UDWRC Research Interns (FY22)

FY22 Student Support
Beginning in June 2021, the UDWRC supported 14 undergraduate and graduate water research internships during FY22 through the annual base (104b) grants. The UDWRC research students presented their research findings at the 57th annual meeting of the UDWRC Advisory Panel on May 5, 2022, at the University of Delaware:

FY22 Delaware Water Resources Center Water Research Internships

Student	Major	Research
Hayley Rost	Master of Public Administration, Biden School	Water Quality Monitoring in the White Clay Creek National Wild & Scenic River
Sophie Phillips	Master of Energy & Environmental Policy, Biden School	Diversity in National Parks: How Understanding our Past Can Help Us Create an Inclusive Experience
Liz Shields	Master of Public Policy, Biden School	Indigenous and European Place Names of Along Streams and Waterways in Delaware (Lenapehocking)
Andrew Blackburn	Chemical Engineering	Phyical and Chemical Effects of Biochar on Soil
Nicole Gutkowski	Marine Science - Oceanography	Investigating the Utility of Bivalves As Biomonitors of Heavy Metal Contamination in the Delaware Bay
Megan Jarocki	Environmental Engineering	Water Quality Sampling and Analysis Along the White Clay Creek National Wild & Scenic River in Delaware and Pennsylvania
Brian Kennedy	Energy and Environmental Policy	Water Quality Analysis of the Water Supply System in and Around Newark, Delaware
Nathaniel Levia	Insect Ecology and Conservation	How Mill Dams Affect Insects and Spiders in Aquatic and Riparian Ecosystems
Erik Rodriguez	Environmental Engineering	Water Quality Analysis of the Water Supply System in and Around Newark, Delaware
Andreanna Roros	Geological Sciences	Impact of Stormwater Infiltration on Groundwater Radium Levels in Delaware
Sophia Talley	Environmental Engineering	PFAS Analysis Along the Four Drinking Water Streams in New Castle County, Delaware
Megan Wassil	Environmental Engineering	Water Quality Sampling and Analysis Along the White Clay Creek National Wild & Scenic River in Delaware and Pennsylvania

UDWRC Undergraduate Intern Research

Physical and Chemical Effects of Biochar on Soil

Andrew Blackburn
Major: Chemical Engineering

The addition of biochar to roadway soils has shown promising results in its ability to filtrate water more efficiently and reduce the pollutants found in runoff. In order to understand both the physical and chemical effects of adding biochar, two experiments were performed. The first experiment analyzed the effects of biochar on water-stable aggregation and other physical structures, while the second experiment looked at the ability of biochar to leach phosphorus from the soil. In the aggregation study, a wet-sieving device was used to delicately sift through soil cores in order to establish a distribution of aggregate sizes for a variety of soils, half of which contained biochar. When properly analyzed, the laboratory soils showed a decrease in aggregation, most of which was due to the disappearance of large cemented soil particles when biochar was applied. These laboratory produced results were contradictory to those yielded by the field sites that showed an overall increase in aggregation when biochar was applied. Thus, the current laboratory practices must be revised in order to properly mimic field site conditions. In the second experiment, batch reactors were made with a pseudo-soil complete with a storm event and centrifuge to simulate and separate a leachate. Biochar is known to affect the pH of soil, and as a result, the storm water pH varied between 7 and 8.5. When phosphate concentrations were measured in the leachate, increasing the pH and biochar content both decreased the phosphorus leaching ability. These findings indicate that applying biochar to roadway soils can decrease the amount of phosphorus that is brought into watersheds and limit the eutrophication of natural water resources.

Investigating the Utility of Bivalves as Biomonitors for Heavy Metal Contamination in the Delaware Bay

Nicole Gutkowski
Major: Marine Science - Oceanography

Due to the expansion of industry and urbanization, there are expected to be high contamination levels in the Delaware Bay. While concentrations of contaminants in water are generally too low to measure, bivalve’s filtration of water and sediment allows contaminants to bioaccumulate within their tissues. This project aims to investigate the utility of bivalves as biomonitors for heavy metal contamination in the Delaware Bay. Field samples of bivalves, water, and sediment were collected from selected sites spaced along the Delaware Bay to perform this investigation. The Direct Mercury Analyzer was used to measure mercury concentrations in the field samples. Measured concentrations were utilized to assess the spatial distribution of contaminants in the Delaware Bay. Bioaccumulation of heavy metals in bivalve tissues and the spatial distribution of contaminants within the Delaware Bay presents important applications for the aquaculture industry.

Water Quality Sampling and Analysis Along the White Clay Creek National Wild & Scenic River in Delaware and Pennsylvania

Megan Jarocki
Major: Environmental Engineering

The first of two projects conducted water quality sampling and analysis of the White Clay Creek Wild & Scenic River Watershed in Delaware and Pennsylvania with the goal of determining the quality of the drinking water in the White Clay. High-quality drinking water is essential for the health and safety of those who inhabit the watershed and potentially consume the water. Within this project, there were three central aims: to test drinking water for common contaminants, to determine what branch of the White Clay Creek was getting heavy nitrogen runoff, and to look for long- and short-term trends in the water quality of the White Clay. The second project relates to PFAS analysis along the four drinking water streams in New Castle County, Delaware. The purpose of this project was to determine if there is significant PFAS contamination in northern Delaware's drinking water. Two samples were taken from each of the five drinking water sources examined in this study, sent to the lab, and analyzed. Delaware did not yet have regulations regarding PFAS concentrations in drinking water, therefore we compared our findings to the regulations of Vermont and Massachusetts (both states have PFAS regulations). The analysis determined that the concentration of PFAS in the Red Clay Creek site is greater than expected and is at a level higher than the advised amount.

Water Quality Analysis of the Water Supply System Along the White Clay Creek in and Around Newark Delaware

Brian Kennedy & Erik Rodriguez

Major: Energy and Environmental Policy   *Major: Environmental Engineering*

This research aimed to determine whether the White Clay Creek forest is adequately filtering water that becomes the City of Newark's drinking water by tracking the levels of various nutrients within the Creek. The researchers took probe measurements in the field with portable testing equipment and grab samples to be analyzed at the agricultural campus lab. Data were collected on nutrients such as nitrates, chlorine, and phosphorus. After analyzing the nutrient data by site and over time, no trend of reduction was identified through the sites moving down along the White Clay Creek. The results suggest that while the overall nutrient levels in the White Clay Creek were significantly below the health standard since there was not a reduction in nutrient levels between samples taken upstream and downstream, the forest is not adequately filtering nutrients from the water.

How Mill Dams Affect Insects and Spiders In Aquatic and Riparian Ecosystems

Nathaniel Levia

Major: Insect Ecology and Conservation

Mill Dams have dotted the landscape of Delaware since the colonial era; however, they are now starting to be removed from waterways. The mill dam located at the end of Paper Mill Road in Newark, Delaware, was once part of the Curtis Paper Mill, which has since been demolished, and turned into a public park. The final standing remnant of the Curtis Paper Mill is the mill dam, which was scheduled to be removed in 2021. While the dam removal has yet to occur, data collected on both sides of the mill dam show how the dam is affecting the stream. In this study, the stream was split into six search zones, three zones located downstream of the dam and three zones located upstream of the dam. Insects and spiders were collected from the riparian and aquatic ecosystems in each zone utilizing pitfall traps and hand sampling. Isotopic analysis was performed on specimens from the suborder Ensifera, due to them being opportunistic feeders. The aquatic macroinvertebrates collected were also analyzed and used as bioindicators. The Hilsenhoff Biotic Index, a method that uses the presence and abundance of invertebrates and their pollution tolerance to estimate water quality, was used to calculate biotic index values for each of the six zones, as well as for above and below the dam. The results of this project indicate that there is a difference in aquatic fauna above and below the dam, and no major difference in fauna in the riparian zones above and below the mill dams.

Impact of Stormwater Infiltration on Groundwater Radium Levels in Delaware

Andreanna Roros

Major: Geological Sciences

This study investigated the impacts of stormwater infiltration on groundwater by measuring radium isotopes in samples collected periodically from monitoring wells at the BMP-663 infiltration basin at Route 301 and Bunker Hill Road. The intent of this investigation was to characterize potential risks to groundwater quality from de-icing practices at the Delaware Department of Transportation (DelDOT), which include the spreading of brines and rock salt during the winter months. The gradual increases in chloride concentrations and the movement of salty water within the Rancocas Aquifer beneath these sites have a significant probability of exacerbating radionuclide release in groundwater—with radium isotopes being the most likely to be mobilized in the aquifer by an increase in groundwater salinity. This study is imperative not only because of the geologically derived radionuclides coming from the aquifer but also because it is a source of drinking water for thousands of people in southern New Castle and northern Kent Counties. For that reason, it was also important to ensure that the wells did not exceed the EPA maximum contaminant level (MCL) for radium in drinking water, as high and chronic levels of ingestion can be carcinogenic.

PFAS Analysis Along the Four Drinking Water Streams in New Castle County, Delaware

Sophia Talley

Major: Environmental Engineering

The first project sought to determine if there are significant levels of PFAS contamination within Northern Delaware's drinking water supply. Per-and polyfluoroalkyl substances, better known as PFAS, are "forever chemicals" that remain within the environment. Samples from five different drinking water sources throughout Northern Delaware found that there was only one site with PFAS levels greater than the recommended threshold; however, further testing is needed to draw concrete conclusions. The second project involved testing the Pennsylvania portion of the White Clay Creek for nitrogen contamination to determine where the source of nitrogen contamination is located. Tests were conducted in the Eastern, Western, Middle, and Main branches of the White Clay to hone in on the potential source, or sources, of the nitrogen contamination.

Water Quality Sampling and Analysis Along the White Clay Creek National Wild & Scenic River in Delaware and Pennsylvania
Megan Wassil
Major: Environmental Engineering

This project focused on the nitrogen levels in the White Clay Creek. The goal of this research was to determine the source of high concentrations of nitrogen in the City of Newark's drinking water. Field samples were collected along White Clay Creek and assessed utilizing variables such as turbidity, conductivity, and nitrogen concentration. The research team analyzed the data yielded by these samples to determine which branch of the White Clay Creek has the highest levels of nitrogen present and is potentially the source of nitrogen contamination.

Water Resources Graduate Research Assistant Research

Diversity in National Parks: How Understanding our Past Can Help Us Create an Inclusive Experience
Sophie Phillips
Master of Energy & Environmental Policy, Biden School

Throughout the year, National Parks are busy with activity. From hiking and camping to museum visits and ranger-led tours, there are options for everyone to enjoy. In 2019 alone there were 327,516,619 visitors to the National Parks (NPS, 2020). On the surface, it appears the National Parks are doing very well, but looking deeper, there are concerns about the demographics of visitors and employees. A survey by the National Park Service in 2016 showed only 7 percent of park visitors are African American, and only 20 percent of visitors are minorities, even though African Americans make up 13 percent of the U.S. population and minorities make up 40% (Rott, 2016). The history of African American experiences with nature, forests, and national lands provides some insight as to why National Park engagement within this population is so low.

The history of segregation in the United States national lands, the lack of representation of African Americans in the National Parks workforce, and a system that pushes kids out of environmental fields leave us with a lot of work to do. Creating programs within the park system that invite youth to become part of that space is an important first step. The creation of an app and podcast series about black history can build understanding and help address the knowledge gap around the history of this nation, while the hiring of more African American employees in leadership positions will allow for the increase of that vital representation. We are far from solving this problem, but those in leadership positions of our national lands are ready to make the changes needed to truly show that we all have ownership in this land.

Water Quality Monitoring in the White Clay Creek National Wild & Scenic River

Hayley Rost
Master of Public Administration, Biden School

In partnership with the White Clay Watershed Association Wild and Scenic Program (WCWA), UDWRC graduate students conducted biweekly fieldwork in the White Clay Creek to assist with the WCWA ongoing water quality monitoring program. The White Clay Creek is a designated National Wild & Scenic River and was the first Wild & Scenic River to be protected on a watershed basis. Approximately 124,000 people live in the watershed basin, according to the 2010 census, which is nearly double from the 1970 basin population. One of the central purposes of the water quality monitoring program was to improve science-based knowledge of stream conditions within the watershed. By assessing the streams, how the surrounding land use affects the streams, and how the streams are impacted by weather events over time, the WCWA will be able to develop a more effective plan for restoration, preservation, and management efforts in the White Clay Creek watershed. Ultimately, the goal of the program is to successfully manage the streams so the waterways are able to fulfill their designated uses and be delisted as impaired. Data collected through the program will be shared with elected officials, who make decisions that can potentially affect water quality and stream habitat, as well as watershed residents, so they are able to make informed decisions concerning their own properties.

Indigenous and European Place Names Along Streams and Waterways in Delaware (Lenapehocking)

Liz Shields
Master of Public Policy, Biden School

Beginning in Summer 2021, this project was created to initiate important research, conversation, and recognition around the names of waterways and places in our state. There is a rich and long history of the relationships between the Lenape Haki-nk, Susquehannock, Choptank, Nentego/Nanticoke, and Pokomoke peoples and this land we now know as Delaware. We acknowledge both the history and the maintained presence of these Indigenous peoples, as well as the existence of their original connections and name associations to the land and water. The goal of this living project is to begin to uncover what available records show and tell of the lineage and possible meanings behind the Indigenous, early European settlers, and commonly known names. Through an analysis of the 1966 United States Geological Survey "Delaware Place Names" Report, a current total of 107 waterways and key land points have been organized, interpreted, and placed, producing a new alternative visual for mapping in Delaware. The next steps of the project will play out in the evolution of the printed sample into a living online map with additional content and context. Given the limitations of the 1966 USGS report, we plan to collaborate with other sources and initiate communication with Indigenous tribal leadership and members around the state for their input on variants, translations, locations, and other vital elements to this process.

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UDWRC Photogallery

Attendees gathered at the 57th Annual meeting of the UDWRC Advisory Panel last month at Hillside Park in Newark.

UDWRC Graduate fellows outside the office: Hayley (left) and Sophie (middle) graduated in May.

Physical and Chemical Effects of Biochar on Soil

Andrew Blackburn, Chemical Engineering Major

University of Delaware

1. Introduction

- During urban development, soil structure is often modified in order to make the ground more stable for man-made structures. This is often done by removing topsoil, compacting the soil, or otherwise inhibiting the permeability of the soil.
- Decreasing permeability leads to increased runoff and flooding, which can not only spread pollutants into the watershed, but also destroy the landscape.
- In previous research, applying biochar to roadway soils has shown to increase their permeabilities and counteract the effects of urban development.
- The increase in soil filtration is possibly due to its ability to increase the aggregation of the soil, which will be rigorously tested against multiple soil types and settings.

2. Purpose & Research Question

- Examine the effects of applying biochar to both roadway and laboratory soils in terms of the water-stable aggregate size distribution.
- Obtain a better understanding of the affect of biochar on soil structure.

3. Methods

- Soil samples were taken from 4 different states: Delaware, Maryland, North Carolina, and California.
- The soil was then grinded and packed into columns. Storm events were also performed in the columns to set a good moisture content and to mimic natural conditions.
- A small plastic tube was used to pierce the soil column and take out two 10 cm cores of each soil column.
- A 53 µm, 0.25 mm, and a 2 mm sieve were stacked on top of each other from the smallest opening on the bottom to the largest on top.
- Two cores were taken from each column, one would be used for wet-sieving, and another would be dried and weighed in order to determine the moisture content of the soil.

4. Procedures & Analysis

Wet Sieving

- The soil core designated for wet-sieving would first be sliced into sections no longer than 1 inch.

- The cores are then carefully placed on the top layer of the sieving device and slowly submerged. After 5 minutes of complete submersion, the sieves are delicately moved up and down about 2 cm fifty times, slowly breaking apart the cores into aggregates.
- The sieves, along with what is left of the soil, is then removed from the water and separated according to aggregate size.

- Once each layer is separated, they are all dried and weighed to obtain a mass distribution.

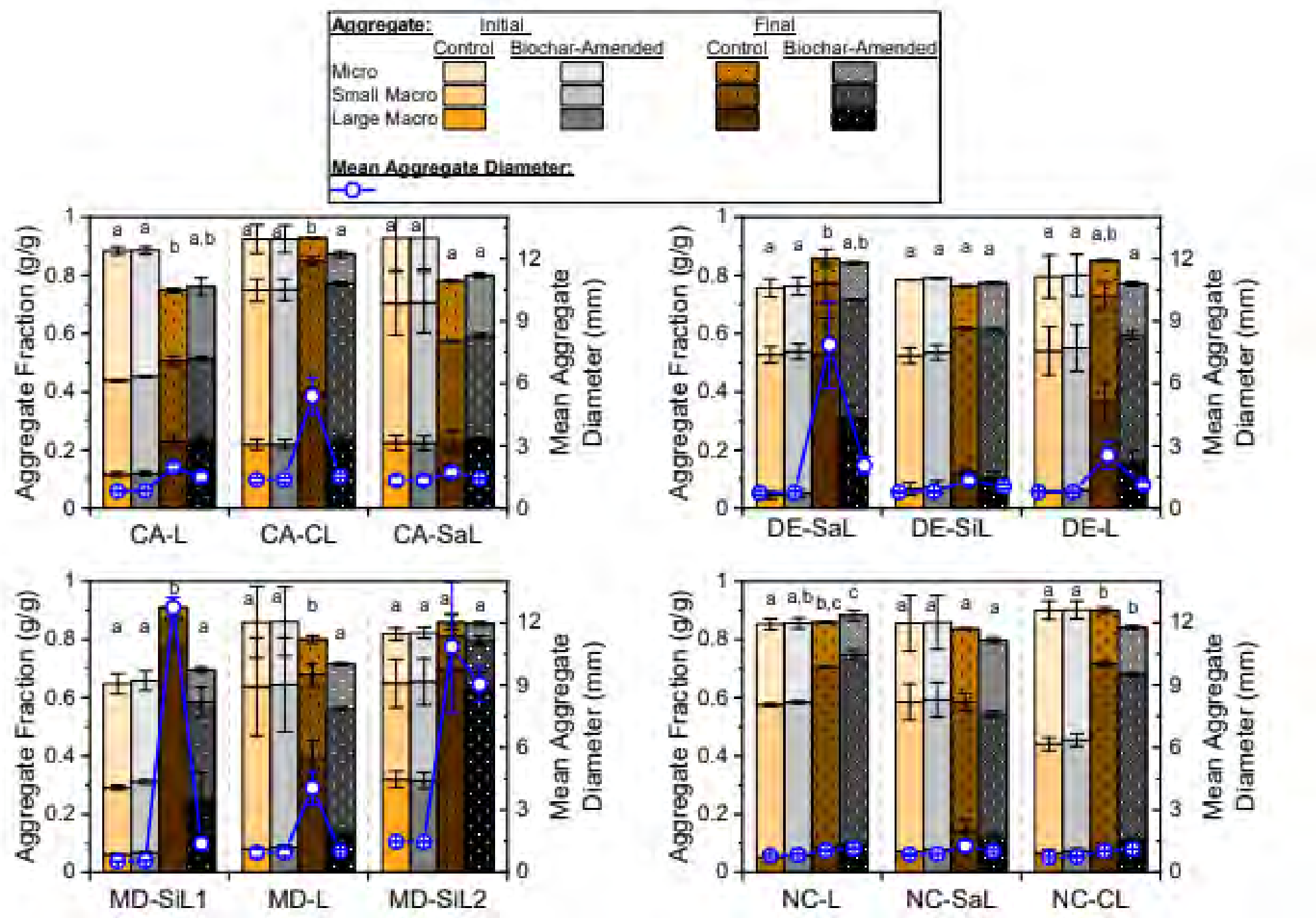
Sand Correction and Analysis

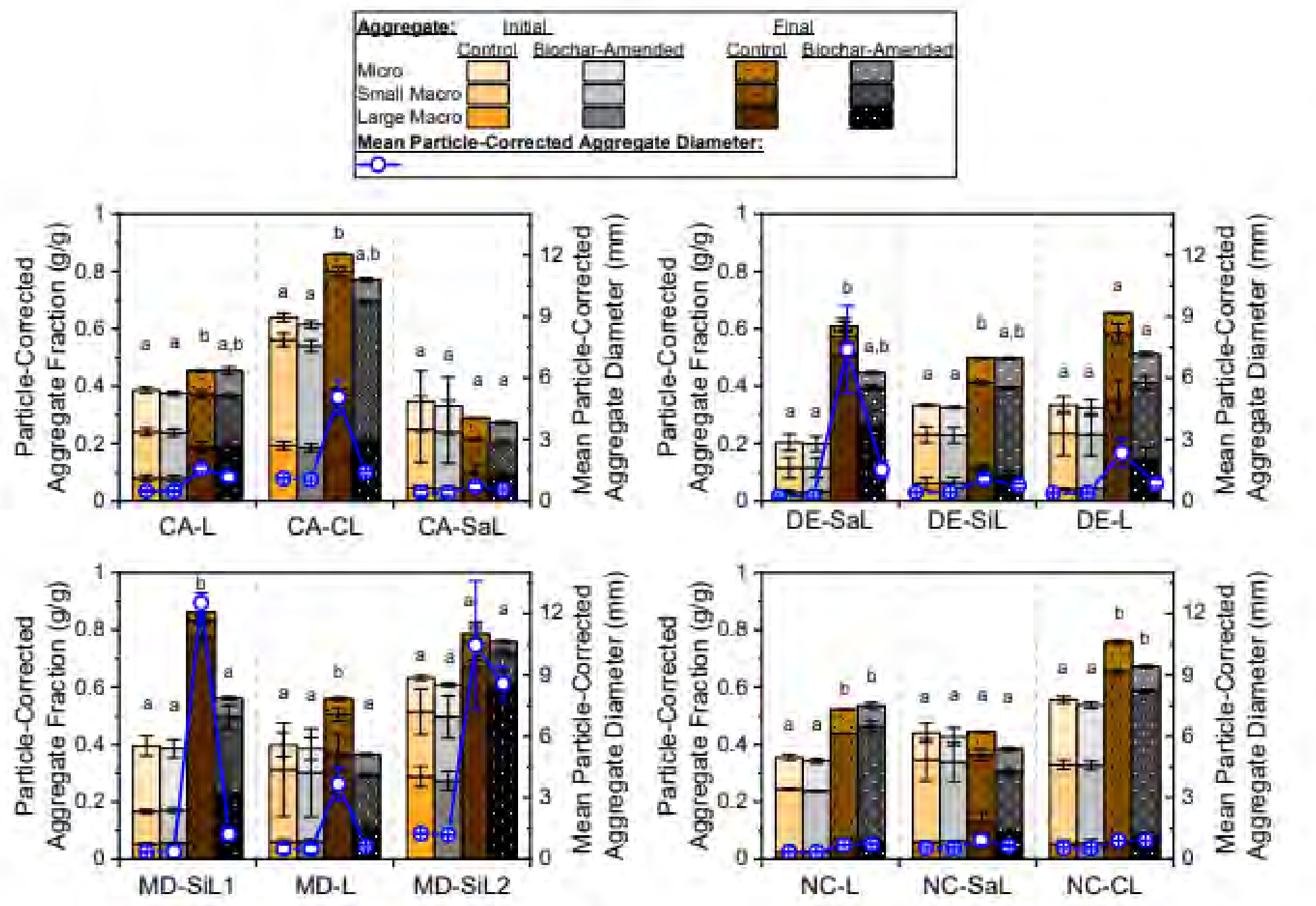
- Since this analysis is only analyzing aggregate sizes and not particle sizes, a sand particle correction is performed to remove all the particles from the mass distribution.
- Each set of soil is vigorously scrubbed until only the particles too large to fit through their respective sieves remain. The results are then dried, weighed, and subtracted from the original mass distribution.
- In order to summarize the mass distribution into one statistic, the mean weight diameter was calculated for each soil by multiplying the mass fraction and mean diameter for each category.

$$MD = \sum_{i=1}^{n} M_i * D_i$$

5. Results

- After performing this analysis for the soil right after they were grinded and packed into columns, as well as after they had aged, the following figures were produced for the original and sand-corrected mass distributions.





