Nitrate Relationship between Soil, Pond, and Stream

Molly Fleming, Sophia Willard, Gabe Woods

GLOBE International Virtual Science Symposium

Feb. 20, 2020

Abstract

Water quality is important throughout all watersheds, especially the Chesapeake Bay Watershed. Soil and its contents have a direct effect on water quality. This project investigates the question how does the nitrate content in the school campus soil, pond, and stream relate? The hypothesis states that due to the frequent algae in the pond and the fact that the school is surrounded by farms on three sides, the nitrate levels in the soil above the pond and in the stream adjacent to the pond will be high. Soil was collected in the fall and winter. Water was collected from the Pond and Stream once each week. In the fall, fish were caught for one hour to determine the fish population. The hypothesis was partially supported by the data. The results showed that the nitrate levels in the pond ranged from 1.8-8.0 mg/L, which is much higher than the recommended level of less than 1 mg/L. The nitrate level at the school soil site showed depleted in the fall and deficient in the winter. Nine bluegill fish were caught. The revised hypothesis states that the stream and pond will have above normal nitrate values due to the farm fields surrounding the school. The soil that is still in the natural state near the farms will most likely have high nitrate values as well. Problems included lack of test solution, o-rings not forming a solid seal, and difficulty getting dirt due to dry soil. It will be important to find the true source of the nitrates in order to try to decrease the current nitrate levels.

Keywords: Nitrate, stream, pond, soil, pH, nutrients, water quality

Nitrate Relationship between Soil, Pond, and Stream

Research Question

This project investigates the question how does the nitrate content in the school campus soil, pond, and stream relate? The hypothesis states that due to the frequent algae in the pond and the fact that the school is surrounded by farms on three sides, the nitrate levels in the soil above the pond and in the stream adjacent to the pond will be high. The independent variable is time. The dependent variables are nitrate levels in the pond, stream, and soil on the school campus. The controlled variables were controlled by following the GLOBE protocols and collecting stream and pond water at the same time.

Introduction and Research

Nitrate gets into waterways from runoff and aquatic animal waste, and can be harmful or beneficial. Nitrate is made up of the nitrogen anion which is formed by a loss of a protons from nitric acid (U.S. National Library of Medicine, 2019). Nitrate is a nutrient that plants use to grow. It is part of the nitrogen cycle, and it is part of the decomposition of fish waste. It also enters water through runoff that contains excess fertilizers from farm fields or ranches. Too much nitrate in something, including water, can be harmful. Excess levels of nitrate in water can make conditions that will make it tough for fish to live because too much nitrate is like poison to them as it is to humans. Too much of it can harm and kill the fish (Gallant, 2019). No one can taste, smell or see nitrate in any water. Consuming too much nitrate in any water can be very harmful, to fish and humans alike. Nitrate in any sort of water can affect how blood holds oxygen and can cause a disease called Methemoglobinemia/Blue Baby Syndrome (Minnesota Department of Health, 2019).

The recommended range of nitrates is less than 1 mg/L. If levels would exceed that, however, it is likely that an algal bloom will occur. When an algal bloom occurs, the plants reproduce quickly because there are lots of nitrates to help them. This large amount of plants on the surface of the water keep the plants at the bottom of the pond from receiving sunlight. Those plants die. Once the nitrate is quickly used up, the algae are no longer able to access that nutrient and many of them die. When the plants die, they sink to the bottom and are no longer able to produce dissolved oxygen. Then the decomposers use up the oxygen as well while they decompose the extra dead plant matter. This reduces the available dissolved oxygen for the fish (Leaverton, 2109).

"Nitrate is a compound that is formed naturally when nitrogen combines with oxygen or ozone (Centers for Disease Control and Prevention, 2015)." Algae and other plants under water use nitrates as a nutrient. If there is a lot of algae in a water body, there will be problems other than not enough nitrates. This could also lead to a problem with the dissolved oxygen in that body of water (Gallant, 2019).

When there is a normal amount of nitrates (1mg/L or less) in the water, it will not affect the aquatic insects and fish. When there are too many, more than 1 mg/L, it will be harder for insects and fish to survive because too much nitrate can cause dissolved oxygen to decrease in water because plants and algae will soak up the nitrates and cause overgrowth. Overgrowth of algae can cause low transparency and plants lower in the water column will not be able to thrive. While plants and algae die, bacteria grow and use up all of the dissolved oxygen in the water as they consume the dead plants (TAMU, 2020). "Natural levels of nitrates are usually less than 1 mg/L (Behar, 1997)." Estuaries and coastal waters are suffering from oxygen depletion because of high levels of nitrates and phosphates creating algal blooms in many bodies of water (Thurston, p. 32). This is a huge problem in the Chesapeake Bay and results in dead zones each summer.

If there is an excess amount of nitrate in a stream, it could be due to the stream flowing through areas of farmland or golf courses. Some runoff containing fertilizer may have entered the stream. Past water quality tests show that fertilizer can add nitrates to a body of water that is similar to the stream on the St. Francis campus (Ward et al., 2018).

A study by Johns Hopkins University showed that 75% of ingredients washed from homes survive wastewater treatment. These chemicals impact the ecosystem, including humans (Prud'Homme, p. 350-351). Many aquatic species have been damaged by agricultural runoff, dams, mines, and other human interferences. "Ineffective federal laws, combined with an inability of state governments to work collectively against water pollution, have allowed rich fisheries and commercially important waterways such as the Chesapeake Bay or the Mississippi River, to become severely impaired (Prud'Homme, p. 350)."

Even though it seems that not many people are making an effort to prevent things like poor water quality, people fed up with pollution-plagued rivers have worked together to write, pass, and enact the Clean Water Act. Thirty years ago, citizens also joined environmentalists to end mega-dams (Barnett, p. 9). Citizens in Napa, California wanted to help improve water quality in waters near them so much so that policy makers and scientists were able to let volunteers measure water quality, flow, velocity, and rainfall (Barnett, p. 223). "States that share water resources and disagree about how to divvy them up generally solve their disputes in one of three ways: states can come up with their own water-sharing agreement and enter into a compact.

Congress, with its authority over interstate commerce, can approve a division of water. Or states can put their fate in the hands of the U.S. Supreme Court, which has original jurisdiction in such disputes (Barnett, p. 76)." These examples show just what can happen when people work together to fix a problem like water pollution, however measurement and tracking data is very important in really understanding the problem.

"The Safe Drinking Water Act directs the U.S. Environmental Protection Agency (EPA) to establish national drinking-water standards for chemical and biological contaminants in public water supplies." The standards are to be set at concentrations at which no adverse effects on human health occur or are expected to occur from lifetime consumption (National Academies, p. 1). The Division of Water Quality (DWQ) has many programs to protect clean water and public health. The water quality standards are to check whether or not PA's rivers and lakes are clean and healthy enough to support fish and other aquatic animals (DEP, 2020). If humans work together to protect and monitor the health of waterways, they will also be helping make it safe for the aquatic life living there. Monitoring the health of local waterways is an important part to improving and protecting bodies of water.

