Buffalo Creek Watershed Implementation Plan

Audubon Western Pennsylvania

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Acknowledgments

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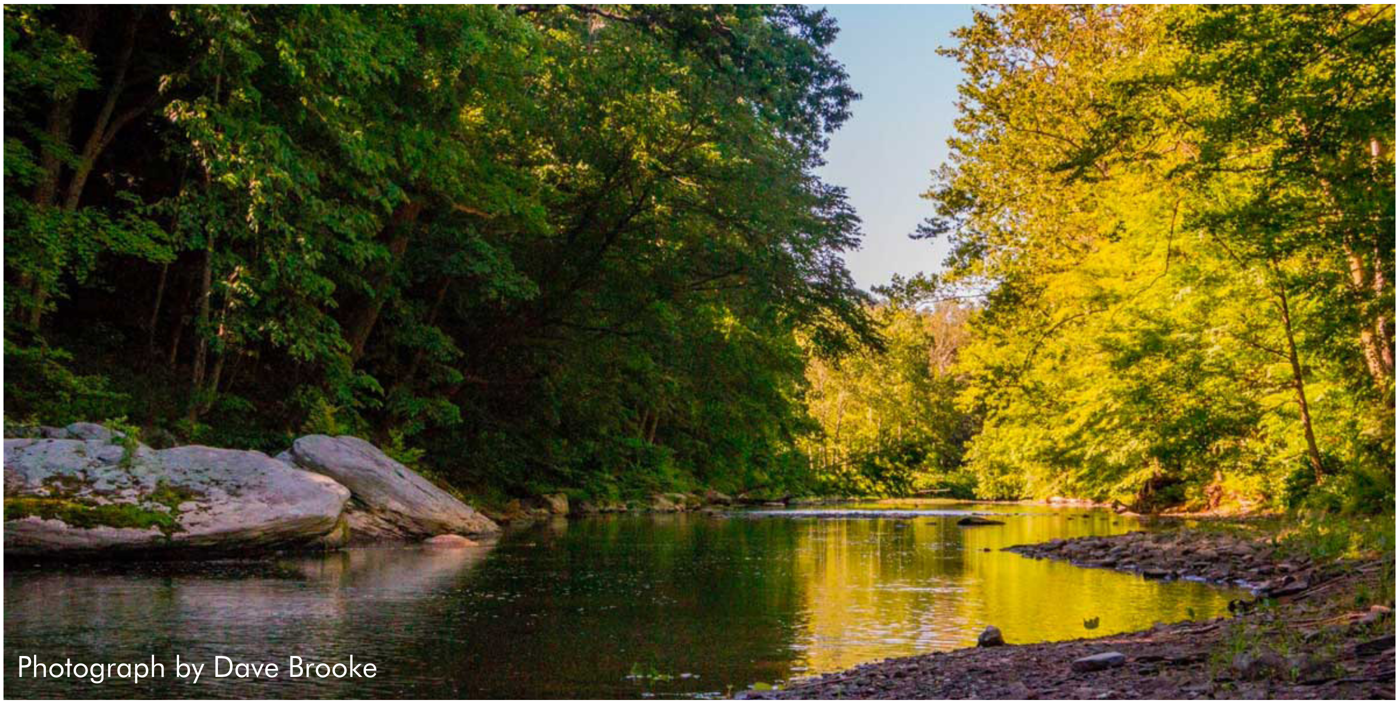
Photograph by Dave Brooke

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Introduction

Project Background

The Buffalo Creek-Cornplanter Run HUC-12 watershed, encompassing 54.1 square miles across Armstrong, Butler, and Allegheny Counties, is a critical ecological area with significant water quality and water resources challenges. The development of long-term Watershed Implementation Plan (WIP) is paramount for environmental stewardship. The WIP for this watershed, led by the Audubon Society of Western Pennsylvania and guided by EPA's policy and aligned with the Nine Elements for Watershed-Based Plans, will address key issues such as agricultural runoff, urban development impact, and acid mine drainage (AMD). This strategic initiative is also designed to uphold and further the objectives of past watershed planning efforts, emphasizing restoration and protection efforts within the watershed.

About ASWP

Audubon Society of Western Pennsylvania (ASWP) is an environmental education and conservation engagement organization that serves a seven-county region surrounding Pittsburgh. ASWP is a member-supported, legally and fiscally independent chapter of National Audubon Society. Through programs, projects, and places, ASWP educates and inspires the people of southwestern Pennsylvania to be effective stewards of the natural world and to help create more bird-friendly communities. Each year, ASWP engages over 17,000 students — from pre-K through college — in formal, hands-on, natural history programs. We also reach thousands of adults through informal programs that create environmental literacy and excitement for the natural world. Our projects enable people to participate in meaningful conservation activities and/or help to improve and maintain important habits and resources throughout the region. Our nature centers and reserves — Beechwood, Buffalo Creek, Succop, and Todd — offer over 12 miles of trails through more than 500 tranquil acres that provide an oasis for individuals, families, and groups to explore and reconnect with nature at their own pace.

ASWP owns or protects over 500 acres within the Buffalo Creek Watershed, including 2 public nature sites, Todd Nature Reserve (TNR) and Buffalo Creek Nature Park (BCNP). BCNP is a 5-acre site along the Butler-Freeport Trail and Little Buffalo Creek that serves as a hub for watershed education. TNR is a 220-acre site that serves as important habitat for many species of conservation concern such as the Louisiana Waterthrush and offers recreational opportunities for thousands of people annually.

Clean Water Act

Under the Clean Water Act's Section 303(d), states are required to conduct regular assessments of their surface waters to ascertain compliance with protected uses such as support of aquatic life, provision of drinking water, and recreational and fishing suitability. These evaluations classify water bodies into one of three categories: attaining, impaired, or unassessed. "Attaining" waters are those deemed by state authorities to meet their intended uses effectively. Conversely, "impaired" waters are identified as failing to meet one or more criteria of water quality standards.