- One strange phenomenon was a sort of cementation effect present in a lot of the soil cores. Certain soil cores would hold a cylindrical structure throughout the entire wet-sieving process.

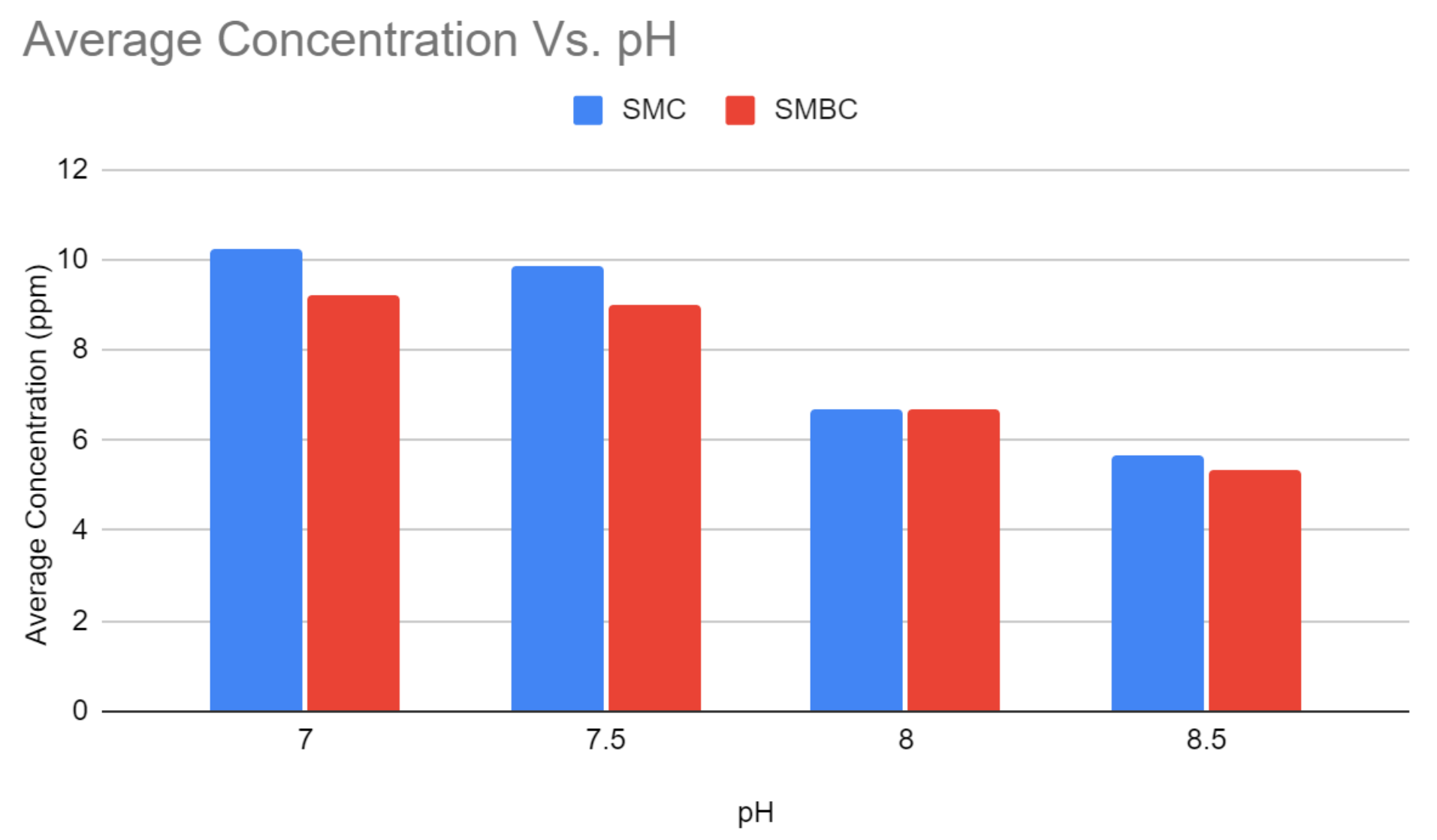
- Whether or not the mass distribution was sand-corrected, the biochar ended up decreasing aggregation in most cases since the cementation only occurred in soils without biochar.

6. Conclusions

- In the laboratory soils, the biochar generally increased aggregation, which is contrary to the results found at the field sites.
- While the aged soil wet-sieving was performed later than planned due the COVID-19 pandemic, the fresh soils also fail to mimic the results found in the field, leading the current procedures to be unfit for predicting the outcomes of applying biochar to roadway soils.

7. Other Research

- Biochar has also been known to both change the pH of the soil and affect the leaching of phosphorus from soil via runoff.
- To test how these could affect each other, a pseudo-soil made of sand, mulch, and compost was hydrated and sorted into centrifuge bottles, with half of the samples containing biochar.
- Storm events were simulated using a sulfate solution at different pH's. Each bottle was then shaken for 16 hours and centrifuged for 30 minutes to mix and separate a leachate from the soil.
- Extracting the liquid leachate from each bottle, the phosphate anion concentrations were measured for each trial using an ion chromatograph.



- Increasing pH and biochar content both lead to a lower phosphorus concentration in the leachate

8. Acknowledgements and References

I would like to thank the Delaware Water Resources Center and U.S. Geological survey, who funded this research along with Professor Paul Imhoff, Gerald Kauffman, Martha Narvaez, Andrew Homsey, and Lisa Moreland Allred who each worked hard to make this research possible.

[1] Nakhli, S. A. A.; Hegberg, C. H.; Imhoff, P. T. Reducing Stormwater Runoff with Biochar Addition to Roadway Soils. *Transportation Research Board* **2021**, No. 211.

Investigating the Utility of Bivalves as Biomonitors for Heavy Metal Contamination in the Delaware Bay

Nicole Gutkowski[1], Shannon Jones[2], Mi-Ling Li Sc.D.[3]

[1]Marine Science – Oceanography, [2]Marine BioSciences, [3]Department of Marine Science and Policy

University of Delaware

1. Background

- Due to the expansion of industry and urbanization, there are expected to be high levels of contamination in the Delaware Bay
- Concentration of pollutants in water levels are generally too low to measure, however bivalve's filtration of water and sediment allows contaminants to bioaccumulate within their tissues
- Bioaccumulation within bivalve tissues presents important applications in the aquaculture industry

2. Research Objectives

- Investigate utility of bivalves as biomonitors for mercury and Per- and Polyfluoroalkyl Substance (PFAS) contamination in the Delaware Bay
- Analyze concentrations of mercury and PFAS for bivalve, water, and sediment samples at each site
- Analyze concentration levels correlated with organism size and species
- Compare mercury and PFAS concentrations in water, sediment, and tissue samples

3. Hypothesis

There will be decreasing contamination concentrations with increasingly southern locations in the Delaware Bay due to reduced industry and increased mixing with the Atlantic Ocean

4. Methods

- Collect field samples from selected sites spaced along the Delaware Bay to assess the state of mercury contamination in the Delaware Bay
- Samples collected included bivalves, water, and sediment

Figure 1: Map of sites sampled in the Delaware Bay
Legend provides site names and characteristics that may have an impact on results

- Analyze field samples using the Direct Mercury Analyzer
- Utilize the samples' heavy metal concentrations to assess the spatial distribution of contaminants in the Delaware Bay

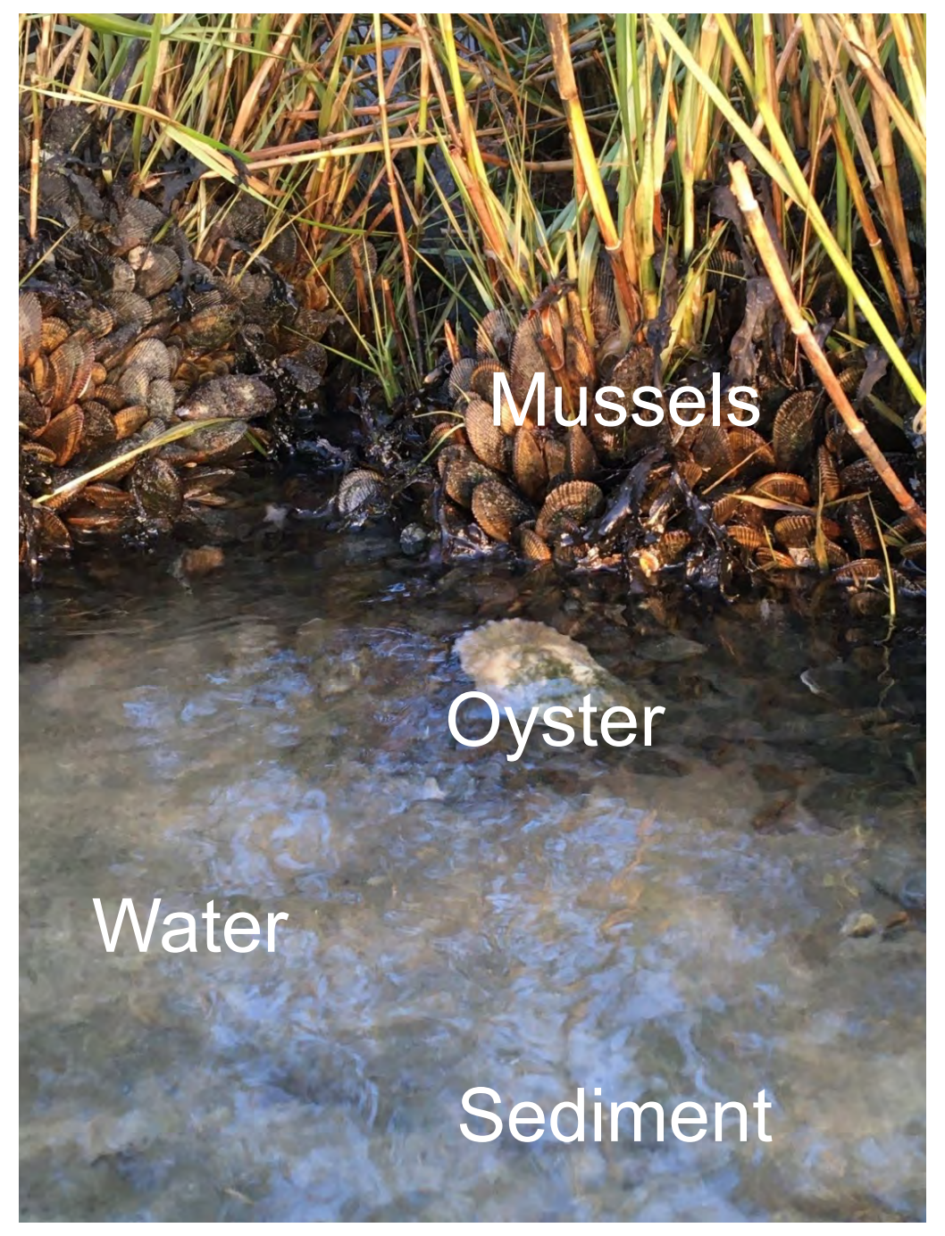


Figure 2: Oysters, mussels, water, and sediment samples were collected at each site

Figure 3: Measurement and weighing of mussel and oyster samples.

5. Results

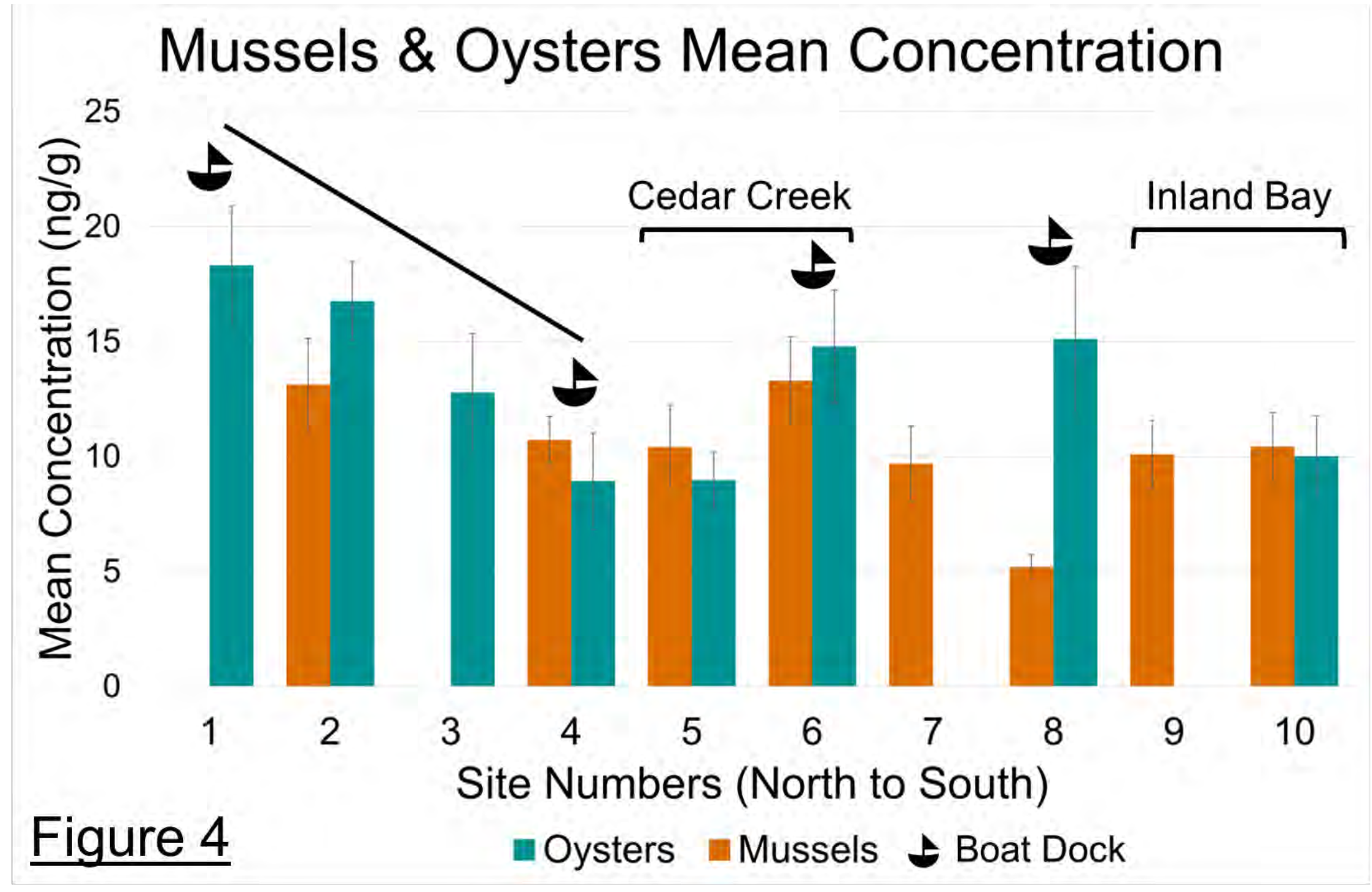


Figure 4

Figure 4:
- Sites 1 through 4 show a clear trend of decreasing mercury concentrations within oyster samples
- Sites 5 and 6 were located approximately 0.5 miles apart, however site 6's location at a boat ramp rather than directly on the bay is likely why concentration levels were higher than the concentrations at site 5
- The similar mercury concentrations at sites 6 and 8 despite their respective locations in the middle and lower bay indicate that the presence of watercraft at sampling locations plays an important role in contaminant concentrations
- Mean mercury concentrations of mussel samples did not appear to have any significant trends due to location.

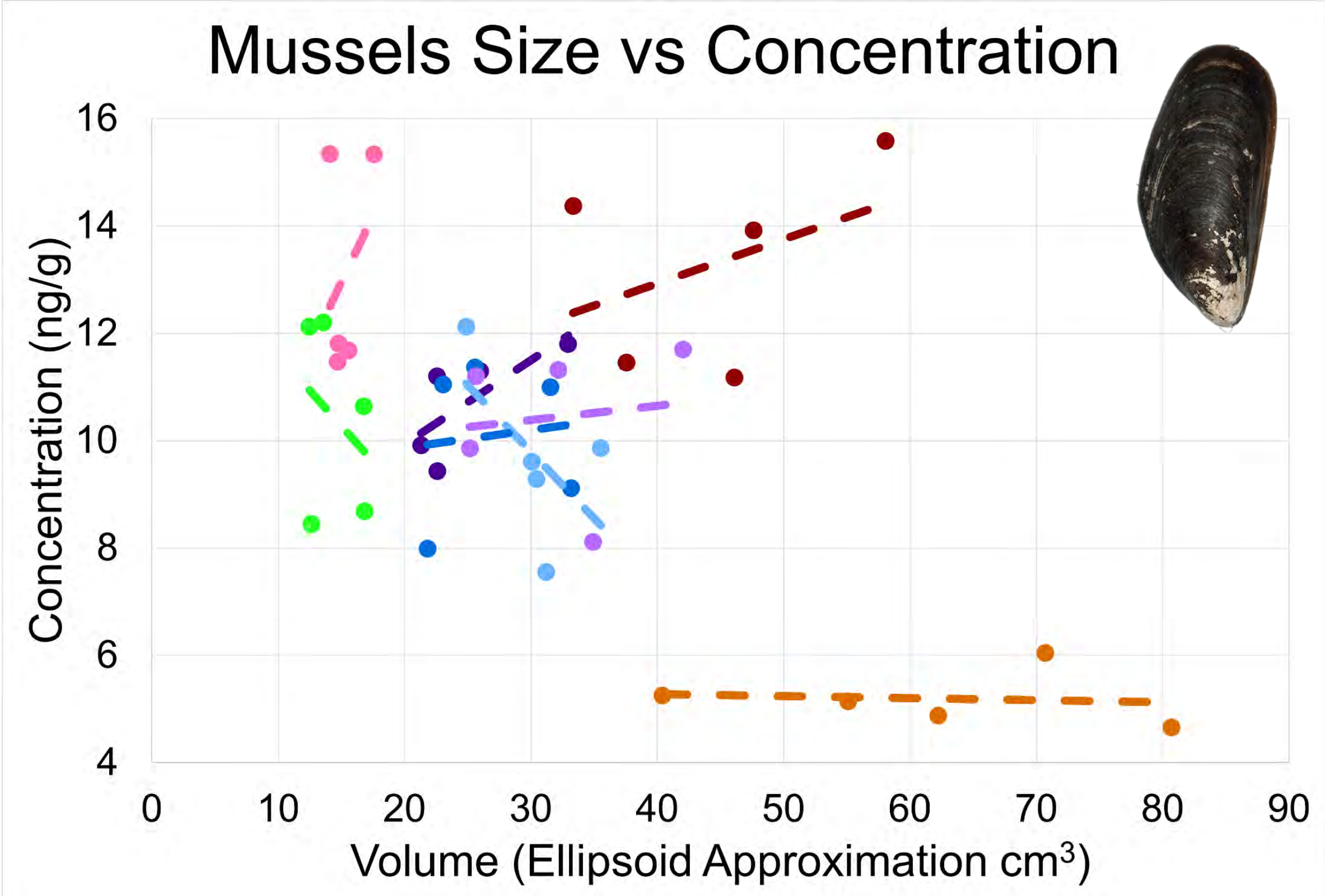


Figure 5: Mussel concentrations did not appear to have a consistent correlation with mussel size across locations. This indicates that the predominant factor in bioaccumulation of mercury in mussels is not mussel size

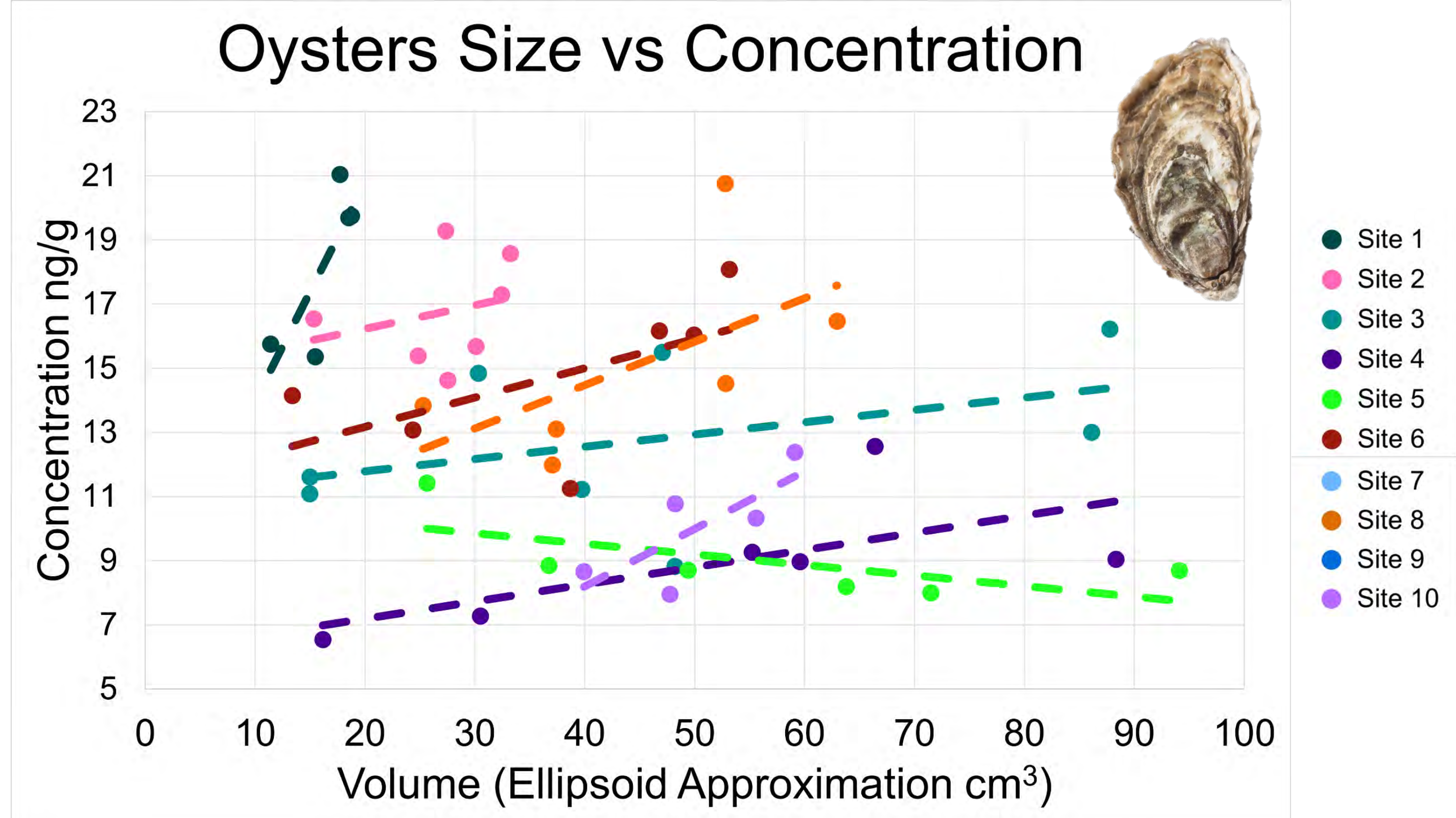


Figure 6: For all sites except for Site 5, there was a positive correlation between oyster size and mercury concentrations. This indicates the role of age in bioaccumulation of mercury in oysters

6. Future Research

- Analyze sediment samples for mercury concentration to assess correlation between mercury content in sediment and bivalve samples
- Analyze bivalve, sediment, and water samples to investigate whether bivalves are good biomonitors for PFAS

7. Acknowledgements

- This project was funded by the United States Geological Survey
- Special thanks to the University of Delaware Water Resources Center for guidance and all members of the Environmental Chemistry and Toxicology Group

