete the study, the collection of precipitation and stream discharge records, along with the separation of baseflow, was necessary. Pollutants such as NO_3 and PO_4, in particular, emphasized the high load values seen in the Nanticoke waters. This report was done to improve the methods of monitoring pollution by analyzing baseflow, stormflow, and ground water samples.

Undergraduate Internship: Field Measurements of Non-Point Source Pollutant Removal Efficiencies of Stormwater BMPs at the UD Experimental Watershed

Basic Information

Title:	Undergraduate Internship: Field Measurements of Non-Point Source Pollutant Removal Efficiencies of Stormwater BMPs at the UD Experimental Watershed
Project Number:	2003DE29B
Start Date:	6/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Management and Planning, Non Point Pollution, Wetlands
Descriptors:	Management and Planning, Non Point Pollution, Wetlands, Water Quality, Conservation, Methods
Principal Investigators:	Kathleen Cormier, Gerald Kauffman, Martin Wollaston

Publication

1. Cormier, Kathleen, Gerald Kauffman, Martin Wollaston, 2004, Field Measurements of Non-Point Source Pollutant Removal Efficiencies of Stormwater Best Management Practices in the University of Delaware Experimental Watershed, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 36 pages.

Undergraduate Internship Project #10 of 10 for FY03

The project is co-sponsored by the ***Delaware Department of Natural Resources and Environmental Control (DNREC) and DWRC***. Ms. Cormier proposes to monitor the quality of stormwater inflow to and outflow from several stormwater ponds and wetlands installed on the University of Delaware campus.

"I'm very interested to see just how efficiently these Best Management Practice, or BMP, strategies are working removing pollutants, as compared to my estimates. There is very little field data currently available on the use of stormwater ponds and installed wetlands to improve water quality; this research should help us to better apply the strategy in future projects. "
--Kathleen Cormier, University of Delaware undergraduate senior, Natural Resource Management major.

Abstract:

On the University of Delaware campus, student researchers sought to examine the pollutant removal efficiency of several installed stormwater Best Management Practices (BMPs). Stormwater BMPs are a candidate restoration strategy for the Christina Basin of northeastern Delaware and Southeastern Pennsylvania. This report seeks to obtain efficiency data for those stormwater BMPs already installed on the Unversity of Delaware campus. Stormwater runoff was collected for three separate rainfall events at designated inflow and outflow stations in two stormwater BMPs – a bioretention site and a combination wetland swale. Results were mixed but promising. The conclusions drawn were that with continued maintenance and planting of native vegetation, stormwater wetlands can be effective in protecting receiving waters.

Graduate Fellowship in Water Engineering and Public Health: Removal and Inactivation of Water-borne Viruses Using Permeable Iron Barriers

Basic Information

Title:	Graduate Fellowship in Water Engineering and Public Health: Removal and Inactivation of Water-borne Viruses Using Permeable Iron Barriers
Project Number:	2003DE30B
Start Date:	7/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Water Quality, Treatment, Groundwater
Descriptors:	Water Quality, Treatment, Groundwater
Principal Investigators:	Liping Zhang, Pei Chiu, Yan Jin

Publication

Project Justification and Objectives:

Microbiological contamination of drinking water continues to be one of the greatest challenges in public health risk management in the 21st century. Among the different classes of microbial pathogens, viruses are of particular importance as they are smaller than bacteria and protozoa, far more mobile in subsurface environments, and also more resistant to the currently available water treatment technologies. The United States Environmental Protection Agency (USEPA) in the proposed Ground Water Rule (GWR) identifies viruses as the target organisms because they are responsible for approximately 80% of water-borne disease outbreaks for which infectious agents were identified.

The proposed research will evaluate the feasibility of using elemental iron in a continuous-flow treatment barrier to remove and inactivate waterborne viruses. ***We hypothesize that iron can be used to remove viruses from water because elemental iron can continuously generate and renew the surface iron oxides and oxyhydroxides through corrosion in water, and iron oxides and oxyhydroxides have been shown to inactivate viruses***. A preliminary column test we conducted recently shows that a very thin layer (3 mm) of iron filings in the flow path of virus-contaminated groundwater (8.8 min residence time) resulted in approximately 2-log (99%) removal of two viruses over 40 pore volumes, and 90% of the removal was due to inactivation rather than reversible sorption. We propose to conduct a series of column experiments to further evaluate the effectiveness of iron to remove two bacteriophages and an avian virus and to investigate the effects of the variables and medium conditions that are relevant to water treatment, including iron type and age, pH, and dissolved oxygen.

The specific objectives are:

1. To test the effectiveness of elemental iron to continuously remove and inactivate viruses from contaminated water,
2. To investigate the effects of important parameters (e.g., residence time, iron type and age, virus type) and medium conditions (pH, dissolved oxygen) on the efficacy of virus removal, and
3. To identify the types of Fe oxides/oxyhydroxides involved in virus removal and inactivation.

The proposed study represents the first attempt to evaluate elemental iron for removing pathogens from water. Although elemental iron has been used in permeable reactive barriers (PRBs) to remove chemical contaminants in groundwater for almost a decade, it has never been shown to remove viruses. The proposed study will help determine whether iron PRBs can potentially be a feasible technology for removing waterborne viruses. The research will also provide information regarding the interactions between virus particles and iron mineral surfaces involved in virus removal. This information will form the basis for elucidating, in our subsequent studies, the mechanisms for virus inactivation and sorption by iron oxides - a process that is important in both natural and treatment systems.

Upon successful completion of the proposed project, we will seek longer-term funding to (1) study the mechanisms via which virus sorption and inactivation by iron oxides occur and (2) establish partnerships with water and wastewater treatment companies and organizations to conduct pilot-scale studies. The proposed research and subsequent studies are expected to yield innovative, effective, robust, and low-cost technologies that can be used to remove viruses (and potentially other pathogens) in drinking water, wastewater, and groundwater. Other potential benefits of the iron technology may include lower disinfectant dosage and cost and reduction in disinfection by-product formation. Such technologies are urgently needed to alleviate increasing

public concerns about drinking water safety and to meet the growing demand for potable water – two critical water resource issues facing Delaware.