Soils are one of earth's most essential natural resources. The majority of people do not realize that the soil is a living world supporting pretty much all of terrestrial life. Some professions like scientists, farmers, engineers, developers, and other professionals use soil to answer questions. Soils develop on top of Earth's surface which is called the pedospere. According to GLOBE, the pedosphere affects every part of the ecosystem so much that it is called the "great integrator" ("Soil Introduction," 2019).

Soils are important in the amount and types of gases released into the atmosphere. They also store and transfer heat. By studying this, students and scientists learn how to interpret a site's climate, geology, hydrology, and human history ("Soil Introduction," 2019).

Soils are made up of five main parts which are mineral particles, organic materials from dead plants and animals, water which fills open space, air that fills pores, and time. Soil is also formed by fossils and microorganisms. There are 70,000 different types of soil in the U.S. Healthy soil takes hundreds of years. Each area of soil has unique characteristics. A vertical section of soil is called a soil profile. The chapters of soil are read in layers and the layers are read by looking at the soil's horizon (Quickcrop, 2008).

There are way more microorganisms in a fist full of soil than there are people in the world. Soil is a living system because it is a media in which plants and animals live and grow. It provides habitat, water, and recycles raw materials ("Soil Solutions," 2019). Also, when there are more fungi in soil, then it will hold more carbon which is the basis of soil fertility (ESF, 2019).

Soils have a giant impact on water quality. Prairies are the most common type of soil in the U.S. Testing mineral amounts is important because minerals help in many ways like helping plants absorb water, adjusting soil pH, and providing nutrients to plants (The Ultimate Guide to Soil, 2019). When plants and animals decay and break down in the soil, it creates nitrates. These nitrates are important for plant growth, but can become a problem if there is too much nitrate in an area, especially if there is water nearby. People have begun using man-made fertilizers in many areas, throwing off the nitrate balance. Usually, the plants take up the nitrate and use it for their proteins, but if there is too much, especially man-made fertilizer containing nitrates, the"nitrate can also be converted to nitrogen gas (N2) or ammonia (NH3) and be volatilized (evaporated or removed as a gas) out of the soil. Therefore, it is important that farmers and gardeners add nitrogen fertilizers when plants need the nutrient the most and can absorb it before it is removed from the soil by leaching (GLOBE, 2014)."

Materials and Methods

Materials

- LaMotte nitrate test kit 3354-01-1
- nitrate protocol field guide-1
- hydrosphere investigation quality control data sheet-1
- hydrosphere investigation data sheet-1
- clock or watch-1
- latex gloves-2
- goggles-1
- distilled water- 1 L every day
- clean paper towels-5
- cloud type and cover protocol field guide-1
- GLOBE cloud chart-1
- access to the stream
- 200 mL beaker-1
- Bottle to hold the distilled water-1
- Heat Lamp-dried, sieved Soil
- Pencil or pen
- Small funnel

- Thermometer
- Balance accurate to within 0.1 g
- Squirt bottle
- Heat lamp
- Oven mitts or tongs
- Meter stick
- 3 370 mL tin cans
- Stir Sticks
- Plastic bags and containers to sort soil
- 2 mm Sieve
- LaMotte NPK Soil Test Kit
- 1 teaspoon
- Hydrion pH Brilliant Dip Sticks
- 250 mL Beaker

Methods

1. Use GLOBE procedure for Nitrates.
    a. Fill out the top portion of the Hydrosphere Investigation Data Sheet. In the Nitrate section fill in the kit manufacturer and model.
    b. Put on gloves and goggles.
    c. Follow the instructions in kit to measure the nitrate nitrogen.
        i. Insert Nitrate-Nitrogen Octa-Slide 2 Bar into the Octa-Slide 2 viewer.
        ii. Fill a test tube to the 5 mL line with sample water.

iii. Add one Nitrate #1 Tablet.

iv. Cap and mix until tablet disintegrates.

v. Add one Nitrate #2 CTA Tablet. Immediately slide the test tube into the Protective Sleeve.

vi. Cap and mix for two minutes to disintegrate the tablet.

vii. Wait 5 minutes. Remove the tube from the protective sleeve.

viii. Insert test tube into Octa-Slide 2 Viewer.

ix. Match sample color to a color standard. To convert to Nitrate, multiply results by 4.4. Record as mg/L Nitrate Nitrogen.

x. Match the color of the treated sample water with a color in the test kit. Record the value as mg/L nitrate-nitrogen for the matching color.

d. Calculate the average of the five measurements within 1.0 mg/L of the average, if using the high range test). If they are, record the average on the Data Sheet. If they are not, read the color measurements again (Note: do not read again if it has been more than 5 minutes). Calculate a new average. If the measurements are still not within range, discuss possible problems with teacher.

e. Record all five nitrate-nitrogen values on the Data Sheet and in logbook.

2. Clean all of the instruments that need to be cleaned, using distilled water and Kimwipes.
3. Put away the nitrate testing materials.

Fish Catch

1. Cast hook and line into pond. Reel in when feel tug.
2. Carefully remove fish from hook.

3. Measure length of fish and look it over for signs of health.

4. Record size and species in logbook.

5. Release safely back into the water.

6. Repeat steps 1-5 until the hour is finished.

GLOBE Soil Moisture Protocols

1. Place distilled water in squirt bottle.
2. At the top of the Data Sheet, note the length of time since the soil was dried in an oven, and how the soil has been stored (e.g. in plastic bag).
3. Measure the mass of the empty flask without its cap. Record the mass on the Soil Particle Density Data Sheet.
4. Measure 25 g of dried, sieved soil. Place soil in the flask using the funnel. Since it is important to have all 25 g of soil in the flask, be careful to transfer all the soil into the flask and not to spill any soil outside the flask (Note: if soil is spilled outside the flask, repeat this step with another 25 g sample).
5. Measure the mass of the flask containing the soil (without the stopper/cap). Record the mass on the Soil Particle Density Data Sheet.

Procedures for LaMotte NPK Soil Test Kit

Extraction 1. Fill the round extraction tube to the 30 mL line with distilled water.

2. Add two Floc-Ex Tablets. Cap the tube and mix until the tablets have disintegrated.
3. Remove the cap. Add one heaping teaspoon of soil.
4. Cap the tube and shake for one minute.
5. Let the tube stand until the soil settles out. The clear solution above the soil will be used

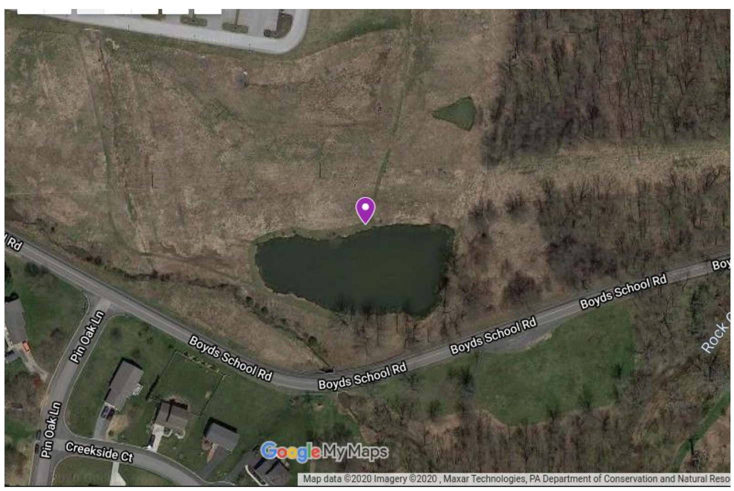
for the Nitrate, Phosphorus, and Potassium tests.