Waters classified as impaired are listed in the state's 303(d) inventory, which is submitted biennially to the EPA. These waters typically necessitate the formulation of a Total Maximum Daily Load (TMDL) plan, which outlines the maximum pollutant level a water body can accept and still meet its designated uses. Within the scope of this initiative, only one subwatershed in the Cornplanter Run-Buffalo Creek HUC-12 area has an established TMDL for the receiving waters. The streams within this subwatershed - known as Moonlight Drive within this document and referred to as an unnamed tributary in the previous TMDL report - are impaired for acid mine drainage. The streams other four subwatersheds studied in this Watershed Implementation Plan (WIP) are impaired in relation to more conventional non-point sources - sediment, nitrogen, and phosphorus. As such, the Reference Watershed method was used to determine loading targets and reduction goals.

Impairments to Buffalo Creek

Sections of the Buffalo Creek-Cornplanter Run HUC-12 were first identified as impaired on the state's 303(d) list in 2000, leading to the development of a TMDL plan in 2020 for the Moonlight Drive subwatershed. Impairment sources include sediment and nutrients from agricultural activities, acid mine drainage, runoff from urban development and various industrial zones. These impairments particularly threaten the High Quality (HQ) attributes of the Buffalo Creek main stem, especially affecting aquatic life through both sedimentation and chemical imbalances. The subsequent sections of this report detail the specific impairments, the pollutant loadings, and the various lengths of these impaired streams on a per-subwatershed basis.

While sedimentation is a natural phenomenon crucial for aquatic habitats, human-induced activities have led to excessive sedimentation and nutrient loading, causing detrimental impacts on the creek's aquatic life. Key contributors include agricultural tillage and unrestricted livestock access to streams. Stretches of the stream that lack riparian buffers and are bordered by crop fields, pastures, and developed area are also lending to the problem. Additionally, acid mine drainage and urban runoff exacerbate the water quality problems, disrupting the natural pH balance and introducing harmful substances. The low-gradient nature of the creek further complicates matters by inhibiting the natural flushing of accumulated sediment and pollutants.

Addressing the complex sedimentation and pollution issues in Buffalo Creek - Cornplanter Run requires a comprehensive, multi-scale, and phased approach. Initial steps include minimizing sediment input by reducing tillage, enhancing soil cover through cover crops, and implementing grazing management plans. Simultaneously, focused efforts must be made to treat acid mine drainage and manage urban and industrial runoff through the use of detention basins and green infrastructure. Riparian buffers, streambank fencing, and carefully designed stream crossings should be installed to filter sediment and stabilize the banks. These measures also offer broader ecosystem benefits, such as temperature regulation and enhanced wildlife habitats.

Despite the challenges, several locations within the watershed have seen successful interventions to reduce sediment and pollutant levels. Moving forward, the key to revitalizing the HUC-12 will be targeted efforts in collaboration with local landowners, focusing on the most critically impaired segments of the watershed.

Project Goals

The WIP for the Cornplanter Run - Buffalo Creek is designed with a multi-faceted approach to achieve sustainable watershed management. The overarching goal of the WIP is to address the complex interplay of environmental challenges identified within the watershed to improve water quality, enhance ecosystem health, and ensure the longevity of natural resources for future generations. Central to the WIP's objectives is the improvement of water quality across the watershed.
This plan prioritizes the reduction of three primary pollutants: sediment, nitrogen, and phosphorus. These constituents are the primary focus of BMP implementation due to their significant role in nonpoint source pollution associated with agriculture and land use. While acid mine drainage (AMD) is also acknowledged as a source of impairment, the WIP's focus regarding AMD is on quantification and characterization of sources.

Water Quality Improvement

Central to the WIP's objectives is the improvement of water quality across the watershed. This encompasses reducing nutrient and sediment loads entering waterways, which are critical issues stemming from agricultural runoff, acid mine drainage (AMD), and other land use activities. Implementing best management practices (BMPs) like riparian buffers, cover cropping, and controlled tillage aims to minimize the adverse effects of agriculture, while targeted remediation efforts seek to mitigate the legacy of AMD.

Ecosystem Health and Biodiversity

Enhancing the health and diversity of aquatic and terrestrial ecosystems within the watershed is another primary goal. This involves the restoration of streambank stability to prevent erosion, the conservation of existing forested buffers to maintain habitat connectivity, and the expansion of green spaces to support a wide range of plant and animal species.

Sustainable Land Use and Development

This includes promoting smart growth strategies that limit impervious surfaces, encourage green infrastructure, and preserve natural landscapes.

Monitoring and Research

Continuous monitoring and research are essential for the adaptive management of the watershed. The WIP establishes a robust monitoring program to track water quality trends, assess the effectiveness of implemented BMPs, and identify emerging issues. Ongoing collaborative research efforts with academic institutions and environmental organizations such as Duquesne University, the Butler and Armstrong Conservation District, and Western Pennsylvania Conservancy (WPC) will provide the scientific basis for decision-making and policy development.

Funding and Resource Allocation

Securing funding and allocating resources efficiently is crucial for the WIP's success. The plan identifies potential funding sources, such as federal and state grants, private foundations, and public-private partnerships, to support the implementation of BMPs, restoration projects, and conservation efforts.

Public Engagement and Outreach for WIP Development

A variety of outreach and education activities were led by ASWP during WIP development to both inform the WIP and support larger watershed stewardship and engagement goals. Key activities include:

WIP-Specific Activities

- The project and process was presented at a quarterly Buffalo Creek Coalition meeting in March 2023.
- A public meeting was held on April 19, 2023 to gather input on WIP development. Attendees could participate in person at BCNP or online.
- Five interviews, reaching 8 people,

were held with experts with deep knowledge of the watershed, including: Ryan Harr and Ian Harrell (Butler County Conservation District), Dr. Brady Porter and Kat Wilson (Duquesne University), Maria Sorce and Jessica Schaub (Armstrong Conservation District), Dave Beale (Dave Beale Forestry), and George Reese (GAI Consultants).

