

A Corresponding Study of Water Quality Evaluation of the Pasquotank Watershed in Northeastern North Carolina with a sea level rise component

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Abstract- The Pasquotank River Watershed covers over 450 square miles and is located in the Coastal Plain of northeastern North Carolina. It flows from the Great Dismal Swamp at the Virginia/North Carolina border into the Albemarle Sound. The watershed is part of the Albemarle-Pamlico Estuarine System, the second largest system in the United States after the Chesapeake Bay Estuary and provides a transition between spawning grounds and the waters of the Albemarle Sound.[17] Forested swamp wetlands border much of the waterways. Increased agricultural and urban development has greatly affected water quality during recent years.

The 2015 Research Experience for Undergraduates Pasquotank River Watershed Team completed various tests along the tributaries and the river itself, adding to the previously gathered data from 2011, 2013, and 2014. The test points were derived during the 2011 Summer Watershed Team research project with four points added during the 2014 summer project. Results were compared with previous readings for analysis. Streams tested were the Newbegun Creek, Knobbs Creek, Areneuse Creek, Mill Dam Creek, and Sawyers Creek. These streams, along with the river, cover a large area of the watershed and provide a wide variety of shore development from swampland and farmland to industrial development.

In-house tests on this year's samples continued to include pH, salinity, 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 where they are correlated to the location of the sample using Google Maps®.

Analysis tools were developed in order to compare the data from all years for any variations or similarities. Excel spreadsheets were developed to look more closely at individual points and tests for each point. Past projects have used a general analysis of the entire stream to determine water quality. Steps were also made to research the development of an online graphing tool for analyzing the data at individual points over several years. Test results collected were added to a

database developed during the 2014-2015 academic year at Elizabeth City State University. This database was connected to a data visualization page utilizing Google Maps®.

The results show that there were variations for the individual water quality scores, but the overall water quality score for all the tested water sources remained at a comparable level from previous years. Mill Dam Creek rose above the previous three scores of 48 (2011), 47 (2013), and 49 (2014) and achieved a medium water quality score of 57. Areneuse Creek improved in water quality with a medium water quality score of 60. Sawyers Creek became the lowest scoring waterway tested at 35. Knobbs Creek decreased from previous years with a water quality score of 42. For a fourth consecutive testing year, Newbegun Creek fell within the medium water quality range with a score of 65. Pasquotank River rose from the previous testing year's score of 35 but still remained within the bad water quality range with a score of 45. The Lower Pasquotank remained the highest scoring tributary for a second consecutive year with a score of 85.

I. INTRODUCTION

A. Overview

A watershed is a group of waterways that flow into a larger body of water. The Pasquotank Watershed was used for testing the water quality in the Northeastern North Carolina area. This was the fourth year for testing water quality in this watershed. The Pasquotank Watershed contains five creeks, which also includes the river itself. The water sources within the watershed are Mill Dam Creek, Areneuse Creek, Sawyers Creek, Knobbs Creek, and Newbegun Creek.

Watersheds can change in size, and every stream, tributary, or river has an associated watershed. Watershed boundaries can easily be delineated using a topographical map that shows the ridges related with the various drainages and the mouth of the stream or river where water flows out of the watershed. The water drains via a network of surface and underground drainage pathways, and generally these

pathways join into a stream or river system that becomes progressively larger as the water moves downstream. Ground and surface waters may also merge or split at various locations along the pathway to the recipient water body that gathers drainage from the watershed. Because the water naturally moves downstream in a watershed, any activity affecting the water quality, quantity, infiltration, or rate of drainage at one location in the watershed can change the physical, chemical, and biological characteristics at downstream locations [2].

The previous periods of testing the Pasquotank Watershed were 2011, 2013, and 2014. Testing done within the waterways was for clarity, turbidity, dissolved oxygen, air temperature, water temperature, wind speed, and wind direction. Other variables recorded in field-testing were time, date, longitude, and latitude. Also, laboratory tests were done for the following variables: pH, salinity, conductivity, and total dissolved solids. This data was utilized to seek trends and find comparisons within the waterways over the testing years of 2011, 2013, 2014, and 2015. The Lower Pasquotank became an addition to the Pasquotank Watershed in the year of 2014. The reason was to continue monitoring the salinity levels, which is an indicator of sea level rise in coastal waterways.

