*An Environmental Assessment of Mill Run in Meadville, Pennsylvania*

**By**
***Colleen Marie Vine***
**Department of Environmental Science and Sustainability**
**Allegheny College**
**Meadville, Pennsylvania**

***May*, 2025**

**Submitted in fulfillment of the senior thesis requirements of the Department of Environmental Science and Sustainability at Allegheny College and approved by the senior thesis committee.**

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| ***Dr. Kelly Pearce*** | **Date** | ***Ms. Wendy Kedzierski*** | **Date** |

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***Acknowledgements***

For Dr. Kelly Pearce,
Thank you for mentoring me over the past three years and being my comp advisor. I am thankful for your guidance and support throughout my years at Allegheny, and I know I would not be where I am today without your support.

For Wendy Kedzierski and Creek Connections,
Thank you for teaching me almost everything I know about water chemistry testing and macroinvertebrate sampling, for which without this project would not be possible. I am also thankful for the water chemistry testing supplies provided to me by Creek Connections. I specifically thank Wendy for helping me brain-storm new comp proposal ideas and sharing the Allegheny College's CEED Environmental Assessment of Mill Run with me. I also want to acknowledge the support of my fellow peers at Creek Connections throughout my data collection and analysis process, which I am very grateful for.

For the Watershed Conservation Research Center and Mark Kirk,
Thank you for providing me with the supplies that were used to collect macroinvertebrate samples and several water chemistry tests, as well as helping me identify the (many) Oligochaeta found within my samples.

For Madison Kyle,
Thank you for spending many cold and rainy hours out in the field with me helping to collect macroinvertebrate and water chemistry samples. I appreciate and admire your constant positive attitude despite the weather conditions and your willingness to help for nothing but my company in return.

For my friends and family,
Thank you for helping shape me into the person I am today, and providing me with constant support, not only through college but through my earlier academic years. I thank my mother for spending over a decade homeschooling me and fostering my love for science (even though you're an English major) and education. I appreciate all of the kindness and love that has been given to me over the years from family and friends.

Special thanks to Christopher Shaffer for helping create Figures 12 and 13 in ArcGIS, and McKenna Manderine for helping identify the macroinvertebrates I collected.

Name: *Colleen Marie Vine* Date: May, 202*5*
Major: Environmental Science
Thesis Committee: *Dr. Kelly Pearce, Ms. Wendy Kedzierski*

Title: *An Environmental Assessment of Mill Run in Meadville, Pennsylvania*

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This project's goal is to compare water chemistry and macroinvertebrate data of Mill Run from 2011 to data collected in this project (2025). Allegheny College's Center for Economic and Environmental Development performed a 2011 Environmental Assessment of Mill Run that reported data on water quality, macroinvertebrates, fish, land-cover, and habitat assessments from a variety of sites along Mill Run. Through the data collection and analysis of water quality and macroinvertebrates in this current project, more data is added to the current bank of knowledge on Mill Run and provides quantitative results that can be used to see if any changes in the stream's health have occurred. Five testing sites along Mill Run have been chosen for this project. Water chemistry tests and macroinvertebrate sampling were performed at each of the sites. Comparison between water chemistry data and the macroinvertebrate index of biotic integrity (IBI) from 2011 and this project (2025) was used to determine if there have been any changes in the water quality of Mill Run. This project's data indicates that Mill Run has experienced some positive changes in water chemistry, but the IBI scores still indicate that the stream is not suitable for aquatic life. Future water quality monitoring should be conducted on Mill Run using the same protocols and methods used in this project to ensure consistent results and allow researchers and community members to understand the condition of Mill Run over time.

***Introduction***

Urban stream syndrome is the term used to define the result of multiple human activities that impact the quality and health of a stream, such as land-use changes, storm and wastewater drainage, stream bank alterations, and chemical pollution (Coles et al., 2012). A stream is said to be experiencing urban stream syndrome when the surrounding urban land use deteriorates the stream's ecological value (Walsh et al., 2005). Recent research on urban stream syndrome has been performed in various parts of the world. One of these studies includes places such as the Brahmaputra River in India where the researchers found through water chemistry testing and macroinvertebrate sampling that the downstream sections of the river were experiencing pollution through sewage and waste being released into the water (Begum et al., 2023). Water pollution comes from other sources as well, such as urban runoff that occurs during heavy rainfalls. This runoff can erode the banks of the streams and consequently decline habitat quality for freshwater organisms (MacKenzie et al., 2022). In a study performed in northeast Patagonia, researchers found that riparian zone quality, habitat features, water chemistry parameters (such as conductivity), and macroinvertebrate indices are most impacted by urbanization (Miserendino et al. 2011**)**. Healthy streams, with "well-vegetated river banks, mixtures of coarse and fine rocks and pebbles on the stream bed and a variety of riffles and pools" (Healthy Waterways Strategy, 2024) have little to no signs of human activity present and have a higher biodiversity when it comes to macroinvertebrate populations because it provides a suitable habitat for macroinvertebrates, especially in comparison to streams with signs of human impacts (Healthy Waterways Strategy, 2024). The Mill Run watershed is an example of a stream experiencing urban stream syndrome, demonstrating poor water quality and overall stream health (CEED, 2011). Mill Run is located within the French Creek watershed, which encompasses approximately 1,250 square miles of land from Western New York to Northeastern Pennsylvania and south to the Allegheny River (French Creek Valley Conservancy, n.d.). In the 2002 French Creek Watershed Conservation Plan, the watershed was stated to be "arguably the most ecologically significant waterway in Pennsylvania" due to the fact that "[i]t contains more species of fish and freshwater mussels than any other comparably sized stream in the Commonwealth and possibly the northeastern United States" (Western Pennsylvania Conservancy, 2002).

Mill Run flows from Tamarack Lake, directly under the city of Meadville, Pennsylvania,

to French Creek. The Historical Marker Database has a page dedicated to the Mill Run Historical Marker (n.d.), which states: “Essential to the growth of an early frontier town, this vigorous stream provided power to early mill wheels and water for fire fighting, and fed the French Creek Feeder Canal. By 1910 it was built over and largely lost to view.” Mill Run has a long history of flooding due to the fact that the city was built over the stream, and rainfall would result in high water levels entering the commercial and residential buildings from directly below their floorboards. The numerous floods are documented in a recent article from *The Meadville Tribune,* where the author describes Meadville during the time of these floods: “It’s difficult to find a photographic history of the city that doesn’t include images of residents walking, driving and even boating across water-covered roadways, sidewalks and yards” (Spicer, 2014). To mitigate the impacts of flooding two dams were constructed in 1963 that helped reduce the severity of the floods (The Center for Economic and Environmental Development at Allegheny College, 2011). One of the two dams was built at Tamarack Lake, which feeds water into Mill Run alongside four tributaries: Dick Run, Cemetery Run, Cora Clark Park tributary, and an unnamed tributary near Rainbow Reservoir (The Center for Economic and Environmental Development at Allegheny College, 2011). The construction of Meadville over the stream, as well as the addition of these two dams to mitigate the flooding, has undoubtedly had a negative impact on the physical characteristics and stream health of Mill Run over the past six decades, and in 2012 Mill Run was labeled as an “impaired” stream by the Department of Environmental Protection (DEP; DEP, 2024). This label of impairment was determined through water chemistry testing, macroinvertebrate sampling, and habitat assessments. These metrics are referred to as the response variables of urban stream syndrome and land-use surrounding a stream described as the predictor variables (Praskievicz, 2022). Over the years, all around the globe, the ecological consequences of urban development have been ignored, which has created an ongoing trend where biological stream life declines as urban expansion increases (Miltner et al., 2004). Current data collection on water chemistry and macroinvertebrates will determine the stream health of Mill Run and provide guidance on whether Mill Run should be continued to be classified as impaired or if the new data shows an improvement in the water quality and biological diversity.

The last public data resource on the ecological state of Mill Run comes from the Allegheny College’s Center for Economic and Environmental Development (CEED) in 2011, when they released an Environmental Assessment on the Mill Run Watershed. This

environmental assessment resulted in Mill Run being listed on Pennsylvania's 2012 Integrated Water Quality Monitoring and Assessment Report as impaired. More recently, in the Pennsylvania Department of Environmental Protection's 2024 Integrated Water Quality Report the 2012 classification was attributed to "Urban runoff/storm sewers," with the cause of impairment coming from "siltation." Mill Run's classification as a impaired stream by the DEP was made in 2012 and there is no evidence that it has been evaluated since. However, in recent years, individuals throughout the Meadville community have advocated for recognition of the historical and ecological importance of Mill Run, including Allegheny College faculty, alumni, and students. One example is Dr. Amara Geffen, who has used her artwork throughout Meadville to spread knowledge of Mill Run's existence and importance to the community. This current assessment could benefit the community of Meadville by providing up-to-date information and data on the stream health status of Mill Run, to not only spread awareness about the status of Mill Run but also to help determine what mitigation techniques can be used to reduce the impacts of urban stream syndrome.

As mentioned prior, Allegheny College's CEED performed an Environmental Assessment on Mill Run in 2011 with the guidance of Pennsylvania DEP resources. In the assessment, water chemistry data was used to collect data on the characteristics of Mill Run. Water chemistry data included temperature, pH, conductivity, alkalinity, total suspended solids, dissolved oxygen concentrations, and more. Looking at the data, the researchers concluded that Mill Run is an example of urban stream syndrome due to the local urban environment's negative impact on physical, chemical, and biological stream properties.