8. References

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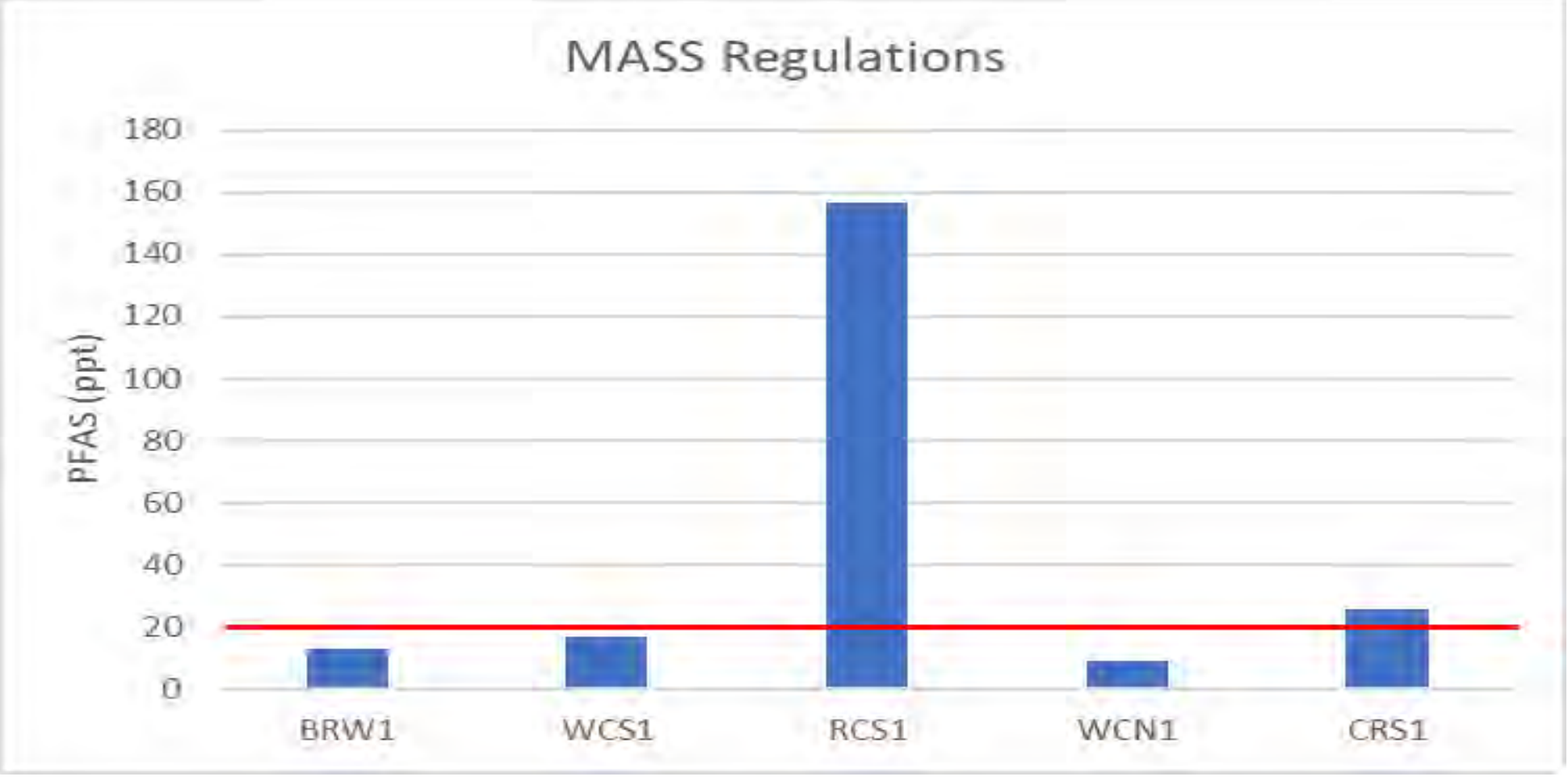
PFAS Analysis Along the Four Drinking Water Streams in New Castle Delaware

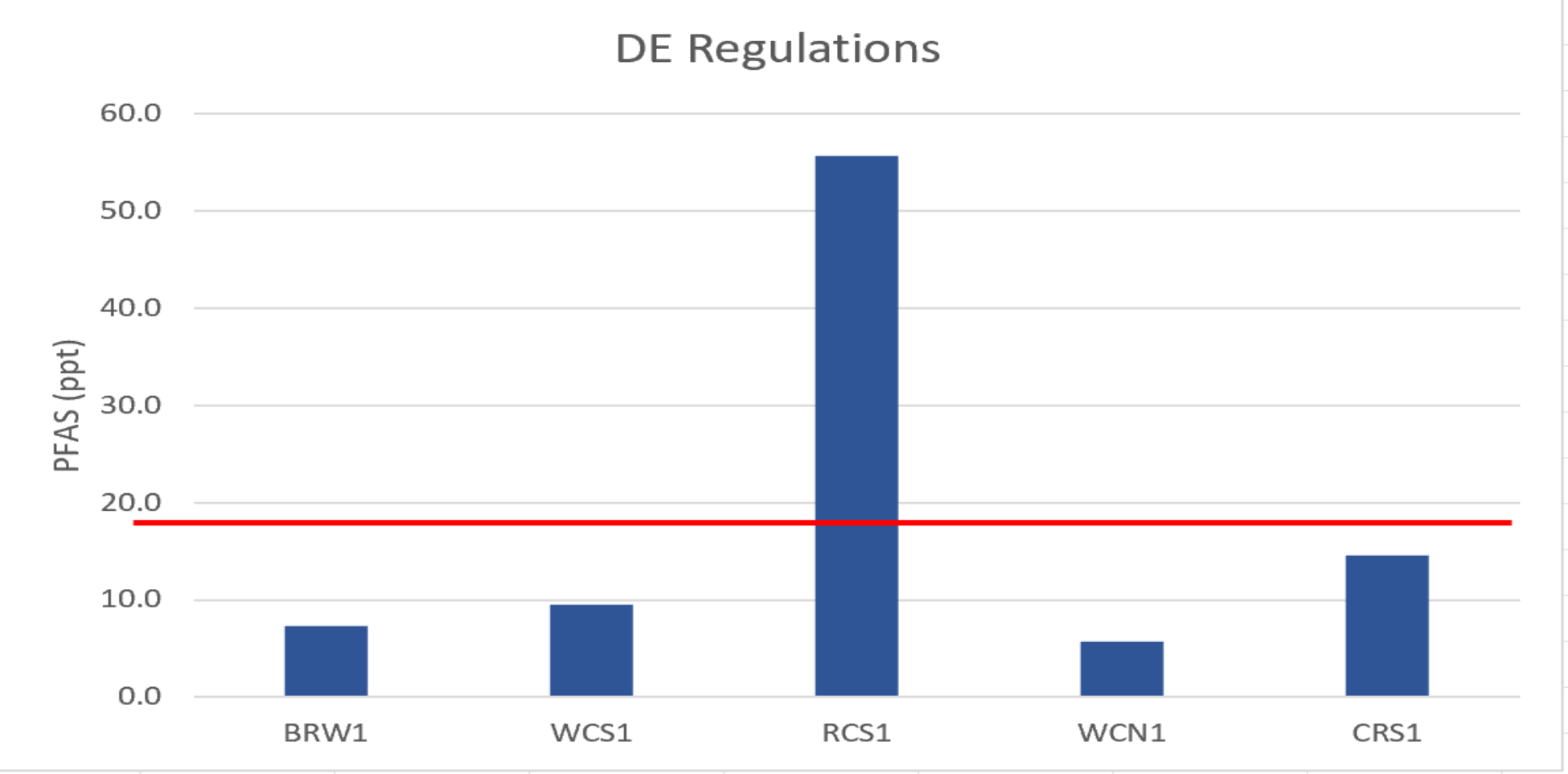
Megan Jarocki, Environmental Engineering; Sophia Talley, Environmental Engineering;
Megan Wassil, Environmental Engineering

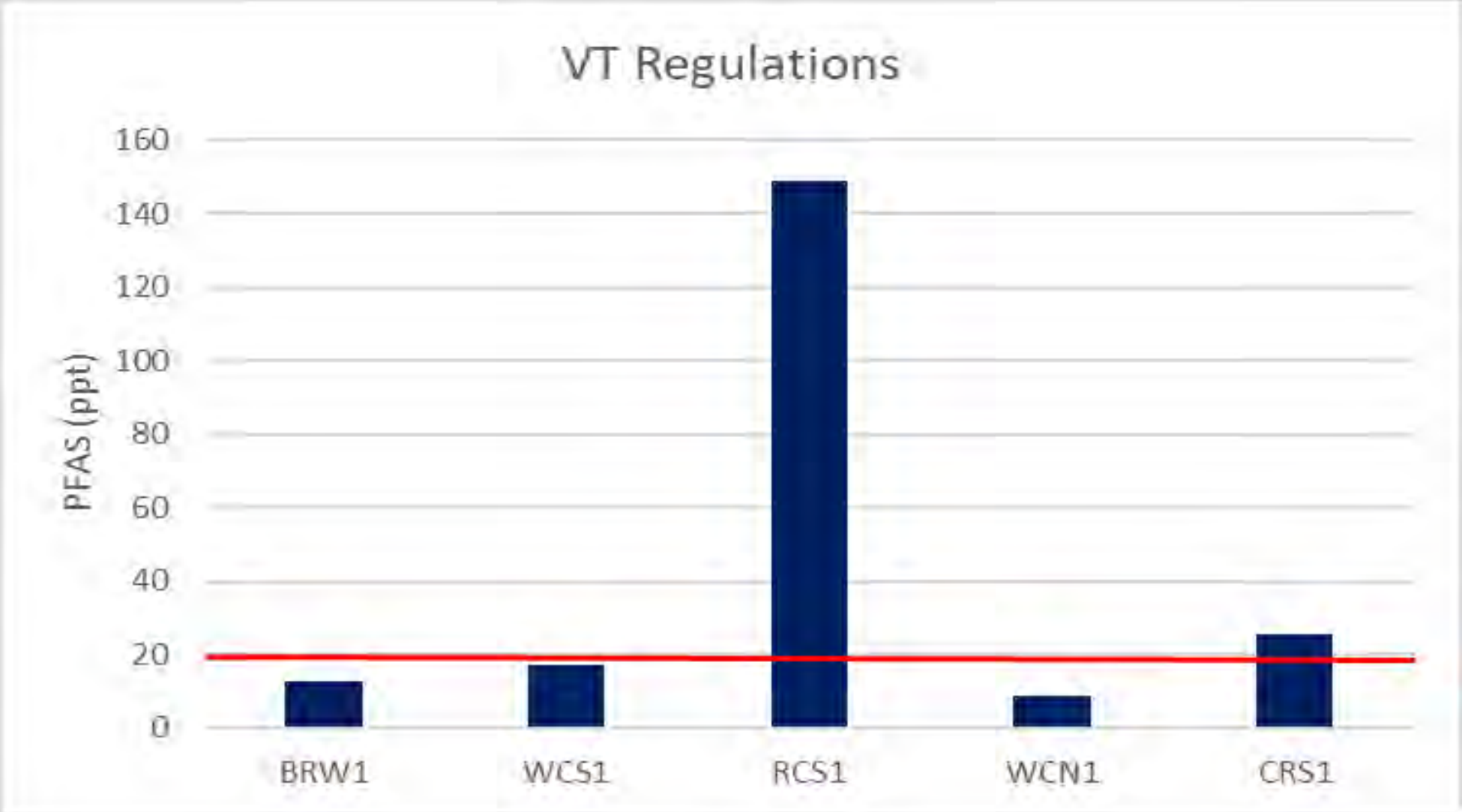
Purpose/Objective

1. Analyze water from Red Clay Creek, White Clay Creek, Brandywine Creek, and Christina River for 40 PFAS, Per- and Polyfluoroalkyl Substances, per US EPA method 1633
2. Understand PFAS prevalence in surface water in Delaware drinking water sources

Initial Testing



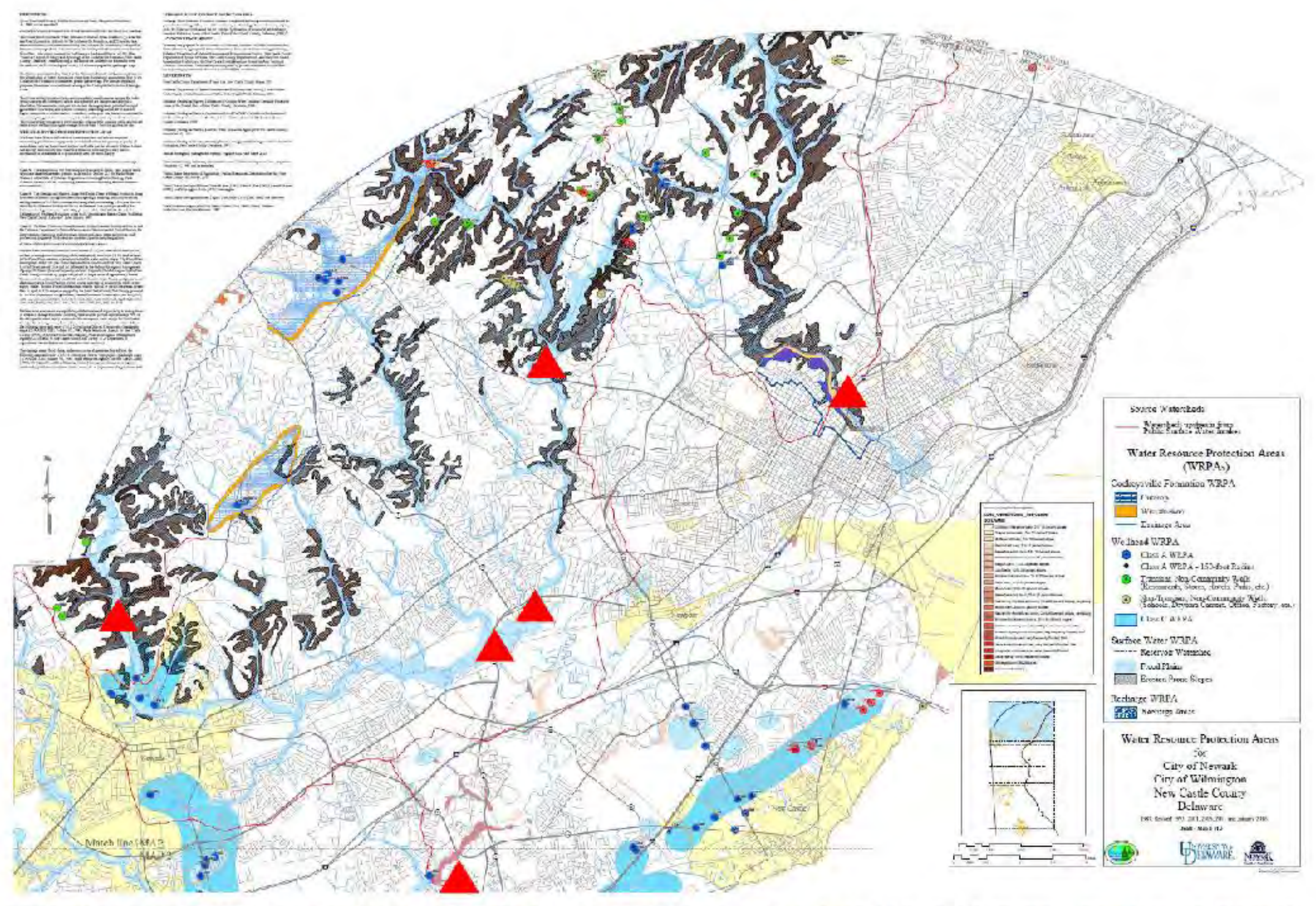




	BRW1	WCS1	RCS1	WCN1	CRS1
SUM MASS	12.9	17.0	156.7	9.0	25.6
SUM VT	12.9	17.0	148.7	9.0	25.6
SUM DE	7.3	9.5	55.6	5.7	14.5

The red line represents the regulated limit of PFAS in drinking water

Sampling Locations



UDWRC undergraduate research students collected PFAS samples along 4 streams upstream from the 5 drinking water intakes in Delaware:

BRW1: Brandywine River at Wilmington - Footbridge just upstream from City Dam 2 above I-95 bridge
RCS1: Red Clay Creek at Stanton (SUEZ DE) - Downstream from Rte 4 bridge near Glenville neighborhood
RCH1: Red Clay Creek at Hoopes Reservoir - Along Barley Mill Road at Hoopes Reservoir outlet
WCS1: White Clay Creek at Stanton (SUEZ DE) - Downstream from Old Rte 7 bridge near Delaware Race Track
WCN1: White Clay Creek at Newark - Creek Road at first footbridge north of Newark
CRS1: Christina River at Smalley's Pond (SUEZ DE) - Salem Church Rd bridge

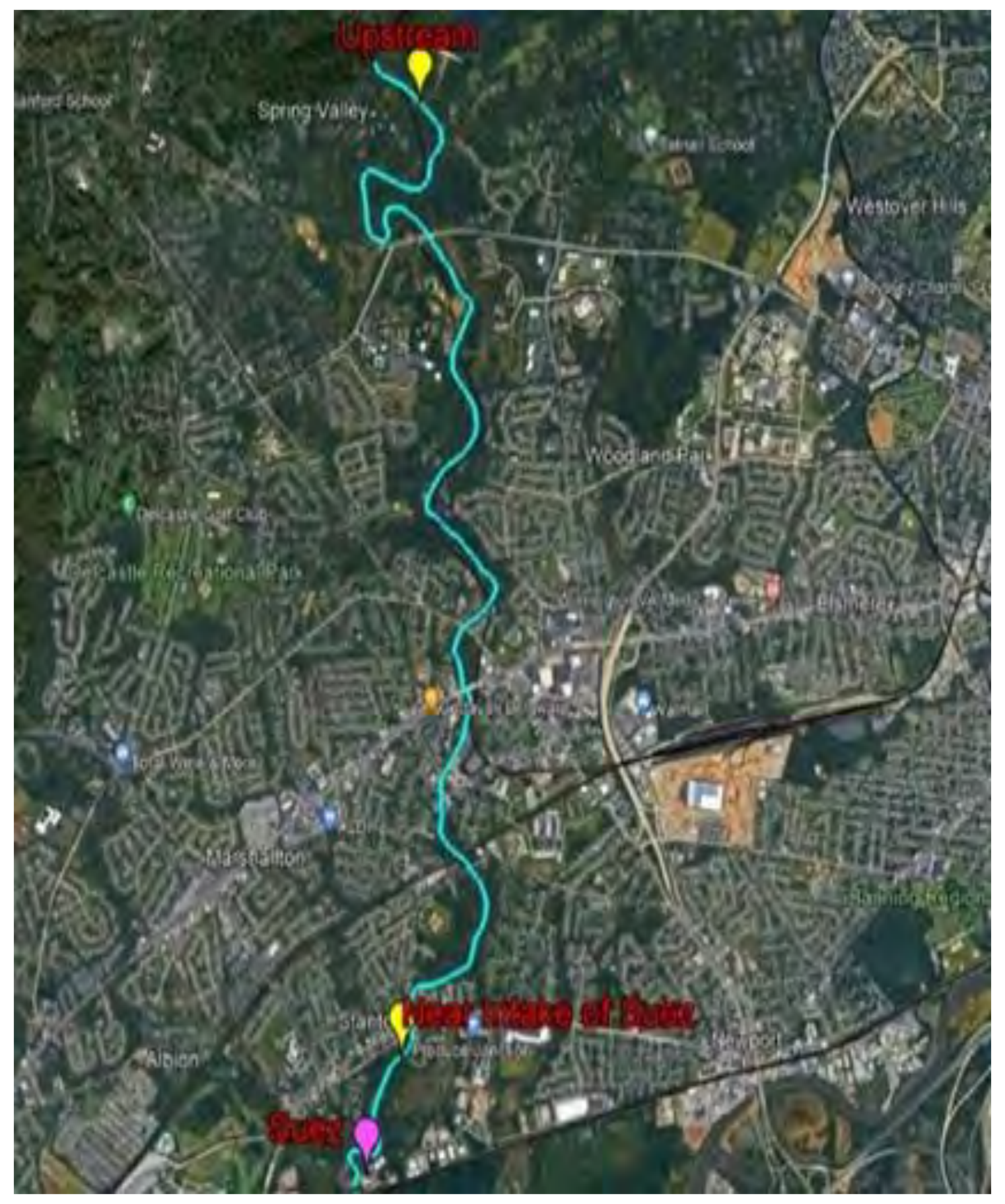
Initial Sampling - (11/19/2021)

- Brandywine Creek at Wilmington - BRW1
- Red Clay Creek at Stanton (SUEZ DE) - RCS1
- White Clay Creek at Newark - WCN1
- White Clay Creek at Stanton (SUEZ DE) - WCS1
- Christina River above Smalley's Pond - CRS1

Repeated Sampling - (2/18/2022)

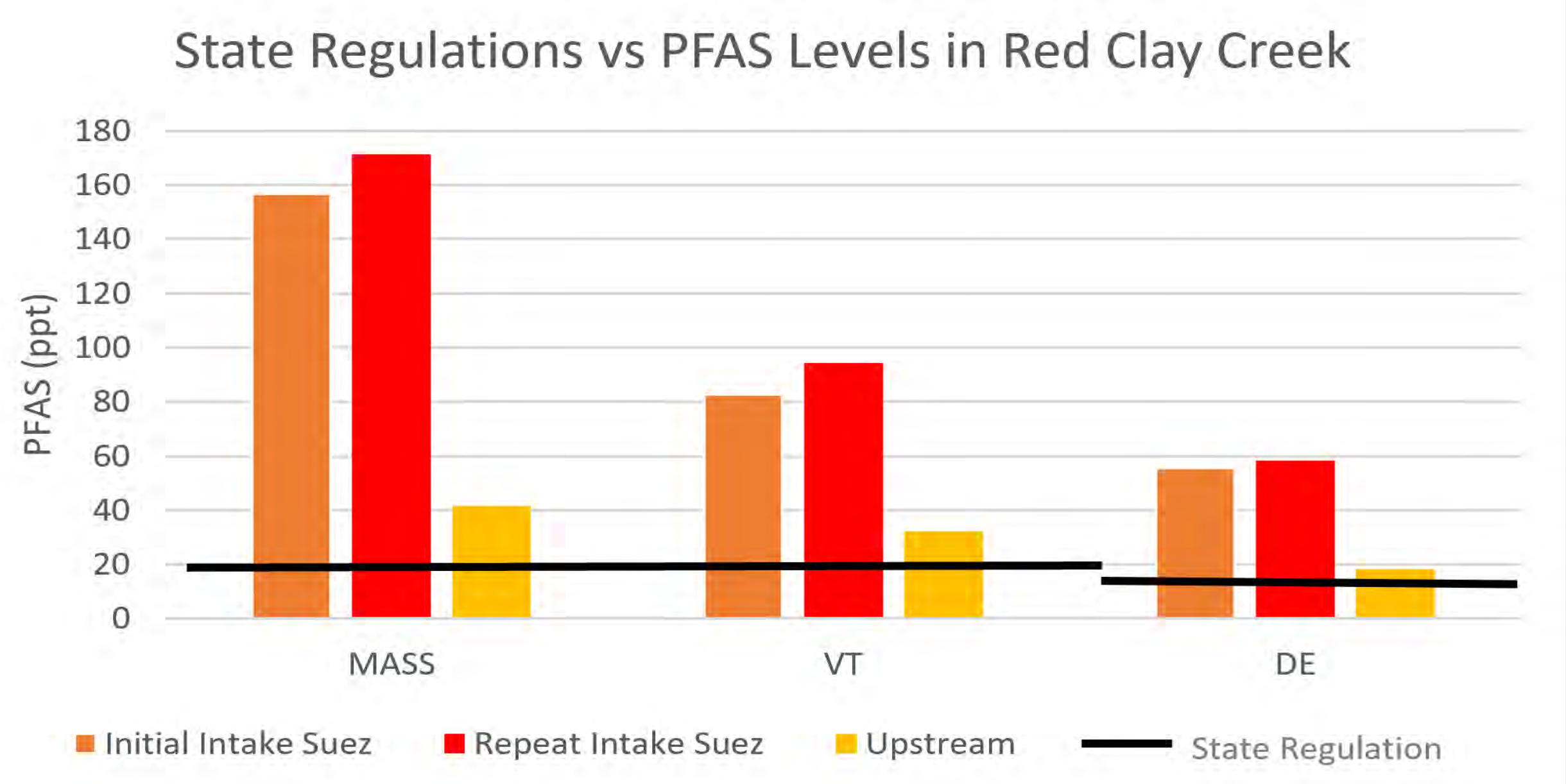
- Red Clay Creek at Stanton (SUEZ DE) - RCS1
- Red Clay at Hoopes Reservoir - RCH1

Sampling at Red Clay



Map of Sampling upstream and downstream of SUEZ intake site

Red Clay Creek



	Initial Sample: RCS1 (ppt)	Repeat Sample: RCS1 (ppt)	RCH1 (ppt)
PFOS	2.6	6.2	6.2
PFOA	53.0	52	12
PFHxS	2.1	2.1	2
PFNA	25.0	34	12
PFHpA	66.0	55	7.7
PFDA	8.0	22	1.8
MASS	156.7	171.3	41.7
VT	82.7	94.3	32.2
DE	55.6	58.2	18.2

Observations

(11/19/2021)

- PFAS values when compared to state standards showed normal concentrations in all sites except the Red Clay Creek
- Due to the higher concentrations found in Red Clay Creek repeat sampling was decided to be the next step

(2/18/2022)

- Sampled upstream and downstream of intake at Red Clay Creek in SUEZ DE
- Found that concentration downstream of the Red Clay Creek at Hoopes Reservoir had elevated levels of PFAS

Since we discovered that the PFAS levels upstream on the Red Clay Creek were low and the levels downstream along the Red Clay Creek were high we know that the contamination is coming from somewhere between the two

State Standards

We compared our site samples with set PFAS standards of Vermont and Massachusetts to contextualize the values.

