Well and Spring Water Quality Assessment in the Pike Run Watershed, PA

A THESIS

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This study assesses the groundwater quality of the Pike Run Watershed, located in Washington County, Pennsylvania. The groundwater quality is valuable since residents use groundwater as their main water source. Domestic wells and springs were sampled and compared with the National Drinking Water Standards established by the EPA. It is hypothesized that acid mine drainage is a non-point source pollutant, and this water source could cause negative health affects to the residents.

Chemical analysis was completed and evaluated based on local stratigraphy, position of aquifers, and locations of mining pools. Health information of the study area was gathered and compared to national averages.

It has been determined that aquifers lie within abandoned mined areas, and are being used as water supplies by local residents. Therefore, acid mine drainage is a non-point source pollutant of the groundwater within the watershed and could be negatively affecting the health of the residents.
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This research thesis is dedicated in memory of Lorraine R. Horvath who taught me that love, laughter, patience, and forgiveness are the keys to life.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>a. Purpose</td>
<td>2</td>
</tr>
<tr>
<td>b. Study Area</td>
<td>4</td>
</tr>
<tr>
<td>c. Acid Mine Drainage</td>
<td>7</td>
</tr>
<tr>
<td>d. Distinctive Signs of Acid Mine Drainage</td>
<td>13</td>
</tr>
<tr>
<td>e. Stream Impacts of Acid Mine Drainage</td>
<td>14</td>
</tr>
<tr>
<td>f. Effects of AMD on Human Health</td>
<td>15</td>
</tr>
<tr>
<td>g. Case Study</td>
<td>17</td>
</tr>
<tr>
<td>h. Biochemistry and Ion Functionality</td>
<td>20</td>
</tr>
<tr>
<td>i. Geology of the Study Area</td>
<td>21</td>
</tr>
<tr>
<td>ii. Bedrocks and their Depositional Environment</td>
<td>21</td>
</tr>
<tr>
<td>iii. Aquifers of the Study Area</td>
<td>34</td>
</tr>
<tr>
<td>iv. Groundwater Geochemistry</td>
<td>37</td>
</tr>
<tr>
<td>j. History of Mining in the Study Area</td>
<td>39</td>
</tr>
<tr>
<td>II. METHODS</td>
<td>43</td>
</tr>
<tr>
<td>a. Sampling Collection</td>
<td>43</td>
</tr>
<tr>
<td>b. Geologic Data</td>
<td>46</td>
</tr>
<tr>
<td>c. Health Data</td>
<td>48</td>
</tr>
<tr>
<td>III. RESULTS AND ANALYSIS</td>
<td>50</td>
</tr>
<tr>
<td>a. Chemistry</td>
<td>50</td>
</tr>
<tr>
<td>b. Geology</td>
<td>67</td>
</tr>
<tr>
<td>c. Health Surveys</td>
<td>77</td>
</tr>
<tr>
<td>d. Cancer Incidence Rates</td>
<td>79</td>
</tr>
<tr>
<td>IV. DISCUSSION</td>
<td>83</td>
</tr>
<tr>
<td>a. Geology and Chemistry</td>
<td>83</td>
</tr>
<tr>
<td>b. Spring and Health Data</td>
<td>87</td>
</tr>
<tr>
<td>V. CONCLUSION</td>
<td>90</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

It has been estimated that more than 3000 years ago coal was discovered and mined for by the Chinese (ACF, 2005.) They used this rock for heat and light, which lasted longer and burned hotter than wood. Since this time, coal has grown in its uses and has become one of the most important sources of energy internationally. The Unites States has a wealth of this energy supply. Annually, it is a $23 billion dollar industry that supplies nearly half of America’s energy needs, as well as providing coke for the nation’s steel mills and serving as a commodity for foreign trade (ACF, 2005). The first record of coal being discovered in the United States was by a French explorer in the Illinois River in 1679 (ACF, 2005.) It was not commercially produced however until 1750 where it was first mined and sold near Richmond Virginia. Pennsylvania is one of the key producers of coal, and has been since the first commercial production of coal. First discovered by an Indian near Nazareth, PA, between the years of 1750-1755, Pennsylvania’s coal production help to power the Industrial Revolution and helped to build Andrew Carnegie’s steel mills to the empires they were. Today, Pennsylvania is the fourth largest coal producer in the United States after West Virginia, Kentucky, and Wyoming (DEP, 2005).

Southwestern Pennsylvania’s history is strongly influenced by coal mining industry. Geologically speaking, Southwestern PA sits on top of a wealth of coal deposits, making it an ideal place to mine. Since the coal was here to mine, the jobs followed, and with that people to build communities. This was wonderful
during high production times, however as time progressed and coal was mined away, mines began to close, jobs were lost, and long-term environmental impacts began to develop. Among environmental problems related to coal mining industry are land that could not sustain any plant life, water that became polluted through a process known as acid mine drainage, and air pollution from the steel mills and factories. Federal reclamation acts were passed to try to avoid these potential devastating problems. However, as many mining companies went out of business the money to reclaim the sites also left, and/or the reclamation efforts did not meet the required standards.

West Pike Run Township, a small community in Washington County, PA is a good example of a mining based community whose livelihoods came from the fossil fuel but who are now paying for it through negative environmental impacts. The residents of this community have noticed problems with their water including a foul, "rotten egg" smell that comes from the water, and an orange discoloration of their appliances and dishes.

A. PURPOSE

The purpose of this study is to assess the groundwater quality of the Pike Run Township. Sources of groundwater as well as possible sources of pollution are being evaluated on a watershed scale (Figure 1).
Figure 1. Sub-watershed of the Pike Run Watershed Region.

Determination of groundwater quality within the watershed is highly valuable since most residents use groundwater as their main water source, since public water is not available. The Pike Run Watershed region has been undermined completely by many coal companies, which increase the risk of AMD pollution to the groundwater system. A study conducted by the Pike Run Watershed Association on these streams revealed that acid mine drainage is a major non-point source pollutant, therefore; since groundwater supplies streams with water it is assumed that the groundwater is also polluted by AMD (Vargo, 1998). The hypothesis for this thesis is thus two-fold: 1. Are the wells and springs in the Pike Run Watershed groundwater system polluted by AMD? 2. If the water is contaminated by AMD, is there a statistical correlation between high
levels of AMD ions in the water supply with health problems associated with these ions for those who drink the water? To determine this, water chemistry was ascertained through water collection and analytical laboratory analysis, geological data, such as lithology, stratigraphy, and petrology of the sedimentary rocks that forms local aquifers were analyzed and interpreted, health data was collected and evaluated, and software programs such as RockWorks and ArcView 9.1 were used to establish spatial relationships between data collected and to determine if there is a correlation between geology, water chemistry, and health issues within the study area.

B. STUDY AREA

West Pike Run Township is located in the southeastern part of Washington County, Pennsylvania (Figure 2).
It is a small rural community with a total population of 1,925 people accounted for in 774 privately owned houses (Census Bureau, 2000). Residents of this community are primarily small private farmers, who grow crops and animals for their own families or for local markets. Figure 3 demonstrates the study area is mostly rural. Public water supply is available only in urban areas, therefore many residents of West Pike Run Township do not have a public water supply.

Residents use wells drilled on their properties for a water supply or cisterns that store the water pumped from the local wells or springs. The groundwater is the major drinking water resource in the area. It has been noticed by residents that local water stains sinks, bathtubs, dishes, and tiles around the
faucets, indicating that the water has a high level of iron solute (Figures 4, 5, and 6).

Figure 4. Dish with iron deposits
Figure 5. Bathtub with iron deposits
Figure 6. Dishwasher with iron deposits

No source ground water assessment has been done to this township.

The study area lays within the Pike Run Watershed, that consists of five sub-watersheds (Figure 1). The recharge area of the local aquifer is located within the Pike Run Watershed. The five sub-watersheds contain three main streams being Gorby Run, Pike Run, and Pigeon Creek (Figure 1.) A study
conducted by the Pike Run Watershed Association on these streams revealed that acid mine drainage is a major non-point source pollutant of surface water (Vargo, 1998).

The watershed is 12 square miles in area, with a relief change of 602 feet between the hills and valleys with the highest relief being 1340 feet and the lowest being 748 feet (Figure 7).

![Digital Elevation of Pike Run Watershed](image)

*Figure 7. Digital elevation model of the watershed (Horvath, 2006)*

### C. ACID MINE DRAINAGE

The process of acid mine drainage typically occurs as a result of mining activities like surface mining, deep mining, or coal refuse piles. The action of AMD is created based on the hydrology, geology, and mining technology that was used at the mining site (DEP, 2003). Acid mine drainage is water or
drainage produced from mining activities that is very acidic due to the oxidation of certain minerals that were exposed to air and water during the mining progression. Remaining coal and rock that is rich in sulfides, such as pyrite and marcasite (FeS$_2$ — iron disulfide minerals), that are commonly found in coal bearing strata, oxidize in the presence of air and water to produce sulfuric acid (H$_2$SO$_4$) and dissolved metals. The sulfuric acid in the water lowers the pH and allows for metal ions to stay dissolved in the water. If the pH rises to a neutral or alkaline level the dissolved metals precipitate out of the water at that time.

There are four chemical reactions that take place in the environment where AMD is being formed. This first equation is the summary of reactions that occurs during the oxidation of pyrite to produce AMD (DEP, 2003).

$$4 \text{FeS}_2 + 15 \text{O}_2 + 14 \text{H}_2\text{O} \rightarrow 4 \text{Fe(OH)}_3\downarrow + 8 \text{H}_2\text{SO}_4$$ (1)

Pyrite + Oxygen + Water $\rightarrow$ "Yellowboy" + Sulfuric Acid

The second equation describes the chemical weathering of pyrite. The reaction of sulfur during oxidation releases sulfate and ferrous iron and produces two moles of acidity for each mole of pyrite oxidized (DEP, 2003).

$$2 \text{FeS}_2 + 7 \text{O}_2 + 2 \text{H}_2\text{O} \rightarrow 2 \text{Fe}^{2+} + 4 \text{SO}_4^{2-} + 4 \text{H}^+$$ (2)

Pyrite + Oxygen + Water $\rightarrow$ Ferrous Iron + Sulfate + Acidity
The second reaction, being the conversion of ferrous iron to ferric iron which consumes one mole of acidity is described by equation 3. This step of the reaction is also known as the “rate determining step” since there are so many factors that affect the speed at which the process occurs. For example, certain bacteria known as *T. ferroxidans* can rapidly accelerate the conversion process, as well as certain pH levels (Singer and Stumm, 1970.) *T. ferrosidans* has been known to increase the oxidation reaction by up to a hundred times the normal speed (Singer and Stumm, 1970.) This bacteria is also classified as a chemolithoautotroph, meaning that it can survive in aerobic or anaerobic conditions, thus it does not need oxygen to survive. This fact allows it to survive in flooded mining voids yet still aid in the production of acidity by attaching onto the sulfur and breaking it apart from the iron (Figure 8 and Table 1).

\[ 4 \text{Fe}^{2+} + \text{O}_2 + 4 \text{H}^+ \rightarrow 4 \text{Fe}^{3+} + 2 \text{H}_2\text{O} \]  

Ferrous Iron + Oxygen + Acidity → Ferric Iron + Water

![Thiobacillus ferroxidan](image.png)

Figure 8. *Thiobacillus ferroxidan* magnified 30,000 times (Ehrlich, 1990)
Another factor in the rate determining step is the pH level. If the pH is very acidic (2.5 pH) with no presence of bacteria, like after years of AMD occurring, the reaction rate is very slow. However, if the pH is near five with bacteria than the reaction rate is extremely fast (DEP, 2003).

