2018/2019

DWRC Water Research Internships

- Michaella Becker (Environmental Engineering), Advisor: Paul Imhoff (Civil and Environmental Engineering). Impact of Biochar-Amended Roadway Soils on Runoff & Pollutant Loads.

- Nicolette Bugher (Environmental Engineering), Advisor: Gerald Kauffman (Public Policy). Recommendations for Addressing Perfluoroalkyl Chemical Contamination in Delaware.

- Chelsea Caplinger (Political Science), Advisor: Gretchen Bauer (Political Science). Interstate Watershed Management:Expanding the Clean Water Act to Include Modern Pollutants.

- Alyssa Cortese (Environmental Science), Advisor: Gerald Kauffman (Public Policy). Nitrate Sources in White Clay Creek.

- Monica Crosby (Environmental Studies), Advisor: Paul Jackson (Geography). Status, Policies & Mitigation for Wetlands in Delaware.

- Veronica Hill (Resource Economics), Advisor: Leah Palm Forster (Resource Economics). The Impact of Sea Level Rise on Seasonal Rental Properties in Delaware.

- Allison Kaltenbach (Environmental Engineering), Advisor: Gerald Kauffman (Public Policy). Tidal Effects of Coastal Flood Inundation along the Atlantic Seaboard.

- Rebecca Steiner (Public Policy), Advisor: Nina David (Public Policy). Where Land Meets Water: An evaluation of whether local plans,ordinances, and development decisions promote growth management and protect water quality in the Delaware Inland Bays Basin.

- Mia Kane (Environmental Science), Advisor: Martha Narvaez (Public Policy) and Kristen Travers (Delaware Nature Society). Coverdale Farm Regenerative Agriculture:A Compilation of Data.

- Liam Warren (Energy/Environmental Policy), Advisor: Phillip Barnes (Public Policy). Stormwater Utility Charge Policies in Delaware: A Sustainability Analysis.

- Natalie Zimmerman (Geology), Advisor: Gerald Kauffman (Public Policy). Determining the Source of Sediment Pollution in White Clay Creek Wild & Scenic River.

- Andrew Dorazio (Mechanical Engineering), Advisor: Gerald Kauffman (Public Policy). White Clay Creek's Potential for Hydroelectric Power Generation.

- Jillian Young (M.S. Water Science and Policy), Advisor: Andrew Homsey (Public Policy and Administration). Analysis of the Watershed Resources Registry Using GIS to Evaluate Stormwater Restoration Practices in the Christina River Watershed.

- Kelly Jacobs (M.S. Energy and Environmental Policy), Advisor: Martha Narvaez (Public Policy), Source Water Protection in the White Clay Creek Watershed.

Impact of Biochar-Amended Roadway Soils on Runoff & Pollutant Loads

Michaella Becker

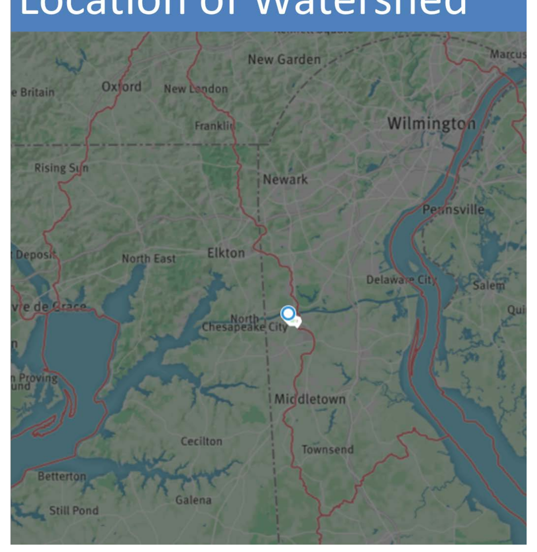
Background

Biochar is an extremely porous charcoal (pyrolyzed biomass) with high specific surface area that when used as a soil amendment, it increases infiltration. Nutrients bind to the biochar as runoff filters through the soil, effectively reducing runoff quality and quantity.

Biochar is mainly used in agriculture today due to its water and nutrient retaining properties which are great for growing crops, however, there is interest in using this soil amendment as a stormwater management BMP.

This research originally focused on modeling the effect that biochar, used as a soil amendment to roadway filter strips located in New Castle County, had on the Chesapeake Bay watershed. However, I was advised to scale down to a more appropriately sized watershed so I could accurately model the reduction in runoff volume, and sediment, nitrogen and phosphorus loads.

Location of Watershed



I delineated the watershed that contains the field site where a biochar filter strip intercepts runoff from 1-acre of impervious pavement. I chose this watershed because it lies within both New Castle County and the Chesapeake Bay Watershed, and because I could use existing data that correlates with this research site. From this research, they were able to conclude that biochar amendment reduced average surface runoff volume by 84%.

Objective

Model the impact of biochar on the reduction in runoff volume, and sediment, nitrogen and phosphorus loads when used as a soil amendment to roadway filter strips within a small-scale watershed.

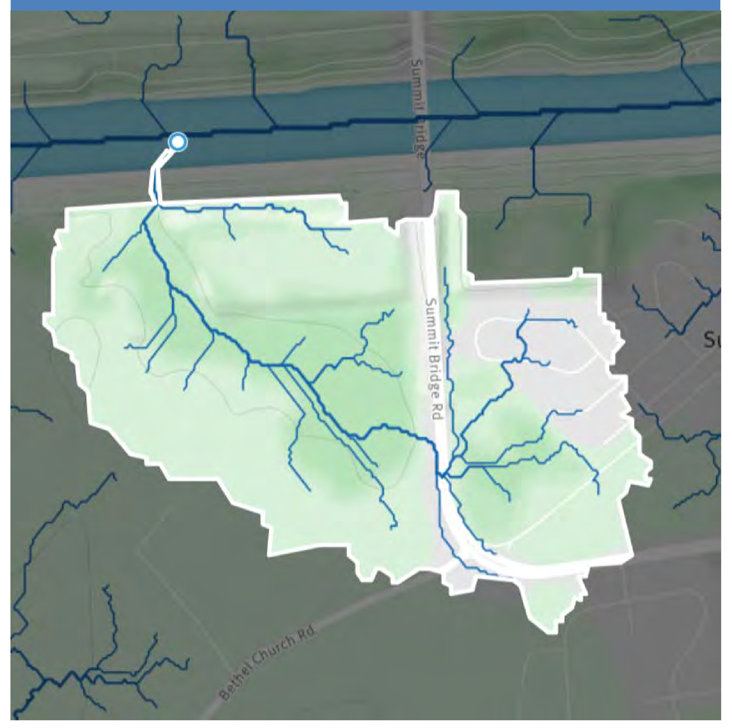
Methods and Results

Model My Watershed created by Stroud Water Research Center was used to calculate the reduction in runoff and the BMP Spreadsheet Tool was used to calculate the reduction of total sediment, nitrogen and phosphorus loads.

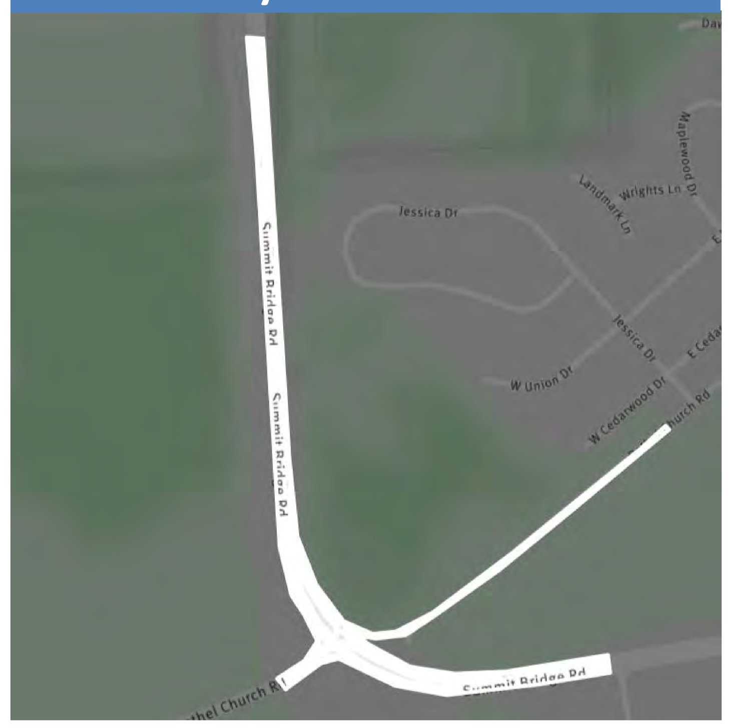
For runoff reduction calculations two different multi-year models were created:

- Watershed: containing the field site, delineated by Delaware High Resolution Stream Network
- Roadway: free-drawn area containing only the impervious pavement from Summit Bridge Rd and Bethel Church Rd located in the watershed described above.

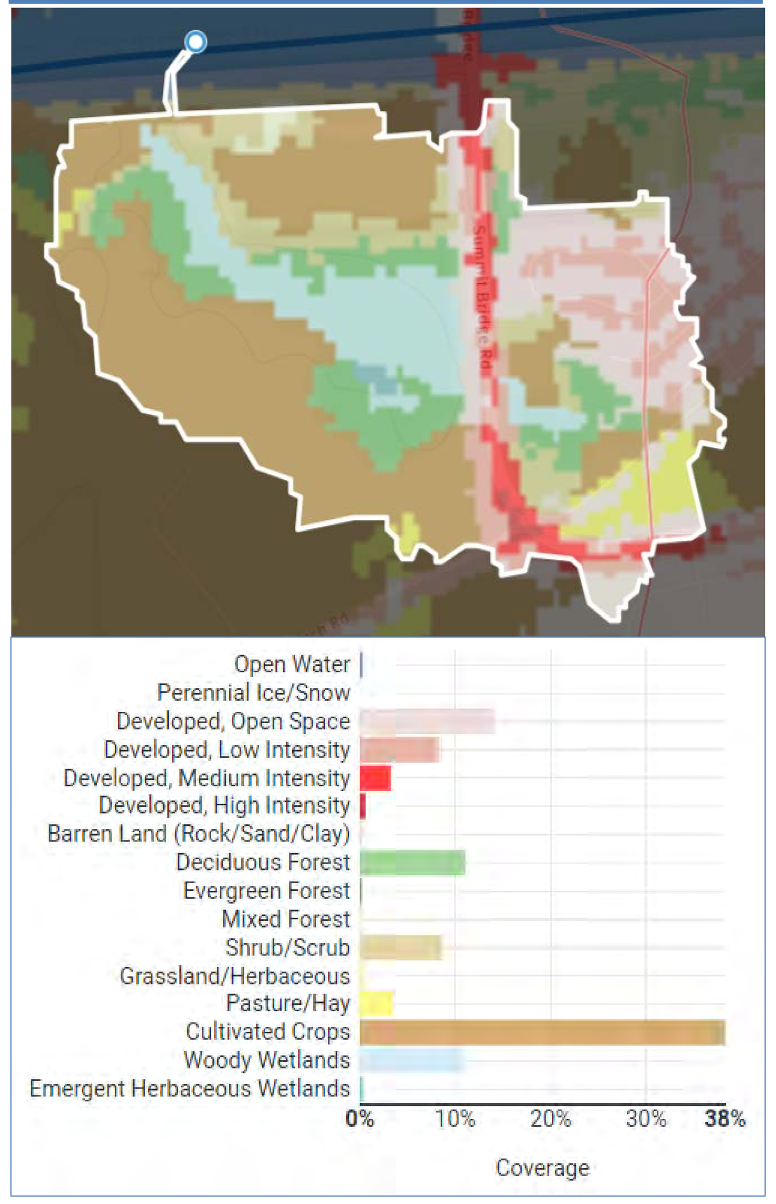
Watershed: 369.4 acres



Roadway: 12.2 acres



Land Cover Distribution



The annual surface runoff depth was calculated by running the 30-yr Multi-year simulation for the roadway model. To calculate the annual reduced runoff depth for the roadway, a series of equations were used as shown below. To model the reduced runoff for the whole watershed and not just the roadway, the land use of the model was altered until approximately 1.46” of annual runoff was calculated within the roadway model. These same land use alterations were then applied to the watershed model. The calculation results are shown below.

$$Total\ annual\ surface\ runoff\ depth = 9.12\ in$$
$$Total\ area\ of\ roadway = 503394\ ft^2 \times (12\ in/ft)^2 = 7.25\text{ E7 } in^2$$
$$Total\ surface\ runoff\ volume = 9.12\ in \times 7.25\text{ E7 } in^2 = 6.61\text{ E8 } in^3$$
$$Total\ reduced\ runoff\ volume = (1 - 84\%) \times 6.61\text{ E8 } in^3 = 1.06\text{ E8 } in^3$$
$$Total\ reduced\ runoff\ depth = 1.06\text{ E8 } in^3 / 7.25\text{ E7 } in^2 = 1.46\ in$$

Surface Runoff Reduction

	Roadway	Watershed
Initial MMW Runoff (in)	9.12	3.46
New Reduced Runoff (in)	1.48	3.28
Percent Reduction	*83.8%*	*5.2%*

To calculate reduction in sediment, nitrogen and phosphorus loads the BMP Spreadsheet Tool was used. The inputs for this tool are downloaded from the 30-yr Multi-Year Watershed Model as described above. Then, based on the type of BMP (in this case biochar was assumed to act as the RR type), treatment depth (quantity of runoff in inches captured by biochar) and the type and area (acres) of land use treated by the BMP, the removal efficiency values for sediment, nitrogen and phosphorus, as well as potential load reductions, are automatically calculated. I assumed all the area that drained to the biochar filter strips was high density mixed land cover and was equal to the roadway area of 12.2 acres. I also assumed 2.5 inches of treatment depth which was the cap in this model. The model outputs are shown below.

Pollutant Load Reductions

	Roadway			Watershed		
	Sediment	**TN**	**TP**	**Sediment**	**TN**	**TP**
Initial MMW Loads (lbs/yr)	1,373	14	2	186,965	2,811	204
Total Loads Removed (lbs/yr)	656	10	1	656	10	1
New Reduced Load (lbs/yr)	718	4	1	186,309	2,802	203
Percent Reduction	*47.7%*	*70.7%*	*51.4%*	*0.4%*	*0.3%*	*0.5%*

Discussion

An overall reduction in runoff and pollutant loads was found, however the magnitude of this reduction is insignificant. As the data shows, the percent reduction of runoff from the roadway model is significant at 83.8% which was as close to 84% as the model would allow. However, within the context of the entire watershed, runoff was only reduced by 5.2%. When it came to reduction of pollutant loads, the roadway model exhibits significant values at 47.7, 70.7 and 51.4%, for sediment, nitrogen and phosphorus, respectively. Whereas, within the entire watershed, biochar amendment only reduced these pollutants by 0.4, 0.3, and 0.5%, respectively.

As seen in the Land Cover Distribution figure, the entire watershed is mostly made up of cropland which accounts for a lot more of the pollutants than the impervious cover. This explains why treating the stormwater from the roadway has insignificant effects on the water quality of the entire watershed. Therefore, biochar would be more useful as an agricultural BMP to treat stormwater, especially when it comes to the area of New Castle County that drains to the Chesapeake Bay, which is mostly made up of farmland.

Limitations include the accuracy and precision of the National Land Cover Database (NLCD 2011). The NLCD 2011 was used for the land cover distribution within the model. This inaccuracy could be impacting both the surface runoff reduction calculations and the pollutant load reduction model. The assumptions that were made for the calculations, such as treatment depth and land cover, could also be inaccurate.

Future Work

If this work is continued it would be beneficial to analyze whether biochar used an Agricultural BMP would result in much higher reduction percentages than when used as an Urban BMP. Model My Watershed and the BMP Spreadsheet Tool could be used to compare because it has agricultural BMP features, as well.