	MASS MCL (ppt)	VT MCL (ppt)	DE MCL (ppt)
PFOS	PFOS	PFOS	PFOS
PFOA	PFOA	PFOA	PFOA
PFHxS	PFHxS	PFHxS	
PFNA	PFNA	PFNA	
PFHpA	PFHpA	PFHpA	
PFDA	PFDA		
SUM	20	20	17

Recommendations

- Annual sampling of sites of the four-drinking water sources
- Determine specific location of PFAS contamination along the Red Clay to be able to begin remediation efforts

References

Kauffman, G., & Homsey, A. (2022). (rep.). *PFAS Sampling Along Delaware Drinking Water Streams*.

Powley, C., Anton, J., Coleman-Kammula, S., & Kauffman, G. (2022). (rep.). *Per- and polyfluoroalkyl substances (PFAS) in Surface water in Delaware*. Newark, DE.

Acknowledgements

We would like to thank the University of Delaware Water Resource Center who provided funding to make this project possible. Continually, we would like to thank Martha Narvaez, Dr. Gerald Kauffman, Andrew Homsey, and Jessica Anton for their support and guidance.

Water Quality Sampling and Analysis Along the White Clay Creek National Wild and Scenic River in DE and PA

Megan Jarocki, Environmental Engineering; Sophia Talley, Environmental Engineering; Megan Wassil Environmental Engineering

1. Objective

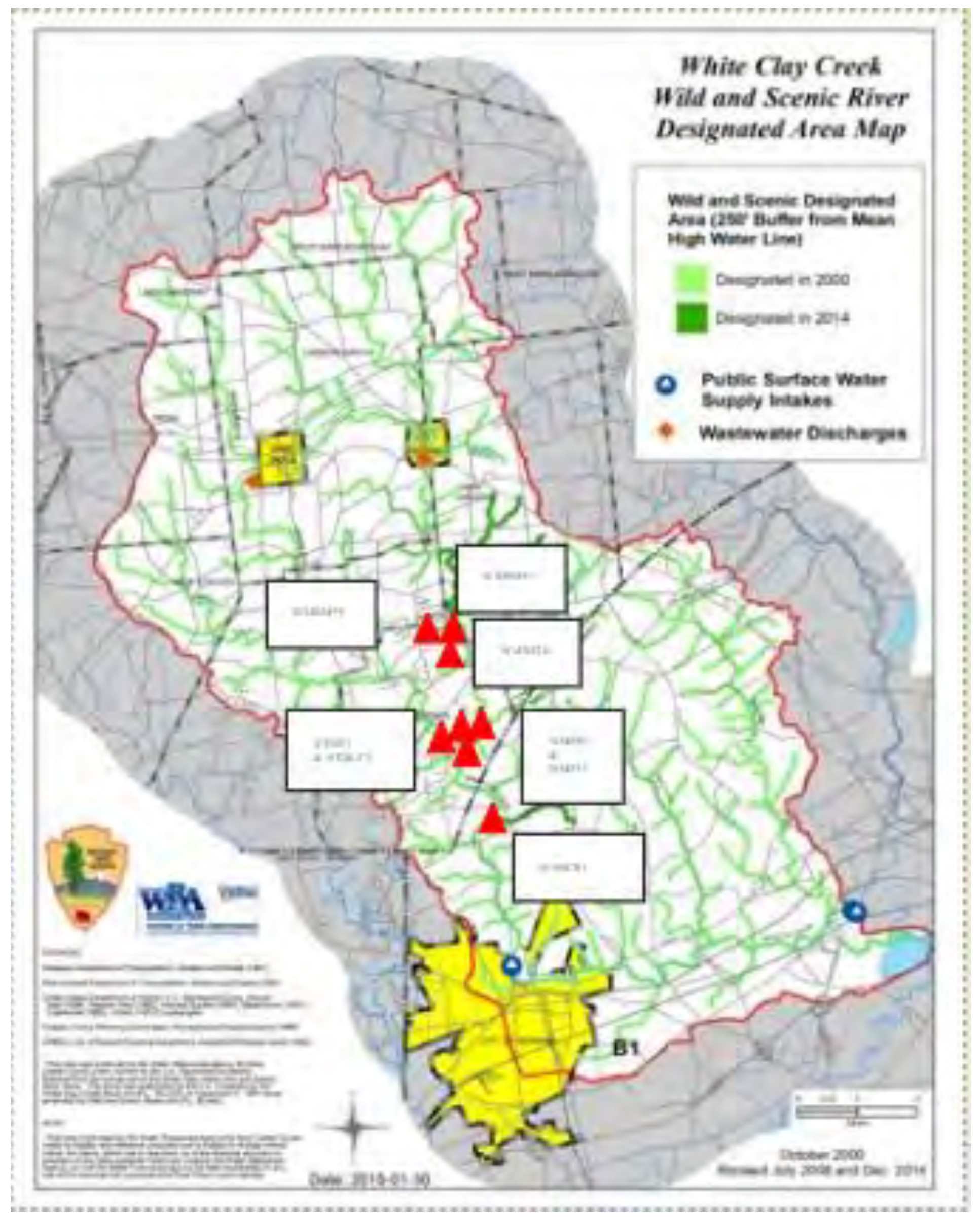
- Sample and test surface water in the PA portion of the White Clay Creek
- Determine the source of high nitrogen concentrations in Newark's drinking water
- Use lab data to analyze other water quality metrics
- Goal: Establish real time monitoring at USGS Stream gauge for the White Clay Creek Station near Strickersville

2. Legend

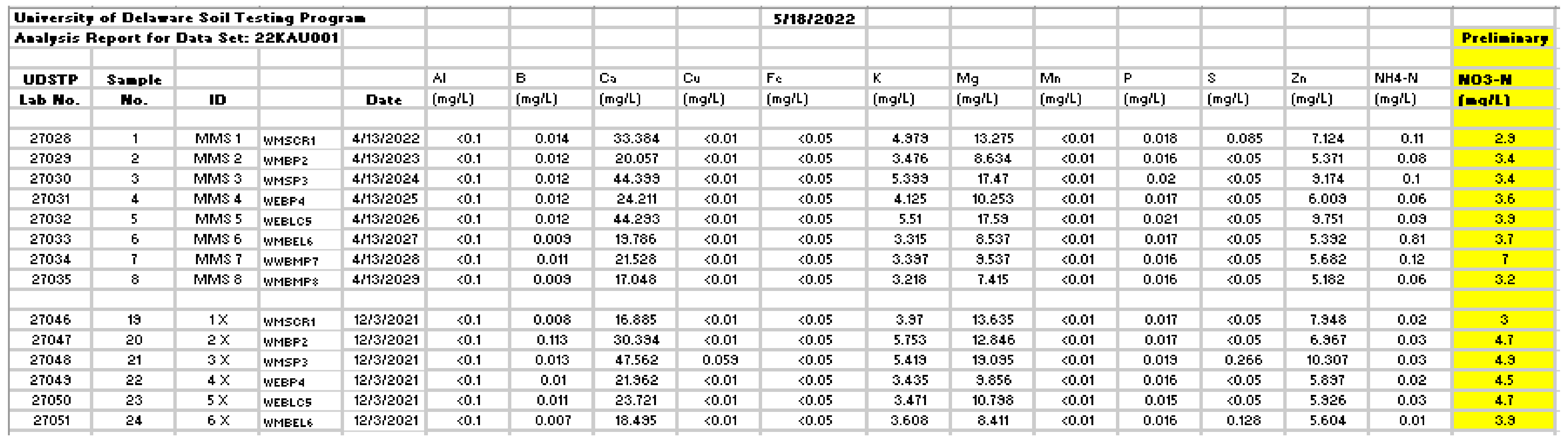
- WMSCR1: Site 1 – Chambers Rock
- WMBP2: Site 2 – White Clay Creek Preserve
- WMSP3: Site 3 – White Clay Creek Preserve
- WEBP4: Site 4 – White Clay Creek Preserve
- WEBLC5: Site 5 – Landenberg Church
- WMBEL6: Site 6 – Edwin Leid Trail
- WWBMP7: Site 7 – Mercer Park
- WMBMP8: Site 8 – Mercer Park

EB – East Branch
MB – Middle Branch
MS – Main stem
WB – West Branch

3. Map of Sites

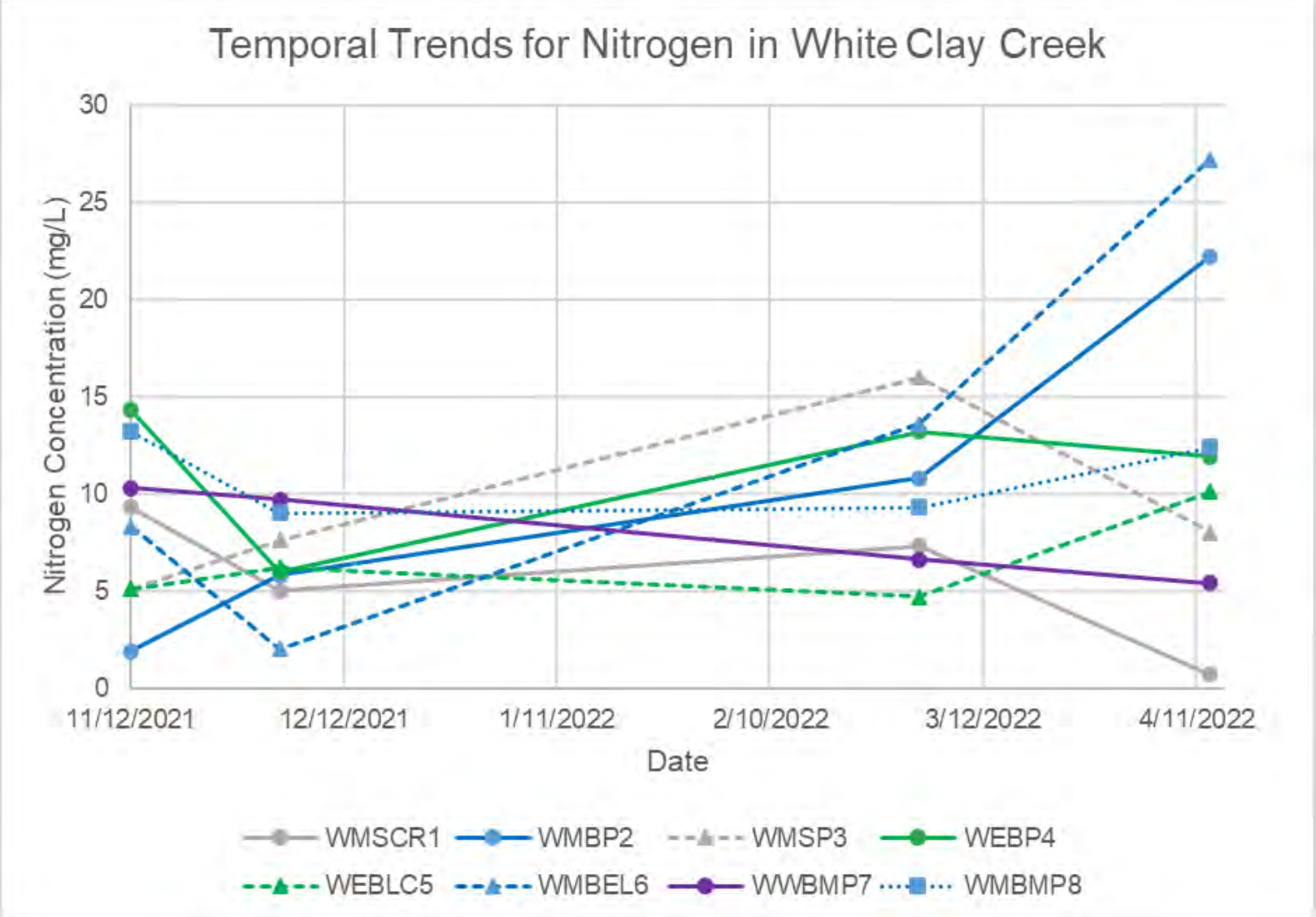


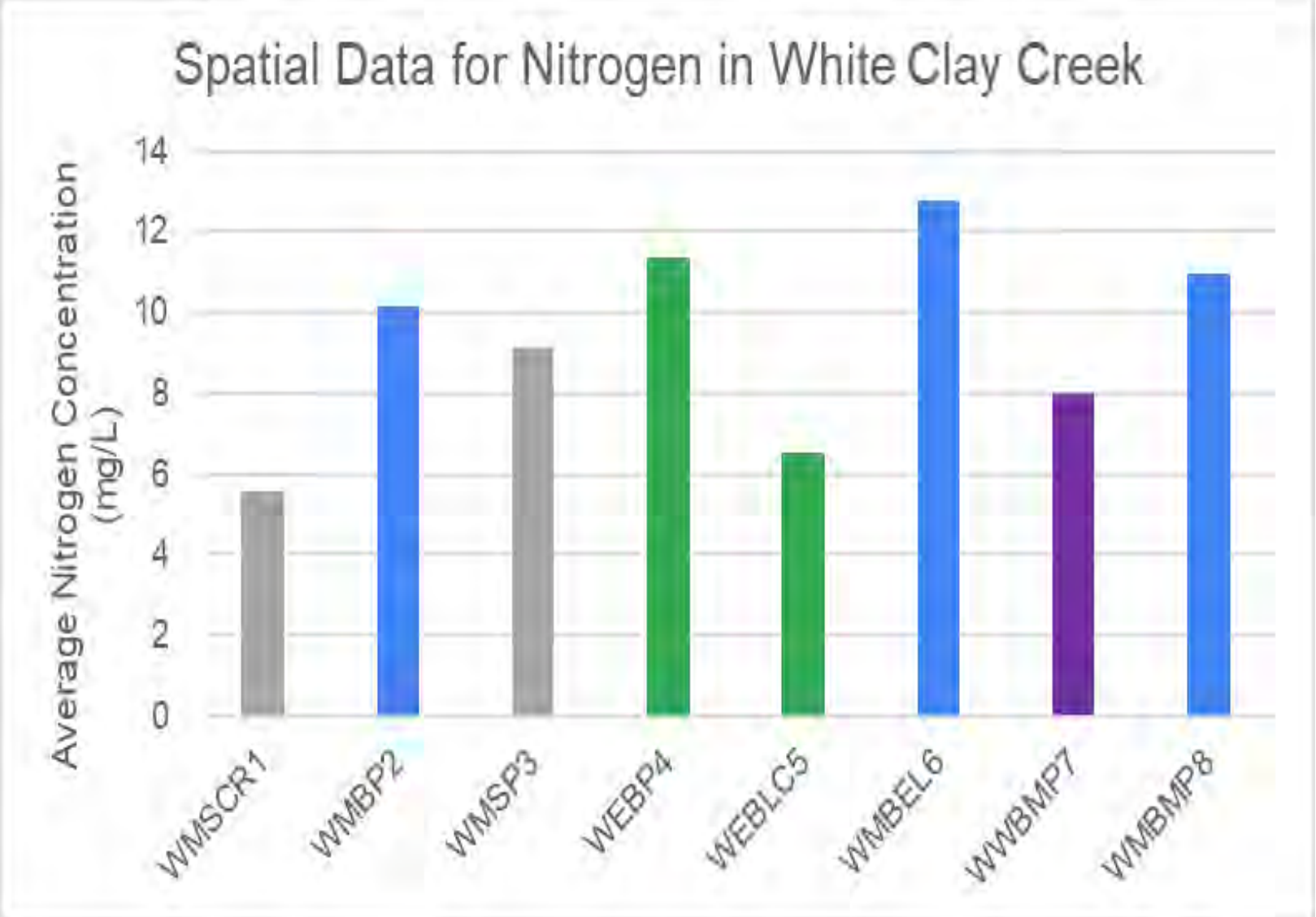
4. Results

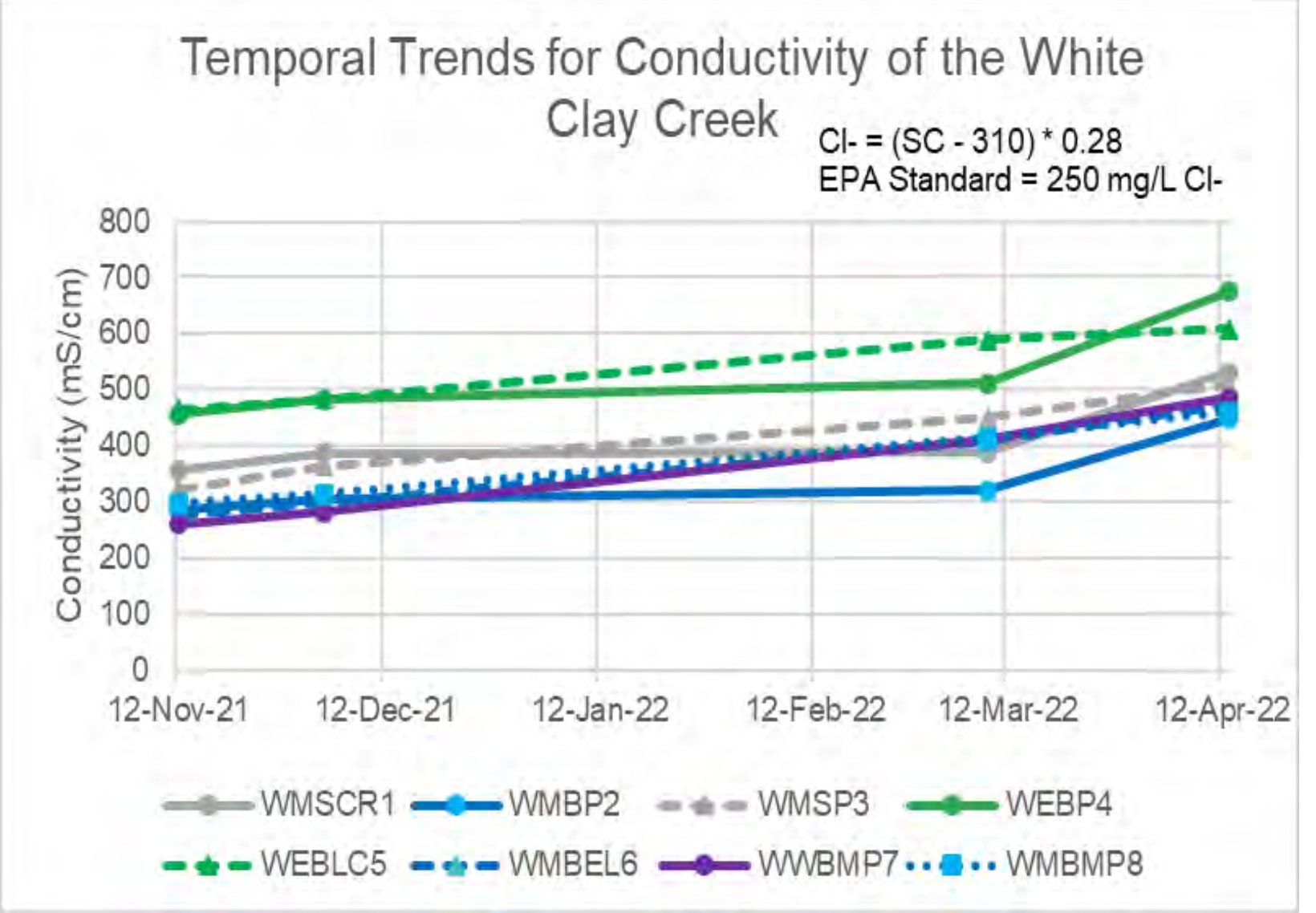


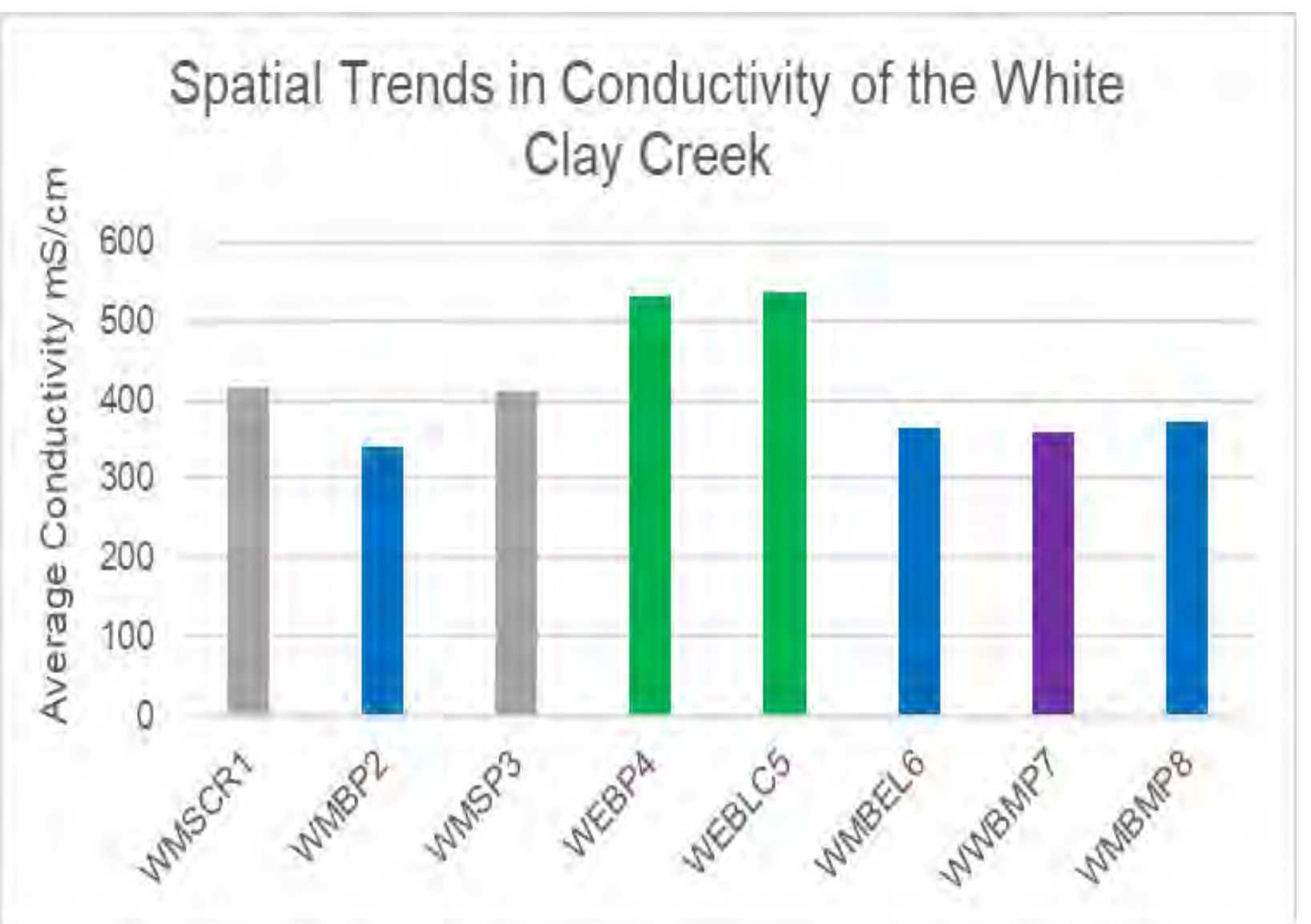
University of Delaware Soil Testing Program **5/18/2022**
Analysis Report for Data Set: 22KAU001 **Preliminary**