Significance and Potential Impact of the Proposed Study:

It has been estimated that 76 million cases of acute gastrointestinal illnesses per year in the U.S. is foodborne
(Mead et al., 1999) and 10-40% of these cases may be associated with drinking water (Payment et al., 1991, 1997). Groundwater contaminated with pathogenic microorganisms has been implied in more than 80% of all waterborne disease outbreaks in the U.S. (Ryan et al., 2002). These outbreaks continue to occur despite improvements in water treatment practices and regulations. Among the different classes of pathogens, viruses pose a particular threat to public health due to its high mobility in groundwater. If our hypothesis is proven, iron can perceivably be used in subsurface barriers or above-ground treatment systems to remove and inactivate waterborne viruses. Such iron-based "virus filters" can be either a stand-alone process or added onto an existing water and/or wastewater treatment system to enhance the overall removal efficiency of viruses and possibly other pathogens. Iron filings are relatively inexpensive and have been used in groundwater PRBs for the past decade. The proposed iron treatment process is passive, continuous, and long-lasting, and involves minimal startup, maintenance, and operation costs. The iron treatment can also potentially decrease the disinfectant dosage required, minimize the formation of toxic disinfection by- products, while achieving reduction of the numbers of pathogens in treated water.

Graduate Fellowship in Water Quality: Fate and Transport of Arsenic in Poultry Litter Amended Delaware Soils: Impacts on Water Quality

Basic Information

Title:	Graduate Fellowship in Water Quality: Fate and Transport of Arsenic in Poultry Litter Amended Delaware Soils: Impacts on Water Quality
Project Number:	2003DE32B
Start Date:	7/1/2003
End Date:	2/28/2004
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Water Quality, Solute Transport, Hydrogeochemistry
Descriptors:	Agriculture, Groundwater, Hydrogeochemistry, Nonpoint pollution,Solute Transport, Surface Water, Water Quality
Principal Investigators:	Jen Seiter, Donald L. Sparks

Publication

Project Justification and Objectives:

There are increasing concerns about surface and ground water quality in the Mid-Atlantic Region of the USA. The primary pollutants of concern on the Delmarva Peninsula have been nutrients such as N and P, but there are ever increasing concerns about trace metals derived from industrial, municipal, and particularly, agricultural sources. Arsenic (As) is a ubiquitous metalloid in soil/water environments due to natural geological processes and anthropogenic inputs. Over the past few decades, environmental health has been jeopardized by As contaminating soil and water in the U.S. because of its high carcinogenic, phytotoxic and biotoxic characteristics. Arsenic is a major concern for the health of plants and crops, microorganisms, farm animals, wildlife, and humans. Long-term human exposure to As in drinking water can result in bladder, lung, skin, kidney, immunological, neurological, and endocrine effects. The USEPA announced that it was lowering the maximum contaminant level (MCL) for As in drinking water from 50 ppb to 10 ppb, and all water systems must comply by January 2006 (USEPA, 2001a). This will necessitate an ever vigilant monitoring of water quality to ensure that human health is not deleteriously impacted. Recent data show that there is still an unacceptable level of risk at the EPA's newly adopted 10 ppb MCL. It has been shown that the consumption of only 3 ppb of As creates risk of bladder and lung cancer in 4 to 10 people per 10,000 people (National Research Council, 2001). This risk level exceeds EPA's maximum acceptable level of risk of 1 in 1,000,000 people by 1000-fold.

The Delmarva Peninsula is one of the most concentrated poultry production areas in the US. In 2000, 620 million broilers were produced, which resulted in manure and poultry litter (PL, a mixture of bedding such as wood shavings or sawdust and manure) containing approximately 2.6 X 104 kg of As (Poultry and Value Summary, 2000; Garbarino et al., 2003). Poultry litter is generally applied at the rate of 8.96-20.16 Mg ha-1 on agricultural lands, and its total annual As inputs on the Delmarva Peninsula are estimated between 20 and 50 metric tons of total As (Christen, 2001a). The As in the PL is initially primarily organic (3-nitro-4-hydroxy-phenl-arsonic acid, Roxarsone, abbreviated ROX), which is the form fed to the poultry to control coccidiosis disease, to enhance growth and to improve feed conversion. The quantity of roxarsone that is excreted by a single broiler when fed the 45.4 g ton-1 formulation is estimated to be 150 mg over the typical growth period of 42 days for the chicken (Garbarino et al., 2003). Feed spillage and digested materials have increased the mean total As concentration in the PL to 14-76 mg kg-1 (Moore et al., 1998). Assuming that PL is applied at a rate of at least 5 metric tons per hectare, about 60-250 g of As per hectare could be introduced with each PL application. Annual total metal(oid) inputs on agricultural lands via PL amendments are not specifically regulated at either the federal or state levels, and continuous PL amendment effects on As contamination in Mid-Atlantic soil and water environments are not known. Moreover, the effects of PL amendments on trace element contamination, e.g., from As, in soils have not been considered in current nutrient management programs.

The As in PL is water soluble, which suggests that after land application, it could be readily mobile in water environments. Limited data have shown ground water from agricultural fields of the Pocomoke River Basin in MD and DE having total dissolved As concentrations as high as 23 µg L-1 (Hancock et al., 2003). There is evidence that the organic As transforms to inorganic As, primarily As (V), after land application. The As (V) is much more toxic than ROX. Data are needed to understand the impacts that PL amendments have on the fate and transport of As in sandy, Mid-Atlantic soils and resultant effects on water quality. However, there are very limited data on the speciation and distribution of As in long-term PL amended Delaware soils, the fate and transport of As in these soils, and how competing ions such as phosphate, which is also found in large quantities in PL and in Delaware soils, affect As retention and release. Such studies will

be conducted in this research and will be invaluable in understanding the fate and transport of As in soils that are quite fragile due to their sandy texture, low organic matter, clay, and metal oxide contents, and the often high water tables.

Accordingly, the objectives of this study are:

1) To determine the As status, retention, and release in Delaware soils that have been amended and unamended with poultry litter (PL) and the effects of competitive sorbates such as phosphate.

2) To determine the transport of As in PL amended and unamended soils as it impacts water quality.

Information Transfer Program

Delaware Water Resources Center FY03 Information Transfer Activities

Basic Information

Title:	Delaware Water Resources Center FY03 Information Transfer Activities
Project Number:	2003DE57B
Start Date:	3/1/2003
End Date:	2/29/2004
Funding Source:	104B
Congressional District:	At Large
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	
Principal Investigators:	J. Thomas Sims

Publication

Information Transfer Program

The following section describes the Delaware Water Resources Center's information transfer activities during FY03, grouped together as one project (#**2003DE57B**) as done in past projects (e.g. #1996DE104B).