B. Dissolved Oxygen

Dissolved oxygen is the measure of oxygen dissolved within a body of water [10]. This is the primary factor in determining the overall water quality for any waterway. Dissolved oxygen is necessary to many forms of life including fish, bacteria, and plants. Fish obtain oxygen for respiration through their gills, while plant life and phytoplankton require dissolved oxygen for respiration when there is no light for photosynthesis. Dissolved oxygen enters water through the air or as a plant byproduct. From the air, oxygen can slowly diffuse across the water's surface from the surrounding atmosphere. Dissolved oxygen is also produced as a waste product of photosynthesis from phytoplankton, algae, seaweed and other aquatic plants [11]. There are some factors that affect dissolved oxygen. The volume and velocity of water flowing, the climate, the water temperature, and the types of organisms living within the water are factors to the dissolved oxygen [15]. Milligrams per liter (mg/L) were the measurement units used for dissolved oxygen. The recorded dissolved oxygen in milligrams per liter is converted to percent saturation. Corrected oxygen, or percent saturation, is obtained by using the formula " $\% \text{ saturation} = (\text{D.O.} / \text{Saturation level}) * 100$ ". This means that the dissolved oxygen reading is divided by the milligrams per liter setting that gives 100% saturation, in this case 8.2, and then multiplies by 100 to get the corrected dissolved oxygen [15].

C. Turbidity

Turbidity is the measure of how much the suspended particles in the water decrease the amount of light to pass through the water. The particles include clay, silt, and sand. Higher turbidity is caused by higher temperature because the

suspended particles absorb heat. Sources of turbidity include soil erosion, waste discharge, urban runoff, eroding stream banks, large numbers of bottom feeders, which stir up bottom sediments, and excessive algal growth [25]. Turbidity is recorded in inches and later converted into Nephelometric Turbidity Units (NTU) using the conversion chart [29] for the water quality index calculator.

D. Clarity

Clarity determines how clear a certain body of water is. Clarity can be used to display how much light can penetrate the water. Several factors can impact the abundance of dissolved substances and/or particles in the water that also impacts water clarity. The abundance of dissolved substances and/or particles in the water can be influenced by the presence of aquatic plants and/or the location of the waterway. Seasonal variations in climate can also impact water clarity [13]. There are two types of water for clarity. These types of color are apparent color and true color. True color is water sample that has had all the substances filtered out of the water, and apparent color is water sample that has not had substances filtered out of the water.

Total Dissolved Solids (TDS)

Total dissolved solids are the amount of mobile charged ions. Dissolved solids consist of calcium, chlorides, nitrate, phosphorus, iron, sulfur, and other ions particles. This includes minerals, salts or metals dissolved in a given volume of water. This is measured in parts per million (ppm) or milligrams per liter (mg/L). [26]

E. Salinity

Salinity is the measure of how much salt is dissolved in a waterway. Salinity is measured in parts per million (ppm) or parts per thousand (ppt). [35] It is affected by evaporation and precipitation. Higher temperatures cause more evaporation which provides more salinity. Precipitation, such as rain, can negatively affect salinity as rain dilutes the salt within the water. Brackish waters are usually high in salinity. For example, Areneuse Creek empties out into the Pasquotank River, which provides more salt to flow into and out of this creek.

F. Conductivity

Conductivity is the measure of a waterway's capability to pass electrical flow. The more ions that are present, the higher the conductivity of water. Higher temperatures also lead to higher conductivity. Conductivity in water is affected by the presence of inorganic dissolved solids that are negatively charged like chloride, nitrate, sulfate, and phosphate anions or positive charged ions like sodium, magnesium, calcium, iron, and aluminum. Conductivity is usually measured in micro- or millisiemens per centimeter (uS/cm or mS/cm) [27].

G. pH

The pH measurement is used to determine if a given medium of water is acidic, basic, or neutral. The range of the pH measurement is from zero to fourteen. Acidic is when a

waterway has a pH is settled within 0 to 6.9. Basic is when a waterway has a pH is settled within 7.1 and 14. A neutral setting is when a pH level is settled at seven. [30]

II. EQUIPMENT

A. Positions

Latitude and Longitude points were taken from the 2011, 2013, and 2014 Water Quality Team projects for each waterway to assist in comparing and analyzing data. The latitudes and longitudes of each point of each waterway were loaded into the Garmin GPSMAP 60CSx, a handheld Global Positioning System (GPS) device, using the Garmin BaseCamp software [12].

B. Research Platforms

A canoe was used to travel through each of the small, narrow tributaries, such as Mill Dam Creek, Areneuse Creek, Sawyers Creek, and Knobbs Creek. The LH Viking was used to travel through the Pasquotank River and Newbegun Creek. During the testing of Newbegun Creek, the kayak was used to travel under a bridge to gather the remaining points of that tributary.

C. Water Temperature

The Mercury thermometer [6] is used to measure water temperature in degrees Celsius. The thermometer is lowered into the water at a depth of three feet for approximately one minute to allow the thermometer to settle and obtain an accurate temperature. The thermometer is then brought up, along with the water sample, and the reading is taken.