The Pennsylvania DEP releases the Integrated Water Quality reports every year and they provide each stream with labels that describe if the stream is impaired, what stream quality is threatened, what the main source and cause of impairment is, and the date that this label was determined. It is important to understand what goes into designating a stream as impaired, which starts with looking at what characteristics are used to define the health of a stream. There are different characteristics that can be studied to help determine a stream's health, including water chemistry, biological indicators, and physical habitat quality. Through performing data analysis on these different characteristics, researchers can determine the current ecological state of a stream, also known as the stream health. A stream's health is important to know when understanding what negative impacts certain anthropogenic activities, such as urbanization, may

have on watersheds. Additionally, looking at water chemistry parameters, such as temperature, pH, alkalinity, conductivity, total dissolved solids [total suspended solids was the tested in CEED's 2011 Environmental Assessment of Mill Run, however total dissolved solids is the measurement commonly used today], and dissolved oxygen can help predict the biological diversity of a stream.

Macroinvertebrates are one of the many cold-blooded organisms that live within a stream, which means that their body temperature is directly corresponding with the temperature of their environment, in this case the water (Jackson, 2024). Higher temperatures within a stream can come from multiple sources, such as dams (Croijmans et al., 2021), which are currently present within the Mill Run Watershed. Particular groups of macroinvertebrates are negatively affected by warmer temperatures, such as Ephemeroptera (commonly known as mayflies), which experience a decline in reproductive productivity in warmer water (Jackson, 2024). Additionally, temperature impacts other water quality parameters, as stated in the Environmental Protection Agency's (EPA) Climate Change Indicators in the United States: Stream Temperature (2016), "Temperature can affect certain aspects of water quality. For example, higher temperatures reduce levels of dissolved oxygen in the water, which can negatively affect the growth and productivity of aquatic life."

Another water quality parameter that macroinvertebrate species have a specific threshold for is pH, with some species being more sensitive to acidity than others (Courtney & Clements, 1998). In Creek Connections' Handbook for Water Quality Analysis of Western Pennsylvania Waterways (1999), it is explained that pH can have negative impacts on aquatic organisms since each organism has a certain pH level (range) it can survive in. If that pH level changes, certain organisms can die and a decrease in biodiversity occurs. One cause of changes in pH within streams comes from rainwater. Pollution causes rain to be more acidic, so when rainwater drains into the streams it can lower the pH (acidifies) of the water (Creek Connections, 1999). Ephemeroptera experience a decrease in population when the pH drops to acidic levels, whereas Plecoptera (stoneflies), Trichoptera (caddisflies), and Diptera experience little to no change in population density, showing a higher tolerance for acidic waters (Courtney & Clements, 1998). Related to pH, there is alkalinity. Alkalinity determines a body of water's ability to regulate a stable pH, for example, allowing the water to neutralize the acidity that may come from acid rain

(Water Science School, 2018). A higher alkalinity indicates that a stream is more likely to have a neutral pH value.

Conductivity is a common tested water chemistry parameter and provides insight into a body of water's ability to conduct electricity and salinity (EPA, 2024). If a stream is found to have a high conductivity, it is more likely to have a higher concentration of salt, which has been found to negatively affect macroinvertebrate populations (U.S. EPA, 2011).

Another water parameter that pertains to the physical substances within water is total dissolved solids, which looks at how much organic matter and inorganic salts is dissolved in the water (Safe Drinking Water Foundation, n.d.). The amount and value of total dissolved solids is known to increase due to anthropogenic activity, such as industrialization, agriculture, and mining (Cañedo-Argüelles et al., 2013). High levels of total dissolved solids (TDS) can be toxic to macroinvertebrates (Peng, 2019), with some species such as chironomid larvae presenting decreased survival rates in water with a TDS value greater than 1,100 mg/L (Chapman et al., 2009).

The final water quality parameter for this project is dissolved oxygen. Dissolved oxygen provides an understanding of not only how much oxygen is in the water, but also how much organic matter is present as the decomposition of organic matter uses up oxygen. Low levels of dissolved oxygen have been correlated with low macroinvertebrate biodiversity, whereas higher levels of dissolved oxygen support more macroinvertebrate biodiversity (Croijmans et al., 2021).

All of these parameters mentioned above were tested in CEED's 2011 Environmental Assessment of Mill Run. It is important to continue gathering this data for many reasons, one including that stream ecology is known to be negatively impacted by water chemistry changes (Halstead et al., 2014). Certain water quality parameters have been observed to decline in quality as urbanization density increases, such as conductivity, which was found to increase as the percentage of urban and impervious land increased (Praskievicz, 2022). Conductivity has shown to be higher in urban streams than in more forested streams in a previous study performed in Virginia (Balerna et al., 2023). Another study in Maine found that increased impervious land cover within a watershed was associated with decreased percentage of dissolved oxygen due to the deposition of sediment and excessive nutrient runoff (Slattery, 2018). Poor water chemistry results can indicate that a stream is suffering from the consequences of urbanization and experiencing urban stream syndrome.

In addition to water chemistry testing, a biological method of evaluating stream health called macroinvertebrate sampling is used. Collecting macroinvertebrates from streams and identifying them can provide researchers with biological indexes that give insight into the biodiversity and health of a stream (Reif, 2002). In an Allegheny College senior project from 2023, the author, Katherine Mowry**,** gathered data on local streams about macroinvertebrate diversity and chemical composition. She used the Shannon Diversity Index for Macroinvertebrates, the Percentage Ephemeroptera, Plecoptera, Trichoptera (EPT) for Macroinvertebrates, and the Hilsenhoff Biotic Index (HBI). These analysis methods can provide insight into the health of the stream by determining the number of macroinvertebrates living within a body of water, as well as the percentage of certain species of macroinvertebrates living in the water in comparison to the entire population. Some species of macroinvertebrates are more sensitive to pollution and other water qualities such as temperature (Vannote & Sweeney, 1980) and pollution. Research has found that streams experiencing urban stream syndrome are found to have a larger number of pollution-tolerant species (specifically oligochaetes and chironomids) than any other species (Walsh et al., 2005). When stormwater runoff is released into streams, it provides a dumping place for chemicals, such as industrial waste and many other pollutants commonly found in urban environments, which creates an unstable habitat for living organisms, such as some non-pollutant tolerant macroinvertebrate taxa (Peter et al., 2022). Using the EPT and HBI scores can help quantify the level of impact.

CEED's 2011 Environmental Assessment of Mill Run reported data on water quality, macroinvertebrates, fish, land-cover, and habitat assessments from a variety of sites along Mill Run. Through the data collection and analysis of water quality and macroinvertebrates through this current project, more recent data will be added to the current bank of knowledge on Mill Run and provide quantitative results that can be used to see if any changes in the stream's health have occurred. Due to a lack of initiative taken post-publication of the CEED's 2011 Environmental Assessment and little to no change in land-use along Mill Run, it is expected that Mill Run will still demonstrate the symptoms of urban stream syndrome, supporting the current label of "impaired." In relation to the specific sites chosen along Mill Run, it is expected that the sites located further from French Creek confluence (i.e., MARC and Shadybrook) will have water chemistry and IBI scores that indicate a healthier stream than the sites located in downtown Meadville, closest to French Creek (i.e., City Building) (Oravec, 2016).

## *Methods*

### DATA COLLECTION

*Site Selection*

Five testing sites along Mill Run were sampled for this project (Figure 1). These sites were selected from CEED's 2011 Environmental Assessment of Mill Run. CEED had a total of nine sites, and these five were chosen based on accessibility. Property line issues were also considered, which eliminated one site that is located by the Meadville Public Library.

**Figure 1**

*Edited map of testing locations for water chemistry and macroinvertebrate sampling*

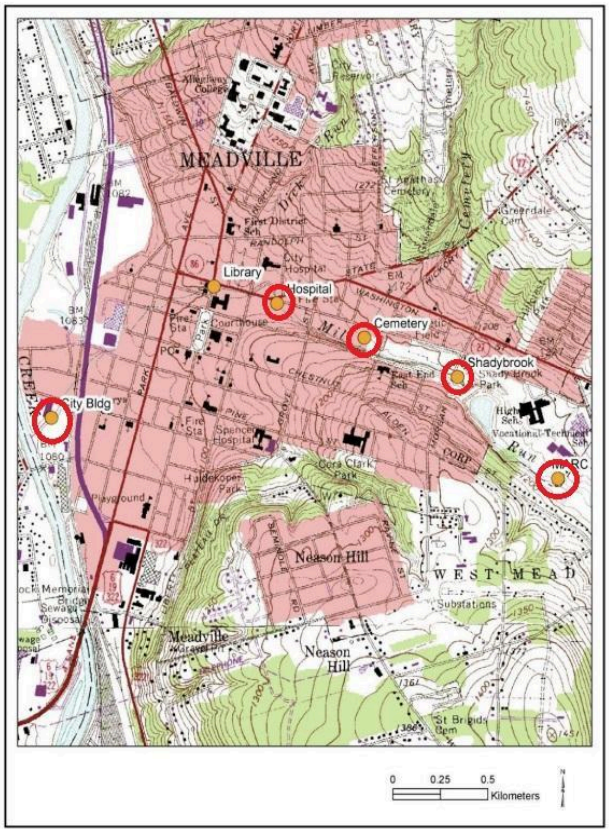



**Figure 3-1**. Map of the GPS points and names of each sampling site

**Figure 1**. Edited map of the GPS points and names for each sampling site from the Center for Economic and Environmental Development at Allegheny College's Mill Run Watershed Environmental Assessment (2011).

The testing sites along Mill Run are all located within different areas of Meadville, with differing levels of anthropogenic activity and urbanization. The Meadville Area Recreation Center (MARC) is the most isolated location out of the five selected for this study. Shadybrook is located within a park, with a dam located upstream and residential homes along either side of the hills surrounding the park. The Cemetery Run site is located next to a steep hill, with residential homes and businesses located on both sides of the stream. At the top of the hill next to this testing site, there were multiple storm water drains flowing down into the stream from the houses above. The Meadville Medical Center site is located right next to the Meadville Medical Center Emergency Department, with a large, paved parking lot and sidewalks surrounding it. Additionally, this is where the tunnels that allow Mill Run to run underneath Meadville begin when moving downstream. The final testing site, located at the Old City Building (now under the ownership of the Meadville Medical Center) is located between a parking lot and the French Creek Parkway.

