Water Resources Center Annual Technical Report FY 2014

Introduction

Delaware Water Resources Center

June 1, 2015

The Delaware 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 2014.

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. Average annual rainfall is plentiful (45 inches/year) and rather constant, averaging 3 to 4 inches/month in winter and spring and 4 to 5 inches/month in summer. Precipitation typically exceeds evapotranspiration by 12 to 18 inches/year, providing 10 to 12 inches/year of ground water 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 is 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.

According to the Delaware Office of State Planning Coordination's most recent Land Use/Land Cover data set, the major land use in Delaware 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 2509 miles of streams and rivers, 2954 acres of lakes/reservoirs/ponds, 841 square miles of estuarine waters, and 25 miles of ocean coastline. Approximately three-quarters of the state's wetlands are freshwater, and one-quarter 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. Ground water 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 and sediment; (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 and floods; (8) treatment and disposal of on-site sewage; (9)protection and restoration of wetlands; (10) prevention of saltwater intrusion to potable water supplies; (11) protection of functioning riparian areas; and (12) climate change impacts on water resources, including water quality and water supply.

The Water Resource Issues and Problems of Delaware

Surface Water Quality

Point Sources: 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 1970s, 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 1970s and early 1980s under the Clean Water Act, 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 individual "point source" permits to discharge wastewater and stormwater from over 200 in the 1970s to 51 as of 2014. Of those, eight are all or almost all stormwater. NPDES permitting programs have been expanded to address pollution in stormwater runoff from concentrated animal feeding operations (“CAFOs," over 400 potential permittees), construction (2250 permittees as of May 2013), and ongoing industrial activities (363 permittees). Current initiatives include implementation of “Total Maximum Daily Load” (TMDL) requirements, in a long term multi-state effort to reduce PCBs in the Delaware River, and implementation of “Best Available Technology” for cooling water intake structures which draw in tens and hundreds of millions of gallons per day of water from Delaware waters. Major reductions in oxygen demanding materials and toxics in surface waters have been achieved. Future investments in water quality will likely weigh the cost-effectiveness of further reducing point source pollution, versus non-point sources of water quality problems. Currently, the State Clean Water Revolving Fund is providing funds for infrastructure to reduce point source pollution and other pollution sources.

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 1930s and 1940s 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.

Delaware's Drainage Program works with tax ditch associations to manage these ditches and restore them when possible. The effects on the biological and habitat quality of the waterway once it is stabilized are just starting to be known. The Drainage Program also manages public ditch projects, which 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. Little is currently 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: 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 to the State of Delaware's 2012 "Combined Watershed Assessment Report (305(b)) and Determination for the Clean Water Act Section 303(d) List of Waters Needing TMDLs" (dated April 2013), Delaware waters are generally considered to suffer from eutrophication and low dissolved oxygen related to nutrient enrichment. 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; commercial inorganic fertilizers used by farmers, other land managers and homeowners also contribute nutrients to ground and surface waters. About 70% of Delaware's cash farm income comes from broilers, with annual production ranging from 260 to 280 million broilers, primarily in Sussex County, the largest broiler chicken producing county in the U.S.

Other Problems: Toxics have affected Delaware waters resulting in fish consumption advisories for the Delaware River and Bay, Atlantic coastal waters including the Inland Bays, and twenty smaller waterbodies in 2009. The primary pollutant is polychlorinated biphenyl (PCB). Chlorinated pesticides, dioxins, and mercury have also been identified. Though PCBs have long been banned, they are persistent in the environment and are transported from land to waters through runoff. Once in runoff, PCBs settle in waterbody sediments where they enter the aquatic food chain. Another problem is pathogenic organisms. New designated uses and surface water quality standards as amended on July 11, 2004 indicate that pathogenic organisms in surface waters have negatively affected shellfish harvesting and caused 86% of Delaware's rivers and streams to not fully support the swimming use; 98% do not fully support the fish and wildlife use. Most waters do not meet standards because of nonpoint source pollution impacts. In 2012 the Department of Natural Resources developed a "Watershed Approach to Toxics Assessment and Restoration" (WATAR), a five year plan to integrate and coordinate assessment and restoration of watersheds impacted by toxics.

Ground Water Quality

The domestic needs of approximately two-thirds of the state's population are met with ground water provided by both public and private wells. Most of the water used for agriculture, Delaware's largest industry, and self-supplied industrial use, is also derived from ground water sources. A shallow water table and highly permeable 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 ground water 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 (USTs) while agricultural activities are the source of pesticides. There are 12,050 regulated underground storage tanks in the state; 9651 have been properly abandoned and 2399 are still in use. Since the 1980s, 314,040 releases to ground water have been confirmed and 2800 of those (USTs) have been closed. Over the period 2002-2003, 142 sites had confirmed releases with 30 confirmed ground water releases.

Saltwater Intrusion: Problems with private wells occur sporadically from seasonal saltwater 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. Saltwater intrusion will become a recurring issue as sea level rises.

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 ground water samples analyzed by Delaware's Office of Drinking Water in 2002 exceeded the secondary contaminant level standard of 0.3 mg/L. Concerns exist about arsenic in ground waters because of the long-term application of this element in poultry manure to soils overlying shallow drinking water aquifers, the presence of brownfield soils in urban areas that had been used as tanneries or other industries, and the lowered drinking water standard for arsenic.

Wetlands Quality: The ambient condition of fresh and salt water wetlands was assessed in the Broadkill, Cedar Creek, Mispillion, Little River and Leipsic watersheds. Scientific reports summarizing the condition of existing wetlands, recent changes in wetland acreage and land use, and management recommendations were created for the Broadkill watershed. Reports and related information can be found on the Delaware Wetlands webpage: http://de.gov/delawarewetlands.

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.

Recent Initiatives Promoting Delaware Water Quality

Non-tidal Wetlands Conservation and Restoration

Governor Jack Markell signed Senate Bill 78 into law in July 2013. This legislation established a Wetlands Advisory Committee to develop comprehensive recommendations for conserving and restoring non-tidal wetlands in Delaware, including evaluating national best practices and standards, evaluating incentive-based programs, and reviewing state and federal wetland permitting processes to identify opportunities to improve efficiency and eliminate redundancy.

Wetlands cover approximately 25 percent of the total land area in the state of Delaware and provide numerous benefits. Wetlands provide flood storage, water purification, and habitat for economically important wildlife. The loss of wetlands in the state has led to flood damage and adverse effects to landowners' safety, welfare, and personal property. Additional information on Senate Bill 78 and the Wetlands Advisory Committee can be found at: http://www.dnrec.delaware.gov/swc/Pages/Wetland-Advisory-Committee.aspx.

Water quality standards for surface waters in Delaware, revised and adopted effective July 11, 2004 by the Delaware Department of Natural Resources and Environmental Control (DNREC), include amendments to protect swimmers by making bacteria standards consistent with U.S. Environmental Protection Agency guidance and 2000 federal Beaches Environmental Assessment and Coastal Health (BEACH) Act requirements.

To ensure that Delaware waters meet state, regional, and national water quality requirements and goals, the state has one of the most extensive water quality monitoring networks in the nation. Our water resources in this state are regularly tested for biological and chemical parameters. The results are reported in even years in the state's Watershed Assessment Report (305(b) report). Waters that do not meet water quality standards are listed in the state's 303(d) list. Both of these reports are available at: http://www.dnrec.delaware.gov/swc/wa/Pages/WatershedAssessment305band303dReports.aspx.

The extensive water quality data have allowed tracking of long term progress made towards improving Delaware's water resources.

Delaware's non-attainment of Clean Water Act standards as described in the 1996 303(d) list was addressed by a federal court order requiring the development of total maximum daily load (TMDL) regulations for nearly the entire state, according to a schedule that concluded in 2010 for nutrients and bacteria. TMDLs establish the maximum amount of pollutants a water body can receive daily without violating water quality standards, allowing the use of these waters for swimming, fishing, and drinking water supplies. TMDLs have been established for nutrients, bacteria, PCBs, and toxics. TMDL analysis documents and regulations can be found at: http://www.dnrec.delaware.gov/swc/wa/Pages/WatershedAssessmentTMDLs.aspx.

Additional programs are in place to ensure continued compliance with the court order and to achieve water quality standards. Now that TMDLs are in place, Pollution Control Strategies (PCSs) and/or Watershed Implementation Plans (WIPs) are developed to address how, where, and when pollutant loads will be reduced to achieve TMDL levels. These plans generally offer voluntary and regulatory strategies for urban, suburban and agricultural land uses and are developed through a public process where recommendations are made by Tributary Action Teams (TATs), groups of stakeholders formed with the purpose of addressing water quality concerns.

The PCSs and/or WIPs for the Appoquinimink, Broadkill, Chesapeake Bay, Christina, Inland Bays, Mispillion and Cedar Creek, Murderkill, Nanticoke, St. Jones, and Upper Chesapeake (Chester and Choptank) watersheds are available online at: http://www.dnrec.delaware.gov/swc/wa/Pages/WatershedManagementPlans.aspx.

Other DNREC Water Quality Initiatives Include:

Sediment and Stormwater Management Program: The Delaware Sediment and Stormwater regulations were revised effective January 1, 2014. The revised regulations address management of stormwater volume, provide for a watershed approach to stormwater management, and strengthen construction site stormwater management requirements. More information on the Delaware Sediment and Stormwater program is available at: http://www.dnrec.delaware.gov/swc/Drainage/Pages/RegRevisions.aspx.

Non-point Source (NPS) Pollution: DNREC continues to reduce non-point source pollution through enhanced coordination of the Division of Watershed Stewardship's Cost Share Programs through the USEPA's NPS Management 319 Program and the National Oceanic and Atmospheric Association's (NOAA) Coastal NPS Management 6217 program along with the Delaware Nutrient Management Commission's (DNMC) program through the Delaware Department of Agriculture (DDA) and other programs. The effort allows DNREC to direct millions of dollars every year toward a comprehensive NPS program to reduce pollutant loads, restore streams and buffers, and install best management practices (BMPs) such as cover crops, nutrient management plans, manure storage structures, manure relocation, and urban best management practices within impaired watersheds. More information on the NPS 319 program is available at: http://www.dnrec.delaware.gov/swc/district/Pages/NPS.aspx and information on Delaware's Coastal Management Program is available at: http://www.dnrec.delaware.gov/coastal/Pages/CoastalMgt.aspx.

Stream and Wetland Restoration: Rehabilitating stream corridors by re-establishing natural floodplains and sinuous low-flow channels, stabilizing stream banks, decreasing erosion, improving water quality, increasing wildlife habitat, providing buffers along the streams, establishing wetlands, promoting ground water recharge and water storage, controlling invasive plant species, reintroducing native plant species, and reducing turbidity and sediment loading into stream channels are examples of the benefits that result from projects DNREC has implemented to improve the ecological quality and biological diversity in the state's watersheds. Over the past few years stream restoration projects have been completed along Mill Creek, Ham Run (tributary to Red Clay Creek), Middle Run (tributary to White Clay Creek) and Silver Lake Park (tributary to Appoquinimink River in Middletown) in New Castle County and along the St. Jones River in Dover (Kent County) at the Silver Lake Park and Mirror Lake projects.

Onsite Wastewater Treatment Systems (Septics): Delaware's "Regulations Governing the Design, Installation and Operation of On-Site Wastewater Treatment and Disposal Systems" were amended in 2002 and 2005 and revised, effective January 11, 2014. The revised regulations include requirements for small residential septic systems of less than 2500 gallons of wastewater treated per day, as well as large community and commercial systems of more than 2500 gallons of wastewater treated per day.

Among other changes, the regulations effective January 11, 2014:

a) Require inspection of all septic systems prior to property transfers. Most, if not all, mortgage lending institutions currently require the inspection of a septic system prior to sale. This requirement informs a buyer of a system's type and condition and protects a home buyer from acquiring a malfunctioning septic system; b) Clarify the permitting process for siting, installing, and maintaining all small systems; c) Create new inspection protocols for system contractors and inspectors; d) Allow homeowners to maintain their own innovative/alternative system, once certified through a homeowner training program; e) Standardize the permitting process for spray irrigation and on-site systems; and f) Include procedures for distributing treated wastewater for agricultural use and other authorized purposes.

Regulations effective January 2015:

a) Require the elimination of cesspools and seepage pits under certain situations; b) Require the upgrade of all new and replacement systems within 1000 feet of tidal portions of the Nanticoke River and Broad Creek, which will assist Delaware in meeting federal targets to clean up the Chesapeake Bay Watershed; c) Establish statewide performance standards for all innovative/alternative systems; and d) Require all manufacturers of concrete system components (septic tanks, dosing chambers, etc.) to be certified through the On-Site Wastewater Accreditation Program.

Regulations effective January 2016:

a) Require waste haulers to report septic tank pump-out; and b) Create a new licensee category for construction inspectors.

The regulations represent the culmination of more than five years of work by DNREC staff that included 13 workshops and three public hearings, answering questions and gathering input from homeowners, state legislators, realtors, businesses, the wastewater industry, and public utilities. After each workshop and hearing, the draft regulations were amended to reflect public comment.

Delaware's Septic Rehabilitation Loan Program (SRLP) is available to help eligible property owners meet regulatory requirements. The program provides low interest or no interest loans to assist homeowners with the costs of replacing malfunctioning septic systems or cesspools. The program is managed by DNREC's Financial Assistance Branch with technical assistance from the Ground Water Discharges Branch, in partnership with First State Community Action Agency of Georgetown/Dover. To view these regulations, go to: http://www.dnrec.delaware.gov/wr/Information/GWDInfo/Pages/default.aspx.

Source Water Assessment and Protection: The DNREC Source Water Assessment and Protection Program (SWAPP) provides for the assessment and protection of sources of public drinking water, both surface and ground water. The assessment consists of three critical steps: first, delineation of source water areas; second, identification of existing and potential sources of contamination; and finally, assessment of the susceptibility of the source water area to contamination. The Site Index Database identifies the location and status of both existing and potential sources of contamination within the state. Most potential point sources have been mapped and rated. In 2004, the Source Water Protection Program developed a guidance manual for local governments. This document was updated in 2005. For more information on source water protection, go to: http://www.wr.udel.edu/swaphome/index.html. Delaware SWAPP is a cooperative effort between DNREC, Delaware Division of Public Health, and the University of Delaware's Water Resources Agency. A citizen's advisory group (CTAC) was formed to assist DNREC in the development and implementation of the program and to ensure public involvement. SWAPP is a multi-phase program that is expected to be completed in the next few years.

Cooperative Efforts: Cooperation among DNREC, residents, other agencies (state and federal), universities, county and municipal governments, conservation districts, and non-governmental organizations (NGOs) helps bring Delaware water goals to fruition. Pollution Control Strategy development and implementation of TMDL regulations is driven by Tributary Action Teams (TATs). The Center for the Inland Bays, Nanticoke Watershed Alliance, Partnership for the Delaware Estuary, Delaware Nature Society, University of Delaware Cooperative Extension, the Sea Grant Program at the University of Delaware College of Earth, Ocean, and Environment, University of Delaware Water Resources Agency, Delaware State Cooperative Extension, the Camden-Wyoming Rotary Club, the State of Delaware's Nutrient Management Commission, New Castle, Kent, and Sussex County governments, Sierra Club, the county conservation districts, USDA, USGS, other DNREC divisions, and many others have been vital contributors in the development and implementation of PCSs and WIPs.