Nitrogen 1. Use the pipet to transfer the clear solution above the soil to a square test tube until it is filled to the shoulder.

2. Add one Nitrate WR CTA Tablet immediately slide the tube into the Protective Sleeve.
3. Cap and mix by inverting for 2 minutes to disintegrate the tablet. Bits of material may remain in the sample.
4. Wait 5 minutes for the color to develop. Remove the tube from the Protective Sleeve. Compare the pink color of the solution to the Nitrogen Color Chart.

Image 1

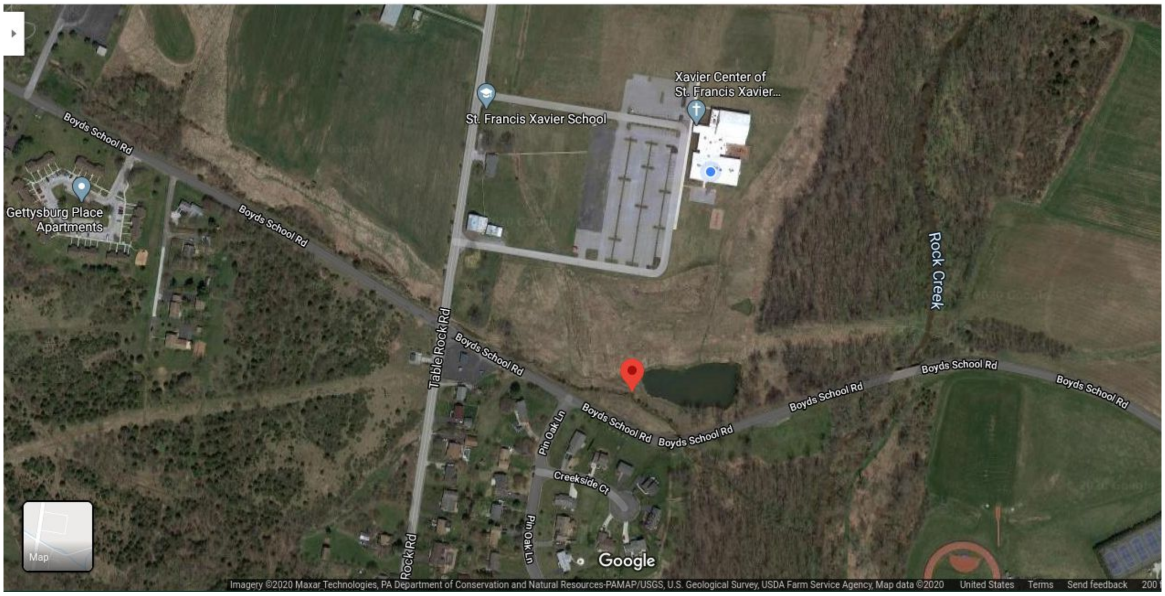
Location of Pond Testing Site



Note. This picture shows the location of the pond testing site. It is surrounded by mowed grass, unmowed meadow, and trees. There is a housing development on the other side of the road. The school campus and parking lot are uphill from the testing site. The coordinates are Latitude 39.85685, Longitude -77.22606, with an elevation of 147.6m.

Image 2

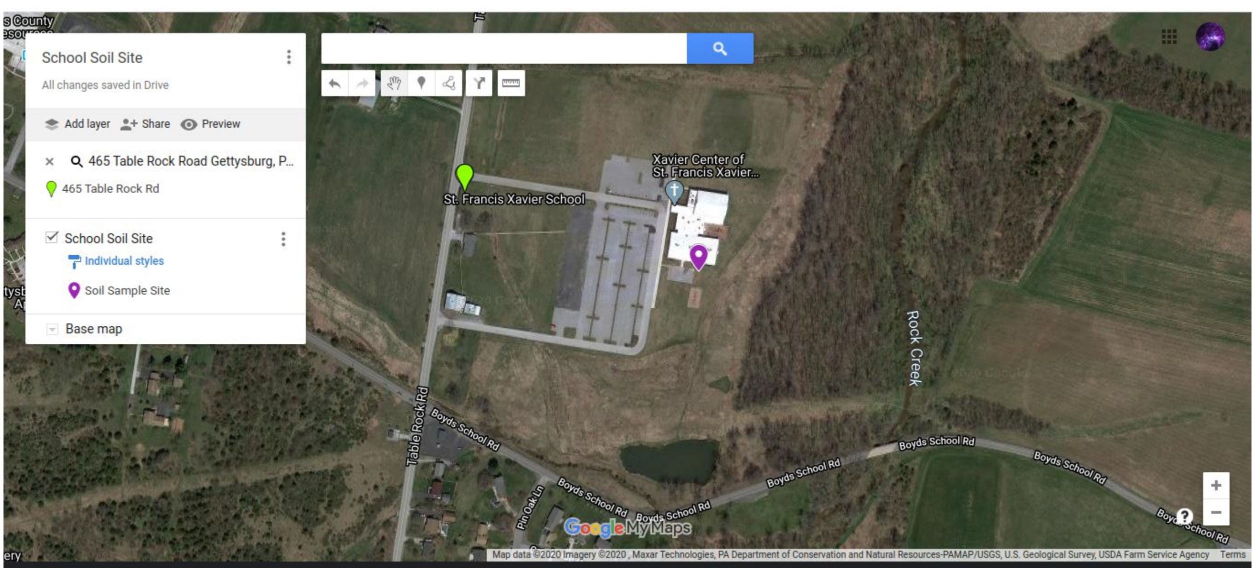
Picture of the Unnamed SFX Stream



Note. This location was chosen because it is near the pond, after an intersection, and before the unnamed stream enters Rock Creek, and it is close to SFX where all of the tests are taken and recorded. GPS Coordinates are: 39.85653, -77.22632, with an elevation of 147.4m.