The FY03 DWRC Information Transfer Activities include:

- Delaware Water Resources Center Print Publication WATER NEWS (formerly #2000DE107B)
- Delaware Water Resources Center Website (formerly #1996DE104B)
- Delaware Water Resources Center E-group /Courses Link (formerly #2001DE112B)
- Delaware Water Resources Center Electronic Newsletter WATER E-NEWS (formerly #2002DE105B)
- Delaware Water Resources Center Intern Project Poster Session / Advisory Panel Annual Meeting (formerly Student Conferences, #2001DE106B)
- Delaware Statewide Water Forum Co-Sponsor & Participant (formerly #2002DE48B and #2002DE125B)
- Delaware Water Resources Center information booth at 2003 Longwood Symposium, Wilmington, DE
- Delaware Water Resources Center information booths at 2003 and 2004 University of Delaware "AG DAY", Newark, DE
- Four Presentations of 2003 M.S. Thesis results based on 2000-2003 DWRC Fellowship Project by Jennifer Jennings (formerly #2002DE52B, based on research project #2002DE1B ending in FY03
- Two Presentations of fellowship research and 2003 PhD dissertation results based on 2000-2003 DWRC Fellowship Project by Lynette Ward (formerly #2002DE51B, based on research project #2002DE3B ending in FY03)
- Presentation based on results of three DWRC internships (#2000DE114B, #2001DE24B, and #2003DE22B) on the University of Delaware Experimental Watershed
- Presentation based on findings of DWRC graduate fellowship project by Stefan Hunger #2002DE4B

Basic Information:
Delaware Water Resources Center Print Publication WATER NEWS

Title:	"WATER NEWS"
NIWR Project No.:	#**2003DE57B,** formerly NIWR #2000DE107B for FY00, FY01, FY02
Issues during FY03:	Volume 4 Issues 1 and 2 (Spring and Fall 2003)
Description:	Newsletter published biannually by the University of Delaware Water Resources Center
Lead Institute:	DE Water Resources Center
Principal Investigators:	Dr. J. Thomas Sims, Director, Amy Boyd, Editor

WATER NEWS is received by nearly 700 recipients in Delaware water-related academia, government, public and private agencies, agriculture and industry. It may be accessed via the Delaware Water Resources Center web site at: http://ag.udel.edu/dwrc/news.html.

Spring 2003 topics included:

- Fall Statewide Water Forum Announced: "Land Use Change and Water Quality"
- Spotlight on Citizen Advocacy: Delaware Sierra Club's Responses to Water Conservation and Quality Issues
- 2000 – 2003 **DWRC** Fellow Lynette Ward Studies Environmental Policies for Poultry Industry
- **DWRC** Annual Meeting & Intern Poster Session
- New 2003 – 2004 **DWRC** Undergraduate Interns
- Water News You Can Use: Thank you Dorothy Miller
- **Center for the Inland Bays** Journal
- Longwood Symposium "Responsible Water Use in the Garden" water-wise tips and **DWRC** survey of Delaware residents drought water pricing preferences
- Christina Watershed Reports
- **HB118** Water Pricing Legislation News
- New **USGS** publications
- Delaware Storm Drain Labeling Programs
- **DWRC** History, Goals and 2003 Advisory Panel
- Water News and **DWRC** Contact Information

Fall 2003 topics included:

- Land Use Planning and Water Quality: State and County Experts Discuss Issues at the 2003 Delaware Water Policy Forum
- Henri Visits Delaware: September 15, 2003 Tropical Storm Floods Red Clay Creek Watershed
- Groundwater Recharge Potential Maps For Water Quality Protection Now Complete
- **EPA NNEMS** Fellowships and **NIWR** National Competitive Grants for 2004
- **DWRC** Awards Two New Graduate Fellowships
- **DWRC** Interns Study Stream Restoration and Storm Ponds for Pollutant Removal
- Christina Watershed group receives $1 million **EPA** grant
- Thank You Ed Jones, Welcome Maria Labreveux
- **DWRC** History, Goals and 2003 Advisory Panel
- Water News and **DWRC** Contact Information

Basic Information: Delaware Water Resources Center Website

Title:	Web site http://ag.udel.edu/dwrc
NIWR Project No.:	#**2003DE57B.** Formerly NIWR #1996DE104B since FY96
Start Date:	Second edition, since 12/2001
End Date:	Ongoing
Description:	Comprehensive site serving Delaware water resources community
Lead Institute:	DE Water Resources Center
Principal Investigators:	Dr. J. Thomas Sims, director, Amy Boyd, administrator

Site contains:

- **Delaware Water Resources Center (DWRC) and Director's News:** Latest updates on DWRC activities and information on the DWRC's mission, history, and role in the National Institute of Water Resources (NIWR).
- **Delaware Water Concerns:** Summary of the major areas of concern related to Delaware's ground and surface waters, with links to key organizations and agencies responsible for water quality and quantity.
- **Projects and Publications:** Descriptions of DWRC's undergraduate internship and graduate fellows programs, annual conference proceedings, and project publications dating back to 1993.
- **Advisory Panel:** Purpose, contact information and e-mail links for the DWRC's Advisory Panel.
- **Request for Proposals and Application Forms:** For undergraduate interns, graduate fellowships and other funding opportunities available through the DWRC.
- **Internships and Job Opportunities:** Information on undergraduate and graduate internships from a wide variety of local, regional, and national sources along with current job opportunities in water resource areas.
- **Water Courses and Faculty:** Link to search engine for current list of University of Delaware water resource courses. List of researchers at Delaware universities with an interest in water resources research; also, science and natural resource curricula links.
- **Water Resources Contacts:** Links to local, regional, and national water resource agencies and organizations categorized as government, academia, non-profit, and US Water Resource Centers.
- **Calendar:** Upcoming local, regional, and national water resources events sponsored by the DWRC and other agencies, such as conferences, seminars, meetings, and training opportunities.
- **Newsletters:** Access to DWRC newsletters dating back to 1993.
- **Annual and 5-year Reports:** DWRC annual and 5-year reports, dating to 1993.
- **KIDS' Zone:** Water Resources Activities and Information for Kids and Teachers

Basic Information: Delaware Water Resources Center E-group /Courses Link

Title:	Delaware Water Resources Center / Water Resources Agency Egroup, originating from the online listing of Delaware water teachers and researchers found on the DWRC site: http://ag.udel.edu/dwrc/faculty.html
NIWR Project No.:	#**2003DE57B.** Formerly NIWR #2001DE112B (FY01, FY02)
Start Date:	Since 12/2001
End Date:	
Description:	E-group and link to university water resources courses taught, serving Delaware water resources community
Lead Institute:	DE Water Resources Center
Principal Investigators:	J. Thomas Sims, director, Amy Boyd, administrator

The online listing of approximately 60 researchers at the University of Delaware, Delaware State University, and Wesley College found on the Delaware Water Resources Center web site at http://ag.udel.edu/dwrc/faculty.html forms the foundation for a broader egroup list maintained by the Center reaching additional academic, public, private, and government water community contacts, who are notified via a monthly email newsletter of events and job postings of interest in water resources. The web site also links to a search engine for water-related courses currently offered by the researchers.