All of the projects implemented in TMDL watersheds to address water quality concerns require a cooperative effort and partnerships to be formed, not just in government interactions, but between members of TATs and the public as well. Finding a solution for cleaner water will require more innovative solutions, greater regulatory control, additional financial resources, and a willingness to make a change by everyone affecting Delaware's watersheds, as we are all part of the problem and we must work together to find a reasonable solution for everyone.

Delaware 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 formally moved to the College of Agriculture and Natural Resources (CANR) where, since 1997, Dr. Tom Sims, Deputy 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 12- to 15-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, the Center for the Inland Bays, the Delaware Nutrient Management Commission, Delaware State University, USDA Natural Resources Conservation Service, Delaware Nature Society, and The Nature Conservancy, 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 Delaware State University's College of Agriculture and Related Sciences and the University of Delaware (UD), including the UD Water Resources Agency in the Institute for Public Administration, the Delaware Environmental Institute, the UD Departments of Biological Sciences, Chemistry, Civil and Environmental Engineering, Geography, Geological Sciences, and Plant and Soil Sciences, as well as the UD Colleges of Agriculture and Natural Resources; Arts and Sciences; Engineering; and Earth, Ocean, and Environment. 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 three-fold mission to meet the goals of the Water Resources Research Act:

(1) To support research that will provide solutions to Delaware's priority water problems;

(2) To promote the training and education of future water scientists, engineers, and policymakers; and

(3) To disseminate research results to water managers and the public.

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

(1) Graduate Fellowship Program: A competitive graduate fellowship program supports graduate fellows to conduct research on a three-year cycle.

(2) Undergraduate Internship Program: We initiated a highly successful undergraduate internship program in 2000. DWRC interns work with faculty to conduct research, prepare a written project report, and present their findings at an annual poster session.

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

Delaware Water Resources Center Program Goals and Priorities

1. Institute Director: Dr. J. Thomas Sims (through mid-January 2015), T.A. Baker Professor of Soil and Environmental Chemistry, Deputy Dean, College of Agriculture and Natural Resources, Director, Delaware

Water Resources Center, 113 Townsend Hall, University of Delaware Newark, DE 19716-2103, Phone: 302-831-2698, email: jtsims@udel.edu / Dr. Gerald J. Kauffman (as of mid-January 2015), Director, Delaware Water Resources Center and concurrently Director of the UD's Water Resources Agency, DGS Annex 261 Academy St., Newark, DE 19716, Phone: 302-831-4929, e-mail: jerryk@udel.edu

2. Administrative Personnel: Maria Pautler, Program Coordinator, Phone: 302-831-0847, email: mpautler@udel.edu

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 non-point 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 DWRC Advisory Panel identified five specific areas for near-term DWRC research efforts: (1) Agricultural nutrient management and water quality; (2) Basic and applied research on sources, fate, and transport of water pollutants; (3) Quantifying 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 FY14 DWRC public water conservation/educational outreach program addressed these issues. The DWRC's research program during the same period addressed these concerns by supporting graduate fellowships in water quality, an undergraduate student internship program, and public information forums including an intern research poster session.

2014-2015 DWRC Fellowship and Internship Research Program

Two fellowships were funded for the first year in 2014-2015 based on a review of proposals submitted to the DWRC Advisory Panel:

a) Nutrient Removal from Stormwater, Wastewater, and Agricultural Runoff Using Scrap Iron and Biochar

Graduate Fellow: Lauren Lechner; Advisor: Pei Chiu, Department of Civil and Environmental Engineering, College of Engineering, University of Delaware.

b) Photoelectrochemical Process for Removal of Contemporary Organic Contaminants from Water

Graduate Fellow: Daniel Sanchez Carretero; Advisor: Chin-Pao Huang, Department of Civil and Environmental Engineering, College of Engineering, University of Delaware.

Eleven internships were awarded for 2014-2015 based on a review of proposals submitted by potential undergraduate interns and their advisors to the DWRC Advisory Panel:

a) Greenhouse Gas Emissions from Sediments in a Protected Estuary in Delaware

Undergraduate Intern: Katelyn Csatari; Advisor: Rodrigo Vargas, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

b) Investigation of Nitrogen Pollution in a Mixed Land-Use Watershed

Undergraduate Intern: Sandra Demberger; Advisor: Luc Claessens, Department of Geography, College of Earth, Ocean, and Environment, University of Delaware.

c) Water Quality Performance for Paired Bioretention Basins

Undergraduate Intern: Amanda Doremus; Advisor: Carmine Balascio, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

d) Quantifying Conservation Practices in the Chesapeake Bay Basin

Undergraduate Intern: Jessica Fedetz; Advisors: Marcia Fox, Delaware Department of Natural Resources and Environmental Control and Jennifer Volk, Cooperative Extension, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

e) Fine-scale Temporal Dynamics of Estuarine Virioplankton and Bacterioplankton Populations

Undergraduate Intern: Amelia Harrison; Advisor: K. Eric Wommack, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

f) Enhanced Pollutant Biodegradation by Electrode Use

Undergraduate Intern: Sarah Hartman; Advisor: Steven Dentel, Department of Civil and Environmental Engineering; College of Engineering, University of Delaware.

g) Understanding Greenhouse Gas Fluxes in Estuaries

Undergraduate Intern: Erica Loudermilk; Advisor: Angelia Seyfferth, Department of Plant and Soil Sciences, College of Agriculture and Natural Resources, University of Delaware.

h) Wetland Restoration and Mitigation Banking along the Cool Run Watershed at the UD Farm: GIS Mapping

Undergraduate Intern: Danielle Notvest; Advisor: Gerald Kauffman, UD Water Resources Agency.

i) Procuring Abatement: Cover Crop Cost Heterogeneity and Optimal Policy Design in Delaware

Undergraduate Intern: Gregory Robinson; Advisor: Joshua Duke, Department of Applied Economics and Statistics, College of Agriculture and Natural Resources, University of Delaware.

j) Wetland Restoration and Mitigation Banking along the Cool Run: Ecosystem Service Analysis

Undergraduate Intern: Radhika Samant; Advisor: Gerald Kauffman, UD Water Resources Agency.

k) Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nutrient Treatment of Stormwater Runoff

Undergraduate Intern: Christopher Youngquist; Advisor: Paul Imhoff, Department of Civil and Environmental Engineering; College of Engineering, University of Delaware.

Research Program Introduction

None.

Photoelectrochemical Process for Removal of Contemporary Organic Contaminants from Water

Basic Information

Title:	Photoelectrochemical Process for Removal of Contemporary Organic Contaminants from Water
Project Number:	2014DE260B
Start Date:	9/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Engineering
Focus Category:	Water Quality, Toxic Substances, Treatment
Descriptors:	None
Principal Investigators:	Chin-pao Huang

Publication

1. Sanchez Carretero, D., and C.P. Huang, 2015, Photoelectrochemical Process for Removal of Contemporary Organic Contaminants from Water, Progress Report, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 11 pages.

Photoelectrochemical Oxidation of PPCPs in Water and Electrochemical Reduction of Dissolved Carbon Dioxide in Water to Hydrocarbons

Department of Civil and Environmental Department

Student: Daniel Sanchez Carretero

Advisor: Professor C. P. Huang

1. Background and Justification

In the last decades, and especially in developed countries, there has been an increasing release of pharmaceutical and personal care products (PPCPs) into the water environment, affecting the water quality worldwide[1]. The persistence of these chemicals makes them hard to be removed from wastewaters in sewage treatment[2, 3]. There has been a recording of data[4] from the literature about the types of PPCP found in the waters in WWTPs including hormones such as estrone, estriol, testoreone and progesterone, and analgesic-anti-inflammatories such as ibuprofean, dickofenac, naproxen, ketoprofen and mefenani acid.

In order to deal with this water quality deterioration, technology, especially "green" and cheap is needed to treat these contaminants. Both biodegradation and chemical treatments have been used, especially the ones that transform the contaminants chemically and render them as non-toxic. Biodegradation, because of its cost-effectiveness and versatility in handling a wide variety of pollutants, is the common treatment process. However, many PPCP can't be treated using this method[5,6] . Other methods, like thermal destruction are effective in destroying the targeted chemicals but they are far too expensive and can't be always applied in water systems since they evaporate the water before destroying the chemicals.

Advanced chemical oxidation processes (AOP) are reactions that change the oxidation state of the key element of recalcitrant organic chemicals by strong oxidizing agents[7]. The most common way is based on the addition of ozone or hydrogen peroxide in the presence of ultraviolet light or catalysts, but this method involves the addition of chemicals into the WWTPs. However, heterogeneous photocatalysis, in which the major source of energy is derived from sunlight, has been prompted. The concerning issue is that, TiO_2, the main photocatalyst used in these processes has a band gap of 365-388nm, located at the unworkable bottom of the light solar spectrum, that, in addition with a fast electron-hole recombination, decreases its photocatalytic quantum yield.

The photoelectrochemical process proposed in this research will allow the instantaneous separation of electrons and holes generated photocatalytically and enable the holes to oxidize the selected PPCP while the electrons will be used to chemically reduce the compound in the cathodic chamber, in this case CO_2, to readily useful hydrocarbons.

Since the beginning of the industrial revolution, massive amounts of CO_2 have been released from factories, vehicles and energy stations, causing a rise of CO_2 levels in the atmosphere. In addition to the pollution issue and the health concerns related to the presence of excess CO_2 in the air[8], CO_2 is also known for causing a positive effect in the heat retention of the atmosphere, taking then, part in global warming[9].

On the other hand, more than 80% of the energy consumed by the U.S. has been produced from hydrocarbon fuels such as coal, natural gas and petroleum[10]. Because of this, and the energetic properties of hydrocarbons such as high energy density, easy transportation and stability[10], it is of interest to find new methods that will readily provide this kind of fuels for future use.

Electrochemical reduction of water dissolved CO_2 provides a solution to both the environmental and energetic issues. The transformation of CO_2 and water into hydrocarbons decreases the amounts of CO_2 in the environment and generates a ready-to-use energy source.

In order to successfully achieve a nonpolluting water treatment process, the energy source for the electrochemical reduction must come from a renewable source of energy. Otherwise, if the energy needed for the electrochemical reduction were obtained from hydrocarbons, there wouldn't be a clear net benefit for the environment. This is why the photoelectrochemical oxidation of PPCP is of such interest in this case. Electrochemical reduction of CO_2 to hydrocarbons would, in a way, allow for storage of the solar energy in form of chemical energy, which would eliminate the need of batteries for its storage, like most solar cells do. For this reason, the produced hydrocarbons have been coined with the term of "Solar Fuels".

There has been research on electrochemical reduction of CO_2 since the 1950's even though it was not too successful due to the Mercury electrodes used in the process[11]. Years later, around the 1980's Hori et al. published a paper proving the exceptional ability of copper electrodes in the selectivity of hydrocarbons due to electrochemical reduction of CO_2 dissolved in water[12]. The issue that scientists and engineers have been facing these last decades is the low selectivity that the electrode shows towards a certain type of hydrocarbon.

2.0 Objectives

There are three main objectives in this research, starting from the synthesization of photocatalysts for the electrochemical oxidation of hazardous organic compounds to the study of the reduction of CO_2 to the selected hydrocarbons.

TiO_2 nanoparticles present the advantage of being a cheap, non-toxic photocatalyst, but its large band gap makes it transparent to visible light and almost inefficient at the solar spectrum. Reducing the band gap will make the photocatalyst sensible to visible light, and therefore more efficient in the solar spectrum. This can be achieved by controlling the particle size[13,14] or adding impurities to the TiO_2 nanoparticles[15,16].

The oxidation of the selected PPCP and the factors that affect it such as pH, concentration of organic compounds, intensity and wavelength of the light source, presence of water cations (Ca^{2+} and Mg^{2+}) and anions (bicarbonate, sulfate, nitrate and chloride), biased potential and dissolved organic matter will be studied.

The study of the properties of copper electrodes in the electrochemical reduction of CO_2 in order to find a mechanism that will allow for a better selectivity towards a certain type of hydrocarbon, in our case, formic acid. Plenty of surface characteristics can be modified in order to accomplish such goal; composition, surface structure and crystalline facet orientation. In this research experimental results along with theoretical calculations using Density Functional Theory (DFT) will be used to find such mechanism.

3.0 Methodology

The 3D TiO_2 photoanodes will be prepared by the method explained in the submitted proposal. First, ITO nanowire arrays are prepared by electronic deposition. Then the ITO sol will be subjected to an electric field with a Pt mesh as the anode. The length of the template growth ITO nanowires will be controlled by deposition time. Finally, layers of TiO_2 will be coated on top of the ITO nanowires by applying a layer of amorphous sol to the ITO arrays. The coating will be dried at room temperature first, and then at 450°C to an approximate thickness of 5-25nm.

The photoelectrochemical oxidation and reduction of the compounds will be conducted using a two-chambered photoelectrochemical (PEC) reactor. Both chambers will be connected through an opening containing a cation exchange membrane (CEM), allowing only H^+ to go from the anodic chamber to the cathodic chamber. The anodic chamber will contain a quartz window that will allow for the complete transmission of light from the source to the photoanode made from the newly prepared TiO_2 nanophotocatalysts. Connecting the photoanode and cathode, there will be a small biased potential that will prevent the electron-hole pairs from recombining and therefore increasing the faradaic efficiency of the system. The selected PPCP for the anodic chamber are triclosan, ketoprofen, carbamazepine and sulfapyrdine. Such PPCP have been chosen because of its persistence in WWPTs due to its resistance to removal by ozonation[17].

Different variables in the electrolyte in both chambers will be modified in order to achieve the higher oxidation and reduction efficiencies such as pH, concentration of electrolyte and other ions in the solution. Another important part of the modifications will be done on the electrodes, to acquire the highest absorption and electron transfer coefficients. The copper cathode is a good adsorbent of CO_2 and can easily reduce the carbon[18,19]. However, other metals have to be deposited onto the electrode in order to create bonding sites for the reduction of water to obtain the required elements for the creation of hydrocarbons[20]. Platinum and gold will be deposited onto the copper surface to facilitate oxygen disassociation near the CO_2 adsorption sites that will then recombine to create formic acid (CH_3OH).

4.0 Progress to date:

On this first part of the project there was an extensive literature review on the role of copper electrode surfaces in the adsorption and reduction of CO_2. Factors affecting the reactivity of surfaces for both electrodes were studied as well as their selectivity by the presence of specific defects. Experimental papers on electrode adsorption and heterogeneous catalysis[18,19] gave an insight about the metals to be deposited onto the electrodes, specially platinum. Theoretical papers, mainly using quantum mechanical software based on density functional theory[21,22] predicted the most likely pathway of the CO_2 reduction. However, these papers only take into account the gas/solid interphase due to the difficulty of modeling water molecules and their behavior close to charged solid surfaces.

Theoretical papers only explain the event partially due to the complexity of water molecules in such surfaces. Water can polarize molecules close to the surfaces and block adsorption sites. Also, water close to the electrode surfaces completely changes the properties the system, especially close to charged surfaces where the electric field is so strong. Nevertheless, the results produced experimentally will be compared to the theoretical ones and study why they agree or not.