The third reaction is described in equation 4. The hydrolysis or the breaking apart of water molecules, of the iron molecule occurs. This produces
three more moles of acidity for every one mole of iron are being produced (DEP, 2003).

\[
4 \text{Fe}^{3+} + 12 \text{H}_2\text{O} \rightarrow 4 \text{Fe(OH)}_3 \downarrow + 12 \text{H}^+ \quad (4)
\]

Ferric Iron + Water → Ferric Hydroxide (yellowboy) + acidity

The final step in the process of AMD is the ongoing oxidation of pyrite by ferric iron until pyrite is completely depleted (Equation 5). Oxygen and water are no longer the oxidizing agents at this step of the process; the ferric iron completes the oxidizing. Even after there is no oxygen left in the mining area (for example when water fills up a mining shaft) the acidity of the water is still building up because the ferric iron in the water acts as an oxidizing agent instead of water and continues the process until all of the pyrite is oxidized (DEP, 2003).

\[
\text{FeS} + 14 \text{Fe}^{3+} + 8 \text{H}_2\text{O} \rightarrow 15 \text{Fe}^{2+} + 2 \text{SO}_4^{2-} + 16 \text{H}^+ \quad (5)
\]

Pyrite + Ferric Iron + Water → Ferrous Iron + Sulfate + Acidity

The above reactions are not the only chemical processes that occur during AMD. Another set of reactions occurs when alkaline bases are forming from the dissolved carbonates and other basic mineral (Equations 6-8). This alkaline reaction would be the buffering capacity of the AMD processes; the carbonate and bicarbonate ions in the presence of AMD converts to carbonic acid that then breaks down into carbon dioxide and water (Brady et al., 1998).
\[
\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{HCO}_3^- \quad (6)
\]

Acidity + Carbonate ions \rightarrow \text{Bicarbonate ions}, then

\[
\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{CO}_3 \quad (7)
\]

Bicarbonate ions + Acidity \rightarrow \text{Carbonic Acid}, then

\[
\text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2 \quad (8)
\]

Carbonic Acid \rightarrow \text{Water} + \text{Carbon Dioxide}

The acidic and alkaline reactions are actually competing against one another in terms of adjusting the pH of the water. The concentration of alkaline materials in the layers of rock, determined the reaction rate for this processes (Office of Surface Mining, 2002.) The acidic reaction rate is based on three phases, consisting of initiation, propagation, and termination. The first phase, initiation, occurs as soon as the pyrite is exposed to the oxidizing agents. The amount of acid produced during this phase is actually small in comparison to the other phases (Office of Surface Mining, 2002.) The acid production does not begin to increase until the propagation phase, where peak acid loads are being reached. The estimation of time to obtain the peak load has been modeled and predicted to occur within five to ten years after mining (Office of Surface Mining, 2002.) There seems to be a decrease in the acid production for the next twenty to forty years, but depletion of the acid leachate, or the termination phase, could take as long as fifty years or more (Office of Surface Mining, 2002.)
The alkaline reaction tends to have a more constant level of production with a slower rate. The alkaline reaction is usually surpassed by the acidic reactions due the acidic speed of production (Office of Surface Ming, 2002.) The reaction rates can be determined also by the mass of the acid and alkaline minerals. The following combinations between relative mineral compositions of rocks are reported by Office of Surface Mining (2002) as indicators of the type of mine drainage.

- Low pyrite, high base content → Drainage is alkaline with low concentrations of dissolved metals.
- High pyrite, low base content → Drainage is acid with high concentrations of dissolved metals.
- High pyrite, high base content → Drainage is usually alkaline, occasionally acid, with high concentrations of dissolved metals.

D. DISTINCTIVE SIGNS OF ACID MINE DRAINAGE

As shown by the AMD equations, many moles of acidity are being produced during the chemical reactions. The acidity causes a reduction in the pH levels in AMD water that usually measures on a pH scale around 2-3.5 or between 6-8. Levels of pH between 6 and 8 are in normal range for groundwater, and therefore pH should not be solely a parameter to detect AMD (EPA’s National Drinking Water Standard, 2002.) The low pH is one of the main detective characteristics when testing for AMD, but not the only. Another visual sign of AMD would be the orange-reddish tint of color that appears in the water.
The color change is a result of ferric hydroxide or “yellowboy” precipitating out of the water as it is being neutralized (Equation 1).

Another strong sign of AMD is the smell of “rotten eggs.” This “rotten egg” smell comes from the sulfur that has been extracted through oxidation from the pyrite and other high sulfur content rocks. These three signs are normally present in all AMD waters and usually indicate that further water testing is needed to determine the severity of the AMD.

E. STEAMS IMPACT FROM ACID MINE DRAINAGE

AMD is Pennsylvania’s largest non-point source pollutant of surface water (Rossman, et al., 1997.) Non-point source pollutant means that the pollution does not come from one defined area, but rather seeps from many sources over large areas. AMD can come from strip-mined areas where rainwater washes over the exposed area and flows into nearby streams, ponds, and lakes. Water used in long-wall mining or deep underground mining to keep the dust down runs through the porous rocks and enters the aquifers. Sealed mines can become mine pools as ground water fills the void. Groundwater continues to flow through the mine converting into AMD and further polluting the groundwater system. As the AMD reaches the streams, the contaminate water effects the ecosystem and stream equilibrium in place, which can significantly impact ecological health of the stream. For example, as the low pH groundwater enters a stream flow, the pH of the stream lowers too. As the pH continues to lower, less and less animal and plant life can survive in such acidic conditions. In many cases, a low pH can effectively kill all of the aquatic life in the stream.
The high metal concentrations of AMD affect the aquatic animal and plant life of the stream as well. Iron, manganese, and aluminum are the most common deposited metals that occur in high concentration in AMD impacted streams. Iron ferrous, an orange-red precipitate, known as “yellowboy,” (previously mentioned) deposits along the stream banks, at the bottoms of stream bed, and covers plant life (DEP, 2003.) The orange film on the plant life decrease the ability of sun light to reach it leaves which then decreases the ability for plants to photosynthesize and leads to plant death. Manganese may interfere with the plant growth by stunting the growth of the plant. This can cause plant death, as well as discoloration of the plant tissues. Aluminum may visually be seen in stream water as a white precipitate, known as gibbsite. Gibbsite can be very toxic to both plant life and humans. Precipitation of gibbsite around plants may prevent plant’s root development. Without root development, the plant can no longer absorb nutrients and water, which are the key ingredients for plant growth.

There are many other metal deposits that can be found in an AMD impaired stream, however, the three metals listed above are the most common. The devastating effects of these three metals, in conjunction with the lowered pH levels are very destructive. Not only for aquatic life but to humans who may consume water contaminated with AMD.

**F. EFFECTS OF AMD ON HUMAN HEALTH**

Geological process that impact human well-being is the focus of medical geology and is a relatively new discipline. Medical geology is a field of
environmental geology that focuses on geological hazards, such as acid mine
drainage, and tries to assess their impact on human health conditions. This is a
complicated area of study because it links different disciplines of science, such
as chemistry, biology, and geology. It is very complex because the nature of the
study is dealing with human health issues, where multiples causes can contribute
to a development of a single disease. For example, a person might have lung
cancer because he or she lived next to a steel mill or because he/she smoked
one pack of cigarettes a day for the last 25 years. These are two most likely
factors and the main contributor is hard to define. The environmental problems
that impact humans are vastly underestimated and under-researched. Even
though it has been established that environmental hazards may seriously impact
human health, all the causes and their long-term effects on humans requires
future research and collaboration between medical and natural sciences.

Just recently, the United States, Great Britain, and Canada have begun to
research the affects of AMD on human health problems (Biagioni, 2003.) All
three of these countries were and still are the leading mining countries of the
world. These same countries are all experiencing major negative environmental
impacts from AMD on stream, lake, and groundwater resources. As it was
discussed earlier, AMD pollution of streams and other fluvial water systems can
kill all aquatic life, both fauna and floral, and make the system inhabitable. It is
assumed that AMD polluted groundwater, if ingested by a person, could have a
damaging impact on the health of an individual. It is hypothesized that the hyper-
ingestion of an assemblage of AMD metals could lead to cases of cancer, Alzheimer’s, birth defects, etc.

G. CASE STUDY I – UNIVERSITY OF VICTORIA, BRITISH COLUMBIA, CANADA - THE PUBLIC HEALTH EFFECTS OF ABANDONED COAL MINE WORKINGS ON RESIDENTS IN SOUTH WELLINGTON, NANAIMO

Introduction

The impacts of AMD from abandoned coal mines on the human health were studied in South Wellington and Nanaimo, Canada (Biagioni, 2003.) The study area included two towns that had a history of coal mining, since 1968. The towns had separate water supplies. Nanaimo’s water supply was coming from the Nanaimo River and reservoir located behind the South Fork dam. Residents of South Wellington relied on groundwater supply from wells. Water quality was tested at both locations for metals, pH, and organic compounds. The wells in this area were drilled to the depth of 50 to 200 feet. Water quality analysis performed on the well water revealed the correlation between decreasing water quality and depth of the wells. Better water quality was determined in shallow wells, while bad water quality was recorded in the deep wells (Biagioni, 2003.)

Summary of Findings

Concentrations of iron and sulfur in the tester well located closer to South Wellington were exceeding the recommended drinking levels. Iron concentration was recorded at 6.79 mg/L, which is well above the recommended 0.3 mg/L by the Canadian health officials (Biagioni, 2003.) Sulfur content was measured to be 1.2 mg/L. This level also exceeds the advised .05 mg/L level (Biagioni, 2003.)
These high values correlate with the presence of AMD, therefore, other AMD metals such as aluminum, manganese, sulphate, decreased alkalinity, low pH, and other heavy metals are thought to be present also, but were not specifically tested for.

The ingestion of high levels of iron and sulfur has been related to high occurrence of diseases in the study area. Ingestion of large quantities of iron can develop into Haemochromatosis, a condition that occurs where regulatory mechanisms do not operate normally and effectively in the circulatory system. This can lead to tissue damage. Neoplasms, or malignant cancerous tumors, have also been linked to the overdose of iron. These neoplasms can occur anywhere in the body and are usually not predictable. Super-saturation of iron in the body causes absorption rates to increase; however, it can take up to twenty years for the body to fully ingest the iron. During that time, cancer develops and can be diagnosed, but trace elements of the iron could be completely absorbed, making it difficult to correlate between high concentration of iron and cancer.

High sulfur concentrations cause increased sulfate levels in the body. Sulfates are a combination of sulfur and oxygen that causes severe dehydration in humans. Elderly and infant populations are especially at a greater risk of dehydration caused by high content of sulfates in the body. High concentrations of sulfur in well water also lead to increased bacteria growth that result in the release of a toxic gas, hydrogen sulphide (Biagiono, 2003.) This gas, which protrudes from the well and water pipes can also cause health hazards. Hydrogen sulfide is a flammable and poisonous gas that primarily affects the
respiratory system. It paralyzes the enzyme which enable cells to utilize oxygen during energy metabolism. This causes a person to experience headaches, nausea, vomiting, epigastric (epiglottis, glottis, esophagus, stomach) pains, and irritation to mucous membranes (Biagiono, 2003.)

Although not tested in this study, it is hypothesized that high levels of aluminum could also be found at these testing sites. AMD usually results in the release of aluminum from local rock during the mineral leaching process. Severe health risks occur when drinking water has high levels of aluminum in combination with low levels of calcium and magnesium. This combination can result in having adverse effects on the human nervous system resulting in various dementia disorders. These disorders can be Alzheimer’s disease, Parkinson’s disease, and amyotrophic lateral sclerosis (Biagioni, 2003.)

**Conclusion**

Karla Biagioni (2003) after conducting research indicated that the main problem of the study was the lack of funding and proposed to increase future funding to support further investigation of AMD impact on human health. Although the impacts of AMD on the environment in South Wellington and Nanaimo could be visually seen and possibly related to increase of health problems within the community, the public did not feel that it was worth investing money into this (or future) research and is essence just wanted to ignore the environmental problems.
H. BIOCHEMISTRY AND ION FUNCTIONALITY

The way the ion affect the human body can be quite complicated. Each ion, metal or non-metal plays a different role in the body. This role is depicted by the characterization of the ion itself. Ions are tagged with roadmap like indicators that direct where the ion can go in the body, and to which organ it can attach itself to (Acu-cell Disorders, 2005.) For example, an ion might be tagged “left”, “right,” or “both” (Acu-cell Disorders, 2005.) This means that if an ion is tagged “left” it will travel to the left side of the body and be absorbed by an organ on that side of the body. If tagged “right” it will travel to the right side of the body. “Both” means that the ion has the ability to travel to any part of the body to be absorbed.

These tags also have indicators that allow for only certain organs to be able to absorb them into their systems. This process works very much like the antibody/virus mechanism that the immune system has the ability to achieve in the body (Acu-cell Disorders, 2005.) Viruses and antibodies have very unique shapes. Their shapes are actually classified in terms of a “lock” and “key” mechanism. This means that for every virus that can infect the body, there is a certain shape to that virus. Only one type of antibody can fit to that shape making it unable to infect, or cause sickness to the human. Therefore, for every lock (virus) there is a key (antivirus) (Acu-cell Disorders, 2005.) The combination of the two, after they are connected, can then be excreted from the body. Ions have the same kind of mechanism. They are shaped so that they can only be adsorbed by certain organs in the body. For instance, iron after being dissolved in the blood stream can be absorbed by the liver. Once the body has achieved a
super saturation state, the organ of absorption tries to compensate for the ion overload by producing more tissue cells in order to absorb the ions. This causes an overproduction of tissue cells, which continue to multiply uncontrollably, and result in cancer. Therefore, if a person ingests an overload of iron, which can be absorbed by their liver, they have a high rate of developing liver cancer (Acu-cell Disorders, 2005.)