The total list of e-group members numbered 108 as of June 2003.

Basic Information:
Delaware Water Resources Center Electronic Newsletter WATER E-NEWS

Title:	"WATER E-NEWS"
NIWR Project No.:	#**2003DE57B.** Formerly NIWR #2002DE105B for FY02
Issues during FY03:	**Vol. 2 Issues 2, 3, 4, and 5: 3/03, 9/03, 10/03, 12/03, and Vol. 3 Issue 1 2/04**
Description:	Online newsletter published periodically and emailed to center's water resources e-group by the University of Delaware Water Resources Center
Lead Institute:	DE Water Resources Center
Principal Investigators:	J. Thomas Sims, Director, Amy Boyd, Editor

WATER E-NEWS is now received by over 100 recipients in Delaware water-related academia, government, public and private agencies, agriculture and industry. The current issue and back issues dating to its July 2002 inception may be accessed via the Delaware Water Resources Center web site at: http://ag.udel.edu/dwrc/news.html.

Featured in each issue of Water E-News are:

I. Undergraduate Internships and Jobs in Water Resources from DWRC and more;
II. Graduate Fellowships, plus post-doc and professional opportunities;
III. Project funding and awards programs;
IV. Upcoming seminars and conferences; and
V. New information and training sources in water resources.

Basic Information:
Delaware Water Resources Center Intern Project Poster Session / Annual Advisory Panel Meeting

Title:	University of Delaware 2003 Undergraduate Research Scholars Poster Session
NIWR Project No.:	#**2003DE57B.** Formerly NIWR #2001DE106B for FY01 and FY02
Date:	4/25/2003
Description:	Undergraduate Interns presented their 2002-2003 DWRC-funded projects.
Lead Institute:	UD Undergraduate Research Program, DE Water Resources Center
Principal Investigators:	Joan Bennett, Director, UD Undergraduate Research Program (jbennett@udel.edu), J. Thomas Sims, Director, Delaware Water Resources Center (jtsims@udel.edu)

On April 25, 2003, six undergraduate student interns who had been funded over the past year by the Delaware Water Resources Center (DWRC) presented the results of their research accompanied by their advisors at an informal poster session sponsored by the University of Delaware Undergraduate Research Program. UD Science and Engineering Scholars joined the ***DWRC*** interns to present to a crowd of over 500 visitors.

The 17-member ***DWRC*** *Advisory Panel* also convened on April 23rd, 2003 for lunch with the interns and their advisors and then held their annual meeting prior to the poster session. **DWRC** Director Tom Sims described the Center's plans for 2003 - 2004 research and public education through WATER NEWS and our web presence. The panel discussed ways to enlist community support for research and training of new water scientists.

Poster Presentations

1) Boyer, L. Poster Presentation April 25, 2003. Chemistry of Phosphorus in the Erodible Fraction of Delaware Soils. University of Delaware Undergraduate Research Scholars Poster Session.
2) Dewire, A. Poster Presentation April 25, 2003. Implementation of Riparian Buffers in Southeastern Pennsylvania, Delaware, and Eastern Maryland. University of Delaware Undergraduate Research Scholars Poster Session.
3) League, M. Poster Presentation April 25, 2003. Understanding the Mechanisms of the Spread of Phragmites: For Better or For Worse. University of Delaware Undergraduate Research Scholars Poster Session.
4) Sentoff, K. Poster Presentation April 25, 2003. Regulating Wetlands in Delaware in a Changing Legal Environment. University of Delaware Undergraduate Research Scholars Poster Session.
5) Smith, K. Poster Presentation April 25, 2003. An Autonomous Full-Water Column Environmental Monitoring System with Telemetry. University of Delaware Undergraduate Research Scholars Poster Session.
6) Strogen, B. and Aditya Sharma. Poster Presentation April 25, 2003. Accelerated Pollutant Biodegradation by Electrode Use. University of Delaware Undergraduate Research Scholars Poster Session.

Basic Information:
Delaware Statewide Water Forum Co-Sponsor & Participant

Title:	Annual Delaware Statewide Water Policy Forum
NIWR Project No.:	#**2003DE57B.** Formerly NIWR #2002DE48B, #2002DE125B for FY02
Date:	Oct. 2, 2003
Description:	Presentation of DWRC recent accomplishments and program goals; DWRC information booth. Forum brochure/agenda for 2003 event may be found on the web at: http://www.wr.udel.edu/publicservice/waterforumbrochure2003.pdf Complete article is found in DWRC Fall 2003 WATER NEWS at http://ag.udel.edu/dwrc/newsletters/fall2003.pdf
Lead Institute:	Co-sponsored by the Delaware Water Resources Center, University of Delaware Institute for Public Administration, Water Resources Agency, Delaware Geological Survey, Center for the Inland Bays, and Delaware Department of Natural Resources and Environmental Control. http://www.wr.udel.edu/publicservice/WaterForum03Sponsors.pdf
Principal Investigators:	J. Thomas Sims, Director, Delaware Water Resources Center (jtsims@udel.edu); Jerome Lewis, Director, University of Delaware Institute for Public Administration (jlewis@udel.edu); Gerald Kauffman, State Water Coordinator, University of Delaware Institute for Public Administration Delaware Water Resources Agency (jerryk@udel.edu); John Talley, Director, Delaware Geological Survey (waterman@udel.edu); Bruce Richards, Director, Center for the Inland Bays (brichard@udel.edu); and Kevin Donnelly, Director, Division of Water Resources, Delaware Department of Natural Resources and Environmental Control (kevin.donnelly@state.de.us)

The third annual Delaware Policy Forum titled *"Land Use Change and Water Quality: Assessing the Impacts and Planning for the Future"* was held for over 150 visitors from Delaware government, water agencies, academia, and the public, on Thursday October 2, 2003 at Clayton Hall on the University of Delaware campus in Newark, Delaware. This was the third annual statewide water resources forum in recent years, and the second co-sponsored by the **Delaware Water Resources Center**. In addition to talks on historical perspectives and state/county policies linking land use with water quality, presentations by seven state water experts explored planning priorities, challenges, strategies, and new information tools, and gave an update on causes and historical relevance of land use to the flooding experienced in New Castle County September 15, 2003 during Tropical Storm Henri. The other event co-sponsors included the University of Delaware Institute for Public Administration (UD IPA), Water Resources Agency (WRA), Delaware Geological Survey, Center for the Inland Bays, and Delaware Department of Natural Resources and Environmental Control (DNREC).

