LACKAWANNA RIVER WATERSHED SPATIAL ANALYSIS

By

JACOB BECKER

MASTER OF SCIENCE
GEOGRAPHIC INFORMATION SYSTEMS TECHNOLOGY
FINAL PROJECT

THE UNIVERSITY OF ARIZONA

2023

To my fiancé Lindsey who provided so much support and feedback during my time on this program and showed me my potential in my field and progressing my education further. Thank you.

ACKNOWLEDGMENTS

I thank every one of my professors at the University of Arizona who provided priceless knowledge in the field of GIST, and all my professors in my undergraduate program at Bloomsburg University for pushing me to pursue this field further. I would not be in the career path I am today without the education and skills I have gained while participating in higher education.

ETHICAL STATEMENT

I find that ethical challenges in GIS are quite ubiquitous. The work you are doing, especially in a public matter, can affect so many things in the world around you. Politics, morals, integrity, education and many more. The work you do can have an impact on how laws can be made or changed. How someone views the issue or task can also affect how they go about making a change whether it be positive or negative. It is extremely important to go about creating or editing your work with due diligence to ensure that its aftermath creates a positive outcome rather than making anything worse or providing an avenue for someone to capitalize on it negatively.

It is also crucial to voice your opinions on whatever it is, the problem or solution. Sometimes saying nothing could be potentially more devastating than saying something you may think is wrong or unreasonable. If you are providing public knowledge or research that could impact society in any way, it is your upmost responsibility to provide your work or whatever it may be with absolute integrity to ensure a better tomorrow.

For my capstone project, I think ethics are extremely important because I am working to provide public knowledge that concerns the health and integrity of our ecosystems that sustain life for humans, plants, and any living organism that requires water and air to live. Making my project accessible to the public could have a profound impact on how the people who hold an interest in this study or to the people who live in that area view how the people responsible for creating laws and protections against this type of environmental degradation operate. I am hoping my research will provide not only education, but also the first step in the process of turning around something that could be a detrimental issue into a positive future for many generations to come.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

EPCAMR	Eastern Pennsylvania Coalition of Abandoned Mine Reclamation. A non-profit organization dedicated to abandoned mine reclamation and a cleaner water initiative.
PASDA	Pennsylvania Spatial Data Access. Organized by the Pennsylvania State University, a database allowing access to Pennsylvania's geoscientific data
USGS	United States Geological Survey. A federal geoscientific research database.
TRI	Toxics Release Inventory. A program that tracks industrial management of toxic chemicals that can cause harm to environment and human health
Fe	The element Iron
Mg	The element Magnesium.
SO4	Sulfate
EPA	The Environmental Protection Agency. Organized by the U.S. federal government that ensures the initiative of clean air, water and land and the laws to uphold that initiative.
pH	"Potential of Hydrogen" or the study of a water's acidity based on a scale 0-10. 0 being acidic and 10 being basic.

ABSTRACT

The purpose of this study is to create and display a spatial analysis study on the Lackawanna River Watershed in Northeastern Pennsylvania. Specifically, an analysis that displays data containing contaminants in the air and water within the watershed study area, potentially correlating with the areas heavy use of coal mining historically. Using fugitive emission data to measure air contaminants and water pH, sulfates, and hard metals data to examine potentially polluted waters will show how this small yet essential watershed has been impacted. It is extremely important to run these studies to show the damage that is caused by coal mining and create preventative measures for the future. Protection of watersheds is paramount in conserving the local flora and fauna that feed us and nurture their surrounding ecosystems. Education and outreach can be a useful tool to make people aware of the issues at hand in their own backyards. With the devastating impacts a toxin filled watershed can have on its surrounding watersheds and environments, there should be more publicly accessible research studies that are user friendly to provide the proper awareness and education.

Keywords: analysis, mining, statistics, pollution, spatial, watershed, education, awareness, outreach, environment.