Many ions do not just have one location where they can be absorbed. Using iron as an example again, not only can iron be absorbed by the liver, but it also can be absorbed by the stomach, esophagus, and breasts. Thus a person at a super saturation state of iron has a high risk of developing liver, stomach, esophageal or breast cancer depending on where the iron was absorbed the most in the body and at which location had the highest rate of speed of absorption. This is true for other ions like zinc, magnesium, sodium, chlorine, and chromium. Ions, such as copper, that have the ability to be absorbed anywhere in the body due to it being tagged to “both” sides is not predictable in the types of cancers it can form. This makes it a dangerous ion to ingest in large quantities due to its unpredictability making it hard to diagnosis and treat in terms of copper poisoning (Acu-Cell Disorders, 2005).

I. GEOLOGY OF THE STUDY AREA

i. BEDROCKS AND THEIR DEPOSITIONAL ENVIRONMENTS

The rocks that underlay the study area are sedimentary that are exposed along the stream banks and road cuts. These rocks are Pennsylvanian and Permian in age, and consist primarily of shale, sandstone, claystones, limestone,
coal, and siltstone of the Waynesburg, Uniontown and Pittsburgh Formations as shown in Figure 9. These rocks describe the paleogeographic environment that led to their deposition.
Figure 9. Stratigraphic column of Western Pennsylvania (Pittsburgh Geological Society, 2006)
During the Pennsylvanian time period, Pennsylvania was located 5-10 degrees south of the equator, (Scotese and others, 1979.) This equatorial location gave Pennsylvania a tropical climate, which was rainy, humid and conducive to plant growth during the early and middle Pennsylvanian (Camp, 1956.) During this time period, the North American plate was colliding with the African plate, beginning to form the soon to be “supercontinent” Pangaea (Monroe, 2000, Figure 10).

Figure 10. Origin of the Appalachian Orogen, a result of three separate continental collisions involving the North American Continent with the Taconic and Acadian terranes, and finally the collision of the African and North American
continents during the Alleghenian Orogeny at the end of the Paleozoic (Stofer, 2005).

The Acadian and Alleghenian orogenies formed what we now call the Appalachian Mountains and an elongated depositional basin that extended from northeast to southwest as depicted in Figure 11 (Edmunds et al, 2002.)

![Figure 10. Generalized paleogeographic map of the Pennsylvanian depositional basin and source areas (Modified from Edmunds, et al, 1979.)](image)

Sediments were eroding from all surrounding highlands of the north and southeast (Figure 11) and in a depositing geosynclinal trough and an epicontinental shelf (Figure 11). The basin that was formed, known as the Alleghenian Basin was filling with sedimentary sequences produced by series of
repeated transgression and regressions of the Epicontinental Sea to the west (Edmunds, et al., 2002.) These depositional cycles are known as the Pennsylvanian cyclothems (Monroe, 2000.) A cyclothem is a repeating pattern of rock strata that occurred in a specific order, on cyclic changes of depositional environments. The study area was located on the fringes of an epicontinental sea where different depositional environments including shallow coastal marine environments, marshes, alluvial plains, and delta plains. The following sediments were deposited adjusted to each other environment: mud and silt, peat, cross-bedded sands and micaceous muds. As sea level was changing these environments were shifting eastward during transgression or westward during regression of the Epicontinental Sea. As transgression-regression cycles repeated through time, the sedimentary sequences normally existing west to each other were stacking upon each other forming cyclotherms (Figure 12). These oscillations in sea level were caused by repeated expansion and contraction of Gondwanaland glaciers (Monroe, 2000.)
An ideal cyclothem, illustrated in Figure 12 and 14 usually occurs in areas of low relief that experienced repeated alterations of marine and non-marine environments, including non-marine deltaic, shallow-marine inter-deltaic and shelf environments (Monroe, 2000.)

Figure 13. The development of a transgressive sequence as sea level rises and the shoreline shifts inland. (Stanley, 2005)
Cyclothems usually consists of the following rocks: underclay, coal, shale, sandstone, and limestone, underclay, coal, and so on and so forth (Figure 13).

The cyclothems in the study area does not always possess the complete rock sequence, but rather layers are interbedded and individual sequences may not be distinctly defined. The cyclothems that do occur as this layering phenomenon were repeated over an extensive period of time and continued through early Permian time (Edmunds, 2002.)

The rocks of the Pennsylvanian and Permian systems are subdivided into the Conemaugh, Monongahela, and Dunkard groups (Figure 8) and include the Casselman, Pittsburgh, Uniontown, and Waynesburg formations, respectively. Figure 15 shows the geological groups and formations exposed at the surface within the study area.
Figure 15. Bedrock geology of the Pike Run Watershed area with the Pittsburgh Coal seam contour intervals (Horvath, 2006)

The Monongahela group has a wide exposure at the surface of the watershed region and includes the Pittsburgh and Uniontown formations. These formations consist of interlayered coal, limestone (interbedded with shale), shale, claystone, calcareous mudstone and sandstone that were deposited in low energy freshwater environments (Edmunds et al, 2002.) The Pittsburgh Formation is widely known due to its famous Pittsburgh Coal seam. This coal seam is usually continuous over the entire southwestern Pennsylvania, covering thousands of square miles. Its thickness can range from 5-10 ft thick and is the base of the Pittsburgh formation (Brady et al., 1998.) Although not as extensive as the Pittsburgh seam, the Redstone and Sewickley coal seams can also be found in
this formation (Figure 8). Paleodepositional environments in which these coal seams formed are shown in Figure 15. Paleoenvironmental reconstructions are very important in understanding the chemical composition of these coal seams and overburden rocks. For example, the swamp environments were planar which allowed the swamp to gain water from ground and surface sources (Brady et al., 1998.) The ground and surface water addition resulted in swamps with higher than normal pH (ranging from 4-7), more dissolved solids, and a greater nutrient supply as compared to fluvial systems (Cecil et al., 1985.)

Climate was also an important factor that left its signature on chemical composition of coals. During the late Pennsylvania time period, climate was more arid. Dry conditions would allow oxidized plant leaves to dry, in which produced coals with high sulfur content. Coals rich sulfur produce more ash when they are being burned (Cecil et al., 1985.) Dry conditions prevailed during formation of Pittsburgh Coal seam and many other coal seams found in the Monongahela Group (Brady et al., 1998.)
Figure 16. Paleogeographic reconstruction of the Pittsburgh sandstone and Redstone limestone (Donaldson and Shumaker, 1979)

Figure 17. Location, geometry and isopach map of a sandstone channel above the Pittsburgh coal in Greene and Washington Counties. (Modified from Donaldson, 1979)
Understanding the paleodepositional environments are not only important for the coal seam chemistry and composition, but all overburden rock as well. For instance, even though all the overburden was deposited in freshwater, the lithology, chemical component, and the thickness are different for each layer based on the depositional period. This can be shown through two different examples. First, is the Pittsburgh Sandstone that lies directly overtop the Pittsburgh Coal seam. As shown in Figures 16 and 17 a large fluvial system flowed north depositing a large body of sand whose thickness which reaches up to 80 ft and continues for several miles through what is now Washington and Greene counties (Edmunds et al., 2002.) The depositional environments were different to the east and west of the fluvial system which resulted in different rock formations. To the west of the sandstone, bedrocks are primarily composed of limestone and calcareous claystone and to the east the Pittsburgh sandstone changes into shale which contains thinly bedded sandstone (Edmunds et al., 2002.)

Secondly, the limestone units that are parts of the Pittsburgh and Uniontown formations have very different chemical compositions. The Benwood, Fishpot, and Redstone limestones are the thickest and most prevalent limestone in the Pittsburgh formation (Berryhill et al., 1971 and Egglestone, 1993, Figure 9). All of these limestones were deposited in very large freshwater lakes (Figure 16) but experienced different nutrient loads and environmental conditions which changes their petrology (Brady et al., 1998.) Eggleston (1993) studied the
Redstone limestone and concluded that it was deposited in a, “very shallow lake that was subject to periodic subaerial exposure during drier periods.” Berryhill et al, (1971) presented very similar findings for the Fishpot and Benwood limestones that are members of the Monongahela and Dunkard Groups, stating that the limestones were deposited in shallow freshwater lakes that, “probably never exceeded a few feet” of water depth. The slight environmental changes during their depositional periods changed chemical composition of limestone units that are summarized in Table 2.

Table 2. Chemical composition of limestones and dolomites from Pennsylvania (O’Neil, 1964 and Smith)

<table>
<thead>
<tr>
<th>Limestone Name</th>
<th>Geologic Period</th>
<th>Formation</th>
<th>County</th>
<th>CaCO3</th>
<th>MgCO3</th>
<th>SiO2</th>
<th>Al2O3</th>
<th>Fe2O3</th>
<th>Insol.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benwood</td>
<td>Upper Penn</td>
<td>Monongahela</td>
<td>Westmoreland</td>
<td>85.8</td>
<td>2.3</td>
<td>6.4</td>
<td>1</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Fishpot</td>
<td>Upper Penn</td>
<td>Monongahela</td>
<td>Somerset</td>
<td>67.7</td>
<td>12.3</td>
<td></td>
<td></td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td>Redstone</td>
<td>Upper Penn</td>
<td>Monongahela</td>
<td>Somerset</td>
<td>69.4</td>
<td>11.5</td>
<td></td>
<td></td>
<td>13.4</td>
<td></td>
</tr>
<tr>
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<td>Upper Penn</td>
<td>Monongahela</td>
<td>Somerset</td>
<td>86.6</td>
<td>6.2</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

The Dunkard Group is also present in the study area and is subdivided into the Waynesburg, Washington, and Greene Formation, which is comprised of interbedded sandstone, siltstone, claystone, shale, limestone, and coal (Figure 9). The Dunkard Group was deposited during the Pennsylvania-Permian transition and vary from freshwater high-energy to low-energy depositional environments (Edmunds, 2002.) This is demonstrated through the variety of thicknesses and the uncompleted cyclic layering of the rocks. These rocks layers are not continuous across the study area, and many of the rock units such
as the sandstones and shales, pinch out, changing into different rocks (Edmunds, 2002.)

The Waynesburg formation contains only one mineable coal seam, the Waynesburg Coal seam (Brady et al., 1998.) This coal seam has economical value because of its relative thickness and constant occurrence throughout the Dunkard Group compared to the other coal seams (Edmunds, 2002, Figure 8). The rock found above other coal seams in the Waynesburg formation consists of calcareous sandstone and shale that have high sulfur content that would produce severe cases of AMD if mined (Brady et al., 1998.)

There is also notably large sandstone unit, the Waynesburg sandstone that lies directly above the Waynesburg Coal seam (Figure 9). This sandstone is often calcareous in nature (Edmunds, 2002.) However, the mineralogy of this unit can vary based on locations. For example, in Greene County the Waynesburg sandstone contains 33% limestone however, the same sandstone only accounts for 6.2% limestone in Washington County (Berryhill et al, 1971.)

Within the study area, the Waynesburg formation is the highest unit of bedrock found (Figure 8). Therefore further investigation of the Dunkard Group is not needed.

ii. AQUIFERS OF THE STUDY AREA

Water that falls onto the land from precipitation either evaporates back to the atmosphere, runs over the ground making its way to streams, or it infiltrates through the soil to pores and fractures (Newport, 1973.) The water that infiltrates the soil continues to move downward until it reaches a saturations
zone, which is an area that is interconnected voids that are filled with water. These interconnected voids, known as aquifers, are what supply the springs and well of the study area.

The permeability of the rock units for which the water can travel through are primary and secondary in nature. Primary porosity consists of spaces that exist between the grains of the sedimentary rocks. The size of the grain found in the rocks effects the amount of water that can pass through it. Rocks such as shale, dense limestone and firmly cemented sandstone have little interconnected pore space and allow less water permeability (Newport, 1973.) The secondary openings are fractures that occur in the rocks from stresses applied to the units. These stresses could be from mountain building periods or from mining that occurs below the rock formations (Newport, 1973.) Water can easily move through these fracture openings making them great for permeability.

Aquifers in the study area primarily are located in the Monongahela and Dunkard Groups (Newport, 1973.) As previously stated, the rocks in these groups consist of limestone, shale, sandstone, and claystone. The two rock classifications for which aquifers are found in these groups are the limestones and sandstones (Newport, 1973 and Peffer, 1991.) The porosity and permeability in the limestone is the result of enlarged fractures. These fractures were mostly produced from the mining of the Pittsburgh Coal seam (Newport, 1973.) The permeability of the sandstone ranges greatly within this group due to the different grain sizes and the amount of cementing material that holds the sand together (Newport, 1973.)
As was mentioned previously, mining can affect the transport of water due to the fractures it produces, and due to the mine void that was created after the coal was mined. Callaghan et al., stated, “Over large areas of the Appalachian Plateau extensive underground mining has taken place leaving, as a remnant, substantial man-made aquifers (mine-void and subsidence-fracture zones) which can have a profound influence on groundwater.” These underground aquifers can affect the groundwater on a large scale basis due to their ability to act like a sink, drawing water towards it and changing the flow regime both physically and chemically (Callaghan, et al, 1998.) Mine pools can act as either above-drainage or below-drainage mines (Donovan, et al., 2003.) If the mine is an above-drainage mine, the mine often remains dry long after closure of the mine has occurred. This dryness exposes the pyrite minerals (residues from mining) to oxygen allowing for the discharge of acidic water for long periods of time (Chen et al., 1999.) These types of mines have water that flow through them, carrying and transporting the AMD. Below-drainage mines fill up to partially, or in most cases, completely (Burke and Younger, 2000.) These times of mines lack the oxygen needed to produce AMD. These two types of mine voids greatly affect the types of chemistry that may be found in mined areas.