Acknowledgments

- Advisors: Paul Imhoff & Gerald Kauffman
- Funding from DWRC

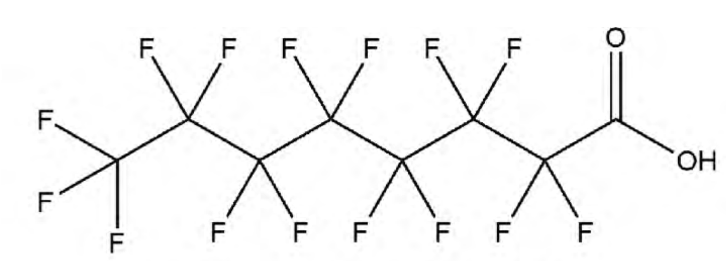
Recommendations for Addressing Perfluoroalkyl Chemical Contamination in Delaware

Nicolette Bugher University of Delaware Water Resources Center

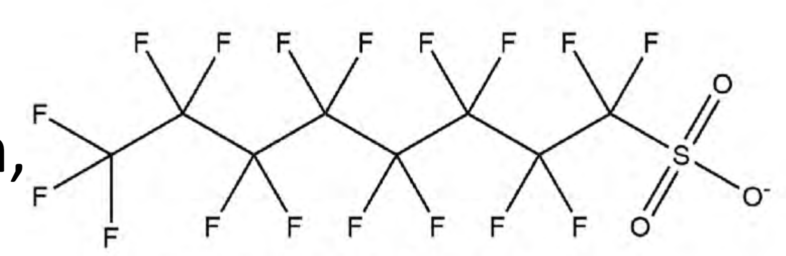
University of Delaware | College of Engineering

PFAS Overview

- Group of fluorinated organic chemicals used in manufacturing and industrial operations
- PFOS and PFOA most extensively used legacy PFAS
- Most prevalent in 1940s to 1970s
- Common to military bases and in locations with use of PFOS/PFOA containing firefighting foams
- Studies indicate PFOS and PFOA cause developmental, reproductive, and other adverse health effects.
- Consumer products, food, and drinking water are sources of contamination
- Conventional treatment, ozonation, biofiltration, and UV disinfection do not remove PFAS



Perfluorooctanoic acid (PFOA)



Perfluorooctane sulfonate (PFOS)

Post, Gloria & Gleason, Jessie & Cooper, Keith. (2017). Key scientific issues in developing drinking water guidelines for perfluoroalkyl acids: Contaminants of emerging concern. PLoS biology. 15. e2002855. 10.1371/journal.pbio.2002855.

Objective

The objective of this research project is to understand the current regulatory environment for PFAS, analyze the scope of PFAS contamination in Delaware, and make recommendations for the State of Delaware.

Research Plan

Literature Review
↓
Regulatory Review
↓
Status of PFA Contamination
↓
Recommendations

Federal Actions

- 2000 – 2015: United States Stewardship Program results in primary manufacturers voluntarily phasing out global production of legacy PFAS
- 2009: EPA Method 537 released to analyze specific PFAS
- 2013: EPA Significant New Use Rule requires notification before future manufacture of over 200 PFAS
- 2016: EPA sets non-enforceable Health Advisory Levels of 70 ppt for PFOA and PFOS individually or combined
- 2017: DoD identifies 401 sites with known or suspected release of PFOS/PFOA and follows CERCLA processes for remediation
- 2018: ATSDR releases toxicological profile for PFAS
- 2018: EPA Method 537.1 includes GenX chemicals and additional PFAs
- 2019: EPA releases comprehensive EPA Action Plan for the future of PFAS

Current Problems

- PFOA and PFOS have been detected in 99% of blood samples representative of the US population collected between 2009 and 2012
- PFAS found in drinking water of over 16 million Americans and 33 states
- No current federal PFAS drinking water standards
- NJ is the only state with a PFAS MCL (13 ppt)
- Federal and state recommended lifetime advisory levels are not in agreement
- Federal agencies lack validated analytical methods for measurements and assessments of PFAS
- Less than 25 laboratories in the United States are approved to test PFAS using method 537 under the Unregulated Contaminant Monitoring Rule 3
- No clear authority to require PFAS sampling

Contamination in Delaware

- 2014: City of New Castle, DE. Municipal wells tested PFOA up to 440 ppt and PFOS up to 2,300 ppt
- 2014: Dover, DE. Dover Air Force Base finds PFOS + PFOA wells contaminated from 77 to 2,800,000 ppt
- 2016: Wilmington, DE. Artesian Water Co. tested wells above EPA lifetime health advisory level (PFOA up to 50 ppt and PFOS up to 1800 ppt)
- 2018: Blades, DE. Municipal wells tested for PFOA + PFAS and found levels 96 – 187 ppt

Response to Contamination

- Treatment options range from GAC, carbon granulated water filtration, ion exchange
- Additional response in Delaware typically includes temporary bottled water, contaminated well shut down, and CERCLA process proceedings
- DE is not one of the 7 states that has set a specific advisory level or reinforced the EPA advisory level
- DE recommended adopting Federal level of 70 ppt as a screening level

Recommendations

- Conduct comprehensive testing and research of Delaware drinking water supplies
- Conduct research to find the appropriate design for advance treatment to address PFA compounds that minimizes capital costs, annual operating costs, and life cycle costs
- Prevent entry into commerce of PFAS that could cause risk as a drinking water contaminant
- Engage with other states and federal agencies to compound research and determine appropriate toxicity, framework for treatment, and proper risk communication to stakeholders
- Develop and implement the use of firefighting foams without PFAS statewide

Interstate Watershed Management:

Expanding the Clean Water Act to Include Modern Pollutants

By Chelsea Caplinger, a Political Science major, Class of 2021

Introduction:

Watershed management is an essential aspect of environmental policy in order to establish a basis for healthy drinking water and appropriate access to water. Based off of the current research, the best way to improve the water quality in Delaware is to expand on the Clean Water Act to include modern pollutants.

The Problem:

There is a lack of communication on the interstate watershed level, and there needs to be intervention on the federal level. Two of the largest issues facing the Chesapeake Bay and the Delaware River Basin are micropollutants and urban runoff, which should be addressed by the EPA through expanding the Clean Water Act to meet modern standards and address modern issues.

Acknowledgements: A special thank you to Gerald Kauffman and the University of Delaware Water Resource Center.

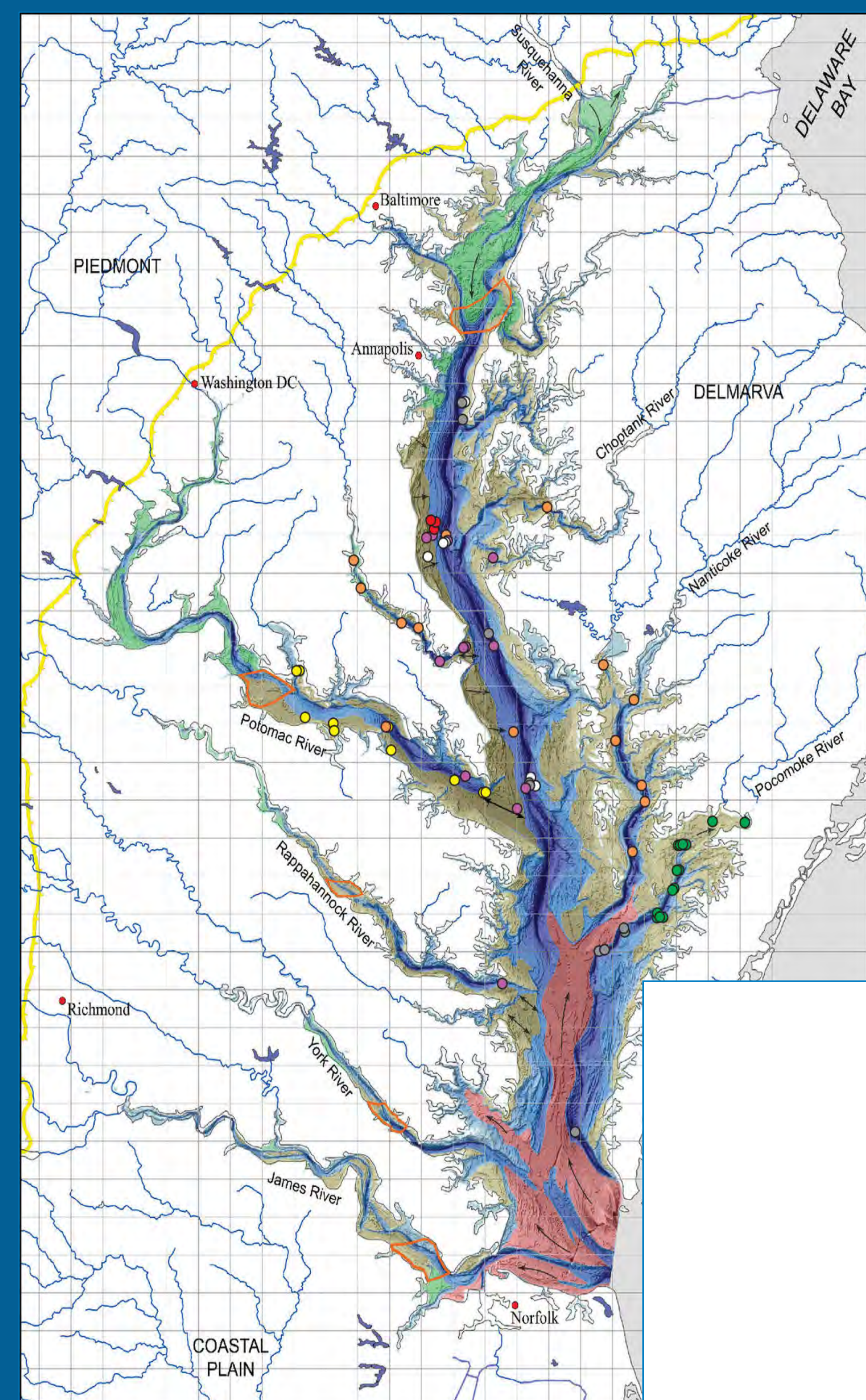


Image 1 – Map of the Chesapeake Bay from USGS

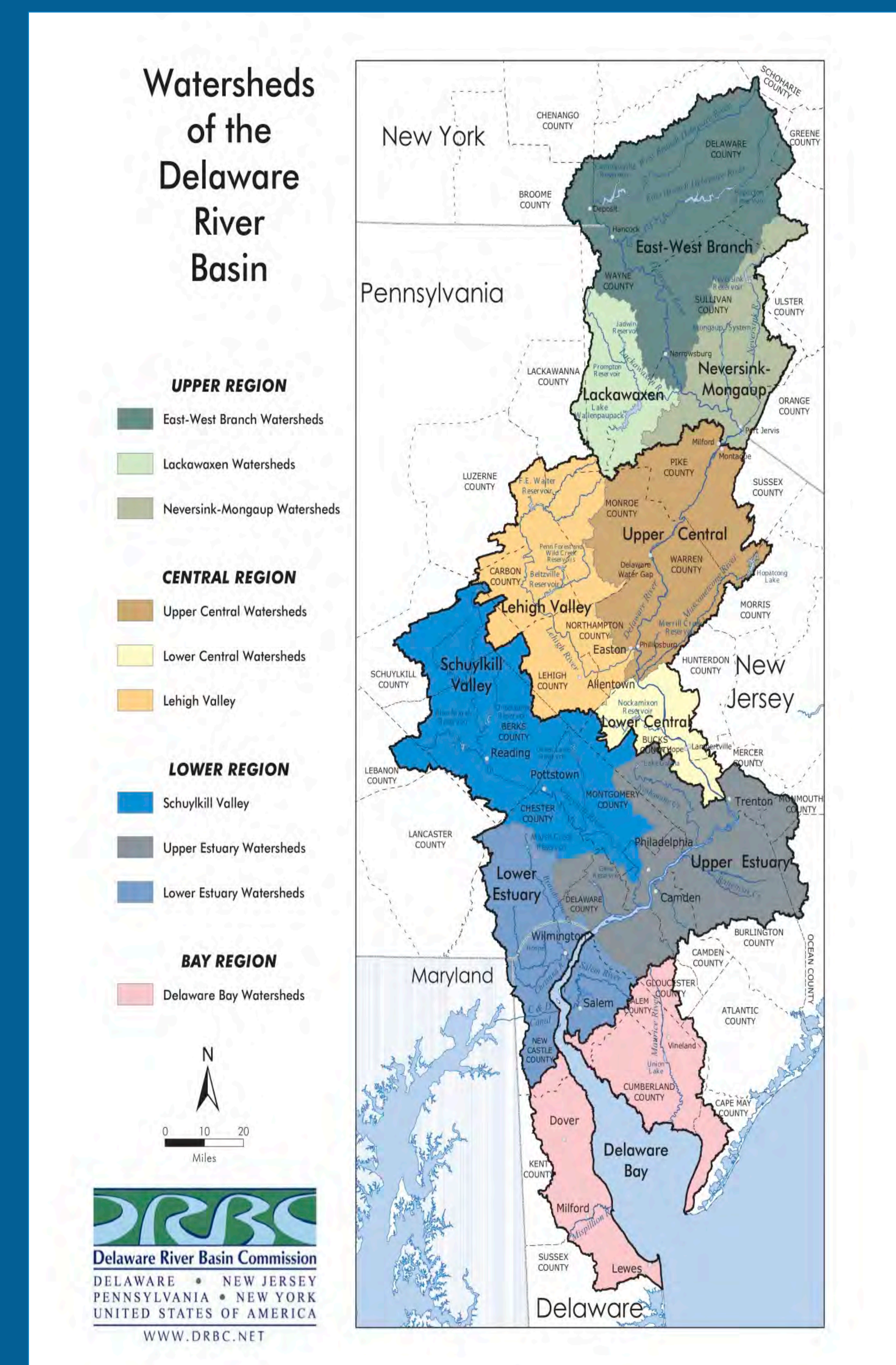


Image 2 – Map of Delaware River Basin from DRBC

	Area	Institution	States	Policies Affecting Watershed
Chesapeake Bay Watershed	4,479 mi²	Environmental Protection Agency (EPA)	Delaware, Maryland, New York, Pennsylvania, Virginia and West Virginia, District of Columbia	- 1983 Chesapeake Bay Program - 1972/77 Clean Water Act - 1998 Chesapeake Bay Initiative Act
Delaware River Basin	14,119 mi²	Delaware River Basin Commission (DRBC)	Pennsylvania, Delaware, New Jersey, and New York	- 1899 River and Harbors Act - 1961 Delaware River Basin Commission - 1972/77 Clean Water Act

Policy Proposal:

Keeping in mind our goal of improving the interstate watershed management for the Chesapeake Bay Watershed and the Delaware River Basin, we will be expanding upon the Clean Water Act on a federal level. A subsection should be added to address the issue of non-point source pollutants by updating the watershed's information technology and incorporating green infrastructure into cities like Wilmington and Philadelphia. In addition, a subsection should be added to the Clean Water Act that addresses micropollutants that cannot be eliminated from traditional water treatment plans.

Recommendations:

These are suggestions on implementation strategies specifically for the Chesapeake Bay and the Delaware River Basin.

1. Update the information systems across the entire watershed, not just on a state by state basis.
2. Specifically in Delaware, Wilmington needs to incorporate permeable pavements, bio swales, and planter boxes to reduce flooding and improve infiltration.
3. Water filtration systems need to be updated across the entire watershed to have a final filtration targeting micropollutants.