Image 3

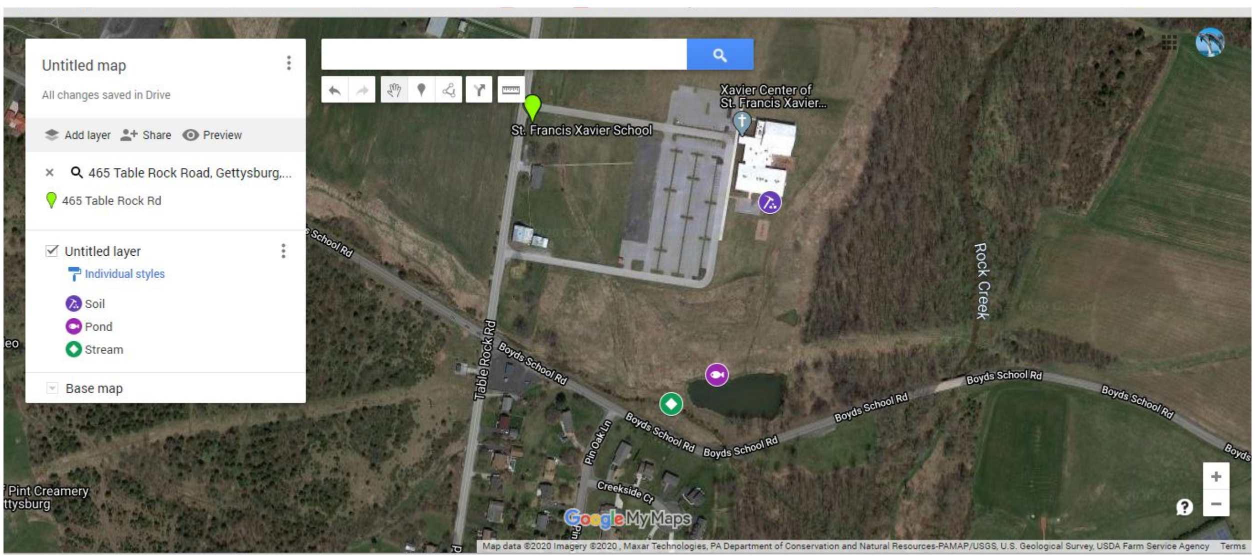
School Soil Testing Site



Note. This is the location of the school soil test collection site. The main school yard is raised up by fill, mostly clay soil. There is short grass growing, while an unmowed meadow is down the slope from the testing site. There are farmlands on three sides, with a forested stream at the back of the property. There is a housing development across the street. The GPS coordinates are Latitude 39.85844, Longitude -77.22538, with an elevation of 149m.

Image 4

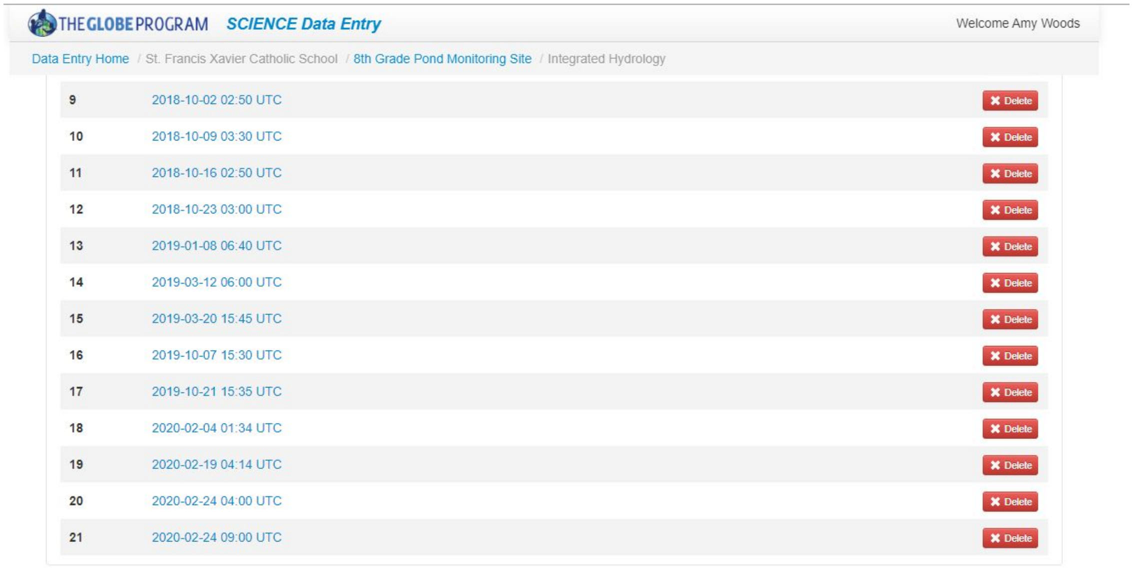
View of all Testing Sites



Note. This shows the location of all testing sites on the school campus.

Image 5

Screenshot of Pond Nitrate Date Entered into GLOBE



THE GLOBE PROGRAM SCIENCE Data Entry Welcome Amy Woods

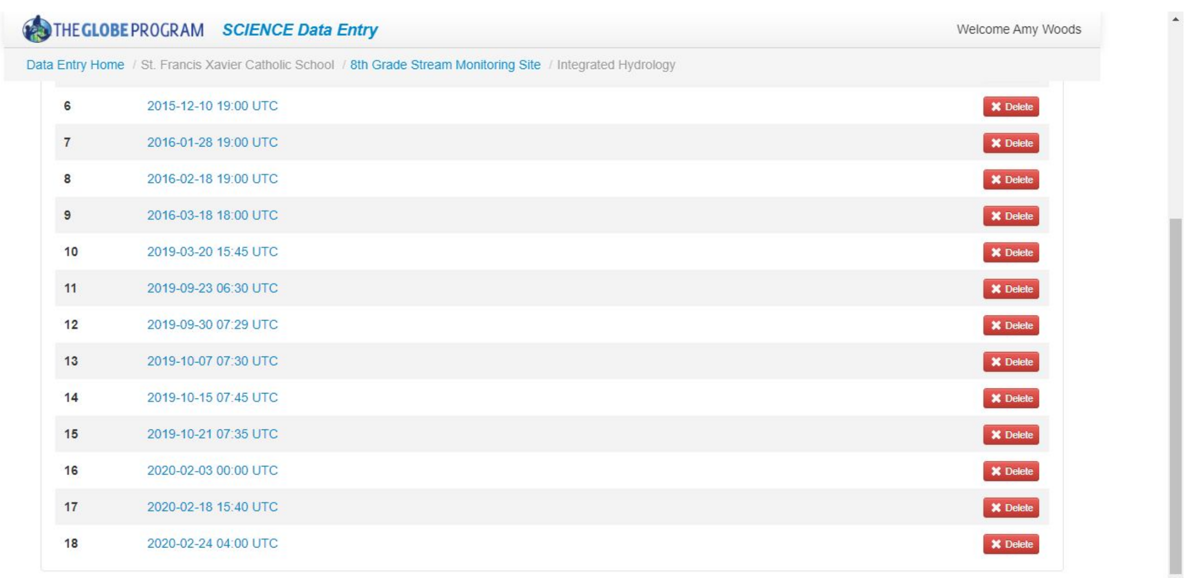
Data Entry Home / St. Francis Xavier Catholic School / 8th Grade Pond Monitoring Site / Integrated Hydrology

9	2018-10-02 02:50 UTC	Delete
10	2018-10-09 03:30 UTC	Delete
11	2018-10-16 02:50 UTC	Delete
12	2018-10-23 03:00 UTC	Delete
13	2019-01-08 06:40 UTC	Delete
14	2019-03-12 06:00 UTC	Delete
15	2019-03-20 15:45 UTC	Delete
16	2019-10-07 15:30 UTC	Delete
17	2019-10-21 15:35 UTC	Delete
18	2020-02-04 01:34 UTC	Delete
19	2020-02-19 04:14 UTC	Delete
20	2020-02-24 04:00 UTC	Delete
21	2020-02-24 09:00 UTC	Delete

Note. This shows much of the nitrate pond data entered into the GLOBE website.