CHAPTER 1
INTRODUCTION

The Importance of Watersheds

Watersheds are an area of land that drains down a slope until it reaches a common area or point. They are also called “drainage basins” or “catchment areas”. Thus, all water from precipitation that is not used by the vegetation it passes through will flow to the lowest point of this area. This low point could be a body of water such as a river, lake, or ocean. All of these bodies of water, no matter the size, will have a watershed area. Small watershed areas for example affect the larger watersheds they are connected to. Everyone and everything live within a watershed or part of one, this is why they are extremely important. Healthy watersheds act as a filter cleaning our drinking water and stabilizing its surrounding soils. This also creates more opportunities for recreation, aesthetics, etc. Impacting the watershed by mining or installing impervious surfaces such as roads, rooftops, and parking lots can have a negative impact on the watershed. This creates potential for increasing the speed and volume of stormwater runoff flowing into bodies of water causing erosion, degraded habitats for wildlife, and turbidity. Runoff carries pollutants, oil, nutrients, sediments, metals, salts, and bacteria to the bodies of water. This all ties into an ecosystem’s health and how it affects its surrounding water and vegetation quality. The importance of these watersheds is essential to quality of life and how flora and fauna can be sustained within them. My goal is to create an analysis of a watershed I have lived in for 25 years. This area was heavily affected by coal mining many years ago during its settlement. I want to establish the relationship between mining and how it negatively impacted this watershed

and changed how the surrounding ecosystem and the way humans, animals, and plants have adapted to its effects.

The Susquehanna River Basin is divided into six subbasins following its three major tributaries, the West Branch Susquehanna, Juniata, and Chemung Rivers. My focus in this project will be in the Middle Susquehanna basin, specifically the Lackawanna River Watershed. This watershed contains the Lackawanna River, roughly 40 miles long within this watershed that is 350-square miles spanning over four different counties. This river eventually flows into the North Branch Susquehanna River. My motivation for choosing this watershed aside from it being within the area I grew up in, is that it contains the largest abandoned mine discharge (AMD) in the Susquehanna River Watershed and possibly the largest AMD source in the Eastern U.S.

Figure 1-1. Area of Study.

Figure 1-1 above is the area of study. Since the late 1700s mines have been active in Pennsylvania's bituminous coalfields. During 1997, there were over 73 million tons of bituminous coal mined. More than 75 percent of this was from underground mining operations. Once all the material that could be mined was extracted, these companies doing the mining operations abandoned these mines not thinking about how this would affect the environment or the future. Capitalizing on the booming industry, this led to a devastating future for watersheds affected by operations such as these. Leaving enormous cavities in the ground seemed harmless but most of them located in highly active watersheds started to fill up with ground water and stream water. Once these mines were filled to their capacity they had to drain somewhere. When discharging mine water, it is near impossible to deal with the built-up water pressure to try and stop or halt these discharges. This leads to things like a designated borehole having to discharge into the watersheds main river and being monitored daily with no real plan on how to mitigate these hazardous waters.

EPCAMR is an organization I worked with while interning at the Lackawanna River Conservation Association that has a main focus of abandoned mine reclamation and how it affects our environment within this watershed. They oversee a 42-inch borehole that drains water from the abandoned mines into the Lackawanna River. The Old Forge Borehole is photographed in figures 1-2 and 1-3.

Figure 1-2. Old Forge Borehole.

Figure 1-3. Old Forge Borehole

This part of the Lackawanna River flows into its confluence with the Susquehanna River, a larger branch of the same watershed. You can see in figure 1-4 the severe staining of iron hydroxide along the bank of the river. This can also be seen via aerial

imagery on Google Earth. As you can see iron hydroxide is insoluble in water creating this reddish-brown tint.

Figure 1-4. Iron Hydroxide

Seeing this type of contamination on a smaller scale such as this makes you question how it looks and affects the environment on a mass scale, and is it able to be stopped and prevented for future generations? How is this affecting fish and drinking water? How are farms using this same water table dealing with growing produce and livestock and are they even aware this is happening?