- An additional public meeting will be held at the completion of EPA- and DEP-approval of the WIP.

Key Education Activities

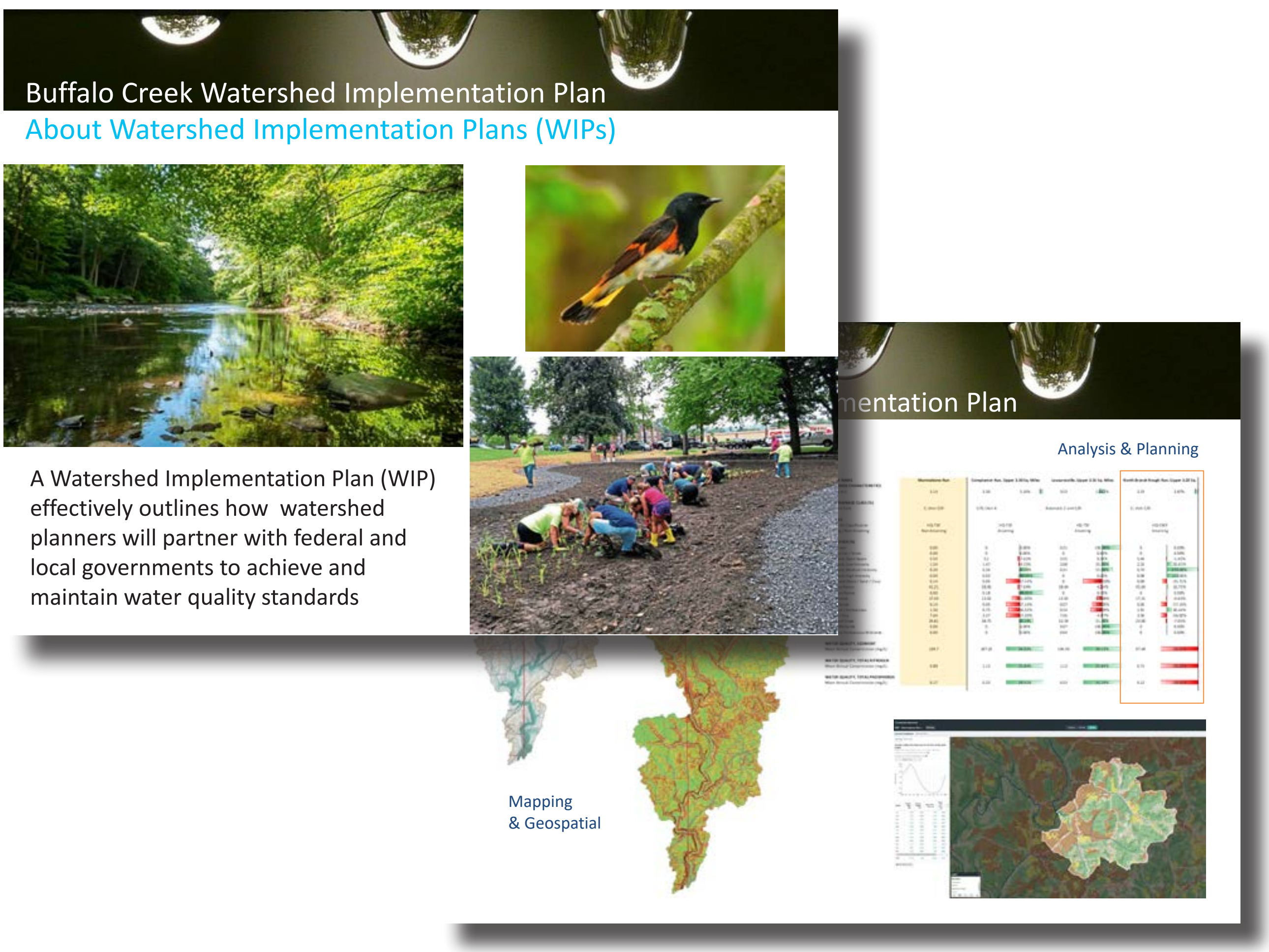
- Annual watershed festival held in September 2022 and September 2023, reaching over 700 people.