Image 6

Screenshot of Stream Nitrate Date Entered into GLOBE



THE GLOBE PROGRAM SCIENCE Data Entry Welcome Amy Woods

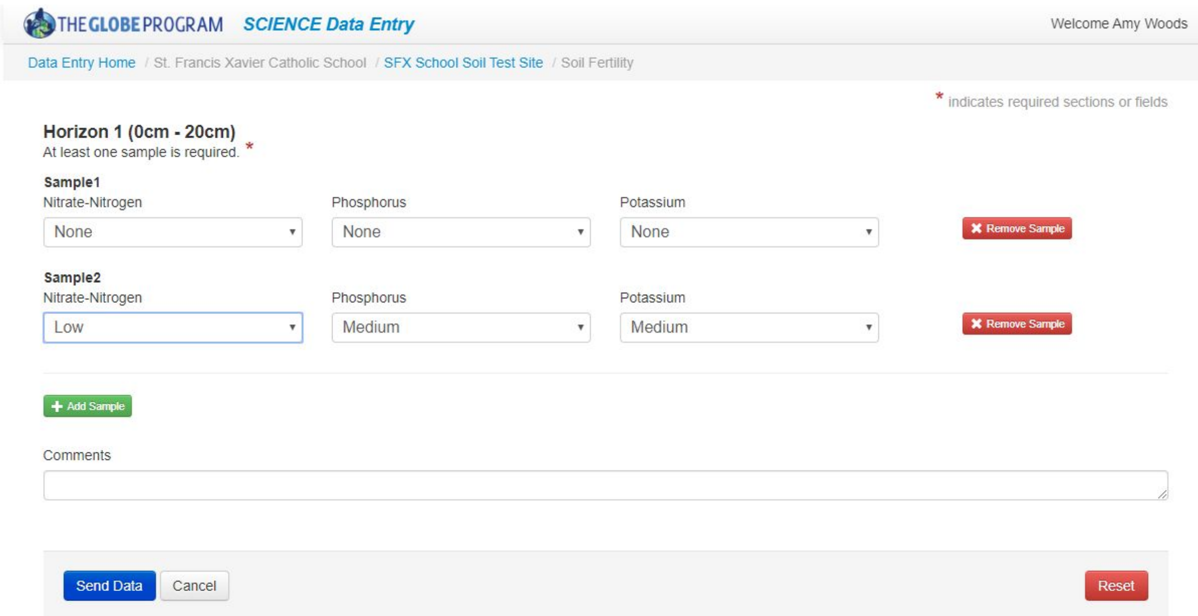
Data Entry Home / St. Francis Xavier Catholic School / 8th Grade Stream Monitoring Site / Integrated Hydrology

6	2015-12-10 19:00 UTC	Delete
7	2016-01-28 19:00 UTC	Delete
8	2016-02-18 19:00 UTC	Delete
9	2016-03-18 18:00 UTC	Delete
10	2019-03-20 15:45 UTC	Delete
11	2019-09-23 06:30 UTC	Delete
12	2019-09-30 07:29 UTC	Delete
13	2019-10-07 07:30 UTC	Delete
14	2019-10-15 07:45 UTC	Delete
15	2019-10-21 07:35 UTC	Delete
16	2020-02-03 00:00 UTC	Delete
17	2020-02-18 15:40 UTC	Delete
18	2020-02-24 04:00 UTC	Delete

Note. This shows much of the nitrate stream data entered into the GLOBE website.

Image 7

Screenshot of Soil Nitrate Date Entered into GLOBE



Note. This shows much of the nitrate pond data entered into the GLOBE website.

Results

Table 1

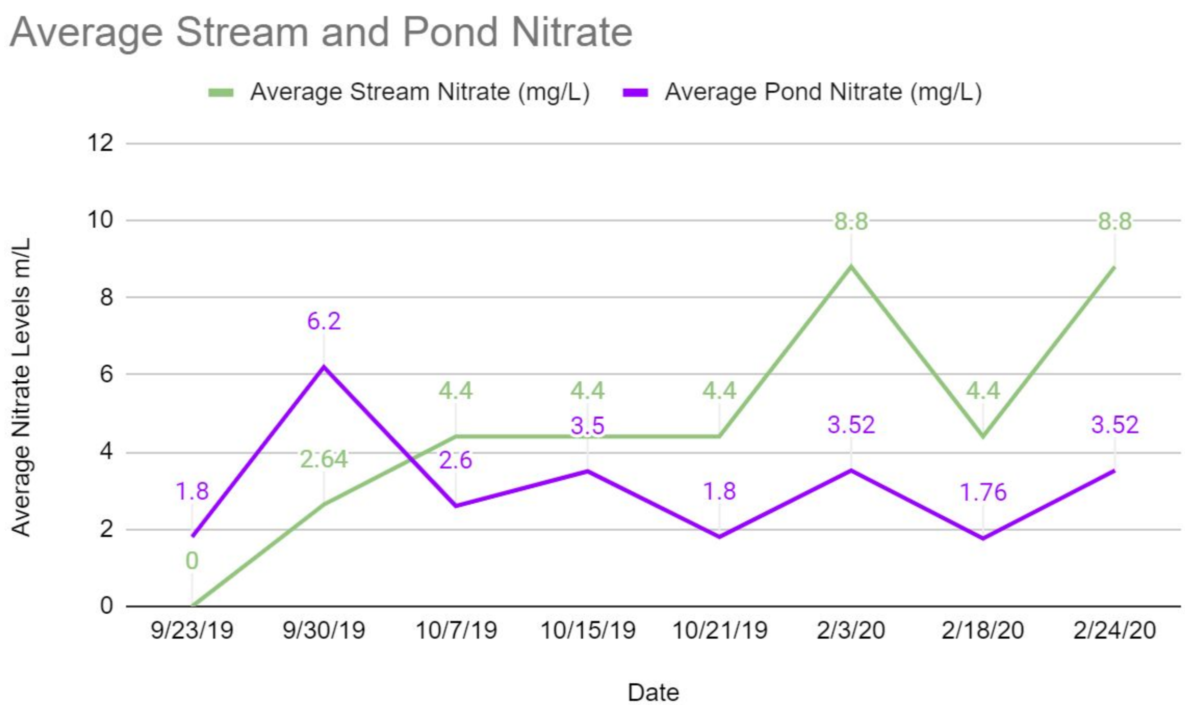
Table of Data Averages

Date	Average Stream Nitrate (mg/L)	Average Pond Nitrate (mg/L)
9/23/19	0	1.8
9/30/19	2.64	6.2
10/7/19	4.4	2.6
10/15/19	4.4	3.5
10/21/19	4.4	1.8
2/3/20	8.8	3.52
2/18/20	4.4	1.76
2/24/20	8.8	3.52

Note. This table shows the average nitrate levels in the pond and stream.

Graph 1

Average Nitrate Levels in Pond and Stream



Note. This shows that all nitrate levels were above the accepted range. The stream levels were generally higher than the pond.

Table 2

Number of Fish Caught in Fall

Fish Type	Fish Number	Fish Size (cm)	Time Caught
Blue Gill	One	17.18	3:14 PM
Blue Gill	Two	19.05	3:24 PM
Blue Gill	Three	N/A	3:39 PM
Blue Gill	Four	17.78	3:41 PM
Blue Gill	Five	N/A	3:43 PM

Blue Gill	Six	16.51	3:49 PM
Blue Gill	Seven	16.51	3:57 PM
Blue Gill	Eight	16.51	3:59 PM
Blue Gill	Nine	19.05	3:59 PM

Note: This table shows the type, size, and amount of fish caught in the pond. Testing was not able to be performed during the winter due to weather and scheduling. Fishing will be attempted again in the spring.