While visiting the sites and collecting data, I always had a partner with me to help perform the water quality testing and macroinvertebrate collection. Both water quality testing and macroinvertebrate collection occurred on the same day. For one data collection date in October, there are partial water chemistry testing results and no macroinvertebrate sampling data. The November data collection has both water chemistry and macroinvertebrate sampling data from all five sites.

*Water Quality Testing*

Water quality testing involved collecting one water sample from each site two times, once during each of the following months: October and November. We performed the following water chemistry tests: temperature, pH, total dissolved solids (TDS), dissolved oxygen, alkalinity, and conductivity. These parameters were chosen because they were tested during CEED's 2011 Environmental Assessment (excluding total dissolved solids). All water tests were taken on-site on the day they were collected.

Supplies for water testing were provided by Creek Connections and the Watershed Conservation Research Center. This included sample bottles, an alcohol thermometer, and the following: the High Level Hach 2314500 Alkalinity Drop Test kit, Hach Dissolved Oxygen Test

kit model OX-2P, the LaMotte Tracer Conductivity/Total Dissolved Solids/Salinity meter, the LaMotte pH 3.0 - 10.5 Test kit. Directions for how to use and conduct these tests were on-site as well as in the Handbook for Water Quality Analysis of Western Pennsylvania Waterways (1999) provided by Creek Connections. Water chemistry results were recorded on-site on paper along with the site location and date of sampling. The data sheets used to record the results can be found in Appendix C.

*Macroinvertebrate Sampling*

Macroinvertebrate sampling occurred after all the water chemistry tests were performed. Supplies for the sampling were provided by Creek Connections and the Watershed Conservation Research Center. At each of the five sites, macroinvertebrates were collected using a D-net facing upstream and the kick-net method, which allows the net to collect any potential organisms and debris. This method comes from the Pennsylvania DEP "A Benthic Macroinvertebrate Index of Biotic Integrity for Freestone Riffle-Run Streams in Pennsylvania (2012).

We chose six sample locations at each site by finding shallow riffle habitats with a high flow velocity. I placed the D-net facing upstream and my partner disturbed the streambed in front of the net for 60 seconds. This was repeated at each of the six riffle locations. The organic matter and debris collected by the nets were dumped into a five-gallon bucket and sifted so that we could put the organic matter into a sample container. Ethanol was poured into the sample container after collection to preserve any macroinvertebrates. Each sample container was labeled with the site location and date.

DATA ANALYSIS

*Water Chemistry Results*

At each of the individual sites, the water quality parameters tested and obtained (temperature, pH, total dissolved solids, dissolved oxygen, conductivity, and alkalinity) were averaged to a numerical value and recorded in an Excel spreadsheet to compare the water quality between the five different testing sites and with CEED's 2011 data.

*Macroinvertebrate Sampling*

The diversity index used in this study is from the Pennsylvania Department of Environmental Protection's "Benthic Macroinvertebrate Index of Biotic Integrity for Wadeable Freestone Riffle-Run Streams in Pennsylvania" (2012). This index uses five different indices to calculate an Index of Biotic Integrity (IBI) score. These indices include the total taxa richness, EPT taxa richness, Beck's index, the Hilsenhoff Biotic Index, the Shannon Diversity index, the EPT percentage, and the percent of sensitive individuals. Each taxon identified from the samples is designated a numerical value based on a scale of pollution tolerance from zero to ten (USGS, 2002), and these pollution tolerance values assist in calculating most of the diversity indices. All of these methods are intended to give insight into the level of pollution and amount of anthropogenic impact on Mill Run as they provide quantitative data that can be compared with stream quality standards.

*Total Taxa Richness* measures the total number of taxa within a sample. In this case, it is the total number of species of macroinvertebrates, identified down to either the genus or family level (some species are identified to class or phylum level, such as Oligochaeta (aquatic worms)).

*EPT Taxa Richness* measures the total number of taxa in the Ephemeroptera, Plecoptera, or Trichoptera orders within a sample. These macroinvertebrate orders have pollution tolerance values equal to or less than 4 (Pennsylvania Department of Environmental Protection, 2012).

*Beck's Index* is a pollution measure used to calculate the taxa richness of species with low pollution tolerance values (Pennsylvania Department of Environmental Protection, 2012).

*The Hilsenhoff Biotic Index* is used to understand the level of pollution in a stream by identifying macroinvertebrate pollution tolerance values. This index "estimates the overall tolerance of the community in a sampled area, weighted by the relative abundance of each taxonomic group (family, genus, etc.)" (University of New Hampshire, n.d. - a).

*The Shannon Diversity Index* is calculated for each site individually to determine the approximate diversity of macroinvertebrates within the stream site. This calculation "accounts for both abundance and evenness of the species present" (Beals, Gross, and Harrell, 2000).

*The EPT Percentage* looks at the number of macroinvertebrates that are part of the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) within a collected sample and can indicate stream health since these orders are more sensitive to water pollutants (University of New Hampshire, n.d. - b). It is calculated through dividing the total number of EPT taxa by the total

number of taxa, with high EPT percentages indicating better water quality versus low EPT percentages indicating poor water quality (USGS, 2002*)*.

*Percent of Sensitive Individuals* calculates the number of individuals within a sample that have a pollution tolerance value of 3 or lower (Pennsylvania Department of Environmental Protection, 2012).

All of these indices were calculated individually for each of the five sites along Mill Run, and then metric standardization was used to calculate the IBI score for each site. An example of the metric standardization used for the Mill Run IBI scores is shown below in Table 1. The small-stream standardization values were used as Mill Run is categorized as a 1st order stream. IBI values from this study will be compared against the IBI scores from the CEED's 2011 data.

**Table 1**

*Standardization and metric calculations for the MARC sample.*

| Metric | Standardized Equation | Observed Metric Value | Standardized Metric Score | Adjusted Standardized Metric Score |
|---|---|---|---|---|
| Total Taxa Richness | observed/33 * 100 | 22 | 66.7 | 66.7 |
| EPT Taxa Richness | observed/19 * 100 | 6 | 31.6 | 31.6 |
| Beck's Index | observed/38 * 100 | 6 | 15.8 | 15.8 |
| Hilsenhoff Biotic Index | (10 - observed)/(10 - 1.89) * 100 | 5.28 | 58.0 | 58.0 |
| Shannon Diversity | observed/2.86 * 100 | 2.25 | 78.7 | 78.7 |
| % Sensitive Individuals | observed/84.5 * 100 | 10.87 | 12.9 | 12.9 |
| Arithmetic average of adjusted standardized core metric scores = | | | **IBI Score =** | **43.995** |

**Table 1.** The standardization and metric calculations for the MARC sample that was collected on November 23, 2024.

*Geographical Information System Maps*

To see if there were any differences between the land-use around the time that data was collected in 2011 and during this project, I requested GIS maps of the land-use data surrounding Mill Run from existing data from 2010 and 2022 land surveys. They were constructed and provided by Chris Shaffer at Allegheny College. 30 meters was chosen as the surrounding buffer-zone because the U.S. Environmental Protection Agency (2004) indicates that a riparian corridor should typically include 100 feet on each side of a stream (100 feet = 30.48 meters)

## Results

*Water Quality*

The pH increased slightly as the sites moved from upstream to downstream (Figure 2). Meadville Area Recreation Center had the lowest pH at 7, Shadybrook Park and Cemetery Run had pHs of 7.5, and The Meadville Medical Center and the Old City Building had pHs of 8.

**Figure 2**

*The pH for five different sites along Mill Run*

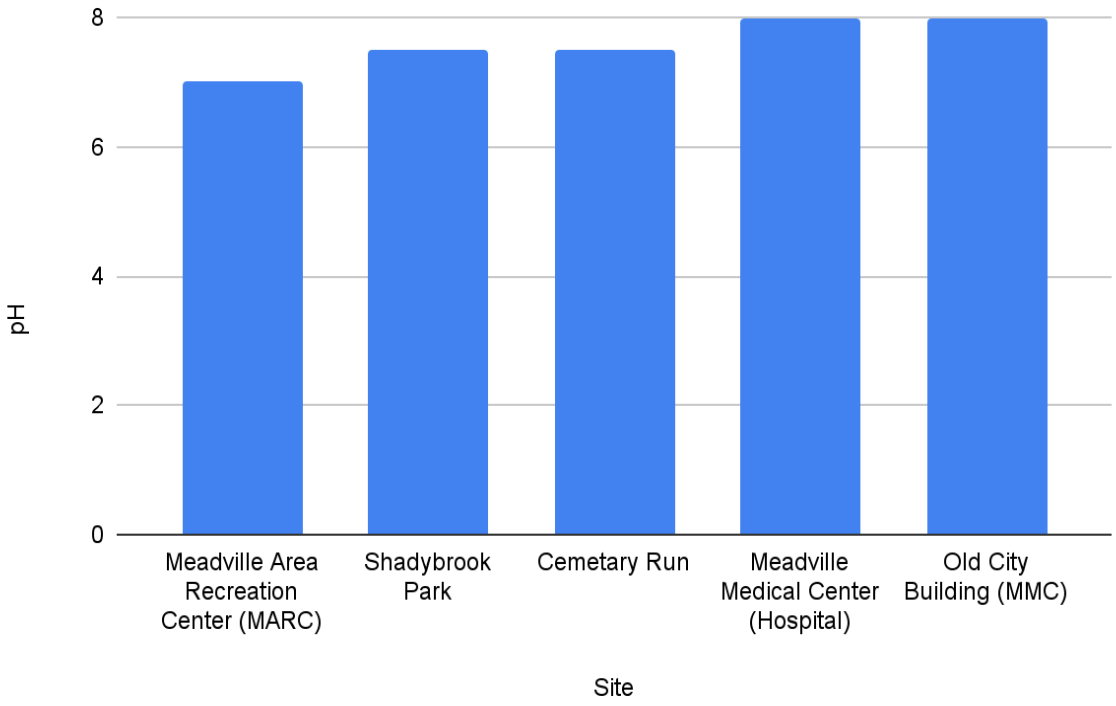



**Figure 2**. pH values for five sites along Mill Run collected on November 23, 2024, listed left to right from upstream to downstream. An ideal pH value for supporting aquatic life is between 6.4 to 8.4 (DataStream, n.d.)