D. Wind Speed/Air Temperature

The Skymate Wind Meter is an anemometer that was used to measure wind speed and determine the air temperature. [33] The wind speed is measured in knots and the air temperature is measured in degrees Celsius.

To measure wind speed, the anemometer is held directly in the air away from anything that may restrict the wind from the anemometer. The meter will rarely settle due to variations in the wind speed. The same procedure is done to obtain the air temperature.

E. Dissolved Oxygen

The MW600 Dissolved Oxygen Meter is an instrument used to measure dissolved oxygen in water. This device is calibrated at two points, 100% saturation air and 0% oxygen solution. This device has an automatic temperature compensation that will guarantee accurate readings. [16]

When using this device, ensure that the device is set to 0.0 milligrams per liters. Unscrew the cap, and the probe is exposed. Then, fill the cap with electrolyte and allow it to settle for 5 to 10 minutes. While the meter calibrates, press and hold the "CAL" button and calibrate the meter to 100% saturation. Releasing the CAL button and the LCD will display a value in milligram per liter (mg/L) of oxygen. When the calibration is complete, place the plastic cap back on the membrane. [14]

Before using it in water, remove the plastic cap to exposes the membrane. Set the membrane in the water at a depth of three feet. Give the device time to reach a stable reading for dissolved oxygen. This may take within three to five minutes. When the reading is given, place the plastic cap back on, so the meter will reset back to the neutral setting.

F. Turbidity/Clarity

The secchi disk is a two-sided disk, one with quartered sides of black and white and the other being entirely black. Turbidity is measured used the whole black side and clarity is measured using the quarterly black and white side. The plate is attached to a rope that has measurements of inches. The plate is detached to change the sides of the plate.

For turbidity and clarity, the plate is lowered into the water until it is no longer seen. The mark at which the plate is no longer seen is the first reading to be taken. Then the disk is lowered further then gradually brought up until it is noticeable. Again, the mark where it is noticeable is the second reading to be taken. After taking both measurements of each test, the average is calculated.

Clarity is a measurement of how deep light is able to penetrate through the water. [19] Turbidity is a measure of the amount of transparency water losses due to suspended particles, which causes it to cloudy. With clarity and turbidity, the lower the plate the more the water is transparent.

G. Conductivity/Salinity/Total Dissolved Solids

The Tracer Pocket Tester is a self-calibrated tester that measures conductivity, salinity, and total dissolved solids (TDS). Salinity determines the saltiness of the water and is measured in parts per million. Conductivity is the measure of the water's capability of passing electrical flow and is measured in Siemens (mho). TDS measures all the dissolved solids in the water and is measured in parts per million (ppm). This pocket tester has two probes that are always protected and should only be touched by water. If the probes come in contact with anything else, it will cause the readings to be inaccurate. [20]

There are three modes to change between to obtain readings. Those three modes are salinity, conductivity, and total dissolved oxygen readings. To do this, press and hold "MODE" until SAL, CON, or TDS appears at the bottom of the screen. SAL is salinity, CON is conductivity, and TDS is total dissolved solids. On the screen there is also an indication of the current measurement unit that is being used. In SAL mode, "ppm" will appear in the top left corner and S will appear in the middle. In CON mode, \square S or mS will appear in the middle. In TDS mode, "ppm" will appear in the top left corner. Once the pocket tester is placed in the sample water, gently stir the water to be sure that no air bubbles are present. Allow the pocket tester to settle in order to obtain a reading from each mode.

H. pH

The Aquarium Testing Unit is an instrument used to measure pH, which is determining whether it is acidic or basic. [24] pH readings range from 0.0 (acid) to 14.0 (base). The pH levels from 0.0 to 6.9 are considered acidic, from 7.1 to 14.0 are considered basic, 7 is considered neutral. [28]

This testing unit is always calibrated before using it. The calibration should set the pH meter to a neutral reading of 7.0 by using distilled water and a 7.0 mini-buffer tablet. The tablet must be completely dissolved into the distilled water, then the pH meter is placed into the water, and using a small screwdriver, change the reading until it gets to 7.0. After calibration is done, the testing unit is used to determine the specific pH levels.

III. SOFTWARE APPLICATIONS

A. Overview

A variety of software applications were used for analyzing data. All of the software was a contribution for the final analysis. The following software packages were used throughout this research: Garmin BaseCamp, Google Maps, Adobe Dreamweaver, Microsoft Excel, and the Water Quality Index Calculator.