The fractures that occur in overburden from mining affects the chemistry of the water as well as water transport. If dolomite or calcite is present in overburden rock as far as 30 meters away, the production of alkaline waters would result (Donovan et al., 2003.) Fractures that result from mining can affect the overburden rock as far up as 50 meters, allowing for all of these different rock
units, based on the locale of the area, to interact with the aquifer. Therefore in summary, the mining created a void that attracts water towards the area. The mining also caused fractures, which allow groundwater to move with greater ease to these void regions. Once the mine fills to a certain extent it can discharge AMD water either above or below the mine. This AMD water can then react with overburden rock nearly 30-50 meters above it changing its hydrologic chemistry.

iii. GROUNDWATER GEOCHEMISTRY

Based on the paleodepositional environments, the paleoclimatic conditions, and the stratigraphy that was discussed, a prediction of the water chemistry produced from aquifer that lie within the lithological units can be predicted. The high sulfur content of the coal seams within the study area, as well as the sulfur content of the overburden rock, contain pyrite that causes AMD to occur after the coal seams were mined (Brady et al., 1998.) This is the important starting process of the chemistry that occurs within the study area, but is not the key reactions. Based on the knowledge that the rock structures of the area contain large structures of limestones, the key reaction series is the alkaline reaction series. Once the acidic waters are produced from the oxidation of iron disulfides (pyrite) they dissolve the limestone structures that the acidic water comes in contact with allowing for the release of the limestone’s ionic composition. The mineralogy of limestones in the study area varies from calcite ($\text{CaCO}_3$), dolomite ($\text{CaMg(CO}_3\text{)}_2$), and siderite ($\text{FeCO}_3$). Siderite was described within this area but not fully researched (Berryhill et al., 1971.) Reaction with
carbonate ion would allow for the acidic water from the mining to be buffered, neutralizing the acidity produced by the first reaction. However, the reaction of neutralization does not stop once the acidity is buffered and results in production of alkalinity which is known as neutral or alkaline mine drainage (NAMD) (Rose, et al., 1998.) Alkaline mine drainage is high in sulfate, manganese, magnesium, and calcium, and usually removes iron and aluminum from water that was previously produced by AMD (Rose et al., 1998.) The neutral AMD reaction series begins with the reaction between calcite or dolomite with acidic waters produced from AMD. The products often react with calcium ion and carbonic acid (Rose et al., 1998.)

$$\text{CaCO}_3 + 2\text{H}^+ = \text{Ca}^{2+} + \text{H}_2\text{CO}_3(aq) \quad (8)$$

The carbonic acid, in favorable conditions will decompose to produce carbon dioxide and water.

$$\text{H}_2\text{CO}_3(aq) = \text{CO}_2(g) + \text{H}_2\text{O}(l) \quad (9)$$

If the pH value of the water is greater than 6.3, further neutralization occurs and results in the production of bicarbonate ions.

$$\text{CaCO}_3 + \text{H}^+ = \text{Ca}^{2+} + \text{HCO}_3^- \quad (10)$$

Silicate minerals found in limestones can also be dissolved releasing ions such as potassium, sodium, aluminum, magnesium, calcium, and sometimes iron into alkaline waters. Examples of these reactions are presented below (DEP, 1998.)

Potassium Feldspar:

$$2\text{KAISi}_3\text{O}_8 + 2\text{H}^+ + \text{H}_2\text{O} = 2\text{K}^+ + \text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 + 4 \text{ SiO}_2 \quad (11)$$
Kaolinite:

\[ \text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 + 6\text{H}^+ = 3\text{Al}^{3+} + 2\text{SiO}_2 + 5\text{H}_2\text{O} \]  

Chlorite:

\[ \text{Mg}_2\text{A}_2\text{SiO}_5(\text{OH})_4 + 4\text{H}^+ + \text{SiO}_2 = 2\text{Mg}^{2+} + \text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 + 2\text{H}_2\text{O} \]  

Based on mineralogy of aquifers and chemical reaction series described above the chemistry of the water at each formation can be made.

The water chemistry found at the Waynesburg and Pittsburgh Formations will be high in alkalinity, sulfate, and metals (Newport, 1973, Brady et al., 1998.)

The water chemistry at the Uniontown formation will be high in alkalinity, but low in metals and sulfate (Newport, 1973, Brady et al., 1998.) Prediction of water chemistry based on stratigraphy and mineralogy of local aquifers are very useful in the further evaluation of water quality and determination of stage and degree of AMD pollution with in the watershed.

J. History of Mining in the Study Area

The towns within the study area have very similar history related to mining operations that began more than two centuries ago. The coal, a natural fossil fuel, brought in mining companies into the area. Towns grew around the mining operations and are very apparent in the names of the local towns. The town of Ellsworth was named after John W. Ellsworth owner of Ellsworth Coal Company (Connors, P., 1998.) The nearby town of Cokeburg inquired this name because of coke that was produced there and supplied the Ellsworth Coal and Collieries Company (Connors, P., 1998.) Coal Center, a town found right at the side of the Monongahela River, comes from being at the center of the coal mines in the
area, and had one of the first commercial mines here in Washington County. These towns are just a few that apparently show how important and influential the coal industry was. Two other larger towns also have strong ties to coal mining (Connors, P., 1998). California and Pike Run Township both have the same original owner of Robert Jackman, who bought 304 acres of land off of Samuel Young in 1784, after he may or may have not taken it from the Native Americans (still disputed (Connors, P., 1998)).

California's ties to coal began after a tragedy occurred. California once had a boat yard that was destroyed 1881 due to a fire. It never opened again and since this was the major source of revenue for California the town started to decline afterwards. Just when the town was thought to be doomed, Solomon Sibbitt, a resident, took a small boat and drove it up Pike Run (Creek) and filled it with coal he mined from the hillside. During flood stage, he floated the boat to the Monongahela River to Cincinnati where he sold the nearly 4000 bushels of coal he mined (Hornbake, N., 1949.) This publicized California and Pike Run's rich coal seam and soon coal companies began to spring up, thus saving California, Pike Run, and many other nearby towns. The first coal mining company in the township was Stoney Hill. Other mines including Cedar Hill, Coal Center, Mimford Coal Company, The Monongahela River Consolidated Coal & Coke Company, J&L and Vesta Coal Company opened later (Hornbake, N., 1949).

These coaling companies are very important to our existence here today. First off, without them these towns would not be in existence, and with them,
these towns might be suffering from environmental impacts coal mining left for years after the operation closed. The Figure 18 below illustrates the extent of underground mining in the area. The grey depicts the mined out areas.

![Figure 18](image)

Figure 18. Geographical areas that have been undermined. (PA DEP, 2005)

At the same time as mining was going on underneath the land, farming was going on above ground. The land in this area is perfect for dairy farming and crop growing, mainly for corn, straw, and other cattle crops. Dairy farms were found in many areas all over the Pike Run Watershed and are still very active today. Referring to Figure 18, the northeastern part of the map is in white showing that this area has not been undermined. It just so happens that the owner of this land was the great-grandfather to the author. The owners of this
land were the Ballas’s, and Zippay Road, shown on the map, was named after the maiden name of Mrs. Balas. The owners of the land also owned the mineral rights, and therefore the land was not mined, but was a 200+ acre dairy farm (Levy, S, 2005). This undoubtedly shows that there were two large occupations in the area, farming and mining.

The history of the area is very important in understanding the overall environmental condition of the area. This is especially true in the study area, where agriculture and coal mining were two of the staples that allowed for the towns within the watershed to survive. Both of these industries are also associated with leaving detrimental environmental affects like water pollution. It must not be forgotten though, that without these industries, there would be no towns to worry about whether or not they are environmentally altered.
CHAPTER II

METHODS

A. SAMPLING COLLECTION

Selection of sample sites was done by acquiring volunteers within the study area through newspaper advertisements, phone calls, letters, and word of mouth. Twenty-seven residents of West Pike Run Township agreed to have their water analyzed and to complete surveys. A total of two surveys were distributed among the participants of the study. The first survey dealt with the health history of the household member. All personal information that was gathered from this survey is and will remain confidential. The second survey was used to collect all possible information, well water depth, etc. Once the participants were selected, each was assigned a location identification number that consisted of the watershed initials, the sub-watershed initials, and a reference number so that no volunteer names would be used for confidentiality purposes. After the completion of assigning ID’s, the first collection date was July 16th, 2005. On the collection date, two teams divided the locations and conducted the same sampling procedures at each household. The procedures consisted of the following: For well water samples the water was collected at the kitchen sink if the household had no system install in the well, or at an outside faucet before water was going through the treatment process. For spring samples, the water
was collected directly from the water bearing rock before it entered any home. In many cases, there was a hose installed into the hillside where the spring was located, by the local residents who use the water. For both the well and spring sampling, the water was run for 3-5 minutes before it was collected in 2-500mL polyethylene terephthalate (plastic) bottles, labeled, sealed, and stored in coolers until further stabilization could be performed in the lab (APAH, 1998.) Water was also collected in a 500mL beaker and for temperature (Celcius) and pH. The pH was measured using handheld Oakton Testrs. Both the pH and temperature instruments were calibrated in the lab before the sampling date. During sample the presence of any water odor (i.e. rotten egg smell) or discoloration to the sinks or appliances were documented. The well/spring water survey was given to the residents of the home for them to complete while the water samples were being collected (Appendix 1). Upon completion water samples were taken to the lab. 70% nitric acid was added to each sample until a pH level reach a value of 2, that stabilized any metals in the sample. (This usually required 1mL of nitric acid.) All samples were stored at 4°C until further analysis (APAH, 1998).

The second collection date was set for November 5, 2005. Selected residents were notified by letter of this date. Water collection procedures were repeated in the same manner as collection 1, with two exceptions. The first exception being that instead of a well/spring survey to complete, volunteers completed an Institutional Review Board approved health survey (Appendix 1). Based on the results of the first round of water sampling, five sites were selected for detailed water quality tests performed at the analytical facility at Heidelberg
College, Ohio. These five sites give a comprehensive water quality snapshot for the whole watershed. At these five locations addition water was collected, stabilized, and refrigerated as previously described to be analyzed by Heidelberg College’s Water Quality Laboratory for the following parameters: nitrate, nitrite, ammonia, chloride, sulfate, soluble phosphorus, silica, specific conductivity, fluoride, aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, potassium, selenium, silica, nickel, sodium, strontium, vanadium, and zinc. The samples were kept in refrigerated foam coolers and delivered to the water quality lab overnight. Results received by the lab were compared to the EPA’s National Drinking Water Standards and stored in the database. All other data collected at the sampling sites, such as pH, temperature, water odors, or stains were also recorded.

On October 9, 2005, Jay Winter, a license geologist for the Department of Environmental Protection Agency, sampled water from four springs located in the study area. He collected the samples as described above and sent them to the DEP’s Bureau of Laboratories for chemical analysis. He forwarded these results to the researcher upon hearing that this study was being conducted. He also took the researcher to these spring sites so that they could be added last collection sites for further analysis.

The third sampling occurred on February 12, 2006, and selected residents were notified by mail. One team went for collection on this date. Water samples were collected following the same procedure as before. One sample collected was stabilized immediately with 1mL of 70% nitric acid, tested to ensure the pH
was 2 or less and immediately refrigerated at 4°C (Stewart, 2006.) The non-stabilized samples placed in the refrigeration immediately after collection (Stewart, 2006.) The following parameters were analyzed and recorded in the field: pH, temperature, water odor, and discoloration. The samples were kept refrigerated overnight and driven the next morning to Morgantown, WV to the National Research Center for Coal and Energy where they were analyzed at their analytical laboratory for hot acidity, alkalinity, aluminum, sulfate, manganese, iron, calcium, magnesium, and conductivity. Results were entered into a database.

On February 12, 2006, a mid-ranged Geographic Positioning Systems (GPS) unit by Garmin was used to georeference each collection site. The data was entered into ArcView 9.1 and used to create geographical information systems (GIS) maps.

B. GEOLOGICAL DATA

Stratigraphic data was collected along roadside outcrops within in the study area. Once an outcrop was discovered, GPS coordinates including the site elevation was recorded. Sedimentary rock strata were then identified, described, measured, and referenced to the *Generalized Geologic Columnar Section Bituminous Coal Measures* stratigraphic column created by Robbins (2000) for the Bureau of Abandoned Mine Reclamation (BAMR) to established stratigraphic framework.