CHAPTER 2
Methods and Data

Spatial Analysis and Data Sources

For this project I will be using spatial analysis data to display if and why mining in the watershed historically has negatively impacted the watershed. Statistical analyses allow you to display data represented on a map also using charts and tables for visual representation. Specifically, I will be using the TRI data to display fugitive and stack air that represent air pollution within the area in pounds. In addition to this I will be mainly using pH, sulfate, and hard metal (iron and magnesium) data gathered from EPCAMR. Watershed data gathered from PASDA will serve as a shapefile to show the Lackawanna River Watershed. An additional data source credit goes to PASDA for a Pennsylvania county shapefile used as an inset in my map analysis.

First, I started by gathering my data from numerous sources. What I needed to start with was the shapefiles for my study area and watershed. After some symbolic editing of where and how I wanted to orient the data and how much I wanted it to be zoomed in I can start applying my data to the area of study.

Next, I took the TRI data gathered from the EPA and needed to isolate fugitive air and stack air contaminant data. Once I isolated the data I needed to, I layered the data on top of my watershed and abandoned mine data. Using graduated symbols, I symbolized the data shown in the final map with different sizes, from small to large in classes of low to high harmful particulate matter. In the final map you can see that in the area where cities are is where the higher harmful particulate matter resides. Otherwise, the air quality is in fairly good shape. This led me to believe that the air quality was not really an issue in correlation to the historic mining in that watershed area.

Following the air, for the water data I had an extremely large data set from EPCAMR which I narrowed down to iron, magnesium, sulfates, and water PH. Once I normalized these data sets, I repeated the same process using graduated symbols to show different sizes for water pH levels. This display showed the biggest violet-colored circles on the map to being the most acidic waters which turned out to be at the confluence of the Lackawanna and Susquehanna Rivers. After that I needed the proper attributes I wanted to display in chart form. These can be created directly from the attribute table of the map data and exported for display.

Once I had the attributes and charts made, I once again corrected the symbology using graduated symbols and colors for a display that can be easily read to show the numbers the reader is looking for. I had to ensure the colors and shapes that I used for displaying these data points did not clash too much or blend to make the map and picture look “muddy”. Using dark reds and purples to show the extreme or harmful data seemed to fit perfectly with a common standard people associate with harmful or negative impact. Using yellow triangles for the air reminded me of a type of “cautionary” symbol which could catch the reader’s eye and make you find the brightest and biggest one which is the most harmful. I also made the watershed shapefile color a light blue to remind the readers of water or perceive it that way. Lastly, the abandoned mine shapefile areas were a dark grey, almost black fill color to properly blend with the lighter colors of the topographical base map and light blue watershed color without bleeding into the data point color symbols. Finally, after some final editing to make the map aesthetically pleasing with components such as a Pennsylvania inlay map, north arrows

for proper orientation, scale bar to get an idea of the size of the study area and topped it off with a proper title and credits.

I tried running OLS regression models to try and predict possible outcomes or models to display future data. Whenever I tried running the model using different data normalizations, I repeatedly received error messages and modeling was not working out. I think this was due to a lack of data sets and possibly different sources interfering with the software tools' functioning.

I created three histograms from the data I gathered using the tool on ArcGIS Pro. The first table is a mean, median, and standard deviation of the water pH level in the abandoned mine area within the watershed. The second table is the measure of fugitive air contaminants using mean and standard deviation within the watershed area measures in pounds. The third histogram table I created is a measure of stack air measured in pounds also using mean and standard deviation to portray these results. These three tables are further explained in detail within the results section of this project.

In the future I would like to create additional analyses with better data, more data sets, and proper regression models to showcase a better understanding of how the future of this data can be displayed for future generations. Estimation models can help formulate and regulate how lawmakers can propose their environmental laws for the betterment of the community. I think this would increase awareness and allow people to have a better grasp of how this affects them and the environment around them.

CHAPTER 3
RESULTS

The results of my analysis study were not very surprising due to having formally worked with the organization the data was gathered from. The southern end of the watershed seen in figure 3-1, showed extremely high acidity in the water. This is where the Old Forge borehole flows into the Susquehanna River, its parent watershed area.