Due to the complexity of the project, no results have been produced yet. Instead, a literature review has been done and classes related to the topics were taken. A Quantum

Mechanics course was taken to further understand the nature of band gap engineering and how to decrease it for the photoelectrochemical applications discussed earlier. A Practical Electron Microscopy course provided with the tools to characterize the electrodes to the nanometer scale. A Chemical Aspects of Environmental Engineering course involving the role of pH and pE in aquatic systems was taken to study their influence on reduction and oxidation processes. This semester, two classes involving the physical and chemical phenomena near surfaces, such as adsorption and electron exchanges were taken: Physical Aspects of Environmental Engineering, and Physics and Chemistry of Surfaces and Interfaces. Finally a NMR Spectroscopy course provided the tools for hydrocarbon classification.

5.0 Research activities for the next 6 months:

In order to maximize the productivity of laboratory work, two different tasks will be run concurrently. Even though both reduction and photoelectrooxidation are meant to work together, they can be run separately for the purpose of being tested. The first activity will consist on the production of doped TiO_2 nanotubes as well as testing their band gap by their photocatalytic activity to certain wavelengths. This will be done in a one-chambered reactor with a quartz window and PPCP in the solution to reproduce the turbidity and light-absorption characteristics of the solution used in the final experiment. The cathode will be included in the chamber to complete the electric circuit and test the creation of electron-hole pairs. The second task consists on the modification of the surface of the copper electrode to achieve a complete selectivity towards the reduction of CO_2 to formic acid. This experiment will be done in a two-chambered box. The cathodic chamber will contain the copper cathode with CO_2 dissolved in water, and the anodic chamber will contain a carbon electrode submerged in water with an electrolyte. The potential difference between the electrodes won't be created from a light source but from a biased potential coming from a power supply. This will allow for a better study of the selectivity of the reduction while not depending on the photocatalytic materials until they are not fully created.

6.0 Conclusion and project implications

The proposed research allows for the treatment of hazardous chemicals such as PPCP by photoelectrochemical oxidation and the generation of hydrocarbons by reducing CO_2 dissolved in water. The energy for the oxidation is collected by the photoelectrocatalysts present in the photoanode that transform the solar light into electron-hole pairs that are used for both oxidation of PPCP and reduction of CO_2. Only a small amount of external energy is needed to transport the electrons from the photoanode to the cathode. The overwhelming presence of these persistent hazardous chemicals will be reduced with this treatment. The photocatalysts are made so that anyone anywhere in the world can recreate this experiment as long as there is solar light, making it cheaper and cleaner than regular electrochemical processes. In addition to the treatment of waters, this experiment also allows for the creation of hydrocarbon fuels that can also be used to generate energy for any other purpose as needed.

7.0 References

1 Ashton, D., M. Hilton, et al. (2004). "Investigating the environmental transport of human pharmaceuticals to streams in the United Kingdom." Science of the Total Environment 333(1-3): 167-184.

2 Daughton, C. G. and T. A. Ternes (1999). "Pharmaceuticals and personal care products in the environment: Agents of subtle change?" Environmental Health Perspectives **107**: 907-938.

3 Matamoros, V., J. Garcia, et al. (2008). "Organic micropollutant removal in a full-scale surface flow constructed wetland fed with secondary effluent." Water Research **42**(3): 653-660.

4 Miege, C., J. M. Choubert, et al. (2008). "Removal efficiency of pharmaceuticals and personal care products with varying wastewater treatment processes and operating conditions - conception of a database and first results." Water Science and Technology **57**(1): 49-56.

5 Daughton, C. G. and T. A. Ternes (1999). "Pharmaceuticals and personal care products in the environment: Agents of subtle change?" Environmental Health Perspectives **107**: 907-938.

6 Oppenheimer, J., R. Stephenson, et al. (2007). "Characterizing the passage of personal care products through wastewater treatment processes." Water Environment Research **79**(13): 2564-2577.

7 Cohon, J. L. The Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use; National Academies Press 2009, ISBN-10: 0-309-14640-2

8 IPCC Third Assessment Report-Climate Change 2001 (http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/339.htm).

9 Energy Information Administration. Annual Energy Review; U.S. Department of Energy, 2008.

10 Teeter, T.E.; Van Rysselberghe, P. Reduction of Carbon Dioxide on Mercury Electrodes. J. Chem Phys. 1954, 22, 759-160.

11 Hori, Y.; Murata, A.; Takahashi, R.; Suzuki, S. Enhanced Formation of Ethylene and Alcohols at Ambien Temperature and Pressure in Electrochemical Reduction of Carbon Dioxide at a Copper Electrode. J. Chem. Soc., Chem. Commun. 1988, 17-19

12 Huang, C. P., C. D. Dong, and Z. H. Tang (1993). "Advanced Chemical Oxidation: Its Present Role and Potential future in Hazardous Waste Treatment." Waste Management **13**: 361-377.

13 Lin, H., C. P. Huang, et al. (2006). "Size dependency of nanocrystalline TiO_2 on its optical property and photocatalytic reactivity exemplified by 2-chlorophenol." Applied Catalysis B-Environmental **68**(1-2): 1-11.

14 Singh, A. P., S. Kumari, et al. (2008). "Iron doped nanostructured TiO_2 for photoelectrochemical generation of hydrogen." International Journal of Hydrogen Energy **33**(20): 5363-5368.

15 Carneiro, J. O., V. Teixeira, et al. (2007). "Iron-doped photocatalytic TiO_2 sputtered coatings on plastics for self-cleaning applications." Materials Science and Engineering B-Solid State Materials for Advanced Technology **138**(2): 144-150.

16 Haber, J., P. Nowak, et al. (2008). "Preparation of TiO_2 for photocatalytic

applications - Doping of TiO_2/Ti with transition metal ions." Polish Journal of Chemistry **82**(9): 1753-1766.

17 Nakada, N., H. Shinohara, et al. (2007). "Removal of selected pharmaceuticals and personal care products (PPCPs) and endocrine-disrupting chemicals (EDCs) during sand filtration and ozonation at a municipal sewage treatment plant." Water Research **41**(19): 4373-4382.

18 Chorkendorff, I., Nørskov, J., et al. (2012). "The importance of surface morphology in controlling the selectivity of polycrystalline copper for CO_2 electroreduction." Phys. Chem. Chem. Phys., **14**: 76-81.

19 Huang, C.P.,Shah I., et al. (2012) "Concurrent photoelectrochemical reduction of CO2 and oxidation of methyl orange using nitrogen-doped TiO_2". Applied Catalysis B: Environmental **123** (2): 414-423.

20 Rodriguez, J., et al., (2014). "Highly active copper-ceria and copper-ceria-titania catalysts for metanol synthesis from CO_2". **345**: 546-550

21 Nørskov, J., Durand, W., et al. (2011) "Structure effects on the energetics of the electrochemical reduction of CO_2 by copper surfaces." AAP.

22 Nørskov, J., Shi, C., (2014) "Trends in the electrochemical CO_2 reduction activity for open and close-packed metal surfaces." Phys. Chem. Chem. Phys., **16**: 4720-4727.

Nutrient Removal from Stormwater, Wastewater, and Agricultural Runoff Using Scrap Iron and Biochar

Basic Information

Title:	Nutrient Removal from Stormwater, Wastewater, and Agricultural Runoff Using Scrap Iron and Biochar
Project Number:	2014DE261B
Start Date:	9/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Engineering
Focus Category:	Surface Water, Water Quality, Non Point Pollution
Descriptors:	None
Principal Investigators:	Pei Chiu, Daniel Cha, Paul Imhoff

Publication

1. Lechner, L., and P. Chiu, 2015, Nutrient Removal from Stormwater, Wastewater, and Agricultural Runoff Using Scrap Iron and Biochar, Progress Report, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 6 pages.

Project Title: Nutrient Removal from Stormwater, Wastewater, and Agricultural Runoff Using Scrap Iron and Biochar

Investigators: Lauren Lechner (Ph.D. Student) and Dr. Pei Chiu (Advisor)

Background/Justification:

Nutrient pollution is a challenging environmental issue that the U.S. is faced with, especially since this leads to polluted bays, rivers, and groundwater. Nutrient pollution is caused by excess nitrogen and/or phosphorus present in the water. This excess can cause harmful algal blooms, human health concerns, and economic and ecological losses (U.S. EPA, 2015). Specifically, in Delaware, the Chesapeake Bay is in poor condition due to nutrient pollution, which results from urban, suburban and agricultural runoff, wastewater treatment plant effluent, and air pollution (Chesapeake Bay Program, 2012). In order to treat nutrient pollution, we propose a method for using zero-valent iron (ZVI) and biochar to remove nitrogen and phosphorus simultaneously from multiple water sources, including stormwater, agricultural runoff, and wastewater.

The iron-biochar technology is based on the demonstrated abilities of iron filings to 1) remove phosphate from water through surface adsorption and 2) support biological nitrate reduction to nitrogen gas (N_2), and the ability of biochar to 3) remove ammonium through cation exchange, and 4) support nitrate reduction. A preliminary study currently funded by Delaware Department of Transportation (DelDOT) has shown great promise of the iron-biochar technology for potential application in bioretention cells, bioswales, and other stormwater facilities to reduce nutrient discharge.

Previously, ZVI has been shown to bind phosphate, either through adsorption or precipitation at the iron surface (Saxe et al., 2006). It was also reported that iron supported phosphate removal could be sustained for one year (Erickson et al., 2012), as well as remove large amounts of phosphate (Allred, 2012).

Biochar, which is an ash product of pyrolysis of different feedstocks (straw, wood, animal manures), has been shown to be a sorbent and redox catalyst for organic contaminants, including nitroaromatic compounds and explosives (Oh & Chiu, 2009; 2013), and brominated phenols (Oh et al., 2012). Biochar also has the ability to promote nitrogen removal, but has not been demonstrated in the literature.

Objectives:

1. To determine the removal efficiency of phosphate and the mass of phosphate removed using ZVI.

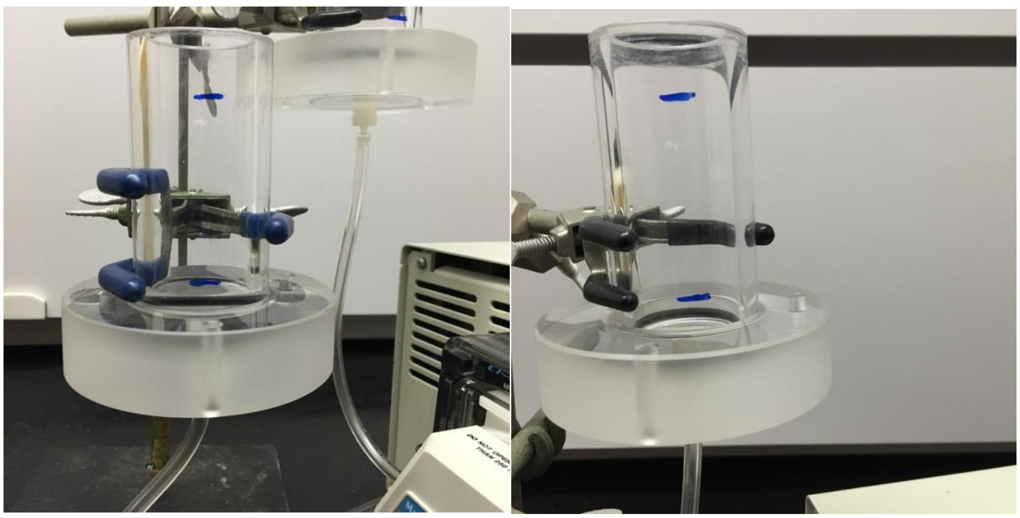
2. To determine the phosphate-containing minerals on ZVI surface.

3. To determine the mechanisms for phosphate removal

Methodology

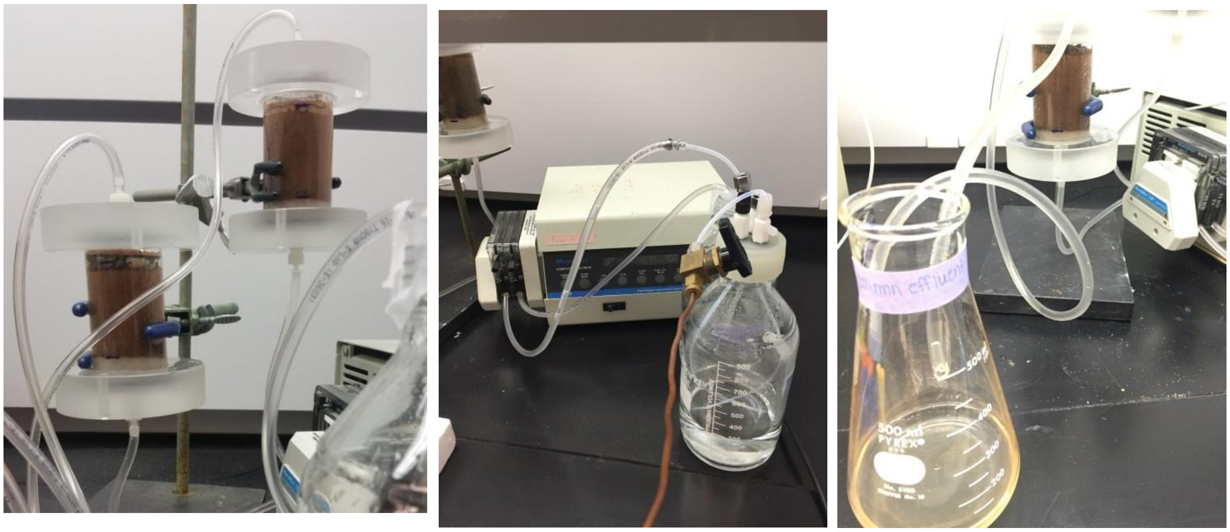
The studies mentioned prior will be laboratory-based investigations. The ZVI used is in the form of scrap iron granules from Peerless Metal Powders and Abrasive, in Detroit MI. The biochar used is prepared either from wood or corn stover, from Delaware State University's College of Agriculture and Natural Resources. Nitrate, phosphate, and ammonium removal from water sources will be studied using different techniques. *Column Studies*

Currently, we are preparing to run column studies regarding the phosphorus removal from stormwater via ZVI. The columns are acrylic, with a total volume of 113.41 cm^3 that were manufactured in the College of Engineering's Machine Shop. There are two columns running in parallel, one as a control and one containing ZVI. The column set-ups, prior to packing, are pictured in Figures 1a and b. The packed columns are shown in Figures 2a, b, and c.



Figures 1a and b: Columns set up in parallel prior to packing.

Before packing the columns, the sand (Accusand 40/50, particle sizes in desired range of 250-500 micron) was treated with citrate to remove excess iron oxides (or manganese oxides, if present). This was done by submerging about 800 mL of dry sand in 500 mL of 10 mM sodium citrate, with low pH (4.75), and warm temperature (≤ 40°C) overnight. Sodium citrate (10 mM) was used as a complexing agent (Deng & Zhou, 2009), and low pH with higher temperatures were used to solubilize iron or manganese. 5-mL samples from the aqueous layer were taken and analyzed using the 1,10-phenanthroline method measured on UV-Vis at 510 nm. The sand was then washed thoroughly with deionized water. This process was repeated for a total of six times to ensure that the iron oxides were removed from the sand. This was confirmed by packing the sand layer, and testing the effluent, which had no detectable iron leaching from the sand in the column. The data for sand washing and sand effluent are in Table 1, in the "Results" section.