B. Google Maps

Google Maps is a mapping application provided by Google that can be embedded into a site by using the Google map asset and Google Map Application Programming Interface (API). [21] This application is used to get specific locations, which also allow for a variety of features to display the specific location. Google Maps was used to display test points and data collected from each point.

C. Dreamweaver

Adobe Dreamweaver is a software application for designing web pages. This application provides a what-you-see-is-what-you-get (WYSIWYG) interface to create and edit web pages in a user-friendly environment. [4] It allowed the use of HTML, JavaScript, and program editors to display the research that was done as well as the results.

D. Microsoft Excel

Microsoft Excel is a spreadsheet program included in the Microsoft Office suite of application. Spreadsheets present tables of values arranged in rows and column that can be manipulated mathematically. [34] This program was utilized to input data collected from field and in-house testing, for comparisons, analysis, averaging, and identifying trends through charting. It was also used to calculate the Water Quality Index.

E. Water Quality Index Calculator

The Water Quality Index is an attempt to represent overall quality of water collected from waterways. [31] The water quality index calculator is an excel spreadsheet that allows factors to be entered for calculation. The factors entered are multiplied by the respective weight factors. The sums are added together to get the water quality index. The water quality index ranges from 0 to 100. From 0 to 25 is very bad, 25 to 50 is bad, 50- 70 is medium, 70-90 is good, and 90 to 100 is excellent. [32]

F. Google Drive

Google Drive is an application that allows people to store and share files online. [23] This application was used for compiling documents and spreadsheets. Those shared files were necessary for analysis and the final report.

A. Pre-Field Work

In preparation for the fieldwork, the Global Positioning Systems (GPS) devices were loaded with points and routes by using the Garmin BaseCamp software for each waterway. Before each waterway was tested, the Dissolved Oxygen (DO) meter was calibrated using zero solutions and distilled water. Once calibration was completed, a checklist was completed to ensure that all necessary gear was gathered and prepared for testing.

B. Field Work

The canoe, or boat and kayak was launched into the water and loaded with all the gear needed such as paddles, test equipment, and data recording equipment. All of the test equipment was secured to the platforms in case of accidents.

At each test point, there were several tests performed and recorded and water samples were obtained. The time was documented as a reference for water samples being taken as test results may vary throughout the day. Once the time was recorded, the wind speed and direction, air temperature, and water temperature were also recorded. Clarity and turbidity were observed and recorded using the secchi disk. The dissolved oxygen was obtained using the dissolved oxygen (DO) meter.

C. Post-Field Work

After collecting data from each waterway, in-house tests were done to obtain the pH, conductivity, salinity, and total dissolved solids readings. The water samples from the field water were poured into small Styrofoam cups for testing. The pH meter is calibrated in distilled water and a pH tablet set for 7.0. The pocket tester, which is used to test for salinity, conductivity, and total dissolved solids, is a self-calibrated meter. Each meter was placed in the water sample to obtain readings.

D. Offline Data Visualization

Data was entered into Google Drive Excel sheets. These spreadsheets were used for recording the data in field and laboratory testing. The data was also used in Microsoft Excel spreadsheets to compare using visual graphs. The spreadsheet contains the following data: name, date, points, time, dissolved oxygen, corrected dissolved oxygen, pH, clarity, turbidity, salinity, conductivity, total dissolved solids, air temperature, water temperature, wind speed, and wind direction. The data in the spreadsheet is merged with HTML and JavaScript to be used in Google Maps to display the data in the web browser.

A Microsoft Excel file was developed in order to analyze in detail each point with each test. This file began as a table containing the data collected each year for this project dating back to 2011. A new spreadsheet was created to house the different pull down bars from which data would be selected for analysis. There were three pull down bars that were validated [3]: source, point, and test data. Once the lists were made and functioning properly a new table was created to

display information based on what was selected from the source and point pull down bars. Once that was done, another chart was made that would display only the test data from that specific point. This is the data that was used to create a dynamic chart [1] in which the title, x and y-axis would change with the selection of a source, point, or test. It was concluded that this feature could be very helpful for future works because of its ability to allow researchers to isolate any given point and find any variations in the data.

E. Online Data Visualization

The feasibility of online data visualization was also researched. This online data visualization was used for comparisons of a specific test factor of a specific waterway for the four years of water testing. This visualization was placed on the team’s webpage as a reference for analyzing the data.

“Highcharts Product” is a free charting library that contains charts that are written in JavaScript. [9] Utilizing the software’s template, jsFiddle, an activity was conducted to determine if this software would be eligible to display to desired data. JSFiddle is an application that provides a custom environment to test, or fiddle, with JavaScript, HTML and CSS code inside of a browser.[22] A basic bar graph was created that displayed data manually entered.