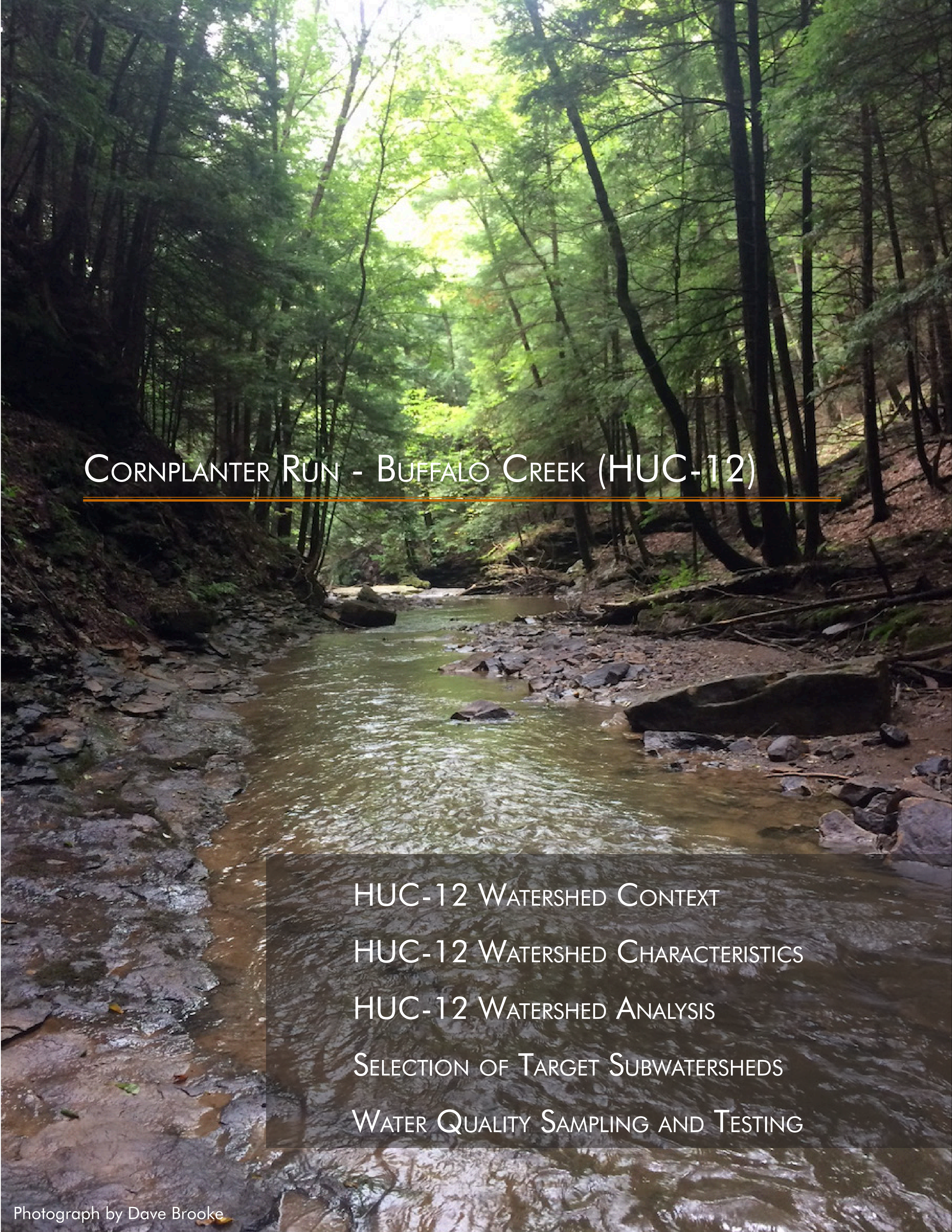
- Ten (10) landowner workshops on topics such as What is a Healthy Stream?, Private Landowner Resources, Managing Invasive Species, and Hemlock Woolly Adelgid.

- Over 20 public education programs including Stream Exploration Field Days for families, Salamanders of Buffalo Creek, and various habitat gardening and natural history topics.

- Weekly naturalist-led walks from April - October at TNR and BCNP.

- Municipal-focused workshops on stormwater and funding as well a 1-day summit focused on coming together for shared solutions for water quality, communities, and habitat.





Cornplanter Run - Buffalo Creek (HUC-12)

HUC-12 Watershed Context

HUC-12 Watershed Characteristics

HUC-12 Watershed Analysis

Selection of Target Subwatersheds

Water Quality Sampling and Testing

Photograph by Dave Brooke

Figure 1:
Aerial Imagery of
Cornplanter Run -
Buffalo Creek
(HUC-12)

Cornplanter Run - Buffalo Creek (HUC-12)

HUC-12 Watershed Context

Major Watershed

Denoted in blue, the Cornplanter Run - Buffalo Creek HUC-12 watershed, located in west-central Pennsylvania, is depicted in Figure 2 below. The larger Buffalo Creek watershed is shown in blue and purple. The Cornplanter Run - Buffalo Creek HUC-12 generally encompasses parts of Butler County, Armstrong County, and a small section of Allegheny County. The map below also highlights the major watersheds of Pennsylvania, delineated by black boundaries.

Both the Cornplanter Run - Buffalo Creek subwatershed (at approximately 54-square-miles) and the larger Buffalo Creek watershed are located within the much larger Allegheny River Major Watershed, which is approximately 11,747 square miles.