Nitrate Sources in White Clay Creek

Alyssa Cortese

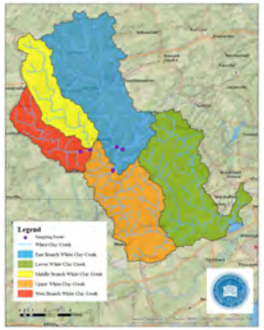
Advisor: Gerald Kauffman, UD Water Resources Center

Introduction

- White Clay Creek Watershed covers area in both Delaware and Pennsylvania with its head waters in Pennsylvania. White Clay Creek consists of three branches flowing into the main stem; the west, east, and middle branches
- White Clay Creek supplies the reservoir with water which is one of the main sources of drinking water for Newark, Delaware
- Excess nitrates has negative impacts on ecological health causing eutrophication and dead zones
- Mitigation of nitrate inputs is important and this study hopes to illustrate that importance

Methods

- Water was tested once a week for five weeks from February. to April 2019, at five different sampling sites (fig. 1)
- Grab samples at each site and brought them to the University of Delaware Soil Testing Lab where they tested for nitrate-nitrogen
- Data from USGS/ PADEP reports were also taken for 2013- 2018 data (fig. 2 and 3)
- Land cover map was analyzed to theorize nitrate sources (fig. 6)



Results

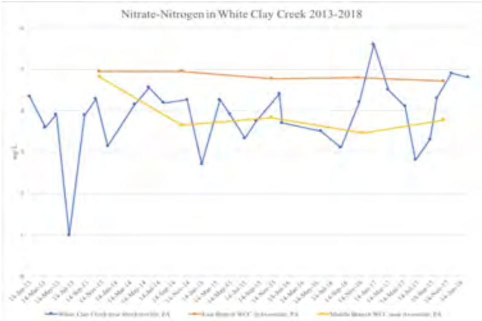


Figure 2: Data courtesy of USGS/ PADEP

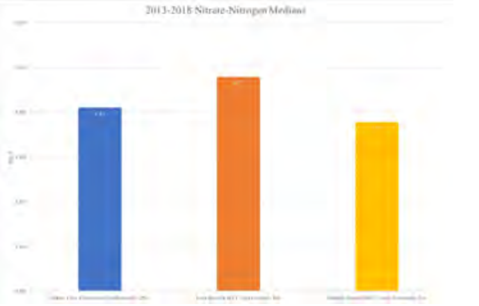


Figure 3: Data courtesy of USGS/ PADEP

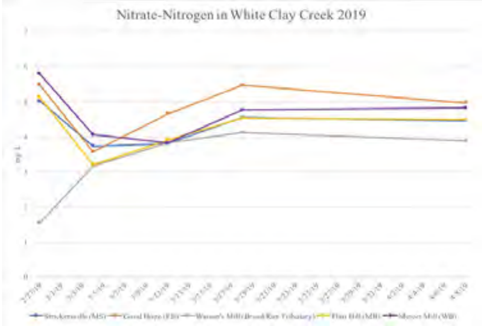


Figure 4

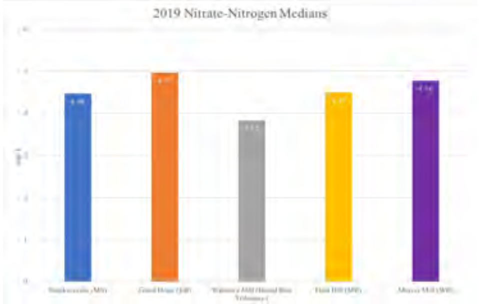


Figure 5

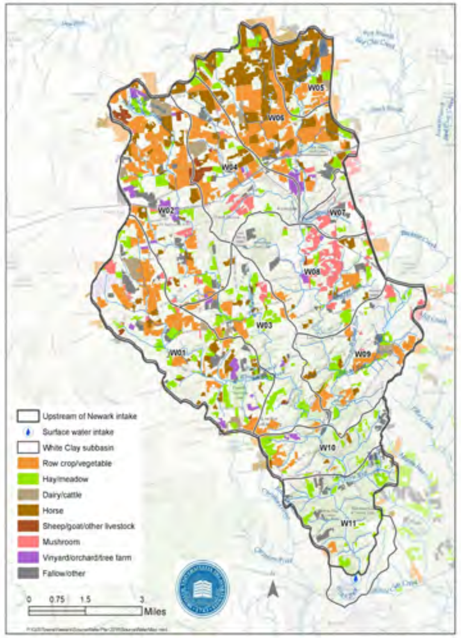


Figure 6: Agricultural land cover data courtesy Kelly Jacobs

Discussion

- As expected, the east branch had the highest amount of nitrates with a median of 4.97 mg/ L during the 5 weeks, however surprisingly, the west branch came back with high nitrates as well at 4.76 mg/L
- Land cover data (fig. 6) suggests horse farms and mushroom farms could be a major cause for nitrogen inputs
- There is a slight increase in the 2019 medians from the 2013- 2018 data, despite a declining trend in the 2013- 2018 data in nitrates suggesting a need for additional regulations in nitrate inputs
- Future studies should set sampling sites farther up in the watershed to look further into nitrates sources

Acknowledgments

Thank you to Gerald Kauffman, Natalie Zimmerman, Jillian Young, and Kelly Jacobs for all of your support.

Status, Policies & Mitigation for Wetlands in Delaware

Delaware Water Resource Center
Monica Crosby, College of Earth Ocean & Environment

Overview

Taking up 25% of Delaware and serving as one of the most productive ecosystems found on Earth, Wetlands are a critical resource across many scopes.

Wetlands not only serve as a habitat for a vast array of terrestrial and marine species, but they also serve as a vital migration and spawning site for various species as well. Wetlands are also proven to be extremely crucial in the water filtration process. As agriculture and development contribute extra nutrients, pesticides, and silt to local rivers, wetlands help to trap and filter these toxins maintaining healthy water systems.

Additionally, wetlands are an important resource in terms of combating climate change. Acting as a natural sponge, wetlands help sequester carbon and protect against sea level rise and increased flooding. These natural barriers protect valuable ecosystems and can lower overall flood heights, protecting people, infrastructure, and agriculture from devastating flood damages (NOAA). Aside from their environmental benefit, wetlands are also a vital economic resource. They serve as a popular recreation spot for fishing, bird watch, etc. Studies have found for Delaware specifically, sport fishing generates approximately $110 billion year in Delaware Inland Bays alone. With that said, the loss of wetlands could be devastating to Delaware's economy.

The Functions of Wetlands
Image courtesy of *NC Wetlands*

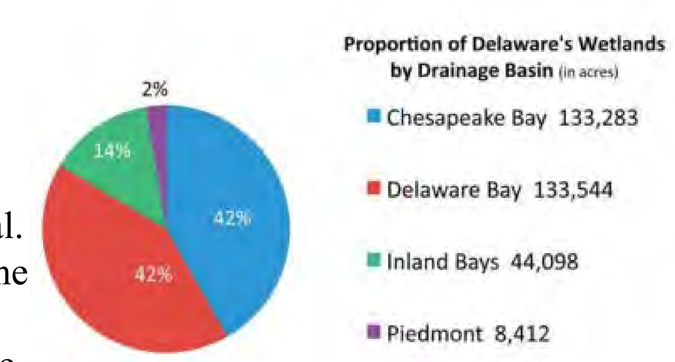
Purpose & Methods

What are the current conditions of Delaware's wetlands, what essential functions do they serve, and what can the state of Delaware do for better management?

This research included an analysis of the state of Delaware's policies regarding wetlands and how they compare to legislation held elsewhere. It also looked at what the state can do for better management and mitigation. As climate change becomes a pressing issue, the condition of wetlands is proving to be extremely crucial. As research develops, the United States will be able to gain more insight around the areas needing more focus, and the best possible solutions to manage them. While there are several different types of wetlands, including inland, tropical, and coastal, this research fixated on the management of coastal wetlands. This research hoped to collect, not only the current condition of wetlands, but projections for the future conditions, and what Delaware can do for further protection.

Results

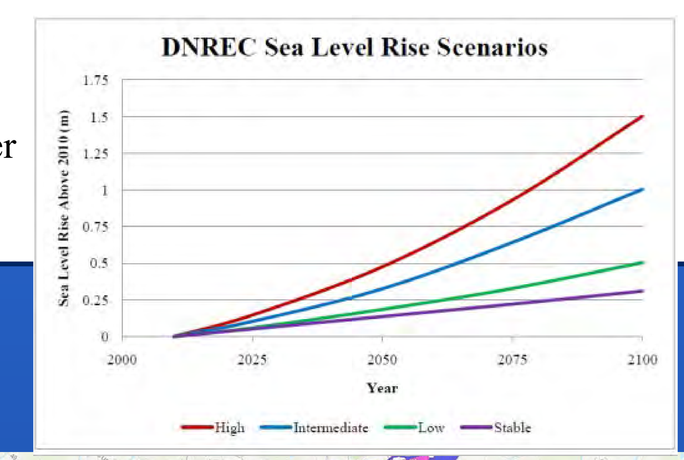
Regarding natural wetlands located within the campus of University of Delaware, with the help of ArcGIS, I was able to locate wetlands within Phillips Park, along Elkton Road & Christiana Parkway, and adjacent to Suburban Plaza. More interestingly, in Delaware Wetlands, 23 species of wetland plants are considered globally rare, and 9%, or 66 species are non-native. Concerning invasive species, 15 species are currently said to be invasive, with an additional 17 species being on the invasive watch list. The top three major causes of change are industrial, commercial, and residential. (1992-2007) there was a net loss of 3,126 acres with 3,900 acres lost and 769 acres created. Of that change, for Palustrine wetlands, 3% came from conversion to agriculture, 28% came from extraction/transition of land, 4% came from pond and lake construction, and 2% came from the construction of highways and roads. For the estuarine wetlands, 83% came from conversion to open water, 10% came from intertidal shores, 4% came from development and urbanization, and the rest came from beach over wash and pond construction (DNREC Status & Trends).

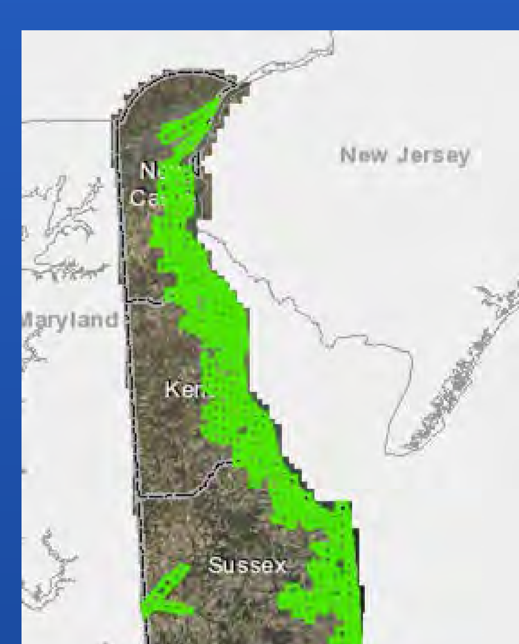


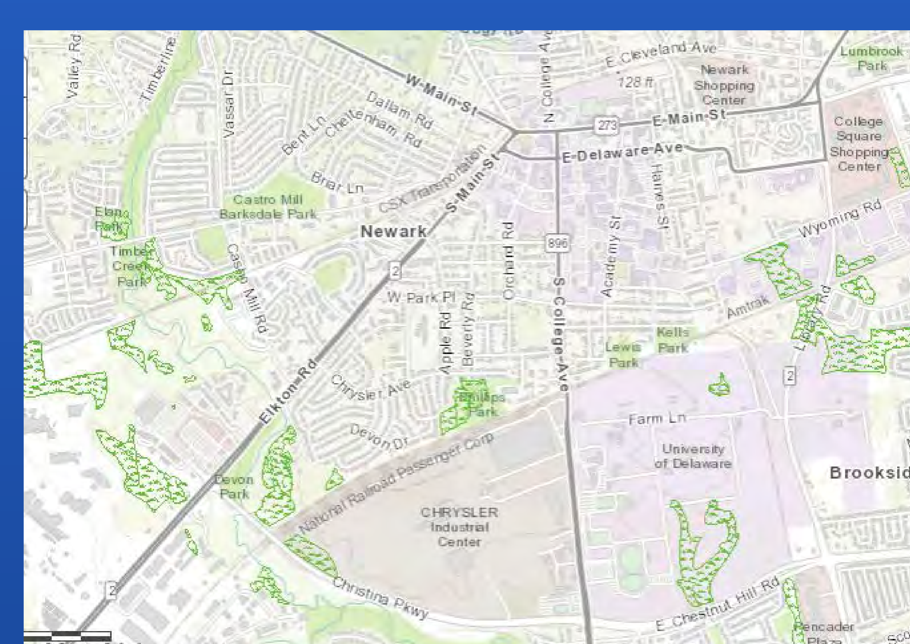
DNREC has compiled a projection of three scenarios for sea level rise: 0.5, 1.0, 1.5 meters. Even at a steady rate, sea level is projected to rise and that shall cause serious challenges for Delaware's coasts. In fact, the Delaware Bay and Inland Bays are classified as one of the areas with the greatest amount of land at risk due to rising sea levels.

Delaware Wetlands are regulated through the requirement of §401 certification for all activities that require a federally issued permit, such as a §404 permit, to ensure that all projects will not violate Delaware's surface water quality standards (WQS). In addition, tidal wetlands are protected under the Wetlands Act of 1973, the Subaqueous Lands Act, the Coastal Zone Act, and the Beach Preservation Act. Current Monitoring and Assessment policies towards Delaware wetlands fall under the responsibility of Delaware's Department of Natural Resources and Environmental Control and follows The Delaware Management Plan.

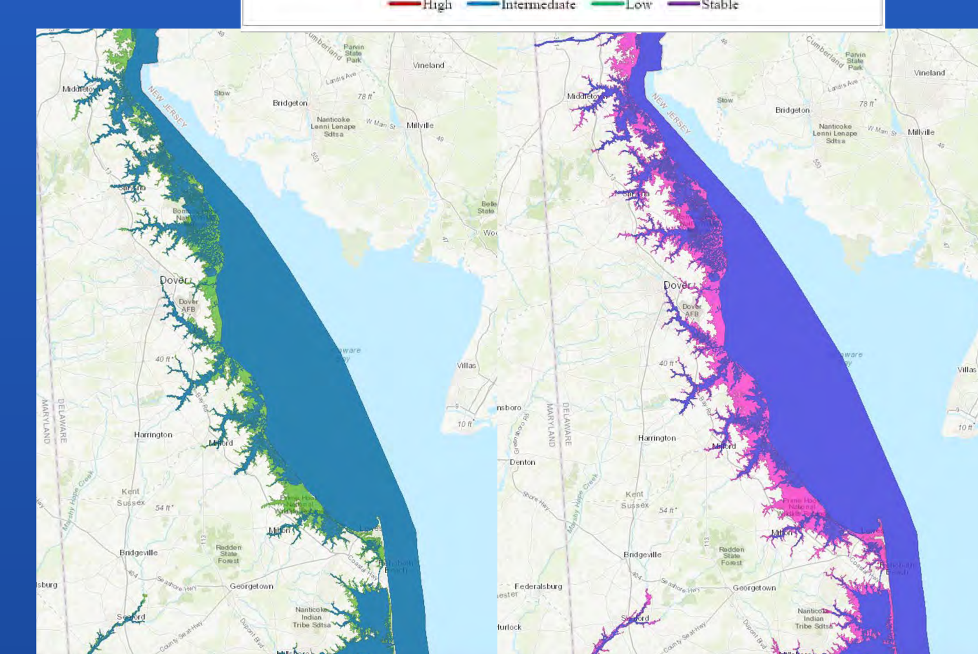
One main challenge lies in that there is no current regulation provided for non-tidal wetlands. Another main challenge is that Delaware does not currently possess an overall gains and loss tracking system, and there is an overall lack of adequate funding for state wetland programs. The greatest challenge wetlands face however is the threat of climate change, and as result, sea level rise.



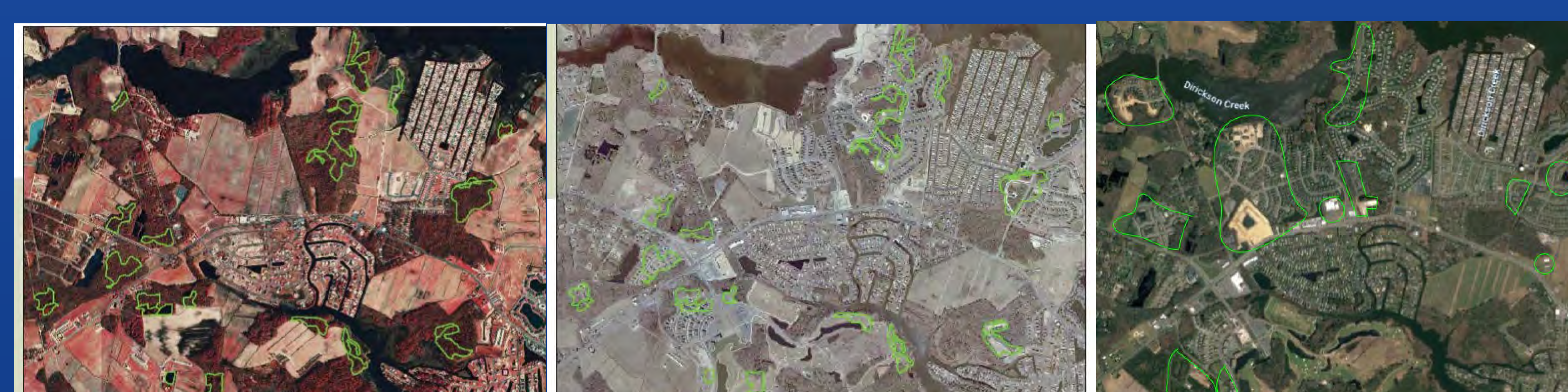




A) A map showing the state regulated wetlands within Delaware. Map was acquired from DNREC using Esri software.
B) is the recognized wetlands within University of Delaware's campus. Image was acquired using GIS software.