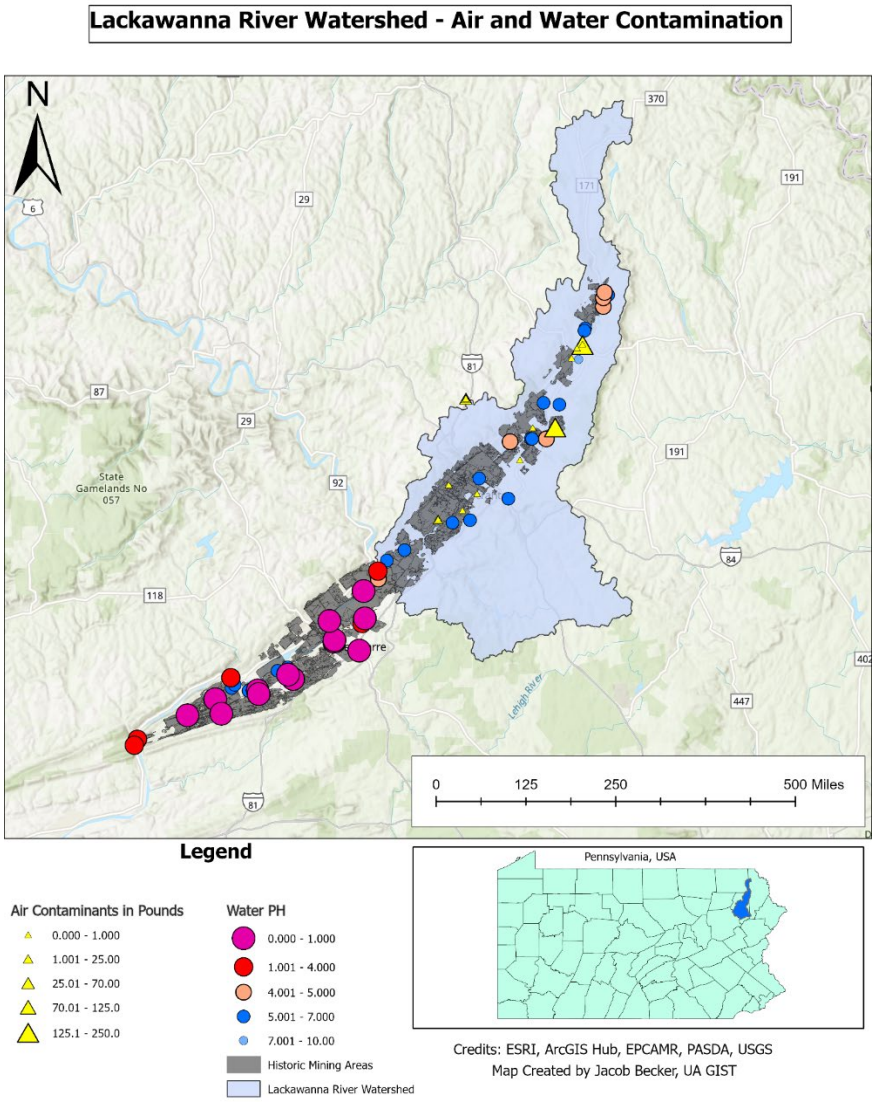


Figure 3-1. Final Map Result

Throughout the majority of the watershed, it showed very little basic level water. The middle of the watershed being with the least amount of contamination, towards the headwater and where it flows into its next watershed showed the highest levels of acidity. Based on the map that was created I think there is an extreme correlation between historic mineral and coal mining with how it has devastated the water table. At the Old Forge borehole, where the abandoned mine water is released into the Lackawanna River, it is at a rate of a tremendous one hundred to one hundred and fifty million gallons of water discharging per day. It is almost unfathomable to try and picture this amount of water. For example, a large swimming pool about the length of a football field with a depth of ten feet and a width of 50 feet can hold approximately a million gallons of water. That would be approximately a hundred of those pools being discharged into the river and watershed every single day. It is still very difficult to try and perceive that amount of water. To make matters worse, that same water is unfortunately contaminated with hard metals such as iron hydroxide, magnesium and harmful sulfates that decimate the local flora and fauna. This eventually spreads to the mighty Susquehanna River which reaches its destination at the well renowned Chesapeake Bay.