Table 3

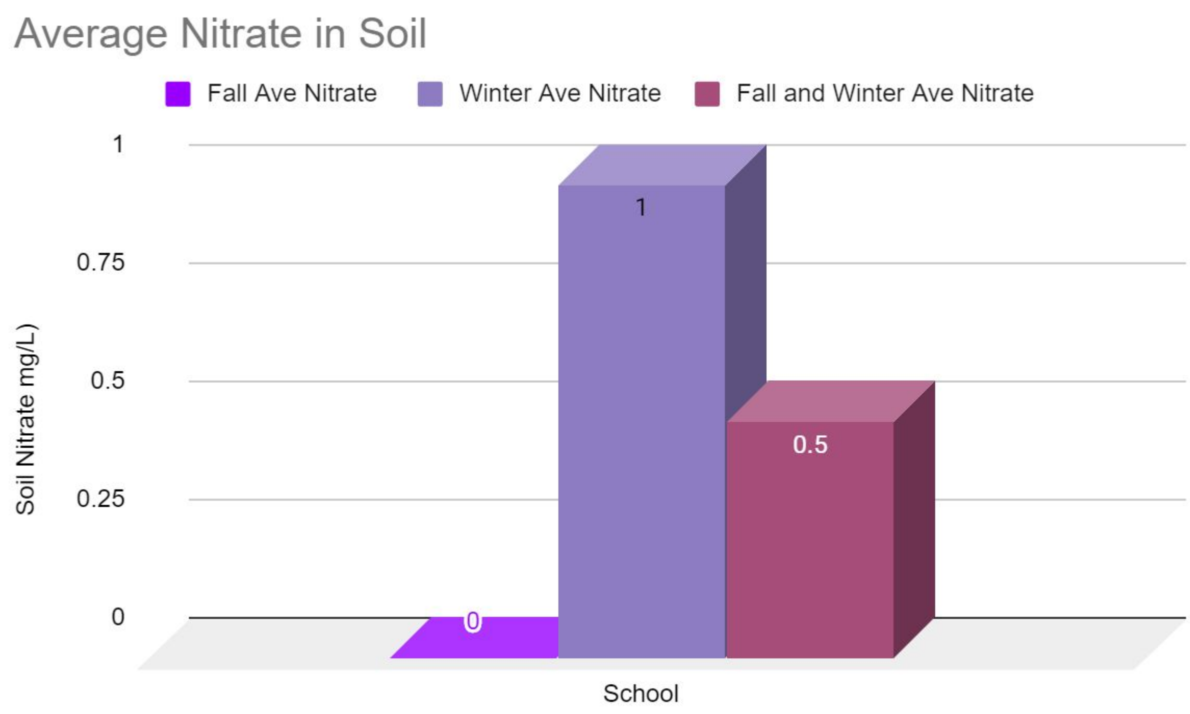
Average Nitrate Content in Soil

	Fall Ave Nitrate	**Winter Ave Nitrate**	**Fall and Winter Ave Nitrate**	4= Surplus
Home	2	4	3	3= Sufficient
School	0	1	0.5	2= Adequate
MFP	0	1	0.5	1= Deficient
Beach	0	1	0.5	0= Depleted

Note. This table shows the average nitrate for the school in fall and winter.

Graph 2

Average Nitrate Content in Soil



Note. This shows that there was no nitrate present in the soil in the fall. The winter showed a deficient level of nitrates in the soil.

Discussion

During the nitrate testing, the readings were all very low, with levels of 0.0 and 4.4 mg/L. During the second week of testing, it was realized that the final step was missed for the nitrate kit being used and that the level needed to be multiplied by 4.4 to get the actual nitrate level value. All values were then multiplied by 4.4, so the highest reading for nitrate was 8.8 mg/L. The averages of these tests ranged from 1.8 to 6.2 mg/L, all above the recommended less than 1.0 mg/L natural level of nitrate. However, just looking at the pond, the water was very brown or green most of the time and had a lot of algae in it. Nine fish were caught in the SFX pond. They were all Bluegills. All nine of the fish were in good health and size.

Nitrates in the stream started out very low at 0 mg/L, but by the second and third week it had gone up to 4.4 mg/L. The average of the data collected was determined. The nitrate levels were well over the recommended level of 1 mg/L or lower. The highest average for nitrates was 7.92 mg/L which is definitely higher than the ideal level.

Some outliers did appear. One other outlier that appeared was that the nitrate tests in the seventh week went from very high to very low and then back up again.

The testing in the fall showed no nitrate in the soil. The testing in the winter showed that the soil was deficient in nitrate. The average nitrate content in the soil was deficient.

Conclusion

The nitrate levels of the pond ranged from 1.8-8.0 mg/L, which is much higher than the recommended level of less than 1 mg/L. Nine bluegill fish, ranging in size from 16-19cm, were caught and released within one hour. This seems to indicate a healthy fish population, but algae is often present and the water is consistently murky. The nitrate testing is one of the most important tests because the results are very crucial to the health of the lake, and therefore also the health of the fish. Water needs nitrate in it, but too much of it can harm and kill life in that body of water.

The nitrate of the stream was very low for the first two weeks, but about halfway through the second week, the nitrate test levels went up. The tests did not meet the recommended levels, going way above 1 mg/L. One other outlier that appeared was that the nitrate tests in the seventh week went from very high to very low and then back up again. It is unclear exactly why this happened, but something might have gone wrong while testing was in progress, possibly with the tablet dissolved to measure the nitrate content. The nitrate levels were too high to be in healthy ranges, which is a concern.

This project investigates the relationship of nitrate levels in the campus pond, stream, and soil. The hypothesis stated that due to the frequent algae in the pond and the fact that the school is surrounded by farms on three sides, the nitrate levels in the soil above the pond and in the stream adjacent to the pond will be high.There was much less nitrate in the soil above the pond than expected. The data did not support the hypothesis.

The deficient value indicates that this may not be where the nitrate is coming from in the pond and stream. The soil may have had a deficient reading because the soil close to the school is construction fill which is packed solid. The nutrients may likely runoff.

The revised hypothesis states that the stream and pond will have above normal nitrate values due to the farm fields surrounding the school. The soil that is still in the natural state near the farms will most likely have high nitrate values as well.

This may be investigated in the future, along with other water quality parameters. The fish population was healthy in the pond, but it is also important that the pond and stream do not contribute additional nitrates to the Chesapeake Bay. It will be important to find the true source of the nitrates in order to try to decrease the current nitrate levels.

During the course of the project, problems and struggles occured like not catching any fish in the first half hour of fishing for the project, and sharing one testing kit with at least three other students for each test. Weather at times also prevented the collection of a water sample or the ability to fish safely. A new soil testing kit was purchased for the fall testing due to difficulty with the filters in the original test kit. It was also difficult to collect the soil in the fall because it was so dry and hard packed. The new kit was tested with the old to make sure the results matched properly.