A core log obtained from the Pennsylvania Turnpike Commission. The core was used for stratigraphic correlation between units observed in the
outcrops and units documented in other studies (Robbins, 2000.) The core was drilled to a depth of 320ft near Vesta, PA (Heirendt, 2006.) All geological data was compiled into a local stratigraphic column (Figure _). Once the column was developed, the stratigraphic position of each unit was established and a rock strata calculator was created to determine the elevation of rock strata associated with the well and spring sampled during the study.

The rock strata calculator was a tool created using Microsoft Excel that included the height of each rock strata in a reference to the local stratigraphic column was created. Stratigraphic position of Pittsburgh coal seam was used as a reference point to establish the elevation of the surface bedrock. This was done by locating the sample point on the USGS geological topographic map and determining the elevation of the Pittsburgh coal seam. The coal seam elevation was then entered into the rock calculator. This elevation was then added to the heights of the rock strata that lay above the coal seam until the surface elevation was established. At this point, the rock stratum that was highlighted in the excel program at the surface elevation value was the surface rock. Using the above calculations, the well depth (obtained from the residents’ well/spring survey completed during field sampling) was subtracted from the strata heights and the rock unit that was highlighted by Excel was the aquifer that supplied well or spring. The rock layers positioned between the surface and the aquifer were recorded and a stratigraphic column for each sampling site was developed. Once stratigraphic columns for each well/spring site were created, they were correlated to determine the hydrologic units that supply the Pike Run Watershed.
region. RockWorks software was used to visualize stratigraphy of the study area, to perform correlations, and to create fence diagrams.

C. **Health Data**

Incidence rates of cancer for the communities of Coal Center, Daisytown, California, and West Pike Run Township, which are all encompassed by the watershed, were obtained from the Pennsylvania State Department of Health's database. The data was grouped year by year according to specific cancer types for the years from 1995 until 2003. No data before 1995 and after 2003 was available to the general public. For example, every case of cancer that was diagnosed for the community of Coal Center during the year of 1995 was recorded. Once all the data was gathered, incidence rates for each type of cancer for each year were summarized to calculate an overall incidence rate for an eight year time period. Each specific cancer type was then plotted to obtain the top five cancers diagnosed in the watershed region.

The incidence rates of cancer within the watershed were compared to the national incidence rates for the year 2000. This was done by dividing the incidence rates of the whole area by the total population of the area and multiplied by 100000 to obtain the percent incidence rate. This methodology was adapted after the Center of Disease Control's National Program of Cancer Registries (U.S. Cancer Statistics Working Group, 2002.) The rates of cancer were plotted and analyzed.

Results of statistical analysis were compared to the information gathered from the health surveys completed by residents of the West Pike Run Township.
who had their water analyzed. Results of comparisons were used to identify geographical trends in developing “hot spots” of certain diseases in the study area.
CHAPTER III

RESULTS AND ANALYSIS

A. CHEMISTRY

The results from the July 16th sampling date are presented in Table 3. pH values at all sampling sites meet the EPA’s National Drinking Water Standards being between 6 and 8 (EPA’s Office of Water, 2003) except for one location (PR-GR-01b) where pH value was measuring to be 8.7. This site was retested during the next two sampling dates. Foul rotten egg odor coming from water was documented at two houses, but only one had orange stains in their sink (Table 3).
### Location ID

<table>
<thead>
<tr>
<th>Location ID</th>
<th>Temperature [°C]</th>
<th>pH</th>
<th>Odor (Rotten Egg)</th>
<th>Orange Stains</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-WPR-01a</td>
<td>13</td>
<td>7.2</td>
<td>No</td>
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</tr>
<tr>
<td>PR-WPR-01b</td>
<td>21</td>
<td>7</td>
<td>Yes (Strong)</td>
<td>No</td>
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<td>7.4</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-GR-01a</td>
<td>12</td>
<td>7</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-GR-01b</td>
<td>43</td>
<td>8.7</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-LPR-03</td>
<td>15</td>
<td>6.6</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-GR-02</td>
<td>16</td>
<td>7.6</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-LPR-04</td>
<td>12</td>
<td>7</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-WPR-04</td>
<td>23</td>
<td>6.8</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-WPR-06</td>
<td>23</td>
<td>6.9</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-LPR-06</td>
<td>22</td>
<td>7.5</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-WPR-07</td>
<td>22</td>
<td>7.5</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-WPR-08</td>
<td>18</td>
<td>7.2</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-LPR-07</td>
<td>25</td>
<td>6.9</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-WPR-05</td>
<td>22</td>
<td>6.9</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-WPR-09</td>
<td>23</td>
<td>7.7</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PR-WPR-10</td>
<td>19</td>
<td>6.8</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 3. Water quality parameters recorded on July 16th, 2005.

Results from November 5, 2005 collection date are summarized in Table 4. Four more sampling sites were added to survey after the first collection date (Highlighted in Table 4 in red.) These residents volunteered to have their water sampled after being referred to collection teams by residents who participated in the first round of sampling. Site, PR-WPR-11, water was not sampled on November 5, because the owners of the property could not be reached. Upon analyzing the well and spring water surveys that were filled out by residents during the first collection date, and interviewing the homeowners during the second round of testing, three locations, being PR-WPR-04, PR-LPR-05, and PR-LPR-07, had to be excluded from the study. (Highlighted in blue in Table 4.) Residents at PR-WPR-04 and PR-LPR-05 sites used a public water source and
at PR-LPR-07 rainwater that is being collected and stored in a cistern to be used for domestic needs. These three locations would have compromised the outcome of the study, and hence were removed from further analysis.

All but four of the pH measurements meet the healthy ingestible water standards set by the EPA. Four samples did not fall into the acceptable drinking water category having pH that measured at 5.9, 5.95, 8.1, and 9.2 levels (highlighted in yellow in Table 4). Three samples, PR-GR-01c, PR-WPR-07, and PR-LPR-07, were extremely close to the range with one, PR-WPR-11 being extremely alkaline. This site was added to the study during the second round of sampling. Seasonal variability is thought to be affecting the pH’s, and these differences were noted and were examined during the last sampling date. Sample PR-GR-01b had a pH that was higher than the standard during the first collection but dropped to 7.8 for this collection, returning it back into the acceptable range. A “rotten egg” smell was documented at PR-WPR-01a and PR-LPR-06 (Table 4). PR-WPR-01a had this odor documented at the previous collection, but at PR-LPR-06 site the smell was newly noted. White spots and black color water were recorded for the first time.
<table>
<thead>
<tr>
<th>Location ID</th>
<th>Temp C</th>
<th>pH</th>
<th>Collected From</th>
<th>Presence of Odor, Discoloration, and other Comments.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-WPR-01a</td>
<td>18</td>
<td>6.7</td>
<td>Kitchen sink</td>
<td>Rotten Egg Smell</td>
</tr>
<tr>
<td>PR-WPR-01b</td>
<td>16</td>
<td>7.4</td>
<td>Spring</td>
<td>N</td>
</tr>
<tr>
<td>PR-WPR-02</td>
<td>18</td>
<td>7.1</td>
<td>Kitchen sink</td>
<td>N</td>
</tr>
<tr>
<td>PR-WPR-03</td>
<td>15</td>
<td>6.5</td>
<td>Outside Spigot</td>
<td>N</td>
</tr>
<tr>
<td>PR-LPR-08</td>
<td>18</td>
<td>6.3</td>
<td>Kitchen sink</td>
<td>N</td>
</tr>
<tr>
<td>PR-LPR-02a</td>
<td>15</td>
<td>6.6</td>
<td>Kitchen sink</td>
<td>N</td>
</tr>
<tr>
<td>PR-LPR-02b</td>
<td>18</td>
<td>6.3</td>
<td>Well</td>
<td>N</td>
</tr>
<tr>
<td>PR-GR-01c</td>
<td>14</td>
<td>5.9</td>
<td>Kitchen sink</td>
<td>N</td>
</tr>
<tr>
<td>PR-GR-01b</td>
<td>11</td>
<td>7.8</td>
<td>Kitchen sink</td>
<td>N</td>
</tr>
<tr>
<td>PR-GR-02</td>
<td>15</td>
<td>7.7</td>
<td>Spring</td>
<td>N</td>
</tr>
<tr>
<td>PR-LPR-04</td>
<td>16</td>
<td>6.9</td>
<td>Spring</td>
<td>N</td>
</tr>
<tr>
<td>PR-WPR-04</td>
<td>14</td>
<td>6.1</td>
<td>Kitchen sink</td>
<td>City Water</td>
</tr>
<tr>
<td>PR-LPR-05</td>
<td>13</td>
<td>6.2</td>
<td>Kitchen sink</td>
<td>City Water</td>
</tr>
<tr>
<td>PR-LPR-06</td>
<td>19</td>
<td>8.1</td>
<td>Kitchen sink</td>
<td>Rotten Egg Smell</td>
</tr>
<tr>
<td>PR-WPR-07</td>
<td>13</td>
<td>5.95</td>
<td>Kitchen sink</td>
<td>N</td>
</tr>
<tr>
<td>PR-WPR-08</td>
<td>13</td>
<td>6.5</td>
<td>Spring</td>
<td>N</td>
</tr>
<tr>
<td>PR-LPR-07</td>
<td>12</td>
<td>7.2</td>
<td>Cistern</td>
<td>Rain Water Collection</td>
</tr>
<tr>
<td>PR-WPR-09</td>
<td>14</td>
<td>7</td>
<td>Kitchen sink</td>
<td>White Spots</td>
</tr>
<tr>
<td>PR-WPR-10</td>
<td>18</td>
<td>6.8</td>
<td>Spring</td>
<td>N</td>
</tr>
<tr>
<td>PR-LPR-09</td>
<td>17</td>
<td>7.3</td>
<td>Kitchen sink</td>
<td>N</td>
</tr>
<tr>
<td>PR-WPR-11</td>
<td>16</td>
<td>9.2</td>
<td>Outside spring</td>
<td>Black water</td>
</tr>
</tbody>
</table>

Table 4. Water quality parameters recorded on November 5th, 2005.

Five samples collected in the field, PR-LPR-08, PR-WPR-02, PR-WPR-01b, PR-GR-01b, PR-GR-01A, were sent to Heidelberg College’s Water Quality Laboratory in Tiffin, Ohio for further analysis. The results of lab analysis are presented in concentrations of the following ions in mg/L and ppb: nitrate, nitrite, ammonia, chloride, sulfate, soluble phosphorus, silica, specific conductivity, fluoride, aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, potassium, selenium, silica, nickel, sodium, strontium, vanadium, and zinc found in Table 5. The samples were higher than normal: iron, manganese, copper, sodium, calcium and hardness.
Total dissolved solids were also higher than normal. At PR-GR-01b site, an unusually high amount of copper (2261.00 ppb) was measured. The owner was of the house where the sample was collected from contacted immediately and informed about the problem. It appeared that the house had old copper plumbing, which would explain the high concentrations of ions in their water supply.