The first statewide water forum co-sponsored by the Delaware Water Resources Center had been held the previous year on Oct. 9, 2002. Nearly one hundred attended the second annual Delaware Policy Forum event entitled "Drought.02: A Debate and Panel Discussion Concerning Water Supply Policy in Delaware" and co-sponsored by the UD IPA, WRA and Delaware DNREC.

Basic Information:
Delaware Water Resources Center Information Booth at 2003 Longwood Symposium, Wilmington, DE

Title:	DWRC presentation at 2003 Longwood Symposium **"Responsible Water Use in the Garden"** Mar. 29, 2003, Winterthur Museum, DE
NIWR Project No.:	**#2003DE57B**
Date:	Mar. 29, 2003
Description:	Information booth of DWRC recent accomplishments, program goals, water conservation/protection tips for homeowners, public survey
Lead Institute:	DE Water Resources Center
Principal Investigators:	Amy Boyd, Program Coordinator, Delaware Water Resources Center (aboyd@udel.edu)

The **"Responsible Water Use in the Garden"** symposium co-hosted by the Longwood Graduate Program , Winterthur's Garden Division, the Delaware Water Resources Center, and others Mar. 29th, 2003, featured experts in water policy, landscape architecture, ornamentals, xeriscapes, irrigation, and sustainable designs. The ~165 participants received a new DWRC brochure prominently displayed in their conference packet and had an opportunity to visit the Center's information table, which featured:

1. DWRC Poster display featuring current research projects of 3 fellows and 6 interns
2. Brochures describing the DWRC Internship program for 2003-2004
3. Copies of DWRC print newsletters "Water News" and printed copies of "Water E- News", DWRC's electronic periodical emailed currently to an egroup of over 100 recipients. Signups for both were included.
4. Water conservation / quality protection tip sheet for homeowners.
5. Comment board for participants to request information or Center support.

The **DWRC** surveyed Delaware residents attending the symposium for their **favored actions during droughts** to lower water demand. For survey results and an article on the event highlights, visit: http://ag.udel.edu/dwrc/newsletters/spring2003.pdf page 6.

Basic Information:
Delaware Water Resources Center information booths at
2003 and 2004 University of Delaware "AG DAY", Newark, DE

Title:	DWRC "Ag Day" public Water Conservation information / training booths
Dates:	Apr. 27, 2003, and Apr. 24, 2004
NIWR Project No.:	#**2003DE57B**
Description:	Public education outreach
Lead Institute:	DE Water Resources Center, Institute of Soil and Environmental Quality at the University of Delaware
Principal Investigators:	Amy Boyd, Program Coordinator, Delaware Water Resources Center (aboyd@udel.edu), and Maria Pautler, Program Coordinator, Institute of Soil and Environmental Quality at the University of Delaware (mpautler@udel.edu), presenters

Boy Scout Soil and Water Conservation Merit Badge Training was provided to 32 area Boy Scouts by **DWRC** and **UD** Institute of Soil and Environmental Quality staff at **UD Ag Day April 24, 2004.** Visit http://ag.udel.edu/dwrc/publications.html and click "Public Programs" link for highlights and photos.

Estimated attendance at the overall 2004 public event was between 3,000 and 4,000. At the DWRC booth, free soil and water conservation literature were available. A large public information display of watershed and contour maps was provided by the University of Delaware Institute for Public Adminstration Water Resources Agency and Delaware Geological Survey. The public could also pick out Newark area water features on an aerial map provided by the UD College of Agriculture and Natural Resources and the Water Resources Agency.

The 2004 public training program expanded the DWRC's education outreach efforts at this annual event. At the **previous Ag Day on April 27, 2003**, attended indoors on a rainy day by an estimated 2,000 people, the Center provided an information table, which featured:

1. DWRC Poster display featuring current research projects
2. Brochures describing the DWRC and its Internship program for 2003-2004
3. Copies of 2002 print newsletters "Water News" and printed "Water E-News"
4. Signups to receive these free periodic newsletters.

Basic Information:
Four Presentations of 2003 M.S. Thesis results
based on 2000-2003 DWRC Fellowship Project by Jennifer Jennings

Title:	Four Presentations of 2003 M.S. Thesis results based on 2000-2003 DWRC Fellowship Project "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays"
NIWR Project No.:	#**2003DE57B.** Based on research project #2002DE1B and former NIWR information transfer project #2002DE52B
Dates:	May 20, June 4, June 20, and October 20-22, 2003
Description:	Conference presentations
Principal Investigators:	Jennifer Jennings, University of Delaware M.S. 2003 recipient
Other Principal Investigators:	William Ullman ullman@udel.edu, and Joseph Scudlark scudlark@udel.edu, College of Marine Studies, University of Delaware, advisors.

1. Jennings, Jennifer. "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays", Delaware Nutrient Management Commission (DNMC) meetings of the "Technology" and "Program and Education" committees, Dover, DE. May 20, 2003.

> The DNMC-developed statewide plan implements best management practices (BMPs) to reduce nutrient loading to surface and groundwaters. Jennings' research provided a quantitative estimate of relative nutrient loading to Delaware's Inland Bays by base flow and storm flow vital to the DNMC efforts to identify the most effective BMPs for water quality protection.

2. Jennings, Jennifer. "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays", Meeting of the Delaware Department of Natural Resources and Environmental Control (DNREC), Watershed Assessment Branch, Dover, DE. June 4, 2003.

3. Jennings, Jennifer. "The Role of Land Use and Land Cover in the Delivery of Nutrients to Delaware's Inland Bays", Meeting of the Center for the Inland Bays (CIB) "Scientific and Technical Advisory" committees, Lewes, DE. June 20, 2003.

