

A comparative study of the 2011/2013 water quality assessments in the Pasquotank Watershed in Northeastern North Carolina

Linda Hayden, Principal Investigator
Elizabeth City State University
1704 Weeksville Road, Box 672
Elizabeth City, North Carolina 27909

Robin Brice
Fayetteville State University
1200 Murchison Rd
Fayetteville NC, 28301

Jeff Wood, Mentor
Elizabeth City State University
1704 Weeksville Road, Box 672
Elizabeth City, North Carolina 27909

Dorothy Brice
Virginia Union University
1500 N Lombardy St
Richmond, VA 23220

Anthony Lynn
Winston Salem State University
601 S Martin Luther King Jr. Dr
Winston Salem, NC 27110

Abstract-The Pasquotank River Watershed is found in Northeast North Carolina beginning in the Great Dismal Swamp at the Virginia/North Carolina border and flows into the Albemarle Sound. The watershed provides a transition between spawning grounds and the waters of the Albemarle Sound. The sound serves as a nursery area for many fish species and is home to numerous sport and commercial species. Tributaries enclosed by various landforms such as swamp, farmlands, and increased housing development supply the watershed. These landforms make both negative and positive contributions to the water quality of the watershed.

The 2013 Research Experience for Undergraduates Pasquotank River Watershed Team completed tests of five tributaries and the river itself. These test points were derived from the 2011 Watershed Team research project in order to compare the results. Streams tested were Newbegun Creek, Knobbs Creek, Areneuse Creek, Mill Dam Creek, and Sawyers Creek. These streams, along with the river, covered a large area of the watershed and provided a wide variety of shore development from swampland and farmland to industrial development.

In-house tests performed on this year's samples included pH, salt, total dissolved solids, and conductivity. Air/water temperature, dissolved oxygen, wind speed/direction, and turbidity/clarity measurements were taken in the field. The results from these readings were placed into an online database and correlated to the location of the sample using Google Maps. The data were then compared to the 2011 project data and analyzed for any variations or similarities.

Keywords: Water Quality, Pasquotank, Watershed, dissolved oxygen, pH, salt, conductivity, clarity, turbidity

I. INTRODUCTION

A. Overview

A watershed describes a range of land that includes a common set of streams and rivers that all drain into a single larger body of water, such as a superior river, lake, or ocean. [1]. Watersheds can come in all shapes and sizes. They divide counties, states, and national boundaries [2]. "In the continental US there are 2,110 watersheds; including Hawaii Alaska, and Puerto Rico, there are 2,267 watersheds." [2] All streams, tributaries, and rivers are associated to a watershed. In most cases, small watersheds gather together to become larger watersheds. Watershed activity that affects the water quality, quantity, or flow at any location, can also alter the features of the watershed at downstream locations. A watershed has four important functions, collecting water from rainfalls, storing water, releasing water, and providing a home for fauna and flora. [3] Watersheds support life, in more than one way. According to the Environmental Protection Agency, "more than \$450 billion in foods, fiber, manufactured goods and tourism depend on clean, healthy watersheds." The Earth consists of 70% of water and out of that, 40-50% of our land's waters are impaired or endangered. This could lead to insufficient water, meaning that the water will be inhabitable leaving no drinking water or produce. "Watershed protection is a means of protecting a lake, river, or stream by managing the entire watershed that drains into it." To ensure a healthy watershed the community must get informed on how humans can impact a body of water. [4]

In the 2013 project the following factors were evaluated: dissolved oxygen (DO), clarity, turbidity, pH, total dissolved solids (TDS), salinity, and conductivity. All of these parameters can affect the overall quality of a watershed.

B. Dissolved Oxygen

Dissolved oxygen in water is a necessity for aquatic life. [5] Water temperature, clarity, turbidity, TDS, and salinity all affect DO [6]. Other factors that contribute to the rise or fall of DO levels are the volume and velocity of a water source [6].

C. Turbidity

Turbidity is the measurement of the scattering effect of the dispersed and suspended solids on light. These solids can promote the growth of harmful microorganisms and can block light from reaching aquatic vegetation. This can affect the DO levels in stream, rivers, and lakes. [13]

D. Clarity

Clarity is a measurement of how clear the water is. While this does take into account the suspended solids in the water, it mainly focuses on colored particles in the water that absorb light. Color is created by the material in the water such as iron and manganese, but is also a product of the organic material in the water including tannins, which provide a dark brown color to the water. [14]

E. Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) are the total amount of traveling charged ions, which includes minerals, salts or metals. TDS correlates with the purity of water. A higher concentration of TDS indicates improved conductivity however it can also cause a reduction in dissolved oxygen [9].