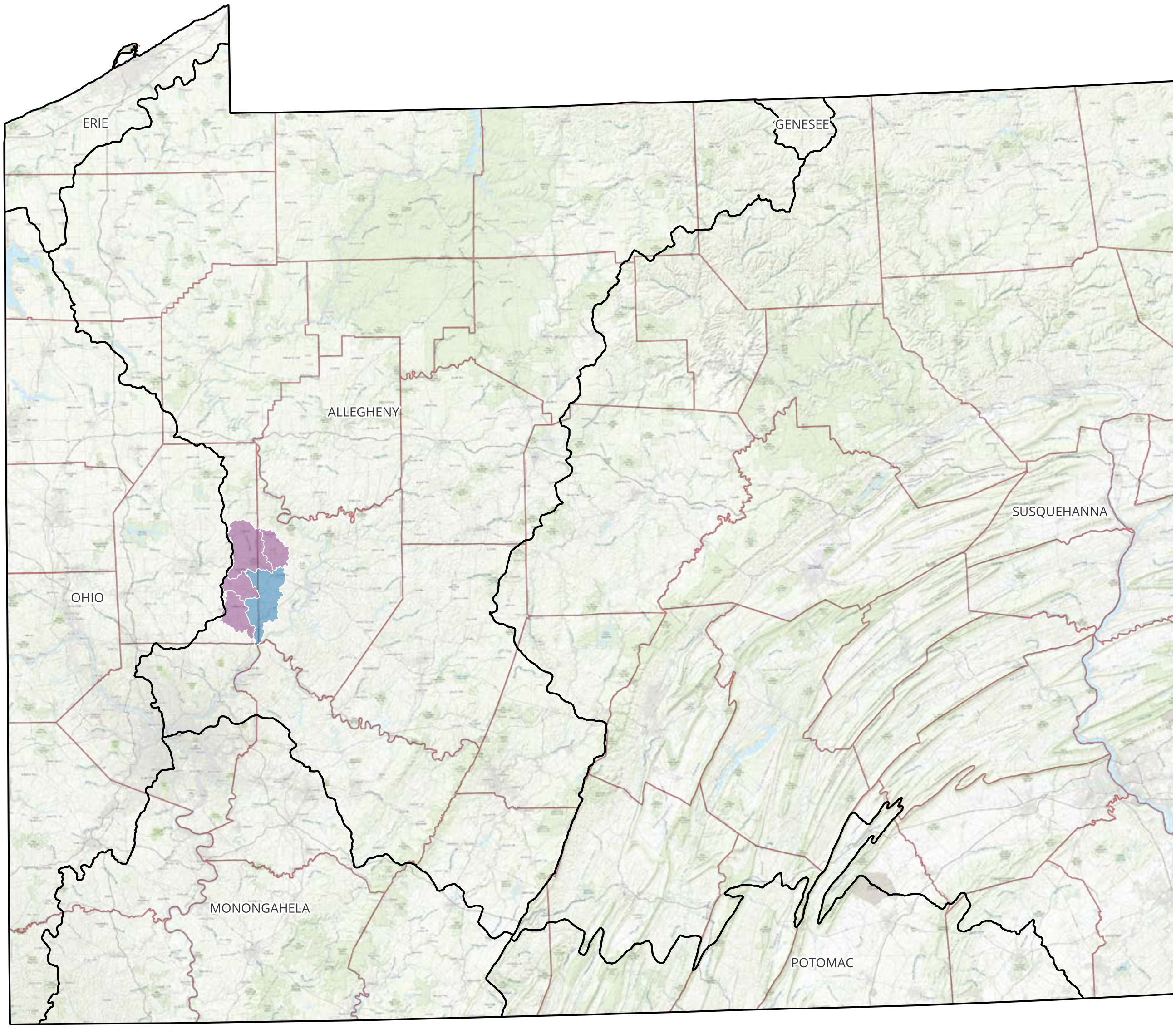
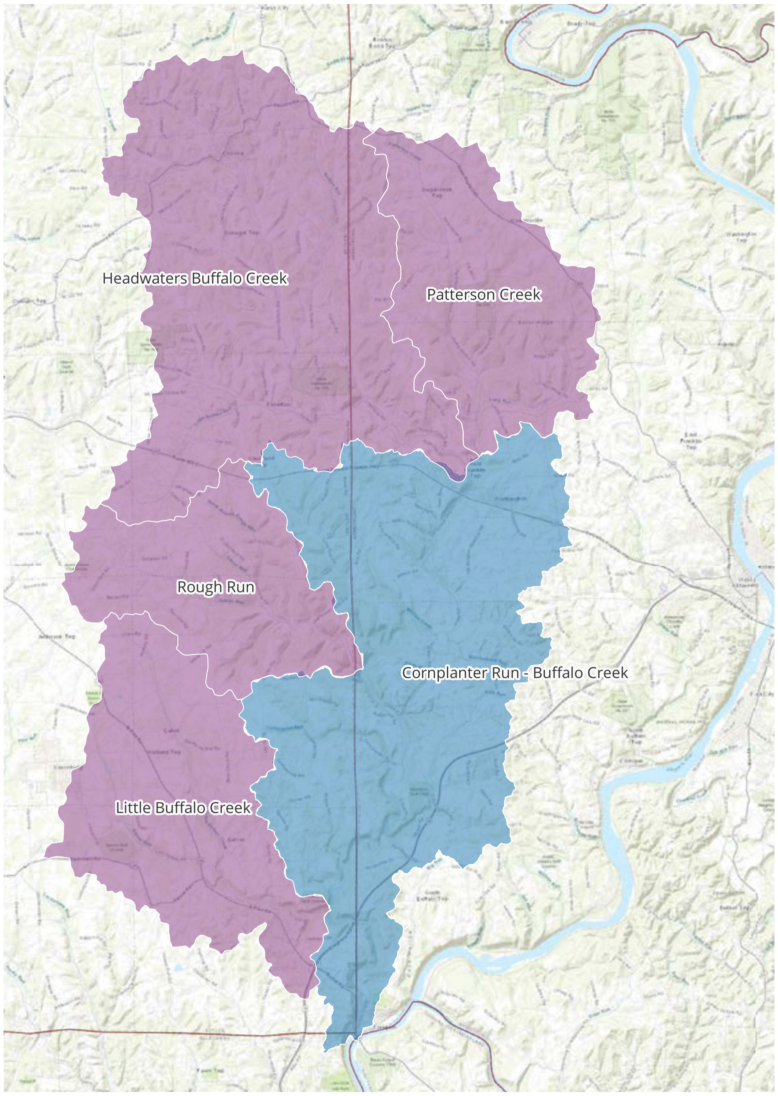


Figure 2 Major Watershed and Buffalo Creek Huc-12 Geographic Context

Upper and Lower Buffalo Creek (HUC-12)

Figure 3 delineates the HUC-12 watersheds that comprise the larger Buffalo Creek watershed, with a distinct emphasis on the Cornplanter Run-Buffalo Creek subwatershed, in blue. Surrounding this focal area are the neighboring subwatersheds: Headwaters Buffalo Creek, Patterson Creek, Rough Run, and Little Buffalo Creek, shown here in purple.

Figure 3 Buffalo Creek Huc-12 Overview



The surrounding subwatersheds are illustrated to provide context and acknowledge their upstream contributions. However, the project's focus remains steadfast on Cornplanter Run-Buffalo Creek, understanding that actions within this subwatershed directly impact the water quality and ecosystem services of Buffalo Creek as a whole.