Conductivity varied based on site location, as shown in Figure 3. The site farthest upstream, Meadville Area Recreation Center, had the lowest conductivity reading at 239 µS, and the Old City Building had the highest conductivity reading at 311 µS.

**Figure 3**

*The conductivity reading values for five different sites along Mill Run*

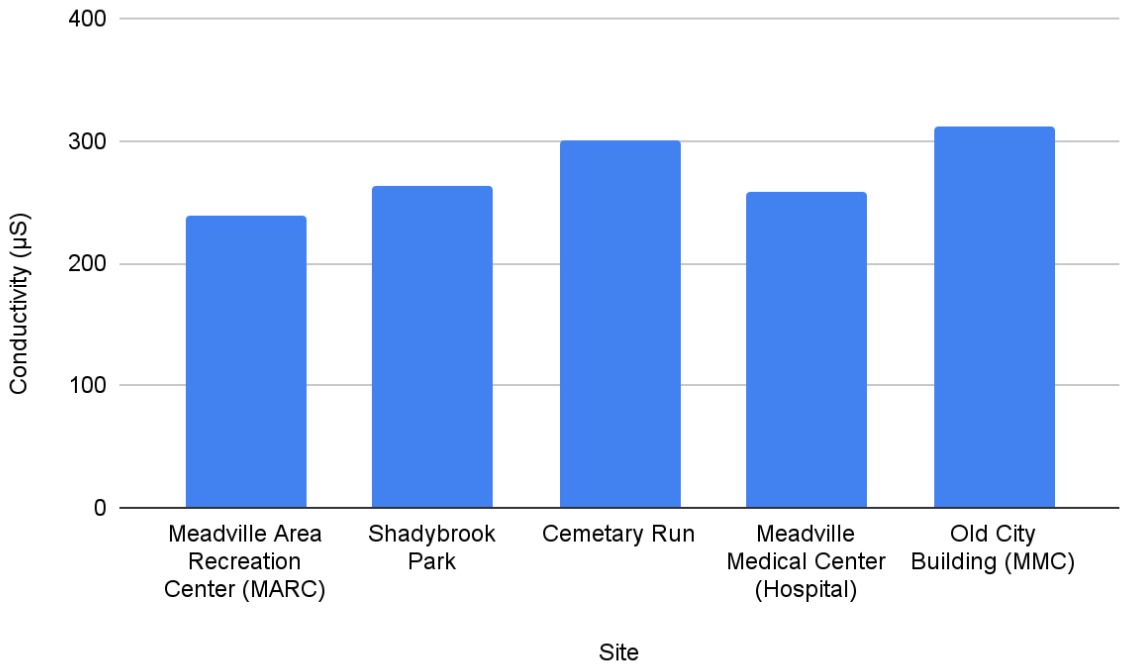



**Figure 3**. Conductivity reading values measured in µS for five sites along Mill Run collected on November 23, 2024, listed left to right from upstream to downstream. Conductivity reading values in streams above 247 µS can potentially negatively impact the population richness and diversity of macroinvertebrates (Maryland Department of Natural Resources, n.d.).

MARC, Shadybrook Park, and Cemetery Run all had the same alkalinity result (102 mg/L $CaCO_3$), and the Meadville Medical Center had the lowest alkalinity result at 68 mg/L $CaCO_3$ as shown in Figure 4.

**Figure 4**

*The alkalinity values for five different sites along Mill Run*

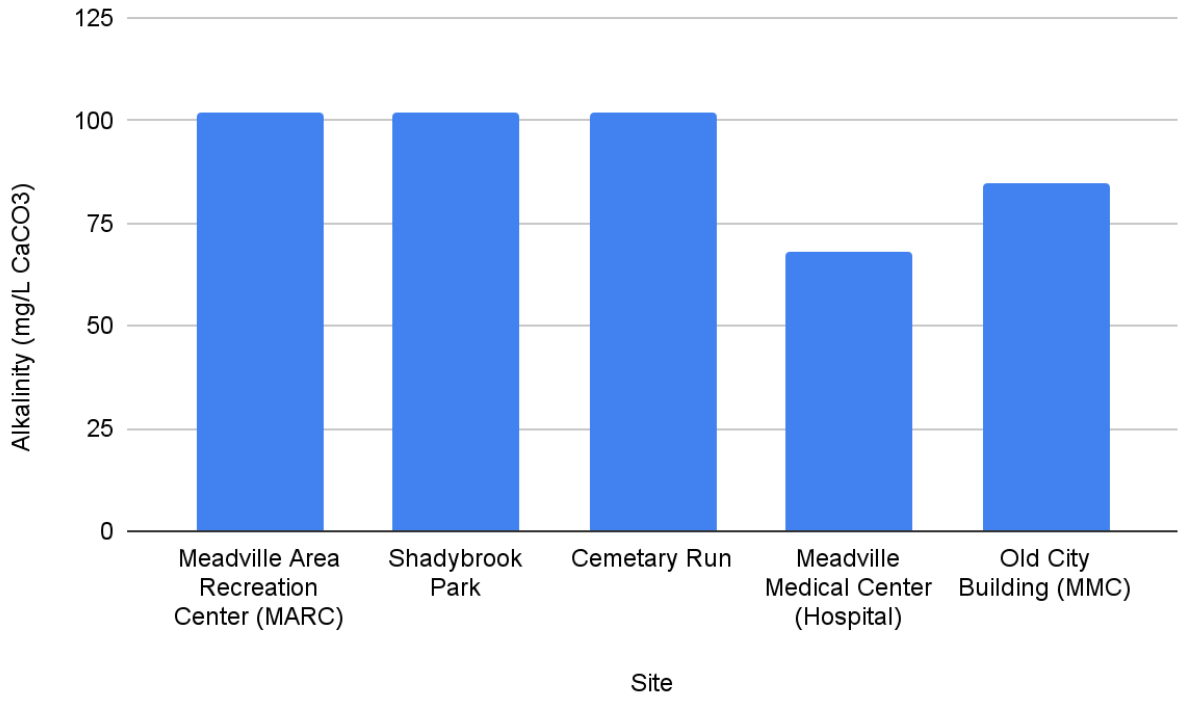



**Figure 4.** Alkalinity values for each of the five sites along Mill Run collected on November 23, 2024, measured in milligrams per liter of calcium carbonate (mg/L $CaCO_3$). Alkalinity results for freshwater watersheds are typically between 20-200 mg/L $CaCO_3$ (Lehigh Environmental Initiative at Lehigh University, 2011).

The dissolved oxygen values for the testing sites are shown in Figure 6. These values range from 9 to 11 mg/L. Cemetery Run and the Old city building had the highest dissolved oxygen values at 11 mg/L, and the Meadville Medical Center had the lowest dissolved oxygen value at 9 mg/L.

**Figure 5**

*The dissolved oxygen values for five different sites along Mill Run*

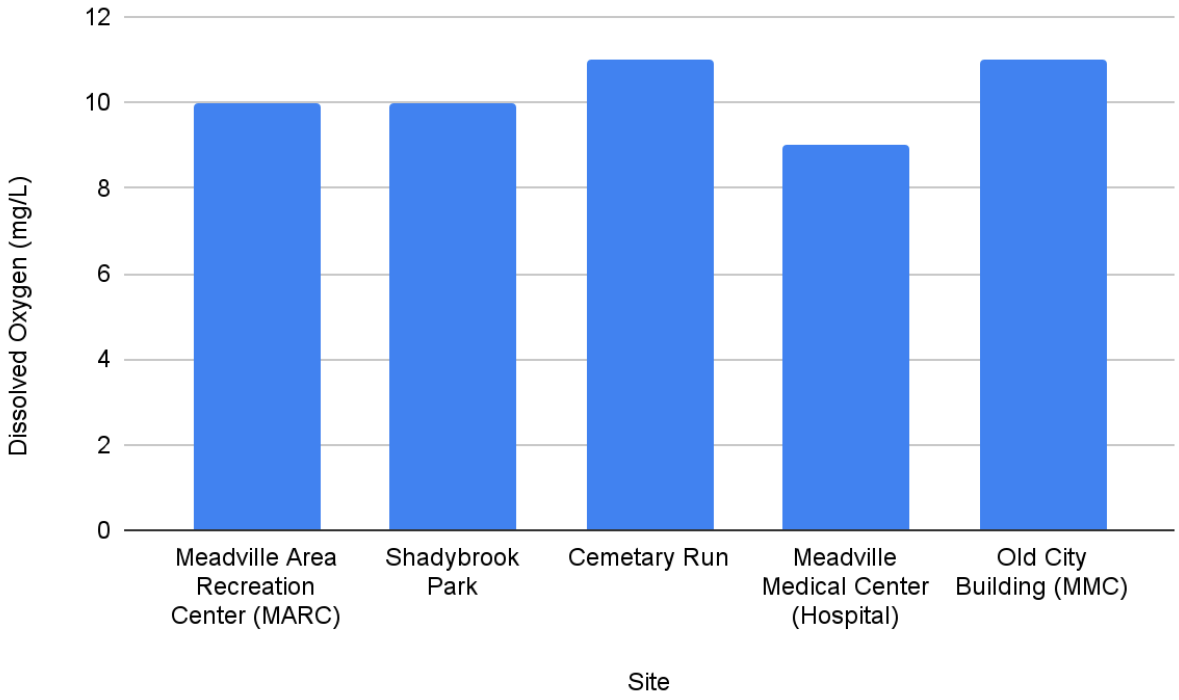



**Figure 5.** Dissolved oxygen values for each of the five sites along Mill Run measured in milligrams per liter, collected on November 23, 2024. Dissolved oxygen values for healthy water should be above 6.5-8 mg/L (Government of Northwest Territories, n.d.).