The next step in creating this tool was connecting the JavaScript based file to the online database using PHP Hypertext Preprocessor (PHP) and MySQL, which would

allow researchers to identify trends at specific points from the web browser versus the Excel file created during this project.

V. ANALYSIS

A. Water Quality Index

The overall water quality for all the waterways combined remained at a consistent level. Mill Dam Creek increased in its water quality score and went from a bad water quality score in the high 40’s for the testing years of 2011, 2013, and 2014 to a medium water quality. Areneuse Creek, along with Mill Dam Creek, has reached its highest point of the four testing years. Areneuse Creek reached the medium water quality score range. Sawyers Creek was the worst waterway tested during this research. Sawyers Creek fell from a medium water quality score range for the years of 2011, 2013, and 2014 to a bad water quality score in 2015. Knobbs Creek also obtained its worst water quality index score of the four testing years. Newbegun Creek fell between the two previous testing years of 2014 and 2013 with a medium water quality score. The Pasquotank River increased from the 2014 testing year but remained at a bad water quality score. This is the second consecutive year that the Lower Pasquotank has been tested. It remained constant in the good water quality range and remained the highest scoring waterway tested. See Appendix A to view the full analysis.

Water Source	2015 WQI	2014 WQI	2013 WQI	2011 WQI
Mill Dam Creek	57	49	47	48
Areneuse Creek	60	57	47	49
Sawyers Creek	35	51	50	54
Knobbs Creek	42	63	50	52
NewBegun Creek	65	59	66	50
Pasquotank River	45	35	44	64
Lower Pasquotank	85	86		

Figure 1. Water Quality Comparison between the 2014, 2013 and 2011 Projects

B. Dissolved Oxygen

The dissolved oxygen readings for 2015 went through some variations over the years. One factor is the temperature. This is because different temperatures can bring out different plant and animal life, which can also affect the dissolved oxygen [15]. This may be the cause for the low dissolved oxygen readings for Sawyers Creek and Knobbs Creek. Another factor of dissolved oxygen is the width of the waterway. The Lower Pasquotank had the highest dissolved oxygen reading due to the width of this waterway as it flows into the Albemarle Sound.

C. TDS/Salinity/Conductivity

Overall, the readings for total dissolved solids, salinity, and conductivity have decreased from the previous testing years. The rain during nights before testing may have affected the readings. Rain dilutes the salt in the water by

mixing the freshwater with the salinity of the waterways. Point N11, also referred to as point NA11, correlates with point 31 of the Lower Pasquotank in salinity, conductivity, and total dissolved solids.

D. pH

The pH readings for this testing year changed slightly. This year, most of the waterways were acidic than basic compared to the previous testing year. Mill Dam Creek, Areneuse Creek, Sawyers Creek, Knobbs Creek, and the Pasquotank River all have an acidic reading of 6.99 or lower. Newbegun Creek and the Lower Pasquotank settled at basic readings of 7.1 or higher. After further analysis, the data shows that Areneuse Creek, Mill Dam Creek, and Newbegun Creek correlate in pH as they have averaged basic water. Sawyers Creek and Knobbs Creek have mainly resulted in acidic water.

E. Clarity/Turbidity

This year's clarity readings have decreased from the 2013 and 2014 testing years. Because clarity determines how clear the water is and turbidity determines the number of suspended particles, clarity was four to ten inches higher than turbidity. The clarity for Areneuse Creek and Knobbs Creek increased between one and two inches. Individually, the remaining waterways decreased in clarity between 0.2 and nearly 4 inches from the 2014 readings. This year's turbidity readings remained consistent with the 2013 and 2014 testing years.

VI. CONCLUSION

A. Overall

The overall Water Quality Index (WQI) score of the Pasquotank Watershed was calculated by using the Water Quality Index Calculator. Percent saturation of dissolved oxygen; NTU measurements of turbidity, and pH measurements were used to determine the individual scores for each waterway. Mainly due to their dissolved oxygen readings, the lowest score came from Sawyers Creek and the highest score came from the Lower Pasquotank.

B. Variations and Correlations

The pH readings for Mill Dam Creek, Areneuse Creek, and Newbegun Creek correlate with one another as basic waterways, and the same applies for Sawyers Creek and Knobbs Creek as they were proven to be acidic waterways. The rain during nights before testing the next morning may have affected the readings. Rain dilutes the salt in the water by mixing the freshwater with the salinity of the waterways, which cause the lowering of the readings of salinity, conductivity, and total dissolved solids. The Excel chart showed that each point that was near the Pasquotank River shared similar pH readings and the mouth of both the lower Pasquotank River and Newbegun Creek had similar readings in conductivity, salinity, and total dissolved solids.