Another example of how this small yet essential watershed can affect society is economically. Since this contaminated water leads to Chesapeake Bay, 18 million people live in this area. Seafood, water, produce grown, thousands of species and millions of jobs rely on this profound body of water to be sustainable. This small watershed is just one small scale example of contamination that’s negatively affecting this very bay.

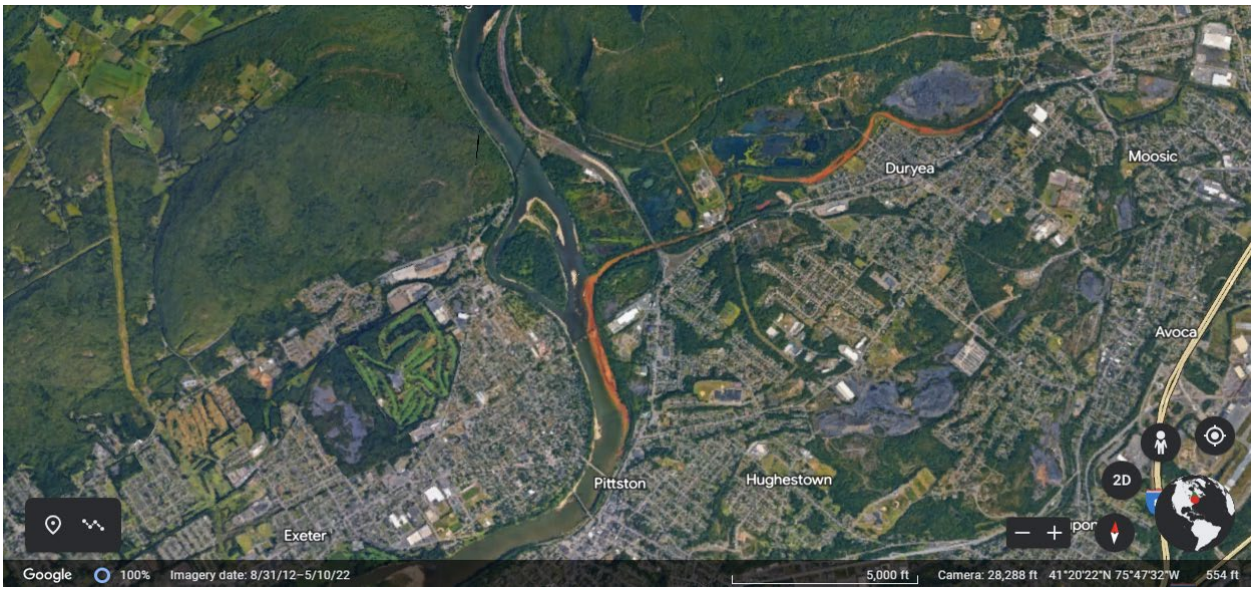


Figure 3-2. Aerial View

Above is a figure I obtained from Google Earth. It shows where the Old Forge borehole discharges into the Lackawanna River and follows to the confluence point at the Susquehanna River. If you follow where the town of Moosic is located, you will see a stream of orange pass through Duryea and into Pittston where the Susquehanna flows.

This is the iron hydroxide rich water that stains the water and riverbed. It is quite alarming to imagine that this is the same water that mixes in with the water where a lot of the eastern United States grows crops and raises livestock in addition to being one of the largest seafood providing areas in the entire East Coast.

To my surprise, the air contamination was not showing to be on the extreme side. The highest levels being in the watershed's metropolitan area. This can be analyzed as typical contamination levels that are not completely out of the ordinary.

See tables 3-1 to 1-3 for the results of the water contaminants in graph form.