4. Jennings, J.A., J.R. Scudlark, K.B. Savidge, and W.J. Ullman, 2003, Estuarine eutrophication by atmospheric phosphorus, in National Atmospheric Deposition Program 2003 Ammonia Workshop proceedings, Washington, D.C. 20-22 October 2003.

Presentation Abstract

Annual total nitrogen and phosphorus loads have been determined at one sub-watershed of Delaware's Inland Bays (Bundicks Branch) using an extensive water quality data set and flow-based loading calculations, where load is determined as the product of concentration and discharge. The total discharge, which was measured, was separated into the baseflow and stormflow components using a baseflow minimization separation technique that reduces the baseflow component of discharge during storm periods in proportion to storm-related stage height increases. High frequency sampling experiments were conducted to determine the uncertainty associated with estimated baseflow loads. Dissolved constituent concentrations appear to be less variable then the particulate counterparts and as such, the dissolved baseflow loads have less uncertainty (<12% compared to >40% for particulate loads). Storm loads can be estimated for unsampled rain events by normalizing loads to storm discharge, which produces annual storm loads with uncertainties less then 10% during monitored periods of time. Based on an analysis of water budgets, a

considerable amount of water and nutrients appear to bypass the Bundicks Branch gauging station and discharge further downstream or directly into Rehoboth Bay. This underflow component can be estimated using a water budget at Millsboro Pond to calculate average monthly evapotranspiration. The loading rates utilized in several land use loading models were applied to Bundicks Branch. The annual nitrogen loads determined at Bundicks Branch during this study (28,000-34,000kg/yr) are within 30% of the annual average load estimated by the Horsley & Witten (1998) N-model (40,000kg/yr). The annual phosphorus loads determined during this study (170-290kg/yr), however, are substantially less then the annual average load estimated by the USDA P-model (1,365kg/yr) (Cassell and Meals, 1999). This implies that the non-point source P load from the entire Rehoboth Bay sub-basin is also likely less then previously believed. As a result, P contributions to Rehoboth Bay from the Rehoboth Wastewater Treatment Plant (RBWTP) and direct atmospheric deposition are both relatively greater than anticipated. Atmospheric deposition of P, which has been assumed to be negligible, actually contributes 14% of the annual P load, while the RBWTP may contribute anywhere from 50-75% of the P load, depending on the season.

Basic Information:
Two Presentations of fellowship research and 2003 PhD dissertation results based on 2000-2003 DWRC Fellowship Project by Lynette Ward

Title:	Two Presentations of fellowship research and 2003 PhD dissertation results based on 2000-2003 DWRC Fellowship Project "Environmental Policies For A Sustainable Poultry Industry In Sussex County, Delaware"
NIWR Project No.:	#**2003DE57B.** Based on research project #2002DE3B and former NIWR information transfer project #2002DE51B
Dates:	March 25, 2003, and June 26, 2003
Description:	Conference presentations
Principal Investigators:	Lynette Ward, University of Delaware PhD recipient 2003
Other Principal Investigators:	William Ritter william.ritter@udel.edu, Department of Bioresources Engineering; John Byrne jbbyrne@udel.edu and Young-Do Wang youngdoo@udel.edu, Center for Energy and Environmental Policy, University of Delaware, advisors.

1. Ward, Lynette. March 25, 2003. Paper: Overcoming Market and Technical Barriers to Poultry Litter Compost. International Solid Waste Management and Technology Conference, Philadelphia, PA.

2. Ward, Lynette. June 26, 2003. Paper: Phosphorus Management Options for the Delmarva Poultry Industry. World Water and Environmental Resources Congress, Philadelphia, PA.

Abstract: (Taken from the DE Water Resources Center fellowship final report and University of Delaware PhD dissertation upon which these presentations were based.)

Sussex County, Delaware produces more broilers than any other county in the United States, producing 247.4 million broilers in 2001. While poultry production is the primary economic activity in the county, it is also the primary source of nutrient pollution. Poultry litter is applied to the county's cropland at rates that exceed the crop's agronomic needs. As a result, phosphorus levels have built up in the soils and nutrients now enter the county's waterways causing water quality problems. Consequently, land application can no longer be the sole disposal method for poultry litter in Sussex County.

The intent of this research was to develop environmental policies that promote the creation of a sustainable poultry industry in Sussex County, Delaware. Sustainable poultry industry practices meet the triumvirate goals of being environmentally sound; economically viable in both the short-term and long-term; and socially responsible in the sense of promoting equity, and preserving rural communities and quality of life. This research evaluated the economic feasibility of methods to reduce the phosphorus content of poultry litter, bind soluble phosphorus to soils, or to find beneficial uses other than direct land application. The following nutrient management strategies were evaluated in terms of their technical and economic feasibility: 1.) the use of high availability phosphorus corn in poultry rations, 2.) the addition of the enzyme phytase in poultry rations, 3.) biogas production, 4.) energy generation, 5.) composting, 6.) use as a cattle feed supplement, and 6.) pelletizing.

The economic analysis of nutrient management strategies was conducted using Implan Professional 2.0, a PC based economic analysis software system that uses both data files and software to create regional models. Implan was used to do an economic analysis of not only the alternative uses for poultry litter, but to measure

the economic and social impacts of developing a sustainable poultry industry in Sussex County in terms of factors such as dollars of sales, local taxes received, impact on tourism revenues, and jobs created.
The results of this research indicated that a combination of pelletizing and composting poultry litter to create value-added products and the use of the enzyme phytase to lower the concentration of phosphorus in the litter were the optimal nutrient management strategies for the study area. The adoption of these strategies would enable the study area to achieve nutrient management sustainability, which results in improved economic viability of the region, enhanced water quality and preservation of rural community structure and values.

Presentation based on DWRC internships research by Jennifer Campagnini, Tara Harrell, and Kristen Sentoff

Title:	The University of Delaware Experimental Watershed
Description:	Presentations through 2003 based on this research, previously NIWR projects #2000DE114B, #2001DE24B, and #2003DE22B, by former DWRC interns Jennifer Campagnini, Tara Harrell, and Kristen Sentoff, respectively. Final report, dissertation, conference presentations, invited talk.
Lead Institute:	DE Water Resources Center
Principal Investigators:	Gerald Kauffman (jerryk@udel.edu), University of Delaware Institute for Public Administration Water Resources Agency, internships advisor

1. Kauffman, Gerald, 2003, The University of Delaware Experimental Watershed, in Watershed Management and the University: A Working Conference for Higher Education, Institutions, Watershed Managers and Other Watershed Stakeholders, Event sponsored by the New Jersey Water Resources Research Institute, Rutgers University, New Brunswick, NJ.