Figures 2a, b, and c: Columns
packed with sand and commercial soil mix: the left column is the control column and the right column contains 10% ZVI in the middle layer; Column influent reservoirs and peristaltic pump; Column effluent collector.

The columns were wet packed to eliminate any air bubbles, with the following layer compositions:

- Bottom layer (2 cm height) of citrate-treated sand, obtained from Accusand.
- Middle layer containing a commercial soil mix (Luckstone Biofilter Media) (6 cm height, one column containing 10% ZVI by mass)l this soil mix is chosen as it will be used in a field bioretention cell in Charlottesville, VA for stormwater treatment.
- Top layer (2 cm height) of citrate-treated sand, obtained from Accusand.

The column solution is a modified synthetic stormwater (Hsieh & Davis, 2005), containing 2 ppm (as nitrogen) sodium nitrate, 2 ppm (as nitrogen) ammonium chloride, 120 ppm calcium chloride (total dissolved solids), and 1.5 mM sodium bicarbonate (You et al., 2005); no phosphorus species was added. In order to prevent fast corrosion of the ZVI particles by O_2, and to keep the pH buffered at 7, this solution is degassed with 1% CO_2/99% N_2. This will also model how ZVI is placed in a bioretention cell, in the anoxic zone, where oxygen is depleted.

Due to an unknown capability of phosphorus leaching from the soil mix, the columns are flushed continuously with synthetic stormwater, until constant background concentrations of phosphate and total iron are determined. This data is shown in Tables 2 and 3 in the “Results” section.

During the column experiments, phosphorus, in the form of orthophosphate, in column effluents will be measured via phosphate/molybdate complex and ascorbic acid reduction; measured on UV-Vis at 880 nm. Periodically, total iron will be measured, via 1,10-phenanthroline indicator measured on UV-Vis at 510 nm. In addition, effluent pH will be monitored continually.

Results and Future Work

By using citrate, low pH, and warm temperatures, we were able to clean the sand (of iron or manganese oxides) before use in our column. Over the course of six washes, a significant amount of iron was removed each time (seen in Table 1) by complexation with citrate. Once we finished the six washes, and packed the first sand layer, we confirmed that no additional iron was leaching out of the sand.

Wash Number	**Total Fe conc. removed from sand (ppm)**
1st wash	6.9901
2nd wash	3.0132
3rd wash	8.7157
4th wash	1.4485
5th wash	3.1795
6th wash	2.4570
Date	**Total Fe conc. leaching from sand layer (ppm)**
4/15	Not Detected

Table 1: Sand washing and sand effluent total Fe concentrations; detection limit is 0.02 ppm total Fe; concentrations were averages of three concentration readings.

Tables 2 and 3 present the results of the column flushing; the concentration values are averages of three measured concentrations. The detection limit for both analyses of total Fe and OP were 0.02 ppm. From the control column, we can see some leaching of iron and a small amount of phosphate from the soil media used. From the ZVI column, there is more Fe and less OP, as expected. As the surface of the ZVI particles become corroded, iron oxides may be released from the column, plus whatever Fe that was present in the soil media to begin with. Also, the less amount of OP being released is due to the complexation/precipitation with ZVI particles

	Total Fe Concentration (ppm)	
Date	**Control Column**	**ZVI Column**
4/17	0.0734	1.4310
4/21	0.0285	0.1269
4/22	Not Detected	0.0836
4/23	Not Detected	0.3673
4/27	0.0538	1.2608
4/28	Not Detected	0.0804
4/29	0.0646	0.4870

Table 2: Total iron concentration in column effluent during flushing with blank stormwater (no phosphate); Detection limit is 0.02 ppm total Fe.

	OP Concentration (ppm)	
Date	**Control Column**	**ZVI Column**
4/17	Not Detected	Not Detected
4/23	0.0701	Not Detected
4/27	0.0314	0.0765
4/28	Not Detected	Not Detected
4/29	Not Detected	Not Detected

Table 3: Orthophosphate (OP) concentration in column effluent during flushing with blank stormwater (no phosphate); Detection limit is 0.02 ppm OP.

Over the course of this study, we hope to determine the phosphorus removal efficiency (%) of ZVI, the total mass of phosphorus removed, and the mechanism and rate of phosphorus removal (using a batch test, to determine kinetic and equilibrium conditions of removals). We also will characterize the ZVI particles, both used and unused, to determine the morphology, which will be done with SEM, EDX, and XRD. The column will also be characterized using a bromide tracer test to determine the water flow conditions.

The column study will continue with additions of a biochar-packed column, as well as a biochar + ZVI column. These additional columns will be used as described above. All four columns may also be used for further testing on nitrogen removal, measuring nitrate and ammonium using ion chromatography, as well as with experiments involving wastewater and agricultural runoff.

Conclusions

This column study will show how the use of ZVI can affect phosphate removal from stormwater, which has field applicability as a bioretention cell. We will be able to report removal efficiencies using this technique, as well show how phosphate removal can affect the morphology of ZVI particles over time. This study can also be expanded to use biochar as a removal technique, and to test nitrate removal.

Abstract

Nutrient removal from water sources is becoming increasingly important as nutrient pollution is emerging as a challenging and critical environmental issue. Nutrient pollution(excess nitrogen and phosphorus) can cause algal blooms, human health issues, and ecological and economic losses. Currently, we are doing work to study the removal of phosphorus using zero valent iron (ZVI). This will be accomplished by monitoring the concentration of phosphorus in the form of orthophosphate over a period of time during a column study. ZVI has been shown to bind phosphate, either through adsorption or precipitation at the iron surface, with the potential for large mass removal over longer periods of time (one year). We are looking forward to studying the removal mechanisms of phosphate using ZVI, and being able to apply this to other nutrient removal techniques.

References

Allred, B. (2012). Laboratory evaluation of porous iron composite for agricultural drainage water filter treatment. *Transactions of the ASABE, 55*(5), 1683-1697.

Chesapeake Bay Program. "Nutrients." Chesapeake Bay Program, 2012. Web.

Deng, Y., & Zhou, Z. (2009). Manganese citrate complexes: Syntheses, crystal structures and thermal properties. Journal of Coordination Chemistry, 62(5), 778-788.

Erickson, A. J., Gulliver, J. S., & Weiss, P. T. (2012). Capturing phosphates with iron enhanced sand filtration. *Water Research, 46*(9), 3032-3042.

EPA. "Nutrient Pollution." *Nutrient Pollution*. U.S. EPA, 17 Mar. 2015. Web.

Hsieh, C., & Davis, A. (2005). Evaluation and optimization of bioretention media for treatment of urban storm water runoff. *Journal of Environmental Engineering, 131*(11), 1521-1531.

Oh, S., & Chiu, P. C. (2009). Graphite- and soot-mediated reduction of 2,4-dinitrotoluene and hexahydro-1,3,5-trinitro-1,3,5-triazine. *Environmental Science & Technology, 43*(18), 6983-6988.

Oh, S., Son, J., & Chiu, P. C. (2013). Biochar-mediated reductive transformation of nitro herbicides and explosives. *Environmental Toxicology and Chemistry, 32*(3), 501-508.

Oh, S., Son, J., Lim, O., & Chiu, P. (2012). The role of black carbon as a catalyst for environmental redox transformation. *Environmental Geochemistry and Health, 34*(1), 105-113.

Saxe, J. P., Lubenow, B. L., Chiu, P. C., Huang, C., & Cha, D. K. (2006). Enhanced biodegradation of azo dyes using an integrated elemental iron-activated sludge system: II. effects of physical-chemical parameters. *Water Environmental Research, 78*(1), 26-30.

You, Y., Han, J., Chiu, P. C., & Jin, Y. (2005). Removal and inactivation of waterborne viruses using zerovalent iron. Environmental Science & Technology, 39(23), 9263-9269.

Greenhouse Gas Emissions from Sediments in a Protected Estuary in Delaware

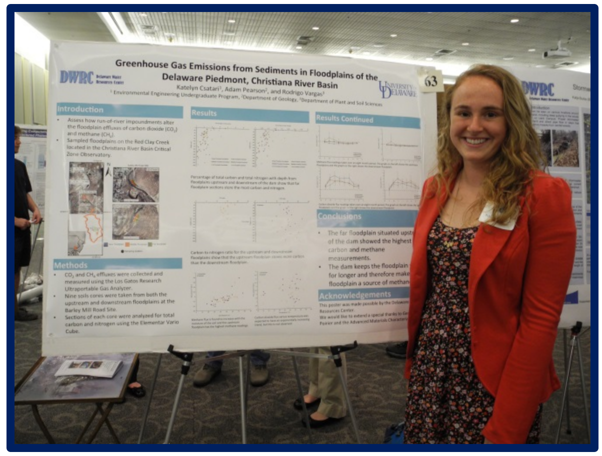
Basic Information

Title:	Greenhouse Gas Emissions from Sediments in a Protected Estuary in Delaware
Project Number:	2014DE262B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Geochemical Processes, Sediments
Descriptors:	None
Principal Investigators:	Rodrigo Vargas, Rodrigo Vargas

Publications

There are no publications.

Undergraduate Internship Project #1 of 11 for FY14



Intern ***Katelyn Csatari's*** project, sponsored by the ***DWRC***, was titled "Greenhouse Gas Emissions from Sediments in a Protected Estuary in Delaware." She was advised by Dr. Rodrigo Vargas of the ***UD's*** Department of Plant and Soil Sciences.

Abstract

For this project we observed how run-of-river impoundments affect streams and their floodplains. We assessed how run-of-river impoundments alter the floodplain effluxes of carbon dioxide (CO_2) and methane (CH_4).

We sampled two pairs of floodplains on the Red Clay Creek (140 km^2) located in the Christina River Basin Critical Zone Observatory. The floodplain pairs were centered on a current and a former location of a run-of-river dam (one floodplain upstream, one downstream of each dam location). Each floodplain was subjected to a suite of measurements that included bi-weekly gas flux (CO_2, CH_4, H_2O), bi-weekly soil moisture and temperature, monthly biomass sampling, C/N ratio sampling from O and A horizons, and cores that constrain the total organic carbon and nitrogen at depth as well as provide a description of the stratigraphy.

The gas fluxes were taken for three minutes and were measured using the Los Gatos Ultraportable Gas Analyzer. O and A horizons soil samples as well as the cores were collected, dried, ground, and sieved before being put through a surface area and grain size analyzer using the Beckman Coulter LS 12 320 SW laser diffraction particle size analyzer. The soil samples were then analyzed for total carbon, total nitrogen, and the carbon to nitrogen ratio using the Elementar Vario EL Cube.

The preliminary findings of this project show that both upstream and downstream floodplains at either location are sources of CH_4 and CO_2. The upstream floodplains produce more CH_4 and CO_2 than downstream floodplains. We observed that the longer a floodplain stays underwater, the more CH_4 that is produced. This would explain why the upstream floodplain at the impoundment site produced a large amount of CH_4. Our results may suggest that run-of-river dams enhance release of carbon from floodplains into the atmosphere.

Quantifying Conservation Practices in the Chesapeake Bay Basin

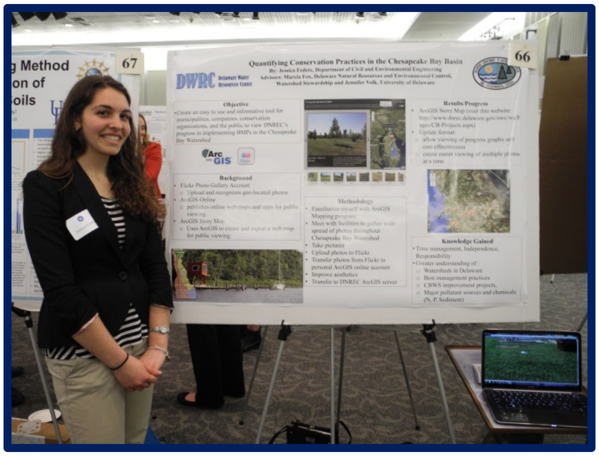
Basic Information

Title:	Quantifying Conservation Practices in the Chesapeake Bay Basin
Project Number:	2014DE263B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Conservation, Management and Planning, Non Point Pollution
Descriptors:	None
Principal Investigators:	Jennifer Volk

Publication

1. Fedetz, J., J. Volk, and M. Fox, 2015, Quantifying Conservation Practices in the Chesapeake Bay Basin, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 11 pages.

Undergraduate Internship Project #2 of 11 for FY14



Intern ***Jessica Fedetz's*** project, co-sponsored by the ***DWRC*** and the ***Delaware Department of Natural Resources and Environmental Control***, was titled "Quantifying Conservation Practices in the Chesapeake Bay Basin." She was advised by Marcia Fox of the Delaware Department of Natural Resources and Environmental Control and Jennifer Volk of the ***UD's*** Department of Plant and Soil Sciences.

Abstract

The goal of this research is to create an easy to use and informative tool for municipalities, companies, conservation organizations, and the public to view DNREC's progress in implementing best management practices, BMPs, in the Chesapeake Bay Watershed. BMPs are practices that reduce nitrogen, phosphorus, and suspended solid content in a given water supply. This research aims to further educate the public about BMPs through the use of a Story Map, created with ArcGIS map modeling. The Story Map is created using photos taken by the researcher and obtained from both public and private organizations. Photos are monitored for the location they are taken, geo-located, and uploaded to an online photo program, Flickr. The researcher then transfers the photos to an online ArcGIS account as a web map and publishes an ArcGIS web app called a Story Map. The Story Map provides photos of various types of BMPs, documents how effective each BMP is in lowering nutrient levels and tracks the progress made in implementing these practices. The Story Map acts as an interactive way for the public to tour the use of BMPs throughout the Chesapeake Bay Watershed. It also provides a resource for conservation organizations to more easily find ways of improving the environment and also may serve as a way for municipalities or companies to easily view ways of offsetting their pollution.

Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nutrient Treatment of Stormwater Runoff.

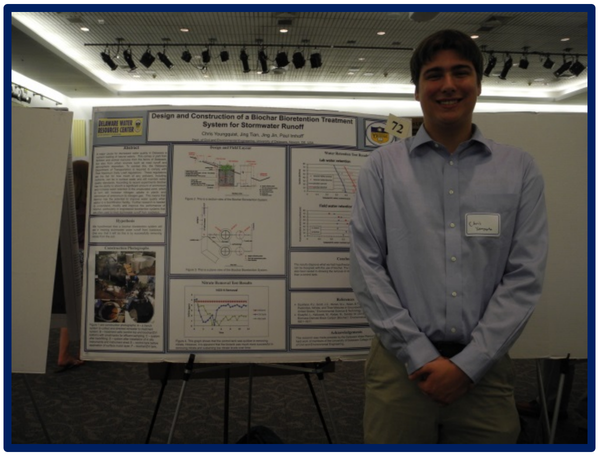
Basic Information

Title:	Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nutrient Treatment of Stormwater Runoff.
Project Number:	2014DE264B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Surface Water, Nutrients
Descriptors:	None
Principal Investigators:	Paul Imhoff, Daniel Cha, Pei Chiu

Publications

There are no publications.

Undergraduate Internship Project #3 of 11 for FY14



Intern ***Christopher Youngquist's*** project, sponsored by the ***DWRC***, was titled "Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nutrient Treatment of Stormwater Runoff." He was advised by Dr. Paul Imhoff of the ***UD's*** Department of Civil and Environmental Engineering.

