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A Water Quality and Contaminant Source Assessment of Arbuckle Creek in Fayette County, West Virginia

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A WATER QUALITY AND CONTAMINANT SOURCE ASSESSMENT OF ARBUCKLE CREEK IN FAYETTE COUNTY, WEST VIRGINIA

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Master of Science
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by
Sarah Ashby Simonton
Approved by
Dr. D. Scott Simonton, Committee Chairperson
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Dr. Autumn Starcher

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APPROVAL OF THESIS

We, the faculty supervising the work of Sarah Ashby Simonton, affirm that the thesis, *A Water Quality and Contaminant Source Assessment of Arbuckle Creek in Fayette County, West Virginia,* meets the high academic standards for original scholarship and creative work established by the Master of Science in Environmental Science and the College of Engineering and Computer Sciences. This work also conforms to the editorial standards of our discipline and the Graduate College of Marshall University. With our signatures, we approve the manuscript for publication.

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ABSTRACT

Arbuckle Creek, located in Minden, West Virginia, is a stream that runs through Oak Hill, WV and is characterized by the presence of the Oak Hill Wastewater Treatment Plant and the history of the contamination of polychlorinated biphenyl (PCBs) from the copious amount of contamination from the Shaffer Equipment Site and the pollution from mining completed in the area throughout the 1900's. In order to assess the reaches of the current water quality, samples were collected and assessed for benthic macroinvertebrates, water parameters, benthic algae, and habitat. This was accomplished using the West Virginia Department of Environmental Protection (WVDEP) agency's Stream Condition Index to conduct two separate surveys at three different sites to analyze each aspect pertaining to the water quality. This was also accomplished through assessing water quality data obtained through the United States Environmental Protection Agency (USEPA) and other agencies. In summation, it was found that all of the West Virginia Stream Condition Index (WVSCI) scores were under 60, indicative of a stream with poor health conditions. So, while the USEPA water quality data is indicative of impairment, the benthic macroinvertebrate surveys performed confirms it. In terms of water parameters, the temperature and dissolved oxygen levels increased between the sampling of Round One in May 2021 and Round Two in September 2021, while the conductivity and pH lowered slightly between the two sampling sets. Regarding the benthic algae, there were multiple shifts between the populations of diatoms, green algae, and cyanobacteria. The habitat clearly indicates the stream has been impacted by the historic mining that has taken place, as well as the damage done by the Shaffer Equipment Site. Overall, the contamination from mining and the leaching from the Shaffer Equipment Site appears to have data supporting the negative implications on Arbuckle Creek and its inhabitants.

CHAPTER 1

Introduction

A Brief History

Tucked away within the mountains of Appalachia, southeast of the city of Charleston, remains the small town of Minden, WV located in Fayette County amongst the Lower New watershed, seen in **Figure 1.** highlighted in yellow. According to the decennial census conducted in 2010 by the United States Census Bureau, this small town is comprised of roughly 250 people. Previously known in the early 1900's as Wrenville, Minden was eventually named after the German city of Minden in Westfalen, Germany after quickly becoming established as a coal town. (Kenny, Hamill Thomas)

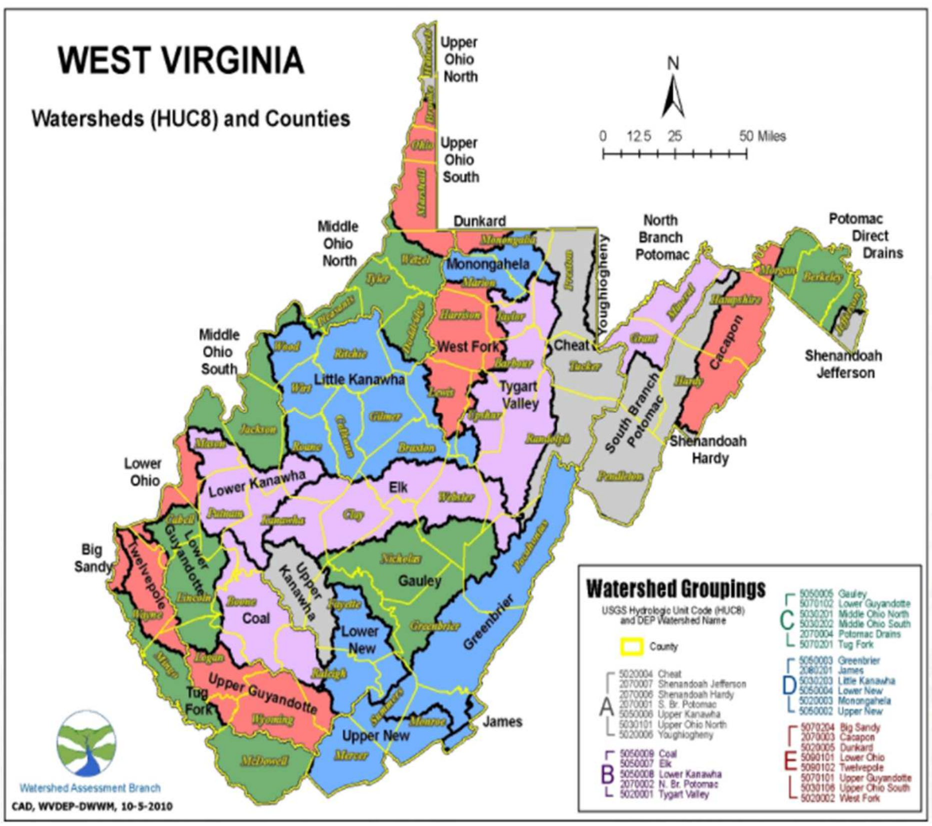

Figure 1. The Lower New Watershed and Fayette County highlighted. ("West Virginia Watersheds.")

Minden itself is near the quaint town of Oak Hill, which was first incorporated in 1903 and stands to be the largest city in Fayette County. With a population of around 8,300, this town got its name through the presence of a giant white oak tree near the building of the first post office within the community. ("Welcome to Oak Hill.") As a result of the proximity between the two towns, they are important to differentiate. Arbuckle Creek is a stream that goes through Minden, WV from Oak Hill in a southeastern direction, eventually flowing in an easterly direction through approximately 3 miles of residential properties into the New River. The New River is important to note because whatever contaminates Arbuckle Creek flows into the New River. At this location, the river is used extensively for recreational activities as well as fishing. The Lower New watershed itself is primarily forest, with it being covered in 83.9 % and having 24 impaired streams within its existence. ("A Lower New River Watershed Appendix.") It begins in the northwest area of Oak Hill in Summerlee, WV, an area characterized by the presence of coal waste piles from historic past coal mining influences. "Residential, commercial, vacant, and undeveloped properties border the creek on both the north and south banks, primarily within the creek's designated floodplain." ("Final Expanded Site Inspection Report Shaffer...) In the Public Health Assessment for the Shaffer Equipment Site, it is explained that the singular school in Minden eventually shut down and that there is a complete lack of parks, playgrounds, nursing homes, or hospitals within approximately a one-mile radius. It is also said that around 65-75 people live close to the Shaffer Equipment Site, meaning less than 600 feet away.

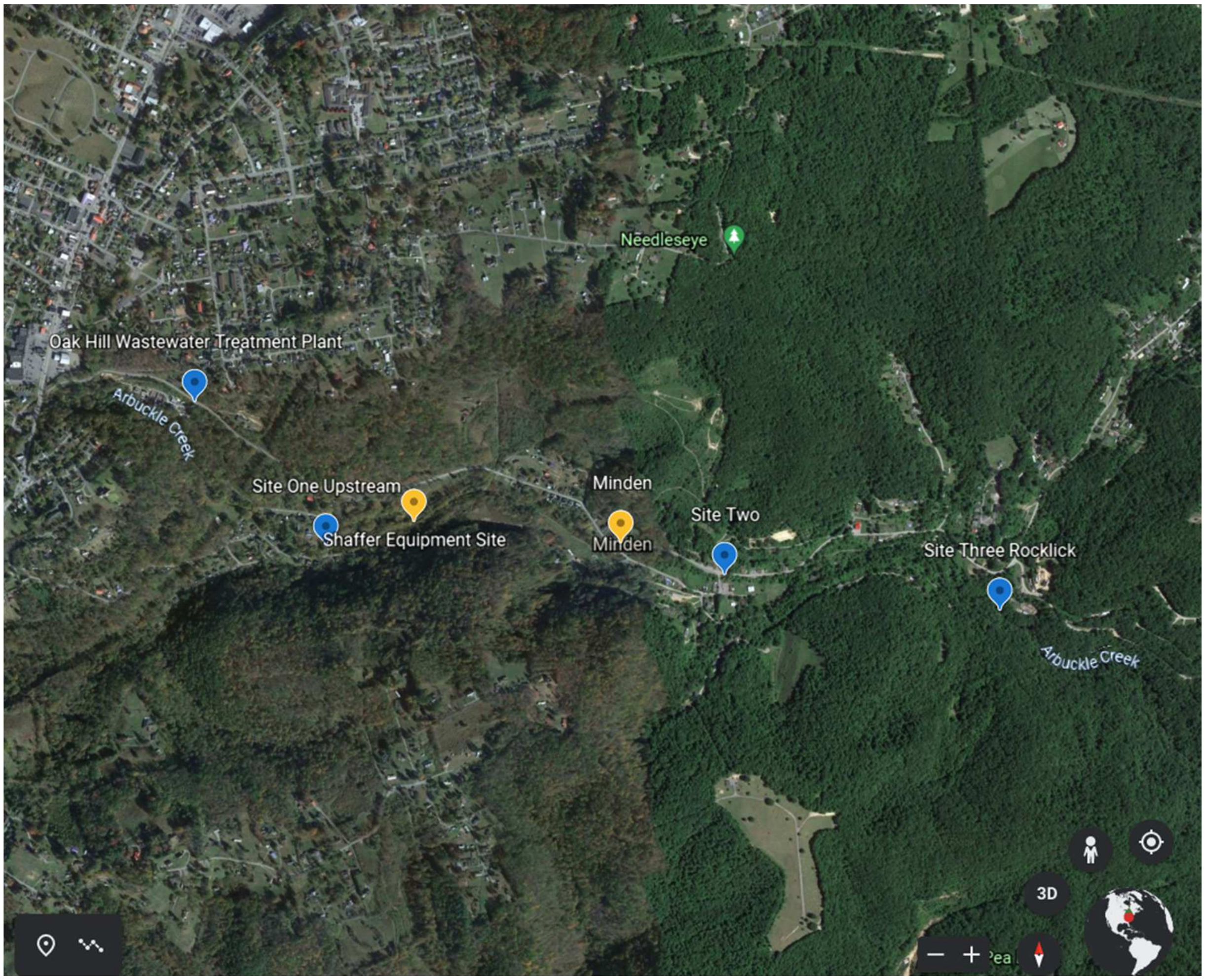

Figure 2. Google Earth view of each site in relation to Minden, the Shaffer Equipment Site, Oak Hill, and the Oak Hill Wastewater Treatment Plant. (*Google Earth,* Google)

The Shaffer Site

The town of Minden, WV is characterized by the presence of polychlorinated biphenyls (PCBs) that have likely contaminated the area since the 1970's. Throughout the production of PCBs over 50 years, it was estimated that over 400 million pounds of the chemicals entered into the environment. PCBs damage the natural equilibrium the environment holds due to the fact that they leach into soils and water sources and infiltrate the balance of the systems through their high toxicity levels. This began when the Shaffer Equipment Company, seen within **Figure 2.** in relation to the study sites and the Oak Hill Wastewater Treatment Plant, built electrical substations for the local coal mining industry and manufactured equipment used in mining from 1970 to 1984. Oil containing PCBs was used in the electrical transformers and other equipment being produced. "The equipment leaked coolant and lubricants containing PCBs into onsite soils and into nearby Arbuckle Creek." (May Shaffer Equipment/Arbuckle*...)* According to the USEPA, "The Shaffer Equipment Company stored nonessential, damaged or outdated transformers and capacitors on the site property." (*EPA*, Environmental Protection Agency) In September of 1984, the West Virginia Division of Natural Resources (WVDNR) found elevated levels of PCBs in Arbuckle Creek soils after composite surface soil samples and a grab soil/sediment sample from a site drainage ditch indicated the levels in the material. The WVDNR later requested the USEPA do two separate soil removal actions, the first from 1984-1987 and the second from 1990-1991. (*EPA*, Environmental Protection Agency) The United States Army Corps of Engineers were later called upon to design a cap in order to seal the contaminated soils and debris that was left, completed in 2002. According to the USEPA, "In early 2017, residents contacted WVDEP and USEPA to express their continued concern about the potential migration of contamination from the Shaffer Equipment Company Site into the surrounding area." (*EPA*, Environmental Protection Agency)

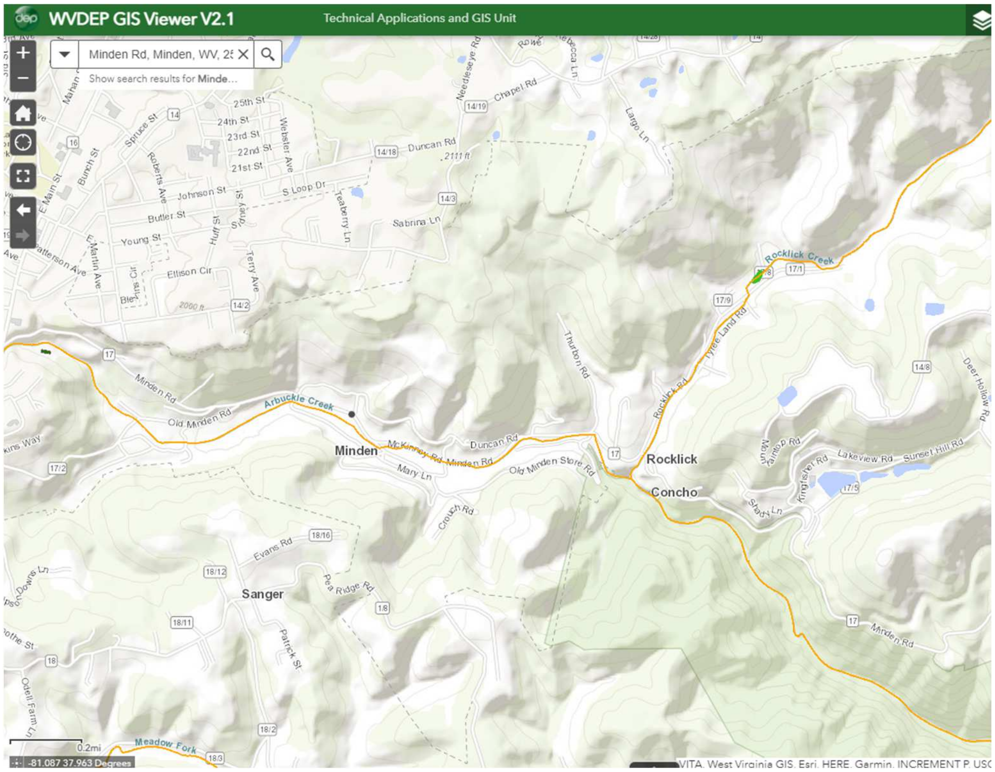

Figure 3. Map of Arbuckle Creek highlighted in orange and watershed features highlighted in blue. (*ArcGIS Web Application*)

Eventually, in June 2017, the USEPA were called upon for further sampling. This resulted in samples being collected at the Shaffer Equipment Company Site and one-mile down Arbuckle Creek, highlighted in orange within **Figure 3.**, which ended in further testing done in December 2017. After using a split samples methodology to analyze the soil samples, the USEPA indicated that PCBs were present at a laboratory level but deemed it no immediate threat to human health. Laboratory levels in this instance mean levels of PCBs that have been flagged due to the fact that they are above background levels or risk levels. For PCBs, the USEPA standard for drinking water is 0.5 parts of PCBs per billion parts of water, or 0.0005 ppm. (Polychlorinated biphenyls (PCBs) Fact…) According to the USEPA, the environmental risk levels for PCBs in sediment are 1ppm and in surface water, the risk level is 50 ug/L. ("Shaffer Equipment Site Fact Sheet 2017.") This indicates at what point the environment and its inhabitant are starting to be affected by the pollutant loads. In October of 2017, soil, groundwater, and stream investigations were completed looking specifically for PCBs, although inorganics and metals were also analyzed for. After taking 41 samples, subsurface (2-6 ft.) and surface (0-2 ft.), near the Shaffer Equipment Site, the USEPA found that the cap placed on it in 2002 was doing a relatively good job at maintaining its duties. These duties include preventing the spread of contaminants such as the previously mentioned PCBs, inorganics, and metals by preventing an open source and environment. For sediment sampling in Arbuckle Creek during this time, the only measurements flagged were two, showing levels of PCB contamination over the environmental risk level of 1 ppm. ("Shaffer Equipment Site Fact Sheet 2017") Everywhere else, the sampling resulted in levels so low they were not flagged or levels that were not flagged at all because they did not exist in the immediate area. Regardless, eventually in 2019, the site was added to the United States National Priority List of Superfund sites.