The ions from this analysis that were higher than recommended standards are all associated with AMD pollution, which then allowed this study to primarily focus on AMD analysis.
<table>
<thead>
<tr>
<th></th>
<th>Standard for Drinking Water (EPA)</th>
<th>PR-LPR-08</th>
<th>PR-WPR-02</th>
<th>PR-WPR-01B</th>
<th>PR-GR-01B</th>
<th>PR-GR-01A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate (mg/L)</td>
<td>10.00</td>
<td>0.1</td>
<td>1.80</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Nitrite (mg/L)</td>
<td>1.00</td>
<td>0.0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>ammonia (mg/L)</td>
<td>30.00</td>
<td>0.0</td>
<td>0.03</td>
<td>0.38</td>
<td>0.20</td>
<td>0.00</td>
</tr>
<tr>
<td>sulfate (mg/L)</td>
<td>250.00</td>
<td>59.0</td>
<td>71.00</td>
<td>66.00</td>
<td>1.00</td>
<td>99.0</td>
</tr>
<tr>
<td>chloride (mg/L)</td>
<td>250.00</td>
<td>136.0</td>
<td>20.00</td>
<td>91.00</td>
<td>76.00</td>
<td>9.00</td>
</tr>
<tr>
<td>conductivity (mg/L)</td>
<td>not regulated</td>
<td>645.0</td>
<td>598.00</td>
<td>825.00</td>
<td>1047.00</td>
<td>742.0</td>
</tr>
<tr>
<td>Total Dissolved Solids (mg/L)</td>
<td><strong>500.00</strong></td>
<td>323.0</td>
<td>299.00</td>
<td>413.00</td>
<td>524.00</td>
<td>371.0</td>
</tr>
<tr>
<td>Fluoride (mg/L)</td>
<td>2.00</td>
<td>1.1</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td>1.00</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>silica (mg/L)</td>
<td>not regulated</td>
<td>15.5</td>
<td>10.80</td>
<td>13.70</td>
<td>8.00</td>
<td>7.60</td>
</tr>
<tr>
<td>phosphorus (mg/L)</td>
<td>not regulated</td>
<td>0.0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Arsenic (ppb)</td>
<td>10.00</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Antimony (ppb)</td>
<td>6.00</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Barium (ppb)</td>
<td>2000.00</td>
<td>86.0</td>
<td>95.00</td>
<td>101.00</td>
<td>131.00</td>
<td>57</td>
</tr>
<tr>
<td>Beryllium (ppb)</td>
<td>4.00</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cadmium (ppb)</td>
<td>5.00</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Chromium (ppb)</td>
<td>100.00</td>
<td>&lt;1</td>
<td>1.90</td>
<td>1.50</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Lead (ppb)</td>
<td>15.00</td>
<td>1.9</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>10.90</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Selenium (ppb)</td>
<td>50.00</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>2.3</td>
</tr>
<tr>
<td>Iron (mg/L)</td>
<td>0.30</td>
<td>2.4</td>
<td>0.26</td>
<td>1.68</td>
<td>0.41</td>
<td>0.13</td>
</tr>
<tr>
<td>Manganese (mg/L)</td>
<td>0.05</td>
<td>0.6</td>
<td>0.01</td>
<td>0.43</td>
<td>&lt;0.01</td>
<td>ND</td>
</tr>
<tr>
<td>Aluminum (ppb)</td>
<td>200.00</td>
<td>6.4</td>
<td>99.80</td>
<td>&lt;0.2</td>
<td>54.90</td>
<td>14.5</td>
</tr>
<tr>
<td>Copper (ppb)</td>
<td>1000.00</td>
<td>48.0</td>
<td>57.00</td>
<td>2.00</td>
<td>2261.00</td>
<td>4</td>
</tr>
<tr>
<td>Silver (ppb)</td>
<td>100.00</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Zinc (ppb)</td>
<td>5000.00</td>
<td>31.0</td>
<td>14.00</td>
<td>&lt;2</td>
<td>30.00</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Nickel (ppb)</td>
<td>100.00</td>
<td>4.0</td>
<td>&lt;2</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>1.0</td>
</tr>
<tr>
<td>Stontium (mg/L)</td>
<td>4.00</td>
<td>0.5</td>
<td>&lt;0.1</td>
<td>1.03</td>
<td>&lt;0.1</td>
<td>1.94</td>
</tr>
<tr>
<td>Sodium (mg/L)</td>
<td>20.00</td>
<td>44.8</td>
<td>10.20</td>
<td>42.50</td>
<td>210.20</td>
<td>51.8</td>
</tr>
<tr>
<td>Calcium (mg/L)</td>
<td>not regulated</td>
<td>42.5</td>
<td>79.70</td>
<td>79.90</td>
<td>2.00</td>
<td>61.5</td>
</tr>
<tr>
<td>Cobalt (mg/L)</td>
<td>not regulated</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>magnesium (mg/L)</td>
<td>not regulated</td>
<td>13.7</td>
<td>17.30</td>
<td>23.00</td>
<td>&lt;1</td>
<td>39.6</td>
</tr>
<tr>
<td>Potassium (mg/L)</td>
<td>not regulated</td>
<td>&lt;2</td>
<td>20.10</td>
<td>25.60</td>
<td>&lt;2</td>
<td>40.5</td>
</tr>
<tr>
<td>Vanadium (mg/L)</td>
<td>not regulated</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Hardness (mg/L)</td>
<td>not regulated</td>
<td>162.5</td>
<td>270.40</td>
<td>294.10</td>
<td>8.10</td>
<td>316.8</td>
</tr>
</tbody>
</table>

Table 5. Water chemistry results reported by Heidelberg College’s Water Quality Laboratory.
Several springs in the study area were tested on October 9, 2006. Spring samples were collected by a DEP employee, Jay Winter, and sent for analysis by the DEP’s Bureau of Laboratories. The results from the chemical analysis are presented in Table 6. The results indicate high concentrations of sulfate, calcium, sodium, and higher hardness of the water. (highlighted in yellow in Table 6.)

<table>
<thead>
<tr>
<th>Parameter (mg/L)</th>
<th>Standards for Drinking Water (EPA)</th>
<th>SP-Granville</th>
<th>SP-Vesta</th>
<th>SP-Wooded Area</th>
<th>SP-springdr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>0.3</td>
<td>0.069</td>
<td>&lt;0.02</td>
<td>&lt;0.02</td>
<td>0.187</td>
</tr>
<tr>
<td>Alkalinity</td>
<td>not regulated</td>
<td>217.8</td>
<td>328.8</td>
<td>260.8</td>
<td>172.4</td>
</tr>
<tr>
<td>Sulfate</td>
<td>250</td>
<td>313</td>
<td>318</td>
<td>309</td>
<td>114</td>
</tr>
<tr>
<td>Total Residue</td>
<td>not regulated</td>
<td>760</td>
<td>882</td>
<td>860</td>
<td>412</td>
</tr>
<tr>
<td>Nitrite N</td>
<td>1</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Calcium</td>
<td>not regulated</td>
<td>86.9</td>
<td>98.4</td>
<td>110</td>
<td>77.8</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.1</td>
<td>&lt;0.004</td>
<td>&lt;0.004</td>
<td>&lt;0.004</td>
<td>&lt;0.004</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>not regulated</td>
<td>1.6</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>5.61</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.002</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Acidity</td>
<td>not regulated</td>
<td>-180.8</td>
<td>-257.4</td>
<td>-214</td>
<td>-154</td>
</tr>
<tr>
<td>Sodium</td>
<td>20</td>
<td>68.4</td>
<td>138</td>
<td>63.1</td>
<td>11.2</td>
</tr>
<tr>
<td>Aluminum</td>
<td>0.2</td>
<td>&lt;0.2</td>
<td>&lt;0.2</td>
<td>&lt;0.2</td>
<td>&lt;0.2</td>
</tr>
<tr>
<td>pH</td>
<td>8</td>
<td>7</td>
<td>7.6</td>
<td>7.8</td>
<td>7.9</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.05</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.005</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Lead</td>
<td>0.015</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nitrate</td>
<td>10</td>
<td>0.05</td>
<td>0.08</td>
<td>0.1</td>
<td>0.38</td>
</tr>
<tr>
<td>Barium</td>
<td>2</td>
<td>0.02</td>
<td>0.023</td>
<td>0.027</td>
<td>0.043</td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.01</td>
<td>&lt;0.004</td>
<td>&lt;0.004</td>
<td>&lt;0.004</td>
<td>&lt;0.004</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>500</td>
<td>2</td>
<td>&lt;2</td>
<td>&lt;2</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Magnesium</td>
<td>not regulated</td>
<td>34.5</td>
<td>32</td>
<td>47.35</td>
<td>17.3</td>
</tr>
<tr>
<td>Hardness</td>
<td>not regulated</td>
<td>359</td>
<td>378</td>
<td>470</td>
<td>266</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.05</td>
<td>&lt;0.007</td>
<td>&lt;0.007</td>
<td>&lt;0.007</td>
<td>&lt;0.007</td>
</tr>
</tbody>
</table>

Table 6. Spring results of water analysis conducted in collaboration with the PA’s Department of Environmental Protection (Winter, 2005)
Table 7 and 8 present results of the water chemistry analysis sampled on February 12, 2006. Seven spring sites were added to the sampling locations, which were the Crescent, Vesta, wooded area, G-3, gas-well, Crescent-3, and Gorby-2 springs named by the researcher based on their location in the study area. Nine samples collected in the July 16th sampling were not collected on the February 12th. Two samples were eliminated from the study after it was determined that water samples PR-LPR-01 and PR-LPR-02a were supplied by the same spring. It was decided by the water collection team to eliminate sample PR-LPR-01 to eradicate redundancy. The same was done for samples PR-WPR-08 and PR-WPR-09 due to the same reason. Therefore, sample PR-WPR-08 was eliminated. The remaining seven samples, PR-LPR-02b, PR-GR-01a, PR-LPR-05, PR-LPR-07, PR-WPR-09, PR-WPR-10, and PR-WPR-11 could not be collected due to the absence of the homeowners.

The pH value of the twenty-one samples that were collected only three were below the 6 and 8 range recommended (EPA, 2002.) The pH values of these samples were 5.9, 5.8, and 5.3. The pH values lower than 6-8 (recommended by EPA) were documented only in three samples out of twenty-one during the February 12th collection. Figure 18 shows pH levels recorded at the source sites at different dates. It appears that pH values were higher in July and November compare to value measured in February at most sites except for two. All of the pH’s measured throughout the sampling period decreased with each date (Figure 19). This would correlate to the decrease in temperature that was experienced throughout the testing period (Figure 20). The pH’s throughout
the study did respond to the changes in the temperature as can be seen in Figure 21.

<table>
<thead>
<tr>
<th>Location ID</th>
<th>Temp C</th>
<th>pH</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-WPR -01a</td>
<td>10</td>
<td>6.3</td>
<td>Rotten Egg Smell</td>
</tr>
<tr>
<td>PR-WPR-01b</td>
<td>9.4</td>
<td>5.9</td>
<td>Rotten Egg Smell</td>
</tr>
<tr>
<td>PR-WPR-02</td>
<td>6.7</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>PR-WPR-03</td>
<td>13</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>PR-LPR-08</td>
<td>25</td>
<td>6</td>
<td>Rotten Egg Smell</td>
</tr>
<tr>
<td>PR-LPR-01</td>
<td>5</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>PR-GR-01c</td>
<td>14</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>PR-GR-01b</td>
<td>30</td>
<td>7.4</td>
<td></td>
</tr>
<tr>
<td>PR-LPR-03</td>
<td>20</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>PR-GR-02</td>
<td>9</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>PR-LPR-04</td>
<td>11</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>PR-LPR-06</td>
<td>18</td>
<td>7.2</td>
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<td>PR-WPR-07</td>
<td>15</td>
<td>6.9</td>
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<tr>
<td>PR-LPR-09</td>
<td>15</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>SP-Cresen</td>
<td>10</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>SP-Vesta</td>
<td>11</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>SP-Wooded</td>
<td>9</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>G-3</td>
<td>5</td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>Gas-well spring</td>
<td>9</td>
<td>5.3</td>
<td></td>
</tr>
<tr>
<td>Cresent-3</td>
<td>9</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>Groby-2</td>
<td>10</td>
<td>6.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 7. Temperature and pH measurements from February 12, 2006 collection
Figure 19. pH levels recorded at ten sites sampled in July, November, and February

Figure 20. Temperature recorded at ten sites at different collection dates.
Figure 21. Correlation between temperature and pH throughout.

Twenty-one samples collected on February 12, 2006, were sent to the National Research Center for Coal and Energy to be tested for AMD. AMD includes the following parameters: concentrations of bicarbonate alkalinity, hot acidity, conductivity, sulfate, iron, aluminum, calcium, manganese, and magnesium. The results from the testing are plotted and presented in Figures 22-29. The graphs depict the concentrations (mg/L) for each sample as well as the EPA standard for each ion if the ion tested has an established standard.
Figure 22. Concentrations of iron detected on February 12, 2006 compared to EPA Standards.

Figure 23. Concentrations of aluminum February 12, 2006 collection compared to the EPA standard.
Figure 24. Concentration of sulfate from the February 12, 2006 compared to the EPA standard.

Figure 25. Concentrations of bicarbonate alkalinity, February 12, 2006 collection.
Figure 26. Concentration of calcium, February 12, 2006 collection date.

Figure 27. Conductivity levels from the February 12, 2006 collection.
Figure 28. Concentration of manganese, February 12, 2006 compared to EPA standards.

Figure 29. Concentration of magnesium, February 12, 2006 collection.
The spring water samples were analyzed at two analytical facilities, DEP and the National Research Center for Coal and Energy (NRCCE) laboratory. Even though two different laboratories were used which could affect the consistency of the results, it was assumed that results reported by both laboratories should be comparable (See Figures 30-33). The comparison could be carried out if the same parameters were analyzed from samples collected on different dates. For example, no iron concentrations were measured for samples collected in February. Therefore, no comparison of iron concentrations could be done.

![Figure 30. Concentration of sulfate in spring water reported by the DEP and NRCCE.](image-url)
Figure 31. Concentration of magnesium in spring water reported by the DEP and NRCCE.

Figure 32. Concentration of calcium in spring water reported by the DEP and NRCCE.
Figure 33. Concentration of alkalinity in spring water reported by the DEP and NRCCE.