HUC-12 Watershed Characteristics

Climate and Weather

The climate profile for the Buffalo Creek-Allegheny River Subwatershed reveals a temperate climate with distinct seasonal patterns that significantly influence the region's hydrology. The area experiences a mean annual precipitation of 40.8 inches and an average temperature of 50.1°F, indicative of the moderate yet variable climate that shapes the watershed's environmental responses.

Precipitation peaks during the summer, with the highest rainfall occurring in June, reflecting a period of potential water surplus that could increase runoff, affect water quality, and lead to flooding. These months of high precipitation, combined with warm temperatures, can also accelerate biological processes in aquatic ecosystems, increasing the demand for oxygen and affecting species diversity and abundance.

Winter months, while cooler and drier, present their own set of hydrological challenges. Lower precipitation and freezing temperatures result in a landscape less responsive to precipitation events, where snow and ice dominate the terrain. The subsequent thaw and meltwater in the spring are critical components of the watershed's annual water cycle, replenishing streams and groundwater reserves.

These climate data underscores the need for adaptive watershed management that accounts for both the lush growth-promoting conditions of the summer and the dormant, potentially erosive conditions of the winter. Planning must incorporate strategies that address the dynamic nature of water flow and storage throughout the year, ensuring that infrastructure is capable of handling seasonal extremes and protecting the watershed's ecological integrity.

Terrain and Slope

Figures 4 and 5 provide a detailed visualization of the terrain and slope characteristics within the Cornplanter Run - Buffalo Creek watershed. The terrain map (Figure 4) uses varying shades to illustrate elevation changes throughout the watershed. The lighter beige areas indicate higher elevations, which generally correspond to ridges and upland areas. In contrast, the darker areas suggest lower elevation valleys, where water accumulation and runoff are more common.

The Steep Slope Map (Figure 5) vividly depicts the slopes within the same region using a color-coded gradient. Green areas represent gentler slopes, which are typically more stable and less prone to erosion. These areas are often associated with agricultural viability and are less likely to contribute to rapid surface runoff. In contrast, the yellow to red spectrum indicates increasingly steeper slopes. Steeper slopes are critical areas for watershed management due to their susceptibility to erosion, rapid runoff, and potential for landslides, which can contribute to sediment in waterways and impact water quality.

From a hydrologic perspective, the terrain and slope maps are deeply interconnected. The terrain map's high elevation areas are the watershed's primary recharge zones, where precipitation infiltrates down through the soil profile to replenish groundwater. These areas often give rise to the headwaters of streams and rivers, with their flow characteristics being influenced by the underlying topography.

The slopes map highlights areas where water movement is accelerated due to gravity, which can lead to increased erosion and sediment transport, particularly in the absence of sufficient vegetative cover. Steeper slopes marked in yellow and red require careful management to ensure that runoff does not carry pollutants into the watershed's watercourses. Gentle slopes in green areas are more conducive to infiltration and can support riparian buffers that help to filter and slow water movement, thereby enhancing groundwater recharge and reducing pollution.

The integration of these maps can inform effective watershed management by identifying areas where conservation efforts, such as reforestation or the installation of erosion control measures, can be prioritized. It also assists in understanding the potential movement of water and the distribution of various hydrological features within the landscape, which is crucial for maintaining the health of aquatic ecosystems and ensuring the quality of water resources.

Figure 4: Terrain and Elevation Map

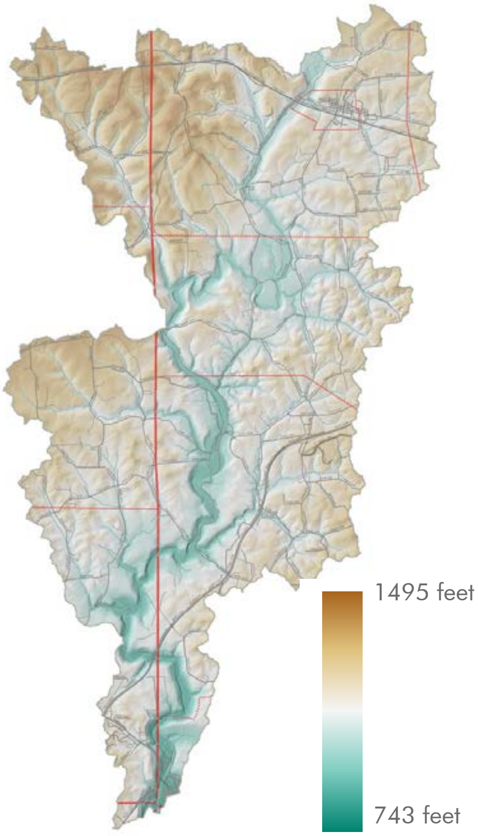
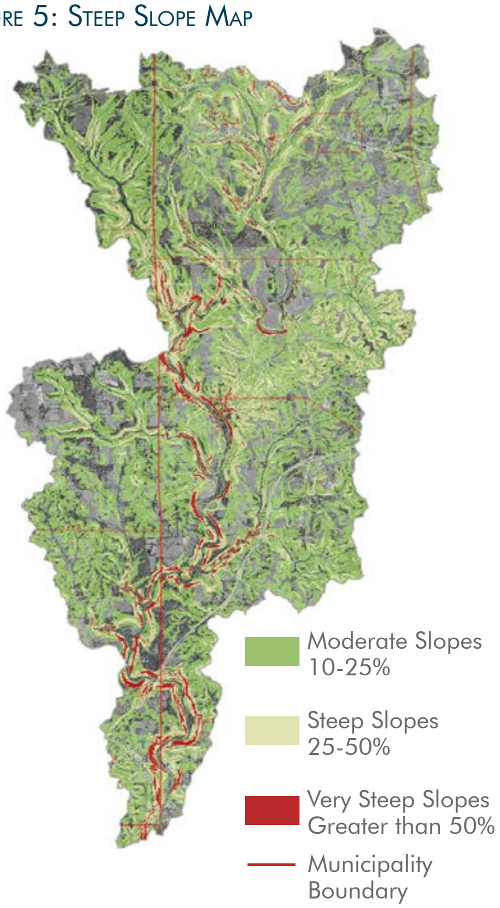


Figure 5: Steep Slope Map



Bedrock Geology and Lithology

Figure 6 presented here provides a geological overview of the Cornplanter Run - Buffalo Creek watershed, detailing the distribution of various rock formations and materials. The top map illustrates the geological formations, each color representing a different type of formation: Allegheny Formation, Casselman Formation, Glenshaw Formation, and Pottsville Formation. These formations are indicative of the region's geological history and influence the landscape's topography, soil types, and hydrology.