*Macroinvertebrate Sampling*

The Index of Biotic Integrity (IBI) scores for each of the five sites along Mill Run (Figure 6). Scores range from 18.1 to 43.9.

**Figure 6**

*The Index of Biotic Integrity (IBI) scores for five different sites along Mill Run*

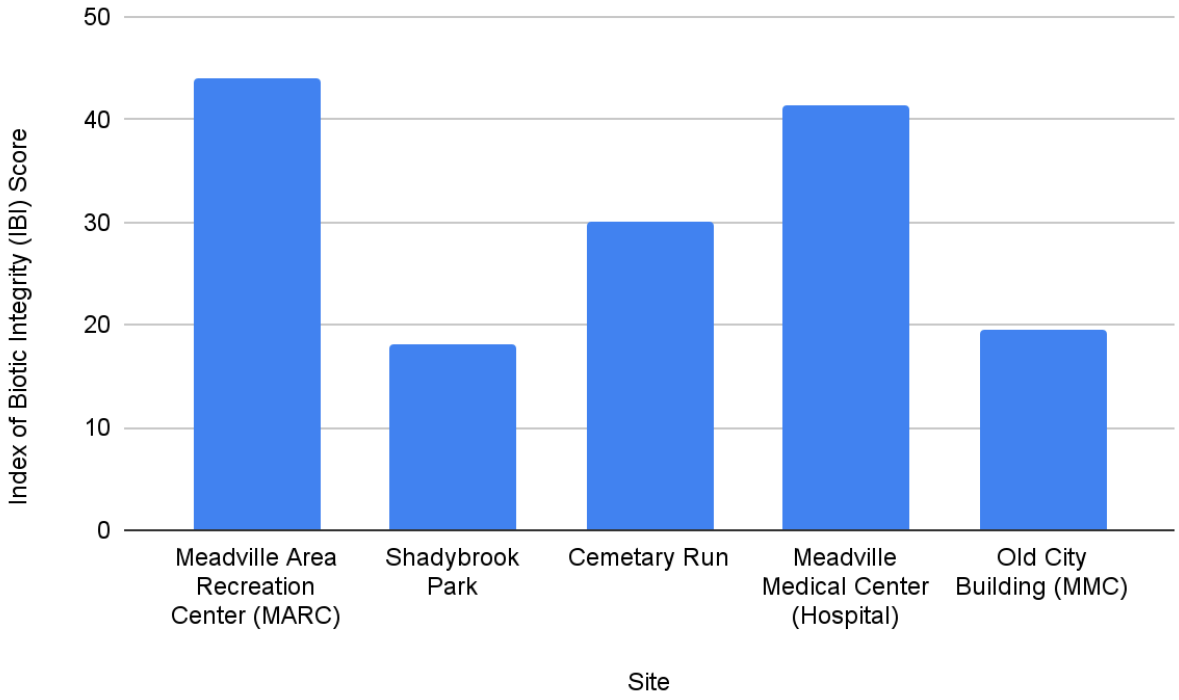



**Figure 6.** The Index of Biotic Integrity (IBI) scores for each of the five sites along Mill Run, calculated from macroinvertebrate data collected on November 23, 2024. IBI scores are on a scale from 0 to 100, with a higher score indicating a healthier stream (Pennsylvania Department of Environmental Protection, 2012).

**Discussion**

The purpose of this study is to determine if there have been any changes in the water quality of Mill Run, through comparison of water chemistry data and macroinvertebrate sampling data from 2011 and 2025. It is expected that the sites further from French Creek will have better stream quality/health due to the urban stream syndrome concept (Oravec, 2016), as the density of urban land use decreases upstream along Mill Run. The data collected for this project is compared below to the data collected in the CEED's 2011 Environmental Assessment of Mill Run. The data is labeled and differentiated by the year of publication, 2025 being this project and 2011 being the CEED's 2011 data. Water chemistry data from the Cemetery Run site has been excluded from the comparisons as there is no 2011 data from Cemetery Run. Complete data results of both water chemistry and macroinvertebrate sampling are provided in the appendices.

For the sake of comparison, pH values from 2011 were rounded to the nearest half (exact values with two significant figures can be found in Appendix A.) The mean pH value for the 2011 data is 7.75, and the mean for the 2025 data is 7.625. The results of the pH test give little insight into the water quality at different locations within Mill Run and indicate that throughout the stream there is a consistent pH that is neither acidic nor basic, falling within the neutral range of approximately 7. If pH levels were considerably lower, this could indicate the stream is being polluted by outside factors, such as acidic rain (U.S. Geological Survey, 2019). However, results from 2011 and 2025 indicate that Mill Run has a healthy and consistent pH from the MARC to downstream toward French Creek, despite the increasing urbanization associated with the downstream sites.

**Figure 7.**

*Comparison between the pH values from 2025 and 2011*

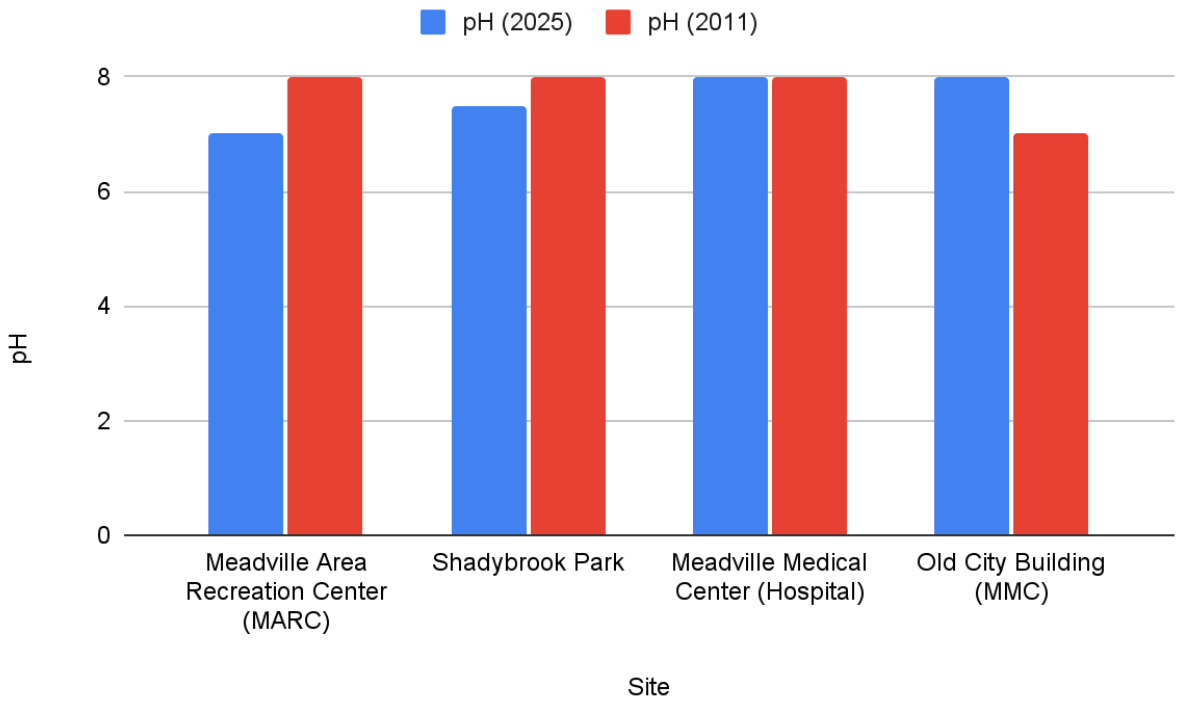



**Figure 7**. pH values for four different sites along Mill Run. 2025 data was collected on November 23, 2024. 2011 data was collected on four different dates, from November 2008 to March 2009.

Conductivity indicates the number of dissolved salts within a body of water and the ability for electricity to flow through the water (Data Stream, n.d.). The conductivity at the four sites from 2025 data increased as sites moved downstream and toward downtown Meadville (Figure 7). The increase in conductivity at sites closer to downtown Meadville is consistent with data in Pennsylvania that finds a correlation between increased impervious surface cover and higher conductivity readings (Willistown Conservation Trust, 2022). One explanation for this increase is that rainwater run-off can result in salts from the soil and road salt to be emptied into the stream (Queen Mary University of London, n.d.). In general, an increase in urbanization is associated with increases in conductivity readings, especially in comparison to the conductivity reading in forested and agricultural sites (U.S. EPA, 2025)

Conductivity has increased from 2011 to 2025 at all testing sites except the Old City Building. This increase could be an indicator of increased pollution at those three sites, as streams normally maintain a constant range of conductivity (Datastream, n.d.). However, it is likely that differences between data collection dates and increased number of data collection days between the 2011 and 2025 data could explain this discrepancy. Only one day of data collection was performed in this project, occurring in November, whereas four days of data collection occurred in the CEED's 2011 Environmental Assessment, spanning from November to March. Additionally, weather conditions, such as the amount of rain and the season have an impact on conductivity (Datastream. n.d.).