Presentation based on DWRC graduate fellowship research by Stefan Hunger

Title:	Mechanisms of Phosphorus Stabilization in the Soil Environment: A Molecular Scale Evaluation
Start Date:	3/1/2000
End Date:	2/28/2003
Description:	Presentation based on this research, previously NIWR research project #2002DE4B and former NIWR information transfer project #2002DE50B.
Lead Institute:	DE Water Resources Center
Principal Investigators:	Stefan Hunger, University of Delaware PhD. 2003 recipient
Other Principal Investigators:	Donald L. Sparks (dlsparks@udel.edu), Department of Plant and Soil Sciences, University of Delaware, advisor.

1. Hunger, Stefan, H. Cho, and D.L. Sparks, 2004, P-31 NMR investigations of phosphate sorption reactions in the soil environment, in Geochemistry Seminar Series, Spring 2004, School of Earth Sciences, University of Leeds (invited talk).

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	10	0	1	0	11
Masters	1	0	0	0	1
Ph.D.	5	0	0	0	5
Post-Doc.	0	0	0	0	0
Total	16	0	1	0	17

Notable Awards and Achievements

Research Program: The Delaware Water Resources Center (DWRC) has funded fourteen research grant projects during March 2003 through February 2004 that address state water resources priorities identified by the DWRC's 17-member Advisory Panel. Four of these projects are graduate fellowships in nutrient management, the impact of soil arsenic on water quality, and the removal of water-borne viruses. The other ten projects are undergraduate internships investigating food processing wastewater treatment; stream habitat restoration; water pollutant maximum daily loads, uptake by specialized plants, biodegradation through electrode use, and removal through stormwater best management practices; estuarine virus characterizations; and factors affecting West Nile virus transmission from stormwater basins and constructed wetlands.

New Graduate Fellowship Program: The Delaware Water Resources Center (DWRC) announced the availability of two new graduate fellowships on March 21, 2003. These graduate fellowships will support the ongoing efforts of the state of Delaware to protect and improve water quality and to ensure a safe and adequate water supply for all desired end uses. Annual stipends of $19,000 are provided by the DWRC for each of these fellowships. Each fellowship may be renewed a maximum of three years and requires 2:1 matching funds from other sources. Based on the DWRC Advisory Panel's reviews of the proposals submitted, the following outstanding research projects were selected for funding:

" Removal and Inactivation of Water-borne Viruses Using Permeable Iron Barriers. Graduate fellow is Liping Zhang; faculty advisors are Dr. Yan Jin, Department of Plant and Soil Sciences, and Dr. Pei Chu, Department of Civil and Environmental Engineering, University of Delaware; and

" Fate and Transport of Arsenic in Delaware Soils: Impacts on Water Quality. Graduate fellow is Jen Seiter; faculty advisor is Dr. D. L.Sparks, Department of Plant and Soil Sciences, University of Delaware.

First USGS internship coordinated by the DWRC: During 2003 - 2004, Marie Stewart, Hydrologist and Judith Denver, Supervisory Hydrologist for the Dover, Delaware USGS Sub-District, advised University of Delaware senior geology major Eric Lang in an internship coordinated by the DWRC. Eric assisted with field data collection of ground water, surface-water, and rainfall samples, and with development of

geologic cross sections for a drilling project. As a special project for a geology class, Eric mapped the base of Kent County's unconfined surface aquifer. The Delaware Department of Natural Resources and Environmental Control (DNREC) will use the information in a Kent County groundwater availability assessment project and also when issuing various drilling or water supply permits. A USGS report on Eric's project will be published within the year.

Creation of new research scientists in water resources fields: The Water Resources Research Act of 1984 was amended in 1990 to state that one of the purposes of the Act is to foster "the entry of new research scientists into the water resources fields." Since 2000, the Delaware Water Resources Center (DWRC) has funded five graduate fellowships and forty-one undergraduate internships in water resources. The investment of Section 104 funding in the careers of these young people has paid off in a variety of water-resource related positions in science, management, and policy, or further academic pursuits. Among the DWRC fellows, the three graduates have now completed research on topics in environmental soil chemistry, water resource policy, and water quality modeling, and have successfully defended their PhD dissertations and M.S. thesis, all based on their DWRC research efforts. Stefan Hunger is now doing post-doctoral work in the School of Earth Sciences, University of Leeds, continuing his work with spectroscopic techniques in the field of environmental chemistry studying how contaminants are retained and degraded in natural media and how their mobility and bioavailability is influenced by environmental factors. Lynette Ward started her own company, Generations Environmental Consulting, and is working for clients such as the Environmental Defense Fund as a livestock manure consultant studying agricultural nutrient management for watershed planning. She also has smaller clients for whom she performs asbestos, lead, arsenic, and mold air monitoring services. Jennifer Jennings is now employed as an environmental scientist in the Watershed Assessment Branch of the Delaware Department of Natural Resources and Environmental Control, where she is applying the models that she developed as part of her DWRC fellowship to determine more useful land use export factors for nutrient management in Delaware. Among the twenty-two DWRC undergraduates completing internships through FY03, seven are employed in environmental management, consulting, planning, and policy, and design; eleven are pursuing advanced degree work in environmental policy, science, and education; the remaining two are completing their undergraduate work in water-related areas.

New DWRC public education program teaches Boy Scout Soil and Water Conservation Merit Badge: Training was provided to 32 area Boy Scouts by DWRC and UD Institute of Soil and Environmental Quality staff at UD Ag Day April 24, 2004. Visit ag.udel.edu/dwrc/publications.html and click "Public Programs" link for highlights and photos. Free soil and water conservation literature were also made available to the estimated 2,000 attending this public event. A large public information display of watershed and contour maps and aerial photos was provided by the DWRC with assistance from the University of Delaware Institute for Public Adminstration Water Resources Agency and College of Agriculture and Natural Resources, and the Delaware Geological Survey.

DWRC-co-sponsored Statewide Water Forum addresses land use change and water quality: The third annual Delaware Policy Forum titled "Land Use Change and Water Quality: Assessing the Impacts and Planning for the Future" was held for over 150 visitors from Delaware government, water agencies, academia, and the public, on Thursday October 2, 2003 at Clayton Hall on the University of Delaware campus in Newark, Delaware. This was the third annual statewide water resources forum in recent years, and the second co-sponsored by the Delaware Water Resources Center. In addition to talks on historical perspectives and state/county policies linking land use with water quality, presentations by seven state water experts explored planning priorities, challenges, strategies, and new information tools, and gave an

update on causes and historical relevance of land use to the flooding experienced in New Castle County September 15, 2003 during Tropical Storm Henri.