Badge Selection

"I'm A Collaborator" This badge was chosen because this is a group project and each team member assisted in the project and is an important part to the making of this project possible. We also spoke with Mr. Hallinan from the Adams County Conservation District, Mrs. Bird from Advancing Science and Gettysburg College, and Mr. Rupp for Gettysburg High School to help us plan our project and understand our data.

"I Make An Impact" This badge was chosen because our project makes an impact on our town in multiple different ways. It has three different types of nitrate data in it that are all being compared together. This could provide data that could be used to solve nitrate problems in Gettysburg and the Chesapeake Bay.

"I Am a Data Scientist" This badge was chosen because we all collected and graphed a sufficient amount of data. It was also chosen because we all did many tests on the water and soil we collected.

Citations

Advance Local Media LLC. (Ed.). (2020, January 1). How much do anglers in your area spend on fishing? Retrieved March 5, 2020, from https://www.pennlive.com/pa-sportsman/2017/03/how_much_do_anglers_in_your_ar.html.

Barnett, Cynthia. *Blue Revolution: Unmaking America's Water Crisis*. Boston, Beacon Press, 2011.

Bramwell, Martyn. *Ocean Watch Protecting Our Planet*. Compiled by Dr. Philip Whitfield, New York, Dorling Kindersley, 2001.

Center for Educational Technologies. Wheeling Jesuit University, 1999-2019, www.cet.edu/. Accessed 1 Oct. 2019.

Chesapeake Bay Program. "Water Quality" 2019, www.chesapeakebay.net/. Accessed 11 Sept. 2019.

Citizens' Observatory for Coast and Ocean Optical Monitoring (Ed.). (2019). What is Water Transparency? Retrieved February 25, 2020, from CiTCLOPS website: http://www.citclops.eu/transparency/what-is-water-transparency

"Definition of Water Quality Parameters." *Friends of Sligo Creek*, 1997, fosc.org/WQData/WQParameters.htm. Accessed 8 Sept. 2019.

"Drinking Water Nitrate and Human Health: An Updated Review." *Environmental Research and Public Health*, PMC, 23 July 2018, www.ncbi.nlm.nih.gov/pmc/articles/PMC6068531/. Accessed 11 Sept. 2019.

Ebeling, Eric, et al. *Composting Basics: All the Skills and Tools You Need to Get Started*.

Stackpole Books, 2017.

Engines for Rural Economic Development Engines for Rural Economic Development. (n.d.). Retrieved February 23, 2020, from https://www.fishandboat.com/AboutUs/AgencyOverview/Funding/Documents/hatchinfsm.pdf

Ernst, Howard E. *Fight for the Bay*. Plymouth, Roman and Littlefield Publishers, 2010.

ESF Office of Communications. “SUNY ESF: College of Environmental Science and Forestry.” *ESF*, 2019, http://www.esf.edu/. Accessed 31 July 2019.

Eyler and Swope. Assistance Needed for 7th Grade Student Project on Water Quality and Fish Population [E-mail to David Swope & Sheila Eyler]. (2019, September 30).

Fishman, Charles. *The Big Thirst: The Secret Life and Turbulent Future of Water*. New York, Simon and Schuster, 2011.

Gallant, Micah. “Home.” *Wheatley River Improvement Group*. 2019. www.wheatleyriver.ca/. Accessed 1 Aug. 2019.

Gallant, Micah. "Nitrates and Their Effect on Water Quality – a Quick Study." *Wheatley River ImprovementGroup*,-a-quick-study/. Accessed 31 Aug. 2019.

GLOBE (Ed.) "Hydrosphere Protocols." *Water Transparency*, GLOBE, Hydrosphere+Protocol/6384d688-d6bc-4d35-bf5d-cf3b1292a9b3. Accessed 12 Sept. 2019.

GLOBE (Ed.). (2014). Nitrate Protocol [PDF]. Retrieved from https://www.globe.gov/documents/11865/354449/Nitrate+Protocol/cb21cfd4-6eb6-4479-af0d-d7a5a0b7468d.

GLOBE. “Soil Bulk Density”. *The GLOBE Program,* NASA, 2019. https://www.globe.gov/. Accessed 31 July 2019.

GLOBE. “Soil Characterization”. *The GLOBE Program,* NASA, 2019. https://www.globe.gov/. Accessed 31 July 2019.

GLOBE. “Soil Fertility”. *The GLOBE Program,* NASA, 2014. https://www.globe.gov/. Accessed 31 July 2019.

GLOBE. “Soil Introduction”. *The GLOBE Program,* NASA, 2019. https://www.globe.gov/. Accessed 31 July 2019.

GLOBE. “Soil Moisture Star Pattern”. *The GLOBE Program,* NASA, 2019. https://www.globe.gov/. Accessed 31 July 2019.

GLOBE. “Soil Particle Density”. *The GLOBE Program,* NASA, 2019. https://www.globe.gov/. Accessed 31 July 2019.

GLOBE. “Soil pH.” *The GLOBE Program*, NASA, 2019 https://www.globe.gov/. Accessed 31 July 2019.

GLOBE. “Soil Site Definition”. The GLOBE Program, NASA, 2019. https://www.globe.gov/. Accessed 31 July 2019.

GLOBE. “Soil Temperature”. The GLOBE Program, NASA, 2019. https://www.globe.gov/. Accessed 31 July 2019.

GrowJourney. “Recommended Reading.” *GrowJourney*, 19 Aug. 2019, https://www.growjourney.com/. Accessed 28 August 2019.

GLOBE (Ed.) "Water Transparency Protocol." *Water Transparency*, GLOBE, Water+Transparency+Protocol/6384d688-d6bc-4d35-bf5d-cf3b1292a9b3. Accessed 12 Sept. 2019.

Hess, Anna. The Ultimate Guide to Soil: the Real Dirt on Cultivating Crops, Compost, and a Healthier Home. Skyhorse Publishing, 2016

Homme, Alex Prud'. *The Ripple Effect*. New York, Alex Prud'Homme, 2011.

"How Much Water Flows during a Storm?" *Science for a Changing World*, USGS, 2019. Accessed 11 Sept. 2019.

"Improving Health in Africa." *Heath and Water*, The Water Project, 2007, thewaterproject.org/why-water/health. Accessed 18 Sept. 2019.

Leaverton, K. (Ed.). (2019). An Educator's Guide to the CBF Water Quality Interactive Map [PDF]. Retrieved from https://www.cbf.org/document-library/education-resources/guide-to-water-quality-interactive-map.pdf

Little, Jeanne S. The Nature Company Guides Rocks and Fossils. Time-Life Books, 1996.

Lumen (Ed.). (2019). The pH Scale. Retrieved February 23, 2020, from https://courses.lumenlearning.com/wmopen-nmbiology1/chapter/the-ph-scale/

Minnesota Department of Health (Ed.). (2019). Water Quality/Well Testing/Well Disinfection Well Management Program. Retrieved October, 2019, from https://www.health.state.mn.us/communities/environment/water/wells/waterquality/index.html

Montour Area Recreation Commission (Ed.). (2015). Fossil Pit. Retrieved from Montour Preserve website: https://montourpreserve.org/fossil-pit/

Morris, Neil. *Saving Water*. California, QEB Publishing, 2008.