**Figure 8**

*Comparison between the conductivity reading values from 2025 and 2011*

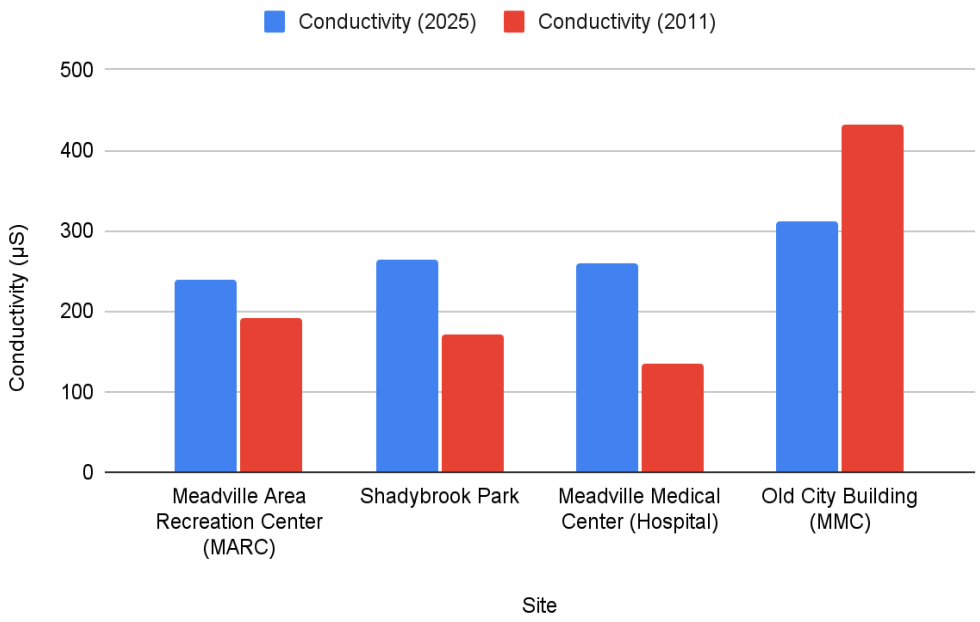



**Figure 8.** Conductivity reading values for four different sites along Mill Run. 2025 data was collected on November 23, 2024. 2011 data was collected on four different dates, from November 2008 to March 2009.

Alkalinity measures a stream's ability to maintain a balanced pH value, also known as the buffering capacity (Datastream, n.d.). The Pennsylvania Department of Conservation and Natural Resources (2015) states that the typical range for freshwater is 20-200 mg/L, with the acceptable range for freshwater organisms set at 100-200 mg/L. According to these parameters, the alkalinity of Mill Run is acceptable for supporting freshwater organisms. The cause of the drastic differences between the 2011 and 2025 is unclear as alkalinity is mostly influenced by the type of rock within a stream. Limestone streams tend to have higher alkalinity values due to the greater amount of calcium carbonate within limestone rocks (Datastream, n.d.), and there are limestone deposits within the Mill Run watershed (The Center for Economic and Environmental Development at Allegheny College, 2011) which would not have changed over the past 14 years.

Both data sets show that the Meadville Medical Center (MMC) site had the lowest alkalinity value of all four sites (Figure 10). The exact alkalinity values for the 2011 and 2025 data are shown in Table 2.

**Figure 9**

*Comparison between the alkalinity values from 2025 and 2011*

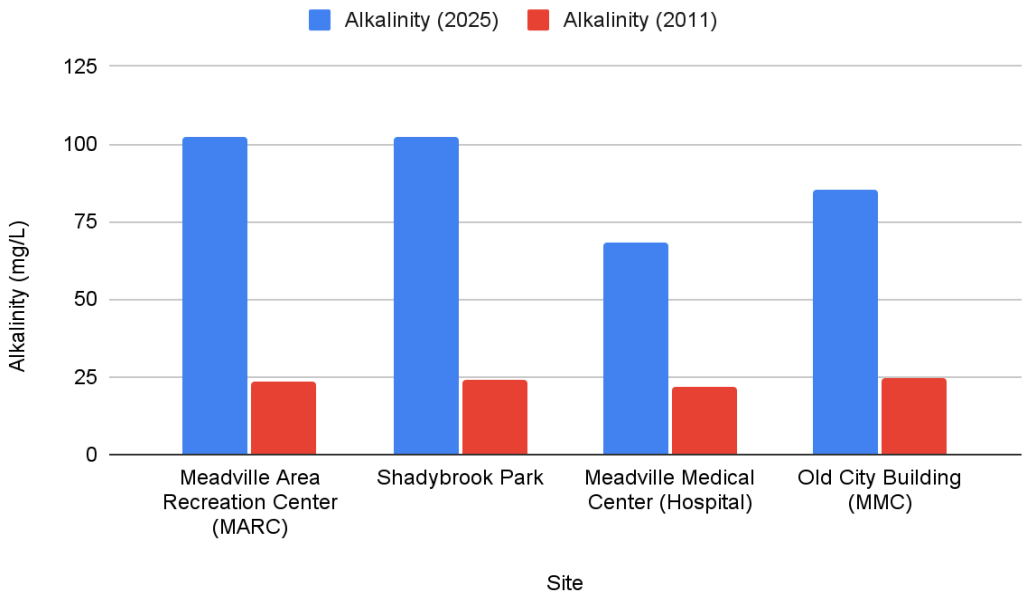



**Figure 9.** Alkalinity values of four different sites along Mill Run. 2025 data was collected on November 23, 2024. 2011 data was collected on four different dates, from November 2008 to March 2009.

Dissolved oxygen (DO) indicates the amount of oxygen within water, with low levels of DO being detrimental to freshwater life (Pennsylvania Fish and Boat Commission, 2018). Low concentrations of DO can indicate that a stream is experiencing urban stream syndrome due to wastewater pollution (Huang et al., 2017) or even chemical run-off from agricultural land. DO levels have increased between 2011 and 2025 according to the data collected (Figure 10). This increase is a positive change in water quality, as the ideal average DO concentration is approximately 9 mg/L and most organisms are not able to survive in DO concentrations below 3 mg/L (Pennsylvania Department of Conservation and Natural Resources, 2015). The average DO concentration of all sites in the 2011 data was 4.7 mg/L and the average DO concentration in the 2025 data was 10. While freshwater organisms all require a different concentration of DO to thrive, the most recent DO concentrations from the 2025 data are ideal for supporting most freshwater organisms according to the PA Department of Conservation and Natural Resources (2015) and the PA Fish and Boat Commission (2018).

**Figure 10**

*Comparison between the dissolved oxygen from 2025 and 2011*

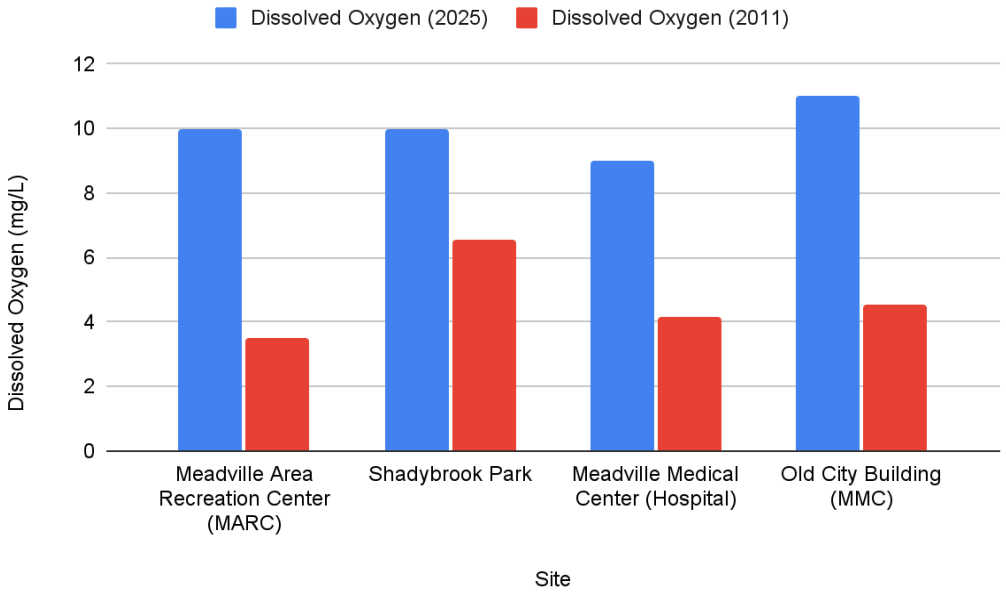



**Figure 10.** Dissolved oxygen (DO) concentration values for four different sites along Mill Run. 2025 data was collected on November 23, 2024. 2011 data was collected on four different dates, from November 2008 to March 2009.

While exact IBI scores are not provided within the CEED's 2011 Environmental Assessment, graphs are provided showing the trend of the IBI scores and macroinvertebrate diversity at five different sites along Mill Run (Figure 11). The Library testing site included in Figure 11 was not used in this project and is excluded in the following comparison.

Out of all the IBI scores from CEED's 2011 Environmental Assessment, the Cemetery Run site had the highest IBI score and highest macroinvertebrate diversity, while the Old City Building (City Bldg) had the lowest score and the lowest macroinvertebrate diversity. For the 2025 macroinvertebrate data, the Meadville Area Recreation Center (MARC) had the highest IBI score and highest macroinvertebrate diversity, with Shadybrook Park having the lowest IBI score and macroinvertebrate diversity (Table 2).

**Figure 11**

*Graphs of data from CEED's 2011 Environmental Assessment of Mill Run*

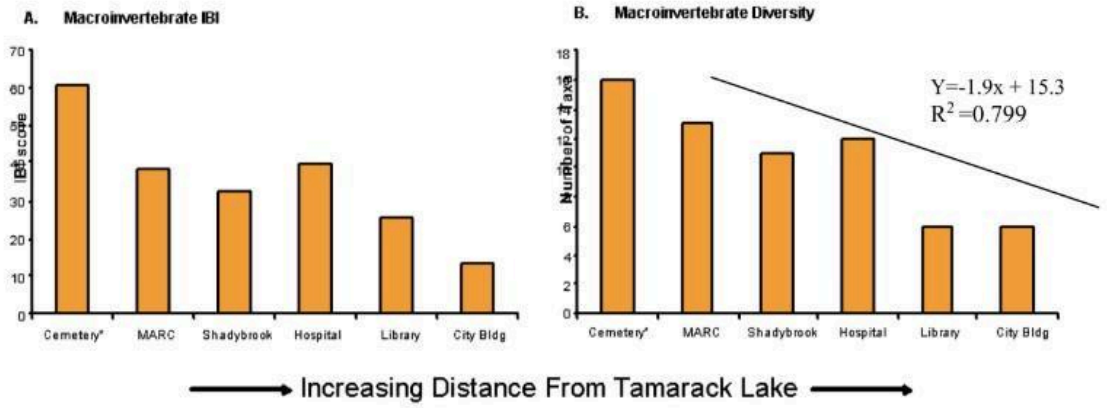



**Figure 4-2**. Macroinvertebrate IBI and Diversity per site. The sites are arranged in descending order starting downstream of Mill Run's Outlet from Tamarack Lake and traveling closer towards French Creek. *Cemetery Run was excluded from each regression but is still seen in the graphs. A. IBI scores for benthic macroinvertebrates of Mill Run ($P$=0.074) and B. The macroinvertebrate taxa diversity among each site ($P$=0.0041, $R^2$=0.799).