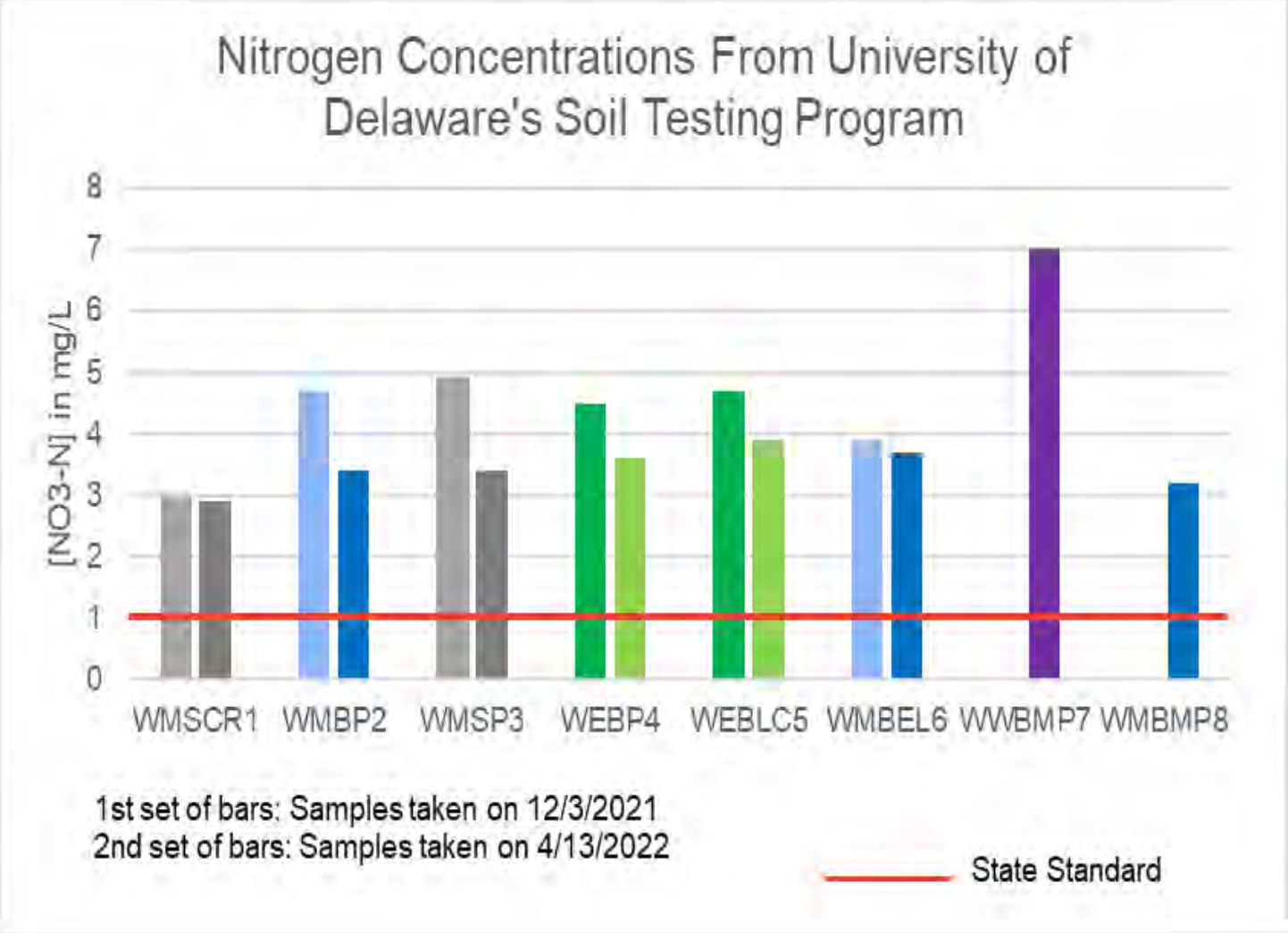
UDSTP Lab No.	Sample No.	ID		Date	Al (mg/L)	B (mg/L)	Ca (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	P (mg/L)	S (mg/L)	Zn (mg/L)	NH4-N (mg/L)	NO3-N (mg/L)
27028	1	MMS 1	WMSCR1	4/13/2022	<0.1	0.014	33.384	<0.01	<0.05	4.979	13.275	<0.01	0.018	0.085	7.124	0.11	2.9
27029	2	MMS 2	WMBP2	4/13/2023	<0.1	0.012	20.057	<0.01	<0.05	3.476	8.634	<0.01	0.016	<0.05	5.371	0.08	3.4
27030	3	MMS 3	WMSP3	4/13/2024	<0.1	0.012	44.399	<0.01	<0.05	5.399	17.47	<0.01	0.02	<0.05	9.174	0.1	3.4
27031	4	MMS 4	WEBP4	4/13/2025	<0.1	0.012	24.211	<0.01	<0.05	4.125	10.253	<0.01	0.017	<0.05	6.009	0.06	3.6
27032	5	MMS 5	WEBLC5	4/13/2026	<0.1	0.012	44.293	<0.01	<0.05	5.51	17.59	<0.01	0.021	<0.05	9.751	0.09	3.9
27033	6	MMS 6	WMBEL6	4/13/2027	<0.1	0.009	19.786	<0.01	<0.05	3.315	8.537	<0.01	0.017	<0.05	5.392	0.81	3.7
27034	7	MMS 7	WWBMP7	4/13/2028	<0.1	0.011	21.528	<0.01	<0.05	3.397	9.537	<0.01	0.016	<0.05	5.682	0.12	7
27035	8	MMS 8	WMBMP8	4/13/2029	<0.1	0.009	17.048	<0.01	<0.05	3.218	7.415	<0.01	0.016	<0.05	5.182	0.06	3.2
27046	19	1 X	WMSCR1	12/3/2021	<0.1	0.008	16.885	<0.01	<0.05	3.97	13.635	<0.01	0.017	<0.05	7.948	0.02	3
27047	20	2 X	WMBP2	12/3/2021	<0.1	0.113	30.394	<0.01	<0.05	5.753	12.846	<0.01	0.017	<0.05	6.967	0.03	4.7
27048	21	3 X	WMSP3	12/3/2021	<0.1	0.013	47.562	0.059	<0.05	5.419	19.095	<0.01	0.019	0.266	10.307	0.03	4.9
27049	22	4 X	WEBP4	12/3/2021	<0.1	0.01	21.962	<0.01	<0.05	3.435	9.856	<0.01	0.016	<0.05	5.897	0.02	4.5
27050	23	5 X	WEBLC5	12/3/2021	<0.1	0.011	23.721	<0.01	<0.05	3.471	10.798	<0.01	0.015	<0.05	5.926	0.03	4.7
27051	24	6 X	WMBEL6	12/3/2021	<0.1	0.007	18.435	<0.01	<0.05	3.608	8.411	<0.01	0.016	0.128	5.604	0.01	3.9


Temporal Trends for Nitrogen in White Clay Creek

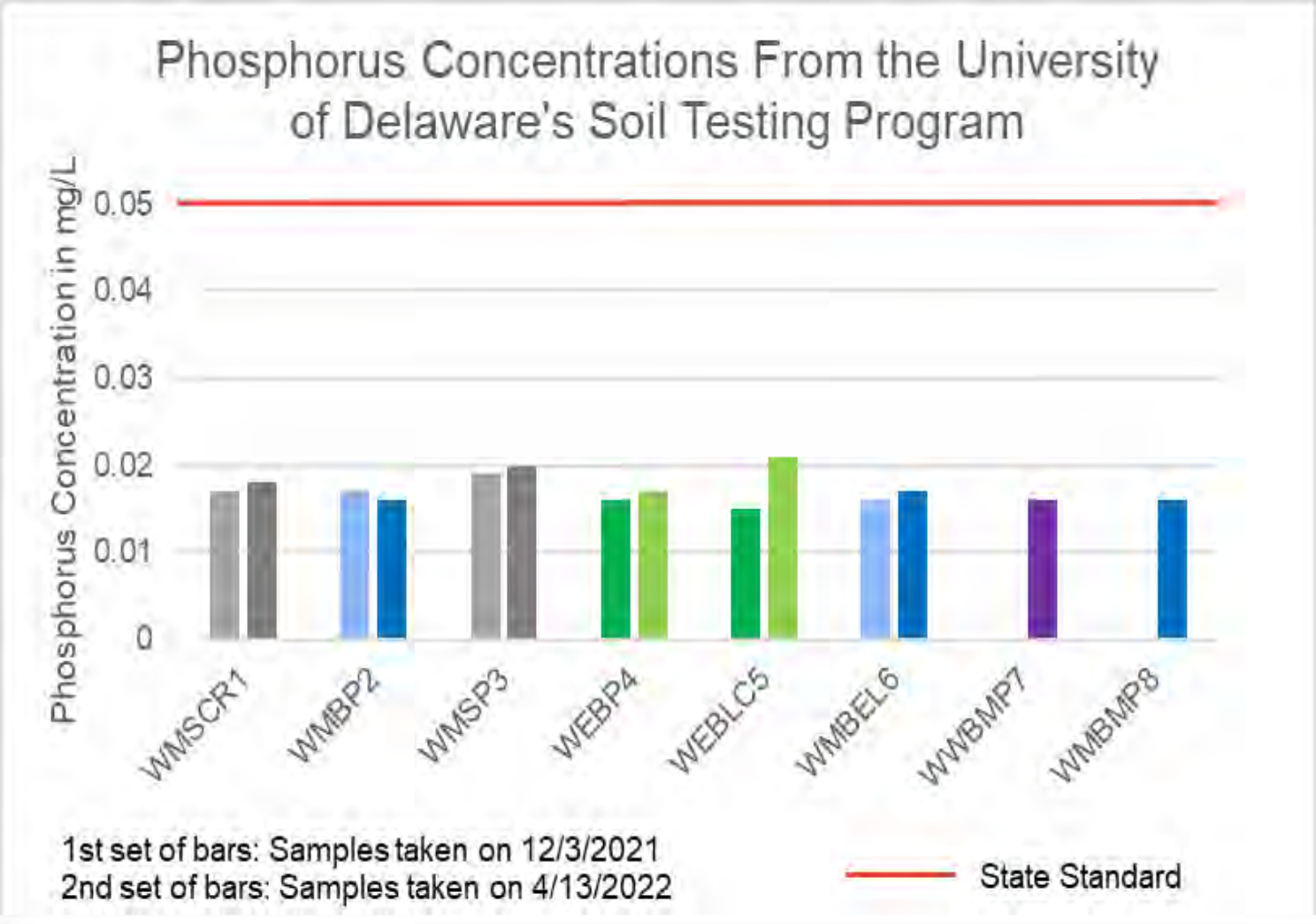

Spatial Data for Nitrogen in White Clay Creek


Temporal Trends for Conductivity of the White Clay Creek

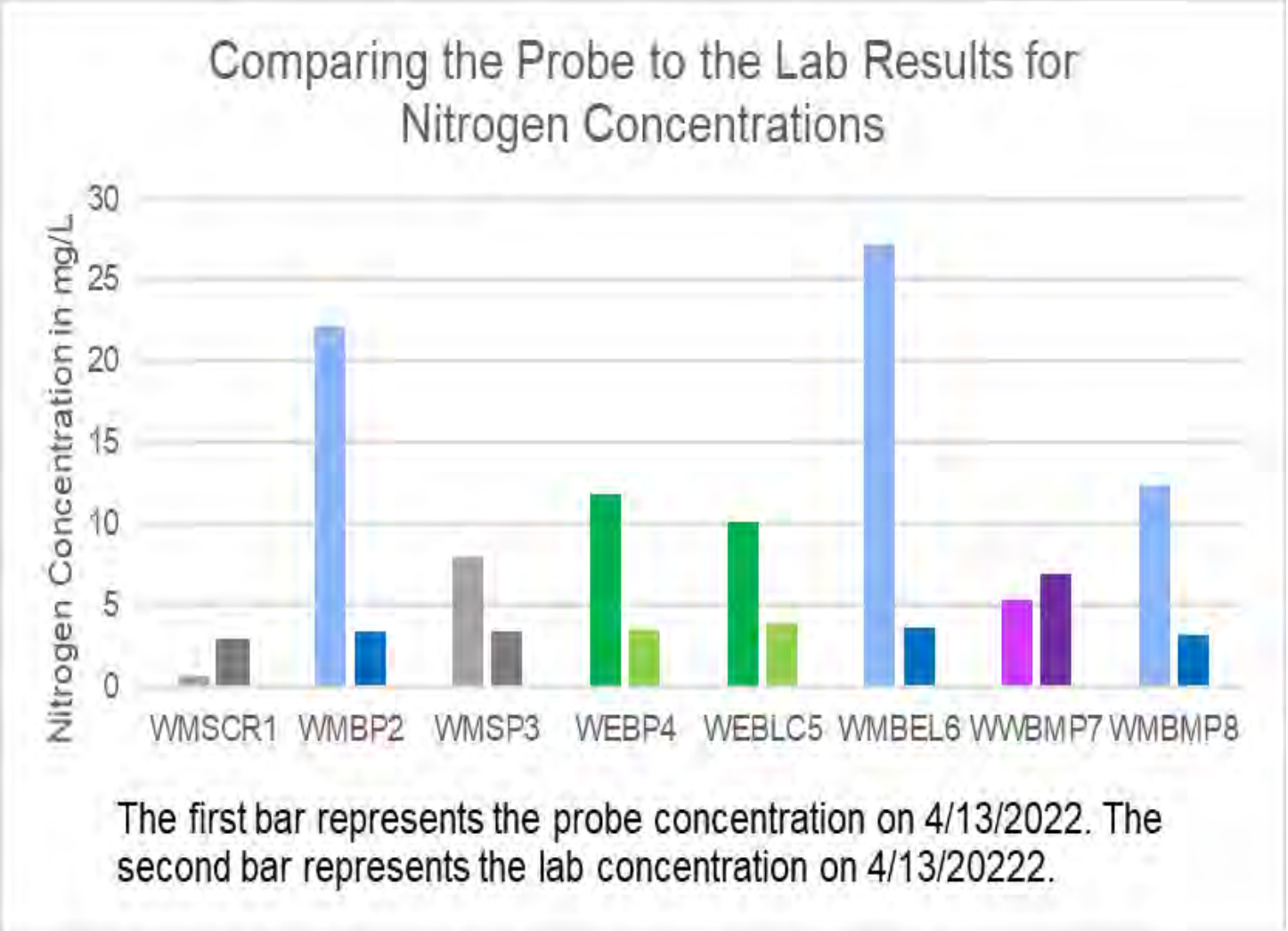

Spatial Trends in Conductivity of the White Clay Creek


Nitrogen Concentrations From University of Delaware's Soil Testing Program

1st set of bars: Samples taken on 12/3/2021
2nd set of bars: Samples taken on 4/13/2022


Phosphorus Concentrations From the University of Delaware's Soil Testing Program

1st set of bars: Samples taken on 12/3/2021
2nd set of bars: Samples taken on 4/13/2022


Comparing the Probe to the Lab Results for Nitrogen Concentrations

The first bar represents the probe concentration on 4/13/2022. The second bar represents the lab concentration on 4/13/20222.

The red line represents the allowable limit of nutrients in drinking water from DNREC standards.

5. Observations

- Each branch of the White Clay has had concentrations of nitrogen above the allowable limit over the course of our testing
- The middle branch of the White Clay has had the highest concentrations
- The east branch is contributing more nitrogen to the main branch compared to the west branch
- Nitrogen concentrations in the White Clay Creek increased in the spring with warmer water temperatures
- When comparing the probe concentrations to the lab concentrations the probe tended to overestimate the amount of Nitrogen in the water
- We did take measurements of turbidity at every site however, the meter was often broken or read a value of 0.0 when that was not accurate

6. Recommendations

- More testing is needed to be able to draw concrete conclusions about the source of nitrogen in the White Clay Creek
- The east and middle branches seem to be areas of concern, so specific monitoring and efforts to reduce nitrogen may be called for
- Establish a real time monitoring USGS stream gauge at White Clay Creek near Strickersville

7. Acknowledgements

We would like to thank the University of Delaware Water Resource Center who provided funding to make this project possible. Continually, we would like to thank Martha Narvaez, Dr. Gerald Kauffman, and Andrew Homsey for their support and guidance.

Water Quality Analysis of the Water Supply System Along the White Clay Creek in & Around Newark Delaware

Brian Kennedy[1], Erik Rodriguez[2]
Advisor Dr. Gerald Kauffman & Andrew Homesy
[1]Energy and Environmental Policy, [2]Environmetnal Engineering

1. Abstract

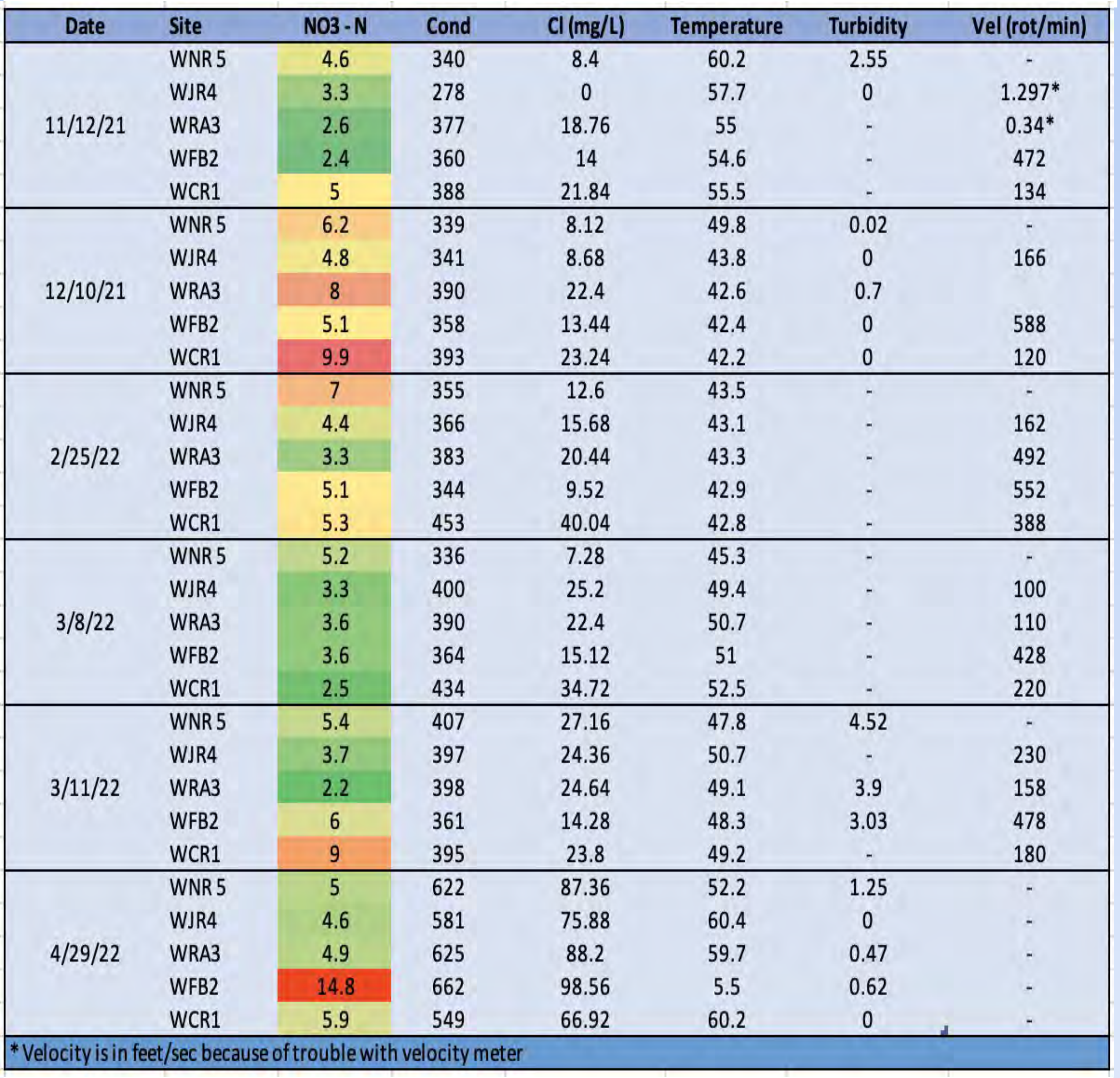
Through tracking different nutrient levels throughout the White Clay Creek Watershed, we were tasked with determining whether or not the White Clay forest is doing an adequate job at filtering the water that ends up becoming the City of Newark's drinking water. We did this by taking probing samples while in the field with portable testing equipment and taking grab samples to be analyzed at the agricultural campus lab. We collected data on nutrients such as nitrates, chlorine and phosphorus and their levels in the White Clay Creek. Even though nutrient levels were majorly held below the health standard, we determined that the forest is not doing an adequate job of filtering nutrients as we are not seeing reductions below as we tested down the stream. This was concluded after analyzing and graphing our data by site and over time, we did not see a trend of reduction through our sites moving down along the White Clay Creek.

2. Methods

Probing Samples- Throughout the past year Erik and I took field equipment out and would do live tests at our sites to collect our data. We collected conductivity, temperature, flow, turbidity and nitrate concentration. We then logged this data into excel.

Grab Samples- Twice throughout the semester we collected samples of the water from our five testing locations and sent this data to be further analyzed by the University Agricultural Department. We collected our samples in non degradable containers to prevent sample contamination.