F. Salinity

Salinity is the measurement of salt that is dissolved into the water. The amount of salt in the water can determine what lives and grows in different zones. Salinity is a large factor in testing water quality as the higher the amount of salt, the lower the amount of dissolved oxygen the water can hold. Salinity is measure in parts per million (ppm). [15]

G. Conductivity

Conductivity is the measurement of the water's ability to conduct electricity. The measurement is affected by dissolved solids for example nitrate, which carries a negative charge, and sodium, which carries a positive charge). The area in which the water flows can also be a determining factor of the measurement. It is measured in micromhos per centimeter ($\mu\text{mhos/cm}$) or microsiemens per centimeter ($\mu\text{s/cm}$). [16]

H. pH

The pH is a measurement of how acidic or basic something is. The pH is measured on a scale form 0-14 where 0-6.9 is acidic, 7 is neutral and 7.1-14 is basic. Water with a particularly high or low pH is lethal. Water with a

fairly low pH can deplete the amount of hatching fish eggs and can affect fish and macroinvertebrates. [10] Amphibians are predominantly defenseless, mostly because of their delicate skin. [10] Some scientists concluded that the current decline in amphibian numbers globally is due to acid rain, which can cause the pH levels to decrease. [10] A pH level between 6.5 and 8.2 is considered standard for bodies of water [11].

The land that surrounds the watershed can influence many different factors in positive and negative ways. Pollution, agricultural, and development are some of the biggest factors.

II. METHODOLOGY

A. Positions

Latitude and longitude points were taken from the 2011 Water Quality Team project for each of the streams to aid in comparison of the data. Prior to visiting the field the longitude and latitude for each location were loaded into the Garmin GPSMAP 60CSx, a handheld Global Positioning System (GPS) device.

B. Research Platforms

A canoe and a kayak were used to navigate each of the small creeks that were inaccessible to larger boats. The LH Viking, a 22-foot Sea Pro Model 210-fiberglass boat, was used on the Pasquotank River and a second trip to Newbegun Creek. While this vessel greatly increased the amount of samples gathered in a shorter time, it drew too much water for use in smaller creeks.

C. Water Temperature

A mercury thermometer was attached to the bottom of the dowel. This allowed the water temperature ($^{\circ}\text{C}$) to be recorded at a three-foot depth.

D. Wind Speed/Air Temperature

The Skymate Speedtech Hand-Held Sm-18 Wind Meter was used to determine wind speed in knots. In order to achieve the most accurate reading the wind meter was lifted up and away from the person measuring. The meter also measured the outside air temperature, which was recorded in degrees Celsius.

To choose a particular unit to calculate wind speed, navigate through the wind meter by holding down the hold button and pressing the "units" button. In order to switch from the wind speed screen to the air temperature screen, push the "units" mode button until the temperature screen appears.

E. Dissolved Oxygen

The Milwaukee Dissolved Oxygen MW 600 Meter measures the amount of oxygen in the water. Similar to the pH meter, the DO meter does not self-calibrate. To calibrate the DO meter, fill the probe membrane with electrolytic water and place the probe into zero oxygen solution. While the probe is in the solution, use the screwdriver to turn the screw slowly until the meter reads zero. To do actual testing,

place the probe in a given solution and wait for the numbers on the meter to stabilize to take a clear reading.

The Milwaukee Dissolved Oxygen Meter MW-600 was attached to the canoe and lowered three feet into the water. When the water currents are strong the meter began drifting under the vessel. To avoid this, the meter was placed straight down into the water at an arm's length distance. This meter takes approximately one to two minutes to record the dissolved oxygen levels. Care must be taken to not damage the sensitive membrane on the probe. The meter probe was filled with electrolytic water each morning and calibrated to ensure accurate readings.

F. Turbidity/Clarity

The Secchi disk is a round black and white disk used to measure clarity. When using the Secchi disk allow the same person to take the readings in order for them to remain consistent. Turbidity was measured by using the reverse side of the Secchi Disk, which was painted all black. The Secchi Disk is attached to a rope, which is marked in one-inch intervals. The disk is lowered into the water until the disk is completely unseen; this is where the first measurement is taken. The disk is slowly raised until it becomes visible again. This is where the second reading is taken. The average of the two readings is the clarity of that location.