C. Microsoft Excel

It was concluded that this feature could be very helpful for future works. It has the ability to allow researchers to isolate any given point and find both correlations and variations in the data as well as analyze a specific data point whereas the water quality index gives the general reading for all the points at once.

VII. FUTURE WORKS

A. Thermometer

The Mercury thermometer was a very subjective device and should be replaced with a digital thermometer. It is recommended that the Control Company VWR Waterproof Thermometer, a digital thermometer that is waterproof and shockproof, be acquired for this test. The thermometer ranges from -50 to 300 degrees Celsius. It has the ability to recall its lowest and highest readings over any period. [5]

B. Online Visualization

The online data visualization should represent a basic graph that displays a data point and the tests completed at that point over the number of years tested. The data should be drawn from the compiled MySQL database that is currently being utilized. The database will be connected with PHP coding to the Highcharts open-source templates that are coded in JavaScript. jsFiddle will be used to edit the JavaScript coding. [18]

C. Secchi Disk

The secchi disk was used to measure the clarity and turbidity. The secchi disk was a very subjective test that varied greatly between individuals and the water sources tested. This project recommends that the Portable Turbidity and Bentonite Check Meter be acquired for future testing. This unit guarantees an accurate reading and minimizes stray light and color inference. It can also display turbidity in nephelometric turbidity units (NTU) units, which is necessary for the Water Quality Index Calculator. [8]

D. Adding Test

There are many tests that can be added. The most preferred test is the nitrate test. This test can increase the accuracy of the Water Quality Index score of each waterway that would be used for testing. The HI764 Marine Nitrite Ultra Low Range Checker HC, which is manufactured by Hanna Instruments, is capable of measuring Nitrate. The measuring unit is parts per billion, and it has a retail price at about fifty dollars. [7]

Another test that can be added without adding new test equipment is the change of water temperature. This measures the difference in temperature between the beginning of a tributary and the end. This would make an addition to the water quality index chart.

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REFERENCES

- [1] Cantu, A. (2012). "Using VLOOKUP and MATCH To Retrieve Data from A Table Excel Tutorial." [Online]. Available. <https://www.youtube.com/watch?v=xOB-gA87oAk>
- [2] Carlsbad Watershed Management Plan. "www.projectcleanwater.org/pdf/car/Chap2_L.pdf." [Online]. Available. www.projectcleanwater.org/pdf/car/Chap2_L.pdf.
- [3] Chuesheva, S. (2003). "Excel drop-down list- how to create, edit and remove a drop box down box." [Online]. Available. <https://www.ablebits.com/office-addins-blog/2014/09/24/excel-drop-down-list/>.
- [4] Computer Hope. "What is Dreamweaver?." [Online]. Available. <http://www.computerhope.com/jargon/d/dreamweaver.htm>.