Abstract

A major cause for decreased water quality in Delaware is nutrient loading of natural waters. This comes in part from fertilizer and animal manures from the farms of Delaware but also from urban sources such as road runoff and atmospheric deposition. To combat this, the Delaware Department of Transportation is required to comply with Total Maximum Daily Load regulations. These regulations set the bar for how much of any pollutant, including nutrients, can be in surface water and still maintain water quality standards. According to recent experiments biochar has the ability to absorb a significant amount of ammonium and increase water retention in the unsaturated zone, which in turn will increase nitrogen uptake in plants and conversion of ammonium to nitrogen gas. This means that biochar has the potential to improve water quality when added to a biofiltration facility. Further research is needed to understand, modify and improve the performance of biochar, particularly in engineered bioretention systems that are often used to treat stormwater runoff from roadways.

Nutrient Loading in the Murderkill River

Basic Information

Title:	Nutrient Loading in the Murderkill River
Project Number:	2014DE265B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Nutrients, Surface Water, Hydrogeochemistry
Descriptors:	None
Principal Investigators:	Alan Scott Andres

Publications

There are no publications.

For Undergraduate Internship Project 2014DE265B the student who initially accepted the internship withdrew her acceptance before beginning any work.

Fine-Scale Temporal Dynamics of Estuarine Virioplankton and Bacterioplankton Populations

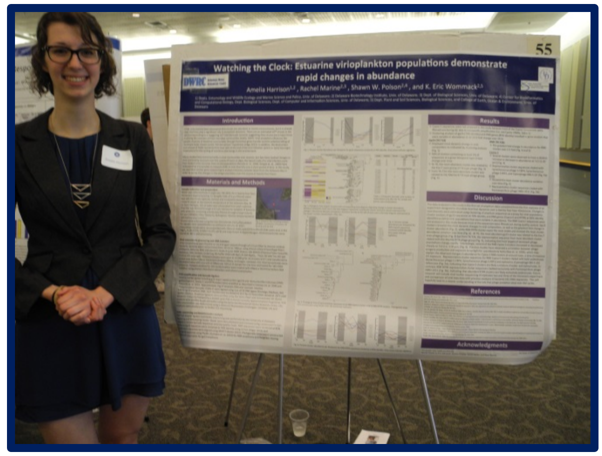
Basic Information

Title:	Fine-Scale Temporal Dynamics of Estuarine Virioplankton and Bacterioplankton Populations
Project Number:	2014DE266B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Biological Sciences
Focus Category:	Hydrogeochemistry, Surface Water, Nutrients
Descriptors:	None
Principal Investigators:	Eric Wommack

Publication

1. Harrison, A., and K.E. Wommack, 2015, Fine-scale Temporal Dynamics of Estuarine Virioplankton Populations, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 8 pages.

Undergraduate Internship Project #4 of 11 for FY14



Intern ***Amelia Harrison's*** project, sponsored by the ***DWRC***, was titled "Fine-scale Temporal Dynamics of Estuarine Virioplankton and Bacterioplankton Populations." She was advised by Dr. K. Eric Wommack of the ***UD's*** Department of Plant and Soil Sciences.

Abstract

Viral communities play a large role in influencing marine ecosystem dynamics mostly through the infection of bacterial hosts. Most studies on the population turnover time of aquatic viruses have been conducted over longer periods of time (months and seasons). This study, however, examines population dynamics over a much shorter time course (twenty-four hours), a scale more typical of viral infections. Water was collected from the Delaware Bay and incubated at ambient temperature. Subsamples were taken at six-hour intervals for twenty-four hours. Viruses were recovered by means of $FeCl_3$ flocculation. Viral concentrates were then purified. The marker genes g23 major capsid protein (gp23) and ribonucleotide reductase (RNR) genes (Cyano 1, Cyano 2, and RTPR) were amplified. Adapter ligation and PacBio sequencing followed. Data analysis revealed that the Cyano 1 RNR marker gene produced sequences that were fewer and of poorer quality comparatively. The clusters that displayed the most change over the twenty-four hours were those that were the most abundant, while the less abundant clusters tended to remain more stable. The gp23 sequences showed more diversity over time than the RNR sequences. From these results we can conclude that the Cyano 1 gene marker is either flawed or simply ineffective. It seems that the gp23 marker gene may be the most revealing marker gene. It can also be assumed that the more abundant virus groups are the most dynamic. Future work will include gene amplification and sequencing of viral concentrates from the other replicates.

Investigation of Nitrogen Pollution in a Mixed Land-Use Watershed

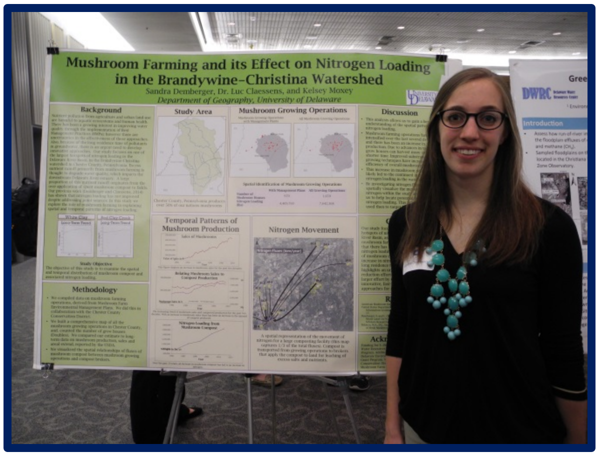
Basic Information

Title:	Investigation of Nitrogen Pollution in a Mixed Land-Use Watershed
Project Number:	2014DE267B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Nutrients, Hydrogeochemistry
Descriptors:	None
Principal Investigators:	Luc Claessens

Publication

1. Demberger, S., and L. Claessens, 2015, Mushroom Farming and its Effect on Nitrogen Loading in the Brandywine-Christina Watershed, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 2 pages.

Undergraduate Internship Project #5 of 11 for FY14



Intern ***Sandra Demberger's*** project, sponsored by the ***DWRC***, was titled "Investigation of Nitrogen Pollution in a Mixed Land-use Watershed." She was advised by Dr. Luc Claessens of the ***UD's*** Department of Geography.

Abstract

This study investigated the mushroom industry in Chester County and how it affects the region's water quality. Improving water quality has become a growing interest. Nitrogen runoff largely originated from the over application of spent mushroom compost to fields. Mushroom Farm Environmental Management plans were used to guide the study. The data that were gathered were georeferenced to get a comprehensive map of mushroom farms in Chester County with management plans. Our data were compared to reports from the USDA. A visual of nitrogen migration through the watershed was adapted to understand the movement of nitrogen across watershed boundaries. Our results show that many Chester County mushroom operations are not accounted for and that the movement of nitrogen is far more complex than originally thought. The increase of mushroom production has potentially affected the water quality through nitrogen loading.

Enhanced Pollutant Biodegradation by Electrode Use

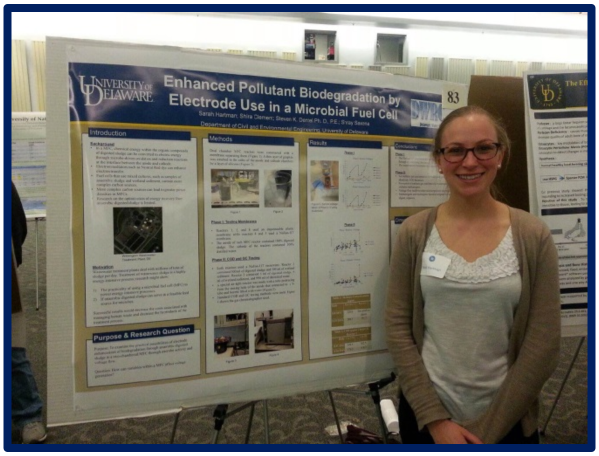
Basic Information

Title:	Enhanced Pollutant Biodegradation by Electrode Use
Project Number:	2014DE268B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Engineering
Focus Category:	Water Quality, Toxic Substances, Treatment
Descriptors:	None
Principal Investigators:	Steven K Dentel, Steven K Dentel

Publication

1. Hartman, S., and S. Dentel, 2015, Enhanced Pollutant Biodegradation by Electrode Use, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 10 pages.

Undergraduate Internship Project #6 of 11 for FY14



Intern ***Sarah Hartman's*** project, sponsored by the ***DWRC,*** was titled "Enhanced Pollutant Biodegradation by Electrode Use." She was advised by Dr. Steven Dentel of the ***UD's*** Department of Civil and Environmental Engineering.

Abstract

This study examines microbe activity and voltage flow under varying operational conditions within a two-chamber microbial fuel cell (MFC) using anaerobic digested sludge. In a MFC, chemical energy within the organic compounds of the digested sludge can be converted to electric energy through oxidation and reduction reactions at the interface between the anode and cathode. Numerous studies have been conducted demonstrating that anaerobic microorganisms are capable of utilizing graphite electrodes to drive electrochemical processes in a MFC. Anaerobically digested sludge is capable of driving similar electrochemical processes, but research on the optimization of such a type of energy recovery is limited. Efficient energy recovery from wastewater sludge could be used to power highly energy-intensive processes in wastewater treatment plants.

During this study, different experimental conditions examined included the quality of the membrane between the cathode and anode chambers and the type of graphite used as an electron mediator. Methane generation and COD degradation were also measured. The permeable nature of the membrane used determined the ability of the MFC to generate voltage.

Experimentation showed that an impermeable plastic membrane inhibited all exchange of electrons between the chambers. A permeable membrane allowed for a small current. The type of graphite being used did not appear to significantly alter voltage generation. During experimentation, methane concentration within the airtight chamber was increased as COD decreased, as predicted. The level of voltage produced under all conditions did not exceed 37mV, and the corresponding power production did not surpass 1.37 μW. Results showed that a MFC using anaerobic digested sludge, under varying conditions, was not a major power generator.

Understanding Greenhouse Gas Fluxes in Estuaries

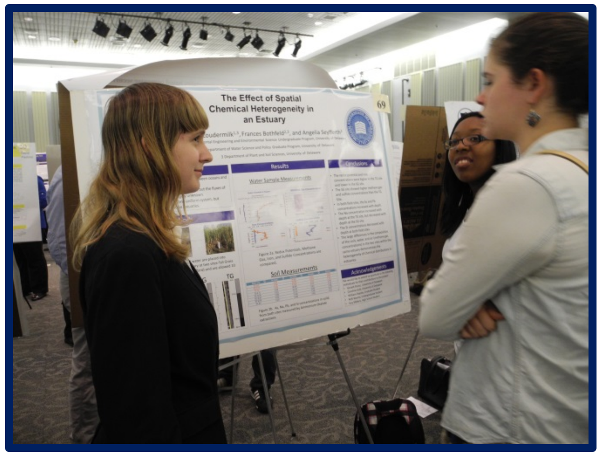
Basic Information

Title:	Understanding Greenhouse Gas Fluxes in Estuaries
Project Number:	2014DE269B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Geochemical Processes, Nutrients
Descriptors:	None
Principal Investigators:	Angelia Seyfferth, Rodrigo Vargas

Publication

1. Loudermilk, E., and A. Seyfferth, 2015, Understanding Greenhouse Gas Fluxes in Estuaries, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 11 pages.

Undergraduate Internship Project #7 of 11 for FY14



Intern ***Erica Loudermilk's*** project, co-sponsored by the ***DWRC*** and the ***UD's College of Agriculture and Natural Resources,*** was titled "Understanding Greenhouse Gas Fluxes in Estuaries." She was advised by Dr. Angelia Seyfferth of the ***UD's*** Department of Plant and Soil Sciences.

"Throughout the course of my internship, I gained valuable skills in field research techniques, such as extractions, ion chromatography, and spectrometry. In addition to laboratory-specific skills, I was able to experience working on a collaborative research team where problems occurred and we had to improvise new ways to address these unforeseen challenges. This internship has aided me in preparing for and directing me towards my future career goals in research." – Erica Loudermilk

Abstract

The goal of this project was to understand the sediment biogeochemical processes that drive greenhouse gas fluxes in estuaries and to compare the differences in chemical compositions in two distinct areas in our field site at St. Jones Reserve in Dover, Delaware. The two sites were the Tall Grass site, which is overrun by *Phragmites* and is located in an area near a channel, and the Short Grass site, which contains *S. alterniflora* and is located away from the channel. We constructed sampling devices called peepers that held test tubes with DDI water at different depths. We placed three peepers in the ground at each of the two sites and allowed the tubes to equilibrate for at least ten days. We then measured pH and redox potentials using probes at the field site and measured iron and sulfide concentrations using spectrometers the next day. We also characterized soil samples obtained at the estuary through ammonium oxalate, barium chloride, and calcium chloride extractions. The results showed that at the Tall Grass site, the redox potentials were higher than the Short Grass site, but the methane gas concentration was significantly lower. Sulfide concentrations were higher at the Short Grass site, with relatively no iron, but at the Tall Grass site, there were large concentrations of iron below the surface layer and insignificant amounts of sulfide. In the soil measurements, we found sodium concentrations increased with depth at the Tall Grass site, but decreased with depth at the Short Grass site. Silicon concentrations decreased with depth at the Tall Grass site and increased with depth at the Short Grass site. Methane gas concentrations in the atmosphere could be linked to sediment processes. The more likely chemical species in the sediment are to accept electrons, the lower the methane gas concentration in the air. These very large variations in the atmosphere, sediment, and water measurements are important to consider when conducting further research in estuaries. Although it makes it simpler to consider an estuary as one entity, it can be very diverse in composition. Further research is needed to take into consideration the spatial and chemical heterogeneity of estuaries.

Water Quality Performance for Paired Bioretention Basins

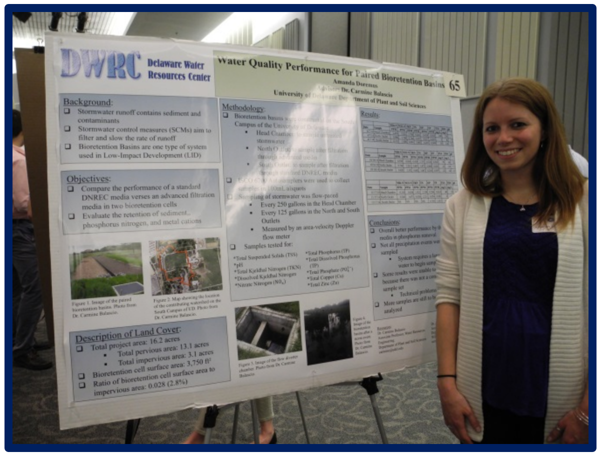
Basic Information

Title:	Water Quality Performance for Paired Bioretention Basins
Project Number:	2014DE270B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Surface Water, Non Point Pollution, Nutrients
Descriptors:	None
Principal Investigators:	Carmine Balascio

Publication

1. Doremus, A., and C. Balascio, 2015, Water Quality Performance for Paired Bioretention Basins, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 7 pages.

Undergraduate Internship Project #8 of 11 for FY14



Intern ***Amanda Doremus'*** project, co-sponsored by the ***DWRC*** and the ***UD's*** Department of Plant and Soil Sciences, was titled "Water Quality Performance for Paired Bioretention Basins." She was advised by Dr. Carmine Balascio of the ***UD's*** Department of Plant and Soil Sciences.