To measure turbidity reverse the disk to the dark side and repeat the above steps. Turbidity required an addition of four inches due to an extension attached to the disk to allow swapping of sides.

G. Conductivity/Salinity/Total Dissolved Solids

At each location water samples were taken using a sample bottle attached to a four-foot dowel. Each water sample was acquired at a three-foot depth and taken back to the lab for testing. In the lab, the LaMotte Tracer PockeTester was used to test conductivity in millisiemens (ms), salinity in parts per million (ppm) and Total Dissolved Solids (TDS) in parts per million (ppm).

The PockeTester self-calibrates upon being powered on. When looking at the screen, while powered on, there are two sets of numbers. The top, larger number will be the conductivity, TDS, or salinity reading; the bottom, smaller number will be the temperature. To test for conductivity, hold down the mode button until CON appears at the bottom of the screen. Testing for TDS and salinity will be the same, except TDS will appear for TDS and SAL will appear for salinity. Care must be taken in reading the meter as the units will change (mS/cm and μ S/cm) without warning.

H. pH

The Aquarium Portable Digital pH meter measures the waters acidity and basicity. Unlike the PockeTester, the pH meter does not self-calibrate. To calibrate the pH meter, place it in acidic (4), neutral (7), and basic (10) liquids. While the meter is sitting in each liquid, use the screwdriver to turn the screw in the back until the meter shows the exact pH of that liquid. Once calibrated testing is simple. To test,

place the meter in the sample and wait for the number on the pH meter to stabilize to get a clear reading.

III. SOFTWARE APPLICATIONS

A. Overview

Once all of the data was gathered the results were placed into several computer applications to make the data easier to interpret. The applications used were Adobe Dreamweaver, Google Maps, the online Water Quality Index Calculator, and Microsoft Excel.

B. Google Maps

Google Maps is an online mapping application that is offered through Google. Google Maps gives locations, direction, and real-time street views of locations worldwide. Google Maps displayed the latitudes and longitudes for each point and allowed for visual confirmation of the points entered into the GPS navigation systems. The test results for this project were also placed online using Google Maps to give a visualization of what the readings were at each test point.

C. Dreamweaver

Adobe Dreamweaver is used to create and design webpages. Dreamweaver allowed for the use of JavaScript and HTML to create the visualization pages for the test results. Test results were coupled with the Google Map code in JavaScript and presented using HTML code. The project also utilized Dreamweaver to create the Water Quality Team's project documentation pages.

D. Excel

Microsoft Excel is used to make spreadsheets to organize and manage data. The purpose for using Microsoft Excel was to create tables and charts to assist in analyzing the data gathered. Microsoft Excel also allows calculations to be used within the spreadsheet such as averages and conversions.

E. Water Quality Index Calculator

The Water Quality Index (WQI) is a single number ranging from 1-100 that scores the health of a stream based off of certain parameters. An environmentalist by the name of Mr. Brian Oram created the online application, which computes streams WQI based on weighted measurements. This project utilized four of the nine available inputs in the calculator to determine the WQI of each stream. Dissolved oxygen inputs had to be converted from mg/l to saturation %. This can be completed using a chart such as the one found at: <http://ciese.org/curriculum/waterproj/saturation/> or a second calculator located such as the application at: <http://www.hbuehrer.ch/Rechner/O2satur.html>. This project utilized the calculator application.

IV. ANALYSIS

A. WQI 2011/2013

The overall change between the Water Quality Indices of 2011/2013 was slight. Table.1 illustrates that the Pasquotank River had a higher water quality than the other tributaries in 2011, while in 2013 Newbegun Creek had the highest. The change in which waterway had the top water quality was

possibly due to the amount of wind that was encountered on the first day of sampling at Newbegun Creek. During this trip, the wind levels were high causing a great amount of churning of the water. This had a large affect on the dissolved oxygen levels, which impacted the water quality of Newbegun Creek. Other than the change in which waterway had the top water quality, the other water quality indices all remained consistent with each other.

TABLE I. Is a comparative table that shows 2011 /2013 Water Quality Index for each location.