(A) DNREC Projections of Sea Level Rise.
B & C) The Inundation of Sea Level Rise on Delaware's Coast using 3 ft and 7 ft projections. Images were acquired using GIS software.



Satellite Imagery showing land use change in Fenwick Island, Delaware. Image A and B are courtesy of DNREC. Image C was acquired manually using Google Earth Satellite Imagery.

Conclusions

The existence of wetlands is crucial to the quantity and quality of water. Further, without wetlands, cities have to spend more money to treat water for their citizens, floods are more devastating to nearby communities, storm surges from hurricanes can penetrate farther inland, animals are displaced or die out, and food supplies are disrupted, along with livelihoods (WWF).

Recently, in late October of 2018, the EPA warded $341,691 to DNREC to help build the state's capacity to protect, manage, and restore wetlands, and the water bodies they connect to. DNREC will use the funds to develop and refine methods of assessing wetlands and stream habitats. Additionally, DNREC will also use the funds for demonstrating and documenting the most successful techniques for restoring coastal habitat, in addition to providing opportunities for improving public education and outreach about wetland conservation

Some challenges that remain in managing wetlands in Delaware is the lack of comprehensive non-tidal freshwater wetland protection, a need to improve the enforcement of existing regulations, a lack of updated guidance on wetland mitigation, a need to improve the data tracking of wetland permits and certifications, a need for more and better coordination with local and use decision-makers, lack of adequate funding for state wetland programs, including enforcement, lack of consistency in Delaware's wetland protection statutes and regulations regarding the protection of species and habitat, a need for more and better coordination with local landowners, and the effects of climate change and sea level rise on wetland protection.

Directions for Future Research

Future research should analyze the conditions of sea level rise projections more closely and what Delaware is doing to manage wetlands with that concern.

Regarding future management, non-tidal freshwater wetlands should gain a protection program Delaware will have to intensely consider the creation of new wetlands through elevation. Additionally, a management option could arise in enabling wetland migration. The state of D.E. should not omit the idea of preventing development, especially in coastal areas. This could occur through some kind of regulatory flat, or it could occur through the purchase of properties associated with development rights.

However, the most logical approach would be the buying of easements. This approach would be relatively inexpensive and an excellent use of wetland mitigation resources under §404 of the Clean Water Act.

Acknowledgements

Advisor: Gerald J. Kauffman, Ph.D.
Director/ Associate Professor

Funded by The Delaware Water Resource Center, University of Delaware

The Impact of Sea Level Rise on Seasonal Rental Properties in Delaware

Veronica Hill
Environmental and Resource Economics
College of Agriculture and Natural Resources

OVERVIEW

Research Question: How will 0.5m and 1.5m sea level rise damage the economy of Delaware's seasonal recreational use that contributes to tourism around the inland bays and beaches?

With no sales tax, great shoreline beaches, and industry, tourism has won its position as being the 4th largest private industry sector in Delaware. People may be less willing to purchase vacation homes due to the risk of flooding With many people retiring, vacationing, and residing near Delaware's coast, action on sea level rise has become extremely prevalent.

METHODS

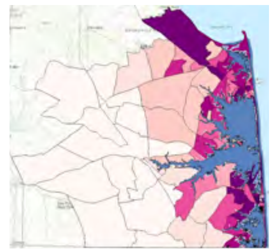
Using Geographic Information Systems, I have obtained the percentages of block groups with high and low concentrations of seasonal rental units that will be inundated under the scenarios of 0.5 meters and 1.5 meters of sea level rise. I took the difference in the mean high water of the bays, and the water that will exist with flooding to determine a percentage of how many units that will be severely impacted by sea level rise. I gathered the block group information from the 2010 U.S. census. The sea level rise data was provided by DWRC.

The average vacation rental price during the summer month of July in the Delaware beaches is $345 per night. Using this data and assuming that most rational people will be attracted to Delaware beaches in the middle of the summer, I have created an economic impact assessment on the revenue that will be lost from flooding to these rentals.

RESULTS

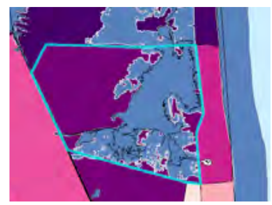
Figure 1: Map of 0.5m of SLR

The image shows 0.5 meters of sea level rise on the inland bays of Delaware.



Density of seasonal units per block group
Darker Shades: Higher density
Lighter Shades: Lower density

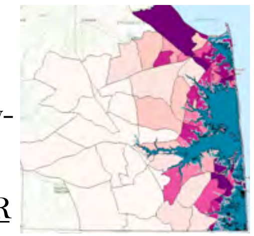
Figure 2: Zoom of 0.5m SLR



The highlighted light blue block group section in Bethany Beach has 791 seasonal units in it. With 0.5 meters of sea level rise the block group will have 31.2% of its seasonal units flooded, that is 246.51 units inundated. With $345 per day of rental stays and 0.5m sea level the seasonal recreational economy would lose $85,045. in revenue per day. With these numbers, this means that for the busy month of July, this Bethany Beach block group would lose $2,636,424.

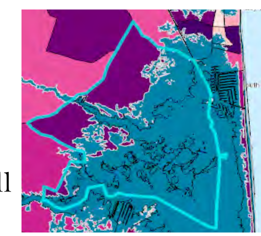
Figure 3: Map of 1.5m of SLR

The image shows a map of 1.5 meters sea level rise on the inland bays of lower Delaware.



Figures 4 and 5: Zoom of 1.5m SLR

This block group sits in the middle of the bays and has 486 seasonal units. With 1.5 meters of sea level rise, 73.5% of the block group will be inundated. Because there were 357.2 units flooded, this means that with the average rental price of $345 a night, the loss of this group would be $123,234 every day in the summer. In July, rental units would suffer $3,820,254 in losses.



The second example is yet another from the Bethany Bay area. In this block group there are 718 units and with 1.5 meters of sea level rise, it will suffer from 53.2% of inundation. There will be 381.9 units flooded and an economic loss of approximately $131,755 per day in damages. During the month of July, this 53% of will cost $4,084,420.

CONCLUSIONS

Although sea level rise is a world-wide crisis, Delaware can still do a lot. In terms of policy, the state should encourage construction to avoid building or buying within the perimeters of the discussed flooding events. Stilted houses are another key adaptation device to use against sea level rise. This technique can save some houses and rentals on the shore or around the bays from permanent flood damages. A combination of high-rise houses and moving out of the floodplain will save the seasonal rental market from injury and losing millions.

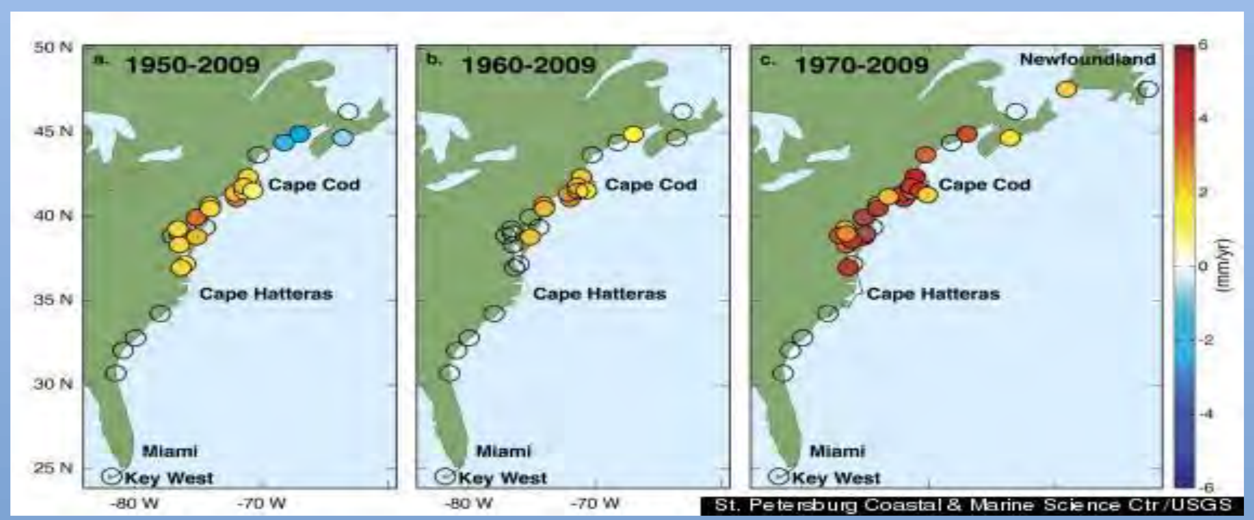
Tidal Effects of Coastal Flood Inundation Along the Atlantic Seaboard

Allison Kaltenbach (B.S Environmental Engineering) and Gerald Kauffman (UD Water Resources Center)

Delaware Water Resources Center

Introduction

Sea levels along the Atlantic Seaboard are increasing at a level 3 to 4 times faster than the global average. In the next century alone, scientists have estimated the sea level will continue to rise anywhere from 0.5-1.5 meters along the Atlantic coast as sea temperatures rise and polar ice melts. Using USGS gages, the three most severe storms were used to recreate Delaware's three most severe storms from 2000-2019. Resulting analysis can provide insight into when storms peak, how they move, and their effects on coastal flood inundation along the coast.



(Above) A "hotspot" for sea level rise spans 600 miles where sea level rise is greater than the global average

Objectives

(1) Use data from USGS tidal gages in NY,NJ, and DE to recreate the three most severe storms and examine when tides peak during each storm

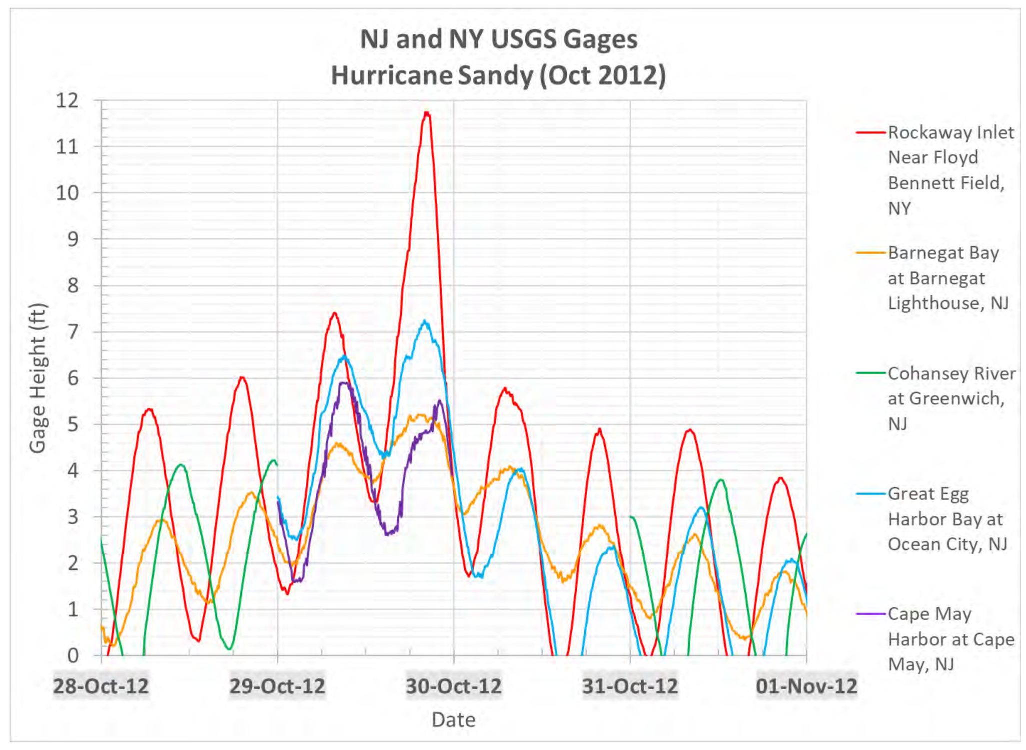
(2) Use data to draw conclusions about coastal flood inundation and examine how storms move along the Atlantic Seaboard

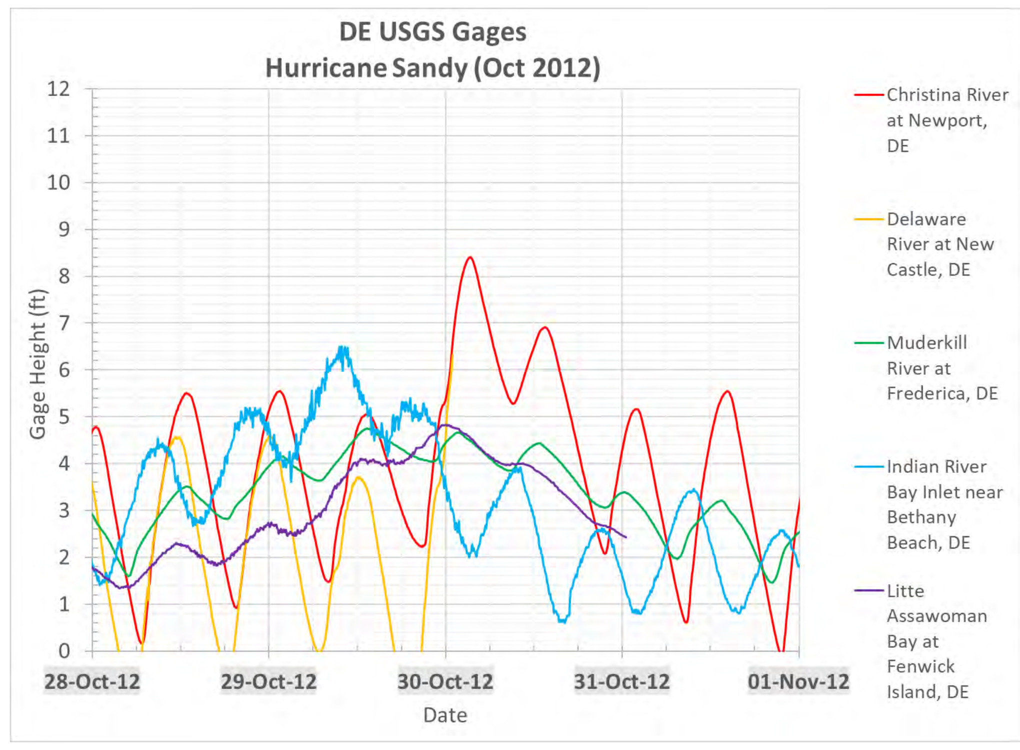
Methods

1. Literature Review
2. Determine Five Most Severe Storms
3. Choose USGS Gages From NY to NJ to Use for Analysis
4. Reconstruct Tidal Flood Inundation
5. Draw Conclusions and Identify Next Steps