The Allegheny Formation, typically associated with coal-bearing strata, is shown in dark blue, suggesting the presence of coal seams which could impact land use and water quality due to the potential for mining activities and related pollutants. The Casselman Formation, in lighter blue, indicates areas where sedimentary rocks such as sandstone, shale, siltstone, and coal may be found, influencing soil permeability and erosion patterns.

The Glenshaw Formation, displayed in steel blue, is known for its shale and limestone, which can be significant for the watershed's alkalinity and may affect the buffering capacity of streams and rivers within the area. The Pottsville Formation, colored gold, is typically characterized by a mix of sandstone, conglomerate, shale, coal, and limestone, providing a variety of soil types and supporting diverse ecosystems.

Figure 7 delineates the specific distribution of sandstone and shale, two prevalent rock types in the watershed. Sandstone, in green, is often associated with more permeable soils that can store and transmit groundwater, playing a role in the creation of springs and influencing stream flow. Shale, in light blue, is less permeable and can contribute to surface runoff, potentially affecting erosion rates and sediment transport within the watershed.

The intersection of these geological features with the watershed's hydrology is critical. Rock types can influence the pH and mineral content of water, affecting aquatic habitats and water chemistry. The geological underpinnings shown in these maps are fundamental to understanding the natural processes at play within the watershed and are essential for informed land use planning and management.

In essence, these geological maps serve as a baseline for assessing the watershed's capacity for supporting wildlife, forestry, agriculture, and human settlement, as well as for anticipating challenges such as acid mine drainage or sedimentation. They provide a foundational understanding that is crucial for the design and implementation of conservation strategies and for predicting the responses of the watershed to various land use and climate scenarios.

Figure 6: Bedrock Geology Map

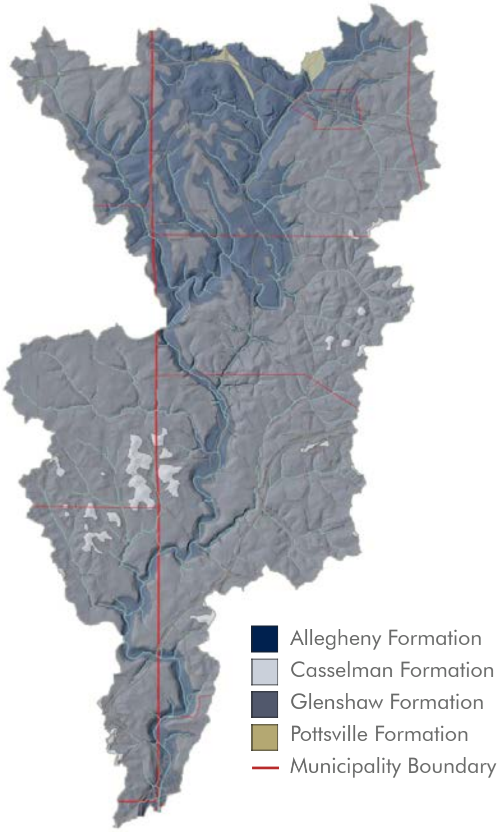
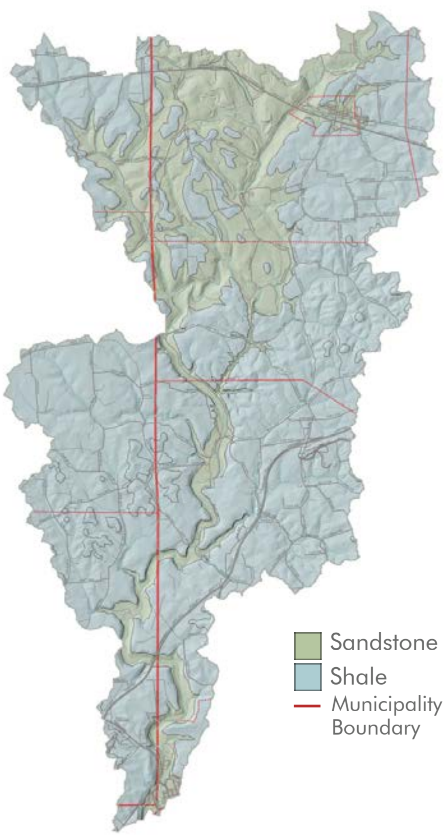


Figure 7: Bedrock Lithology Map



Soils

Figure 8: Hydrologic Soils Group

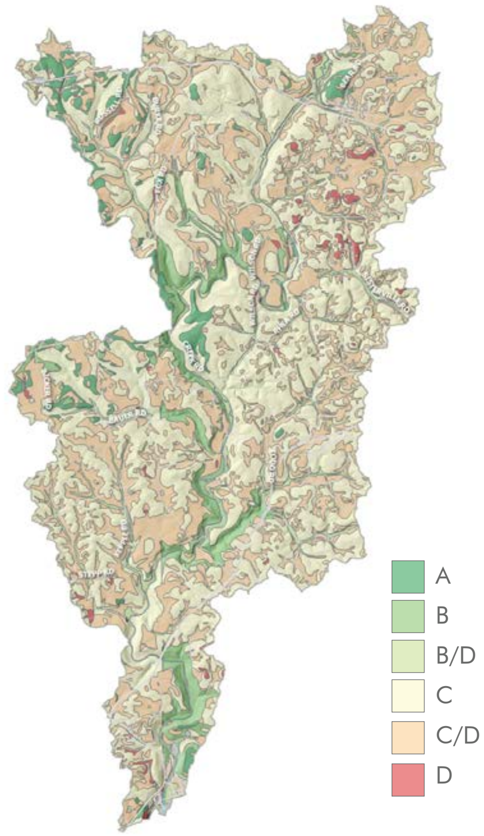


Figure 8 presents the hydrologic soil groups of the Cornplanter Run - Buffalo Creek, offering crucial insights into the watershed's soil composition and its capacity to support infiltration and runoff. The hydrologic soil groups, designated from A to D, are categorized based on their infiltration rates when thoroughly wet.