Fig. 1
Water Quality monitoring equipment; Nitrogen and Turbidity meters



Date	Site	NO3 - N	Cond	Cl (mg/L)	Temperature	Turbidity	Vel (rot/min)
11/12/21	WNR 5	4.6	340	8.4	60.2	2.55	-
	WJR4	3.3	278	0	57.7	0	1.297*
	WRA3	2.6	377	18.76	55	-	0.34*
	WFB2	2.4	360	14	54.6	-	472
	WCR1	5	388	21.84	55.5	-	134
12/10/21	WNR 5	6.2	339	8.12	49.8	0.02	-
	WJR4	4.8	341	8.68	43.8	0	166
	WRA3	8	390	22.4	42.6	0.7	
	WFB2	5.1	358	13.44	42.4	0	588
	WCR1	9.9	393	23.24	42.2	0	120
2/25/22	WNR 5	7	355	12.6	43.5	-	-
	WJR4	4.4	366	15.68	43.1	-	162
	WRA3	3.3	383	20.44	43.3	-	492
	WFB2	5.1	344	9.52	42.9	-	552
	WCR1	5.3	453	40.04	42.8	-	388
3/8/22	WNR 5	5.2	336	7.28	45.3	-	-
	WJR4	3.3	400	25.2	49.4	-	100
	WRA3	3.6	390	22.4	50.7	-	110
	WFB2	3.6	364	15.12	51	-	428
	WCR1	2.5	434	34.72	52.5	-	220
3/11/22	WNR 5	5.4	407	27.16	47.8	4.52	-
	WJR4	3.7	397	24.36	50.7	-	230
	WRA3	2.2	398	24.64	49.1	3.9	158
	WFB2	6	361	14.28	48.3	3.03	478
	WCR1	9	395	23.8	49.2	-	180
4/29/22	WNR 5	5	622	87.36	52.2	1.25	-
	WJR4	4.6	581	75.88	60.4	0	-
	WRA3	4.9	625	88.2	59.7	0.47	-
	WFB2	14.8	662	98.56	5.5	0.62	-
	WCR1	5.9	549	66.92	60.2	0	-

* Velocity is in feet/sec because of trouble with velocity meter

Fig. 2 Water Quality Probing Samples Data

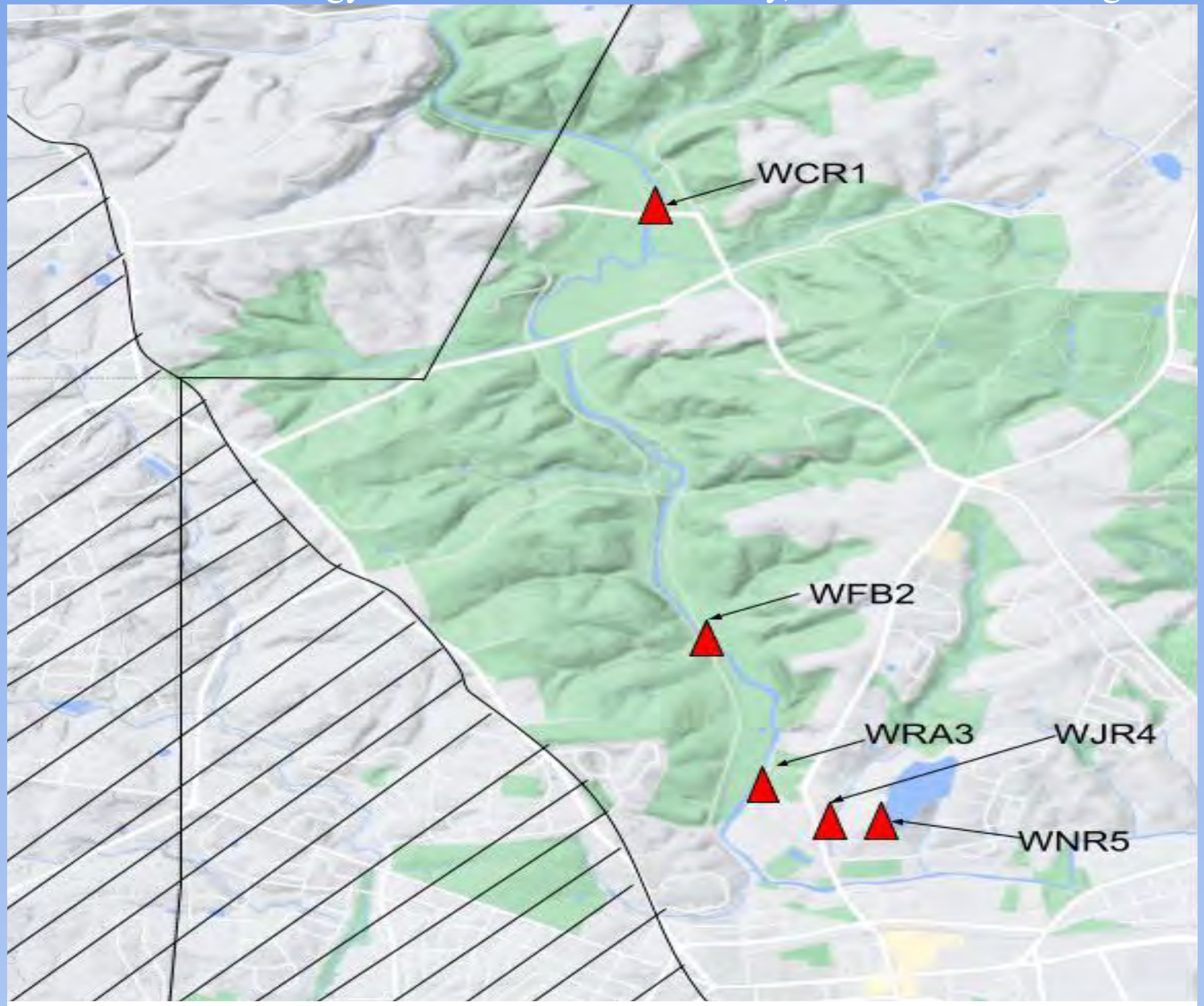


Fig. 3 Water Quality Monitoring Sites "Along the White Clay Creek"

Fig. 4 Nitrate, Phosphorus and Chlorine graphs of data by site and over time

3. Results

We created two types of graphs to analyze our data of the nitrate, turbidity, and chlorine levels from our probing samples. We charted out the nutrient levels over time as well as by site, we created the same two types of graphs for our grab sample data of nitrogen and phosphorous levels. We can see that typically the values are below the standard from our probing samples, but were unable to conclude if the White Clay Creek is filtering these contaminants effectively as they move downstream.

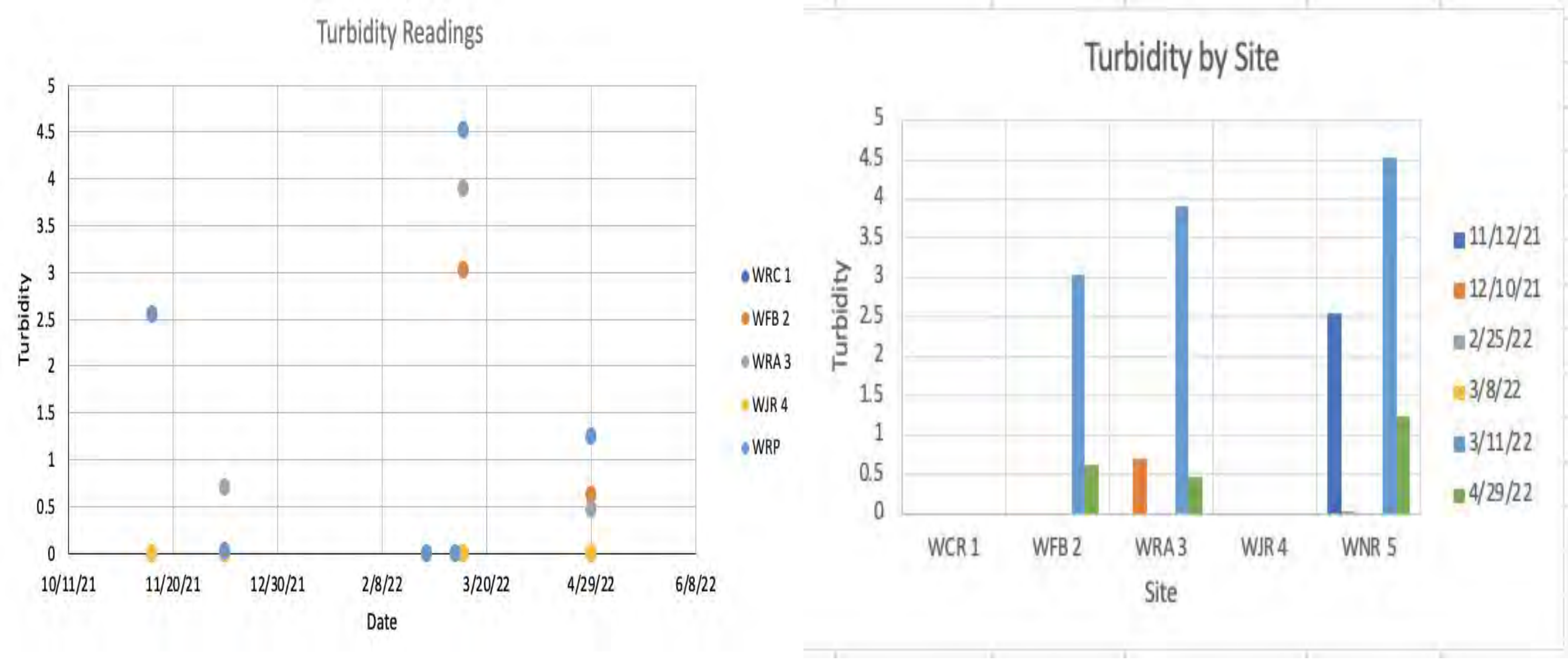


Fig. 5 Turbidity Graph by site and over time

4. Conclusion

Through our analysis we have seen that nitrate and chlorine levels have in most instances been below the established health standards of 10 mg/L and 4mg/L respectively. While this is good to see we also do not see a consistent trend of reductions in nutrients along the White Clay Creek. This indicates that the White Clay forest ecosystem is not doing an adequate job of removing nutrients efficiently enough before it reaches the City of Newark and is added into the drinking water. Further research into where these excess amounts of nutrients are entering the White Clay would be beneficial in order to find a more efficient way at removing these nutrients before they enter the City of Newark's water supply. We recommend that future monthly monitoring at our designated sites continue and that automated monitors be put in place so that data can be relayed and analyzed instantly instead of relying on individuals to go out monthly and manually collect data.

5. Acknowledgments

This work was performed under the supervision of Dr. Gerald Kauffman and Martha Narvaez with support from the USGS and UD Water Resources Center.

Sustainable UD water

WATERSHED ACTION TEAM FOR ECOLOGICAL RESTORATION

The Effects Mill Dams Have on Insects and Spiders in Aquatic and Riparian Ecosystems in the White Clay Creek

Nathaniel Levia, Insect Ecology and Conservation, Collage of Agriculture and Natural Resources

1. Introduction

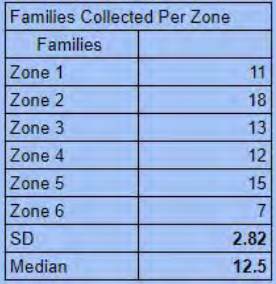
The mill dam at the end of Paper Mill rd in Newark Delaware, was once part of the Curtis Paper Mill, which has since been demolished, and turned into a public park. The final standing remnant of the mill left is the mill dam, which was scheduled to be removed in 2021. The goal of our project was to determine if the dam had any effect on the biodiversity in the riparian and aquatic ecosystems.

2. Object

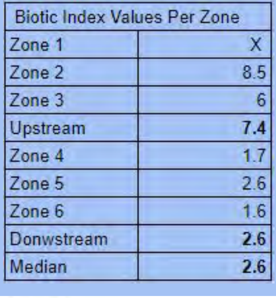
To determine if there are differences in the insect and spider fauna in the riparian and aquatic ecosystems above and below the mill dam.

Fig. 1
View of White Clay Creek from upstream of the mill dam

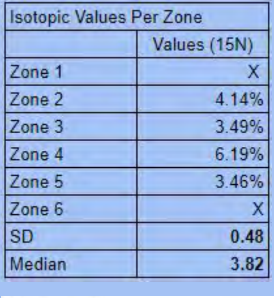
Fig. 2
Map of collecting zones. 3 zones above the dam and 3 zones below



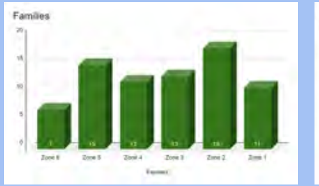
Families Collected Per Zone	
Families	
Zone 1	11
Zone 2	18
Zone 3	13
Zone 4	12
Zone 5	15
Zone 6	7
SD	**2.82**
Median	**12.5**



Biotic Index Values Per Zone	
Zone 1	X
Zone 2	8.5
Zone 3	6
Upstream	**7.4**
Zone 4	1.7
Zone 5	2.6
Zone 6	1.6
Donwstream	**2.6**
Median	**2.6**



Isotopic Values Per Zone	
	Values (15N)
Zone 1	X
Zone 2	4.14%
Zone 3	3.49%
Zone 4	6.19%
Zone 5	3.46%
Zone 6	X
SD	**0.48**
Median	**3.82**



3. Methods

The stream was split into six collecting zones, with three zones above and below the mill dam. This was to see if there was a difference in fauna further from the mill dam, as opposed to closer to the dam. The riparian Zones were sampled using pitfall traps, and by hand collecting methods, such as turning over rotting logs, and sweep netting. Three pitfall traps were placed in each zone. Hand collecting was done, by turning over dead logs, and collecting insects found on plants. Sweep netting was also used to collect insects, hiding in vegetation. Sampling the aquatic habitat below the mill dam was done through hand sampling, by flipping over rocks. Aquatic sampling above the mill dam was done by netting, and sorting through leaf litter, and other debris in the stream. This was done above the dam, due to the water being very deep, and the bottom of the stream being muddy, with few to no rocks visible above the sediment, leading to a lack of habitat for macroinvertebrates, other than the debris on the edges of the stream. The isotopic analysis was done on crickets captured in the pitfall traps in each zone. Once captured and dispatched, the crickets were dried for 48 hours, and then crushed into a rough powder using a mot and pedestal. The samples were then placed into glass vials, and sent to University of Maryland's Appalachian Laboratory for analysis. All insects were identified to the family, and the aquatic insects were used to calculate biotic indexes for each zone, using the Hilsenhoff biotic index.

4. Results

No major difference was seen in the biodiversity in the riparian zones above or below the mill dam. This is likely due to the fact that the habitat on both sides of the stream is the same, with both being forested. There also was no major difference in the isotopic analysis, most likely due to the crickets on each side eating the same things. There was a major difference in the aquatic macroinvertebrates. The biotic indexes show that the stream below the dam is much healthier than the stream above the dam. This is because there is more habitat below the stream, due to there being more rocks for these insects to live on/under. There is a lack of suitable habitat for most aquatic insects above the dam, because the bottom of the stream is mostly mud.

5. Conclusion

Unfortunately the mill dam was not removed in the timeframe of this project, however we did get good data about how the dam is negatively affecting the health of the aquatic environment. The results show that there is a major discrepancy in the fauna present in the aquatic environments, above and below the dam. They also show there is no major difference in the fauna in the riparian zones, above and below the dam. This is most likely due to the fact that the habitats are the same, and the dam is not splitting those habitats in two, like it is with the aquatic habitats. Because the habitats are the same above and below the dams, the crickets on each side, have the same or very similar diets, leading to the isotopic analysis values to be very similar. We predict that over time the areas above and below the dams would revert back to normal, once the dam is removed. We believe this will be the case, because streams that have had dams, the area upstream of the dam, reverted into a healthy habitat like the area that was downstream of the dam. This is a topic for future research once the dam is removed. This data is important, because it tells how the dam affects the biota in the aquatic ecosystems, and how it can improve once the dam is removed.

6. Acknowledgments

I would like to thank: Shreeram Inamdar, Erin Pek, Gerald Kaufmann, Martha Narvaez, Elizabeth Shields, the University of Delaware Water Resources Center, USGS.

Fig. 1
View of White Clay Creek from upstream of the mill dam

Fig. 2
Map of collecting zones. 3 zones above the dam and 3 zones below

IMPACT OF STORMWATER INFILTRATION ON GROUNDWATER RADIUM LEVELS IN DELAWARE

Andreanna Roros, Geological Sciences & Neil C. Sturchio, Department of Earth Sciences, U. Delaware

Rachel McQuiggan, Changming He & A. Scott Andres, Delaware Geological Survey

1. BACKGROUND

The Delaware Geological Survey (DGS) has been monitoring groundwater beneath stormwater management basins (BMPs) with the intent of characterizing potential risks to groundwater quality from de-icing practices at DelDOT that include spreading brines and rock salt during winter months. As a result, about 6.4 metric tons of chloride drains into the basin each winter. Previous work at BMP-663 has shown the infiltration and movement of salty water into and through the Rancocas Aquifer beneath the basin. As a result of the increase in saltwater in the BMPs from de-icing, there is concern that naturally occurring radium will be released and possibly exceed the EPA maximum contaminant level (MCL) for public drinking water supplies. The Coastal Plain of North America, including Delaware, has been identified as one of the regions within the U.S. in which exceedances of the MCL for combined radium (^{226}Ra and ^{228}Ra) occur most frequently.

2. ABSTRACT

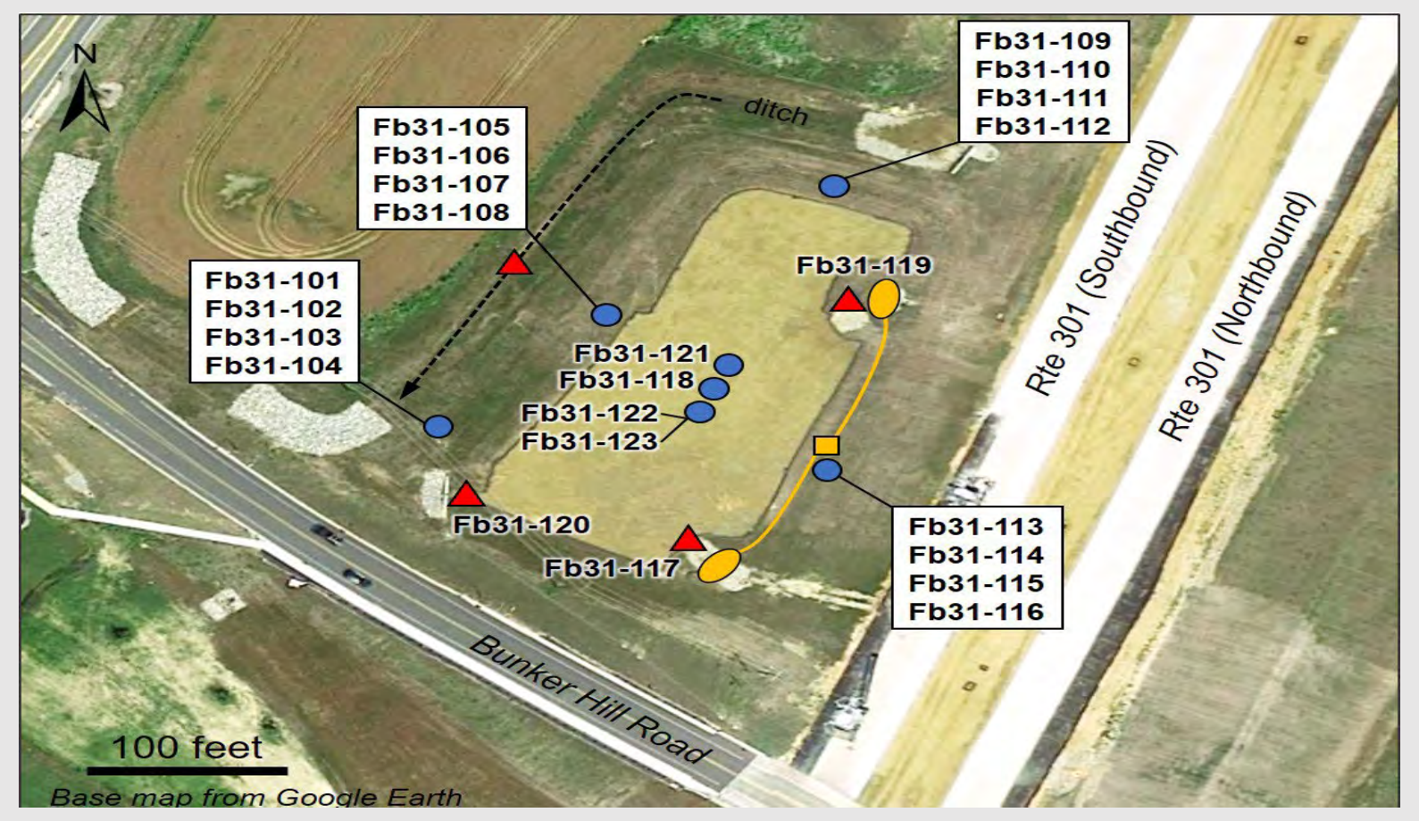
The gradual increases in chloride concentrations and the movement of salty water within the Rancocas Aquifer beneath the BMP-663 sites have a significant probability of driving radionuclide release from aquifer rocks, such as glauconite, to the groundwater. Radium isotopes are the most likely to be mobilized in the Rancocas Aquifer by an increase in groundwater salinity. A significant correlation between salinity and radium was observed during this study, with seasonal fluctuations caused by stormwater infiltration.

3. PURPOSE

This project investigated groundwater impacts from stormwater infiltration by measuring radium isotopes and other water quality indicators in samples collected periodically from monitoring wells at the BMP-663 infiltration basin at RT 301 and Bunker Hill Road. It is imperative to monitor this issue because stormwater infiltrates the Rancocas Aquifer which is a source of drinking water to thousands of people in southern New Castle and northern Kent Counties.

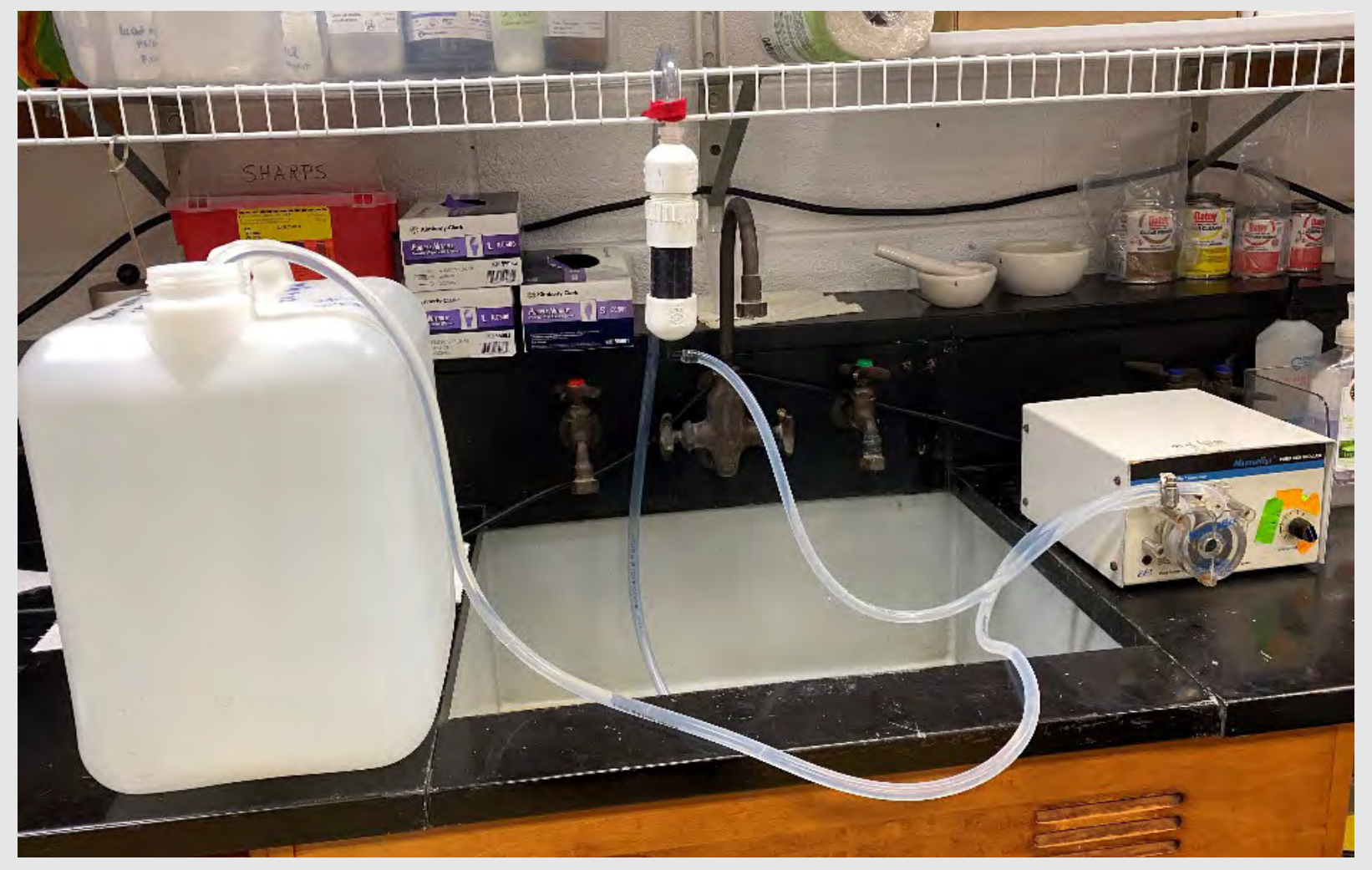
4. METHODS

1. **Monitoring Stations:** Analyze the regional hydrogeology of the Rancocas Aquifer, which is a major source of drinking water in New Castle and northern Kent Counties. Then, discuss with DGS BMP areas of interest associated with the aquifer and determine dates to conduct fieldwork.