Abstract

My research project, Water Quality Performance for Paired Bioretention Basins, studied bioretention basins as a stormwater control measure to treat water in compliance with regulations. The purpose of this research was to compare the results of water treatment using a standard DNREC media versus an advanced media within the bioretention system. Stormwater samples were collected using ISCO 6700 Autosamplers. The first sampler collected water at the head of the system to capture untreated stormwater. Water was divided and passed through a standard DNREC media, and separately through an advanced media. The water was again sampled at the end of each of these outlets. Some of the results show that the advanced media has better phosphorus retention. Since technical issues have caused incomplete data sets, more data are needed to make further conclusions.

Procuring Abatement: Cover Crop Cost Heterogeneity and Optimal Policy Design in Delaware

Basic Information

Title:	Procuring Abatement: Cover Crop Cost Heterogeneity and Optimal Policy Design in Delaware
Project Number:	2014DE271B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Social Sciences
Focus Category:	Economics, Non Point Pollution, Management and Planning
Descriptors:	None
Principal Investigators:	Joshua Duke

Publication

1. Robinson, G., J. Egan, and J. Duke, 2015, Cover Crop Adoption Cost Heterogeneity and Policy Design in Delaware's Part of the Chesapeake Bay, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 6 pages.

COVER CROP ADOPTION COST HETEROGENEITY AND POLICY DESIGN IN DELAWARE'S PART OF THE CHESAPEAKE BAY

University of Delaware Water Resource Center
Undergraduate Internship Program 2014-2015

Image (top) James J. Hoorman "Using Cover Crops to Improve Soil and Water Quality" Ohio State University Fact Sheet.

BRIEF ABSTRACT

A cover crop cost effectiveness analysis was performed for corn production fields in Delaware to generate knowledge about how abatement-procurement cost for nitrogen and phosphorous varies between modeled emissions and current incentive payments. The results indicate that the variation in per-acre subsidy payments does not match heterogeneity in modeled nutrient reduction, expressed in pounds.

Report prepared by Dr. Joshua Duke and Jennifer Egan. Study design by Duke and Egan. Intern Gregory Robinson contributed to data collection as work-for-hire.

March 17, 2015

Abstract - Cover crops are thought to be a cost effective nutrient management practice that include environmental and on-farm benefits. The former may reduce nitrate leaching to surface waters as much as between 45-90%, depending on agronomic factors (Snapp et al., 2005; DNREC WIP Phase II), while the latter includes a potential increase in cash crop yield, a reduction in nutrient loss, an increase in soil biomass and organic carbon content, and improved water infiltration and holding properties (Fageria et al., 2005; Singer at al., 2006; Snapp et al., 2005; Wilke and Snapp, 2008).

In response to the Chesapeake Bay TMDL, the Delaware WIP Phase II seeks 92,000 acres of traditional and non-commodity cover crops within its Chesapeake Bay drainage by 2025. Delaware's cover crop program currently has approximately 18,000-23,000 acres in cover crop and subsidies of flat per acre fees ($30-$50) based on when the cover crop is planted (Kent and Sussex County Conservation District fact sheet).

Incentive payment flexibility provisions are a promising strategy for greater adoption. Maryland has intensively focused on building a cohesive statewide cover crop program using dedicated funding. In recent years at least $18 million per year has been spent to pay farmers for planting over 400,000 cover crop acres. Maryland's program has a matrix of flexibility options for farmers to choose from with corresponding per-acre payments for non-harvested cover crops that range from $45-$100. Flexible payments are designed to target practices that reduce nutrients to waterways such as early planting, using cover crops in fields where manure was spread, and planting rye (MDA Cover Crop fact sheet).

This research focused on increasing cost effectiveness in cover crop procurement by using Maryland's cover crop program payment flexibility in Delaware. The integrated analysis utilized Maryland's Nutrient Trading Tool (NTT) which simulated nutrient load reductions of twelve cover crop treatment options on 144 randomly selected Delaware cornfields. This was to be compared to cover crop treatment options, which have six corresponding per-acre subsidy payments. The project goals were to first estimate the heterogeneity in cover crop treatment reductions in pounds of nitrogen and phosphorous. The second goal was to determine if the mean reductions per treatment were equal. The third goal was to impute the cost per pound reduced based on the variable payment structure. This step involved utilizing the scientific efficiency removal for the cover crop treatments by assigning a percentage to each dollar spent for nitrogen and phosphorous.

Results show highly heterogeneous reductions ranging from 0.14 to 12.16 (lbs/ac) for nitrogen and 0.01 to 41.91 (lbs/ac) for phosphorous based on field and cover crop treatment, as hypothesized. What is unexpected is that late planting, which currently receives lower payments than early and standard planting reduces as much as, if not more than, early and standard planting. The per-acre payments, when converted to per-pound payments for nitrogen and phosphorous, also, as hypothesized, are highly heterogeneous with large ranges. Nitrogen payment ranges from $2.34 per pound for early no-till/drill wheat up to $485.87 for standard no-till/drill rye. Phosphorous payments exhibit the greatest heterogeneity of payment from zero (because there is no scientific efficiency applied to late planting) to $1,091.69.

Conclusions are that the cover crop payment structure, although attempting to pay for the greatest environmental benefit per acre, does not match the heterogeneity in modeled nutrient reduction (on the average) that the individual fields are expected to produce. The current incentive structure for cover crop payment on a per acre basis assumes the acres deliver similar reductions. Thus, there is incongruence between predicted load reductions and current payments.

In this research, heterogeneity in reduction was modeled using the NutrientNet interface. The current payment per acre structure does not match the dollar per pound reduction paid for the nutrient removal. This is also important to consider as nutrient credit trading is proposed for payment on a per pound basis. Payments made for nitrogen and phosphorus, whether made by government or private entities, should display similar prices per pound. The heterogeneity indicates that the current per acre payment for cover crops is unlikely to be cost effective.

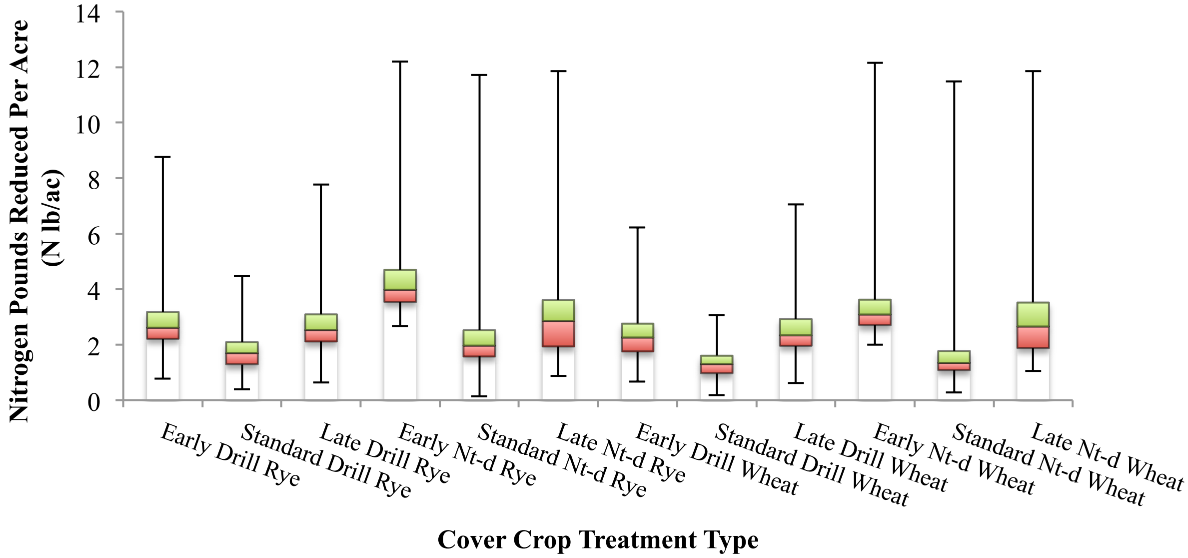


Figure 1: Nitrogen pounds reduced per acre.

This graph shows heterogeneity in the cover crop treatments for reducing nitrogen. For the planting date variable, early planting has the greatest reductions, followed by late, and then standard. This is notable as Maryland's payment program pays more per acre for standard than it does late. For seed type, rye reduces more than wheat, with planting date held constant. Furthermore, no-till/drill tends to reduce more and has a greater reduction range than conservation-till/drill, with planting date held constant.

Notes:

1)Planting dates

Early September 5

Standard October 15

Late November 1

2) Conservation till indicates <30% residue on field, no-till indicates >30% residue. These are two tillage options in NutreintNet. In the figures, drill is conservation till and Nt-d indicates no-till drill.

3) All fields were assigned drill seed method, other planting method options (broadcast and aerial) resulted in the same reductions as drill planting method in NutrientNet.

4) Agronomic variables such as P205 soil phosphorous concentration (ppm) and manure concentration were randomly assigned to the fields within a range of values based on previous data colleciton. Three levels were selected from the ranges to randomly assign to the 144 fields, therefore each field was assigned one of nine combinations.

5) Reductions for nitrogen and phosphorous based on simulation through Maryland's Nutrient trading Tool for 144 randomly selected corn fields in Delaware.

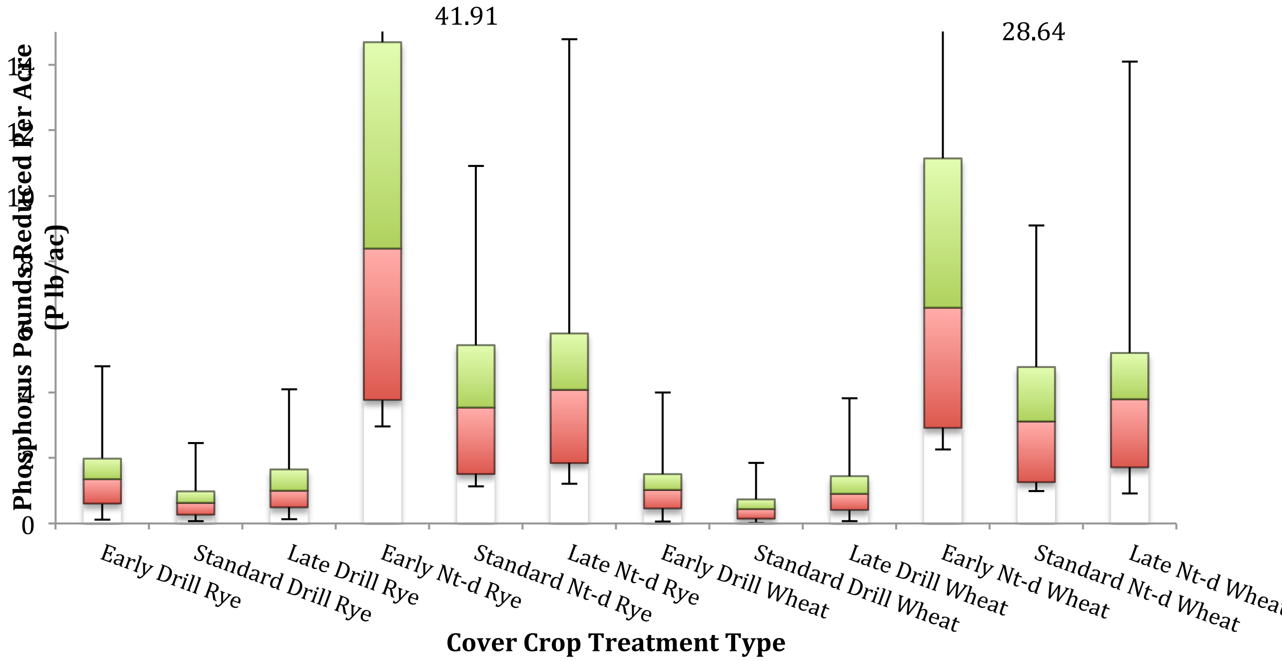


Figure 2: Phosphorus pounds reduced per acre.

Similar to Figure 1, this graph reflects heterogeneity in the cover crop treatments for reducing phosphorus. For planting date, there is low heterogeneity between the planting dates for conservation-till/drill fields, but reductions still followed the pattern of early showing the greatest reductions and standard showing the least reductions. No-till/drill crops showed much greater reductions (ten fold) at reducing phosphorus than conservation-till/drill. Furthermore, rye seed choice shows greater reductions than wheat seed choice.

Notes:
1)Planting dates
- Early September 5
- Standard October 15
- Late November 1

2) Conservation till indicates <30% residue on field, no-till indicates >30% residue. These are two tillage options in NutreintNet. In the figures, drill is conservation till and Nt-d indicates no-till drill.
3) All fields were assigned drill seed method, other planting method options (broadcast and aerial) resulted in the same reductions as drill planting method in NutrientNet.
4) Agronomic variables such as P205 soil phosphorous concentration (ppm) and manure concentration were randomly assigned to the fields within a range of values based on previous data colleciton. Three levels were selected from the ranges to randomly assign to the 144 fields, therefore each field was assigned one of nine combinations.
5) Reductions for nitrogen and phosphorous based on simulation through Maryland's Nutrient trading Tool for 144 randomly selected corn fields in Delaware.

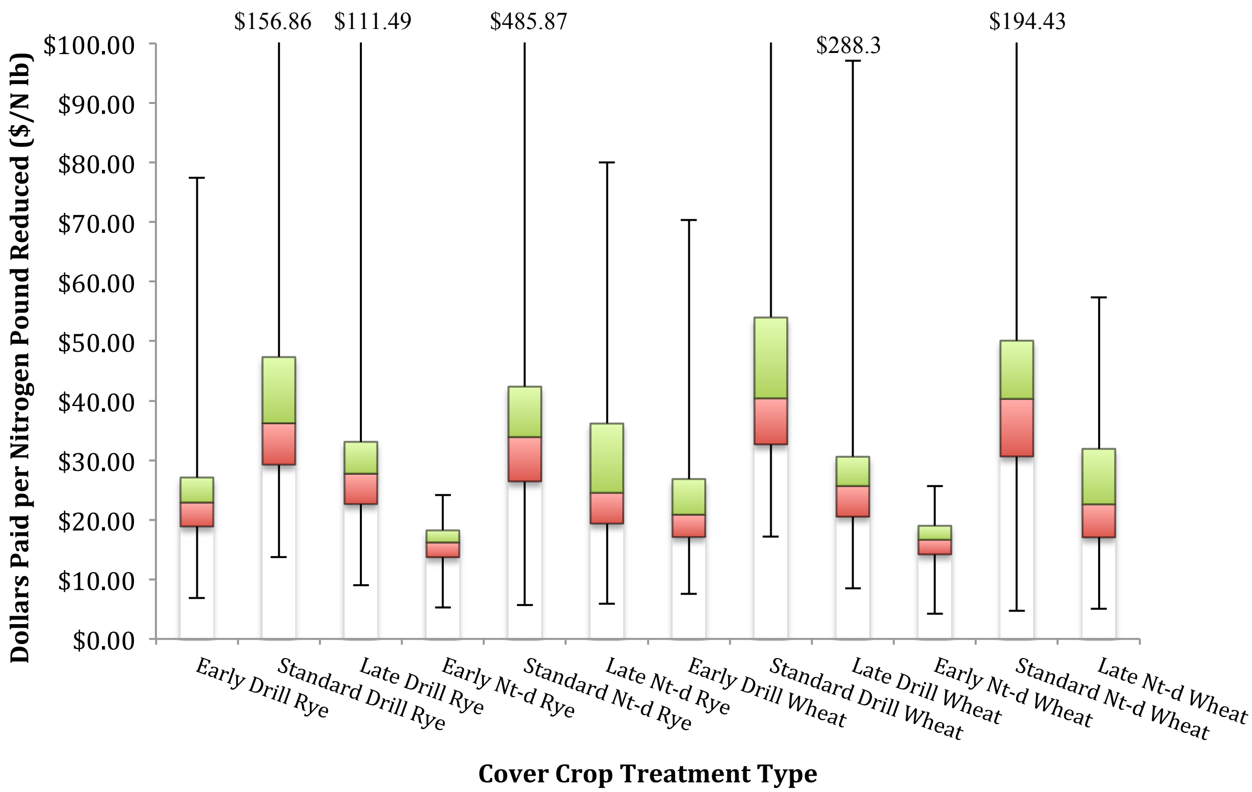


Figure 3: Dollars paid per nitrogen pound reduced (adjusted for scientific efficiency of removal for treatment types).