B. GEOLOGY

Three outcrops along the road cuts were visited and rock units were described in terms of lithology and measured. The location of these outcrops, Elco, Daisytown, and the rock quarry, along with the location of the PA Turnpike core that was obtained can be found in Figure 34. From the measured lithology, a stratigraphic column was produced in RockWorks for each outcrop and for the core sample (Figures 35-40). Figure 35 is the generalized column for the Elco outcrop. The Elco outcrop lies just outside of the study area, but can be used as a reference due to its proximity. This road cuts begins in the Waynesburg Formation and ends in the Pittsburgh Formation.
Figure 34. Locations of the Outcrops and the PA Turnpike core sample in the study area.
Figure 35. Lithological description of the Elco outcrop.
The Daisytown outcrop included the Pittsburgh Coal seam and the overburden rock units that make up the Pittsburgh Formation (Figures 37 and 38).
Figure 37. Lithological description of the Daisytown outcrop.
The last outcrop, the rock quarry outcrop, had only one rock unit visible which was a medium to fine grain sandstone that measure eight feet thick. After obtaining the surface elevation and GPS coordinates, the rock unit was identified as the Sewickley Sandstone. This was done by locating this coordinate position on a USGS Geological Map California Quadrangle, determining the coal elevation at this point from the coal contour lines, and then correlating this information to the stratigraphic column (Figure 9). Figure 39 shows the Sewickley Sandstone unit.
A mentioned previously, a core sample log was obtained from the PA Turnpike Commission. The data gathered from this log was inputted into RockWorks to get a graphical representation (Figure 40).
A local stratigraphic column was produced for the area after correlations were made between road outcrops, the core log sample (Appendix 3), and the generalized stratigraphic column for Southwestern PA (Figure 9). The local column was then used by the researcher to create the “rock calculator” that assisted in the determination of the hydrologic units. For each well and spring.
that was sampled, a surface elevation was obtained, the well depth, as well as
the Pittsburgh Coal seam elevation from an USGS Geological Map. The
elevation of the coal was the starting point and the thickness of each of the
described overburden rock units from the local column was added until the
surface elevation was reached. The rock unit that was found at the surface
elevation became the new starting point, to then subtract the rock thickness from
the local column again for the depth of the well. This was the hydrologic unit.
(Table 8 shows an example of how the rock calculator was used to determine the
hydrologic units of a sampled well.) The hydrologic units for the wells of the
study are were determined to be Waynesburg sandstone, the Uniontown shale to
shaly sandstone, the Benwood limestone, the Connellsville sandstone, and the
Pittsburgh Coal seam (Figure 41). Table 9 shows each of the sample wells in
their determined hydrologic unit.

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Stratigraphic Units</th>
<th>Hydrologic Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>Upper Members of Waynesburg Fm</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Waynesburg Sandstone</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Little Waynesburg Coal</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Waynesburg Limestone</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Uniontown Shale to Shaly Sandstone</td>
<td>Aquifer</td>
</tr>
<tr>
<td>2</td>
<td>Uniontown Coal</td>
<td>Aquitard</td>
</tr>
<tr>
<td>12</td>
<td>Uniontown Limestone</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Shale or shaly sandstone</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>Benwood Limestone</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Sewickly Coal</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Pittsburgh Sandstone</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Fishpot Limestone</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Shale or shaly sandstone</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Redstone Coalbed</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Redstone Limestone</td>
<td></td>
</tr>
<tr>
<td>930</td>
<td>Pittsburgh Coal Seam</td>
<td></td>
</tr>
</tbody>
</table>

Table 8. Rock Strata Calculator Example.

<table>
<thead>
<tr>
<th>Well Site Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Depth: 85</td>
</tr>
<tr>
<td>Coal Elevation: 930</td>
</tr>
<tr>
<td>Surface Elevation: 1274</td>
</tr>
</tbody>
</table>
| **Waynesburgh Sandstone** | PR-WPR -01a  
PR-WPR-01b  
PR-LPR-01 |
|---------------------------|--------------------------------------------------|
| **Uniontown Sandstone**   | PR-WPR-02  
PR-LPR-08  
PR-LPR-04 |
| **Benwood Limestone**     | PR-WPR-07  
PR-WPR-10  
PR-LPR-09 |
| **Pittsburgh Coal Seam**  | PR-GR-01c  
SP-Cresent Mine  
PR-GR-02  
SP-Gorby 2  
SP-Vesta Mine  
SP-Wooded Area |
| **Connellsville Sandstone** | PR-WPR-03  
PR-GR-01b  
PR-LPR-06 |

Table 9. Wells and springs sampled under their determined hydrologic unit.
C. **HEALTH SURVEYS RESULTS**

The voluntary surveys completed by the homeowners were used to collect additional information about the wells and springs tested during the study, to learn about homeowners’ awareness about coal mining impact of their water resources and evaluate overall health or issues within the study area.

The following three questions were the focus of our interest: What do you use this water supply for? Do you believe that the area under your home was mined? And have you ever had your water tested before? The summary of responses are presenting in Figures 41-44.
Figure 42. Graph displaying the percentages water use from domestic wells and springs.
Results of the health survey revealed the incidence of different cancer within the township. Table 9 shows the cancer types and how many cases were diagnosed in an eight year time span. Although this information was valuable, due to the small number of surveys completed, a true representation of the total population of the residents of the study area was not obtained. Therefore, cancer incidence rates were obtained from the Pennsylvania State Health Department Vital Statistics.

D. CANCER INCIDENCE RATES

Cancer incidence rates for 2000 were collected for the communities that fall in the watershed region (Figure 45). These communities were West Pike Run Township, Coal Center, Daisytown, and California. The information
obtained from the Pennsylvania State Health Department was compared to the National incidence rates, which was gathered from the Center for Disease Control's National Cancer Registry for the year 2000. Figure 46 shows all of the cancers that were diagnosed in 2000 and Figure 47 compares the study area incidence rates against the national average. The study area was higher than the national average for lung, lymphoma, multiple myeloma, leukemia, stomach, pancreas, colon and rectum, esophagus, cervix, kidney, larynx, and testis.

Figure 45. Municipalities within the watershed region.
Figure 46. Cancer incidence rates for the study area in 2000

Figure 47. Comparison of the incidence rates between national and study area.
Incidence rates were gathered over an eight year period, from 1995 until 2003. Figure 48 shows the results of the data gathering.

Figure 48. Incidence rates for the study area over an eight year time period.
CHAPTER IV

DISCUSSION

A. GEOLOGY AND CHEMISTRY

The aquifer locations of the study area were determined to be the Waynesburg sandstone, the Uniontown shale to shaly sandstone, the Benwood limestone, the Connellsville sandstone, and the Pittsburgh Coal seam. These findings lead to the initial conclusion that the mining has disturbed the aquifers up to the Uniontown Coal seam, but has not disturbed aquifers that lie above this point (Figure 9). As stated by Newport (1973) and Peffer (1991) the aquifers in the Monongahela and Dunkard Groups, which contain all the rock units listed as aquifers, should lie in sandstone and limestone regions, primarily. Above the Uniontown Coal seam, the aquifers do lie within these units, being the Waynesburg sandstone and the Uniontown shale to shaly sandstone. Below this point, the aquifers change to the Benwood limestone and the Pittsburgh Coal seam.

Newport (1973) stated the limestones in the Washington County regions have become aquifers due to the mining in the area creating large fractures. The Benwood limestone lies between 50 to 75 meters above the Pittsburgh coal seam, which does fall into the area affected by mining activities published by Hobba (1981). Hobba stated that mining affected overburden rock as far as
approximately 75 meters above the coal seam creating large fractured areas whose width is much greater than normal fractures created by bending and folding. These large fractures that now occur in the Benwood limestone allows for water to move freely, creating an aquifer system. A high yield of water (enough that can be used by residents without ever drying up) flows freely to the surface for the use of the public, and downward, to supply the mine void with water.

A man-made aquifer has resulted in the Pittsburgh Coal seam void. Where the Pittsburgh Coal elevation is at its highest point, this void is the aquifer that now supplies the residents of the community with their water for wells and springs (Figure 41). The mine void in this study area is an underground void that never fully fills with water, allowing for oxygen to easily react with the water and pyrite to continuously produce AMD (Chen et al., 1999.) Since the coal elevation sits close to the surface elevation in two areas of the watershed, being the Northeast (1025 ft) and Southwest (875 ft) (Figure 41), it allows for the natural flow of the groundwater to run through the mine void, create AMD, and then transport the AMD discharge. This in turns contaminates nearly the entire watershed region. This is evident in the areas where the arising of many springs where coal seam is above the valley has occurred. The water from this void can also easily transport through the cracks and fractures created by mine subsidence, polluting the overburden rock as well.

Three well samples were obtained from the Connellsville sandstone unit that is found in the Casselman formation of the Conemaugh Group (Figure 8.)
This formation lies underneath the Pittsburgh Coal seam and is only exposed in
the study areas in low elevation areas. It is not thought that mining has disturbed
the aquifers below the Pittsburgh Coal seam, since the aquifer again lies within
the sandstone region.

The chemistry results from this study does emphasize the impacts of
underground mining. Iron, manganese, sodium, and calcium are ions associated
with acid mine drainage. Hardness is not a diagnostic parameter of AMD, but
due to its very high value it is a sign of high amounts of minerals, including
dissolved calcium. High concentrations of calcium indicate that acidic water is
dissolving limestone releasing Ca $^{2+}$ into the water.

High alkalinity values are documented in eighteen of the sites (Figure 25).
This is due to the existence of limestone as an overburden that can be found
consistently through the study region reacting with the AMD water. Donovan et
al (2003) noted a significant alkaline output in regions where limestone laid
approximately 30 meters above the mine void, which fits the geology of this study
region.

The chemistry also verifies the displacement of the aquifers that was
found, and emphasizes the disturbed aquifer/undisturbed aquifer line that was
placed at the Uniontown coal seam as was mentioned previously. The chemistry
of the water obtained from the aquifers above the Uniontown coal seam was high
in alkalinity, calcium, magnesium, iron, and aluminum (Figure 22-29 and Figure
41). This is very characteristic of these rock units who naturally contain these
ions (Newport, 1973 and Brady et al., 1998.) However, the chemistry from the
water that came from the Benwood limestone aquifer was also high in metals, such as aluminum and iron, as well as in alkalinity, calcium, and magnesium.

The Benwood limestone should produce water that is high in alkalinity, but low in metal concentrations. This is due to the fact that the limestone serves as a buffer lowering the pH values and allowing for the metal ions, like iron and aluminum, to precipitate out. However, their presence in the water, at this aquifer suggests that the water is transport from the mine void (pooled area), through the crack and fractures within the limestone unit. Groundwater reacts with the Benwood limestone when it is in contact with it, and then continuing to flow into the well locations that are supplying the residents. The reduction of the concentration of the metal ions, compared to the Uniontown and Waynesburg sandstone, does demonstrate that the limestone or alkaline buffering reactions are occurring in this aquifer to some extent. An analysis of water over a longer time period would help in better understanding of local water chemistry and in predicting the overall impact the limestone has on the AMD.

The water from the Pittsburgh Coal seam was high in alkalinity, metals including iron, aluminum, manganese, calcium, and magnesium, as well as being high in sulfate at two locations. These results indicate that acidic waters are being produced from reactions with oxygen and pyrite, and being buffered by the limestone found in the overburden (Donovan et al., 2003) raising the pH values and producing alkaline mine drainage. Only two samples were high in sulfate, which was different from the samples collected from the DEP, where three of the four samples were high in sulfate (Table 6). It is thought that this is due to
seasonal variations. Seasonal variations are a natural phenomenon that occurs in groundwater (Nelson, 2002.) The best way to determine if seasonal variability is a factor effecting the groundwater chemistry is to test the water throughout each of the four seasons (Nelson, 2002.)

B. **Springs and Health Data**

It is a common practice in mining operation to insert pipes into the entrance of mines to prevent mines from flooding, and allowing the workers to continue to mine. They left these pipes in place after all mining activities were over to allow the mine to drain. Over time, the residents of the community forgot that mining occurred in these areas and mistaken the pipes coming from the mine voids as natural springs. The residents just thought that the home-owner near the area, or just some nice neighbors placed a pipe into a natural spring to make for an easier water collection. Looking at mine maps, and locating so-called “natural springs” on the mining maps led us to the discovery that what resident believe are “natural springs” are actually the old mining pipes that the mining companies placed into the mine shafts. Therefore, many residents are collecting their water directly from the mine pool. This is true for every spring that was tested in this study (Figures 21 and 22). At each location, the researcher had to wait to gather a water sample due to the number of residents collecting water for their household use, which is just an example of how many people use this water.
Figure 48. Pipe coming from the Pittsburgh Coal Seam

Figure 49. Pipes coming from the Pittsburgh coal seam leading right to people's homes.
Results of the water chemistry analysis show that these residents are drinking water that contains concentrations of metal that are more than the EPA’s Drinking Water Standards. AMD has been proven harmful to the environment including streams and lakes in many studies. This study however demonstrates this same water is being ingested by the residents of this community as a palatable water source. It can not be such a far stretch to connect this polluted water source to negative health effects.