2. Collect Samples: Prior to sampling, allow DGS to purge the wells so that samples are representative of aquifer conditions. Collect one or two 20-liter samples of 0.45-micron filtered water from each well. Label the sample containers with the well ID and date of collection.

3. Prepare Samples: Weigh the water samples. Pump the water slowly through a cartridge containing ~17 g of fluffed Mn-coated acrylic fiber. The Mn-fiber adsorbs the radium quantitatively from the water. Transfer the wet Mn-fiber to an aluminum container and dry the samples overnight in an oven at 80 °C. Then, burn the Mn-fiber samples for two hours at 650 °C and let them cool overnight. Transfer the residual MnO_2 from the burned Mn-fiber to labeled 7-mL polypropylene vials for gamma spectrometry.

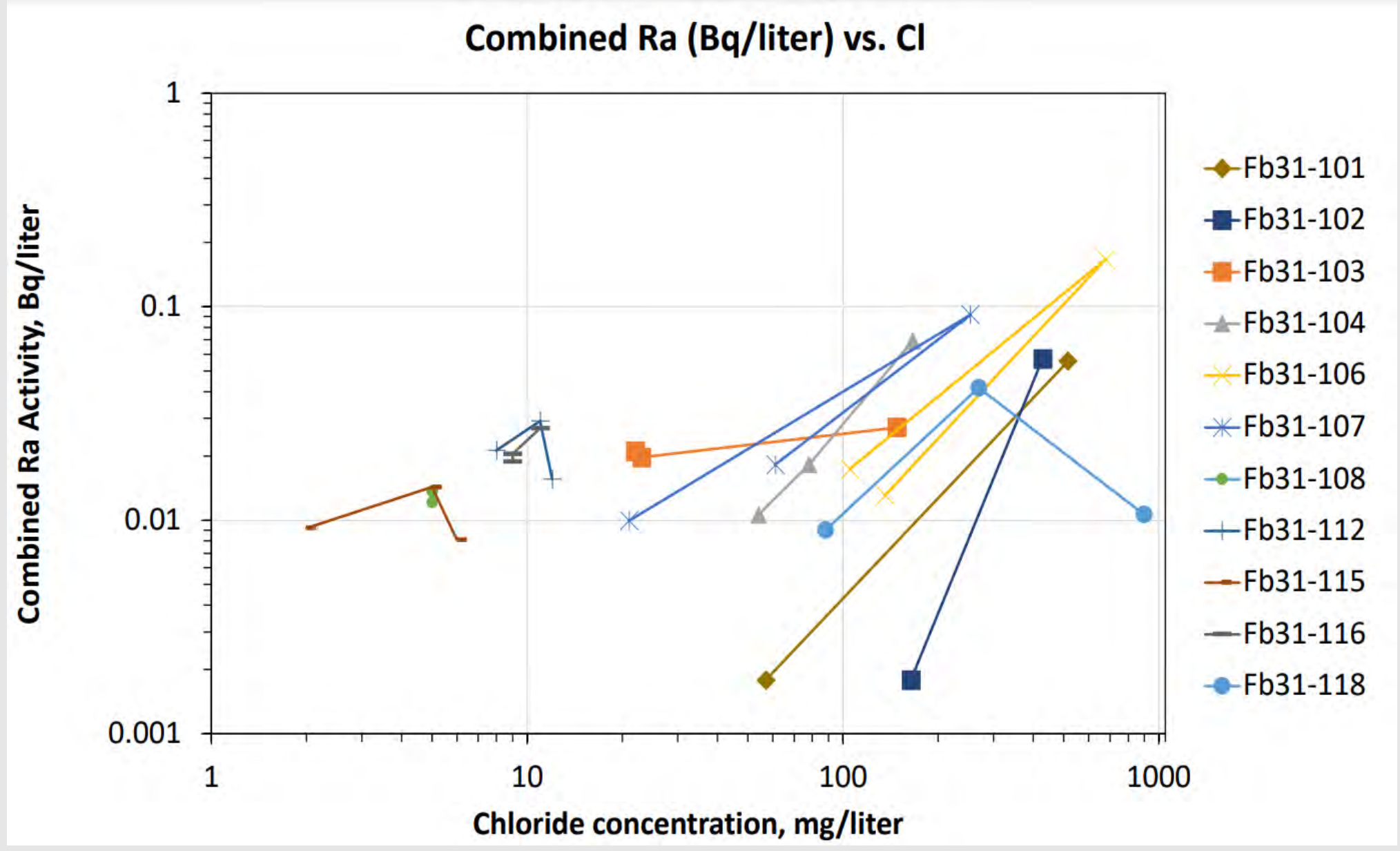


4. Gamma Spectrometry: Measure the activities of ^{226}Ra and ^{228}Ra using a calibrated low-background Ortec HPGe well detector within a 10-cm lead shield. The spectrometer is connected to a PC so that the Maestro multichannel analyzer software can be used for spectral analysis. The sample vial is placed in the detector well data are acquired until both of the photopeaks of interest (186.2 keV for ^{226}Ra, 911.3 keV for ^{228}Ra) have accumulated at least 400 counts above background (typical counting times ~48 hours).

5. Data Analysis: Determine the concentrations of combined ^{226}Ra and ^{228}Ra in the water and whether the levels are above or below the EPA MCL (5 pCi/liter). Data are corrected for background subtraction, detector efficiency, and date of sampling/sealing. Evaluate correlation of radium concentrations with other water quality parameters, especially sodium and chloride concentrations.

5. RESULTS

The combined Ra vs. Cl graph below shows that an increase in chloride corresponds to an increase in combined radium while a decrease in chloride corresponds to a decrease in combined radium. It generally appears that chloride and radium are directly correlated indicating desorption and re-adsorption.



6. CONCLUSIONS

Monitoring the groundwater quality at BMP-663 with seasonal sampling (March, June, November) has shown that March and November samples had the lowest Ra and Cl concentrations while June samples had the highest concentrations. From these results, we can assume that by June the salinized stormwater is able to infiltrate the aquifer, and this appears to cause an increase in the combined radium activity in the groundwater. As the seasonal saltwater plume moves downgradient, the site monitoring wells show a decrease in Cl and Ra. In the wells sampled during three seasons, the observed Ra vs. Cl correlations indicated that a reversible Ra sorption /desorption process may be controlling Ra behavior in the groundwater in the Rancocas Aquifer.

7. FUTURE RESEARCH

We recommend that DelDOT should continue monitoring the stormwater management sites, and also consider decreasing road salt applications during winter months to avoid contamination of groundwater. I will continue to investigate the quality of groundwater in wells throughout Delaware with DGS staff during the summer of 2022 .

8. ACKNOWLEDGEMENTS

I would like to thank DWRC and USGS for funding my research and internship this year, especially Jerry Kauffman, Martha Narvaez, and Lisa Moreland Allred. I would also like to thank Neil Sturchio for being my research advisor and helping me find a passion for geochemistry. Lastly, I would like to thank Rachel McQuiggan, Changming He and A. Scott Andres at the DGS for allowing me to take samples from their wells and giving me access to their water quality information.

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Indigenous and European Place Names Along Streams and Waterways in Delaware (Lenapehocking)

Prepared for the University of Delaware Water Resources Advisory Panel by

Elizabeth Shields, Master of Public Policy Candidate 2023

Joseph R. Biden, Jr. School of Public Policy and Administration

July 2022

Lindstrom, 1655

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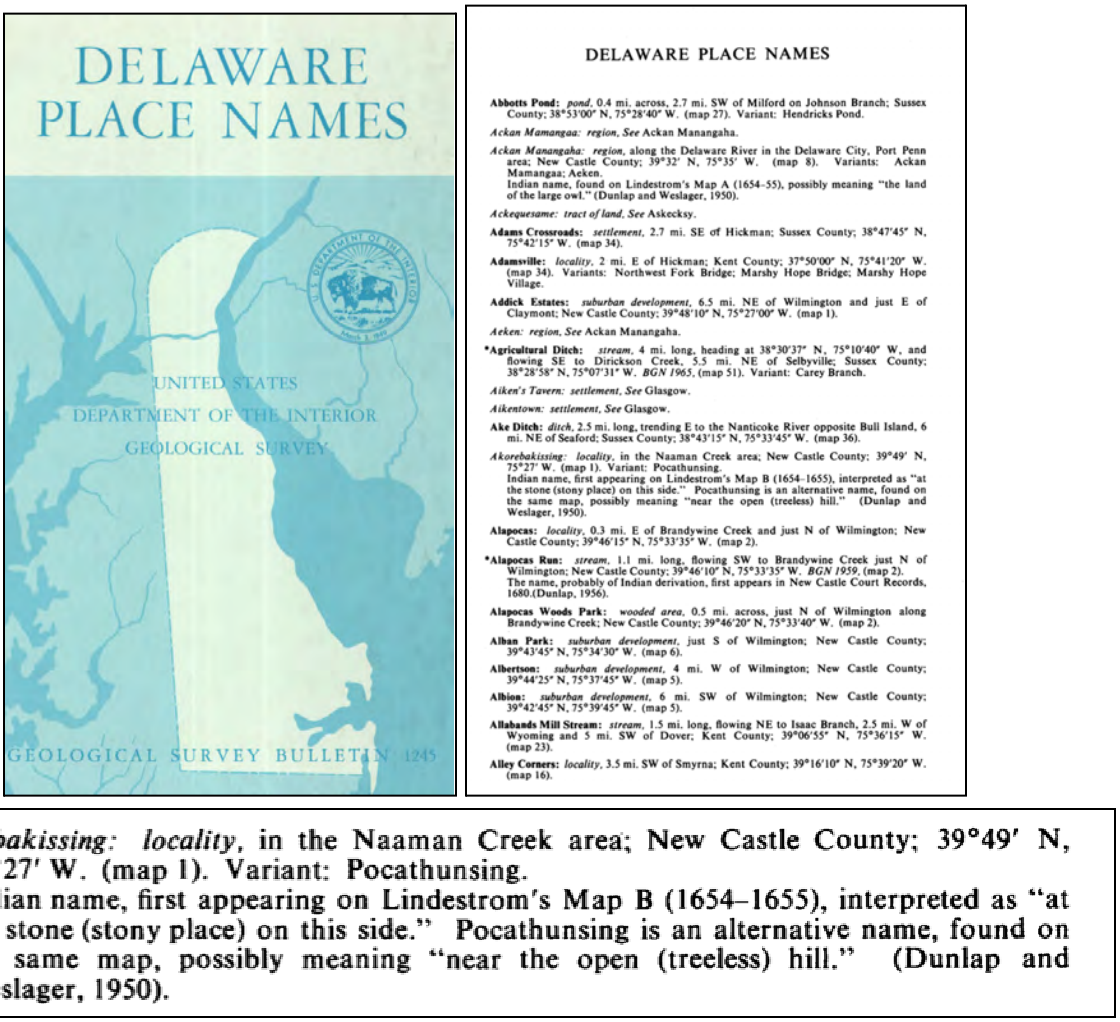
Abstract

Beginning in Summer 2021, this project was created to initiate important research, conversation, and recognition around the names of waterways and places in our state. There is a rich and long history of the relationships between the Lenape Haki-nk, Susquehannock, Choptank, Nentego/Nanticoke, and Pocomoke peoples and this land we now know as the State of Delaware. We acknowledge both the history and maintained presence of these Indigenous peoples, as well as the existence of their original connections and name associations to the land and water. The goal of this living project is to begin to uncover what available records show and tell of the lineage and possible meanings behind the Indigenous, early European settlers, and commonly known names. Through an analysis of the 1966 United States Geological Survey "Delaware Place Names" Report seen in Figure 1, a current total of 107 waterways and key land points have been organized, interpreted, and placed, producing a new alternative visual for mapping in Delaware. Next steps of the project will play out in the evolution of the printed sample into a living online map with additional content and context. Given the limitations of the 1966 USGS report, we plan to collaborate with other sources and initiate communication with Indigenous tribal leadership and members around the state for their input on variants, translations, locations, and other vital elements to this process.



DELAWARE PLACE NAMES

UNITED STATES DEPARTMENT OF THE INTERIOR GEOLOGICAL SURVEY

GEOLOGICAL SURVEY BULLETIN 1245

DELAWARE PLACE NAMES

Abbotts Pond: *pond*, 0.4 mi. across, 2.7 mi. SW of Milford on Johnson Branch; Sussex County; 38°53'00" N, 75°28'40" W. (map 27). Variant: Hendricks Pond.

Ackan Mamangaa: region, See Ackan Manangaha.

Ackan Manangaha: region, along the Delaware River in the Delaware City, Port Penn area; New Castle County; 39°32' N, 75°35' W. (map 8). Variants: Ackan Mamangaa; Aeken.
Indian name, found on Lindestrom's Map A (1654–55), possibly meaning "the land of the large owl." (Dunlap and Weslager, 1950).

Ackequesame: tract of land, See Askecksy.

Adams Crossroads: *settlement*, 2.7 mi. SE of Hickman; Sussex County; 38°47'45" N, 75°42'15" W. (map 34).

Adamsville: *locality*, 2 mi. E of Hickman; Kent County; 37°50'00" N, 75°41'20" W. (map 34). Variants: Northwest Fork Bridge; Marshy Hope Bridge; Marshy Hope Village.

Addick Estates: *suburban development*, 6.5 mi. NE of Wilmington and just E of Claymont; New Castle County; 39°48'10" N, 75°27'00" W. (map 1).

Aeken: region, See Ackan Manangaha.

***Agricultural Ditch:** *stream*, 4 mi. long, heading at 38°30'37" N, 75°10'40" W, and flowing SE to Dirickson Creek, 5.5 mi. NE of Selbyville; Sussex County; 38°28'58" N, 75°07'31" W. *BGN 1965*, (map 51). Variant: Carey Branch.

Aiken's Tavern: settlement, See Glasgow.

Aikentown: settlement, See Glasgow.

Ake Ditch: *ditch*, 2.5 mi. long, trending E to the Nanticoke River opposite Bull Island, 6 mi. NE of Seaford; Sussex County; 38°43'15" N, 75°33'45" W. (map 36).

Akorebakissing: locality, in the Naaman Creek area; New Castle County; 39°49' N, 75°27' W. (map 1). Variant: Pocathunsing.
Indian name, first appearing on Lindestrom's Map B (1654–1655), interpreted as "at the stone (stony place) on this side." Pocathunsing is an alternative name, found on the same map, possibly meaning "near the open (treeless) hill." (Dunlap and Weslager, 1950).

Alapocas: *locality*, 0.3 mi. E of Brandywine Creek and just N of Wilmington; New Castle County; 39°46'15" N, 75°33'35" W. (map 2).

***Alapocas Run:** *stream*, 1.1 mi. long, flowing SW to Brandywine Creek just N of Wilmington; New Castle County; 39°46'10" N, 75°33'35" W. *BGN 1959*, (map 2).
The name, probably of Indian derivation, first appears in New Castle Court Records, 1680.(Dunlap, 1956).

Alapocas Woods Park: *wooded area*, 0.5 mi. across, just N of Wilmington along Brandywine Creek; New Castle County; 39°46'20" N, 75°33'40" W. (map 2).

Alban Park: *suburban development*, just S of Wilmington; New Castle County; 39°43'45" N, 75°34'30" W. (map 6).

Albertson: *suburban development*, 4 mi. W of Wilmington; New Castle County; 39°44'25" N, 75°37'45" W. (map 5).

Albion: *suburban development*, 6 mi. SW of Wilmington; New Castle County; 39°42'45" N, 75°39'45" W. (map 5).

Allabands Mill Stream: *stream*, 1.5 mi. long, flowing NE to Isaac Branch, 2.5 mi. W of Wyoming and 5 mi. SW of Dover; Kent County; 39°06'55" N, 75°36'15" W. (map 23).

Alley Corners: *locality*, 3.5 mi. SW of Smyrna; Kent County; 39°16'10" N, 75°39'20" W. (map 16).

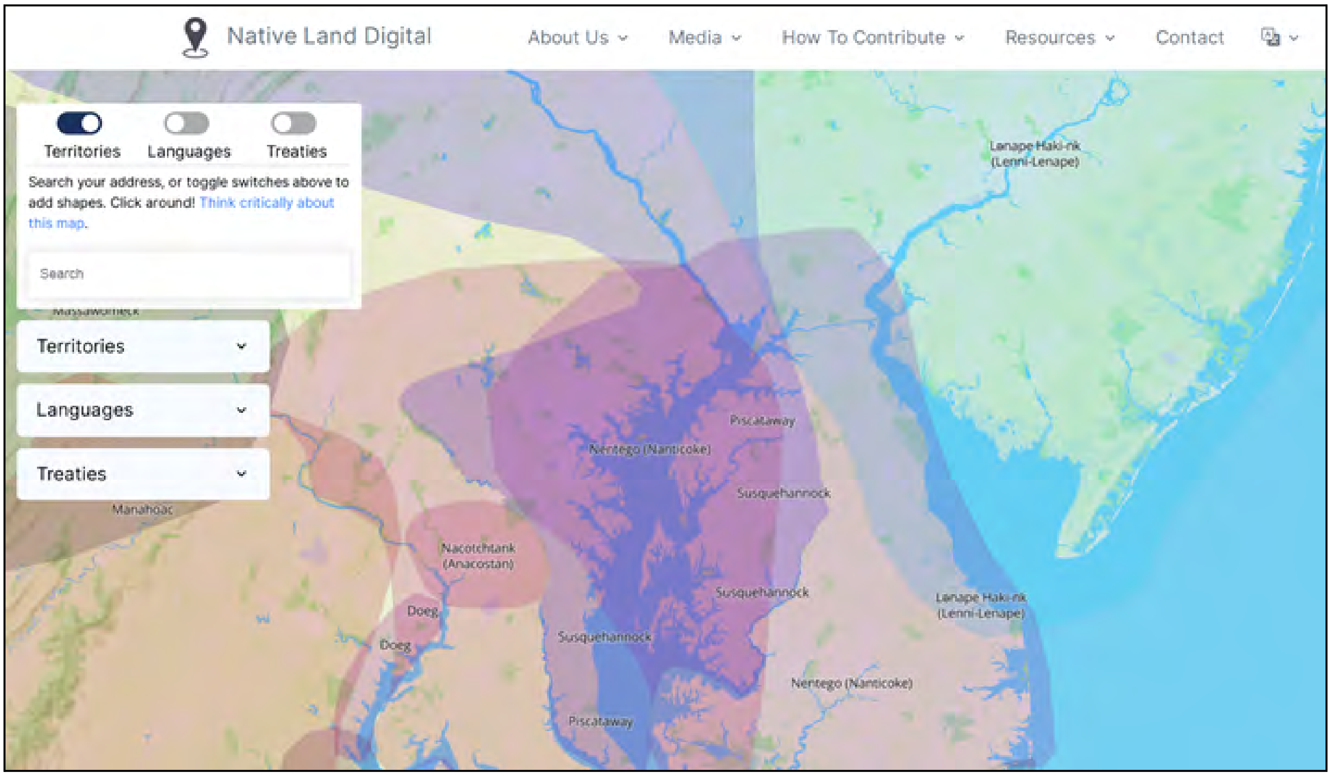
Akorebakissing: locality, in the Naaman Creek area; New Castle County; 39°49' N, 75°27' W. (map 1). Variant: Pocathunsing.
Indian name, first appearing on Lindestrom's Map B (1654–1655), interpreted as "at the stone (stony place) on this side." Pocathunsing is an alternative name, found on the same map, possibly meaning "near the open (treeless) hill." (Dunlap and Weslager, 1950).

Figure 1 shows the cover of the USGS Delaware Place Names Report, a sample page of its contents, and an enlarged entry suitable for reading.

Introduction

What's in a name? And how do names become part of a place? We know that for many thousands of years before European invasion of this continent, Native people had their own system for naming and communicating places where they lived, hunted and fished, and respected boundaries and places of other people. After a few hundred years and many waves of settlers passing through Delaware, some names have stuck and are used today on maps, in writing, and in conversation. Some common names used today are dedicated to important people or early landowners of the state while others are words from the original Lenni-Lenape language. For this study, the 1966 USGS report provided the foundation for what is intended to be a living, growing product aimed at identifying place names and honoring the rich history of the many linguistic, cultural, and historical influences that exist in Delaware.

For water-related places specifically, Indigenous names far outdate the anglicized replacements we often use today. Figure 2 shows the complexity of Native territory that exists in and around Delaware and the now-called Delaware-Maryland-Virginia or "Delmarva" peninsula. Observing the various nations and tribes offers some insight into how names and languages in this area have weaved an intricate lineage from the very beginning. When the Swedish and Dutch settlers made their homes here beginning in the 17th century, they granted names in their own languages. Over time, these names, too, have been lost in similar fashion as the Indigenous originals. After the Dutch and Swedes came the English, who made their influence as well, much of which is still used in present day. As a result of all these changes and combinations of written and oral histories, the United States Geological Survey Bulletin 1245 was compiled to serve as record of the multitude of variants where words, meanings, languages, and translations all attempt to form a general understanding of each location.



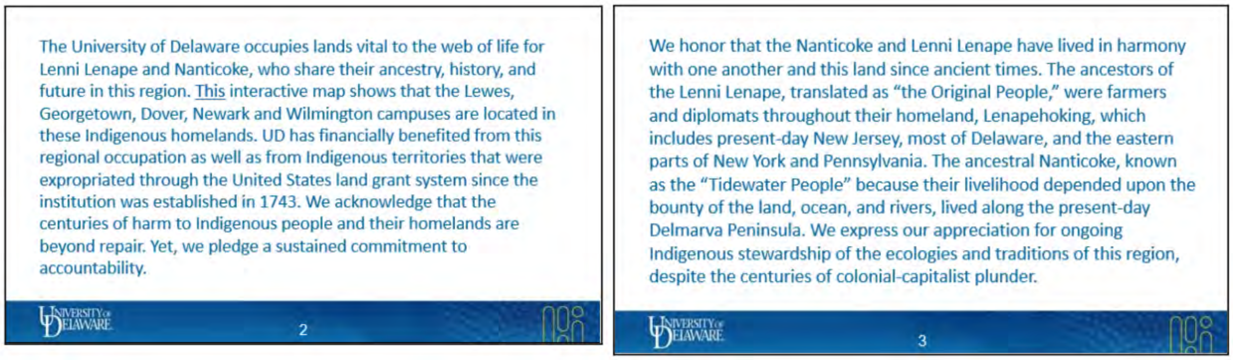
Search your address, or toggle switches above to add shapes. Click around! Think critically about this map.

Figure 2 features a map from Native Land, an online resource for Indigenous territories, showing the various nations in the area before Europeans arrived. https://native-land.ca/

Research Purpose

The purpose of embarking on this study of Indigenous place names lies in recognition of the importance of historical record and acknowledgement of the responsibility to bring diversity, equity, inclusion, and justice (DEIJ) elements into the work of the University of Delaware Water Resources Center (UDWRC). Around the country, states and other entities have taken the lead in prioritizing both the history and modernization of their Indigenous communities. While state and federal recognition and officiation processes do exist, such as in the Office of Federal Acknowledgement, the system has its flaws leaving many peoples without "official" recognition and the associated benefits. So, the responsibility lies in organizations, such as the University of Delaware Resources Center, to work in their own ways to uplift our Native communities. In this particular study, this purpose is addressed by means of allocating resources to study names and translations and produce an end product that can be used as a tool to inform others as well. Robin Wall Kimmerer, an esteemed scientist and citizen of the Potawatomi Nation, says, "Water is a gift for all," (Robin Wall Kimmerer, n.d.). By incorporating this Indigenous perspective on water into the work done with water quality, watershed management, and the various social aspects of water resources through UDWRC, intentions held for justice and inclusion can be ignited into actions. The places named in the USGS report have been shared by all people living in and visiting this area for thousands of years. In addition to utilizing some basic elements of DEIJ in our research, such as using the University of Delaware's "Living Land Acknowledgement" seen in Figure 3 as a regular part of our process via publications, presentation, meetings, etc., creating maps and materials that highlight all the variant names and their histories, both public and professional education can be enhanced by our commitment to this work.