- [5] "Control Company VWR Waterproof Thermometer 4039." [Online]. Available. https://www.google.com/shopping/product/16936676071866290681?q=scientific+water+thermometer+with+a+probe&client=safari&rls=en&biw=1325&bih=891&bav=on.2,or_r_cp.&bvm=bv.96952980,d.eXY&tch=1&ech=1&psi=pSqVdvXBsGYNqLogcgM.1436297953107.29&prds=paur:CmkAsKraX5qxHfcZFvzR3YNLggcuEIRKnYppYSHJ8FATCw8UMeTHEioLAzaOzDWtBuZ84zX51OPynDkoE_w64rD-BeSRJb_addr56HsYo9pKNp6NXea7RuzdMGOCveIWvJryY55EqFWTEvqwSQGBT1R-92N5vqxOZBpm2NfSc2_tWHiMvkFw&ved=0CFMQpis&ei=ky6cVa2IA4GDgWT936iYAg.
- [6] "Digi-Sense Blue Spirit, Pocket Thermometer, Window Plastic Case, 0/220f." [Online]. Available. https://www.google.com/shopping/product/6543123192197077125?sclient=psy-ab&safe=active&client=safari&rls=en&biw=1324&bih=893&q=blue+mercury+thermometer&oq=blue+mercury+thermometer&pbx=1&bav=on.2,or_r_cp.&bvm=bv.96952980,d.eXY&tch=1&ech=1&psi=bCmDVdL1EMOlgwSe5YPQCQ.1436363117130.9&prds=paur:ClkAsKraX0HiC4TWOF9foWl5u-kaVyR7cPe2pWb8GxGUEM35VPBqlwhYISgT4DS0AdUve1hSI3N6WdG9mRTHzfgkW9HUIJZbrytYcZDwqzHLTSHCjgKk2_IvMVhIZAFPVH71O8NxApJmMo0rvP0qwQI0aVkmkyQ&ved=0CDAQpis&ei=rymdVY63IsqngwSR46CYCg.
- [7] "HI764 Marine Nitrite Ultra Low Range Checker HC." [Online]. Available. <http://shop.hannainst.com/hi764-nitrite-ulr-for-marine.html>.
- [8] "HI83749 Portable Turbidity and Bentonite Check Meter." [Online]. Available. <http://shop.hannainst.com/hi83749-portable-turbidity-and-bentonite-check-meter.html?id=010002&ProdCode=HI%252083749>.
- [9] Highcharts. (2015). "Interactive JavaScript charts for your webpage | Highcharts." [Online]. Available. <http://www.highcharts.com>.
- [10] Perlman, H. (2015). "Dissolved oxygen, from USGS Water Science for Schools: All about water." [Online]. Available. <http://water.usgs.gov/edu/dissolvedoxygen.html>
- [11] Kemker, C. (2015). "Dissolved Oxygen - Environmental Measurement Systems." [Online]. Available. <http://www.fondriest.com/environmental-measurements/parameters/water-quality/dissolved-oxygen/>
- [12] MacUpdate. (2015). "Garmin BaseCamp for Mac | MacUpdate." [Online]. Available. <http://www.macupdate.com/app/mac/31527/garmin-basecamp>.
- [13] Milt Putnam/IFAS Communication Services. "http://lakewatch.ifas.ufl.edu/circpddf/ClarityPt1to3.pdf." [Online]. Available. <http://lakewatch.ifas.ufl.edu/circpddf/ClarityPt1to3.pdf>.
- [14] Milwaukee. "http://www.milwaukeeesters.com/pdf/MW600.pdf." [Online]. Available. <http://www.milwaukeeesters.com/pdf/MW600.pdf>.
- [15] Murphy, S. (2007). "BASIN: General Information on Dissolved Oxygen." [Online]. Available. <http://bcn.boulder.co.us/basin/data/NEW/info/DO.html>.
- [16] MW600 Standard Portable Dissolved Oxygen Meter 2011. "Milwaukee - MW600 Standard Portable Dissolved Oxygen Meter." [Online]. Available. <http://www.milwaukeeinst.com/site/component/content/article/36-standard-portable-meters/87-products-g-standard-portable-meters-g-mw600>.
- [17] N.C. Department of Environment and Natural Resources. "The Albemarle Pamlico Estuary." [Online]. Available. Portal.ncdenr.org/web/apnep/our-estuaries
- [18] Oracle. "MySQL." [Online]. Available. <http://www.oracle.com/us/products/mysql/overview/index.html>.
- [19] Radcliffe, G. "TURBIDITY/CLARITY." [Online]. Available. www.qacps.k12.md.us/cms/teachers/SCI/testclar.htm#CLARITY.
- [20] Salt/pH/TDS/Temp TRACER. (2015). "Salt/pH/TDS/Temp TRACER - 1766-KIT-01 - Environmental Science Education - LaMotte." [Online]. Available. <http://www.lamotte.com/en/education/instrumentation/pocketesters/1766.html>.
- [21] Squiz Matrix User Manual Library. "What is Google Maps? - Squiz Matrix User Manual Library." [Online]. Available. <https://manuals.matrix.squizzesuite.net/google-maps/chapters/what-is-google-maps>.
- [22] TechRepublic. (2015). "jsFiddle: An online playground for your JavaScript, HTML, CSS- TechRepublic." [Online]. Available. <http://www.techrepublic.com/blog/software-engineer/jsfiddle-an-online-playground-for-your-javascript-html-css/>
- [23] TechTerms. (2012). "Google Drive Definition." [Online]. Available. techterm.com/definition/google_drive.
- [24] Tibetan Gold. (2005). "Pocket Electronic pH Meter." [Online]. Available. https://www.tibetangold.com/ssl/zc/index.php?main_page=product_info&products_id=130.
- [25] United States Environmental Protection Agency. (2012). "5.5 Turbidity | Monitoring & Assessment | US EPA." [Online]. Available. <http://water.epa.gov/type/rsl/monitoring/vms55.cfm>.
- [26] United States Environmental Protection Agency. (2012). "5.8 Total Solids | Monitoring & Assessments | US EPA." [Online]. Available. <http://water.epa.gov/type/rsl/monitoring/vms58.cfm>.
- [27] United States Environmental Protection Agency. (2012). "5.9 Conductivity | Monitoring & Assessment | US EPA." [Online]. Available. <http://water.epa.gov/type/rsl/monitoring/vms59.cfm>.
- [28] United States Environmental Protection Agency. (2012). "What is pH? | Acid Rain | US EPA." [Online]. Available. www.epa.gov/acidrain/measure/ph.html.
- [29] University of Wisconsin. "http://watermonitoring.uwex.edu/pdf/level1/data-DissolvedOxygen.pdf." [Online]. Available. <http://watermonitoring.uwex.edu/pdf/level1/data-DissolvedOxygen.pdf>.
- [30] Utah State University. (2015). "pH - Water Quality - extensions.usu.edu." [Online]. Available. <http://extension.usu.edu/waterquality/htm/whats-in-your-water/ph>.
- [31] Water Quality Index Calculator. "Water Quality Index Calculator V2." [Online]. Available. http://www.baipatra.ws/water_quality.html.