TMDL Watershed	Code	Trout	Stream Name	Fe	Al	pH	Mn	FC	BIO
Lower New River	WVKN-lo		New River (Bluestone Outlet-Mouth)					X	
Laurel Creek	WVKN-5		Laurel Creek					X	
Mill Creek	WVKN-7	T	Mill Creek					X	
Mill Creek	WVKN-7-0.5A		UNT/Mill Creek RM 1.7					X	
Mill Creek	WVKN-7-B		Osborne Creek	X				X	X
Mill Creek	WVKN-7-B-0.3		UNT/Osborne Creek RM 0.7					X	
Marr Branch	WVKN-9		Marr Branch	X				X	X
Marr Branch	WVKN-9-A		UNT/Marr Branch RM 0.9	X				X	X
Wolf Creek (WVKN-10)	WVKN-10	T	Wolf Creek (WVKN-10)	X				X	X
Wolf Creek (WVKN-10)	WVKN-10-A		House Branch					X	
Wolf Creek (WVKN-10)	WVKN-10-B		Crooked Run					X	
Wolf Creek (WVKN-10)	WVKN-10-C		Short Creek					X	
Wolf Creek (WVKN-10)	WVKN-10-M		UNT/Wolf Creek RM 8.7	X	X	X			
Keeney Creek	WVKN-15	T	Keeney Creek					X	
Coal Run	WVKN-16		Coal Run					X	
Manns Creek	WVKN-17-B		Floyd Creek	X	X	X			X
Arbuckle Creek	WVKN-21	T	Arbuckle Creek	X				X	X
Arbuckle Creek	WVKN-21-A		Rocklick Creek					X	
Dunloup Creek	WVKN-22-K		Mill Creek	X	X	X			X
Glade Creek	WVKN-29	T	Glade Creek					X	X
Meadow Creek	WVKN-32	T	Meadow Creek					X	
Brooks Branch	WVKN-42		Brooks Branch					X	
Madam Creek	WVKN-44		Madam Creek					X	
Beech Run	WVKN-45		Beech Run					X	

Figure 4. Waterbodies and impairments for which Total Maximum Daily Loads (TMDLs) have been developed. ("A Lower New River Watershed Appendix")

The Shaffer Equipment Site is an essential component to analyze in terms of its interconnectedness to Arbuckle Creek. As shown in **Figure 4.**, Arbuckle Creek is amongst other streams for which TMDLs have been developed and implemented. TMDLs are the amounts of pollution able to enter a waterbody while still meeting water quality standards. The site as an entirety has many factors that when examined, hold the key to why the area has suffered throughout the years. "The Site consists of the former SEC (Shaffer Equipment Company) property, contaminated sediments within Arbuckle Creek, and residential properties located within the floodplain of Arbuckle Creek downstream of the former SEC property." ("Final Expanded Site Inspection Report Shaffer...") Within this floodplain, Arbuckle Creek is known to flood up to 7 times per year, with the number of flooding events rising in recent years. ("Final Expanded Site Inspection Report Shaffer") There are many instances in which Arbuckle Creek has suffered and caused suffering to the town of Minden, in particularly due to flooding. "The Site, including the former SEC property and the properties in Minden that border Arbuckle Creek, is located within Arbuckle Creek flood plain, which is a Federal Emergency Management Agency (FEMA)-designated Zone A Flood Hazard Area indicating the area is subject to inundation by the 1-percent-annual-chance flood event (FEMA, 2018a)." ("Final Expanded Site Inspection Report Shaffer…") Before the knowledge of the PCBs in 1984, the creek was dredged for flood prevention measures and the displaced sediment was put into residential areas and mines. This would cause these contaminants to eventually leach into the soil, streams, and groundwater, wreaking havoc environmentally and for the community of Minden. According to the USEPA and the WVDNR, the site was observed in 1984 to have transformers laying on their sides with oil spillage in the area. ("Final Expanded Site Inspection Report Shaffer…") This pathway of contamination is what led to the spread of PCBs in the area, as well as precipitation events and general natural migration of sediment and contaminants. In addition to this, "Groundwater recharge occurs primarily through the infiltration of local precipitation, and groundwater discharge is by wells, seeps, springs, and streams." ("Final Expanded Site Inspection Report Shaffer…") This makes the ease of contaminants movements much more effortless because they have such catalysts like fast moving streams.

Mining and Contaminants

Further distinguishing Minden and the Oak Hill area is the long, intense history of coal mining. Coal mining in Appalachia has a past filled with bouts of different types of mining that have wreaked havoc upon not only the land, but the communities the mining towns were born from. Some of these mining types include surface and underground mining. The geology of the site is important to note because it is the catalyst for mining in the area. "The Shaffer Equipment/Arbuckle Creek Area site is situated in the Appalachian Plateaus Physiographic Province of West Virginia." ("Final Expanded Site Inspection Report Shaffer…") This area is characterized by the presence of Paleozoic age sedimentary rock. Close by is the Pennsylvanian New River Formation which is categorized by having sandstone, shale, and coal. In addition to this, it is known that about 7 percent of the United States' coal is mined from the Kanawha-New River Basin. This indicates the vast presence of mining in Appalachia and the Fayette County area over the continued years. "During the Expanded Site Investigation (ESI) conducted by Weston in 2018, several mine discharge pipes and underground water systems believed to be associated with abandoned mineshafts were identified adjacent to the SEC property and throughout the town of Minden." (Messinger, et al.) This showcases the amount of mining that took place not only near the site property but throughout Minden itself. In the Appalachian region, mountaintop mining is extremely popular and has been for decades as a source of energy and jobs. ""Mountaintop mining" refers to coal mining by surface methods (e.g., contour mining, area mining, and mountaintop removal mining) in the steep terrain of the central Appalachian coalfields. The additional volume of broken rock that is often generated as a result of this mining but cannot be returned to the locations from which it was removed, is known as "excess spoil" and is typically placed in valleys adjacent to the surface mine, resulting in "valley fills."" ("Mountaintop Mining/Valley Fills in Appalachia…") In terms of the types of mining done over the years, "Shallow coal seams were mined by stripping the land to reach the coal. But most mining occurred through the use of underground mining using room and pillar mining methods." ("Phase 1 Remedial Activities Data Summary…") Arbuckle Creek, however, was strongly influenced by underground mining primarily, with the coal seams in study under contracts throughout the 1900's to the 1960's.

In the Kanawha–New River Basin, there is a half and half mixture of coal coming from underground mines and surface mines. According to the EPA in a study done about the Kanawha-New River Basin, "At the more impaired sites, the proportion of total land area as strip mines, quarries, disturbed land, or gravel pits was significantly greater than at the less impaired sites. In addition, sulfate concentration, specific conductance, and alkalinity of stream water were all higher." ("Mountaintop Mining/Valley Fills in Appalachia…") In the same Environmental Impact Statement study performed by the EPA and other environmental agencies, they found that since 1981, there has been a decrease in total iron and manganese in the stream basins in Appalachia where coal mining has continued, yet sulfate has increased. From the study, "During low-flow conditions, sulfate in more than 70 percent of samples from streams downstream from coal mines in both coal regions exceeded the regional background concentration." ("Mountaintop Mining/Valley Fills in Appalachia…") This helps to show a correlation between sulfate concentrations and previous mining sites, as shown directly in **Figure 5.**, which highlights coal production and sulfate in streams by county. The higher the concentrations, the greater the coal production had been.

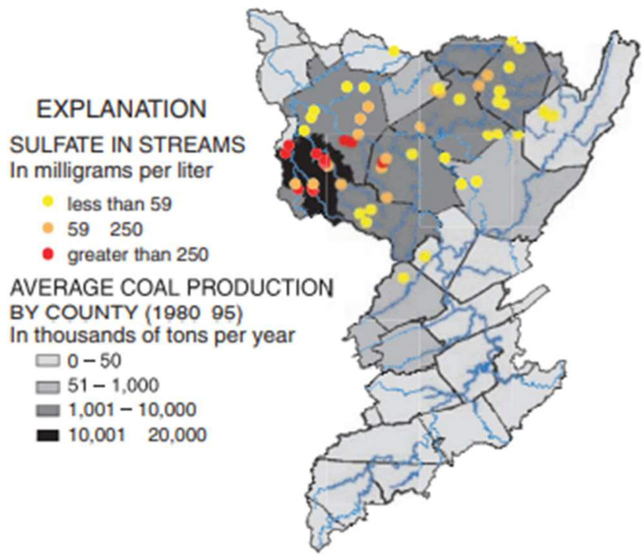

Figure 5. Sulfate concentrations in wadable streams. ("Mountaintop Mining/Valley Fills in Appalachia…")

Not only was sulfate found to be affected but total manganese, aluminum, and iron also ended up exceeding regional background concentrations, regardless of the general decrease in iron and manganese compared to sulfate. Additionally, trace elements were also analyzed, identifying concentrations of cadmium in some parts that were higher than anywhere else in the nation. In terms of benthic macroinvertebrates, communities were more impaired where there was more coal mining. In addition, "Pollution-tolerant species are more likely to be present at mined sites than at unmined sites, whereas pollution sensitive taxa were fewer in number or non-existent in heavily mined basins." ("Mountaintop Mining/Valley Fills in Appalachia…") This indicates that in the basin that Oak Hill and Minden, there is a history of benthic macroinvertebrates having a pattern of tolerance to pollution, dictating their presence or absence.

According to the 2019 Directory of Underground Mine Addresses, there were 14 mines in Oak Hill. (*West Virginia Office of Miners' Health…)* It can be observed in **Figure 6.** that abandoned mines litter the area of Arbuckle Creek. It can be assumed that although some of these companies have since dissolved, their presence had to have impacted the surrounding area of Oak Hill and Minden.

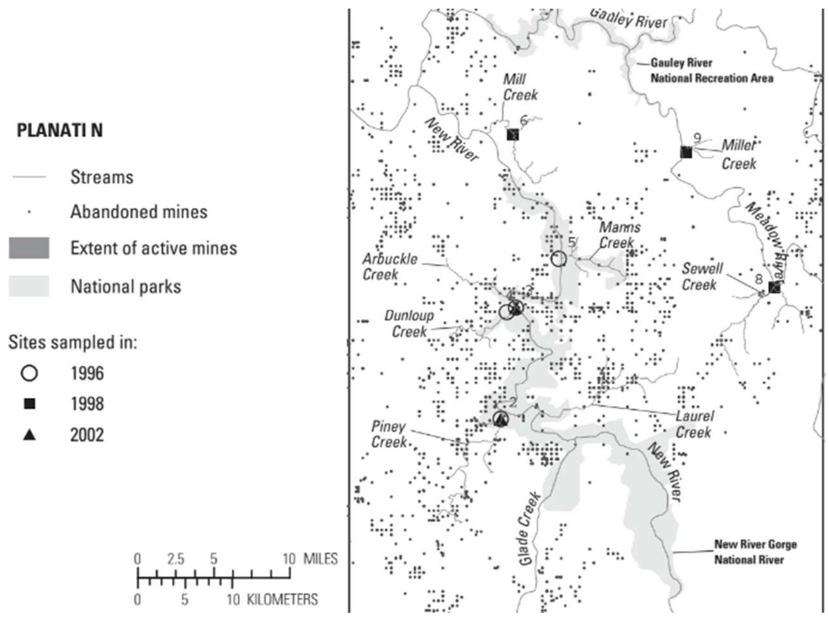

Figure 6. Map showcasing AMLs and current mines. (Messinger, Terrence.)

Not only were there high sulfate, manganese, aluminum, and iron, but there were also exceedingly high levels of polycyclic aromatic hydrocarbons (PAHs) found in the 1990's. Ten out of the 12 known PAH guidelines were found by the EPA in the Kanawha-New River Basin study. In accordance with this study, the USGS proposed another study in the same area with the Gauley region added in the summer of 2002. The aim of this study was to study PAH concentrations in bottom sediment and bioavailability in five different streams. "A "polycyclic aromatic" hydrocarbon is one in which two or more aromatic rings are bonded together," according to the study performed by the USGS. (Messinger, Terrence.) They are dangerous to not only humans but aquatic life as well as they accumulate, with at least 16 PAHs being listed on the priority pollutants list recorded by the USEPA. According to the study, PAHs were found in different levels. "Only 3 PAHs were measured in SPMDs (Semipermeable membrane devices) in only 4 of 13 SPMDs at concentrations high enough to report without qualifiers." (Messinger, Terrence.) Because PAHs can be found in pollutants such as coal, they can naturally have consequences on the aquatic ecosystems and overall environmental health, especially in heavily mined areas.

In an Expanded Site Investigation done at Arbuckle Creek, the Shaffer Equipment Site, and the surrounded residential area, completed by the direction of the USEPA, there were also some key findings related to the history of mining and the creation of mining equipment at the Shaffer site. "Historically, the Town of Minden was a coal mining town dating back to the late 1800s. The New River and Pocahontas Coal Company (a.k.a Berwind Land Company) owned a majority of the land surrounding the town and conducted coal mining operations until the 1950s." ("Final Expanded Site Inspection Report Shaffer…") As imagined, decades of uncensored mining wreak havoc upon the land, and Minden, WV is no different. As shown in **Figure 7.**, Arbuckle Creek has been directly affected by the presence of abandoned mine land and AML seeps.

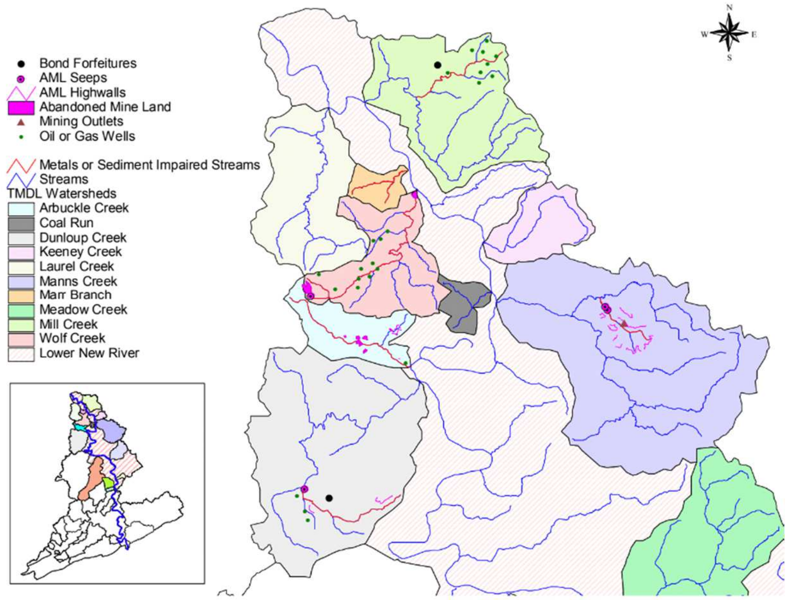

Figure 7. Mining-related sources in the Lower New River watershed; Shows AML near Arbuckle Creek. ("A Lower New River Watershed Appendix.")

History tells us that the majority of the surrounding areas of the study site and Minden and Oak Hill have been mined as well. Referring to the multiple samples taken at the Shaffer Equipment Site during the first investigation, "Analytical data indicated the presence of PCBs at concentrations of 8,200 parts per million (ppm) (0.82%) in the composite sample, 33 ppm in the main transformer area soil sample, 260 ppm in the soil sample collected from the drainage ditch, 260,000 ppm (26%) in the surface soil sample collected from the capacitor spillage area, 40,000 ppm (4 %) in the subsurface soil sample collected from the capacitor spillage area, and 4 ppm and 3 ppm in the sediment samples collected from Arbuckle Creek." ("Final Expanded Site Inspection Report Shaffer…") Additionally, high levels of PCBs were found 300 feet downstream in Arbuckle Creek and in a residential property over a mile away from the Shaffer site. The following year, even higher levels were detected leading to the first initial cleanup of the site by the USEPA. Because PCBs were still detected in significant levels years later in 1990 during samples, the USEPA again removed the affected soil. After which, the cap was placed.