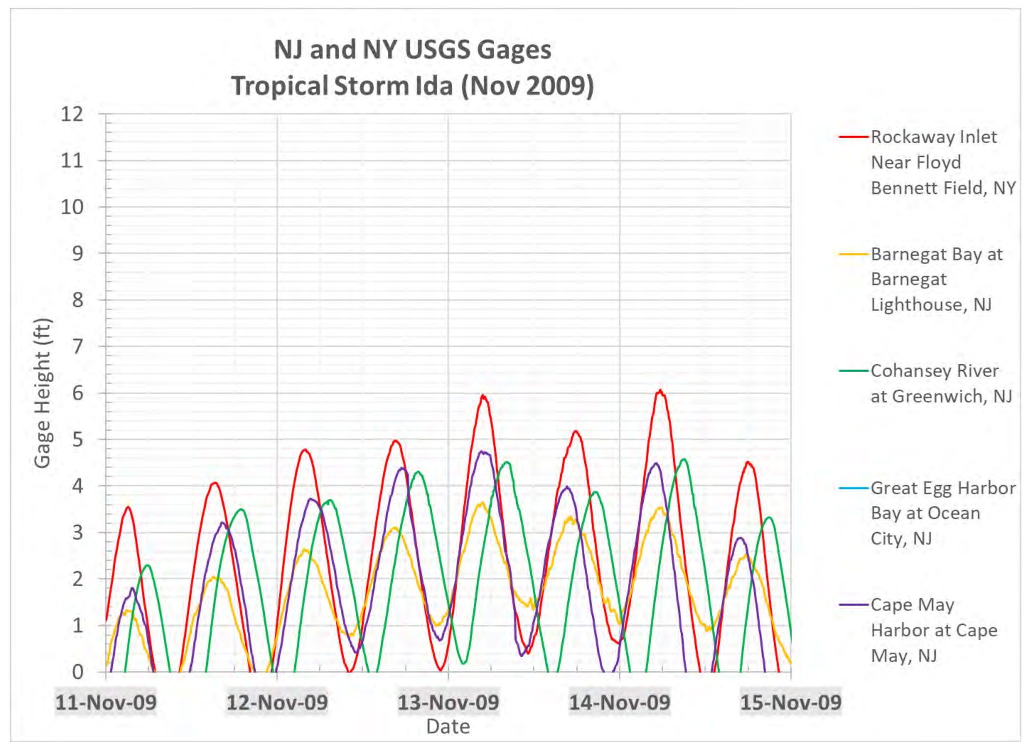
Key Results

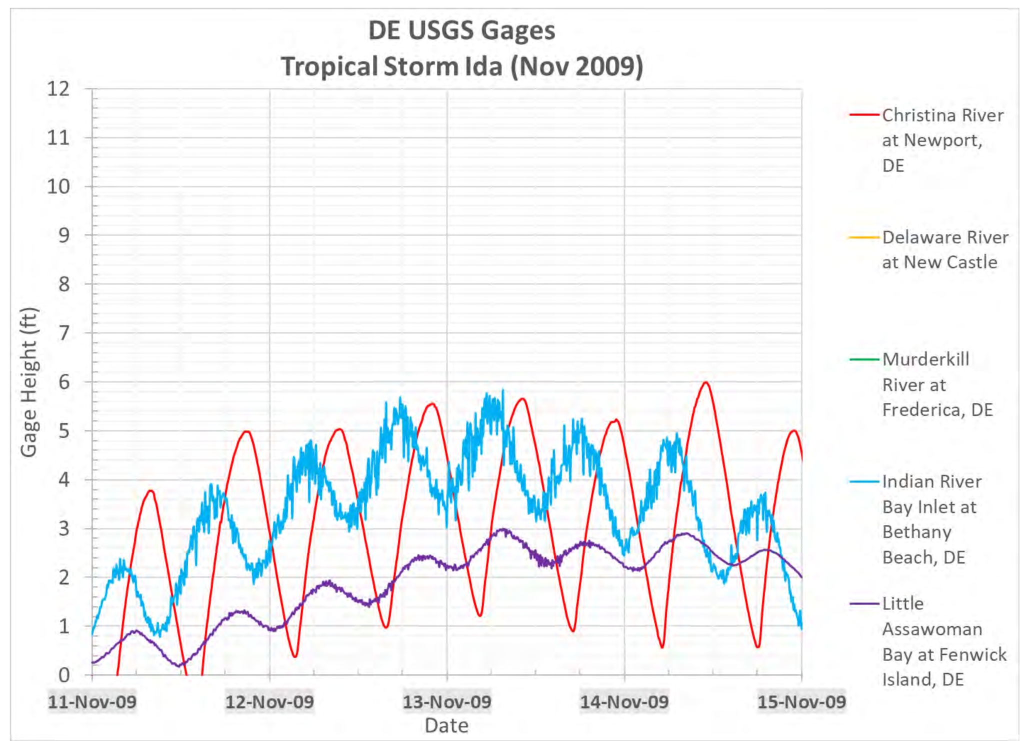
Hurricane Sandy – 10/29/2012



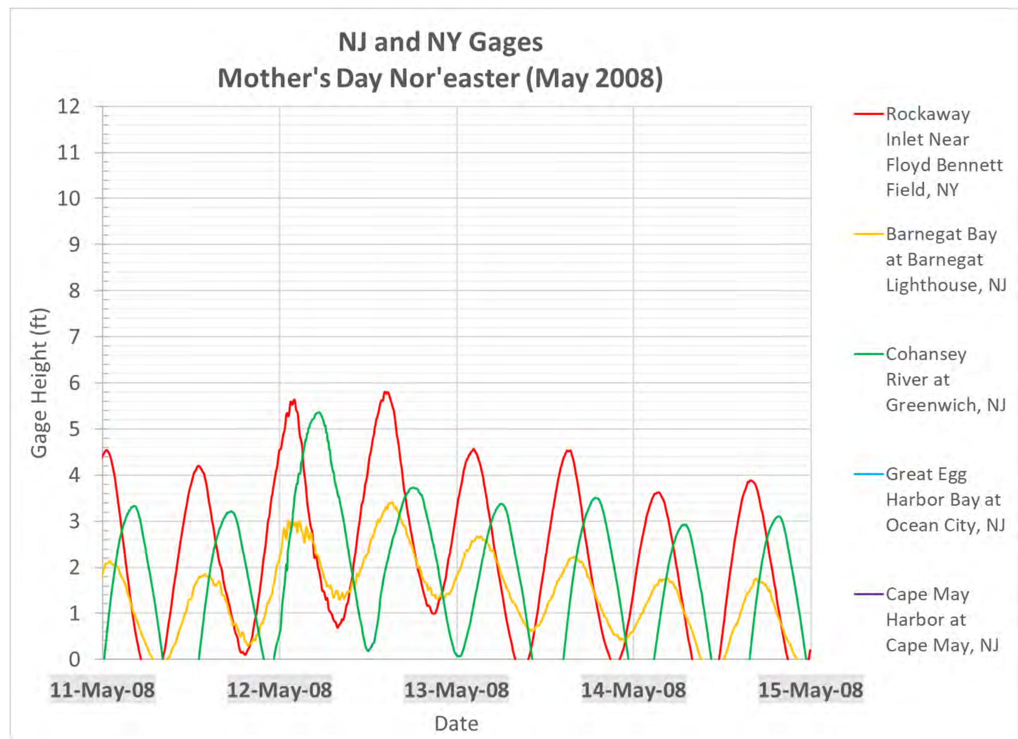


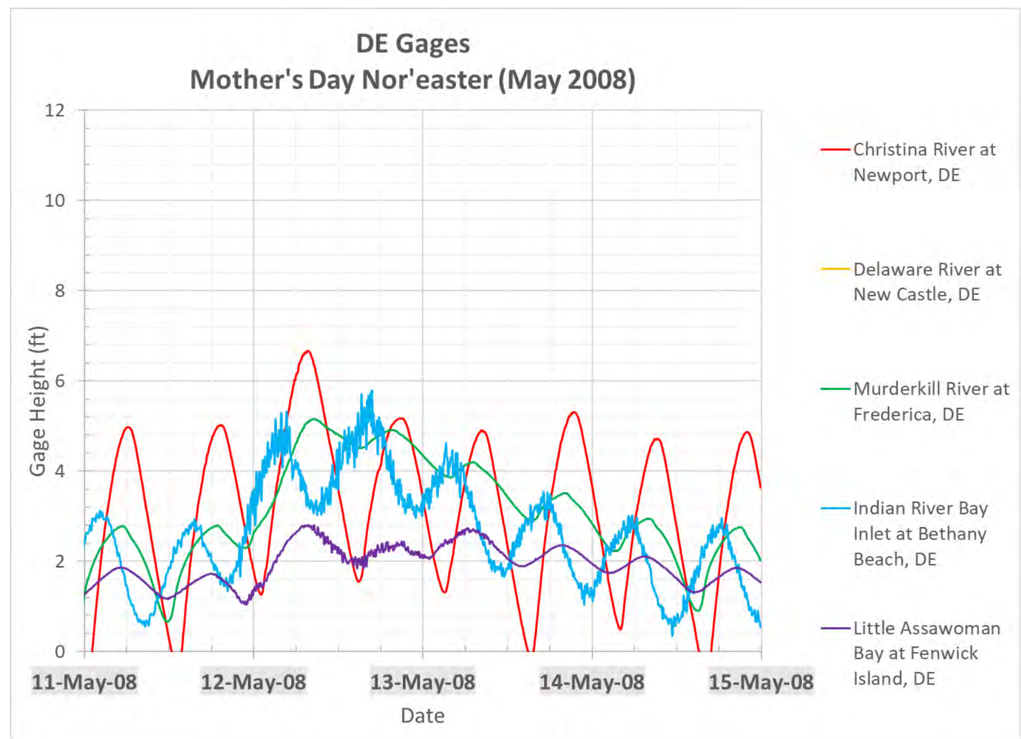
Tropical Storm Ida - 11/10/2009



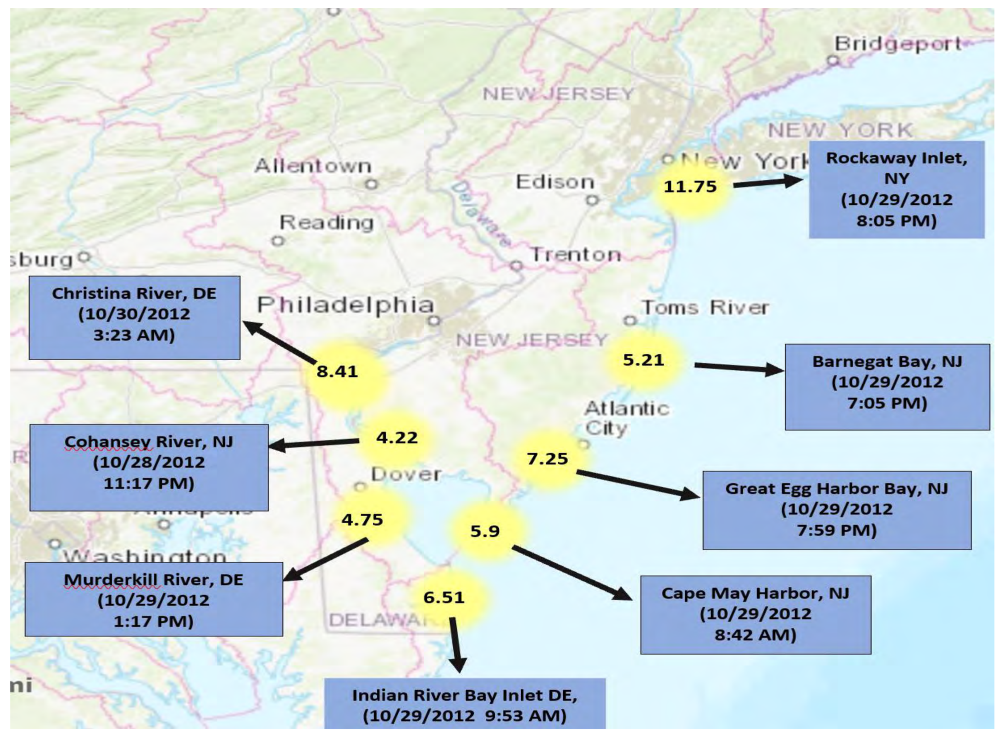


Mother's Day Nor'easter - 5/12/2008





Conclusions



- Date and time of tidal peaks can be compared to see how storms move across Atlantic Seaboard and show what areas are most at risk if sea level continues to rise.

Future Work

(1) Continue analysis for more states along the Atlantic seaboard

(2) Use NOAA gages to expand analysis and for more in depth comparisons

(3) Complete analysis for more big storms that have occurred in the past to compare past storms to more recent ones examined for this project

(4) Continue monitoring sea level rise along the "hotspot" and narrow in on what specifically can be done to decrease how rapidly sea level is rising

Acknowledgments

I would like to thank my advisor, Dr. Gerald Kauffman, for his continued guidance throughout this research. I would also like to thank the Delaware Water Resources Center for funding this project and internship program.

Where Land Meets Water: An evaluation of whether local plans, ordinances, and development decisions promote growth management and protect water quality in the Delaware Inland Bays Basin

Rebecca Steiner and Dr. Nina David

UNIVERSITY OF DELAWARE

Abstract

- Sussex County is experiencing extreme growth and is expected to continue to see large population shifts. This report aims to evaluate whether this area is prepared to accommodate this growth and protect water quality in the Delaware Inland Bays. By evaluating the Sussex County Comprehensive Plan, Sussex County's growth management is analyzed and quantified to determine whether growth management techniques are being implemented. By targeting the geographic area bounded by US-9, US-113, and State Route 244 and looking at the Delaware State PLUS Projects in that area, this study will determine how past and present development decisions impact water quality.

Introduction

- Sussex County has seen 15% population growth between 2000 and 2006. Land Development activities consumed approximately 39,000 acres (about 3% of Delaware's Land area) between 2002 and 2007, and the largest amount (18,000 acres) occurred in Sussex County. Delaware's population is projected to increase by 25% between 2010 and 2040, and Sussex County is expected to see the largest percent increase in population (57%).
- Land use and development decisions have consequences. As population shifts and the demand for infrastructure to support it increases, there is adverse effects on the environment and natural resources. Because Sussex County is expected to grow so much, it will need to implement growth management techniques to protect its natural resources, like its wetlands and waterways.

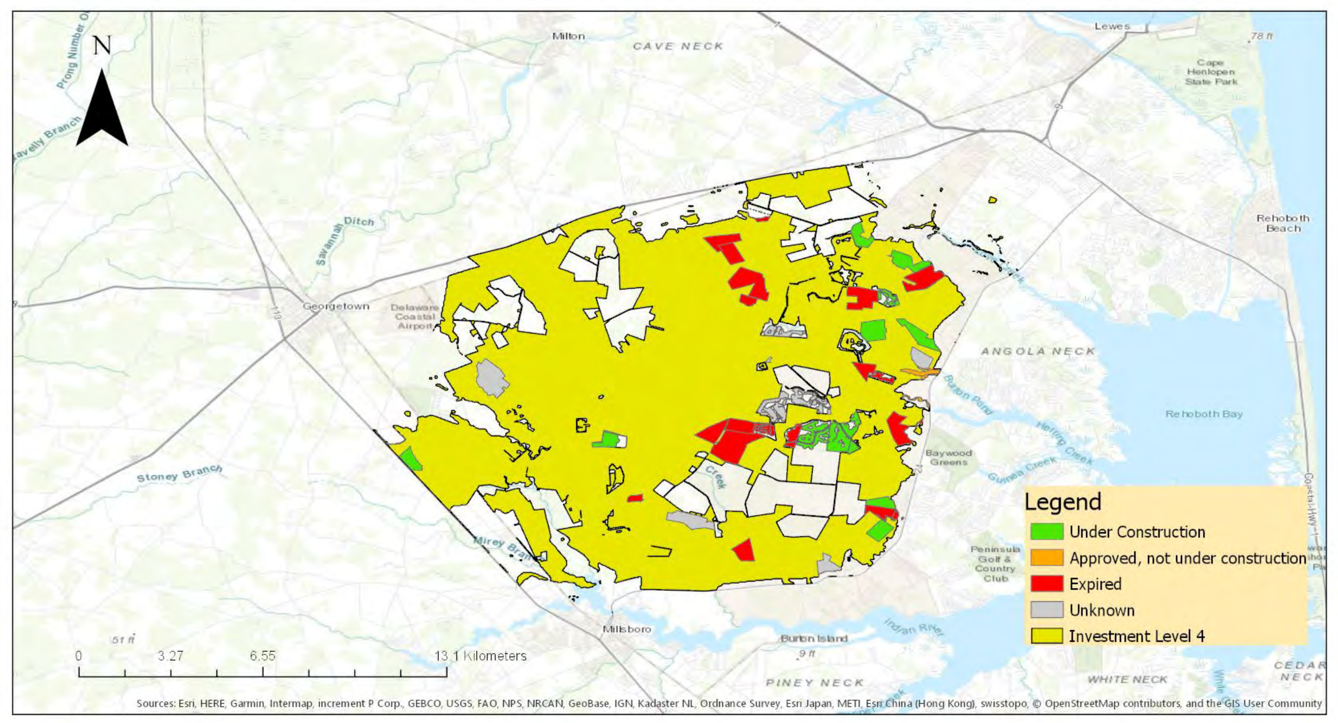
Purpose & Research Question

The purpose of this research project is to answer the two following questions:

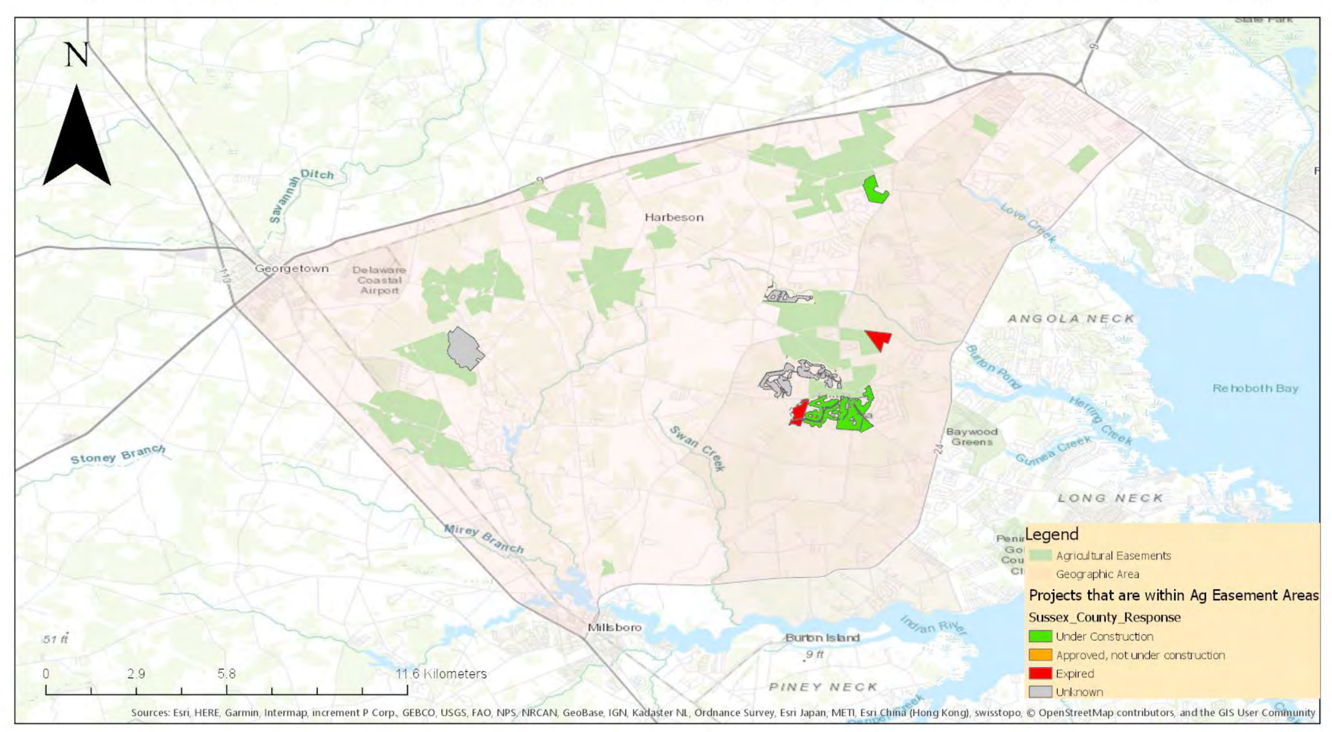
- To what extent do local plans and ordinances promote best practices related to growth management and water quality protection?
- To what extent do local development decisions conform to plans and ordinances and promote water quality protection?

Results

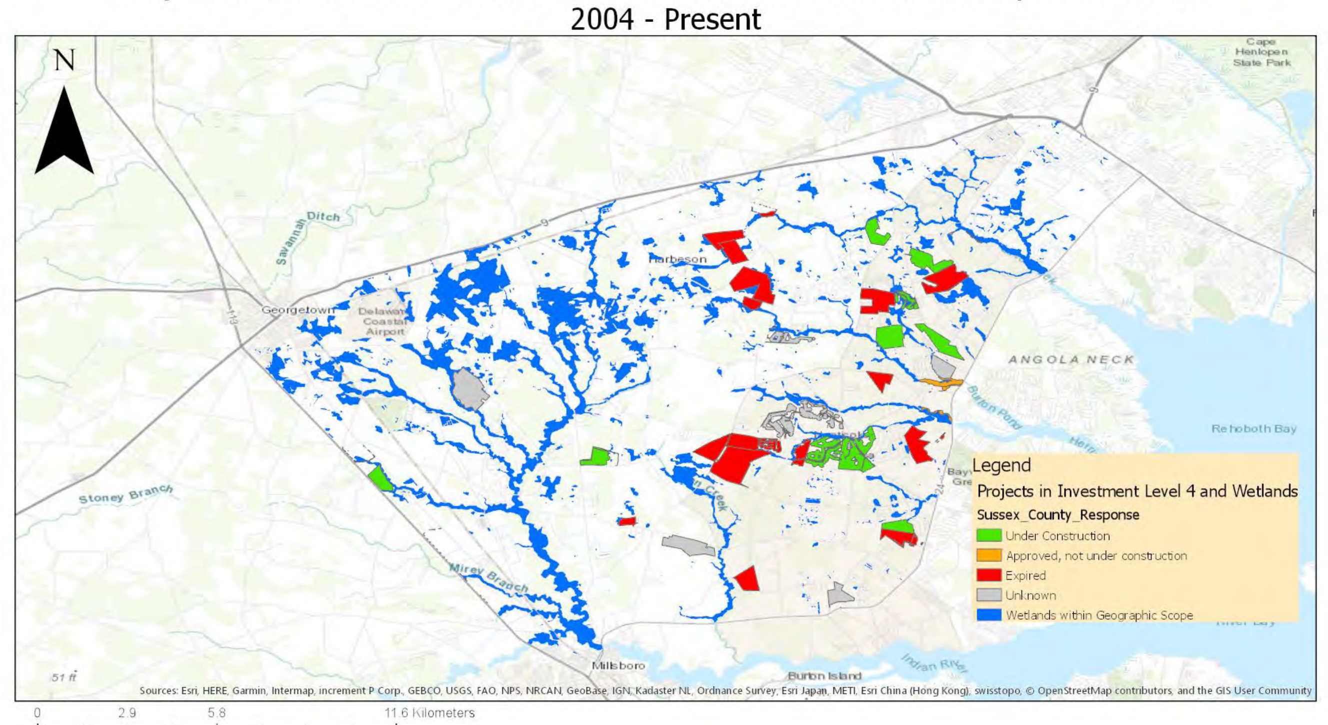
Investment Level 4 Area and PLUS Project Status (2004 - Present)



Agricultural Preservation Lands (Updated 2019) and PLUS Projects (From 2004 - 2019)



Projects that are within Investment Level 4 and within the boundary of a Wetland 2004 - Present



Specific Aim 1

- After evaluating the Sussex County Comprehensive Plan, I found that the plan has a heavy emphasis on constraints to development and resource-production lands.
- The plan exceled in the Natural Resources and Development section, meaning that the plan had the most detail and objectives related to natural resource protection and managing development.
- Regarding water quality, the plan had policies regarding water quality/pollution prevention, surface water protection, groundwater protection, flood management, and setbacks/vegetative buffers.
- Water quality protections: command and control, public education and engagement, use of economic instruments, and legal instruments.
- Plan was lacking in other areas of resource protection; could have added policies regarding pesticide and fertilizer controls, installing parking lot runoff controls, making design criteria for vegetated open channels, and setting controls on new septic installation.

Specific Aim 2

- There are currently 43 PLUS projects in Investment Level 4 areas within out geographic scope. They are exemplified in Map 1.
- After reading the state comments for these projects, it is indicated that the state is particularly concerned with transportation design, preserving agricultural and resource production, and protecting the natural ecosystems located in southern Delaware.
- There are 12 projects that overlap with Agricultural Easements, which are areas that the county intended to preserve for agriculture.
- There are 36 projects within the Geographic Scope that interfere with a wetland.
- These projects would need to seek certain easements before construction can begin.
- Was only able to review one project that is currently under construction in the geographic scope and it is still currently under review.
- This research is still ongoing.

Conclusion

- Within the geographic scope, there are 43 projects that the state has marked that it does not approve of. This is because they are within Investment Level 4 areas, which the state would like to keep for preservation of open space and agricultural production.
- Sussex County said that the state comments are not enforceable, just recommendations for developers and the county to take into consideration. However, Sussex County ultimately approves whether a project gets built or not.
- The Developers and Sussex County take into account the State Comments, but there are other factors as well.
- According to Sussex County, Developers usually only do what they have to do in order to get the project moving. More often than not, they do not go through additional measures to make the project more sustainable unless required by the County.

Directions for Future Research

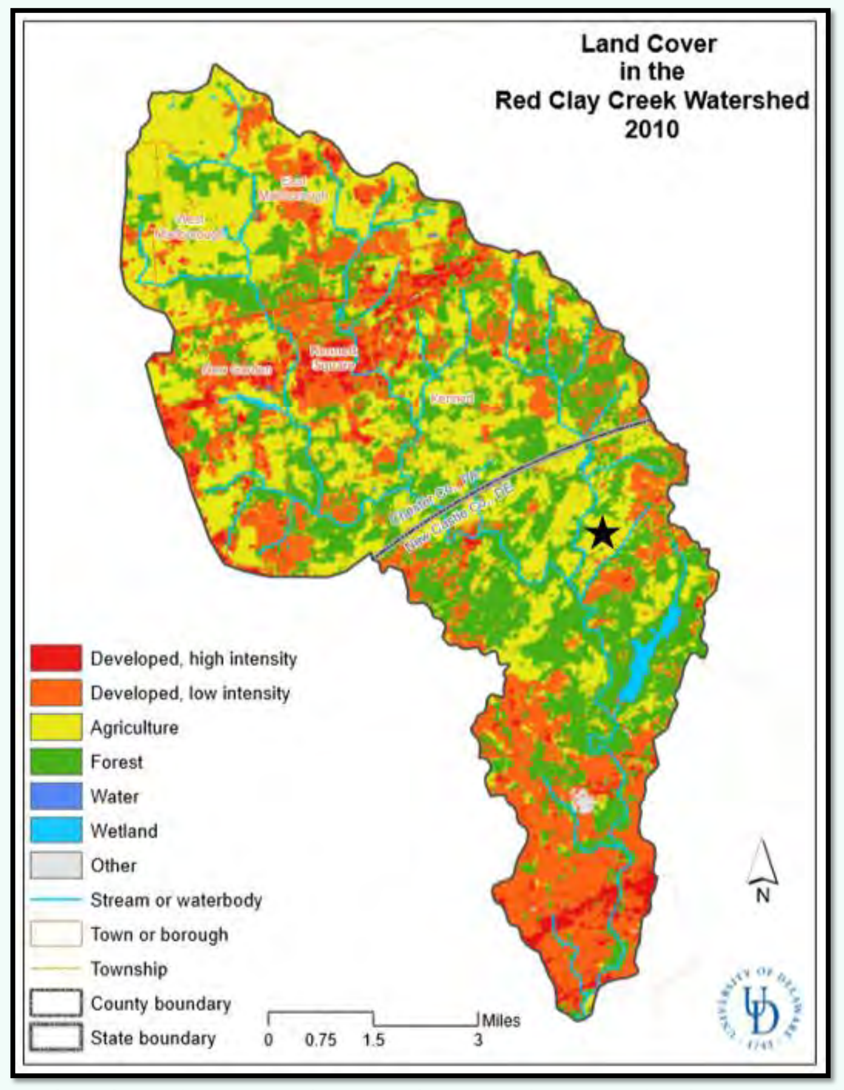
- Local ordinances and municipal plans should be evaluated using the protocol method that I used when evaluating the Sussex County Comprehensive Plan. This will show coordination and consistency between the county and local jurisdictions. Many of these ordinances and policies can be found on local municipality websites. Ordinances pertaining to growth, water quality, and development are of high interest when looking into how growth is going to be directed and how it pertains to water quality.
- Other maps should be made using the PLUS geographic areas, ArcGIS, and Delaware's FirstMap data. There can be more analysis over how these projects interact spatially with other concerning areas, such as forest coverage, land use and land cover, sea level rise, and coastal zones.
- A further evaluation of projects in Sussex County that are being constructed should also occur. Data has been collected on projects within the geographic scope that are under construction. The next step would be to evaluate these documents and see how these projects are being implemented, much like I did with the Baylis Project. This will show whether the growth management and water quality protection policies suggested by the state are actually being implemented, or if developers are ignoring these recommendations completely.

Coverdale Farm Regenerative Agriculture: A Compilation of Data

Mia Kane
University of Delaware Water Resources Center Undergraduate Internship
Co-advisors: Martha Narvaez, Kristen Travers

Project Summary

In cooperation with the Delaware Nature Society, through the University of Delaware Water Resources Center Undergraduate Internship, the overall project goal is to assess the feasibility of implementing regenerative agriculture at the Coverdale Farm Preserve. This project consisted of working with the Delaware Nature Society to collect field data as well as synthesize data and content from prior reports on the water chemistry and quality at the Coverdale Farm Preserve. The culmination of this project may be used for the implementation of regenerative agriculture at this site.



This figure depicts the land cove throughout the Red Clay Creek watershed with the black star indicating the location of the Coverdale Farm Preserve.

What is Regenerative Agriculture?

Regenerative Agriculture is a system of farming principles and practices that aims to capture carbon in the soil and aboveground biomass.

In 2018, the Delaware Nature Society began pursuing the concept of implementing regenerative agriculture on the Coverdale Farm Preserve. The initial step in the process was to collect soil and water quality data. The Delaware Nature Society has introduced rotational grazing for cows, sheep, and poultry in a 40-60 day rotation cycle and are establishing more deciduous trees on the land.

Methods

This project involved collecting data from previous reports and current sources and combining them into one report. This report serves as a comprehensive resource for the implementation of regenerative agriculture at the Delaware Nature Society's Coverdale Farm Preserve.

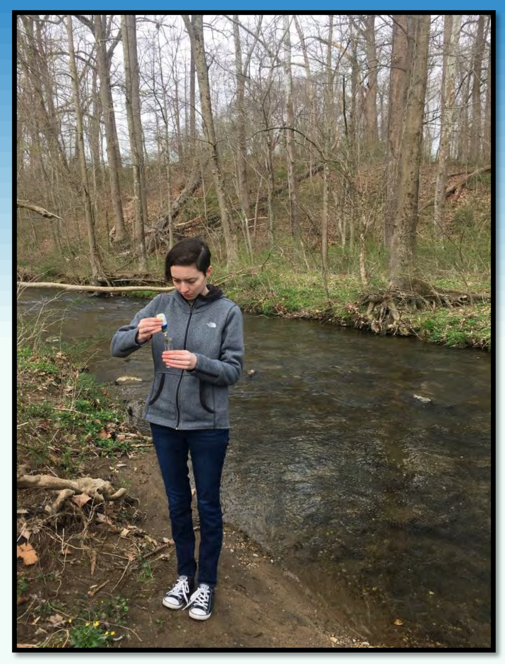
Methods to achieve this goal included:

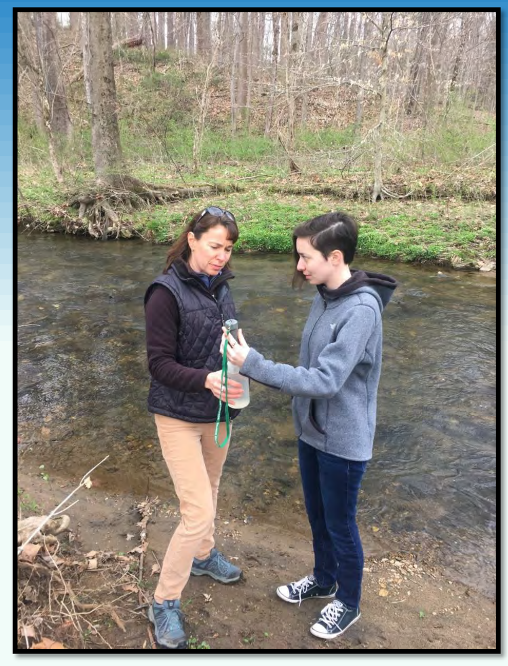
- Identifying data gaps and data availability.
- Gathering data, which included maps of the Red Clay Creek depicting different sources of data (land use, impervious cover, soil, etc.).
- Compiling files of previous Coverdale Farm/Red Clay creek data into succinct and descriptive tables and incorporating the tables into the report.
- Adding contents and data to strengthen the report.
- Organizing the final report into a clear and easy to read format with a table of contents, figure headings, citations, and appendices.