**Figure 11.** Graphs from the CEED's 2011 Environmental Assessment of Mill Run showing the macroinvertebrate IBI scores and macroinvertebrate diversity for five different sites along Mill Run.

**Table 2**
*IBI Scores and Macroinvertebrate Diversity for 2025 data*

| Site | IBI Score | Taxa Richness |
|---|---|---|
| Meadville Area Recreation Center (MARC) | 43.995 | 22 |
| Shadybrook Park | 18.1 | 6 |
| Cemetery Run | 30.1 | 17 |
| Meadville Medical Center (Hospital) | 41.5 | 19 |
| Old City Building (MMC) | 19.5 | 6 |

**Table 2.** IBI scores and macroinvertebrate diversity (determined by taxa richness) for all five testing sites from the macroinvertebrate data collected on November 23, 2024.

GIS maps showing more detail of the land-use data 30 meters around the strip of Mill Run along the five testing sites are shown in Figures 12 and 13. The maps show land-use data from 2010 (Figure 12) and 2022 (Figure 13). There have been very few changes in the land-use around this section of Mill Run over the past 12 years. In both 2010 and 2022, the MARC, Shadybrook Park, and Cemetery Run sites all had the most tree canopy and low vegetation cover out of all the sites, while the Meadville Medical Center (Hospital) and the Old City Building had more impervious structures and roads during both 2010 and 2022.

Previous research performed in the French Creek Watershed that looked at the potential impacts of land use on water quality, using water chemistry and IBI scores, found a connection between lower IBI scores and a lower percentage of forest-only land cover (Oravec, 2016). The high percentage of tree canopy around the MARC site can explain why it had the highest IBI score in 2025; the buffer zone around the stream is more vegetative, which supports aquatic life by preventing outside factors such as runoff. It is unclear from the data gathered why Shadybrook Park had such a low IBI score in comparison to the other higher-vegetated sites, but data collection errors and the heavy flow of the stream due to rain may have resulted in a smaller sample size. From both data sets (2011 and 2025), the Meadville Medical Center (Hospital) had a higher IBI score and macroinvertebrate diversity in comparison to other downstream sites such as the Old City Building (City Bldg). The higher IBI and diversity could be due to previous efforts made by the hospital when they built an outdoor space adjacent to the stream and added

boulders along the riparian zone to reduce erosion and run-off into Mill Run (The Center for Economic and Environmental Development at Allegheny College, 2011). These changes may have created a more supportive environment for aquatic life at the testing site. Overall, all sites had an IBI score below 50, indicating that there are factors at play causing poor stream quality as the environment is not supportive of aquatic life. Low IBI scores are associated with urban stream syndrome, with studies finding that the diversity of macroinvertebrates increases as urbanization land-use increases (Huang & Gergel, 2023; Roy et al., 2003).

**Figure 12**

*GIS analysis of 2010 land cover composition within a 30 meter zone of Mill Run*

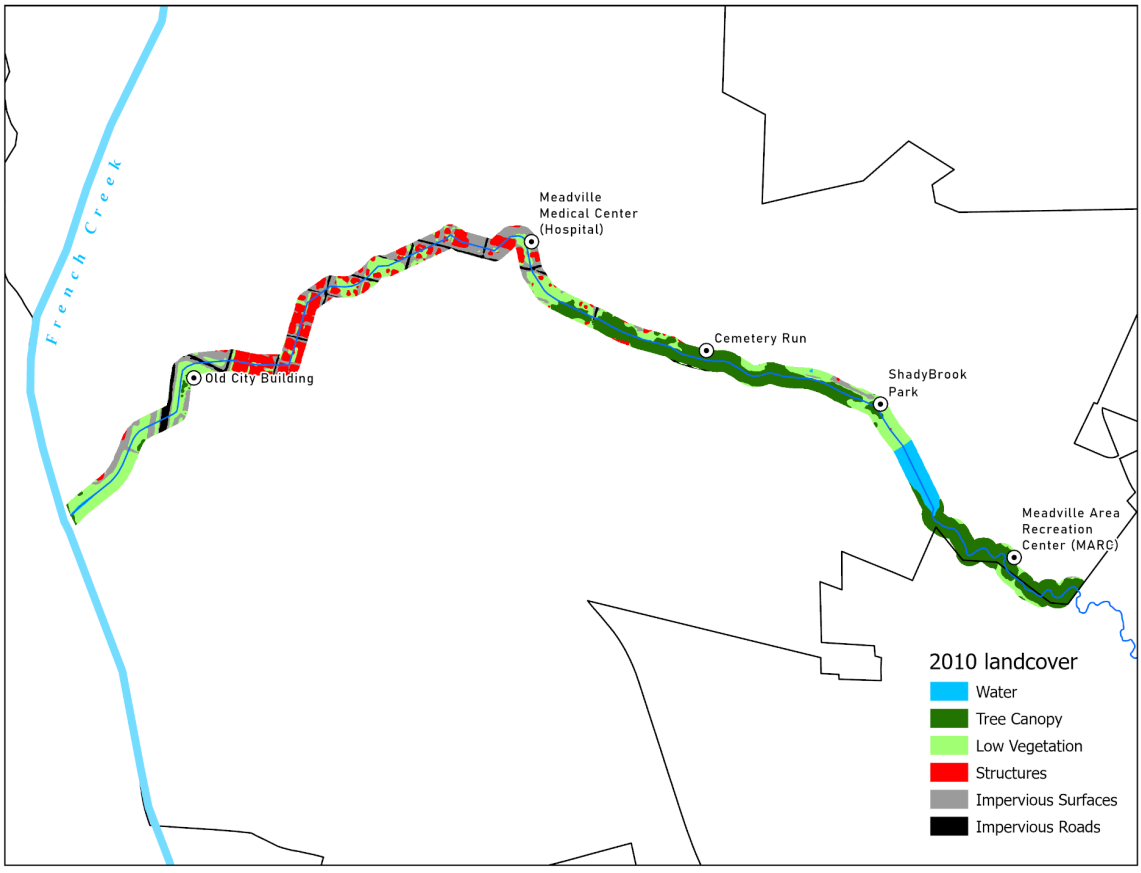



**Figure 12.** GIS map of land use within a 30 meter zone of Mill Run in 2010. Source imagery: National Agricultural Imagery Program, U.S. Department of Agriculture, 2010.

**Figure 13**

*GIS analysis of 2022 land cover composition within a 30 meter zone of Mill Run*

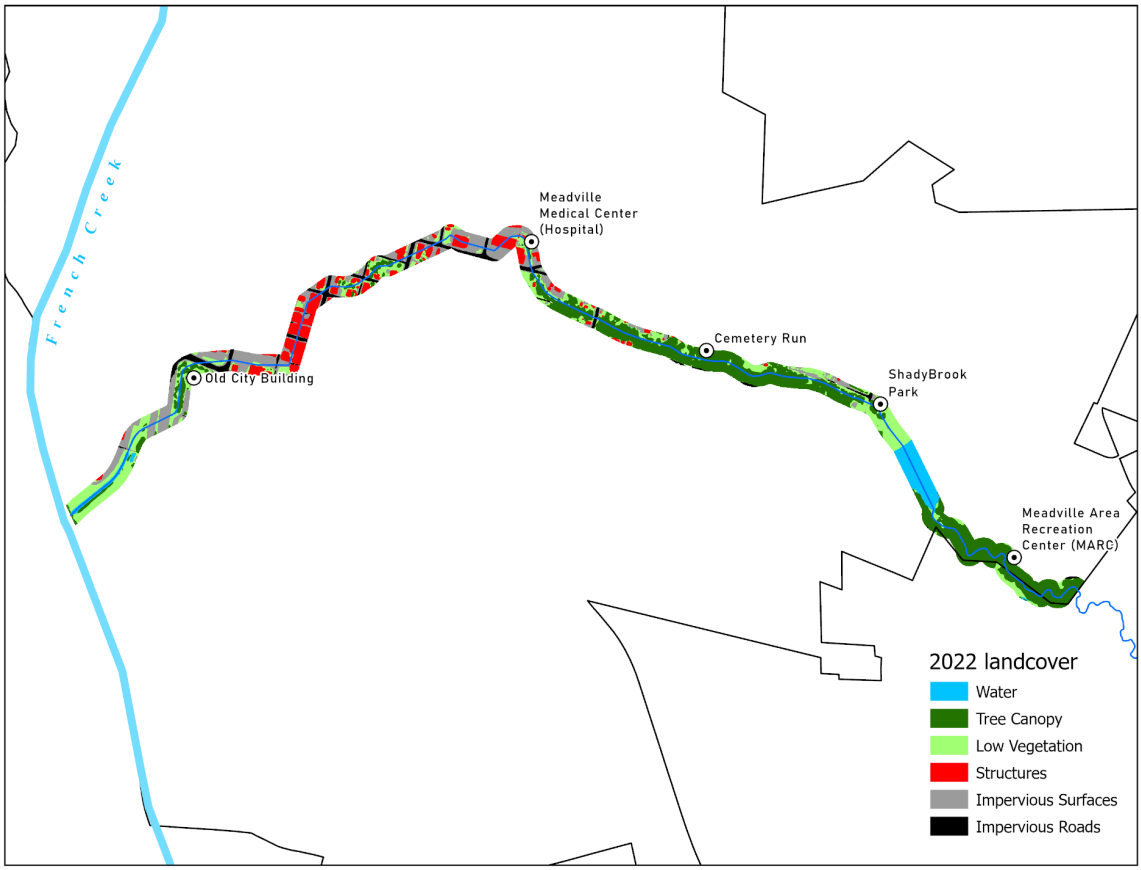



**Figure 13.** GIS map of land use within a 30 meter zone of Mill Run in 2022. Source imagery: National Agricultural Imagery Program, U.S. Department of Agriculture, 2022.