Arbuckle Creek was also sampled extensively, and PCBs were found at different levels in the majority of the samples, regardless of the type of sampling methodology. When the Bath House near Arbuckle Creek and the Shaffer Equipment Site was analyzed, PCBs were found in some samples but not all and in relatively low numbers, although a transformer was still observed to be located on the property. This Bath House was not only used by miners throughout the 1920's but it remained active until the 1960's, showing the extent of years of damage. At the Berwind Green Hill Mine Dump site, there were not any PCBs detected. The New River and Pocahontas Coal Company Supply House (a.k.a Powerhouse) site, located in town, also did not have detectable levels of PCBs. The groundwater was also sampled but not only for PCBs, pesticides, semi volatile organic carbons (SVOCs), PAHs, chlorinated biphenyls congeners (CBCs), and inorganics were also analyzed. Further sampling actions taken happened years later by the USEPA in 2017 and 2018 and resulted in the detection of PCBs in the surface soil samples, although they were low levels. It was found that "…In general, samples contained 4-dichlorodiphenyldichloroethane (DDD),4-dichlorodiphenyltrichloroethane (DDT), 4-dichlorodiphenyldichloroethylene (DDE), Endrin ketone, Endrin aldehyde, and trans-Chlordane at concentrations exceeding applicable EPA Biological Technical Assistance Group (BTAG) screening values for freshwater sediment." ("Final Expanded Site Inspection Report Shaffer…") Regarding the SVOCs and PAHs in the sediment samples, they were found at exceedingly high levels. Eventually it was found that fecal coliform was also problematic to Arbuckle Creek in particular as well. Regarding the inorganics, "Copper, iron, manganese, and nickel were detected in the majority of the sediment samples at concentrations exceeding applicable BTAG screening values. Additionally, arsenic, cadmium, cobalt, lead, selenium, and zinc were detected in at least one sediment sample exceeding applicable BTAG screening values." ("Final Expanded Site Inspection Report Shaffer…")

Final Expanded Site Inspection Report Value Flagged Examples				
Sample Site	**Sample Type**	**Concentration**	**Location**	**Date**
SEC Property	PCBs	8,200 ppm	Surface	1984
SEC Property	PCBs	260 ppm	Surface	1984
SEC Property	PCBs	260,000 ppm	Surface	1984
SEC Property	PCBs	40,000 ppm	Subsurface	1984
Arbuckle Creek	PCBs	73 ppm	Surface	1985
SEC Property	PCBs	260,000 ppm	Surface	1984-1985
Arbuckle Creek	PCBs	200 pm	Surface	1984-1985
SEC Property	PCBs	40,302.8 ppm	Surface	1990
SEC Property	PCBs	772 ppm	Surface	1990
SEC Property	PCBs	2,030 ppm	Surface	1990
SEC Property	PCBs	10,500 ppm	Surface	1990

Table 1. Final Expanded Site Inspection Report Value Flagged Examples

In reference to **Table 1.**, these values are concentrations of PCBs in the soil and in Arbuckle Creek that were found in 1984, 1985, and 1990. These values are important to note because each are flagged due to being higher than the 50 ppm value used to designate a normalized number. It can be seen that although the concentrations fluctuate greatly, they are significantly above 50 ppm in many cases in the surface samples on the SEC property. This correlates with the notion that eventually in 2017, samples indicated levels of elevated concentrations of PCBs with respect to the background. ("Final Expanded Site Inspection Report Shaffer…") This could show the length of time the PCBs stayed in the SEC property area and contaminated the area.

In the Public Health Assessment done, the Agency for Toxic Substances and Disease Registry (ATSDR) found that the actual Shaffer Equipment Site was still a public health hazard for those who come in contact with surface soils and sediments contaminated. Considering the fact that the manufacturing of PCBs was halted in 1977 for its long exposure in the environment and the potential health hazard it is to humans, its presence at the site unsettles many. It also specifies that the area in which PCBs were found is accessible to the public through a cattle gate, so while there may be some protections around the site, there might not be enough for what the contaminants indicate is necessary. While some worry about the bioaccumulation in fish, it does not appear it occurs in the rates that would be harmful to humans. Conversely, the public was told from this report for pregnant women to avoid eating snapping turtles as contaminants do bioaccumulate more in them, making them harmful to humans. In the interviews in which they discussed "oil-soaked hands" and "oil-soaked clothing", it is evident cleaning precautions were not taken at the site during operation. ("Public Health Assessment for Shaffer Equipment Company") Additionally, this study found that the workers at the Shaffer Equipment Site were most likely exposed the most due to their close proximity to all of the fumes as well. In this same study, surface and subsurface soil were sampled and evaluated in 1990. In this, PCBs were found as well as volatile organic compounds (VOCs) and SVOCs, but in small amounts. The ASTDR eventually determined that they could not conclude accurately what the exact risk to the public was, including for children who have previously played in contaminated sediments. In addition to this finding, "The polynuclear aromatic hydrocarbons (PAHs) benzo(a)anthracene, benzo(b)fluorene, benzo(a)pyrene and dibenzo (a, h) anthracene were found at levels exceeding comparison values." ("Public Health Assessment for Shaffer Equipment Company") Because they have been shown to cause cancer, their presence is essential to take note of. Since the rest of the PAHs did not have comparison values, it is unknown what the health risk to the public is.

Within the vast number of studies done to successfully complete the Lower New River Watershed Appendix, contaminants were analyzed for their potential sources. "Mining and non-mining-related permitted discharges are potential metals and pH point sources. Potential metals and pH nonpoint sources (NPS) include non-permitted sources such as abandoned or forfeited mine sites, and sediment producing land disturbance activities and streambank erosion." ("A Lower New River Watershed Appendix.") Due to the discharges coming from point and nonpoint sources, it is essential to understand which is the contributing factor in the overall production and spread of contaminants such as metals. "In the Lower New River watershed there is one mining-related National Pollutant Discharge Elimination System (NPDES) permit with two outlets. Because the permit contains iron and aluminum effluent limitations, the regulated discharges were determined to be contributing point sources of metals" ("A Lower New River Watershed Appendix.") It was also found that iron was produced from non-mining related activities such as other industrial activities. Referring to **Figure 8.**, the Wastewater Treatment Plant of Oak Hill exists and is extremely close to Arbuckle Creek and could discharge effluents. Nonpoint sources are also contributing factors in the pollutants remaining within the Lower New Watershed. Because of the significant number of abandoned mine lands (AMLs), they are a definitive contributing factor to the presence of nonpoint source pollution due to the non-permitted sources of metals and pH impairments. Because fecal coliform is also an issue within the watershed, examining the point and nonpoint sources from which it could be the result from is important. Although the point sources all have permits limiting the discharge flow, nonpoint sources such as straight pipes and failing septic systems from old sewage systems are major points of origin for fecal coliform.

Figure 8. Photo of the Wastewater Treatment Plant; Image produced by Sarah Simonton.

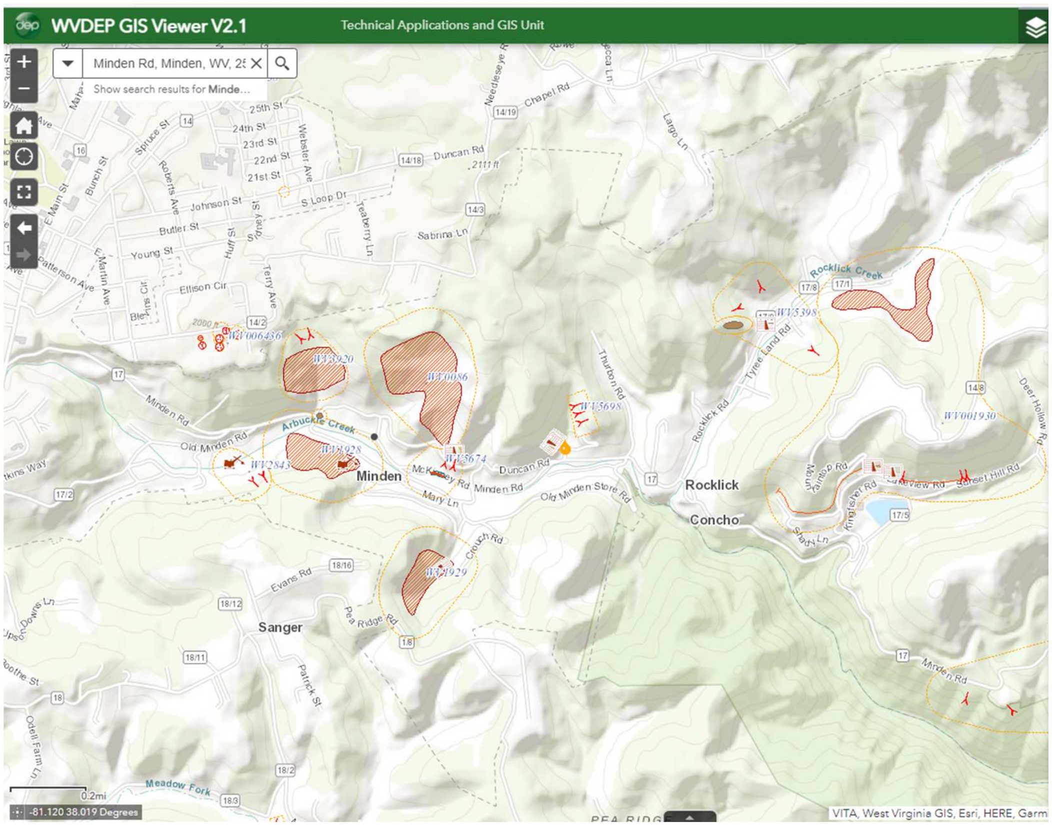

Figure 9. Map highlighting the abandoned mine lands directly in relation to Arbuckle Creek and Rocklick Creek. (*ArcGIS Web Application*)

Within the Phase 1 Remedial Activities Data Summary Technical Memorandum for Shaffer Equipment/Arbuckle Creek Area Site, findings and investigations assist in the generation of Phase 2 recommendations and actions. The project areas where the investigations took place are important to note due to the fact that they have been previously analyzed over the years for contaminants. They are also close to AML land, as seen in **Figure 9.** showing abandoned mine land near Arbuckle Creek and Rocklick Creek. The project areas include the Shaffer Equipment Company, a possible transformer storage area, the Britt Bath House area, the Berwind Green Hill mine dump area, Rocklick Road, NR&P Supply House area, residential properties, Arbuckle Creek, wetlands, the New River, and mines. In addition to numerous soil boring samples, 265 soil samples were also taken near the surface, at the surface, or under the surface at the sites. "All of the samples were analyzed for Target Compound List (TCL) VOCs, TCL SVOCs, TCL pesticides, PCB congeners, dioxins/furans, and Target Analyte List (TAL) metals at fixed-base laboratories designated by USEPA to confirm chemicals of potential concern (COPCs) because a full suite of analyses had not been conducted." ("Phase 1 Remedial Activities Data Summary…") This indicates a possibility of more contaminants than ever previously known within the sampling sites, making it important to study more than PCBs in the area. Surface water and sediment sampling was also completed in an effort to configure the contamination surrounding the Shaffer Equipment Site, and they were also analyzed for TCL VOCs, TCL SVOCs, TCL pesticides, TCL congeners, dioxins/furans, and TAL metals. It is said that "Groundwater flow direction beneath the site is not known; however, groundwater is expected to flow toward Arbuckle Creek." ("Phase 1 Remedial Activities Data Summary…") This indicates the importance of analyzing the contaminants that could possibly move towards the stream and infiltrate its equilibrium. In terms of the soil borings that were done over the course of multiple days, "Soil borings completed on the former SEC Property as part of the Phase 1 RI indicate that the soils consist of a thin veneer (few feet) of fill material consisting of brick, "red dog", gravel, coal, silty sand, and occasional construction and trash debris." ("Phase 1 Remedial Activities

Data Summary…") Although VOCs were detected, the amounts were low enough that indicate minimal impacts. Unlike the VOCs, SVOCs were found in concentrations high enough to impact the property. Numerous pesticides, Aroclors, and PCB congeners, and dioxins/furans were also detected in the soil samples, indicating they have an effect on the site as well. Regarding the metals, "Even though most metal concentrations were less than or similar to background values and given the mining history of the former SEC Property, metal concentrations cannot yet be ruled out as being attributable to former SEC activities." ("Phase 1 Remedial Activities Data Summary…") In attribution to Arbuckle Creek, it is found that PCBs are widespread throughout the sediment. The surface water and sediment of Arbuckle Creek was also analyzed for TCL VOCs, TCL SVOCs, TCL pesticides, TCL congeners, dioxins/furans, and TAL metals. Low amounts of VOCs were detected, while moderate levels of SVOCs were found. It was found that numerous amounts of pesticides and dioxins/furans were discovered, and several metals were found in high amounts. Aroclors and PCB congeners were found through the entirety of Arbuckle Creek and its neighboring wetland.

Biomonitoring

Biomonitoring is a component of studying ecosystems, in particular streams, in ways that assist scientists to better understand the reasoning behind the patterns that create and dictate the life that makes up these complex webs. Monitoring biological systems allows for the inner workings of these structures to be revealed in ways that are conducive to overall environmental health. While the process of biomonitoring can be made of many elements, the main goal remains the same. The widespread goal of biomonitoring is to maintain biological integrity while simultaneously developing methods to better implement protective measures. By quantitatively and qualitatively measuring specific aspects of an environmental system, better means of protecting it can be implemented, as seen through the use of the water quality meter in **Figures 10 and 11.** For these reasons, using macroinvertebrates, water parameters, and benthic algae to study stream health is appropriate.

Figures 10 and 11. Biomonitoring sampling being done in Arbuckle Creek; Images produced by MelQuan Green and Sarah Simonton.

Benthic Macroinvertebrates

Macroinvertebrates are high quality indicators of stream health in that they can be representative of pollution tolerance and intolerance. Some benthic, or bottom-dwelling, macroinvertebrates are indicators of stream health by being tolerant to pollutants or contaminants or intolerant to them. The species that is responding to the pollution in a certain manner tells scientists whether the stream is in good or poor health, or whether it is impaired or unimpaired. They make quality indicators because they spend the majority of their lives in the water, allowing for the constant changes and fluidity of the waters chemical cycles to become very close in nature with them. In addition to these advantages, they also have limited mobility and can indicate exactly what is going on in the water at that time because they cannot remove themselves easily from pollutants or contamination. They are also relatively easy to identify when using keys or manuals, as seen in **Figures 12 and 13.** Benthic macroinvertebrates are also essential components to our biogeochemical cycling. Within *Loss of Biodiversity Alters Ecosystem Function in Freshwater Streams: Potential Evidence from Benthic Macroinvertebrates*, the authors discuss their importance in this fact. "For instance, *Tubificidae* and *Chironomus Larva* can accelerate the decomposition rate of organic detritus, regulate matter exchange between water and sediment, as consumer and transformer play a connection link in matter cycling and energy flowing (Gallepp 1979, Fukuhara and Sakamoto 1987)." (Cao, Xiofeng, et al.)

Figures 12 and 13. Hydropsychidae under the microscope and in plain view; Images produced by Sarah Simonton.

Benthic macroinvertebrates have high biodiversity, so what each species can indicate about water quality is unique. This means different groups can indicate multiple types of contaminants. Macroinvertebrates are also extremely adapted to their surroundings and their adaptations make them suitable for the habitat in which they reside. Because of their claws, hooks, and other grasping tools, these diverse skills possessed by benthic macroinvertebrates make them the perfect candidates for water quality surveys. Not only do they provide important components to the ecosystem, but they produce them as well. Benthic macroinvertebrates are a quality food source for many fish and other benthic macroinvertebrates. This not only means that the fish and other insects are getting energy, but they are gaining the energy the macroinvertebrates took up in the form of consuming detritus and algae. Macroinvertebrates are extremely important to not only their own ecosystems food web but to measuring water quality as well.