Water Source	2013 WQI	2011 WQI
Newbegun Creek	66	50
Mill Dam Creek	47	48
Areneuse Creek	47	49
Pasquotank River	44	64
Sawyers Creek	50	54
Knobbs Creek	50	52

TABLE II. Comparative data for 2011/2013 parameters.

2011 Water Source	pH	DO mg/L	Turbidity (in)	TDS (ppm)	Salinity (ppm)	Conductivity (mS/cm)
Newbegun Creek	5	4	17	3006	2146	4
Mill Dam Creek	5	4	32	3203	2285	5
Areneuse Creek	4	4	19	2460	1758	4
Pasquotank River	6	5	14	761	541	1
Sawyers Creek	7	4	19	856	607	1
Knobbs Creek	5	5	23	1847	1325	3

2013 Water Source	pH	DO mg/L	Clarity (in)	Turbidity (in)	TDS (ppm)	Salinity (ppm)	Conductivity (mS/cm)
Newbegun Creek	7.4	5.0	18.0	9.5	3242.0	2272.5	4.89
Mill Dam Creek	7.0	2.5	24.0	10.5	3263.5	2331.5	4.39
Areneuse Creek	7.4	2.0	22.0	11.0	2455.0	1751.5	3.77
Pasquotank River	6.1	3.0	13.0	5.5	815.5	582.5	1.07
Sawyers Creek	7.5	3.5	17.5	9.5	856.0	611.0	1.09
Knobbs Creek	7.1	3.0	25.5	13.0	1314.5	910.0	2.03

B. Dissolved Oxygen

The stream measurements for 2013 roughly paralleled the measurements for the 2011 project. Dissolved oxygen, the largest factor in stream health, varied from low levels at the head of each waterway to much higher levels at the intersection of the waterway with the Pasquotank River. The Pasquotank River readings also replicated this pattern from the intersection of the Dismal Swamp Canal to the town of Elizabeth City. Factors influencing this include wind, water depth, and width of the waterway. Newbegun Creek came in at the top of the Water Quality Index mainly due to the high dissolved oxygen readings. These high readings may have been shaped by persistent northerly winds entering the mouth of the river creating greater wave action.

C. TDS, Salinity, and Conductivity

TDS, salinity, and conductivity readings remained high as in 2011 in Mill Dam Creek, Areneuse Creek, and Newbegun Creek. These waterways are well below the Elizabeth City where the Pasquotank River narrows greatly, increasing the influence of the brackish water brought in during the summer months. The testing points for the Pasquotank River start at the city and work north towards Knobbs Creek and Sawyers Creek yielding less of an influence by the brackish water in the lower Pasquotank River. From this it can be derived that salt is the main solid in these waterways. Another check of these waters during the cooler months could possibly prove or disprove this conjecture.

D. pH

The pH readings for this year's sampling were higher than the 2011 tests. The almost neutral state of this year's readings was unexpected due to historic records of very low pH. Factors that may have caused this were a dry period without much runoff from the area swamps and a period of extreme heat during the sampling period. The comparison between the two years may also have been influenced by a change in testing methods. The 2011 team utilized test strips with which the color must be interpreted and the 2013 team put into use a digital pH meter that could be calibrated to basic, neutral, and acidic.

E. Clarity/Turbidity

At the recommendation of Mr. Jeff Schloss of the University of New Hampshire, a separate test for turbidity was initiated. Using this black side of the Secchi disk, the team was able to compare the color of the water (clarity) to the suspended particles in the water (turbidity). The readings paralleled each other with clarity having approximately a ten inch greater reading at each test point. The Secchi disk is a very subjective test, greatly affected by the user's perception and other factors such as water reflection and the amount of sunlight during a test.

V. CONCLUSION

A. Overall

In this project, the data show that the overall health of the Pasquotank Watershed, as determined by the Water Quality Index Calculator, has remained consistent compared to the previous 2011 project.

B. Variations

Though minor variations were found in the WQI, the overall health of the Pasquotank and its tributaries remain around the medium range. The most noticeable difference involved the dissolved oxygen of Newbegun Creek and Areneuse Creek. The position of Newbegun and the Pasquotank River switched because in 2011 Pasquotank had the highest WQI in 2013 it is Newbegun.

C. Land Associations

As in the 2011 project very little association was made between the landforms surrounding these waterways and the test results. This may have been as a result of a low rain period during the testing.