## Conclusion

The results of this study vary, with some results indicating a positive change in water quality while others are inconclusive or indicate a negative change. Examples of positive change include the increase in dissolved oxygen concentrations throughout all four sites. Consistencies in the IBI scores were found in the 2011 and 2025 data. In both 2011 and 2025, Shadybrook and the City Building had lower IBI scores in comparison to the other sites, whereas the Hospital, MARC, and Cemetery Run all had the highest IBI scores. In accordance with the Pennsylvania Department of Environmental Protection's standards, an IBI score less than 50 is considered impaired (Pennsylvania Department of Environmental Protection, 2012). All sites from this 2025 data have scores less than 50, meaning that these sections of Mill Run are considered impaired and not supportive of aquatic life.

There were several limitations of this study, including the fewer days of data collection that occurred in comparison to the CEED's 2011 Environmental Assessment. Additionally, sample sizes of macroinvertebrates were less than the target number of organisms for calculating IBI scores. The smaller sample sizes could be an indication of stream impairment due to pollution and/or habitat disturbance (Pennsylvania Department of Environmental Protection, 2012). It is likely that the physical conditions surrounding Mill Run, such as its alteration with dams and a city being built over it could result in these smaller sample sizes.

Future research should take into account the physical state of Mill Run, as it will likely have an impact on the results of water chemistry testing and macroinvertebrate sampling (as mentioned above) due to the heavy urbanization in the downstream portions of Mill Run. More frequent testing should be conducted to monitor the stream health of Mill Run. Having more frequent data (ideally every year) would allow researchers and the community to understand the condition of Mill Run and provide a baseline for future studies. Additionally, during these sample periods there should be more than one testing date, ensuring that results can be averaged so that outside factors (such as errors in data collection or weather conditions) are less likely to skew results.

Proper record keeping of water chemistry data and macroinvertebrate sampling should be a priority in future research as previous studies on Mill Run had inconsistencies in their data or exact data were not published. The same procedures, including the time of year, methods of

water sampling, and macroinvertebrate sampling should be used every time data is collected to allow comparison of data over time.

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## Appendix A
## Water Chemistry Data Results

| Site Name | Date of collection | Water Chemistry | | | | | |
|---|---|---|---|---|---|---|---|
| | | Temperature (°C) | pH | Alkalinity | Total Dissolved Solids (ppm) | Conductivity (µS) | Dissolved Oxygen |
| Meadville Area Recreation Center (MARC) | 11/23/2024 | 7 | 7 | 102 | 150 | 239 | 10 |
| Shadybrook Park | 11/23/2024 | 7 | 7.5 | 102 | 170 | 263 | 10 |
| Cemetery Run | 11/23/2024 | 7 | 7.5 | 102 | 180 | 300 | 11 |
| Meadville Medical Center (Hospital) | 11/23/2024 | 6.5 | 8 | 68 | 170 | 259 | 9 |
| Old City Building | 11/23/2024 | 6.5 | 8 | 85 | 180 | 311 | 11 |

**Appendix B**
**Metric and Index Calculations for Macroinvertebrate Samples**

**MARC**

Total Taxa Richness = 22

EPT Taxa Richness = 6

Beck's Index = 6

Hilsenhoff Biotic Index = 5.28

Shannon Diversity Index = 2.25

Percent Sensitive Individuals = 10.87%

| Metric | Standardized Equation | Observed Metric Value | Standardized Metric Score | Adjusted Standardized Metric Score |
|---|---|---|---|---|
| Total Taxa Richness | observed/33 * 100 | 22 | 66.7 | 66.7 |
| EPT Taxa Richness | observed/19 * 100 | 6 | 31.6 | 31.6 |
| Beck's Index | observed/38 * 100 | 6 | 15.8 | 15.8 |
| Hilsenhoff Biotic Index | (10 - observed)/(10 - 1.89) * 100 | 5.28 | 58.0 | 58.0 |
| Shannon Diversity | observed/2.86 * 100 | 2.25 | 78.7 | 78.7 |
| % Sensitive Individuals | observed/84.5 * 100 | 10.87 | 12.9 | 12.9 |
| Arithmetic average of adjusted standardized core metric scores = **IBI Score** = | | | | **43.995** |

**Shadybrook Park**

Total Taxa Richness = 6

EPT Taxa Richness = 0

Beck's Index = 1

Hilsenhoff Biotic Index = 6.87

Shannon Diversity Index = 0.89

Percent Sensitive Individuals = 15.22%

| Metric | Standardized Equation | Observed Metric Value | Standardized Metric Score | Adjusted Standardized Metric Score |
|---|---|---|---|---|
| Total Taxa Richness | observed/33 * 100 | 6 | 18.2 | 18.2 |
| EPT Taxa Richness | observed/19 * 100 | 0 | 0 | 0 |
| Beck's Index | observed/38 * 100 | 1 | 2.6 | 2.6 |
| Hilsenhoff Biotic Index | (10 - observed)/(10 - 1.89) * 100 | 6.87 | 38.5 | 38.5 |
| Shannon Diversity | observed/2.86 * 100 | 0.89 | 31.1 | 31.1 |
| % Sensitive Individuals | observed/84.5 * 100 | 15.22 | 18.0 | 18.0 |
| Arithmetic average of adjusted standardized core metric scores = IBI Score = | | | | **18.1** |

**Cemetery Run**

Total Taxa Richness = 17

EPT Taxa Richness = 6

Beck's Index = 1

Hilsenhoff Biotic Index = 7.7

Shannon Diversity Index = 1.71

Percent Sensitive Individuals = 5.8%

| Metric | Standardized Equation | Observed Metric Value | Standardized Metric Score | Adjusted Standardized Metric Score |
|---|---|---|---|---|
| Total Taxa Richness | observed/33 * 100 | 17 | 51.5 | 51.5 |
| EPT Taxa Richness | observed/19 * 100 | 6 | 31.6 | 31.6 |
| Beck's Index | observed/38 * 100 | 1 | 2.6 | 2.6 |
| Hilsenhoff Biotic Index | (10 - observed)/(10 - 1.89) * 100 | 7.7 | 28.3 | 28.3 |
| Shannon Diversity | observed/2.86 * 100 | 1.71 | 59.8 | 59.8 |
| % Sensitive Individuals | observed/84.5 * 100 | 5.8 | 6.7 | 6.7 |
| Arithmetic average of adjusted standardized core metric scores = IBI Score = | | | | **30.1** |

**Medical Center**

Total Taxa Richness = 19

EPT Taxa Richness = 10

Beck's Index = 5

Hilsenhoff Biotic Index = 7.1

Shannon Diversity Index = 2.19

Percent Sensitive Individuals = 11.5%

| Metric | Standardized Equation | Observed Metric Value | Standardized Metric Score | Adjusted Standardized Metric Score |
|---|---|---|---|---|
| Total Taxa Richness | observed/33 * 100 | 19 | 57.6 | 57.6 |
| EPT Taxa Richness | observed/19 * 100 | 10 | 52.6 | 52.6 |
| Beck's Index | observed/38 * 100 | 5 | 13.2 | 13.2 |
| Hilsenhoff Biotic Index | (10 - observed)/(10 - 1.89) * 100 | 7.1 | 35.6 | 35.6 |
| Shannon Diversity | observed/2.86 * 100 | 2.19 | 76.6 | 76.6 |
| % Sensitive Individuals | observed/84.5 * 100 | 11.5 | 13.6 | 13.6 |
| Arithmetic average of adjusted standardized core metric scores = IBI Score = | | | | **41.5** |

**City Building**

Total Taxa Richness = 6

EPT Taxa Richness = 2

Beck's Index = 0

Hilsenhoff Biotic Index = 6.1

Shannon Diversity Index = 1.05

Percent Sensitive Individuals = 3.7

| Metric | Standardized Equation | Observed Metric Value | Standardized Metric Score | Adjusted Standardized Metric Score |
|---|---|---|---|---|
| Total Taxa Richness | observed/33 * 100 | 6 | 18.2 | 18.2 |
| EPT Taxa Richness | observed/19 * 100 | 2 | 10.5 | 10.5 |
| Beck's Index | observed/38 * 100 | 0 | 0 | 0 |
| Hilsenhoff Biotic Index | (10 - observed)/(10 - 1.89) * 100 | 6.1 | 48.0 | 48.0 |
| Shannon Diversity | observed/2.86 * 100 | 1.05 | 36.1 | 36.1 |
| % Sensitive Individuals | observed/84.5 * 100 | 3.7 | 4.4 | 4.4 |
| Arithmetic average of adjusted standardized core metric scores = IBI Score = | | | | **19.5** |

## Appendix C
## Water Chemistry Collection Data Sheets

**DATA SHEET: WATER CHEMISTRY** **DATE:**

| SITE LOCATION | TEMPERATURE | pH | DISSOLVED OXYGEN | TOTAL DISSOLVED SOLIDS (TDS) | CONDUCTIVITY | ALKALINITY |
|---|---|---|---|---|---|---|
| | | | | | | |
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**NOTES:**