Water Parameters

Other methods of measuring water quality are essential in configuring the health of a stream. Measuring the contents of the water can in some cases be just as important in showcasing stream health as macroinvertebrate surveys. Temperature, pH, conductivity, and dissolved oxygen should be noted when summarizing the health of a stream. The measurement of water parameters shows the health of the stream through measurements of different methods and units. Temperature is important to measure because certain aquatic life forms depend on specific temperatures to survive and spawn. Temperature can also affect dissolved oxygen which can negatively influence life forms and it can cause chemical reactions to occur faster, increasing nutrient loads in the water. Measuring temperature is extremely important in maintaining water quality. Temperature also has a direct effect on conductivity, meaning if the temperature is higher, the conductivity will likely be higher. The pH of water is also an essential component when dealing with water health because it can dictate a streams condition. The more basic, or alkaline, a stream is, the higher the pH and the more acidic a stream is, the lower the pH is. If water is completely neutral, it has a pH of 7. Because many aquatic life forms have sensitive bodies, with some even breathing through their skin, even slight changes to pH can cause organisms to die or get skin and gill damage. While the vast majority of aquatic organism prefer pH from 6.5-9.0, some can make exceptions to survive. ("Ph of Water.") Pursuant to the Fondriest Environmental Learning Center, "In addition to biological effects, extreme pH levels usually increase the solubility of elements and compounds, making toxic chemicals more "mobile" and increasing the risk of absorption by aquatic life." ("Ph of Water") Therefore, measuring and maintaining pH is abundantly important in stream health. Conductivity is also an essential measurement to observe as it is an indicator of water quality that has an effect of aquatic life as well. Conductivity is a measure of the ability of water to pass an electrical current and is measured in micro siemens per centimeter (μS/cm). Changes in conductivity are important to monitor because they can indicate pollution discharge from a source. Higher amounts of dissolved solids indicate higher conductivity; therefore, their presence could indicate something that could harm the natural equilibrium of the stream. According to the USEPA, "Each water body tends to have a relatively constant range of conductivity that, once established, can be used as a baseline for comparison with regular conductivity measurements." (*EPA*, Environmental Protection Agency) This makes measuring conductivity a useful tool in managing water quality. In addition to this, conductivity can also indicate pollution discharges. "Discharges to streams can change the conductivity depending on their makeup. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity." (Mathur, Abha.) Dissolved oxygen is how much oxygen is available to aquatic life in water and is measured in mg/L^{-1}. Because it is dissolved, it becomes available for organisms to use. "The amount of oxygen that can be dissolved in water depends on several factors, including: water temperature, the amount of dissolved salts present in the water (salinity), and atmospheric pressure." (*Water Quality Notes: Dissolved Oxygen…)* This means that dissolved oxygen can be altered very easily due to a number of different ecosystem components. Dissolved oxygen can be a good indicator of water quality because if there are levels that are too low or too high, organisms will begin to die. "Decreased DO levels may also be indicative of too many bacteria and an excess amount of biological oxygen demand – BOD (untreated sewage, partially treated sewage, organic discharges, anoxic discharges) which use up DO." ("Dissolved Oxygen in Water.") Principally, measuring dissolved oxygen is important in monitoring water quality. Water quality indicators are essential components in measuring the health of a stream in its entirety.

Benthic Algae

Measuring the benthic algae in a stream is a quality indicator of stream health because they are essential parts of the food web of the stream, so their presence and absence can be indicative of good or poor stream health. Benthic algae respond rapidly to changes in their environment, so they are useful in measuring water quality. "Diatoms in particular are useful ecological indicators because they are found in abundance in most lotic ecosystems." ("Chapter 6: Periphyton Protocols.") Bottom-dwelling algae are also important food sources for many fish and benthic macroinvertebrates. In addition, they not only form habitat for other organisms but also act as primary producers. This means they use the sunlight they receive throughout the day to convert inorganic substance into organic compounds able to be later consumed. "Because they are attached to the substrate, the phytobenthic periphyton community integrates physical and chemical disturbances to a stream. Benthic algae also produce vast amounts of oxygen, making them important parts of a stream's dynamic." (*WVDEP Watershed Assessment Program*) In regard to benthic algae, "Since the ecological tolerances for many species are known, changes in community composition can be used to diagnose the environmental stressors affecting ecological health, as well as to assess biotic integrity." ("Chapter 6: Periphyton Protocols.") Algae are necessary components in measuring stream health. Overall, they can help to identify nutrient levels in streams and other aquatic ecosystems.

West Virginia Stream Condition Index

In West Virginia, biological monitoring done by the Department of Environmental Protection is driven by different protocol that help make up a unique system that allows for the analysis of water quality through different measurements. The Watershed Assessment Branch (WAB) was eventually developed to monitor aquatic health. In the development of this branch, certain procedures were undertaken to measure stream health using benthic macroinvertebrates. Surveys are done using the protocol developed by the branch, which is modeled after the Rapid Bioassessment Protocols of the USEPA. The information gained from surveys is then assembled in a Stream Condition Index (SCI). "The index includes six biological attributes, called metrics, that represent elements of the structure and function of the bottom-dwelling macroinvertebrate assemblage. Metrics are specific measures of diversity, composition, and tolerance to pollution, that include ecological information." (A Stream Condition Index for West Virginia…) There are five different metric categories in which the six metrics fall under. They are as follows:

- *Taxonomic richness*- Counts of specific taxa in a group; "Total taxa" and "EPT taxa" used; ""EPT taxa" measures richness in three insect orders known to be generally sensitive to disturbance (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]), thereby conferring information both on variety and community tolerance." (A Stream Condition Index for West Virginia…)
- *Habit*- How a macroinvertebrate moves in regard to its location;" Although habit metrics have been used successfully, they are considered unreliable for family-level data, because there is no assurance that all genera in a family have the same

habit. Because of this, habit metrics were not tested.” (A Stream Condition Index for West Virginia…)

- *Taxonomic composition*- Using specific groups expressed as a percentage and is based on individuals in the sample
- *Feeding group*- The reflection of the main mode of ingestion or feeding; Shredders, grazers, predators, collectors, and filterers
- *Tolerance/Intolerance*- The ability of a macroinvertebrate to survive pollution (long or short term); Using the taxon’s assigned tolerance values and proportion of individuals, the Hilsenhoff Biotic Index (HBI) is weighed; 0 tolerance value indicates least tolerant or most sensitive to stressors, while 10 indicates taxa that are most tolerant or least sensitive

These metrics represent the six-core metrics ultimately used to create the WVSCI score, which are as follows:

- *EPT taxa*- Within the insect orders Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly), the sum of all taxa; Expected to decrease due to increasing disturbance
- *Total taxa*- Measures the variety of the entire aggregation; Expected to decrease due to increasing disturbance
- *% EPT*- The percentage of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly); Expected to decrease due to increasing disturbance
- *% Chironomidae*- The percentage of Chironomids (midges); Expected to increase due to increasing disturbance

- *% Top 2 dominant taxa*- A percentage of the amount of the two most dominant taxa; Expected to increase due to increasing disturbance
- *HBI (Family biotic index)*- Using assigned tolerance scores, it is the weighted average; Expected to increase due to increasing disturbance

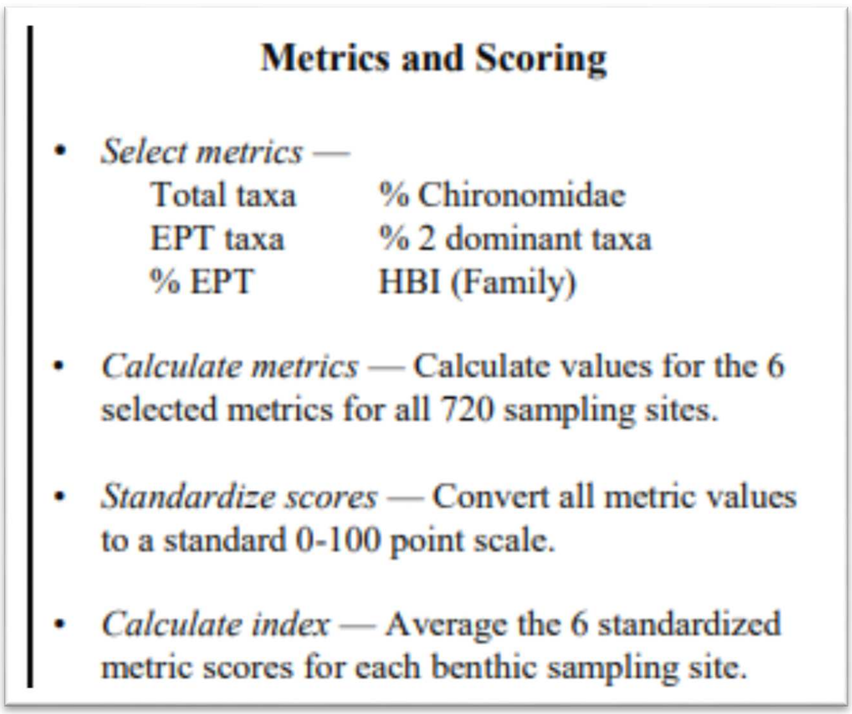

Figure 14. Showcasing the metrics and scoring process. (A Stream Condition Index for West Virginia…)

The metrics, shown with steps and directions in **Figure 14.**, are used to then calculate the WVSCI score. This is completed by using the standards or best values in certain equations that align with each core metric. Once the correct values are generated using the specified equations, a number from 0-100 is assigned. “By standardizing the metric values to a common 100-point scale, each of the metrics contributes to the combined index with equal weighting, and all of the metric scores represent increasingly “better” site conditions as scores increase toward 100.” (A Stream Condition Index for West Virginia…)

SCI score	Rating
> 78 - 100	Highly comparable to reference sites (above 25th percentile)
> 68 - 78	Comparable to below-average reference sites (between 5th and 25th percentiles)
> 45 - 68 > 22 - 45 0 - 22	} Increasingly different from reference condition

Figure 15. Example rating system. (A Stream Condition Index for West Virginia…)

After, these six numbers are averaged, and this is the final WVSCI score. There can be rating systems developed, such as seen in **Figure 15.** Depending on where the score is between 100 dictates whether the stream is deemed to be unimpaired or a score >68, slightly impaired or a score of 45.1-68, moderately impaired or a score of 22.1-45, or severely impaired or a score of 0-22. (Vargo, Emily.)

Habitat Assessments

Habitat assessments are important in analyzing the health of the overall stream through evaluating different aspects of the stream through multiple characteristics. They show a valuable picture of the streams health by organizing certain qualities of the stream into categories and sorting them into a numbering system which ultimately provides a template for stream classification. The classifications for the stream are based on the stream's health and the numbers the stream provides based on observation of the stream. It is important to distinguish between habitats as they can be quite different, with alternative inhabitants at each location, as shown in **Figures 16 and 17.** Optimal=160-200, Sub-Optimal=110-159, Marginal=60-109, and Poor=0-59 are the classifications and can be found on the wadable benthic stream assessment form that is to be completed during the habitat assessment.

Figures 16 and 17. Showcasing the difference between Site One's habitat and Site Three's habitat; Images produced by Sarah Simonton.

Within the stream assessment form, there are many important components.

- *Site Verification*- Basic information about the site is required; directions to the site asked for; picture of the site drawn and shown is where the benthic macroinvertebrate surveys took place, where the water quality was taken, and the general flow of the stream.
- *Activities and Disturbances*- Erosion, scouring, odors, and NPS pollution are covered; stream reach activities and disturbances are rated from low (1) to 4 (extreme); activities include residential, recreational, agricultural, industrial, and management.
- *Physical and Sediment Characterization*- Stream width required; percent of habitat type is covered; sediment odors, oils, and deposits are checked and rated from none (0) to extreme (4); substrate particle layer profile required; dominant substrate type and reach characterization completed.

- *Field Water and Riparian Vegetation Zone Measures*- Goes over water quality including temperature, pH, dissolved oxygen, and conductivity; covers seasonal water levels, water odors, surface "oils", turbidity, and precipitation history; stream bank/riparian buffer zone vegetation/cover type ratings complete from 0 (absent 0%) to 4 (very heavy >75%); invasive species checked
- *Rapid Habitat Assessment: Riffle/Run*- Rates habitat parameters into scores from 0 (poor) to 20 (optimal); 1. Epifaunal substrate/available fish cover, 2. Embeddedness, 3. Velocity/depth regimes, 4. Channel alteration, 5. Sediment deposition, 6. Riffle frequency, 7. Channel flow status; next determined from left to right and rated from 0 (poor) to 10 (optimal) is 8. Bank stability, 9. Bank vegetative protection, 10. Width of undisturbed vegetation zone; then whether it is Optimal, Sub-Optimal, Marginal, and Poor is classified.
- *Benthic and Fish Habitat, Aesthetic, and Remoteness Ratings*- Rates parameters into scores from 0 (poor) to 20 (optimal); Parameters include 1. Benthic macroinvertebrate substrate, 2. Fish habitat, 3. Trash index, 4. Remoteness rating; asks about the potential for being a reference site and about stressor information.
- *Wildlife Observations*- Gives a list open to writing down any wildlife viewed; asked to include Common Name, Genus Species, Comments, Number Observed, Invasive, Observer; asked about mussel and trout observations.
- *Benthic Macroinvertebrate and Periphyton/Algae/Aquatic Plant Information*- Asks about benthic sampling that took place; requires the estimated percent composition for each substrate type; Rates the abundance of periphyton, algae, mosses, and plants from 0 (none) to 4 (extreme) or NR (not rated).

- *Macroinvertebrate Observations Part 1*- A visual guide to the benthic macroinvertebrates to be checked that were collected.
- *Macroinvertebrate Observations Part 2*- A visual guide to the benthic macroinvertebrates to be checked that were collected.
- *Landowners/Stakeholder Information, Recon, and Photos*- Area to put landowner information; area to discuss accessibility; photography log.

These components are filled out in the field as part of the habitat assessment as a whole. It is essential to fill them out for each stream survey because each of the characteristics that make up the stream's equilibrium are different depending on the reach of the stream as an entirety. For instance, in this stream, one survey, Upstream Site One is closer to the Oak Hill Wastewater Treatment Plant and the Shaffer Equipment Site, so the water quality parameters could be different here versus Rocklick Trail Site Three.

CHAPTER 2

Methodology

Benthic Macroinvertebrates

While hypothesizing that the benthic macroinvertebrate community will show impairment due to the past implications of the Shaffer Equipment Site and mining in the area, surveys were performed. In order to assess the stream health of Arbuckle Creek, the benthic macroinvertebrate community was assessed at two separate times of the year, the first during May 2021 and the second during September 2021. This was in order to assess the variability in species and to see if the conditions for the other parameters, in addition to the macroinvertebrates, such as water quality and benthic algae, changed over time. For the analysis of the benthic community, the WVDEP Watershed Assessment Branch Field Sampling Standard Operating Procedures were used. Using this methodology, 6 surveys were completed overall at 3 separate sites. These sites were designated as Upstream Site One, Middle Point Site Two, and Rocklick Trail Site Three. After a pronounced riffle was established as a site point for the surveys, four $0.25m^2$ kicks were completed. With each kick, a bucket catching the rocks and other debris was present and used for collecting, as seen below in **Figure 18.**

Figure 18. Sampling equipment for macroinvertebrates; Image produced by Sarah Simonton.

Next, the debris was filtered, rinsed, and placed in a labeled jar with an ethanol solution. In the lab, the WAB Field Sampling Standard Operating Procedure was followed for 200 (+-40) organisms. This included random sampling using a grid pattern to identify the benthic macroinvertebrates down to taxonomic family using https://www.macroinvertebrates.org/ to actually identify the insects and a board, such as the one in **Figure 19.**

Figure 19. Board for assessing bug species; Image produced by Sarah Simonton.

For further assessing the benthic community, the USEPA Stream Condition Index for West Virginia Wadable Streams was used. This was done to make further sense of the numbers of certain species of benthic populations using the six metrics EPT taxa, total taxa, % EPT, % Chironomidae, % Top 2 dominant taxa, and HBI (Family biotic index). These metrics are individually calculated, then using specific equations in reference to **Figure 20.**, the WVSCI scores can be quantified. (A Stream Condition Index for West Virginia…)

These scores are then averaged to a score from 0-100, resulting in the final WVSCI score for the stream. It is then classified as unimpaired, slightly impaired, moderately impaired, or severely impaired.