D. Areneuse; Mill Dam; and Newbegun Creek

One of the major correlations discovered was the relationship between Areneuse Creek, Mill Dam Creek, and Newbegun Creek. These creeks are well downstream of the other waterways tested (Pasquotank River, Knobbs Creek, and Sawyers Creek) and were found to have much higher concentrations of salt. This affected both the conductivity and the TDS tests. These results were also noted when the 2011 project data were analyzed. The team did not sample at the mouth of the Pasquotank and if that location was tested it

could have shown some insight on the high concentrations of salt.

E. Data Sampling

Better equipment and drawing on the experience of the 2011 team allowed this year's project to make two samplings of each waterway doubling the amount of data acquired. Increased documentation with each project should establish a firm base from which to gather increased data and increase the type of tests performed for a more accurate assessment of the watershed's well-being.

F. Data Presentation

The team used an online visual database of points created in 2011 and tested in 2013. The code was originally written to present one trip of data and expanded during this project to display two trips. The code utilizes Javascript code to incorporate the Google Maps interface.

An extra point was added to the Newbegun section of the trip. The map shown in Figure 1 is located on the NIA webserver at:

<http://nia.ecsu.edu/reuomps2013/teams/water/mapandresults.html>

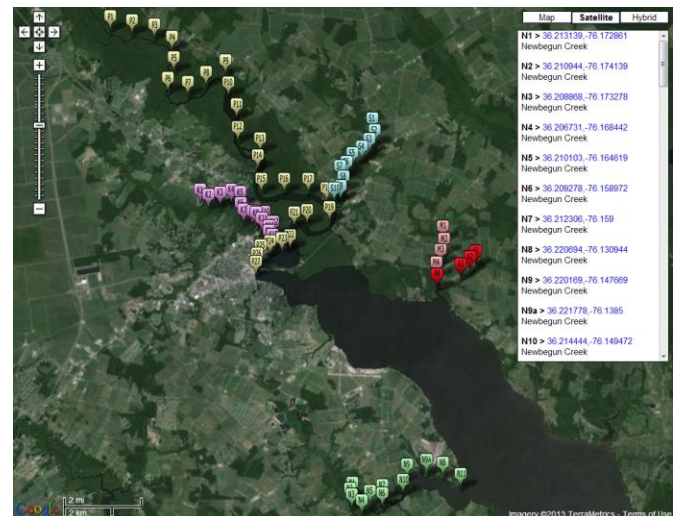


Fig. 1. Test points from all five waterways

VI. FUTURE WORK

A. Meter Capability

For future testing of water samples it is suggested that a more advanced meter be acquired that would be able to perform multiple tests. The YSI Professional Plus Multi-Parameter Meter, which is manufactured by YSI, is capable of measuring dissolved oxygen, conductivity, salinity, total dissolved solids, pH, and temperature. The retail price for the tool is approximately \$1,125 via instrumart.com. There are several different models of this meter, each having a different level of testing capability. This meter could increase the number of tests completed and provide improved accuracy through its internal database management.

B. Research Platform

The acquisition of a small, flat-bottomed, boat with a small engine would decrease the amount of time needed to cover each waterway. This boat should be light enough to carry into locations that do not have launching ramps and have a secondary source of power such as a trolling motor.

C. Added Tests

It is also suggested that the addition of nitrogen, nitrate, and fecal coliform tests be studied. These are just a few of the many tests that the Environmental Protection Agency calls for, but are major factors in determining the health of the water being tested. While these tests are essential parts of water quality tests they may be beyond this program's abilities to test at this level of research.

D. Additional Test Points

There is a large gap in the testing area of the Pasquotank River starting at Elizabeth City and ending at the mouth of the Pasquotank River. It is suggested that this area be added to the test sites currently being monitored. Test points could be at a greater interval due to the larger body of water begin tested.

E. Database Development

An online database should be implemented that would allow one online page to access any set of data from any project year. The current online paradigm requires that each page be hard-coded to a particular set of data. Development of a PHP interface with the data would allow greater access to multiple sets of data for better comparison.

ACKNOWLEDGEMENTS

We would like to acknowledge Dr. Linda Hayden for her leadership of the REU program, Mr. Lee Hayden for his assistance with the boat, Jeffrey Wood for his assistance with the research, CReSIS and the Nation Science Foundation for their funding of this program, and the REU staff for their daily assistance.

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