With the incredible advancements in technology over the last several decades, the nature of historical records has changed drastically. In reading through the 1966 Delaware Place Names report, it is evident that the organization and presentation are of an older form, featuring not more than the basic information listed with coordinates, brief histories believed to be linked to the names, and other supplemental information relevant to each entry. While the amount of information available for a 1966 report is impressive, part of the purpose of the project also lies in modernizing this version of the report into a medium that is rich with information, shareable, interactive, and having capacity to grow and change as new information becomes available. Since the way we educate, research, and receive information has changed, so too must our tools for relaying information. Creating a fresh version of a traditional "Map of Delaware" with Indigenous, Swedish, Dutch, and current name variations, this purpose is fulfilled.



The University of Delaware occupies lands vital to the web of life for Lenni Lenape and Nanticoke, who share their ancestry, history, and future in this region. This interactive map shows that the Lewes, Georgetown, Dover, Newark and Wilmington campuses are located in these Indigenous homelands. UD has financially benefited from this regional occupation as well as from Indigenous territories that were expropriated through the United States land grant system since the institution was established in 1743. We acknowledge that the centuries of harm to Indigenous people and their homelands are beyond repair. Yet, we pledge a sustained commitment to accountability.

We honor that the Nanticoke and Lenni Lenape have lived in harmony with one another and this land since ancient times. The ancestors of the Lenni Lenape, translated as "the Original People," were farmers and diplomats throughout their homeland, Lenapehoking, which includes present-day New Jersey, most of Delaware, and the eastern parts of New York and Pennsylvania. The ancestral Nanticoke, known as the "Tidewater People" because their livelihood depended upon the bounty of the land, ocean, and rivers, lived along the present-day Delmarva Peninsula. We express our appreciation for ongoing Indigenous stewardship of the ecologies and traditions of this region, despite the centuries of colonial-capitalist plunder.

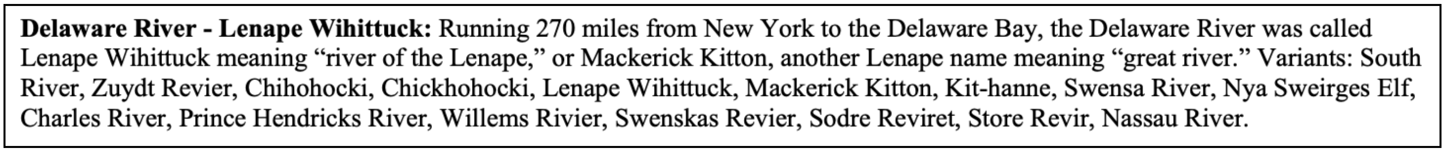
Figure 3 provides excerpts from the University of Delaware, a land grant university from which Native land was taken to provide for creation of the campuses, "Living Land Acknowledgement." (University of Delaware)

Methods

In order to generate the end product of the living Indigenous and European Place Names map, a process for gathering, organizing, and intentional reconstruction was developed by the UDWRC team and carried out over the course of the 2021-2022 academic year.

First, the 1966 USGS Delaware Place Names Report was identified and selected as the basis for initial research. The original 132-page document was read and analyzed in full to understand what kind of content was provided in the text, as well as to highlight any functional or formatting trends used by the report's originators. It was discovered that the authors included an introduction, glossary, abbreviation descriptions, and basic maps of Delaware that would help orient readers to terminology and locations used in the report. The remainder of the report exists as a list of Delaware places, both land and water-based, in alphabetical order including non-English names. As seen in Figure 1, the entries provide the name, description of the entry (i.e. pond), verbal description of location, coordinate location, county, a milage reference to other nearby locations or points of interest, any known variant names, and any known translations or histories of those variants. The entries vary in the amount of information and level of detail in their descriptions, likely based on the availability of context held by the authors. After a thorough analysis of the report in its entirety, the organization stage could follow.

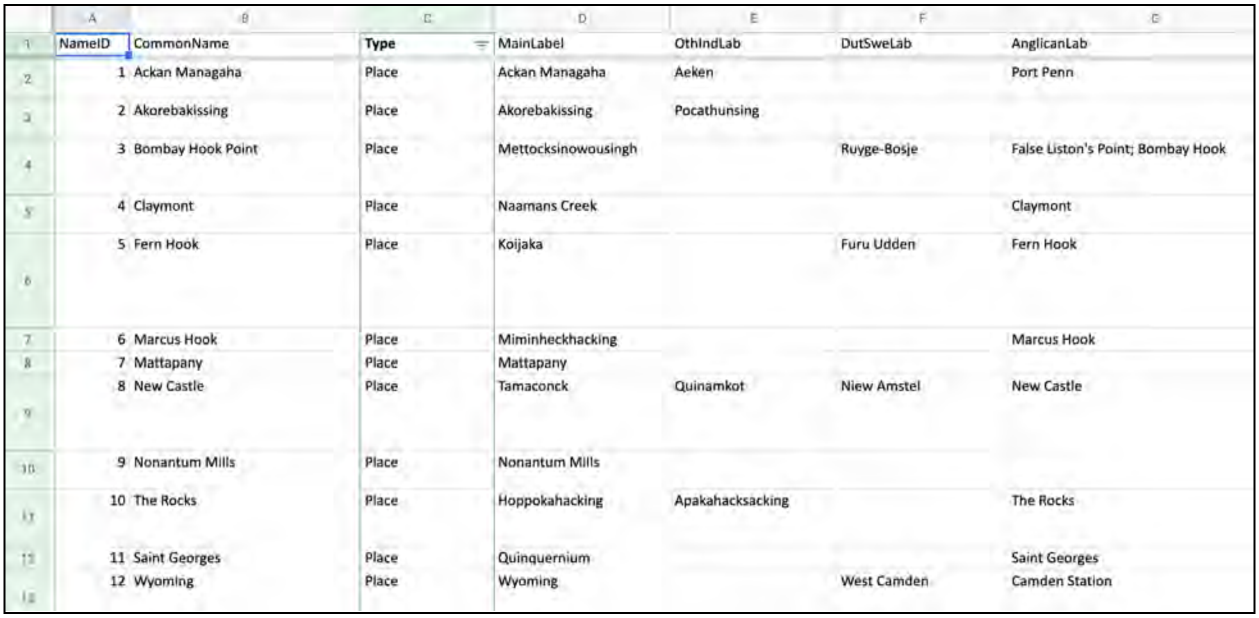
Second, the contents of the document were transitioned into more cohesive descriptions for the individual entries. This was done by taking all the listed content about each place and changing them into full sentences that flow well for easier reading. In Figure 4, the outcome of this step can be seen in the example of the Delaware River, or *Lenape Wihittuck*.



Delaware River - Lenape Wihittuck: Running 270 miles from New York to the Delaware Bay, the Delaware River was called Lenape Wihittuck meaning "river of the Lenape," or Mackerick Kitton, another Lenape name meaning "great river." Variants: South River, Zuydt Revier, Chihohocki, Chickhohocki, Lenape Wihittuck, Mackerick Kitton, Kit-hanne, Swensa River, Nya Sweirges Elf, Charles River, Prince Hendricks River, Willems Rivier, Swenskas Revier, Sodre Reviret, Store Revir, Nassau River.

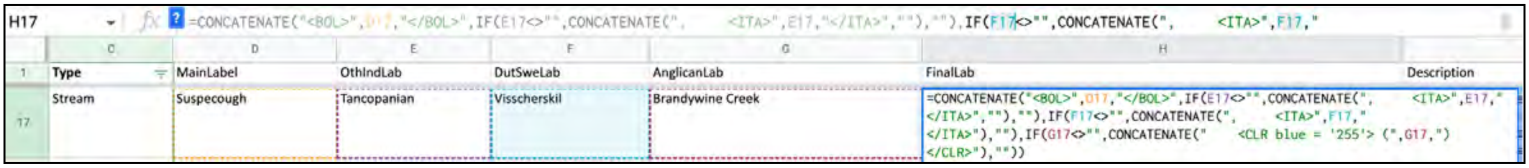
Figure 4 shows an example of the streamlined description writing process used to take all the information in the report entries and create succinct, full sentence narratives.

Next, with the descriptions improved and completed, attention was turned toward preparation for building the map. A spreadsheet was created to match each place name entry with its variants and descriptions to a numerical name identification. Shown in Figure 5, the alphabetical order was maintained for efficient organization and the "Name ID" numbering system ran one through 107. By organizing the data this way, transitioning into the mapping process was made much easier and more direct. For this step in the study, Google Sheets was used so all members of the team could access and edit the content for the map. After the pairing of place names to their individual ID numbers, QUERY language was created to translate the table elements to the map using connections between the sheet and ArcGIS. Using the "=CONCATENATE" function, the contents of each column in the sheet were assigned the selected font style and color: bold and black for the main label, and italic for the second label, and blue for the common name label. Examples of the coding used are shown in Figure 6a and Figure 6b. This was accomplished using the commands "<BOL>" and "</BOL>" for bold font, "<ITA>" and "</ITA>" for italicized font, and <CLR blue = '255'>. While the coding portion of the methods for this project were used strictly on the back end for editing, the results create the main focus of the map--the place name variants matched with their geographical locations.



NameID	CommonName	Type	MainLabel	OthIndLab	DutSweLab	AnglicanLab
1	Ackan Managaha	Place	Ackan Managaha	Aeken		Port Penn
2	Akorebakissing	Place	Akorebakissing	Pocathunsing		
3	Bombay Hook Point	Place	Mettocksinowousingh		Ruyge-Bosje	False Liston's Point; Bombay Hook
4	Claymont	Place	Naamans Creek			Claymont
5	Fern Hook	Place	Koijaka		Furu Udden	Fern Hook
6	Marcus Hook	Place	Miminheckhacking			Marcus Hook
7	Mattapany	Place	Mattapany			
8	New Castle	Place	Tamaconck	Quinamkot	Niew Amstel	New Castle
9	Nonantum Mills	Place	Nonantum Mills			
10	The Rocks	Place	Hoppokahacking	Apakahacksacking		The Rocks
11	Saint Georges	Place	Quinquernium			Saint Georges
12	Wyoming	Place	Wyoming		West Camden	Camden Station

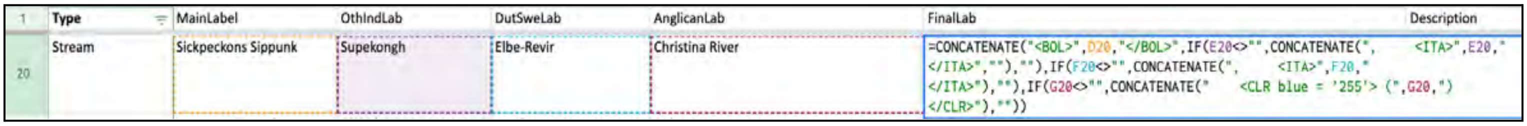
Figure 5 is a snapshot of the beginning of the spreadsheet to assign and organize the entries by Name ID to transition into the mapping process.



Type	MainLabel	OthIndLab	DutSweLab	AnglicanLab	FinalLab	Description
Stream	Suspecough	Tancopanian	Visscherskil	Brandywine Creek	see below	

```
=CONCATENATE("<BOL>",D17,"</BOL>",IF(E17<>"",CONCATENATE(",     <ITA>",E17,"
</ITA>",""),""),IF(F17<>"",CONCATENATE(",     <ITA>",F17,"
</ITA>"),""),IF(G17<>"",CONCATENATE("    <CLR blue = '255'> (",G17,")
</CLR>"),""))
```

Figure 6a. shows the QUERY code generated to translate the name variants to the map for Brandywine Creek or *Suspecough.*



Type	MainLabel	OthIndLab	DutSweLab	AnglicanLab	FinalLab	Description
Stream	Sickpeckons Sippunk	Supekongh	Elbe-Revir	Christina River	see below	

```
=CONCATENATE("<BOL>",D20,"</BOL>",IF(E20<>"",CONCATENATE(",     <ITA>",E20,"
</ITA>",""),""),IF(F20<>"",CONCATENATE(",     <ITA>",F20,"
</ITA>"),""),IF(G20<>"",CONCATENATE("    <CLR blue = '255'> (",G20,")
</CLR>"),""))
```

Figure 6b. shows another example of the QUERY code developed for the Christina River or *Sickpeckons Sippunk.*

Next, after the organization and coding phases of the project, the mapping process began by connecting the QUERY language and spreadsheet to the ArcGIS system. After selecting a suitable basemap for Delaware and the surrounding areas, the coordinates obtained from the original report were matched with the Name ID numbers and the labels were pinned accordingly. Figure 7 shows the first draft of the map. From the first draft of the map, several edits were made to improve the visual and functional qualities. The excerpt in Figure 7 provides an example of some of the difficulties reading the labels and different variants, as well as the indistinction of the general areas of different tribes' locations---originally and currently. In this example, the distinction between Nanticoke and Pocomoke areas is not well defined. To improve the map, edits were made in the ArcGIS platform involving significantly decreasing the number of lines and transparency levels representing waterways resulting in significantly more clarity and simplicity of reading. Over the months of working on this project, additional research beyond the USGS report was carried out to learn more about standards and best practices when working with Indigenous content. New discoveries were also made in correction of spelling and naming of local tribes. These findings helped move the draft map into its current form, seen in Figure 8.

Ultimately, after achieving a satisfactory level of improvement to the map, it was converted into a final version for sharing and presentation. While this project is considered a “living project” that the UDWRC intends to continue building upon, the current version was presented at the 57th Annual Meeting of the UDWRC Advisory Panel on May 5, 2022 at the University of Delaware. The current version of the map was officially published to UDWRC’s Research Library for public access.

As additions, improvements, and corrections come up in the future, these methods can be applied to accommodate such changes. Additional methods may be developed if UDWRC intends to move the map to different platforms or create an interactive component via Story Maps through ArcGIS or other mediums.

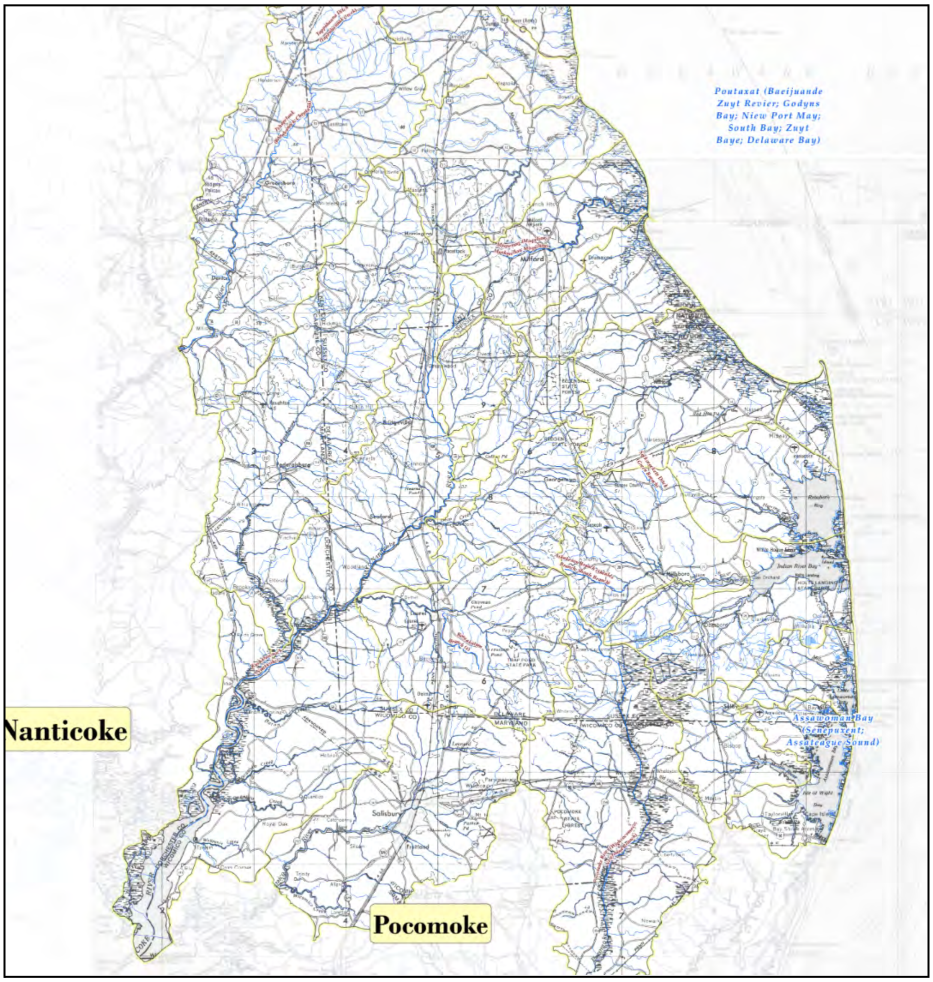


Figure 7 shows an excerpt from the first draft of the Place Names map in ArcGIS.

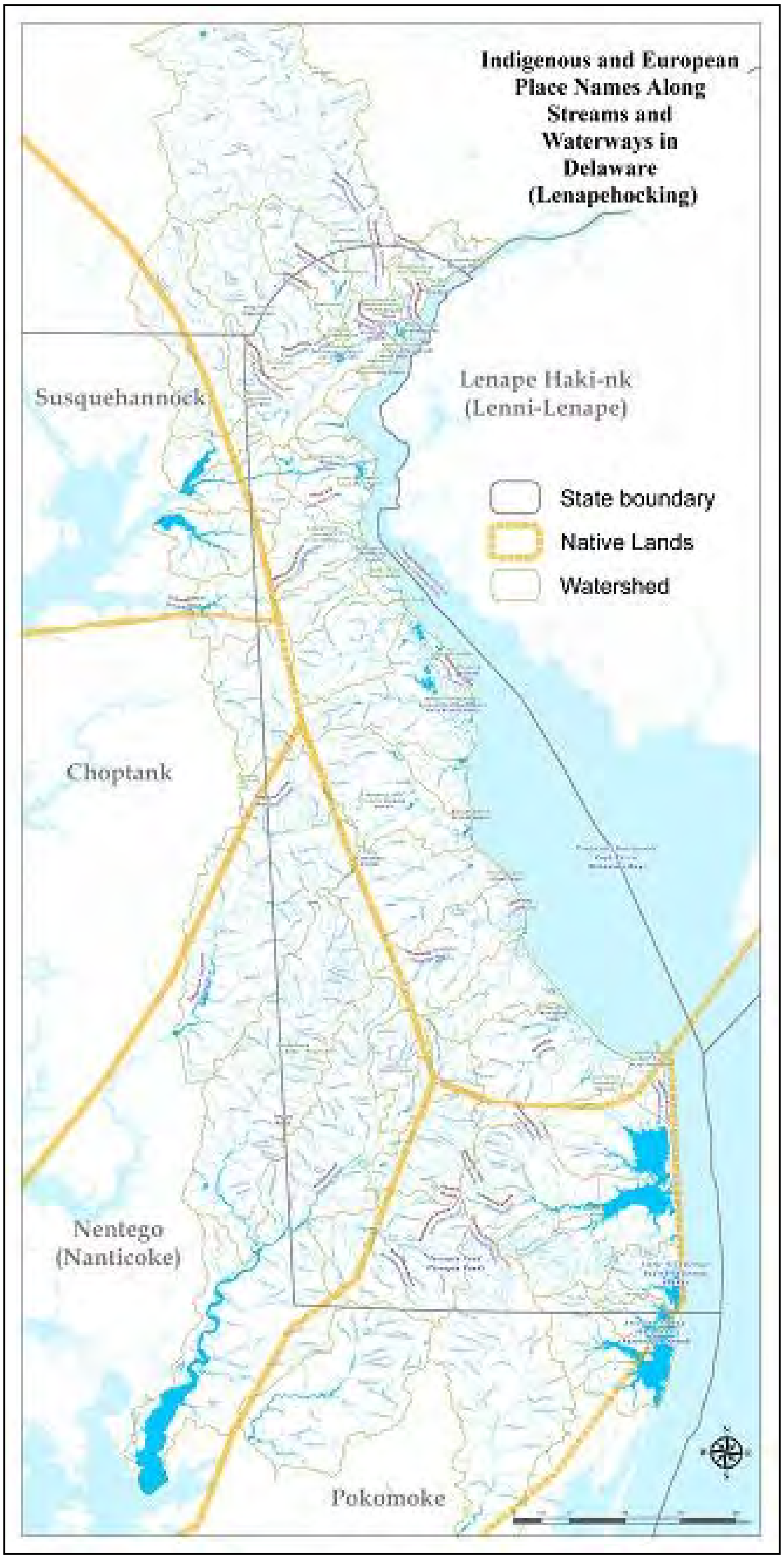


Figure 8 depicts the current, published version of the “Indigenous and European Place Names Along Streams and Waterways in Delaware (Lenapehocking)” map.

Results and Discussion

As a result of this research and mapping process, members of UDWRC have embarked on the first mission to study and highlight the histories of water and land names that we commonly work to protect, visit in the field, and enjoy in our personal lives. In figure 9, the physical result can be seen in action in the form of a poster presentation. While significant practical results show in the drafts and current version of the map itself, this project has produced valuable results in the uncovered descriptions and translations previously hidden away in reports and printed texts. These are the kind of results not typically found by an average web search, but sewn together from a multitude of sources stemming from what was found in the USGS report as the catalyst.

In a write up for the release of this project and current version of the map, UDWRC Director Dr. Gerald Kauffman stated:

> “Place names of Delaware waterways have fascinating stories. Flowing from Pennsylvania to the Christina River, the Brandywine was called Suspecough the indigenous name meaning, ‘at the muddy pond’ and comes from the Swedish snaps Brannvin a potato liquor after the Old Barley Mill built by a 17th century Swedish surgeon near present day Market Street in Wilmington. The Christina River was the Lenape Sickpeckons Sippunk meaning, ‘at the river at the muddy pond.’ Was named after the teenage Swedish queen. Naamans Creek was named after an indigenous chief around 1655 and may refer to an Algonkian word for fish. Nanticoke comes from the indigenous tribe the tidewater people. Hwiskakimensi Sippus is the Lenape name for Red Clay Creek meaning young tree stream.”

These examples exist as a few of many interesting and important results learned through the process in addition to the successful completion of a current version of the map. These translations and unique histories are just the beginning of many possibilities for this project to continue growing.

Figure 9 shows Liz Shields (me), Master of Public Policy Student and Graduate Research Assistant with UDWRC, presenting the current version of the Indigenous and European Names map at the 57th Annual Meeting of the UDWRC Advisory Panel on May 5, 2022 at the University of Delaware.

Conclusions and Recommendations

Through the process of analyzing the 1966 USGS Delaware Place Names report and building an inclusive version of the Delaware or *Lenapehocking* map with respect to the rich history of Swedish and Dutch settlers and maintained presence of Indigenous peoples here, many lessons have become clear.

Foremost, water research in the context of social relationships to place and history is crucial to forming deep, complete understandings of the work. In order to really know a place and begin to address issues of any kind, starting with knowing its full lineage of names and meanings can be majorly impactful. With this kind of information, water researchers could not only improve relationships with locals and experts of a place to become better collaborators and more informed in their roles, but also be inclined to other aspects of a location simply by knowing how it got its name. For Delaware specifically, the results found through this study solidify this argument completely. For the Indigenous and European Place Names Along Streams in Delaware (*Lenapehocking*) map and associated research findings specifically, a clear conclusion is the level of dedication, time, energy, and resources necessary to carry out a project of this nature. Given the importance of any topics involving Indigenous history, culture, and language, UDWRC attempts to always maintain the utmost respect and diligence to accuracy as possible when sourcing information.

A recommendation for the continuation of this project is for UDWRC to embark on a journey of meaningful collaboration with the Native tribal leadership and population in our state. UDWRC are not the experts in this area, but act as a dedicated team starting the process of what is hopefully only the beginning of bringing Indigenous history and presence to the forefront of daily life in Delaware. By branching out to form relationships with the holders of this knowledge, this project can evolve and improve limitlessly. This can begin not by asking Native peoples to do the work for us, but collaborate with us for the benefit of all who live and will live on the lands and waters of *Lenapehocking*.

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