Metrics that decrease with stress	Standard (best value) X_{95}	X_{min}	Standardization formula (Appendix A.5, Equation 2; X=metric value)
Total taxa	21	0	score = 100 × (X/21)
EPT taxa	13	0	score = 100 × (X/13)
%EPT	91.9	0	score = 100 × (X/91.9)
Metrics that increase with stress	**Standard (best value) X_5**	**X_{max}**	**Standardization formula (Appendix A.5, Equation 3; X=metric value)**
%Chironomidae	0.98	100	score = 100 × [(100-X)/(100-0.98)]
% 2 dominant	36.0	100	score = 100 × [(100-X)/(100-36.0)]
HBI (family)	2.9	10	score = 100 × [(10-X)/(10-2.9)]
Final index score (SCI) for a site is determined by averaging the site's 6 standardized metric scores, using a maximum metric score of 100 for any metric whose individual score at a site may have exceeded 100.			

Figure 20. WV Final SCI: Metric Standard Values and Standardization Formulas. (A Stream Condition Index for West Virginia…)

Water Parameters

To get a better sense of the overall quality of the water in Arbuckle Creek, it is essential to take certain measurements of water parameters. In this present study, temperature, dissolved oxygen, conductivity, and pH were measured to better understand the stream. This was done using a YSI Pro DSS water quality meter. In order to obtain the measurements for each parameter, a probe was placed into the stream in different areas. The goal of these placements was to acquire a multitude of water quality characteristics, so 6 individual readings were taken at each stream site, totaling 18 readings per survey round and 36 readings with both survey rounds. Different areas were used to achieve larger variety and a more thorough picture of the stream's totality. The probe was placed in the water long enough to get average readings for each of the water parameters including temperature in Celsius, dissolved oxygen in mg/L^{-1}, conductivity in µS/cm, and pH; an average for each site was also taken. Because of the interconnectedness between these parameters, it is important to monitor them all at the same time, therefore, each measurement was taken consecutively.

Benthic Algae

The benthic algae, or periphyton, of the stream are another important aspect of the overall stream's health. Algae can be quality indicators of stream health because of their presence and absence being indicative of pollution or contaminants. In order to measure the benthic algae of Arbuckle Creek, the bbe BenthoTorch was used. The bbe BenthoTorch is a handheld device used for measuring the phytobenthic fluorescence in a stream. It is utilized through the quantification of chlorophyll-a fluorescence upon a multitude of rocks and sediment. "The bbe BenthoTorch uses the in vivo fluorescence of algal cells: the cell pigments are excited by LEDs of different colours (wavelengths) and emit red fluorescence light as a natural phenomenon with high sensitivity." ("Benthotorch.") The intensity of this fluorescence is used to calculate the amounts of different algae. In this present study, the algae analyzed were diatoms ($\mu g/cm^2$), green algae ($\mu g/cm^2$), and cyanobacteria or blue-green algae ($\mu g/cm^2$). This was completed through placing the calibrated bbe BenthoTorch into the water on a rock large enough for the surface of the Torch to lay as flat as possible, blocking out any permeating sunlight for each reading. Readings were taken in riffles when applicable. The readings took approximately 20 seconds each, with the three different types of algae being analyzed and computed. Four complete readings were taken at each survey site, with 12 total readings per survey round and 24 total readings altogether. The readings were then averaged to get a better understanding of the overall pattern of the different algal biomasses.

WAB Wadable Stream Assessment

The WVDEP has developed a habitat assessment form for the evaluation of the overall health of a stream. "The Visual-Based Habitat Assessment approach (VBHA) used in this protocol is adapted from USEPA's Rapid Bioassessment approach, which was refined from various applications across the country." (*Chapter II. Instructions for Assessing the…)* This form uses a multitude of components for this assessment, which were laid out in Chapter 1. "The approach focuses on integrating information from ten specific parameters (five evaluated within a defined stream reach and five evaluated beyond the stream reach) relating to the structure of the stream habitat." (*Chapter II. Instructions for Assessing the…)* In order to fulfill these elements, certain actions were taken for each aspect of the habitat assessment. To begin, the same reach of stream that is used for the benthic macroinvertebrate survey, the water quality parameters, and the algal biomass is utilized. This is to keep conformity in results and to give a clearer understanding about the certain stretch of stream analyzed by the other routes. Next, the forms are completed for a complete habitat assessment. Because there are so many aspects to the form, there are many different procedures that must be followed in order to obtain accurate results that are a quality portrayal of the streams condition.

- *Site Verification*- Whether the site is verified or not is answered; whether the site is kick sampleable or not; if the site is sampled and sample type is required; specific directions to the site needed; sketch of the assessment and comments are needed; the sketch shows North, flow direction, upper and lower end of reach, bug samples, water sample locations and latitude and longitude of the site.

- *Activities and Disturbances*- Erosion categorized as none to heavy; scouring categorized as none to heavy; odors rated from 0 to 4 or NR; local NPS pollution rated as none too obvious; specific NPS pollution required; point discharges asked for and described; stream reach activities and disturbances rated from low (1) to 4 (extreme) in activities including residential, recreational, agricultural, industrial, and management; site activities and disturbance notes required; watershed activities and disturbance notes required.
- *Physical and Sediment Characterization*- Stream width required; total habitat type percent coverage for reach asked for pool, run, and riffle; sediment odors, oils, and deposits are rated from none (0) to extreme (4); substrate particle layer profile required describing location, habitat type, substrate particle and sand and silt thickness; dominant substrate type and reach characterization table completed using reach location, habitat type, depth, dominant substrate 1, percent aerial coverage 1, dominant substrate 2, and percent aerial coverage 2.
- *Field Water and Riparian Vegetation Zone Measures*- Requires water quality sampling location; sonde and lab water method required; asks for temperature, pH, dissolved oxygen, and conductivity for a single water quality sample; rates water levels, water odors, surface “oils”, and turbidity from 0 to 4 or NR; requires current and past precipitation history; requires the dominant vegetation type in the reach; canopy, understory, ground cover, and barren soil are rated 0 (absent 0%) to 4 (very heavy >75%); stream surface shading percentages required; amphibian pool in the riparian area asked for; invasive species in the reach required.

- *Rapid Habitat Assessment: Riffle/Run*- Rates habitat parameters into scores from 0 (poor) to 20 (optimal); 1. Epifaunal substrate/available fish cover or the number of harder substrates available for insects, snails, and other organisms/ the natural variety of logs, sticks, etc. in the stream. 2. Embeddedness or how much or deeply the rocks in the stream are fixated into the bottom. 3. Velocity/depth regimes or "the availability of each of the four-primary current/depth combinations: (1) slow-deep, (2) slow-shallow, (3) fast-deep, and (4) fast-shallow" (*Chapter II. Instructions for Assessing the…)* 4. Channel alteration or large changes in the streams structure and shape. 5. Sediment deposition or the accumulation of sediment in the stream and how it may have affected the stream., 6. Riffle frequency or the number of riffles in the stream reach. 7. Channel flow status or how much the channel is filled with water; next determined from left to right and rated from 0 (poor) to 10 (optimal) is 8. Bank stability or how much the stream banks are eroded. 9. Bank vegetative protection or how much the bank is covered by native vegetation. 10. Width of undisturbed vegetation zone or the width or changes to the channel due to grazing or human disturbance; whether it is Optimal (160-200), Sub-Optimal (110-159), Marginal (60-109), and Poor (0-59) is classified.
- *Benthic and Fish Habitat, Aesthetic, and Remoteness Ratings*- Rates parameters into scores from 0 (poor) to 20 (optimal); Parameters include 1. Benthic macroinvertebrate substrate or the available habitat for benthic macroinvertebrates. 2. Fish habitat or the habitat for fish throughout the reach. 3. Trash index or the abundance of trash in the area, including in the stream and

around it. 4. Remoteness rating or how far it is from the road and other disturbances; asks about the potential for being a reference site; stressor information is required.

- *Wildlife Observations*- Requires any wildlife viewed to be recorded; includes Common Name, Genus Species, Comments, Number Observed, Invasive, Observer; mussel and trout observations required; asked about Observation Method, Species ID, Count, Size, Notes, and Photo Numbers.
- *Benthic Macroinvertebrate and Periphyton/Algae/Aquatic Plant Information*- Requires benthic sampling information including collection device and habitat type; sample comparability asked for; benthic sampling area depths required; requires the estimated percent composition for each substrate type including Bedrock, Boulder (BL), Cobble (CB), Coarse Gravel (CG), Fine Gravel (FG), Sand (SA), Silt and Fines (ST), and Clay (CL); Rates the abundance of periphyton, algae, mosses, and plants from 0 (none) to 4 (extreme) or NR (not rated).
- *Macroinvertebrate Observations Part 1*- Check marks required for any stream macroinvertebrates that were found including Plecoptera, Trichoptera, Ephemeroptera, Megaloptera, Coleoptera, and Odonata.
- *Macroinvertebrate Observations Part 2*- Check marks required for any stream macroinvertebrates that were found including Diptera, Gastropoda, Bivalva, Annelida, and Crustacea.
- *Landowners/Stakeholder Information, Recon, and Photos*- Landowner/Stakeholder information required; accessibility to the site required;

photography log required including Photo ID, Disk Photo Number, Stream Name, Photo Description, Date, and Photographer.

CHAPTER 3

Results and Discussion

Benthic Macroinvertebrates

After the history of mining across the landscapes of Minden and surrounding Arbuckle Creek, the benthic macroinvertebrate community and their health can have a direct correlation with the impacts from this long line of coal presence. Such results were seen in previous studies done in the area. **“**In all streams sampled that drain areas where large quantities of coal have been mined, the benthic macroinvertebrate community is impaired in comparison to rural parts of the study area where little or no coal has been mined since 1980.” (“Mountaintop Mining/Valley Fills in Appalachia…”) In this present study, six benthic macroinvertebrate surveys were performed at two separate times of the year, May, and September, at three different sites. The sites were known as Site One, Site Two, and Site Three, although each had defining characteristics that made the habitats different. Site One was considered the site closest to the Wastewater Treatment Plant as well as closest to the most significant AML impacts as seen previously in **Figure. 7**, in addition to the Shaffer Equipment Site. Site Two is the middle point between Rocklick Road and the Upstream Site, while Site Three is the closest to Rocklick Road and the mining impacts that occurred there, as well as the impacts from the Shaffer Equipment Site. The alterations in habitats naturally led to a difference in benthic communities in each of the six surveys performed. For each sample, around 200 bugs were identified to family following the protocol laid out in the previous chapters following the WVDEPs methodology. In the next tables, the results are as follows designated by Order, Family, Organisms, and their Total:

Site One Round One		
Order	**Family**	**Organisms**
Annelida	Oligochaeta	2
Diptera	Chironomidae	16
Diptera	Simuliidae	169
Plecoptera	Capniidae	9
Trichoptera	Hydropsychidae	4
	Total	**200**

Table 2.

Site Two Round One		
Order	**Family**	**Organisms**
Annelida	Oligochaeta	1
Coleoptera	Elmidae	1
Diptera	Chironomidae	51
Diptera	Simuliidae	123
Plecoptera	Capniidae	14
Trichoptera	Hydropsychidae	9
Trichoptera	Leptoceridae	1
	Total	**200**

Table 3.

Site Three Round One		
Order	**Family**	**Organisms**
Annelida	Oligochaeta	14
Coleoptera	Elmidae	4
Diptera	Chironomidae	37
Diptera	Limoniidae	1
Diptera	Simuliidae	120
Ephemeroptera	Heptagendiidae	3
Plecoptera	Capniidae	17
Trichoptera	Hydropsychidae	4
	Total	**200**

Table 4.

Site One Round Two		
Order	**Family**	**Organisms**
Diptera	Chironomidae	7
Ephemeroptera	Ephemerellidae	1
Ephemeroptera	Heptagendiidae	15
Trichoptera	Hydropsychidae	172
Diptera	Limoniidae	1
Neotaenioglossa	Pleuroceridae	4
	Total	**200**

Table 5.

Site Two Round Two		
Order	**Family**	**Organisms**
Annelida	Oligochaeta	9
Diptera	Chironomidae	3
Ephemeroptera	Heptagendiidae	15
Trichoptera	Hydropsychidae	189
	Total	**216**

Table 6.

Site Three Round Two		
Order	**Family**	**Organisms**
Annelida	Oligochaeta	15
Basommatophora	Physidae	1
Caudata	Plethodontidae	9
Diptera	Limoniidae	1
Sphaeriida	Sphaeriidae	3
Trichoptera	Hydropsychidae	1
	Total	**30**

Table 7.

Table 2. shows Site One Round One having a significant number of Simuliidae, while **Table 3.** and **Table 4.** also show a great number of Simuliidae. **Table 5.** showcases an alteration in this trend, showing high numbers of Hydropsychidae not only in this table but also in **Table 6.** and **Table 7.**, the trend continues.

Calculating the WVSCI score using the specified equations, Arbuckle Creek's macroinvertebrate impairment levels can be determined. After calculating the individual's metrics specific values, the SCI score can be determined for each site. Each of the metrics have an SCI score that is then averaged into a single score, which results in the overall WVSCI score for the stream. The WVSCI scores for each stream are as follows:

Site One Round One Metrics		
Metric	**Value**	**SCI Score**
Total Taxa	5	22.73
EPT Taxa	2	15.38
% EPT	6.5	7.28
% Chironomidae	8	93.59
% 2 Dominant Taxa	92.5	11.96
HBI	0.74	125.30
	SCI Score	**46.04**

Table 8.

Site Two Round One Metrics		
Metric	**Value**	**SCI Score**
Total Taxa	7	31.82
EPT Taxa	3	23.08
% EPT	12	13.44
% Chironomidae	25.5	75.79
% 2 Dominant Taxa	87	20.73
HBI	2.08	107.20
	SCI Score	**45.35**

Table 9.

Site Three Round One Metrics		
Metric	**Value**	**SCI Score**
Total Taxa	8	36.36
EPT Taxa	3	23.08
% EPT	12	13.44
% Chironimidae	18.5	82.91
% 2 Dominant Taxa	78.5	34.29
HBI	2.06	107.50
	SCI Score	**49.60**

Table 10.

Site One Round Two Metrics		
Metric	**Value**	**SCI Score**
Total Taxa	6	27.27
EPT Taxa	3	23.08
% EPT	94	105.26
% Chironimidae	3.5	98.17
% 2 Dominant Taxa	93.5	10.37
HBI	4.55	73.8
	SCI Score	**56.33**

Table 11.

Site Two Round Two Metrics		
Metric	**Value**	**SCI Score**
Total Taxa	4	18.18
EPT Taxa	2	15.38
% EPT	94.44	105.76
% Chironomidae	1.39	100.32
% 2 Dominant Taxa	94.44	8.86
HBI	4.81	70.3
	SCI Score	**53.13**

Table 12.

Individual Site WVSCI Scores Round One		
Site Number	**WVSCI Score**	**Impairment Level**
One	46.04	Slightly Impaired
Two	45.35	Moderately Impaired
Three	49.60	Slightly Impaired
Average	47.00	**Slightly Impaired**

Table 13.

Individual Site WVSCI Scores Round Two		
Site Number	**WVSCI Score**	**Impairment Level**
One	56.33	Slightly Impaired
Two	53.13	Slightly Impaired
Three	N/A	N/A
Average	54.73	**Slightly Impaired**

Table 14.

Table 8., Table 9., Table 10., Table 11., and Table 12. help to demonstrate the WVSCI scores developed for each of the sites based off of the appropriate values. **Table 13.** and **Table 14.** display the specific Impairment Level's for each of the Sites with their WVSCI score included. For the benthic macroinvertebrate community study, there were not any WVSCI scores above 56. While Site One and Site Three Round One were found to be Slightly Impaired, Site Two Round One was found to be Moderately Impaired. The majority of benthic species retrieved in the first three samples remained to be in the order Diptera and the family Simuliidae, with each sample having over 100 specimens of the family. The second most frequent benthic family for Round One for all three sample sites was Chironomidae in the order Diptera as well. For the sample sites in Round Two, the results differed. For Site One and Site Two, they were found to have WVSCI scores resulting in the streams being Slightly Impaired, which numbers just above 50. Site Three Round Two was inconclusive as there were less than 200 bugs able to be sampled

in the thalweg, so a WVSCI score was unable to be produced. This makes the majority of the streams Slightly Impaired, with only Site Two Round One being Moderately Impaired. When taking the average of the different rounds, there is only a slight difference. The difference shows that both sets of sampling data sets are deemed to be Slightly Impaired according to their WVSCI scores. Although Round Two's WVSCI scores were slightly higher than Round One's, they were not high enough to change impairment categories and therefore did not show a significant difference. Being that the majority of the streams have been appropriately labeled as Slightly Impaired, Arbuckle Creek can be concluded to be Slightly Impaired in terms of its benthic macroinvertebrate community.