Data reflect large variation in payment per pound of nitrogen based on planting times, tillage type, and seed choice (cover crop treatment variables).

Notes:
1) The cover crop treatments have six payment levels based on Maryland's cover crop payment schedule.
2) The per pound reductions in figure 1 and figure 2 were multiplied by the total acres paid according to the payment schedule for that crop treatment.
3) Nitrogen and phosphorous payments were split based on the scientific efficiency of removal assigned to cover crop treatments.

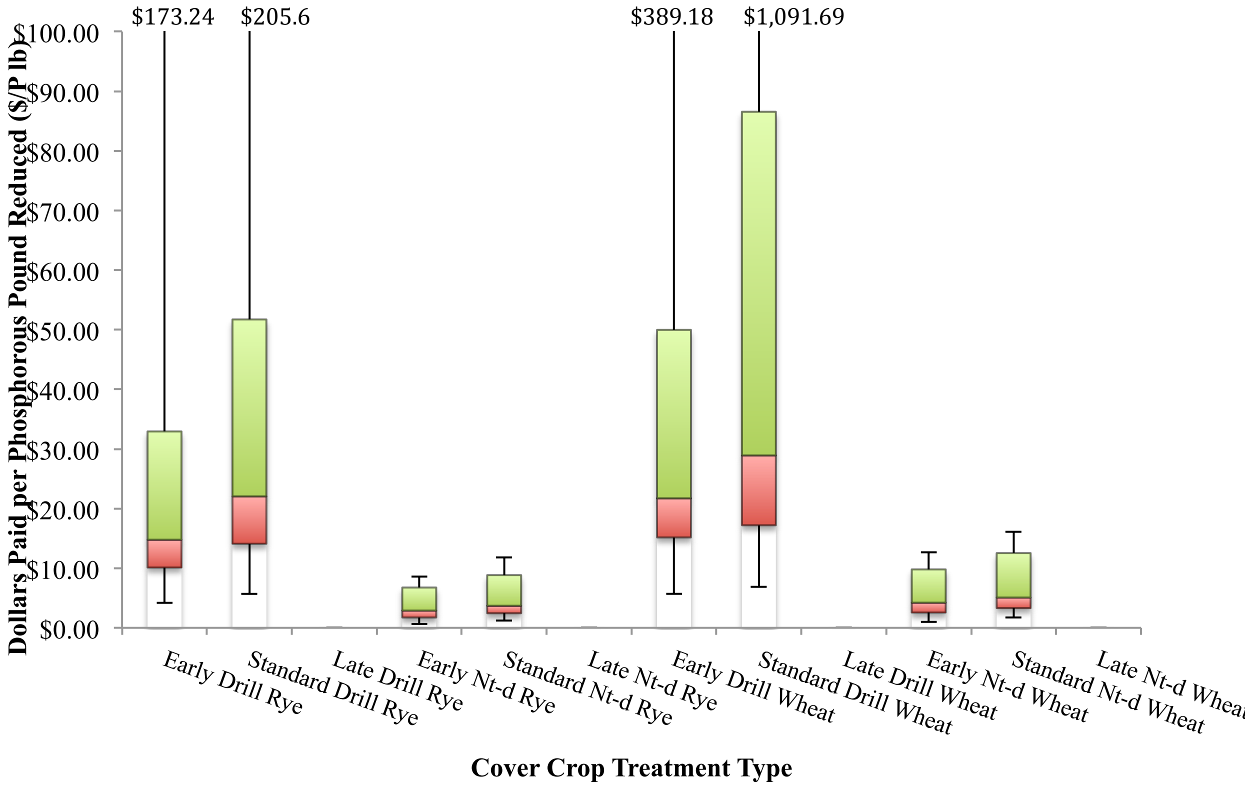


Figure 4: Dollars paid per phosphorus pound reduced (adjusted for scientific efficiency of removal for treatment types).

Data reflect large variation in payment per pound of phosphorous based on planting times, tillage type, and seed choice (cover crop treatment variables).

Notes:
1) The cover crop treatments have six payment levels based on Maryland's cover crop payment schedule.
2) The per pound reductions in figure 1 and figure 2 were multiplied by the total acres paid according to the payment schedule for that crop treatment.
3) Nitrogen and phosphorous payments were split based on the scientific efficiency of removal assigned to cover crop treatments.
4) Phosphorous efficiency of removal for late plantings is assigned a "zero" efficiency of removal therefore in the late planting scenario, all payment would be assigned to nitrogen.

Wetland Restoration and Mitigation Banking along the Cool Run Watershed at the UD Farm: GIS Mapping

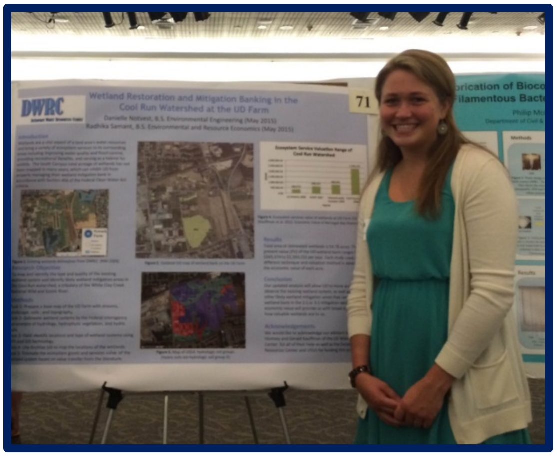
Basic Information

Title:	Wetland Restoration and Mitigation Banking along the Cool Run Watershed at the UD Farm: GIS Mapping
Project Number:	2014DE272B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Wetlands, Non Point Pollution, Management and Planning
Descriptors:	None
Principal Investigators:	Gerald Joseph Kauffman

Publication

1. Notvest, D., and G. Kauffman, 2015, Wetland Restoration and Mitigation Banking along the Cool Run Watershed at the UD Farm, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 7 pages.

Undergraduate Internship Project #10 of 11 for FY14



Intern ***Danielle Notvest's*** project, co-sponsored by the ***DWRC*** and the ***UD's Water Resources Agency***, was titled "Wetland Restoration and Mitigation Banking along the Cool Run Watershed at the UD Farm: GIS Mapping." She was advised by Dr. Gerald Kauffman of the ***UD's Water Resources Agency***.

Abstract

The objective of this project is to map and identify the type and quality of the existing wetland system and identify likely wetland mitigation areas in the Cool Run Watershed that can be established as a wetland bank in accordance to the Act's criteria. By updating this watershed bank, we are able to provide the University with more accurate numbers of the acreage of their wetland bank to use when outside organizations would like to fill or impact other wetland areas. This will allow the University to receive the appropriate funding for their wetland banks, encouraging its continuing advancement and expansion.

Our findings highlight the total area of the wetlands to be 54.782 acres and economic value of the wetland system to be between $343,373 and $2,393,151. This updated analysis will allow the University to more accurately observe the existing wetland system, as well as identify other likely wetland mitigation areas that can be used as a wetland bank in the 2:1 or 3:1 mitigation aerial basis. The economic value of these areas provide us with broad insight as to how valuable wetlands are to us, both ecologically and economically speaking, and it is important that we continue to understand the significance of them.

Wetland Restoration and Mitigation Banking along the Cool Run: Ecosystem Service Analysis

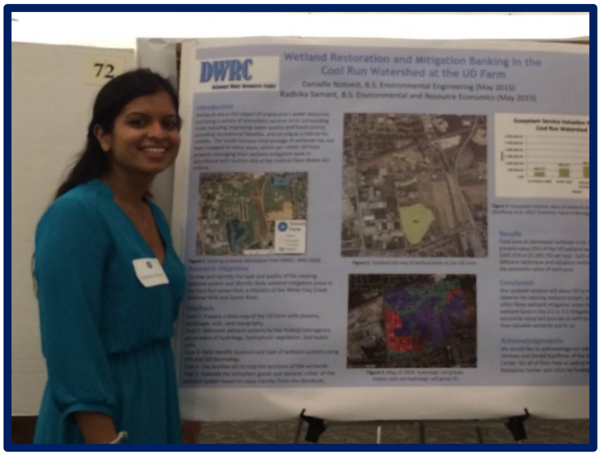
Basic Information

Title:	Wetland Restoration and Mitigation Banking along the Cool Run: Ecosystem Service Analysis
Project Number:	2014DE273B
Start Date:	6/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Water Quality
Focus Category:	Wetlands, Ecology, Non Point Pollution
Descriptors:	None
Principal Investigators:	Gerald Joseph Kauffman, Gerald Joseph Kauffman

Publication

1. Samant, R., and G. Kauffman, 2015, Wetland Restoration and Mitigation Banking along the Cool Run Watershed at the UD Farm, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 7 pages.

Undergraduate Internship Project #11 of 11 for FY14



Intern ***Radhika Samant's*** project, co-sponsored by the ***DWRC*** and the ***UD's Water Resources Agency***, was titled "Wetland Restoration and Mitigation Banking along the Cool Run Watershed at the UD Farm." She was advised by Dr. Gerald Kauffman of the ***UD's Water Resources Agency***.

Abstract

The objective of this project is to map and identify the type and quality of the existing wetland system and identify likely wetland mitigation areas in the Cool Run Watershed that can be established as a wetland bank in accordance to the Act's criteria. By updating this watershed bank, we are able to provide the University with more accurate numbers of the acreage of their wetland bank to use when outside organizations would like to fill or impact other wetland areas. This will allow the University to receive the appropriate funding for their wetland banks, encouraging its continuing advancement and expansion.

Our findings highlight the total area of the wetlands to be 54.782 acres and economic value of the wetland system to be between $343,373 and $2,393,151. This updated analysis will allow the University to more accurately observe the existing wetland system, as well as identify other likely wetland mitigation areas that can be used as a wetland bank in the 2:1 or 3:1 mitigation aerial basis. The economic value of these areas provide us with broad insight as to how valuable wetlands are to us, both ecologically and economically speaking, and it is important that we continue to understand the significance of them.

Information Transfer Program Introduction

None.

DWRC Information Transfer

Basic Information

Title:	DWRC Information Transfer
Project Number:	2014DE257B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Not Applicable
Focus Category:	Water Quality, Water Supply, Education
Descriptors:	None
Principal Investigators:	James Thomas Sims, Maria Pautler, James Thomas Sims

Publications

There are no publications.

Information Transfer Program

The following section describes all Delaware Water Resources Center information transfer activities during FY14, consolidating reporting into a single (extended) project **#2014DE257B**. Most activities from the DWRC's FY13 Information Transfer project (**#2010DE197B)** continued into this year.

The FY14 DWRC Information Transfer Activities include:

- Delaware Water Resources Center Electronic Publication WATER NEWS (2000 – 2006 = print; 2007 – present = electronic)
- Delaware Water Resources Center Electronic Newsletter WATER E-NEWS (2002 – present)
- Delaware Water Resources Center Website (3rd edition launched in 2009)
- Delaware Water Resources Center E-group / Courses Link (2002 – present)
- Delaware Water Resources Center Intern Project Poster Session / Advisory Panel Annual Meeting (2001 – present)
- Delaware Statewide Conference Co-sponsor and Participant (2001 – present, when held)

Basic Information:
Delaware Water Resources Center Electronic Publication WATER NEWS

Title:	“WATER NEWS“
Issues during FY14:	None
Description:	Online 8-page newsletter published biannually by the Delaware Water Resources Center (In FY14 there was a hiatus while the format is being revamped)
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	J. Thomas Sims, Director; Maria Pautler, Editor

WATER NEWS is received electronically by over 300 recipients in water-related academic, government, public and private agency, agriculture and industry positions in Delaware and the surrounding area as well as 100 nationwide contacts for water resource issues. It may be accessed via the Delaware Water Resources Center website at: http://ag.udel.edu/dwrc/newsletters.html.

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

Title:	"WATER E-NEWS"
Issues during FY14:	Mar. 2015, Apr. 2015
Description:	Brief online "highlights" newsletter published periodically by the Delaware Water Resources Center
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	Gerald J. Kauffman, Director; Maria Pautler, Editor

WATER E-NEWS is received electronically by over 300 recipients in water-related academic, government, public and private agency, agriculture and industry positions in Delaware and the surrounding area. The current issue and back issues dating to its August 2002 inception may be accessed via the DWRC website at: http://ag.udel.edu/dwrc/newsletters.html.

Featured in each issue of WATER E-NEWS are:

I. News items about the DWRC, including undergraduate internships and graduate fellowships
II. Jobs in Water Resources
III. Upcoming Water Conferences / Events
IV. Water Resources Information / Training

Basic Information: Delaware Water Resources Center Website

Title:	Website: http://ag.udel.edu/dwrc
Start Date:	Third edition; since February 2009
End Date:	Ongoing
Description:	Comprehensive site serving Delaware water resources community
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	J. Thomas Sims, Director; Maria Pautler, Administrator

The website 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. Abstracts from the undergraduate internship projects are prevalent to educate current undergraduates and faculty about the types of research that can be done under this program.
- **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 Faculty and Courses:** List of researchers at Delaware universities with an interest in water resources research; link from many of the researchers' names to their professional websites to learn about water-related courses currently offered by the researchers
- **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 E-group, originating from the online listing of Delaware water teachers and researchers found on the DWRC website: http://ag.udel.edu/dwrc/faculty_researchers.html
Start Date:	Since December 2001
End Date:	Ongoing
Description:	E-group and link to university water resources courses taught, serving Delaware water resources community
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	J. Thomas Sims, Director; Maria Pautler, 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 website at http://ag.udel.edu/dwrc/faculty_researchers.html forms the foundation for a broader e-group list maintained by the DWRC reaching additional academic, public, private, and government water community contacts, who are notified via an e-mail newsletter of events and job postings of interest in water resources.

The website also provides a link from many of the researchers' names to their professional websites to learn about water-related courses currently offered by the researchers.