A: Herbicide Records Table *"Delaware Nature Society"*

SECTION 1	Herbicide	Gallons Sprayed	Species Targeted
1998	Stinger, Ally	150	Canadian thistle, rose, mile a min.
1999	Stinger	165	Canadian thistle
2000	Stinger, Roundup	150	Canadian thistle, green rose canes, hsv
2001		0	
2002	Stinger, Ally, Roundup Ultra Max	420	Sprayed Canada thistly, rose, hsb, bs, privit, MAM
2008	LV-4/2, 4-D, Weathergurard, Surfac 820 herbicide		
2009	Stinger	50	Canada thistle
2010	Distinct, Relegate, Jette herbicide		Broadleaf weeds, clover, bedstraw
2011	Perspective, Tordon K, MSO		Boradleaf weeds
2012		0	
2013		0	
2014	Clean slate	200	Canada thistle
2015	Clean slate	95	Canada thistle
2016	Clean slate, Pathway, Tahoe, Roundup	50	Canada thistle, bedstraw, poison ivy, privit, bs, porcelin berry
2017	Tahoe, Roundup	5	hsb, hsv, rose, burning bush, porclin berry
2018	Clean slate	37.5	Canada thistle
TOTAL		1322.5	

This figure depicts a table made quantifying the use of herbicide against invasive plant species in one of the sections of the Coverdale Farm Preserve from 1998-2018.





Conclusion and Next Steps

The final report will be finished by the end of the semester (May 2019) with the completion of a section specifically discussing the Burrows Run watershed.

In the upcoming months, the Delaware Nature Society can use the information and data in this report to identify and quantify the health and quality of their streams and land at the Coverdale Farm and in the surrounding watershed. With this report, the Delaware Nature Society will have the data and resources necessary to pursue implementations of regenerative agriculture at the Coverdale Farm Preserve.

The final recommendation for this project is to continue at add information to this report as new data is collecting and identified and becomes available.

Sources

- Brandywine-Christina *State of the Watershed Report*, 2018. Brandywine Conservancy, Brandywine Red Clay Alliance, Chester County Water Resources Authority, Natural Lands, Stroud Water Research Center, The Nature Conservancy in Delaware, University of Delaware Water Resources Center.
- Coverdale Farm Preserve Master Plan, Poole Design LLC, 2017.

Stormwater Utility Charge Policies in Delaware: A Sustainability Analysis

Liam G. Warren, Undergraduate Researcher, Delaware Water Resource Center
Advisor: Dr. Philip Barnes

BIDEN SCHOOL OF PUBLIC POLICY & ADMINISTRATION
INSTITUTE FOR PUBLIC ADMINISTRATION

ABSTRACT

- Urban areas are continuing to develop and expand, and more impervious surface area is being created.
- Impervious surface area prevents precipitation from naturally infiltrating into the ground.
- Stress is put on stormwater infrastructure from excessive runoff capacities.
- Municipalities implement stormwater utility charges (SWUs) to fund stormwater infrastructure
- Sustainable SWU policies must fulfill certain sustainability criteria.

RESEARCH QUESTION

- What makes a stormwater utility policy sustainable?

ANALYSIS CRITERIA

- *Economy*: Is the fee assessed and charged to parcels enough to cover the cost of maintaining, repairing, and operating stormwater utilities, and no more?
- *Environment*: Is water quantity and/or quality within the SWU boundaries improved?
- *Equity*: Is the burden of the SWU charge spread evenly? Is there an appeals process included in the policy and is it easy to rectify wrongs through it?
- *Effectiveness*: Do the fees assessed and charged to parcels incentivize property owners to stop creating and/or reduce the amount of impervious surface on their parcel?

POLICY SUMMARIES

- Each municipality sets a standard value for determining charges based on impervious surface coverage.
  - Newark SWU
    - 1 ESU = 1,620 sq. ft. = $2.95/month
  - Wilmington SWU
    - 1 ESU = 789 sq. ft. = $4.95/month
  - Lewes SWU
    - 1 ERU = 2,250 sq. ft. = $5.00/month
  - Kent County Storm Water Management District (SWMD)
    - 1 EDU = 2,500 sq. ft. = $32.40/year
- Different stormwater classes are established for different types of parcels

ESU = Equivalent Stormwater Unit
ERU = Equivalent Residential Unit
EDU = Equivalent Dwelling Unit

METHODOLOGY

- Each criterium is equally important in determining sustainability value.
- Each policy is given a rating from 0 – 10 based on how they fulfill the given criteria category

EVALUATION RESULTS

SWU Policies in Delaware ratings for each criterium: 0 – 10	Economy *Is the fee assessed and charged to parcels just enough?*	Environment *Is water quantity & quality improved?*	Equity *Is the burden spread evenly?*	Effectiveness *Do the charges incentivize reducing impervious surface coverage?*	*TOTALS* *sum of ratings (highest possible score = 40)*
Newark	10	5	10	5	*30*
Wilmington	5	5	5	5	*20*
Lewes	5	0	2	2	*9*
Kent County SWMD	7	5	3	7	*22*

DISCUSSION & SPECULATIONS

- If a central goal of SWU policies is to reduce impervious surface coverage, charges are currently not high enough to deter property owners.
  - At the same time, restricting charge credits and increasing charges could create a regressive policy.
- Wilmington SWU: example of how SWU charges are not equitably distributed, since only parcels within the corporate limits pay.
- SWU policies have the potential to reduce urban heat island effects.

CONCLUSIONS & RECOMMENDATIONS

- A sustainable SWU policy:
  - Generates enough revenue to cover the cost of stormwater infrastructure and no more
  - Burden of the charge is spread evenly across all who use the infrastructure, charges are structured on a fair ESU standard
  - Water quantity and quality is improved from implementing BMPs incentivized by the SWU
  - Provides incentives to property owners to reduce impervious surface coverage

FUTURE RESEARCH

- Binding versus non-binding policies and their outcomes
- Examining the correlation between population and overall land coverage area and their influences on SWU policies

Determining the Source of Sediment Pollution in White Clay Creek Wild & Scenic River

Natalie Zimmermann

Advisor: Dr. Gerald Kauffman, Delaware Water Resource Center

What is sediment pollution and why is it a problem in White Clay Creek?

Sediment pollution is the contamination of water sources with fine-grained, suspended sediments. It can lead to declines in fish populations, disruptions to the local food chain, algal blooms, alterations to the flow of water, and issues with drinking water supply. Fine-grained sediment polluting the White Clay Creek is currently effecting the availability of drinking water for the city of Newark, DE. After storm events and on high-pollution days the city' s water treatment facility is often unable to process water from the White Clay Creek due to the excessive suspended sediment which clogs the water filters. As a result, the city must acquire potable water from a secondary source, inconveniencing the city. In an effort to identify the source of this fine-grained suspended sediment to develop a management plan, I am conducting a Sediment Fingerprinting analysis.

Sediment Fingerprinting involves the determination of sediment sources on the basis of source material qualities. Currently, many people assume that the sediment polluting White Clay Creek comes from the many nearby agricultural farms. This theory does not account for streambank erosion, which may be a significant factor. I am comparing the sediment grain sizes and elemental tracers between water samples from five sites, streambanks at these sites, and nearby farms to attempt to identify the main source of suspended sediment.

Data collection methods and study area

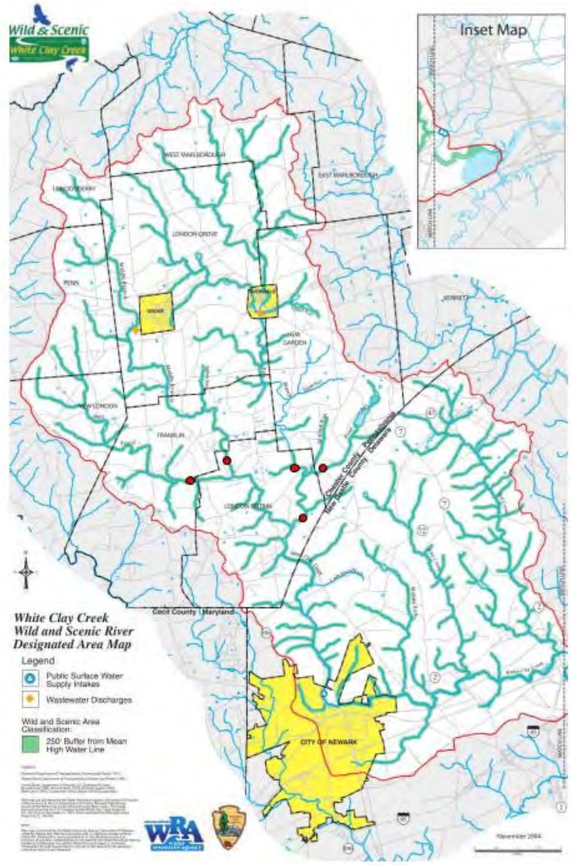
Data was collected from five sites in White Clay Creek Wild and Scenic River. These sites were the Main Stem (Strickersville), Broad Run (Watson Mill), East Branch (Good Hope), Middle Branch (Mercer Mill), and West Branch (Flint Hill).These sites were chosen so that suspended sediment between branches could be compared, in an effort to identify which branch may be the primary source of the pollution. From these five sites, I collected on site Temperature, Turbidity, Nitrate levels, and conductivity data of the water. I also collected water samples, which were sent to the UD Soil Testing Lab to be analyzed for pH, salinity, nitrate levels, and elemental abundances. Soil samples were also collected from nearby farms and sent to the UD Soil Testing Lab to undergo a sieve/ gradation analysis, and have the extractable nutrients tested. I collected 7 rounds of field data, beginning in February, 2019 and extending into May. From this data, the sediment fingerprinting approach is being applied to trace the source of fine grained sediment suspended in White Clay Creek. The elements present in water, farm soil, and streambank soil samples are being used as tracers to track sediment transport.

Sources:

What Is Sediment Pollution? What Is Sediment Pollution?, Mid-America Regional Council. https://cfpub.epa.gov/npstbx/files/ksmo_sediment.pdf

Gellis, A.C., and Gorman Sanisaca, L.. 2018. " Sediment Fingerprinting to Delineate Sources of Sediment in the Agricultural and Forested Smith Creek Watershed, Virginia, USA." *Journal of the American Water Resources Association* 54 (6): 1197– 1221. https://doi.org/10.1111/1752-1688.12680.

Cashman, MJ, Gellis, A, Sanisaca, LG, Noe, GB, Cogliandro, V, Baker, A. Bank-derived material dominates fluvial sediment in a suburban Chesapeake Bay watershed. *River Res Applic*. 2018; 34: 1032– 1044. https://doi.org/10.1002/rra.3325

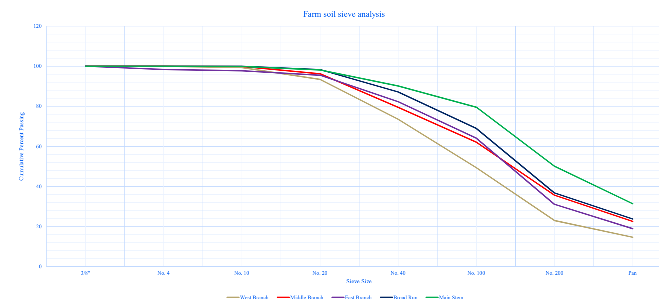


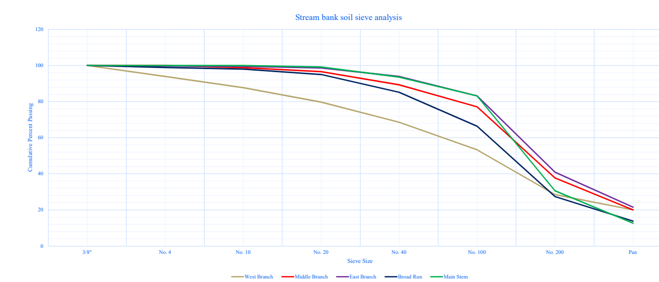
Conclusion

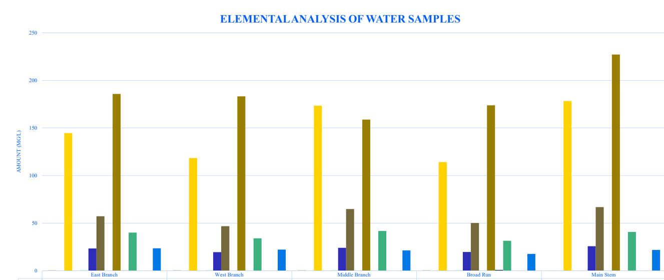
I am currently waiting on results from the UD soil testing lab (elemental analysis of farm and streambank soil samples). I cannot draw any conclusion about the source of sediment pollution in White Clay Creek without this data. I will include the results of the sediment fingerprinting analysis using elements present as tracers in my final research report.

Data & Results

The farm and stream bank soils underwent gradation analyses to be sorted into textural classes. I used the data from each sample at each site to find the average textural classes of the stream bank and farm soil at each site over the course of this study. This information is plotted below to illustrate the similarities and differences– the stream bank soil (specifically at the west branch) is generally more coarse grained compared to the farm soil. The average elements present in the water samples by site are plotted below– this will be compared to the elements present in the soil samples to identify the source material once I receive this data from the lab.







	East Branch	West Branch	Middle Branch	Broad Run	Main Stem
Al	0.457	0.492	0.479	0.502	0.286
B	0.054	0.051	0.056	0.051	0.053
Ca	144.724	118.346	173.491	114.211	178.345
Cu	0.05	0.05	0.05	0.05	0.05
Fe	0.475	0.522	0.52	0.516	0.357
K	23.431	19.542	24.08	19.662	25.701
Mg	57.26	46.892	64.782	50.197	66.782
Mn	0.141	0.166	0.115	0.129	0.094
Na	185.658	183.138	158.743	173.738	227.174
P	0.317	0.135	0.188	0.879	0.186
S	40.035	33.991	41.787	31.504	40.776
Zn	0.025	0.025	0.025	0.025	0.025
NH4-N	0.246	0.136	0.146	0.186	0.283
NO3-N	23.63	22.26	21.39	17.61	21.83

White Clay Creek's Potential for Hydroelectric Power Generation

Andrew Dorazio – University of Delaware Water Research Center

University of Delaware College of Engineering

Background & Motivation

- Newark's White Clay Creek consists of multiple Dams which hold the potential for hydroelectric power generation.
- Dam 4 has a large enough head and consistent flow rate to implement effective hydroelectric turbines.

Problem Definition

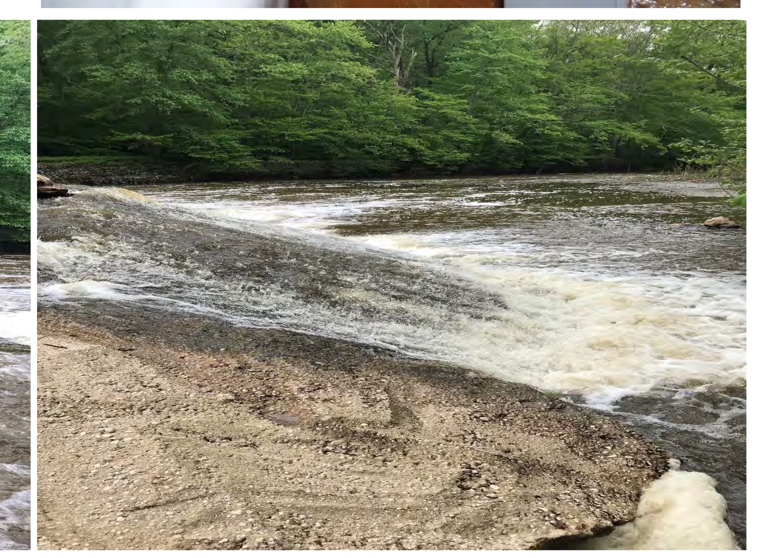
- This project aims to propose a design, budget, and plan of action to implement hydroelectric turbines into White Clay Creek.
- The goal is to create an environmentally friendly design quoting specific manufacturers that could create the highest power generation at the lowest overall cost.