Publications from Prior Projects

1. 1996DE101B ("The Installation and Operation of a Permanent Stream Sampling Site for the Christina River Basin") - Conference Proceedings - Balascio, C.C., D.J. Palmeri, and H. Gao, 1997, Use of genetic algorithms and multi-objective programming for calibration of hydrologic models. In Special Proceedings of the American Society of Agricultural Engineers Mini-Conference: Applications of Emerging Technologies in Hydrology. ASAE International Meeting, Minneapolis, MN. Aug. 10-14, 1997. pp. 45-48.
2. 1996DE101B ("The Installation and Operation of a Permanent Stream Sampling Site for the Christina River Basin") - Conference Proceedings - Balascio, C.C., D.J. Palmeri, and H. Gao, 1998, Use Of A Genetic Algorithm And Multi-objective Programming For Calibration Of A Hydrologic Model. TRANSACTIONS of the American Society of Agricultural Engineers, Minneapolis, MN, 41(3):615-619.
3. 1996DE101B ("The Installation and Operation of a Permanent Stream Sampling Site for the Christina River Basin") - Conference Proceedings - Balascio, C.C., 2000, Multiquadric equations, kriging, and rainfall estimation. In American Society of Agricultural Engineers Annual International Meeting. Paper No. 00-2041: 2950 Niles Rd., St. Joseph, MI 49085-9659, USA.
4. 1996DE101B ("The Installation and Operation of a Permanent Stream Sampling Site for the Christina River Basin") - Articles in Refereed Scientific Journals - Balascio, C.C., 2001, Multiquadric Equations And Other Areal Rainfall Estimation. Journal of Hydrologic Engineering, 6(6):498-505.
5. 1996DE101B ("The Installation and Operation of a Permanent Stream Sampling Site for the Christina River Basin") - Conference Proceedings - Balascio, C.C., and K.B. Wilson, 2001, Rainfall estimation for water-quality modeling on large basins. In American Society of Agricultural Engineers Meeting Paper No. 01-2128: 2950 Niles Rd., St. Joseph, MI 49085-9659, USA.
6. 1996DE101B ("The Installation and Operation of a Permanent Stream Sampling Site for the Christina River Basin") - Other Publications - Kauffman, G.L., S.L.Wozniak, and K.J. Vonck, 2003, A Watershed Restoration Action Strategy (WRAS) for the Delaware Portion of the Christina Basin: A Clean Water Strategy to Protect and Restore the Watersheds of the Brandywine, Red Clay, and White Clay Creeks and Christina River in Delaware. Report prepared for the Christina Basin Clean Water Partnership by the University of Delaware Institute for Public Administration Water Resources Agency, Delaware Geological Survey Annex, Academy Street, Newark, DE 19716.
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8. 1996DE102B ("Geochemistry, Geostatistics, and Hydrology of Phosphorus Losses in Agricultural Drainage; Developing Improved Phosphorus Management Practices for Surface Water Protection ") - Other Publications - Sims, J. T., and P. A. Vadas, 1997, Nutrient management strategies for the profitable, environmentally sound use of phosphorus. Fact Sheet ST-08, College of Agricultural Sciences and Cooperative Extension. University of Delaware, Newark, DE.
9. 1996DE102B ("Geochemistry, Geostatistics, and Hydrology of Phosphorus Losses in Agricultural Drainage; Developing Improved Phosphorus Management Practices for Surface Water Protection ") -

Other Publications - Sims, J. T., and P. A. Vadas, 1997, Soil test phosphorus status and trends in Delaware. Fact Sheet ST-09, College of Agricultural Sciences and Cooperative Extension, University of Delaware, Newark, DE.

10. 1996DE102B ("Geochemistry, Geostatistics, and Hydrology of Phosphorus Losses in Agricultural Drainage; Developing Improved Phosphorus Management Practices for Surface Water Protection ") - Other Publications - Sims, J. T., and P. A. Vadas, 1997, Use of phytase and low-phytate corn to increase phosphorus availability in poultry feed. Fact Sheet ST-10, College of Agricultural Sciences and Cooperative Extension, University of Delaware, Newark, DE.
11. 1996DE102B ("Geochemistry, Geostatistics, and Hydrology of Phosphorus Losses in Agricultural Drainage; Developing Improved Phosphorus Management Practices for Surface Water Protection ") - Other Publications - Sims, J. T., and P. A. Vadas, 1997, Nutrient management planning for poultry-grain agriculture. Fact Sheet ST-11, College of Agricultural Sciences and Cooperative Extension, University of Delaware, Newark, DE.
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15. 1996DE102B ("Geochemistry, Geostatistics, and Hydrology of Phosphorus Losses in Agricultural Drainage; Developing Improved Phosphorus Management Practices for Surface Water Protection") - Articles in Refereed Scientific Journals - Vadas, P. A. and J. T. Sims, 1998, Redox Status, Poultry Litter, And Phosphorus Solubility In Atlantic Coastal Plain Soils. Soil Science Society of America Journal (62):1025-1034.
16. 1996DE102B ("Geochemistry, Geostatistics, and Hydrology of Phosphorus Losses in Agricultural Drainage; Developing Improved Phosphorus Management Practices for Surface Water Protection ") - Conference Proceedings - Vadas, P. A., and J. T. Sims, 1998, Modeling agricultural phosphorus export from a coastal plain watershed in the United States. In Proceedings of the International Conference on Practical and Innovative Measures for the Control of Agricultural Phosphorus Losses to Water. Foy, R.H. and R. Dils (eds.). Belfast, Northern Ireland-UK. p. 194.
17. 1996DE102B ("Geochemistry, Geostatistics, and Hydrology of Phosphorus Losses in Agricultural Drainage; Developing Improved Phosphorus Management Practices for Surface Water Protection ") - Conference Proceedings - Luka, N.J., and J.T. Sims, 1998, Use of iron and aluminum by-products to reduce phosphorus export from Atlantic Coastal Plain soils to surface waters. In Agronomy Abstracts, American Society of Agronomy Annual Meeting, Oct. 18-22, 1998 Baltimore, MD. p. 346.
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