The study area does have a higher incidence rate in lung, colon and rectum, lymphoma, stomach, pancreas, esophagus, and multiple myeloma than the national averages. Although these cancer incidence rates can not be directly tied to the water that is ingested by residents of the study area, it can assumed that area is being impacted by something that is causing higher than normal cancer rates. Also, all of the cancers that are higher than the national averages are either tied to the digestive tract or are related to the blood/lymphoma systems. This suggests that high concentrations of iron and manganese in the water consumed by residents could be the cause of cancers developed in digestive and blood/lymphoma system, as the water obviously is in the most contact with such organs.
CHAPTER V

CONCLUSION

There are four points of conclusion that can be drawn from this study.

1. AMD is a non-point source pollutant to the groundwater of Pike Run Watershed.
2. People are using this water as the primary water source, ingesting higher than recommended standards of ions.
3. Chemistry of the water is directly related to the stratigraphy of the area.
4. Mining activities have changed the natural confined aquifers of the area.

These four statements are just the initial findings from this research. What has been uncovered is that mining causes a complicated network of environmental and health problems, where many more questions need to be asked and researched in the future to gain a better understanding of AMD impact on the environment and humans.

Suggested further research would include using RockWorks to get a graphical visualization of the lithology and interpretive stratigraphy of the area. Study how many mines in the area are flooded vs collapsed. Researching the time scale and weathering capacity of the “pillars” left in mined areas. Collecting
and analyzing water samples for one year period at least to get a better understanding of how water chemistry changes due to seasonal variability. Use of aerial photographs is recommended to see changes in landscape have occurred due to mine subsidence. These areas of study would help in predicting a time span for how much longer AMD will be effective in the study area.

Acid mine drainage is a major environmental problem that needs to be addressed. Although the majority of the scientific community is studying the impacts of AMD on the natural ecosystems of streams, rivers, creeks, and lakes, not much is understood yet on how it may or may not have on humans themselves. This area of study is quite important, not just for ethical reasons, but also for financial. Every year, more and more people are dying from cancer, heart disease, and other diseases at staggering rates. And although many of these conditions are genetic or self-inflicted, some are not. Health care costs are on the rise as many other human services, costing patients more and more money every year. The cost of placing a filter on impaired water from wells is costs much less than the bills for treatment that come when one are diagnosed with cancer. This is just economics of the problem, not even mentioning the physical and emotional costs as.

AMD might have nothing to do with diseases, but this should be proved by detailed research. But since then, the connection between AMD and its deadly effect on the aquatic life in the stream has long been established. We could assume that it is bad for humans as well. The further research is an obligation we owe to the community and future generations. As children we learn that if
you make a mess you need to clean it up. Yet, for some reasons as we reach adulthood and the messes get bigger, there is less and less cleaning up occurring.
REFERENCES


Vargo, Robert, A. The Pike Run Watershed Association. 1/21/05, from [http://workforce.cup.edu/vargo/PRWA_Data.htm](http://workforce.cup.edu/vargo/PRWA_Data.htm)
APPENDIX A
West Pike Run Watershed Well and Spring Testing Program
Participant Information Sheet

Name:

__________________________________________________________________________
First     Middle Initial     Last

Address:

____________________________________________________________________________
Street Address

____________________________________________________________________________
City, State Zip Code

1. Have you had this water source tested before? Yes □ No □

2. Type of Water Supply: Well □ Spring □

3. If your water supply is a well, answer as many of the following questions as accurately as possible:

A. Type of Well (Check One): Drilled □ Dug □ Driven (sand point) □

B. Well Depth: ___________ ft

C. Depth to Bedrock, if known: ___________ ft

D. Year well was installed: ______________

E. Well casing (check one):

Extends above ground □ is level with ground □ is in a well pit □

No casing present □ below ground □ pitless adapter □
F. Has your well ever gone dry?  Yes ☐  No ☐

F. Well log number if known (state number or license):
__________________

4. Use and treatment of the water supply (Check Below):

A. This sample represents water used for (check all that applies):
   Drinking Water ☐  Livestock ☐  Irrigation ☐  Bathing ☐  Laundry ☐  Other:
   ______

B. Has the water sample received any home water treatment?  Yes ☐  No ☐

If yes, what type of treatment is used (check all that apply to the sample taken)?
   Distillation ☐  Carbon Filtration ☐  Ion Exchange ☐  Softening ☐  Aeration ☐  Chlorination ☐  Sediment Filter ☐  Iron Removal ☐  Other:
   __________

5. Potential Sources of Drinking Water Contamination

Please Check One Box for Every Source Listed Below

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<td>of your well</td>
<td>your property</td>
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</tr>
</tbody>
</table>

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<th>NOT</th>
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<tr>
<td>Animal Feedlot or Barnyard</td>
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</tr>
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<td>Chemical Lawn Treatment</td>
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<td>Septic Tank and Leach Field</td>
<td>☐</td>
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<td>Solid Waste Landfill</td>
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<tr>
<td>Hazardous Waste Site</td>
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<tr>
<td>River or Stream</td>
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<tr>
<td>Underground fuel storage tank</td>
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<tr>
<td>Mine Subsidence</td>
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<tr>
<td>Entrance to Mining Shaft</td>
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<tr>
<td>Old Strip Mine</td>
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</tbody>
</table>
6. As far as you are aware, is the property of which this water sample is taken been mined for coal in the past (either strip, long-wall, or underground mining):
   Yes □   No □

If yes, what kind of mining and how long ago if known:
______________________________

7. Please provide the following information:
   a. Location of faucet used for sample (ex. Kitchen sink):
   ____________________________

   b. Do you store, fill, or mix pesticides and/or fertilizer solutions near your well? Yes □   No □

   c. How would you describe the soil around your water system?
      Permeable (sandy) □   In Between □   Impermeable (clay) □
      Don’t Know □

8. Have you ever used nearby spring water to supply your household with drinking water? Yes □   No □
If yes, what spring did you use and for how long (location of spring, years or months used):
_________________________________________________________________________________
________________________

9. Do you give us permission to take pictures of the sampling site? Yes □   No □

Thank you for participating in this survey and in the well/spring water-testing program. The results will be confidential. Only data will be used for the research with no names of participants attached to any of the documents.
This is a voluntary survey, to be used in conjunction with the well and spring water-testing program that is being conducted. The answers in this survey are anonymous and will only be used in terms of statistical data. The answers to these questions will be related to the results of the water samples analyzed in this study. The two will be correlated to see if there is a connection to health problems and water quality. Lisa Horvath, a graduate student at California University of PA and her advisor Dr. Nikitina will be solely responsible for the handling of these surveys which will be stored in Geology Lab under lock and key, until they are destroyed after the thesis project has ended. There is no risk in volunteering to fill out this survey, and the completion and the return of this survey will indicate that there is consent to use this data. Approved by the California University of Pennsylvania Institutional Review Board.

Water ID Numbers: _______________________Well
                         _______________________Spring

1. How long have you lived at this residence?  -
   ________________________________

2. If you recently moved here, did you live in the same township before? Yes ☐ No ☐

3. What is the current number of people that live in this household?
   ____________

4. Have you or anyone who has ever lived in the household been diagnosed with cancer?
   Yes ☐ No ☐
a. What form
_____________________________________________________

b. How long ago?
_____________________________________________________

c. How long did treatments last?
_____________________________________________________

d. Did death result? Yes □ No □

e. At what age did the diagnosis occur?
_____________________________________________________

5. Male or Female? ______________________________

6. Have you or anyone in your household been diagnosed with Alzheimer's disease?
   Yes □ No □

   a. How long ago? _________________
   b. At what age? _________________

7. Have you or anyone in your household been diagnosed with Parkinson's disease?
   Yes □ No □

   a. How long ago? _________________
   b. At what age? _________________

8. Do you or anyone in your household have gastrointestinal problems? Yes □ No □

9. If Yes, please describe:
_____________________________________________________
_____________________________________________________
_____________________________________________________

10. Do you smoke? Yes □ No □

11. Have you smoked in the past? Yes □ No □

12. If yes, for how long? (ex. Years)
_____________________________________________________

13. Do you or anyone in your family suffer from heart disease? Yes □ No □
14. At what age?
___________________________________________________________

15. Do you have a history of cancer in your family? Yes □ No □

16. If yes, what form of cancer is there a history of?
___________________________________________________________

17. If you were diagnosed with cancer, was it the same kind as your family history?
   Yes □ No □

18. Have you or anyone in your family ever complained that the water “tasted-funny”?
   Yes □ No □
   a. If yes, what did it taste or smell like?
      ____________________________________________

19. Have your household ever experienced problems from appliances, dishes, or tubs turning orange in color?
   Yes □ No □

20. Have you or anyone in your family ever experienced Kidney disease?
    Yes □ No □
    a. If yes, at what age?
       ____________________________________________
    b. What kinds of Kidney disease was it?
       ____________________________________________
    c. Was it cured?
       ____________________________________________

21. Have you or anyone in your family every experienced Liver Disease?
    Yes □ No □
    a. If yes, at what age?
       ____________________________________________
    b. What kinds of Liver disease was it?
       ____________________________________________
    c. Was it cured?
       ____________________________________________
22. Is there any other health problems not listed in this survey that you or someone in your household has been diagnosed or suffered with?

_________________________________________________________________
_________________________________________________________________
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_________________________________________________________________

Thank you for completing this survey. Your time and cooperation is very much appreciated! If you have any questions or concerns, please contact Lisa Horvath at 724-612-4298 or by email at hor2589@cup.edu.
APPENDIX C
Appendix D

1/24/2006

Dear Volunteer,

I send this letter with apologies that it took so long to get it out to you. The delay does come with some exciting news for the water testing program conducted by the Pike Run Watershed Association and California University of PA. A grant was received that was able to allow for five random samples that were collected during the last collection date to be sent for analysis at the Heidelberg Water Quality Laboratory. The samples were analyzed through numerous tests that looked for possible pollutants. Each of them was high at least one or all of the following: iron, magnesium, potassium, calcium, sodium, and/or sulfate. The presence of these ions in the water does show that there indeed is acid mine drainage polluting at least part of the groundwater. These findings allowed for the application of another grant, which was recently awarded to us that will pay for everyone’s water sample to be sent to the National Research Center for Coal and Energy, which will analyze each sample for acid mine drainage pollution. This is a nationally known laboratory facility and their testing procedures and protocols will allow for us to determine if acid mine drainage is polluting the whole watershed in West Pike Run.

The pollutants found can be a health risk factor. For example, this can be true if a resident is on a low sodium diet and their water is higher than the national standard for the intake of sodium. It is recommended that if your water sample is found to contain any levels of ions higher that the EPA’s National Drinking Water Standard, which will be provided in the last results letter, that a family physician is contacted with any questions or concerns. If your water sample was selected at random during the last sampling to be analyzed, the results will be discussed and given to you at the next collection date. Also, the results for the bacteria testing that were conducted will also be given to you at the next collection date. If the next collection date does not work out for any given reason, the results will be mailed to you.

With this stated, the last collection date is being set for Sunday, February 12th. If this date is not good for you, please contact Lisa Horvath at hor2589@cup.edu or by phone at 724-612-4298. I will be happy to work around your schedule.

Again, I apologize for the lateness of this letter. I have learned the hard way that sometimes the scientific method along with the grant application process can be a slow and painfully long procedure. Please know that I appreciate your patience and participation in the program.

Sincerely,

Lisa Horvath
Department of Earth Science
Master Student
Project Director’s Certification
Program Involving HUMAN SUBJECTS

The proposed investigation involves the use of human subjects and I am submitting the complete application form and project description to the Institutional Review Board for Research Involving Human Subjects.

I understand that Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects. If the Board grants approval of this application, I agree to:

1. Abide by any conditions or changes in the project required by the Board.
2. Report to the Board any change in the research plan that affects the method of using human subjects before such change is instituted.
3. Report to the Board any problems that arise in connection with the use of human subjects.
4. Seek advice of the Board whenever I believe such advice is necessary or would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board in its effort to provide a continuing review after investigations have been initiated.

I have reviewed the Federal and State regulations concerning the use of human subjects in research and training programs and the guidelines. I agree to abide by the regulations and guidelines aforementioned and will adhere to policies and procedures described in my application. I understand that changes to the research must be approved by the IRB before they are implemented.

Professional Research

| Project Director’s Signature | Department Chairperson’s Signature |

Student or Class Research

| Student Researcher’s Signature | Supervising Faculty Member’s Signature if required | Department Chairperson’s Signature |

ACTION OF REVIEW BOARD (IRB use only)

The Institutional Review Board for Research Involving Human Subjects has reviewed this application to ascertain whether or not the proposed project:

1. provides adequate safeguards of the rights and welfare of human subjects involved in the investigations;
2. uses appropriate methods to obtain informed, written consent;
3. indicates that the potential benefits of the investigation substantially outweigh the risk involved.
4. provides adequate debriefing of human participants.
5. provides adequate follow-up services to participants who may have incurred physical, mental, or emotional harm.

Approved [ ] Disapproved [ ]

Chairperson, Institutional Review Board

[Signature]

Date

Approved, September 12, 2005