An impaired stream can have many causes and simultaneously, many effects, making its catalysts for contamination essential to identify and understand. Sites One, Two, and Three Round One had copious numbers of Simuliidae or Black flies. While closely related to Chironomidae, which were the second highest number of organisms collected at each site, Black flies play a large role in the transference of organic matter through their litter-feeding habits while larvae, which is what was sampled most in the Round One site sampling's. "Because aquatic Diptera are to be found in many different ecological niches in both clean and polluted water and many species are highly selective in their choice of habitat, they constitute one of the most important groups of indicator organisms." (Ciadamidaro, et al.) This makes the Diptera an important part of this discussion as their presence does not simply indicate just one category, impaired or not. In one study in Sweden, the Black fly fecal pellets had such a significant impact as a food source for invertebrate species in the stream system that it also comes in such excess, it could potentially fertilize an entire river valley. (Currie, Douglas C., and Peter H. Adler.) In addition to their importance as a food source, "The immature stages not only play a dominant role in lotic communities by processing organic matter, but also are sensitive to anthropogenic inputs and are thus excellent barometers of water quality.” (Currie, Douglas C., and Peter H. Adler.) The larvae of Black flies are good at remaining in one place regardless of swift moving currents and do not usually remain incredibly tolerant to pollution, although the Diptera’s in general can be different. Chironomidae midges can be quality indicators of polluted waters and waters with low oxygen, which is why it is important to take water parameter measurements as well. Because the Simuliidae breed in such high numbers, this could be why the samples had such high numbers of larvae in them at one time yet still indicated that the stream was impaired. “Still other groups such as the Diptera, or true flies, are represented by forms which may be found in all types of stream habitats from the cleanest situation to the most polluted water.” (PAINE, JR., and GAUFIN.) This could explain why the numbers of both Diptera’s are a bit higher in the Round One samples. In addition to this advantage of having the numbers of Chironomids in the samples, “For example, larval Chironomidae occur in large numbers and provide a major prey base for many other invertebrates as well as for vertebrates such as fish, birds, bats, and amphibians.” (Courtney, G.W., and R.W. Merritt.) In the second round of samples, the majority of benthic macroinvertebrates were from the Hydropsychidae family or the Trichoptera order. “Caddisflies are important in aquatic ecosystems because they process organic material and are an important food source for fish.” (Chapter 10 Trichoptera) Similarly to the Diptera’s, they are found in running or lotic systems. Many caddisflies are relatively sensitive to pollution, but it is species dependent. In addition, common net spinning caddisflies are considered to be some of the most abundant and encountered species in lotic systems. (“Manual for the Identification of the Larvae of the Caddisfly General Hydropsyche…”) The common net-spinning caddisfly is a collector and filterer. Occurring in high numbers at both Site One and Site

Two, this could be because of the proximity to the Oak Hill Wastewater Treatment Plant. "In some situations, such as below pond outflows and downstream of sewage treatment plants, they can reach large densities." (Chapter 10 Trichoptera) This could explain why the large numbers of caddisflies were found at each of the sites even though they are both still regarded as technically impaired based on their WVSCI score. Not only this, but they are also considered to be one of the most abundant caddisfly larvae in lotic systems. ("Caddisfly Larvae (Order Trichoptera)") Site Three Round Two was unsuccessful due to a lack of benthic macroinvertebrates in the sample being much less than 200. Although the stream, which is later discussed, does not have the highest quality habitat, it remains that there is another reason behind the organisms' disappearances. During sampling, a total of nine Black-bellied salamanders were captured, as shown in **Figures 21 and 22.**, and identified. It is believed to be a Black-bellied salamander due to its location and presence specifically in Fayette County, their aquatic habits, the small and slender spots on their sides, and the distinct markings across their bodies.

Figures 21 and 22. Black-bellied salamanders at Site Three; Images produced by Sarah Simonton.

In addition, they are common in aquatic systems. Past research has developed into newer knowledge about the Black-bellied salamanders' range, "Research since Bishop's work has extended the range north into Allegheny and Franklin counties, Virginia, and upstream in the New River in West Virginia to its confluence with the Gauley River in Fayette County." (*Virginia Herpetological Society*) Because this is the farthest site from the initial Shaffer Equipment Site, this could also be why it has the highest WVSCI score in Round One. The presence was unusual due to the fact that the previous sites did not experience this surge in salamanders. "Black-bellied Salamanders are found in swiftly flowing small streams with numerous boulders and waterfalls." (*Black-Bellied Salamander)* This could be a reasoning for their presence specifically at Site Three as it consisted mostly of boulders and waterfalls as seen previously in **Figure 16**. Salamanders forage on benthic macroinvertebrates, making the area that was sampled potentially a feeding opportunity for the species. "In West Virginia, in the northern extreme of the range of Black-bellied Salamanders, larvae prey on larval dipterans and trichopterans, and plecopteran and ephemeropteran nymphs, as well as several other insect taxa (Mills, 1996)." (*Virginia Herpetological Society)* This could explain why there were so many salamanders present and so few benthic macroinvertebrates, they primarily eat what was mostly sampled there, Trichoptera and Diptera. "Juveniles tend to stay in fast moving riffles of the streams." (*Black-Bellied Salamander*) This is could additionally explain the salamander's appearance as many of them were young specimen and eggs were hatched in the later parts of summer. Because water parameters and habitat are also indicators of water quality, they are also studied and examined here.

Water Parameters

Not only are benthic macroinvertebrates essential for studying the health of Arbuckle Creek after its historic mining past and proximity to the Wastewater Treatment Plant, but the water parameters are also important to note. In this present study, temperature (Celsius), dissolved oxygen (mg/L), conductivity (SPC-uS/cm), and pH are measured to identify any stressors that could possibly be affecting Arbuckle Creek and its equilibrium. Six measurements were taken using the water meter and then averaged together to create a more consistent pattern. An additional round of samples was necessary due to the fact that during the sampling of Round Two Water Parameters, the conductivity did not work and was not performing properly in the field while the other parameters were normal. The following tables represent the rounds of water parameter data and their averages:

Round One Water Parameters				
	Temperature (Celsius)	Dissolved Oxygen (DO (mg/L))	Conductivity (SPC-uS/cm)	pH (pH)
Site One				
	15.6	8.67	269.50	7.81
	14.1	9.20	249.30	7.80
	15.7	8.67	268.60	7.75
	14.6	9.19	4.60	7.70
	15.1	8.97	19.50	7.71
	14.9	9.02	5.10	7.70
Site Two				
	16.6	8.70	259.30	8.00
	16.6	8.67	259.30	7.95
	16.6	8.69	259.60	7.94
	15.8	9.07	267.70	7.96
	16.4	8.94	262.60	7.99
	16.5	8.92	262.00	7.98
Site Three				
	14.8	9.54	275.10	8.37
	14.9	9.56	280.20	8.34
	14.8	9.51	276.40	8.31
	15.0	9.55	279.10	8.32
	15.0	9.54	278.20	8.31
	15.0	9.54	277.50	8.29

Table 15.

Round One Average Water Parameters				
	Temperature	Dissolved Oxygen	Conductivity	pH
	(Celsius)	(DO (mg/L))	(SPC-uS/cm)	(pH)
Site One	15.0	8.95	136.10	7.75
Site Two	16.4	8.83	261.75	7.97
Site Three	14.9	9.54	277.75	8.32

Table 16.

Round Two Water Parameters				
	Temperature	Dissolved Oxygen	Conductivity	pH
	(Celsius)	(DO (mg/L))	(SPC-uS/cm)	(pH)
Site One				
	20.2	9.03	18.70	7.37
	19.9	9.15	18.50	7.39
	19.7	9.31	18.50	7.42
	19.7	9.33	18.40	7.44
	19.7	9.23	18.40	7.46
	19.7	9.31	18.30	7.48
Site Two				
	17.1	9.58	19.40	7.37
	16.6	9.68	19.40	7.34
	15.3	9.93	19.30	7.29
	15.8	9.90	19.30	7.26
	16.1	9.82	19.20	7.23
	17.0	9.60	19.20	7.23
Site Three				
	16.4	9.58	18.10	7.61
	15.9	9.78	18.30	7.50
	16.0	9.70	18.60	7.35
	15.9	9.80	18.90	7.20
	15.8	9.86	19.20	7.12
	15.8	9.84	19.30	7.11

Table 17.

Round Two Average Water Parameters				
	Temperature	Dissolved Oxygen	Conductivity	pH
	(Celsius)	(DO (mg/L))	(SPC-uS/cm)	(pH)
Site One	19.8	9.23	18.47	7.43
Site Two	16.3	9.75	19.3	7.29
Site Three	16.0	9.76	18.73	7.32

Table 18.

Round Three Water Parameters				
	Temperature	Dissolved Oxygen	Conductivity	pH
	(Celsius)	(DO (mg/L))	(SPC-uS/cm)	(pH)
Site One				
	7.6	9.79	430.30	7.98
	7.6	9.69	430.40	7.98
	7.6	9.62	430.4	7.98
	7.6	9.83	430.10	7.98
	7.6	9.63	429.90	7.96
	7.5	10.06	427.80	7.99
Site Two				
	6.8	10.00	365.80	8.02
	7.1	9.76	371.80	7.96
	6.9	10.08	374.60	8.10
	6.9	10.09	375.70	8.12
	6.8	10.09	380.40	8.17
	6.8	10.00	380.70	8.01
Site Three				
	6.3	11.47	368.80	8.47
	6.3	11.49	368.60	8.44
	6.3	11.49	369.30	8.43
	6.4	11.42	368.70	8.42
	6.5	11.33	369.00	8.41
	6.4	11.32	367.90	8.38

Table 19.

Round Three Average Water Parameters				
	Temperature (Celsius)	Dissolved Oxygen (DO (mg/L))	Conductivity (SPC-uS/cm)	pH (pH)
Site One	7.6	9.77	429.82	7.98
Site Two	6.9	10	374.83	8.06
Site Three	6.4	11.42	368.72	8.43

Table 20.

Table 15. and **Table 16.** shows Water Parameters for Round One and their values as well as their averages to get a better view of the overall trends occurring in the data. **Table 17.** and **Table 18.** display Water Parameters for Round Two, also with averages shown. **Table 19.** and **Table 20.** showcase Water Parameters for Round Three and their averages. Overall, the temperature shows that the water was relatively warm the first two samples, with averages over 20 and 15 degrees Celsius. Because temperature has such a great effect on the environment and its organisms, it is a key component of the system to monitor. Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases." ("5.3 Temperature.") The dissolved oxygen of Round One shows the highest levels at Site Three and the lowest at Site Two. The DO for Round Two had higher levels in general across the stream, with Site One having the lowest and Site Three still having the highest. Round Three Water Parameters had the highest DO averages, with Site Three having an average of 11.42. The DO is affected by many things, including temperature, so while that could influence its fluctuations, there could be other explanations. It is important to note that DO is essential to monitor due to its importance in aiding oxygen consumption. "The rate of oxygen consumption in a stream is affected by a number of variables: temperature, pH, the presence of certain kinds of microorganisms, and the type of organic and

inorganic material in the water." ("Manual for the Identification of the Larvae of the Caddisfly Genera Hydropsyche…")

Constituents	Excellent	Good	Marginal	Poor	Units
Alkalinity	> 40	21 - 40	5 - 20	< 5	ppm
pH	7.6 - 9.0	6.5 - 7.5	6.0 - 6.5	< 6.0 > 9.0	
Dissolved oxygen	> 10.0	7.0 - 10.0	7.0 - 5.0	< 5.0	ppm
Conductivity	< 150	150 - 300	300 - 500	> 500	µs/cm
Nutrients N/P	< 1.0	1.0 - 2.0	2.0 - 4.0	> 4.0	ppm
Metals	< 1.0	1.0 - 1.5	1.6 - 3.0	> 3.0	ppm
Bacteria	< 100	100 - 200	201 - 400	> 400	CFU

Figure 23. Water parameters and their ideal to unideal measurements. ("Water Quality.")

Because the biochemical oxygen demand also affects the amount of dissolved oxygen is in a stream, it is necessary to sample in Arbuckle Creek near the Wastewater Treatment Plant. Such conditions as low DO or high DO can result in the death of organisms as well. "Sources of BOD include leaves and woody debris; dead plants and animals; animal manure; effluents from pulp and paper mills, wastewater treatment plants, feedlots, and food-processing plants; failing septic systems; and urban stormwater runoff." ("Manual for the Identification of the Larvae of the Caddisfly Genera Hydropsyche…") Because failing septic systems are so problematic in Minden, this could explain why the DO concentrations are high. Because temperature has such an effect on DO, this could be why there are such fluctuations as well. Conductivity is important to monitor in water bodies as it can greatly impact aquatic life. Conductivity can be affected by many factors such as temperature, the warmer the water, the higher the conductivity would be. "Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge)." ("5.9 Conductivity.") "A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity." ("5.9 Conductivity.") While Site One Round One had the lowest conductivity and therefore the closest to the “excellent” condition as regarded by the EPA in **Figure 23.**, it could have been because of some outliers that were present in the sample. Additionally, Site Two and Site Three Round One were considered to be “good”. Conductivity averages were so low at all three sites for the second round of samples, it is difficult to explain them other than the fact that the meter was not working properly and needed to be calibrated again for conductivity. For Sites One, Two, and Three Round Three, Site One had the highest, indicating it was considered “Marginal” at best, while the other two sites were considered to be “Marginal” as well. Again, this could be explained by the fact that Minden has a history and current issue with failing septic systems in the area. This would have a direct effect on conductivity in Arbuckle Creek. In another study in WV, it was found that “conductivity is a poor primary indicator of aquatic health in certain reaches of central Appalachian streams.” (Hart, et al.) So, while still a critical measurement in the balance of the aquatic system, it can be difficult to navigate its quality of indication. pH was analyzed as well, which could also be affected by a number of factors. The pH averages for most of the samples would be considered “excellent” according to the EPA in **Figure 23.**, although some in the Round Two Water Parameters were only considered “good” due to them being lower. Overall, the water parameters tell us that Arbuckle Creek could be affected by the failing septic systems in the area, as well as the Oak Hill Wastewater Treatment Plant.

Benthic Algae

Periphyton are important to analyze because not only do being primary producers make them essential components to the overall environment and its inhabitants, but that makes it more directly affected by physical and chemical alterations. (“5.3 Temperature.”) During the analysis of the diatoms, it is important to note they are relatively sensitive in terms of tolerances. “Diatoms respond to a certain number of environmental and biological variables (light, water temperature, substratum type, water velocity, mineral composition and content, nutrient availability, grazing) by shifting their community composition and growth forms. Because of their sensitivity, they may be reliable indicator organisms." (Likens, G.E.) Not only are diatoms important, but green and blue-green algae or cyanobacteria are also essential to analyze when looking at the components and health of the stream as a whole due to them having direct implications upon many interactions and inhabitants in aquatic systems.

They were sampled as follows:

Round One Benthic Algae			
	Diatoms (µg/cm2)	Green Algae (µg/cm2)	Cyanobacteria (µg/cm2)
Site One			
	3.75	4.06	2.39
	5.80	0.00	3.57
	3.66	3.99	2.67
	1.10	3.18	0.97
Site Two			
	0.28	0.11	0.12
	0.58	0.86	0.40
	0.30	1.50	0.27
	1.66	2.33	1.66
Site Three			
	1.11	0.00	1.23
	3.34	1.27	2.20
	3.34	1.27	2.20
	0.24	0.00	0.27

Table 21.

Round One Average Benthic Algae			
	Diatoms (µg/cm2)	Green Algae (µg/cm2)	Cyanobacteria (µg/cm2)
Site One	3.58	2.81	2.4
Site Two	0.71	1.2	0.61
Site Three	2.01	0.64	1.48

Table 22.