[32] Water Research Center. "Water Quality Index Calculator." [Online]. Available. <http://www.water-research.net/index.php/water-treatment/water-monitoring/monitoring-the-quality-of-surfacewaters>.

[33] Weatherhawk. (2015). "SM -18 Skymate Wind Meter w/Temp & Wind Chill." [Online]. Available. <http://www.weatherhawk.com/sm18>.

[34] Webopedia. "What is Microsoft Excel (Spreadsheet Software)? Webopedia." [Online]. Available. http://www.webopedia.com/TERM/M/microsoft_excel.html.

[35] Windows to the Universe. (2012). "Salinity- Dissolved Salts, Measuring Salinity- Windows to the Universe." [Online]. Available. http://www.windows2universe.org/earth/Water/dissolved_salts.html.

Appendix A

Water Source	D.O.	pH	Water Temp (Celsius)	Air Temp (Celsius)	Clarity Avg (in)	Turbidity Avg (in)	Total Dissolved Solids (ppm)	Salinity (ppm)	Conductivity (milliSiemens)	
2015 Water Source										
Mill Dam Creek		3.65	8.96	28.86	28.50	20.13	12.08	543.8	390.0	0.79
Amenaus Creek		3.8	8.95	28.00	31.85	25.08	15.68	436.3	310.0	0.63
Sawyers Creek		1.08	8.71	27.50	29.85	9.70	5.09	120.8	85.0	0.18
Koobas Creek		1.18	8.73	27.08	38.30	15.78	8.08	150.3	127.3	0.27
Newlogun Creek		4.61	7.31	27.29	29.83	16.71	9.73	874.2	822.5	1.29
Pesquodank river		3.29	8.76	28.58	32.86	8.81	4.89	173.8	122.5	0.18
Lower Pesquodank		7.00	7.45	28.13	29.75	21.06	11.50	1190.3	720.0	1.07
2014 Water Source										
Mill Dam Creek		2.1	7.20	28.50	24.70	23.30	13.93	1097.5	773.8	1.55
Amenaus Creek		3.4	7.40	28.10	32.30	24.00	13.50	1037.5	753.0	1.51
Sawyers Creek		3.7	8.70	28.40	22.50	13.10	5.90	138.5	112.5	0.23
Koobas Creek		4.7	8.50	28.00	21.80	14.60	7.90	271.7	186.4	0.41
Newlogun Creek		3.7	7.80	28.30	38.30	28.70	13.80	931.2	341.2	1.38
Pesquodank river		2.8	8.00	28.90	28.40	9.20	1.30	1100.8	77.6	0.41
Lower Pesquodank		7.2	7.40	27.30	30.20	24.00	10.30	1312.5	350.0	1.87
2013 Water Source										
Mill Dam Creek		2.5	7.00	28.50	24.50	24.00	10.50	3031.5	2311.5	4.38
Amenaus Creek		2	7.40	28.00	24.50	24.00	8.00	2983.0	2713.5	4.77
Sawyers Creek		3.5	7.50	28.90	32.86	17.50	9.50	836.0	511.0	1.09
Koobas Creek		3	7.10	27.00	28.50	25.58	13.00	1374.5	910.0	2.01
Newlogun Creek		5	7.40	27.00	28.00	18.00	9.50	3242.0	2272.5	4.89
Pesquodank river		3	8.40	28.50	30.00	13.00	5.50	815.1	582.1	1.07
2011 Water Source										
Mill Dam Creek		4	5.00	27.80	27.80		32.00	5233.0	2285.0	5
Amenaus Creek		4	4.00	28.30	28.30		19.00	2480.0	1758.0	4
Sawyers Creek		4	7.00	28.50	28.50		19.00	851.0	507.0	1
Koobas Creek		5	5.00	28.80	28.80		21.00	1847.2	1374.0	3
Newlogun Creek		4	5.00	27.90	28.70		17.00	3005.0	2346.0	4
Pesquodank river		5	8.00	28.40	28.00		14.00	761.0	511.0	1