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

Title:	University of Delaware 2015 Undergraduate Research Scholars Poster Session with DWRC Advisory Panel Meeting
Date:	April 17, 2015
Description:	Undergraduate interns presented their 2014-2015 DWRC-funded projects following the annual meeting of the DWRC Advisory Panel
Lead Institute:	University of Delaware Undergraduate Research Program Co-sponsors: Delaware Water Resources Center, Charles Peter White Fellowship in Biological Sciences, Chemistry and Biochemistry Alumni Fellowship, College of Agriculture and Natural Resources, EPSCoR, Helen Pattison Scholars, Howard Hughes Medical Institute, INBRE, Joan Bennett Scholars, McNair Scholars Program, National Science Foundation, Northeastern Chemical Association, NUCLEUS, Roselle Scholars, State of Delaware.
Principal Investigators:	Iain Crawford, Director, UD Undergraduate Research Program (icrawf@udel.edu); Gerald J. Kauffman, Director, DWRC (jerryk@udel.edu)

On April 17, 2015, the undergraduate student interns who had been funded in 2014-2015 by the DWRC, accompanied by their advisors, presented the results of their research at an informal poster session sponsored by the University of Delaware Undergraduate Research Program. Over 95 UD Science and Engineering Scholars joined the DWRC interns to present to a crowd of over 400 visitors. The DWRC Advisory Panel also convened for lunch with the interns and their advisors and then held their annual meeting prior to the poster session. Incoming DWRC Director Gerald Kauffman described the Center's plans for 2015-2016 with regard to research funding and public education outreach efforts.

Poster Presentations by 2014-2015 DWRC Undergraduate Interns – April 17, 2015

1) Csatari, Katelyn. Poster Presentation April 17, 2015. Greenhouse Gas Emissions from Sediments in a Protected Estuary in Delaware. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

2) Demberger, Sandra. Poster Presentation April 17, 2015. Investigation of Nitrogen Pollution in a Mixed Land-use Watershed. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

3) Doremus, Amanda. Poster Presentation April 17, 2015. Water Quality Performance for Paired Bioretention Basins. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

4) Fedetz, Jessica. Poster Presentation April 17, 2015. Quantifying Conservation Practices in the Chesapeake Bay Basin. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

5) Harrison, Amelia. Poster Presentation April 17, 2015. Fine-scale Temporal Dynamics of Estuarine Virioplankton and Bacterioplankton Populations. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

6) Hartman, Sarah. Poster Presentation April 17, 2015. Enhanced Pollutant Biodegradation by Electrode Use. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

7) Loudermilk, Erica. Poster Presentation April 17, 2015. Understanding Greenhouse Gas Fluxes in Estuaries. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

8) Notvest, Danielle. Poster Presentation April 17, 2015. Wetland Restoration and Mitigation Banking along the Cool Run Watershed at the UD Farm: GIS Mapping. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

9) Samant, Radhika. Poster Presentation April 17, 2015. Wetland Restoration and Mitigation Banking along the Cool Run: Ecosystem Service Analysis. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

10) Youngquist, Christopher. Poster Presentation April 17, 2015. Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nutrient Treatment of Stormwater Runoff. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

11) Burke, Katja, Marc Latham, and Chloe Ng. Poster Presentation April 17, 2015. Stormwater Modeling in the Fairfield Run Watershed in Newark, Delaware. 2015. University of Delaware Undergraduate Research Scholars Poster Session, University of Delaware, Newark, Delaware.

UD WATER

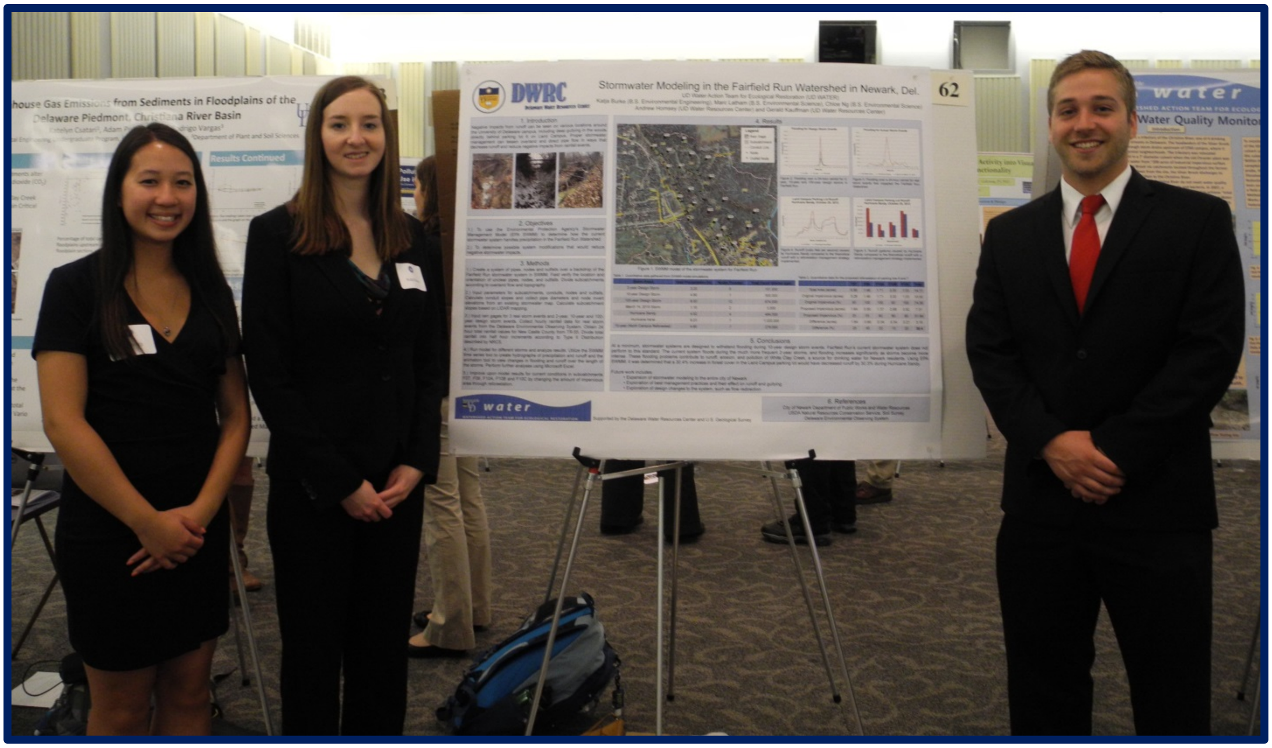
Basic Information

Title:	UD WATER
Project Number:	2014DE258B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	At large
Research Category:	Not Applicable
Focus Category:	Education, Surface Water, Non Point Pollution
Descriptors:	None
Principal Investigators:	James Thomas Sims, Gerald Joseph Kauffman, James Thomas Sims

Publications

There are no publications.

UD WATER Project for FY14



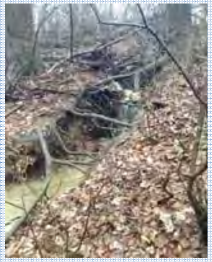
Interns ***Chloe Ng, Katja Burke, and Marc Latham*** (pictured left to right) worked on “Stormwater Modeling in the Fairfield Run Watershed in Newark, Delaware” with Dr. Gerald Kauffman and Mr. Andrew Homsey of the ***UD’s Water Resources Agency***. Their accomplishment poster follows.

Stormwater Modeling in the Fairfield Run Watershed in Newark, Del.

UD Water Action Team for Ecological Restoration (UD WATER)
Katja Burke (B.S. Environmental Engineering), Marc Latham (B.S. Environmental Science), Chloe Ng (B.S. Environmental Science)
Andrew Homsey (UD Water Resources Center) and Gerald Kauffman (UD Water Resources Center)

1. Introduction

Negative impacts from runoff can be seen on various locations around the University of Delaware campus, including deep gullying in the woods directly behind parking lot 6 on Laird Campus. Proper stormwater management can lessen overland and direct pipe flow in ways that decrease runoff and reduce negative impacts from rainfall events.



2. Objectives

1.) To use the Environmental Protection Agency's Stormwater Management Model (EPA SWMM) to determine how the current stormwater system handles precipitation in the Fairfield Run Watershed.

2.) To determine possible system modifications that would reduce negative stormwater impacts.

3. Methods

1.) Create a system of pipes, nodes and outfalls over a backdrop of the Fairfield Run stormwater system in SWMM. Field verify the location and orientation of unclear pipes, nodes, and outfalls. Divide subcatchments according to overland flow and topography.

2.) Input parameters for subcatchments, conduits, nodes and outfalls. Calculate conduit slopes and collect pipe diameters and node invert elevations from an existing stormwater map. Calculate subcatchment slopes based on LIDAR mapping.

3.) Input rain gages for 3 real storm events and 2-year, 10-year and 100-year design storm events. Collect hourly rainfall data for real storm events from the Delaware Environmental Observing System. Obtain 24 hour total rainfall values for New Castle County from TR-55. Divide total rainfall into half hour increments according to Type II Distribution described by NRCS.

4.) Run model for different storms and analyze results. Utilize the SWMM time series tool to create hydrographs of precipitation and runoff and the animation tool to view changes in flooding and runoff over the length of the storms. Perform further analyses using Microsoft Excel.

5.) Improve upon model results for current conditions in subcatchments F07, F08, F10A, F10B and F10C by changing the amount of impervious area through reforestation.

4. Results

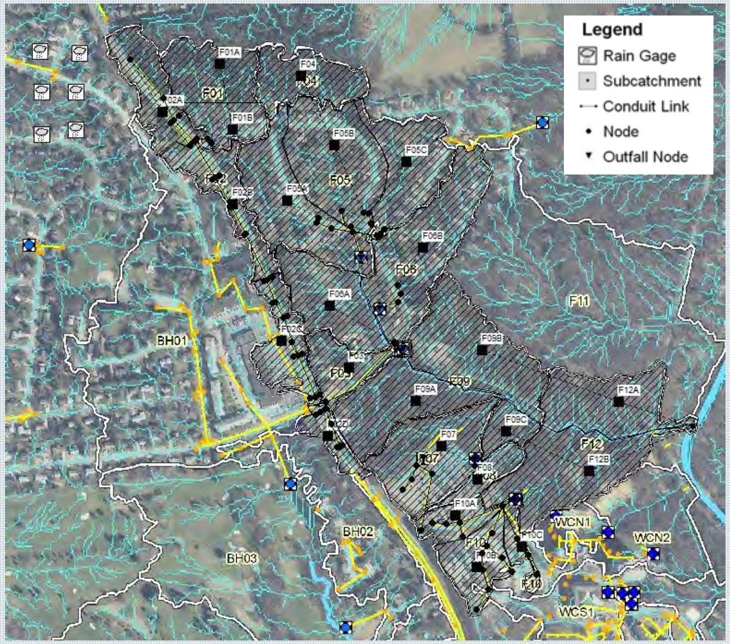


Figure 1. SWMM model of the stormwater system for Fairfield Run

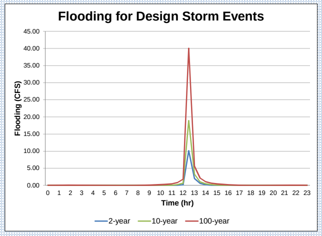


Figure 2. Flooding over a 24-hour period for 2-year, 10-year and 100-year design storms in Fairfield Run

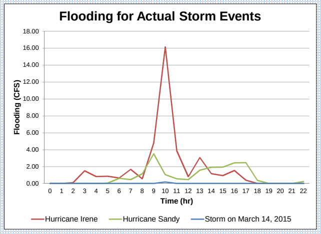


Figure 3. Flooding over a 24-hour period for real storm events that impacted the Fairfield Run Watershed

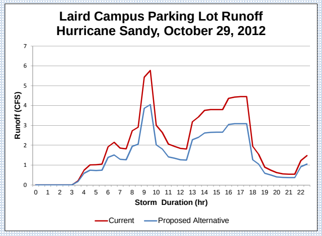


Figure 4. Runoff (cubic feet per second) caused by Hurricane Sandy compared to the theoretical runoff with a reforestation management strategy implemented

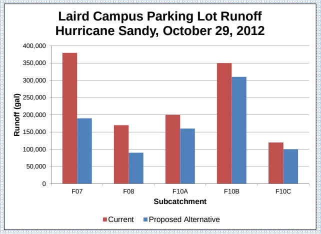


Figure 5. Runoff (gallons) caused by Hurricane Sandy compared to the theoretical runoff with a reforestation management strategy implemented

Table 1. Quantitative data gathered from SWMM model simulations

Storm Event	Total Precipitation (in)	Nodes Flooded	Total Flood Volume (gal)
2-year Design Storm	3.20	5	151,000
10-year Design Storm	4.80	7	300,000
100-year Design Storm	8.00	12	674,000
March 14, 2015 Storm	1.10	2	5,000
Hurricane Sandy	4.52	4	494,000
Hurricane Irene	6.23	7	1,020,000
10-year (North Campus Reforested)	4.80	7	279,000

Table 2. Quantitative data for the proposed reforestation of parking lots 6 and 7

	F07	F08	F10A	F10B	F10C	Total
Total Area (acres)	6.56	1.46	1.71	3.35	1.03	14.11
Original Impervious (acres)	3.28	1.46	1.71	3.02	1.03	10.50
Original Impervious (%)	50	100	100	90	100	74.38
Proposed Impervious (acres)	1.64	0.80	1.37	2.68	0.82	7.31
Proposed Impervious (%)	25	55	80	80	80	51.84
Difference (acres)	1.64	0.66	0.34	0.34	0.21	3.19
Difference (%)	25	45	20	10	20	**30.4**

5. Conclusions

At a minimum, stormwater systems are designed to withstand flooding during 10-year design storm events. Fairfield Run's current stormwater system does not perform to this standard. The current system floods during the much more frequent 2-year storms, and flooding increases significantly as storms become more intense. These flooding problems contribute to runoff, erosion, and pollution of White Clay Creek, a source for drinking water for Newark residents. Using EPA SWMM, it was determined that a 30.4% increase in forest cover in the Laird Campus parking lot would have decreased runoff by 30.3% during Hurricane Sandy.

Future work includes:
- Expansion of stormwater modeling to the entire city of Newark
- Exploration of best management practices and their effect on runoff and gullying
- Exploration of design changes to the system, such as flow redirection

6. References

City of Newark Department of Public Works and Water Resources
USDA Natural Resources Conservation Service, Soil Survey
Delaware Environmental Observing System

Sustainable UD water
WATERSHED ACTION TEAM FOR ECOLOGICAL RESTORATION

Supported by the Delaware Water Resources Center and U.S. Geological Survey

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	11	0	0	0	11
Masters	0	0	0	0	0
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	13	0	0	0	13

Notable Awards and Achievements

Research Program: The Delaware Water Resources Center (DWRC) has funded thirteen research grant projects during March 2014 through February 2015 that address state water resources priorities identified by the DWRC's Advisory Panel. Two of these projects are graduate fellowships with research focuses on 1) removal of organic contaminants from water and 2) nutrient removal in waters using biochar. The remaining projects were undergraduate internships researching 1) greenhouses gases from sediments; 2) nitrogen pollution in a watershed; 3) water retention in bioretention basins; 4) quantifying conservation practices in the Chesapeake Bay; 5) estuarine virioplankton; 6) pollutant biodegradation by electrode use; 7) greenhouse gas fluxes in estuaries; 8) wetland restoration and GIS mapping; 9) cover crop cost and policy design; 10) wetland restoration and ecosystem service analysis; and 11) biochar amendments to stormwater runoff. The UD WATER Project, with three undergraduate interns reporting during this period, shared the latest information regarding stormwater modeling on the UD campus.