Table 3-1. Distribution of water PH

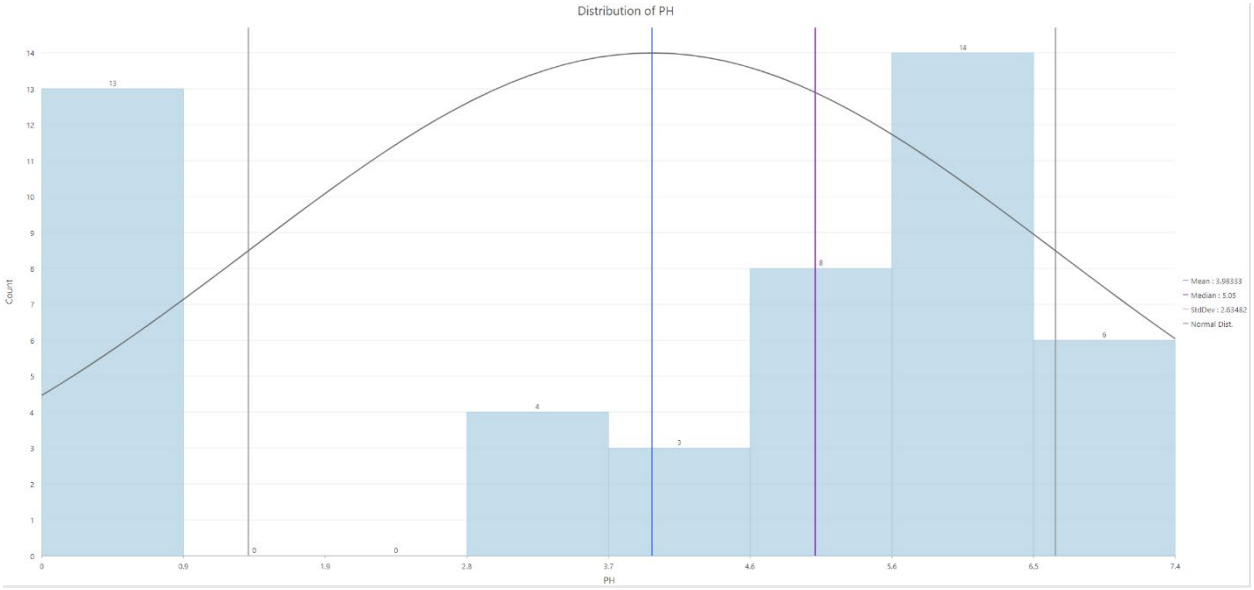


Table 3-2. Distribution of Fugitive Air

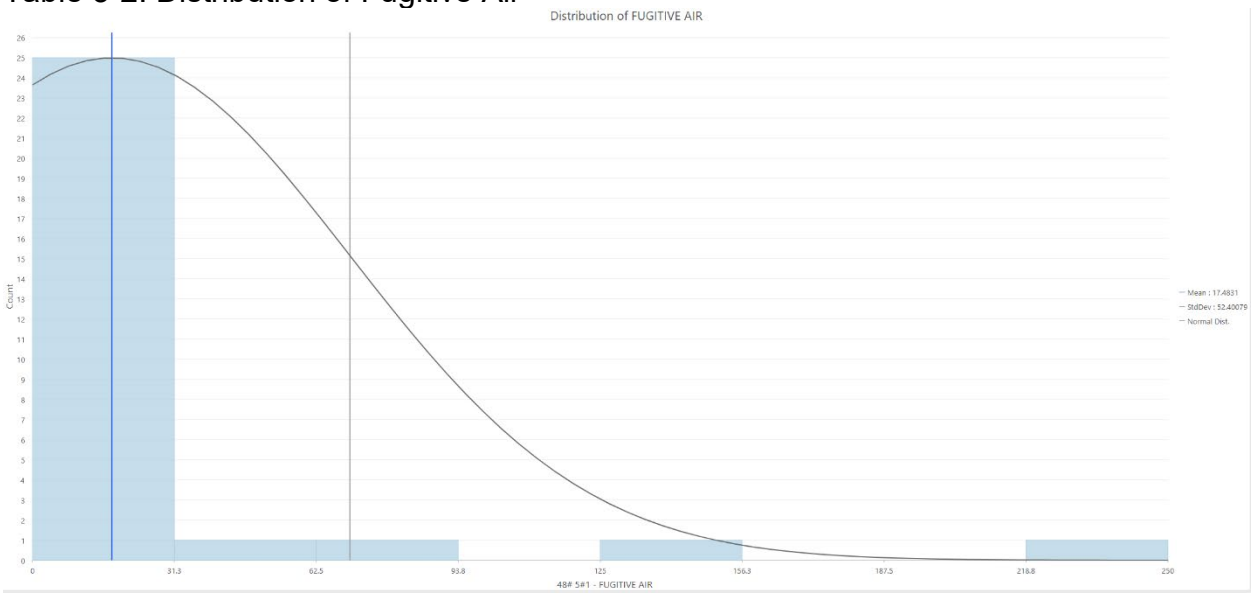
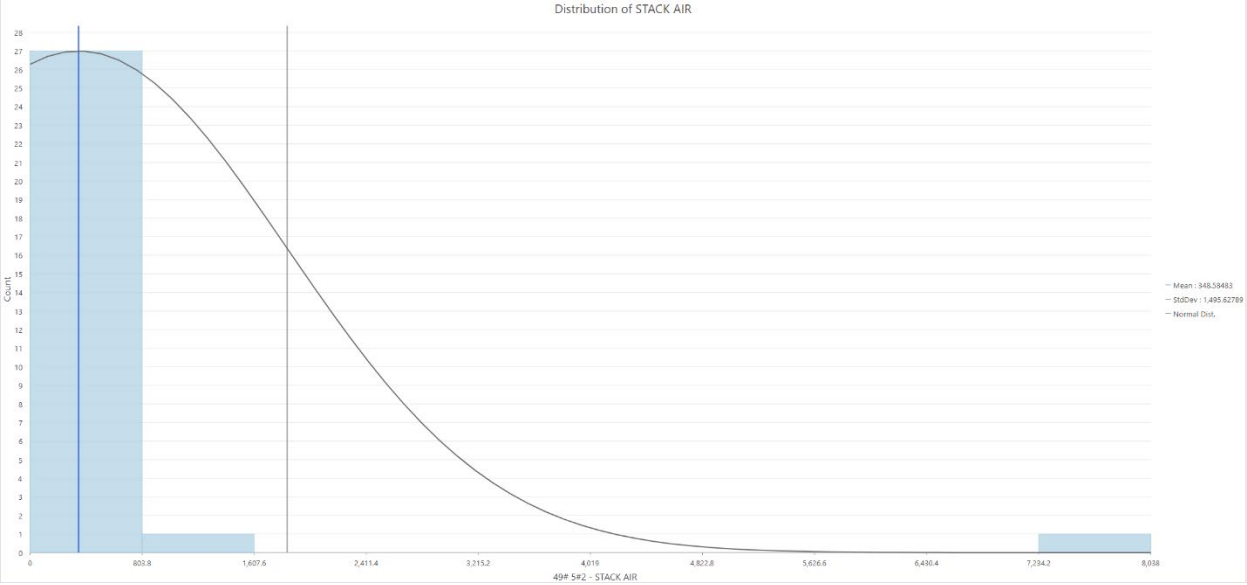


Table 3-3. Distribution of Stack Air



The first table 3-1 shows the mean, median and standard deviation of the pH levels of the water discharging out of the abandoned mine areas into the Lackawanna River via the Old Forge Borehole. pH is a measure of how acidic or basic water is, ranging from 0 to 14. Zero being the most acidic and 14 being the most basic. Potable water tends to be around a 7 on the pH scale which is considered neutral. On the table it showed the average pH of this mine water being discharged was sitting at about a 3.98. This water is considered to be very acidic and toxic. As the natural waters run through the abandoned mine, it absorbs and picks up all kinds of contaminants and

toxins that are discharging directly into the watershed. Though it is heavily monitored, scientists are still struggling with how to correct or stop this problem.