National Academies Press. *Nitrate and Nitrite in Drinking Water*. National Academies Press, 1995.

National Audubon Society. “Your Guide to Taking Climate Action.” *Audubon*, 2019, https://www.audubon.org/. Accessed 14 September 2019.

"Nitrate and Drinking Water from Private Wells." *Centers for Disease Control and Prevention*, 1 July 2015, Accessed 5 Sept. 2019.

NOAA Office for Coastal Management (Ed.). (2019, September 20). Water Quality. Retrieved September 29, 2019, from https://coast.noaa.gov/digitalcoast/topics/water-quality.html

North Carolina Environmental Quality. (n.d.). Algal Blooms. Retrieved February 27, 2020, from https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/ecosystems-branch/algal-blooms

Oram, Brian. "The PH of Water." *Pennsylvania Well Water Testing Private Well Owners Drinking Water Pennsylvania Ground Water Education Program*, 2014, water-research.net/index. php/ph. Accessed 31 Aug. 2019.

Parsons, Paul. *Science 1001: Absolutely Everything That Matters in Science in 1001 Bite-Sized Explanations*. Buffalo, Firefly Books, 2014.

Pellant, Chris. *Rocks and Minerals*. Dorling Kindersley, 1992.

"pH and Water."*USGS: Science for a Changing World*, www.usgs.gov/special-topic/water-science-school/science/ph-and-water?qt-science_center_objects=0#qt-science_center_objects. Accessed 5 Sept. 2019.

"pH Field Guide. "*Globe*, 2019,

www.globe.gov/documents/11865/42e3b8fe-847c-429a-a105-d18691d99e32. Accessed 22 Oct. 2019.

Prud'Homme, Alex. *The Ripple Effect: The Fate of Freshwater in the Twenty-First Century*. New

York, Simon and Schuster, 2011.

Prothero, Donald R. *The Story of Life in 25 Fossils: Tales of Intrepid Fossil Hunters and the Wonders of Evolution*. Columbia University Press, 2018.

Quickcrop. “Tutorials.” *Growers Shop - Everything You Need For The Vegetable Garden*, 2008 https://www.quickcrop.ie/growing. Accessed 8 September 2019.

RAMP. "Water Quality." *RAMP*, www.ramp-alberta.org/RAMP.aspx. Accessed 24 Aug. 2019.

RMB Environmental Laboratories, Inc. (Ed.). (2019). Water Transparency. Retrieved February 25, 2020, from Lakes Monitoring Program website: http://www.rmbel.info/water-transparency/

Rohrbaugh, Piper. "The Reflection of Water Quality on the SFX Pond." GLOBE, 2019, www.globe.gov/do-globe/research-resources/student-research-reports/projectdetail/globe/the-reflection-of-water-quality-on-the-sfx-po-1?backURL=https%3A%2F%2Fwww.globe.gov%3A443%2Fdo-globe%2Fresearch-resources%2Fstudent-research-reports%3Fp_p_id%3Dcommonprojectsportlet_WAR_globegovcmsportlet_INSTANCE_jDnbXQWA73g3%26p_p_lifecycle%3D0%26p_p_state%3Dnormal%26p_p_mode%3Dview%26p_p_col_id%3Dcolumn-4%26p_p_col_count%3D1%26_commonprojectsportlet_WAR_globegovcmsportlet_INSTANCE_jDnbXQWA73g3_reportTypes%3D%26_commonprojectsportlet_WAR_globegovcmsportlet_INSTANCE_jDnbXQWA73g3_yearFilter%3D0%26_co mmonprojectsportlet_WAR_globegovcmsportlet_INSTANCE_jDnbXQWA73g3_orgFilterId%3D0%26_commonprojectsportlet_WAR_globegovcmsportlet_INSTANCE_jDnbXQWA73g3_gradeLevel%3D%26_commonprojectsportlet_WAR_globegovcmsportlet_INSTANCE_jDnbXQWA73g3_protocolIds%3D359014,359007,359002%26_commonprojectsportlet_WAR_globegovcmsportlet_INSTANCE_jDnbXQWA73g3_andProtocolIds%3Dfalse%26_commonprojectsportlet_WAR_globegovcmsportlet_INSTANCE_jDnbXQWA73g3_displayStart%3D0%26_commonprojectsportlet_WAR_globegovcmsportlet_INSTANCE_jDnbXQWA73g3_sortCol%3D4. Accessed 7 Oct. 2019.

"Soil Solutions." *Soil Solutions*, Fibershed, 2019 https://soilsolution.org/. Accessed 15 September 2019.

Soil Quality.Welcome to the Soil Quality Website." *Welcome to the Soil Quality Website*, 2019. http://www.soilquality.org.au/. 25 September 2019.

Stein, Richard. *Water Supply*. Edited by Richard Joseph Stein, H.W. Wilson Company, 2008.

TAMU (Ed.). (2020). Measuring Nitrates and Their Effect on Water Quality. Retrieved February 25, 2020, from Water's the Matter website: https://peer.tamu.edu//curriculum_modules/Water_Quality/Module_5/index.htm

The 71 Percent (Ed.). (2017). A Storm's Impact on Community Water Quality. Retrieved July 31,

2019, from Your Natural Source for all Things Water website: https://www.the71percent.org/storms-impact-community-water-quality/

The Weather Company (Ed.). (2020). Gettysburg, PA Weather Conditions. Retrieved February 11, 2020, from Weather Underground website:

https://www.wunderground.com/weather/us/pa/gettysburg

Thurston, Harry. *The Atlantic Coast: A Natural History*. Illustrated by Emily S. Damstra, Vancouver, Greystone Books, 2011

U.S. National Library of Medicine, et al. "Water." *PubChem*, pubchem.ncbi.nlm.nih.gov/compound/water Accessed 15 Oct. 2019.

U.S. National Library of Medicine, et al. "Water." *PubChem*, pubchem.ncbi.nlm.nih.gov/compound/water Accessed 15 Oct. 2019.

USF Water Institute. "Water Quality." *Sarasota County Water Atlas*, USF Water Institute, 2001-2019, www.sarasota.wateratlas.usf.edu/. Accessed 31 Sept. 2019.

USGS. "Exploring: Water Quality." *USGS.gov*, U.S. Department of the Interior, www.usgs.gov/. Accessed 29 July 2019.

"Water Quality." *NRCD*, Natural Resources Defense Council, 2019, www.nrdc.org/. Accessed 23 Aug.2019.

"Water Quality." *Water Quality*, Department of Environmental Protection, 2019, Business/Water/CleanWater/WaterQuality/Pages/default.aspx. Accessed 7 Oct. 2019.

"Water Transparency Field Guide." GLOBE, www.globe.gov/documents/11865/6384d688-d6bc-4d35- bf5d-cf3b1292a9b3. Accessed 21 Oct. 2019.

"What should be the pH value of drinking water?" *The Daily Star*, 6 Sept. 2019, www.thedailystar.net/ health/what-should-be-the-ph-value-drinking-water-138382. Accessed 12 Sept. 2019.

VanDiver, Bradford B. *Roadside Geology of Pennsylvania*. Mountain Press Publishing Company,

1990.