Design Metrics

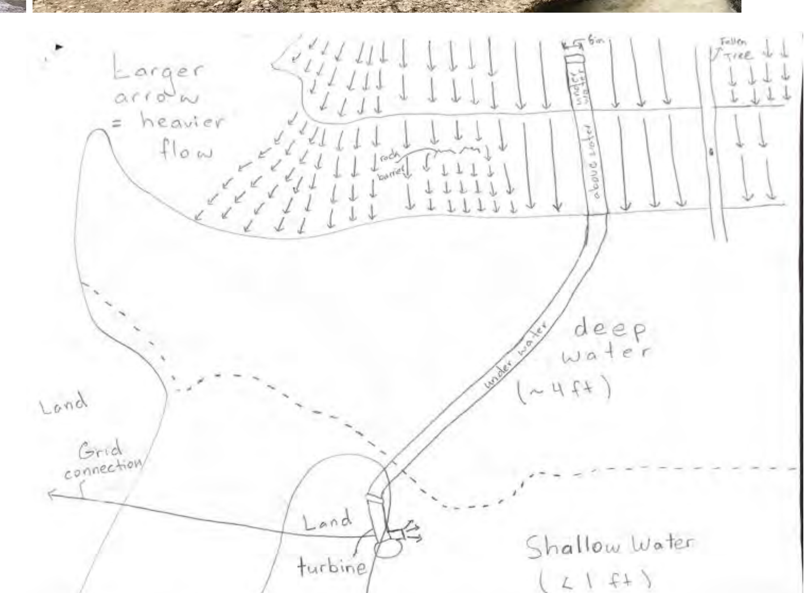
Constraint	Description	Target Value/Metric
Power Generation	Design will generate enough power to negate the costs of implementation and maintenance over a period of time.	10 years @ $0.14/kWh[1]
Environmental Impact	Design will not impede flow of wildlife or cause danger to native species of visible size.	Objects/Species > 2mm in length cannot pass through turbine
Safety	Design will not pose a threat to people swimming in the creek.	0 pinch points as defined by ANSI Standards 1910.211 0 chance of suction entrapment ANSI Standard 112.19.8
Want	**Description**	**Target Value/Metric**
Utilization of weak flow	Design should be able to create power in light flow.	Minimum Flow = 15 ft^3/s
Cost	Design should have a cost relative to the amount of money in energy savings over 10 years.	Cost of power produced overcomes total cost of installation and maintenance over 10 years.
Life expectancy	Turbine should be able to work for a certain time with minimal maintenance.	>10 years
Impact of Installation	The changes to the environment should be as minimal as possible.	No negative impact to wildlife and humans disregarding aesthetics.

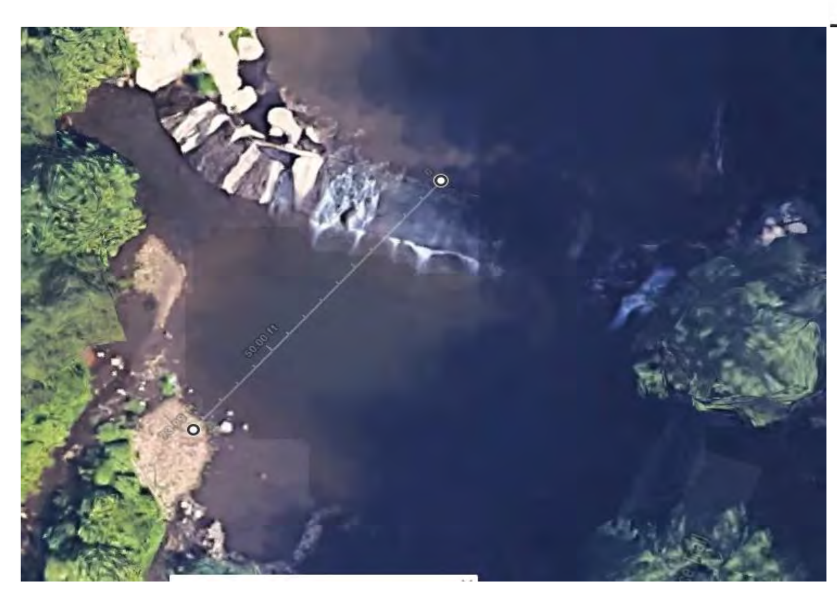
Final Concept

Implementation of Scott Hydroelectric Turbine(s)
Hose will be connected from the top of the dam and connect to one or two turbines on land below.



Due to substantially heavier flow in the middle of the dam, the turbine must be fed from the middle and outlet onto a patch of land.
Right– Flow/Path Drawing
Below – Google Earth Image





The 6'' diameter hose will inlet at the top of the dam in two feet of water. It will then ride over the slope of the dam above water, to then go back under water in the reservoir area until it reaches the turbine on land.

Project Budget

Single Turbine Budget	Price (USD)	Total (USD)
Turbine and Grid - Tie inverter	5890	5890
Stainless Steel self-cleaning water intake screen	485	6375
Fire hose 6'' 100'	1,224	**$7599**
Duel Turbine Budget		
Second Turbine	3900	11499
Second hose	1,224	12723
Second intake screen	485	**$13208**

*Not including cost of installation or maintenance

Concept Validation

Constraint	Result	Pass/Fail
Power Generation	1 turbine at 50% potential = 6570 kWh/year = **$9198 over 10 years** 2 turbines at 50% potential = 13140 kWh/year = **$18369 over 10 years**	Pass
Environmental Impact	Water intake screen results in total blockage of wildlife and debris.	Pass
Safety	No pinch points or chance of suction due to rubber hose and screened/visible inlet.	Pass

- All constraints pass – power generation is very high and has potential to be even higher than 50%.
- Two turbines at max potential = 26280 kWh/year
- Due to this turbine being a cross-flow turbine, It will utilize both very weak flow and very strong flow to its maximum potential.
- A Fire Hose being used as the inlet pipe ensures safety of wildlife and human waders as they cannot be pinched or experience any brute collision force.

Performance Summary & Path Forward

- Five designs were proposed, and after multiple selection matrices it was evident that this concept had the greatest potential with the lowest negative impact.
- This design is a very practical and viable option. There is a grid connection very close in proximity, and I am confident a permit could be quickly obtained.
- The only potential downfall is the possibility of local waders purposely tampering with or harming the machine, but if caution signs were implemented there should be no problem.
- Overall this project went well and hopefully will be seriously considered for implementation.

Acknowledgements

- I would like to thank The University of Delaware Water Resources Center and my Advisor Gerald Kauffman for their help and guidance in the duration of this project.

Analysis of the Watershed Resources Registry Using GIS to Evaluate Stormwater Restoration Practices in the Christina River Watershed

Jillian S. Young

Graduate Research Assistant

54th Annual DWRC Advisory Panel Meeting

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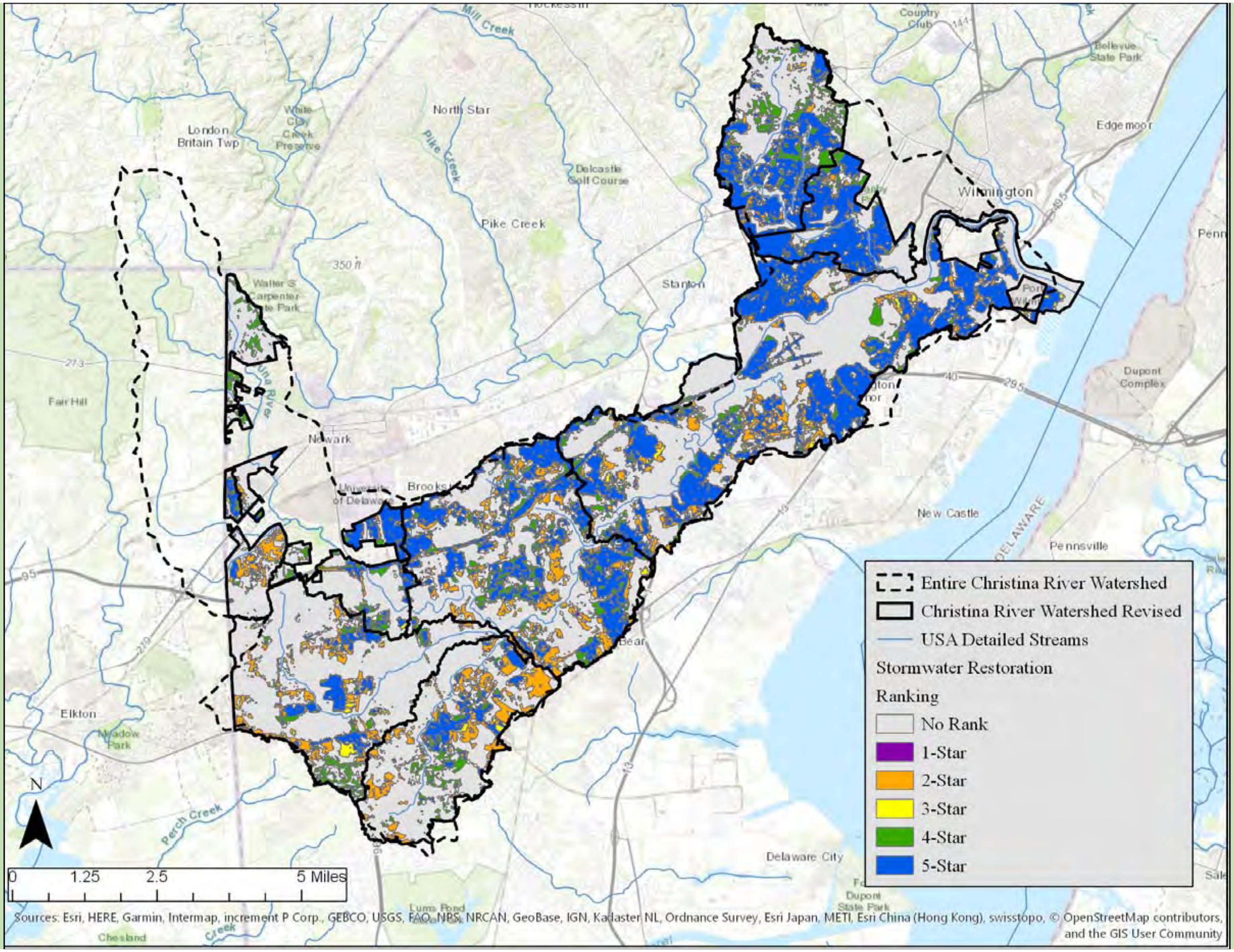
The Watershed Resources Registry (WRR)

- Prioritizes areas for preservation and restoration practices in landscapes across an entire state
  - Delaware, Maryland, Pennsylvania, Virginia, and West Virginia

- Categories: Upland, Wetland, Riparian, and Stormwater natural infrastructure and compromised infrastructure

- Provides a rank: one- to five- stars
  - (least to most suitable areas)



Entire Christina River Watershed
Christina River Watershed Revised
USA Detailed Streams
Stormwater Restoration
Ranking
No Rank
1-Star
2-Star
3-Star
4-Star
5-Star
0 1.25 2.5 5 Miles
N
Wilmington
Newark
Stanton
New Castle
Bear
Elkton
Delaware City
Pennsville
Edgemoor
Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community

Justification

- The WRR has not been analyzed for Delaware
  - A case study was completed for Maryland

    (Maryland Environmental Service)

- This study analyzes if the WRR can be a viable tool to use for DE's WQIPs
  - Determines the approximate resolution the WRR is best suited for when selecting sites
  - Determines if there is an association between pollutant loads and WRR rankings

Research Questions

1. Is the WRR a viable tool to predict suitable sites for WQIPs?

2. How can the WRR's one-to five-star rank be translated into quantitative water quality improvements in terms of Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS)?

3. Does the WRR have a resolution threshold when selecting a viable stormwater restoration project location?

4. If the WRR is a viable tool, how can it be applied to other watersheds within Delaware, Maryland, Pennsylvania, Virginia, and West Virginia?

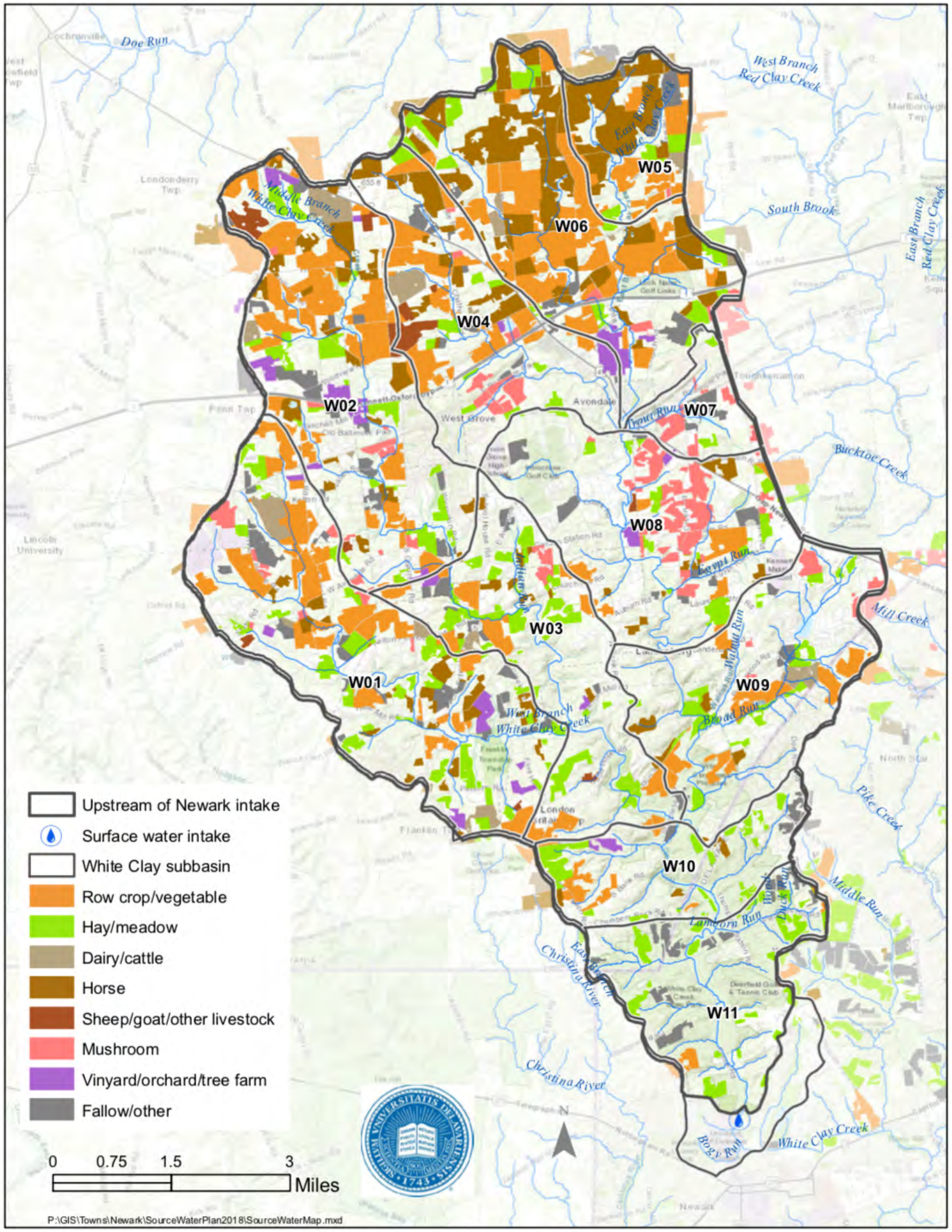
Results

Pollutant	First Quartile	Second Quartile	Third Quartile	Fourth Quartile
TN	0.009	0.332	0.05	0.856
TP	0.009	0.325	0.055	0.857
TSS	0.012	0.320	0.051	0.853
Acres	0.16 to 0.70	0.76 to 3.35	3.82 to 12.35	14.71 to 59.95

First: Weak
Second: Weak
Third: Weak
Fourth: Strong

Conclusions

- The WRR ranks associated with higher pollutant loads
- Best suited for at least a 4-acre resolution
- The DURMM is a model that can be used in tandem with the WRR
- Both the tool and model can help the user decide where to implement or retrofit the best BMP for the best use of funding



Kelly Jacobs (M.S. Energy and Environmental Policy), Advisor: Andrew Homsey and Martha Narvaez (Public Policy), Source Water Protection from Farms and Agriculture in the White Clay Creek Watershed.