Table 3-2 displays TRI data showing Fugitive Air contamination. Fugitive air contamination is significant atmospheric dust that originates from granular material exposed to the air. It is considered “fugitive” due to not being discharged from a confined air stream. Examples of fugitive air are considered to be dust from unpaved roads, agricultural operations and equipment mainly in tilling operations, heavy construction processes and operations and storage piles containing aggregates. The impact of fugitive air particles depends on the quantity and the drift potential of the dust particles into the atmosphere. They tend to remain suspended in the air due to not being overly susceptible to gravitational settling. The fugitive air in this table is relatively low to average. The higher data showing to be in and around the metropolitan areas of the watershed such as the largest city in the watershed, Scranton, Pennsylvania.

Table 3-3 displays Stack Air contamination data. Stack air contamination is particulate matter that is emitted from large industrial smokestacks on industrial sized buildings or operations. They are built of a very tall height, so they do not affect life on the ground around them, but in turn they do affect the atmosphere tremendously. Some examples of these are boiler stacks, flue gas stacks, chimneys, furnace stacks, and DG set stacks. Due to these stacks requiring heavy monitoring on a daily basis there is a lot of data available in addition to studies that exemplify the dangers of these emissions. The table shows particulate matter in pounds as an average of 348. Again, there is no type of “good” emission from these stacks but these numbers are on a lower end of a larger spectrum.

CHAPTER 4
CONCLUSION

In Conclusion the biggest issue at hand for this specific watershed is the quality of the water. With the Old Forge Borehole having 100 cubic feet per second of iron laden water flowing directly into the river that eventually ends up in the Chesapeake Bay.

The question is whether or not this can be stopped, delayed, or even figuring out a solution. I think the biggest takeaway from this is education. Without educating the people, especially the residents directly in the area of study that are affected by this, I do not think stopping it would be possible. Raising awareness is extremely important to unite the people this is affecting and get the ball rolling on initiatives to stop this environmental degradation and its impacts.

At the end of the day, it’s a community who decides the political stance on its environment and to plan for the future. If more of the residents who are voting for these laws or people trying to put a stop to conservation and preservation were aware of the consequences of what’s going on in their environment, perhaps it could be a start.

All life requires water, and if this kind of contamination continues to happen on a larger scale, then there are going to be detrimental consequences. The importance of analyses such as these are the first step to getting knowledge to the people who might not have access to or how to use data that can affect their lives every day.

I personally believe the outreach of education is more important than profit. Unfortunately, in a society today that is driven by capitalism and greed, a lot of people are preventing access to education or awareness to these scientific phenomena. I urge everyone to be a student of the world upon themselves and never stop voicing your

ethical opinions. It all starts with awareness and a want to change something for the better, especially when it could affect how your children and grandchildren live with or without the quality they deserve.

LIST OF REFERENCES

Hughes, R. (2013, August 21). *Old Forge Borehole*. EPCAMR. https://epcamr.org/home/2013/epcamr-awards-4-regional-arippa-amdaml-reclamation-awards-to-improve-local-waterways-in-the-amount-of-2500/

SRBC. (2006). Susquehanna River Basin Commission. https://www.srbc.net/portals/susquehanna-atlas/data-and-maps/major-watersheds/

McGurl, B. (2023, January 1). Lackawanna River Conservation Association. https://lrca.org/about-us

EPA. (2023, July 28). *Toxics Release Inventory (TRI)*. Environmental Protection Agency. https://www.epa.gov/toxics-release-inventory-tri-program

Scott, D. (2023, July 28). Pennsylvania Spatial Data Access. https://www.pasda.psu.edu/about.html

PennShare. (2015, December 23). *Pennsylvania State Border*. ArcGIS Hub. https://hub.arcgis.com/datasets/PennShare::pennsylvania-state-boundary-1/explore

Google.com/earth

Solyst, J. (2020, September 18). *Why is the Chesapeake Bay so important?*. www.chesapeakebay.net. https://www.chesapeakebay.net/news/blog/why-is-the-chesapeake-bay-so-important#:~:text=The%20Bay%20is%20also%20an,Atlantic%3A%20Baltimore%20and%20Hampton%20Roads