Round Two Benthic Algae			
	Diatoms (µg/cm2)	Green Algae (µg/cm2)	Cyanobacteria (µg/cm2)
Site One			
	3.45	0.00	1.27
	0.98	0.00	0.16
	0.81	1.40	0.32
	3.65	0.00	3.93
Site Two			
	7.27	0.00	3.61
	3.09	0.00	0.97
	7.27	0.00	2.61
	3.76	0.00	2.16
Site Three			
	0.39	0.00	0.22
	3.41	0.33	1.77
	1.87	0.00	0.91
	1.93	0.00	1.53

Table 23.

Round Two Average Benthic Algae			
	Diatoms (µg/cm2)	Green Algae (µg/cm2)	Cyanobacteria (µg/cm2)
Site One	2.22	0.35	1.42
Site Two	5.35	0.00	2.34
Site Three	1.90	0.08	1.11

Table 24.

Table 21. and **Table 22.** display Round One Benthic Algae data and their averages while **Table 23.** and **Table 24.** showcase Round Two Benthic Algae data and their averages. Because diatoms were on average the most abundant of the three periphyton sampled at Site One, this could indicate something changing in the nutrients or environmental composition at the other sites. The cyanobacteria or blue-green algae can be indicative of degraded environments, although the numbers were not high like the diatoms, they were higher than the green algae. This could be because of temperature, as algae blooms more during the summer and is heavily

affected by temperature. In addition, “The nutrients that cause an algae “bloom” come from excess or misapplied lawn and agricultural fertilizers, runoff from pastures, feedlots, lawns and golf courses, discharges from non-regulated (residential) sewage treatment systems and many other sources of organic nutrients.” (*Swimming, Boating, and Harmful Algal Blooms*) Although there weren’t any clear patterns throughout the algal data, it is important to compare the numbers and findings to the benthic macroinvertebrates, water parameters, and habitat data as using the algal torch is still a newer design and could be implemented in other experiments when utilized properly.

WAB Wadable Stream Assessment

The overall habitat is a component of Arbuckle Creek that has been deeply impacted by its history of mining. Not only does mining have a direct negative impact on the mountains from blast sites and mountain top removal, but leftover and waste from coal and gob piles and mining sites is detrimental to the environment and its inhabitants. As previously mentioned in other studies, the Shaffer Equipment Site also has had a direct impact on the Minden area and Arbuckle Creek in particular, so its habitat being affected would be expected. The results are as follows:

Wadeable Stream Assessment Habitat Scores		
Site One Round One		
Habitat Parameter	**Score**	**Category**
Epifaunal Substrate/Fish Cover	11	Sub-optimal
Embeddedness	6	Marginal
Velocity/Depth Regimes	8	Marginal
Channel Alteration	13	Sub-optimal
Sediment Deposition	5	Poor
Riffle Frequency	17	Optimal
Channel Flow Status	11	Sub-optimal
Bank Stability	8	Marginal
Bank Vegetative Protection	9	Marginal
Width of Undisturbed Veg. Zone	0	Poor
Total	**88**	**Marginal**

Table 25.

Wadeable Stream Assessment Habitat Scores		
Site Two Round One		
Habitat Parameter	**Score**	**Category**
Epifaunal Substrate/Fish Cover	8	Marginal
Embeddedness	13	Sub-optimal
Velocity/Depth Regimes	13	Sub-optimal
Channel Alteration	13	Sub-optimal
Sediment Deposition	13	Sub-optimal
Riffle Frequency	8	Marginal
Channel Flow Status	13	Sub-optimal
Bank Stability	8	Marginal
Bank Vegetative Protection	8	Marginal
Width of Undisturbed Veg. Zone	8	Marginal
Total	**105**	**Marginal**

Table 26.

Wadeable Stream Assessment Habitat Scores		
Site Three Round One		
Habitat Parameter	**Score**	**Category**
Epifaunal Substrate/Fish Cover	11	Sub-optimal
Embeddedness	8	Marginal
Velocity/Depth Regimes	11	Sub-optimal
Channel Alteration	20	Optimal
Sediment Deposition	13	Sub-optimal
Riffle Frequency	16	Optimal
Channel Flow Status	13	Sub-optimal
Bank Stability	15	Sub-optimal
Bank Vegetative Protection	18	Optimal
Width of Undisturbed Veg. Zone	19	Optimal
Total	**144**	**Sub-optimal**

Table 27.

Wadeable Stream Assessment Habitat Scores		
Site One Round Two		
Habitat Parameter	**Score**	**Category**
Epifaunal Substrate/Fish Cover	8	Marginal
Embeddedness	5	Poor
Velocity/Depth Regimes	8	Margnial
Channel Alteration	13	Sub-optimal
Sediment Deposition	5	Poor
Riffle Frequency	13	Sub-optimal
Channel Flow Status	13	Sub-optimal
Bank Stability	8	Marginal
Bank Vegetative Protection	9	Marginal
Width of Undisturbed Veg. Zone	0	Poor
Total	**82**	**Marginal**

Table 28.

Wadeable Stream Assessment Habitat Scores		
Site Two Round Two		
Habitat Parameter	**Score**	**Category**
Epifaunal Substrate/Fish Cover	8	Marginal
Embeddedness	13	Sub-optimal
Velocity/Depth Regimes	13	Sub-optimal
Channel Alteration	13	Sub-optimal
Sediment Deposition	13	Sub-optimal
Riffle Frequency	8	Marginal
Channel Flow Status	13	Sub-optimal
Bank Stability	8	Marginal
Bank Vegetative Protection	8	Marginal
Width of Undisturbed Veg. Zone	8	Marginal
Total	**105**	**Marginal**

Table 29.

Wadeable Stream Assessment Habitat Scores		
Site Three Round Two		
Habitat Parameter	**Score**	**Category**
Epifaunal Substrate/Fish Cover	13	Sub-optimal
Embeddedness	5	Poor
Velocity/Depth Regimes	10	Marginal
Channel Alteration	20	Optimal
Sediment Deposition	15	Sub-optimal
Riffle Frequency	16	Optimal
Channel Flow Status	13	Sub-optimal
Bank Stability	15	Sub-optimal
Bank Vegetative Protection	18	Optimal
Width of Undisturbed Veg. Zone	20	Optimal
Total	**145**	**Sub-optimal**

Table 30.

Starting with **Table 25.**, the Wadeable Stream Assessment Habitat Scores for each Site are showcased and given a categorical rating of “Optimal”, “Sub-optimal”, “Marginal”, and “Poor”. **Table 26.** and **Table 27.** also show the Habitat Scores for each Site and their categorical rating in terms of the Sites Round One scores. **Table 28.**, **Table 29.**, and **Table 30**

\. display the Wadeable Stream Assessment Habitat Scores for the Sites for Round Two scorings. As seen, there was not a site during either sampling round that got an "Optimal" rating. The highest habitat rating obtained was Site Three Round Two with a score of 145, although it unexpectedly did not get evaluated for a WVSCI score, possibly due to salamander predation. The lowest habitat score obtained was Site One Round Two with a score of 82 resulting in a Marginal rating, such were the other sites excluding both rounds of Site Three. The habitat scores were the result of an accumulation of habitat parameter measurements done in the field. Based on those calculations, a number indicating an average and a rating could then be quantified. These habitat parameters were also showcased in other methodologies within the WAB form. They include Dominant Substrate Type, Stream Bank Cover Type, and the Percent Composition for Each Substrate. Within these parameters, it is revealed what each site habitat was like in terms of their substrate and bank compositions, which greatly affect not only the organisms within the stream but the overall habitat surrounding the stream as well. The following figures showcase the different sites and rounds and their respective habitat information:

Site One Round One

Dominant Substrate Type - Reach Characterization (See Ta

Reach Location (m)[1]	Habitat Type[2]	Depth (m)	Dom Sub 1[3]	% age 1[4]	Dom Sub 2[3]	% age 2[4]
5	RF	15 in	BR	40%	BL	60%
10	RF	8 in	BL	60%	CB	40%
15	PL	10 in	BL	80%	CB	20%
20	RN	7 in.	BL	70%	CB	30%
25	PL	9 in.	BL	70%	CB	30%
30	RN	5 in.	BR	60%	BL	40%

Figure 24.

Stream Bank/Riparian Buffer Zone Vegetation/Cover Type

→→ What is the dominant vegetation type in the reach?
☐ Deciduous ☐ Coniferous (*i.e.*, Spruce, Pine, Hemlock, Rhododendron)
☐ Mixed Deciduous (>10-49% Coniferous) ☐ Mixed Coniferous (>10-49% Deciduous)

Score Codes: 0=Absent (0%) 1=Sparse (0-<10%) 2=Moderate (10-40%) 3=Heavy (>40-75%) 4=Very Heavy (>75%)

Left & Right Bank While Facing Down-Stream	*Determined Within The 1st 18 m (60 Ft) From Stream Edge*	Canopy (>5 M High) (>15 Feet)	Understory (0.5 – 5 M High) (1.5-15 Feet)	Ground Cover (<0.5 M High) (≈1.5 Feet)	Bare / Barren Soil
		Big Trees such as Sycamore, Oaks, Maples, Box Elder, River Birch, Hemlock	*Small trees and shrubby Vegetation such as Willow, Alder, Knotweed (blue devil), Rhododendron, Wingstem*	*Ferns, Grasses, Mosses, Wildflowers*	*Exposed soil surface, Readily erodible – not rock faces or asphalt roads*
LEFT (18 m) (≈60 ft.)		4	4	4	0
RIGHT (18 m) (≈60 ft.)		4	4	4	0

Stream Surface Shading (%)	Indicate % based on cloudless day in summer at noon. Place a √ in box that applies.						
Fully Exposed (0-25%)		Partly Shaded (25-50%)		Partly Exposed (50-75%)		Fully Shaded (75-100%)	✓

Figure 25.

Inorganic Substrate (1 m² Of Kicked Substrate)	Class Codes	Size Class	% Composition
Bedrock	BR	Smooth surface rock/hardpan (>4000 mm – bigger than a car)	60 %
Boulder (BL)	BL	Basketball to car (>250-4000 mm)	20 %
Cobble (CB)	CB	Tennis ball to basketball (>64-250 mm)	10 %
Coarse Gravel (CG)	CG	Marble to tennis ball (>16-64 mm)	0 %
Fine Gravel (FG)	FG	Ladybug to marble (>2-16 mm)	0 %
Sand (SA)	SA	Gritty – up to ladybug (>0.06-2 mm)	5 %
Silt & Fines (ST)	ST	Fine – not gritty (<0.06 mm)	0 %
Clay (CL)	CL	Slick/ hard clay or hard-pan clay	0 %

Enter estimated % composition for each substrate type. ****MACS SITES: estimate over entire 100-meter stream reach.****

Figure 26.

Site Two Round One

Dominant Substrate Type - Reach Characterization (See Ta						
Reach Location (m)[1]	Habitat Type[2]	Depth (m)	Dom Sub 1[3]	% age 1[4]	Dom Sub 2[3]	% age 2[4]
10	rf	3in.	CB	90%	CG	10%
15	rf	5in	CG	80%	FG	20%
20	rf	3in	SA	60%	ST	40%
25	rn	5in	CG	90%	ST	10%
30	rf	5in	FG	80%	SA	20%

Figure 27.

Stream Bank/Riparian Buffer Zone Vegetation/Cover Type

→ What is the dominant vegetation type in the reach?
☒ Deciduous ☐ Coniferous (*i.e.*, Spruce, Pine, Hemlock, Rhododendron)
☐ Mixed Deciduous (>10-49% Coniferous) ☐ Mixed Coniferous (>10-49% Deciduous)

Score Codes: 0=Absent (0%) 1=Sparse (0-<10%) 2=Moderate (10-40%) 3=Heavy (>40-75%) 4=Very Heavy (>75%)

Left & Right Bank While Facing Down-Stream	*Determined Within The 1st 18 m (60 Ft) From Stream Edge*	Canopy (>5 M High) (>15 Feet)	Understory (0.5 – 5 M High) (1.5-15 Feet)	Ground Cover (<0.5 M High) (≈1.5 Feet)	Bare / Barren Soil
		Big Trees such as Sycamore, Oaks, Maples, Box Elder, River Birch, Hemlock	*Small trees and shrubby Vegetation such as Willow, Alder, Knotweed (blue devil), Rhododendron, Wingstem*	*Ferns, Grasses, Mosses, Wildflowers*	*Exposed soil surface, Readily erodible – not rock faces or asphalt roads*
LEFT (18 m) (≈60 ft.)		2	2	4	1
RIGHT (18 m) (≈60 ft.)		3	3	4	1

Stream Surface Shading (%)	Indicate % based on cloudless day in summer at noon. Place a √ in box that applies.						
Fully Exposed (0-25%)		Partly Shaded (25-50%)	✓	Partly Exposed (50-75%)		Fully Shaded (75-100%)	

Figure 28.

Inorganic Substrate (1 m² Of Kicked Substrate)	Class Codes	Size Class	% Composition
Bedrock	BR	Smooth surface rock/hardpan (>4000 mm – bigger than a car)	5 %
Boulder (BL)	BL	Basketball to car (>250-4000 mm)	40 %
Cobble (CB)	CB	Tennis ball to basketball (>64-250 mm)	40 %
Coarse Gravel (CG)	CG	Marble to tennis ball (>16-64 mm)	0 %
Fine Gravel (FG)	FG	Ladybug to marble (>2-16 mm)	5 %
Sand (SA)	SA	Gritty – up to ladybug (>0.06-2 mm)	5 %
Silt & Fines (ST)	ST	Fine – not gritty (<0.06 mm)	10 %
Clay (CL)	CL	Slick/ hard clay or hard-pan clay	0 %
Enter estimated % composition for each substrate type.	****MACS SITES: estimate over entire 100-meter stream reach.****		

Figure 29.

Site Three Round One

Dominant Substrate Type - Reach Characterization (See Ta						
Reach Location (m)[1]	Habitat Type[2]	Depth (m)	Dom Sub 1[3]	% age 1[4]	Dom Sub 2[3]	% age 2[4]
5	RF	15in	BR	40%	BL	60%
10	RF	8in	BL	60%	CB	40%
15	PL	10in	BL	80%	CB	20%
20	RN	7in.	BL	70%	CB	30%
25	PL	9in.	BL	70%	CB	30%
30	RN	5in.	BR	60%	BL	40%

Figure 30.

Stream Bank/Riparian Buffer Zone Vegetation/Cover Type					
→ → What is the dominant vegetation type in the reach? ☐ Deciduous ☐ Coniferous (*i.e.*, Spruce, Pine, Hemlock, Rhododendron) ☐ Mixed Deciduous (>10-49% Coniferous) ☐ Mixed Coniferous (>10-49% Deciduous)				Score Codes: 0=Absent (0%) 1=Sparse (0-<10%) 2=Moderate (10-40%) 3=Heavy (>40-75%) 4=Very Heavy (>75%)	
Left & Right Bank While Facing Down-Stream	*Determined Within The 1st 18 m (60 Ft) From Stream Edge*	Canopy (>5 M High) (>15 Feet)	Understory (0.5 – 5 M High) (1.5-15 Feet)	Ground Cover (<0.5 M High) (≈1.5 Feet)	Bare / Barren Soil
		Big Trees such as Sycamore, Oaks, Maples, Box Elder, River Birch, Hemlock	*Small trees and shrubby Vegetation such as Willow, Alder, Knotweed (blue devil), Rhododendron, Wingstem*	*Ferns, Grasses, Mosses, Wildflowers*	*Exposed soil surface, Readily erodible – not rock faces or asphalt roads*
LEFT (18 m) (≈60 ft.)		4	4	4	0
RIGHT (18 m) (≈60 ft.)		4	4	4	0
Stream Surface Shading (%)	Indicate % based on cloudless day in summer at noon. Place a √ in box that applies.				
Fully Exposed (0-25%)		Partly Shaded (25-50%)		Partly Exposed (50-75%)	
Fully Shaded (75-100%)	✓				

Figure 31.

Inorganic Substrate (1 m² Of Kicked Substrate)	Class Codes	Size Class	% Composition
Bedrock	BR	Smooth surface rock/hardpan (>4000 mm – bigger than a car)	60 %
Boulder (BL)	BL	Basketball to car (>250-4000 mm)	20 %
Cobble (CB)	CB	Tennis ball to basketball (>64-250 mm)	10 %
Coarse Gravel (CG)	CG	Marble to tennis ball (>16-64 mm)	0 %
Fine Gravel (FG)	FG	Ladybug to marble (>2-16 mm)	0 %
Sand (SA)	SA	Gritty – up to ladybug (>0.06-2 mm)	5 %
Silt & Fines (ST)	ST	Fine – not gritty (<0.06 mm)	0 %
Clay (CL)	CL	Slick/ hard clay or hard-pan clay	0 %
Enter estimated % composition for each substrate type. ****MACS SITES: estimate over entire 100-meter stream reach.****			

Figure 32.

Site One Round Two

Dominant Substrate Type - Reach Characterization (See Ta						
Reach Location (m)[1]	Habitat Type[2]	Depth (m)	Dom Sub 1[3]	% age 1[4]	Dom Sub 2[3]	% age 2[4]
5	rf	.25	BR	70%	FG	30%
15	rn	9in.	BR	90%	ST	10%
25	pl	5in	BR	90%	ST	10%

Figure 33.

Stream Bank/Riparian Buffer Zone Vegetation/Cover Type

→→ What is the dominant vegetation type in the reach?
☑ Deciduous ☐ Coniferous (*i.e.*, Spruce, Pine, Hemlock, Rhododendron)
☐ Mixed Deciduous (>10-49% Coniferous) ☐ Mixed Coniferous (>10-49% Deciduous)

Score Codes: 0=Absent (0%) 1=Sparse (0-<10%) 2=Moderate (10-40%) 3=Heavy (>40-75%) 4=Very Heavy (>75%)

Left & Right Bank While Facing Down-Stream	*Determined Within The 1st 18 m (60 Ft) From Stream Edge*	Canopy (>5 M High) (>15 Feet)	Understory (0.5 – 5 M High) (1.5-15 Feet)	Ground Cover (<0.5 M High) (≈1.5 Feet)	Bare / Barren Soil
		Big Trees such as Sycamore, Oaks, Maples, Box Elder, River Birch, Hemlock	*Small trees and shrubby Vegetation such as Willow, Alder, Knotweed (blue devil), Rhododendron, Wingstem*	*Ferns, Grasses, Mosses, Wildflowers*	*Exposed soil surface, Readily erodible – not rock faces or asphalt roads*
LEFT (18 m) (≈60 ft.)		1	1	4	0
RIGHT (18 m) (≈60 ft.)		4	3	4	0

Stream Surface Shading (%)	Indicate % based on cloudless day in summer at noon. Place a √ in box that applies.						
Fully Exposed (0-25%)		Partly Shaded (25-50%)		Partly Exposed (50-75%)	✓	Fully Shaded (75-100%)	

Figure 34.

Inorganic Substrate (1 m² Of Kicked Substrate)	Class Codes	Size Class	% Composition
Bedrock	BR	Smooth surface rock/hardpan (>4000 mm – bigger than a car)	0 %
Boulder (BL)	BL	Basketball to car (>250-4000 mm)	0 %
Cobble (CB)	CB	Tennis ball to basketball (>64-250 mm)	40 %
Coarse Gravel (CG)	CG	Marble to tennis ball (>16-64 mm)	40 %
Fine Gravel (FG)	FG	Ladybug to marble (>2-16 mm)	10 %
Sand (SA)	SA	Gritty – up to ladybug (>0.06-2 mm)	10 %
Silt & Fines (ST)	ST	Fine – not gritty (<0.06 mm)	0 %
Clay (CL)	CL	Slick/ hard clay or hard-pan clay	0 %
Enter estimated % composition for each substrate type.		*****MACS SITES*: estimate over entire 100-meter stream reach.****	

Figure 35.

Site Two Round Two

Dominant Substrate Type - Reach Characterization (See Ta						
Reach Location (m)[1]	Habitat Type[2]	Depth (m)	Dom Sub 1[3]	% age 1[4]	Dom Sub 2[3]	% age 2[4]
10	rf	5in	CB	70%	CG	30%
15	rf	7in	CB	60%	CG	40%
30	rn	9in	CG	60%	FG	40%
35	pl	10in	FG	50%	SA	50%

Figure 36.

Stream Bank/Riparian Buffer Zone Vegetation/Cover Type

→/→ What is the dominant vegetation type in the reach?
☑ Deciduous ☐ Coniferous (*i.e.*, Spruce, Pine, Hemlock, Rhododendron)
☐ Mixed Deciduous (>10-49% Coniferous) ☐ Mixed Coniferous (>10-49% Deciduous)

Score Codes: 0=Absent (0%) 1=Sparse (0-<10%) 2=Moderate (10-40%) 3=Heavy (>40-75%) 4=Very Heavy (>75%)

Left & Right Bank While Facing Down-Stream	*Determined Within The 1st 18 m (60 Ft) From Stream Edge*	Canopy (>5 M High) (>15 Feet)	Understory (0.5 – 5 M High) (1.5-15 Feet)	Ground Cover (<0.5 M High) (≈1.5 Feet)	Bare / Barren Soil
		Big Trees such as Sycamore, Oaks, Maples, Box Elder, River Birch, Hemlock	*Small trees and shrubby Vegetation such as Willow, Alder, Knotweed (blue devil), Rhododendron, Wingstem*	*Ferns, Grasses, Mosses, Wildflowers*	*Exposed soil surface, Readily erodible – not rock faces or asphalt roads*
LEFT (18 m) (≈60 ft.)		1	1	4	0
RIGHT (18 m) (≈60 ft.)		4	3	4	0

Stream Surface Shading (%) — Indicate % based on cloudless day in summer at noon. Place a √ in box that applies.

Fully Exposed (0-25%)		Partly Shaded (25-50%)		Partly Exposed (50-75%)		Fully Shaded (75-100%)	
	√				√		

Figure 37.

Inorganic Substrate (1 m² Of Kicked Substrate)	Class Codes	Size Class	% Composition
Bedrock	BR	Smooth surface rock/hardpan (>4000 mm – bigger than a car)	0 %
Boulder (BL)	BL	Basketball to car (>250-4000 mm)	0 %
Cobble (CB)	CB	Tennis ball to basketball (>64-250 mm)	40 %
Coarse Gravel (CG)	CG	Marble to tennis ball (>16-64 mm)	40 %
Fine Gravel (FG)	FG	Ladybug to marble (>2-16 mm)	10 %
Sand (SA)	SA	Gritty – up to ladybug (>0.06-2 mm)	10 %
Silt & Fines (ST)	ST	Fine – not gritty (<0.06 mm)	0 %
Clay (CL)	CL	Slick/ hard clay or hard-pan clay	0 %

Enter estimated % composition for each substrate type. ****MACS SITES*: estimate over entire 100-meter stream reach.****

Figure 38.

Site Three Round Two

Dominant Substrate Type - Reach Characterization (See Ta

Reach Location (m)[1]	Habitat Type[2]	Depth (m)	Dom Sub 1[3]	% age 1[4]	Dom Sub 2[3]	% age 2[4]
5	RF	8in.	BR	60%	BL	40%
10	RF	10in	BR	40%	BL	60%
15	PL	7in.	BL	80%	CB	20%
20	PL	15in	BL	70%	CB	30%
25	RN	5in	BL	70%	CB	30%
30	RN	9in	BL	50%	CB	50%

Figure 39.

Stream Bank/Riparian Buffer Zone Vegetation/Cover Type

→→ What is the dominant vegetation type in the reach?
☐ Deciduous ☐ Coniferous (*i.e.*, Spruce, Pine, Hemlock, Rhododendron)
☐ Mixed Deciduous (>10-49% Coniferous) ☐ Mixed Coniferous (>10-49% Deciduous)

Score Codes: 0=Absent (0%) 1=Sparse (0-<10%) 2=Moderate (10-40%) 3=Heavy (>40-75%) 4=Very Heavy (>75%)

Left & Right Bank While Facing Down-Stream	*Determined Within The 1st 18 m (60 Ft) From Stream Edge*	Canopy (>5 M High) (>15 Feet)	Understory (0.5 – 5 M High) (1.5-15 Feet)	Ground Cover (<0.5 M High) (≈1.5 Feet)	Bare / Barren Soil
		Big Trees such as Sycamore, Oaks, Maples, Box Elder, River Birch, Hemlock	*Small trees and shrubby Vegetation such as Willow, Alder, Knotweed (blue devil), Rhododendron, Wingstem*	*Ferns, Grasses, Mosses, Wildflowers*	*Exposed soil surface, Readily erodible – not rock faces or asphalt roads*
LEFT (18 m) (≈60 ft.)		4	4	4	0
RIGHT (18 m) (≈60 ft.)		4	4	4	0

Stream Surface Shading (%)		Indicate % based on cloudless day in summer at noon. Place a √ in box that applies.					
Fully Exposed (0-25%)		Partly Shaded (25-50%)		Partly Exposed (50-75%)		Fully Shaded (75-100%)	√

Figure 40.

Inorganic Substrate (1 m² Of Kicked Substrate)	Class Codes	Size Class	% Composition
Bedrock	BR	Smooth surface rock/hardpan (>4000 mm – bigger than a car)	70 %
Boulder (BL)	BL	Basketball to car (>250-4000 mm)	20 %
Cobble (CB)	CB	Tennis ball to basketball (>64-250 mm)	5 %
Coarse Gravel (CG)	CG	Marble to tennis ball (>16-64 mm)	0 %
Fine Gravel (FG)	FG	Ladybug to marble (>2-16 mm)	0 %
Sand (SA)	SA	Gritty – up to ladybug (>0.06-2 mm)	5 %
Silt & Fines (ST)	ST	Fine – not gritty (<0.06 mm)	0 %
Clay (CL)	CL	Slick/ hard clay or hard-pan clay	0 %

Enter estimated % composition for each substrate type. ****MACS SITES: estimate over entire 100-meter stream reach.****

Figure 41.

As seen, **Figure 24.**, **Figure 25.**, and **Figure 26.** show the differences that characterize Site One and its habitat. They show the dominant substrate as having boulders and cobble. In terms of the stream bank riparian zone coverage, Site One had a 4 in each section excluding the barren soil part, making it good in terms of its buffering capacity. The inorganic substrate was found to be mostly made up of bedrock, boulders, and cobble. As shown in **Figure 27.**, **Figure 28.**, and **Figure 29.**, Site Two is quite different than Site One. The dominant substrate is shown to be coarse gravel and silt and fines. While the stream bank riparian zone coverage is characterized by 1, 2, 3, and 4, showing more variety but not as quality of a riparian zone as Site One Round One. The inorganic substrate for Site Two Round One was characterized again by bedrock, boulder, and cobble. Further in **Figure 20.**, **Figure 31.**, and **Figure 32.**, it was showcased that Site Three Round One had some differences between the sites as well. The dominant substrate for Site Three Round One was shown to be primarily bedrock and boulder. For the stream bank riparian zone coverage, it was characterized by having a 4 in each section except barren soil such as Site One Round One. The inorganic substrate was mostly bedrock and boulder. The Round Two data sets were similar overall but some remained to be altered when compared to the initial data in Round One. **Figure 33.**, **Figure 34.**, and **Figure 35.** shown the results for Site One Round Two habitat assessments. The dominant substrate found this time was bedrock, gravel, and silt and fines. The stream bank riparian zone for Round Two was less stable than Round One, with the results being characterized less by the presence of 4 and more by \the presence of 1 and 2. The inorganic substrate for this Round were cobble, coarse gravel, fine gravel and sand, which is different for this particular Site compared to Round One results. Alternatively, **Figure 36.**, **Figure 37.**, and **Figure 38.** show that Site Two Round Two also had some differences when compared to the Site during Round One's data collection. The dominant substrate this Round were found to be cobble, coarse gravel, and fine gravel. For the stream bank riparian zone for Round Two, the site had low numbers like 1 and 2 except for ground cover which was characterized by 4 for both sides. The inorganic substrate was found to be primarily of cobble, coarse gravel, and fine gravel. Finally for Site Three Round Two, **Figure 39.**, **Figure 40.**, and **Figure 41.** show the contrast between the two Rounds. For the dominant substrate, it was showcased by the presence of bedrock, boulder, and cobble. The stream bank riparian zone for Site Three Round Two shows a 4 in all categories, again, excluding the barren soil. For the inorganic substrate, the presence of bedrock, boulder, cobble, and sand are important to note. Overall, the habitat showed some variations between not only Sites but also Rounds. These variations reinforce the notion that it is exceptionally important to overview a multitude of habitats when collecting scientific data because of the fact that alternate habitats can showcase different substrate forms and stream bank varieties.

Study Limitations and Next Steps

Although there was a sufficient amount of data provided by benthic macroinvertebrates to obtain five credible WVSCI scores indicative of an impaired stream, water parameter data that provided insight into the water quality, benthic algal data to assist in the evaluation of the algal community, and the WAB habitat forms to assess the overall habitat and confirms its sub-optimal to marginal quality, there are still problematic infiltrations that allow for experimental limitations. These study limitations include issues with calculating complete WVSCI scores for all six surveys with the presence of Black-bellied salamanders greatly affecting Site Three Round Two. This resulted in collecting less than 200 benthic macroinvertebrate samples from Site Three during Round Two so the WVSCI score could not be calculated. Due to the fact that nine Black-bellied salamanders were captured at the time of sampling, this could be indicative of predation as previously explained. An additional study limitation includes the lack of accessible information. Due to Minden's small-town history, it was difficult to obtain data in relation to Minden and Arbuckle Creek specifically. Without much of the USEPA data and studies, it would have been virtually impossible to analyze the complete source of contamination due to a lack of basic information. Even papers about Minden were difficult to access and without being a local to the area, much of Arbuckle Creek's information would have been difficult to access as well.

In terms of what should be done next to better the overall water quality of Arbuckle Creek and its overall environment, which includes its sediment, there are different possibilities. A significant number of benthic macroinvertebrate studies should be completed in order to assess more reaches of the stream and its health. In addition, water parameters should be measured more frequently in order to obtain more accurate and well-rounded results. For better algal comparisons, taking a variety of more samples in the future across the entirety of Arbuckle Creek would be important and vital to learning new information about the nutrients that reside in the stream. Regarding the habitat, there should be much more work done to improve the conditions. Because the habitat scores were consistently low and showed impairments for a multitude of reasons, addressing these reasons, and fixing their attributes is essential in creating a higher quality environment.

Conclusion

Overall, it can be clearly indicated that the past of Minden and Arbuckle Creek has infiltrated the land and waters of the area in capacities that are still difficult to quantify, but that clearly are indicative of a negative impact. The detriment that was caused by the Shaffer Equipment Site and the mining from the decade's past have created problems bigger than PCBs. Not only are there more contaminants located in the sediments and surface waters, but through benthic macroinvertebrate surveys, water parameters, benthic algae, and habitat assessments, it is evident Arbuckle Creek is affected by a multitude of factors. These factors have created a habitat that is conducive to low WVSCI scores indicating impaired waterbodies. Not only do the WVSCI scores show impairment, but the habitat scores simply equating to “Marginal” and “Sub-optimal” show the stream has been affected by its scarring history. While remaining somewhat inconclusive, the algal data remains an important source of information especially when pertaining to the blue-green algal concentrations found. The water parameters measured showed fluctuations that could be attributed to many factors, some of which include previous mining but also current issues with septic systems that are known in Minden. Arbuckle Creek has been through trauma in terms of its historic mining past and the tragedy of the Shaffer Mine Equipment Site. In terms of ecological balance, it can be said that there is still a significant amount of work and environmental compensation that needs to be done.

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Office of Research Integrity

November 30, 2021

Sarah Simonton
1919 McCoy Road
Huntington, WV 25701

Dear Ms. Simonton:

This letter is in response to the submitted thesis abstract entitled *"A Water Quality and Contaminant Source Assessment of Arbuckle Creek in Fayette County, West Virgina."* After assessing the abstract, it has been deemed not to be human subject research and therefore exempt from oversight of the Marshall University Institutional Review Board (IRB). The Code of Federal Regulations (45CFR46) has set forth the criteria utilized in making this determination. Since the information in this study does not involve human subjects as defined in the above referenced instruction, it is not considered human subject research. If there are any changes to the abstract you provided then you would need to resubmit that information to the Office of Research Integrity for review and a determination.

I appreciate your willingness to submit the abstract for determination. Please feel free to contact the Office of Research Integrity if you have any questions regarding future protocols that may require IRB review.

Sincerely,

Bruce F. Day, ThD, CIP
Director

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