Soil group A, represented in dark green, indicates soils with high infiltration rates even when thoroughly wet and a low runoff potential. These soils are typically well-drained sands, loamy sands, or sandy loams. Their presence is crucial for groundwater recharge and reducing surface runoff, making them optimal for supporting healthy aquatic ecosystems and mitigating flood risks.

Soil group B, shown in lighter green, has a moderate infiltration rate when thoroughly wet and consists mainly of silt loams or loams. These soils are more fine-textured than group A and are less permeable, offering moderate drainage and supporting diverse agricultural needs while still providing sufficient water filtration.

The B/D designation is an intermediary, demonstrating transitional areas where soil properties may vary, affecting their drainage and runoff behaviors and influencing site-specific management practices.

Soil group C, colored in beige, encompasses soils with slow infiltration rates when wet and a moderately high runoff potential, often including clay loams, sandy clays, and silty clays. These soils can pose challenges for water management due to their higher potential for flooding and erosion, necessitating strategic planning to manage excess surface water effectively.

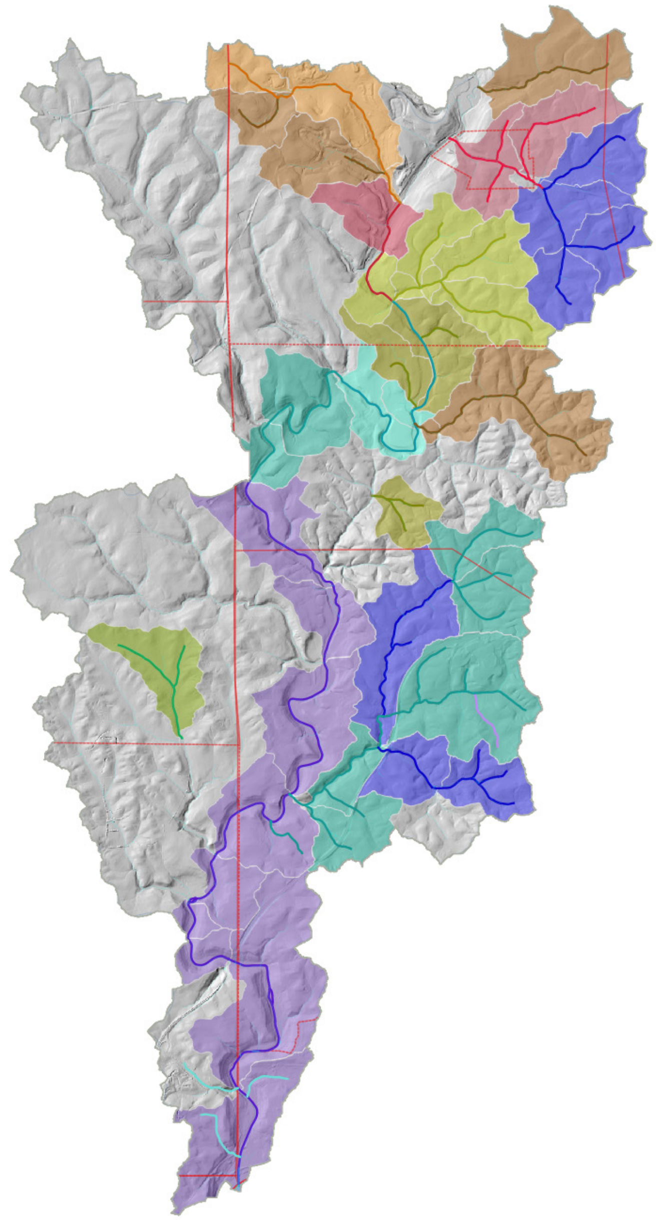
Soil group D, the least permeable, depicted in red, has very slow infiltration rates and a high runoff potential. These clayey soils are often associated with poor drainage and are commonly found in areas with high water tables. Their management is critical as they are prone to producing a lot of surface runoff, which can carry pollutants into the watershed and require robust stormwater management systems.

Understanding the distribution of these soil groups is vital for the watershed's management, informing decisions about land use, conservation practices, and infrastructure development. The ability of these soils to absorb and hold water affects not only agricultural productivity and forest health but also the resilience of the watershed to weather extremes and the overall hydrologic cycle.

In summary, this map serves as a detailed guide for land-use planners, conservationists, and agricultural managers in the Cornplanter Run - Buffalo Creek watershed. It informs the implementation of best management practices that align with the hydrological characteristics of the soils, ensuring sustainable land development and watershed management that protects and enhances the natural resources of the area.

Hydrology and Stream Impairments

Figure 9: Impaired Streams



Agriculture - Nutrients, Siltation; Habitat Modification
AMD - Metals
AMD - Siltation
Crop Production -Siltation
Crop Production - Siltation, Grazing in Riparian
Natural Sources - Siltation
Natural Sources - Siltation, On-Site Treatment Systems, Algae
On-Site Treatment System - Toxicity
On-Site Treatment Systems - Algae, Natural Sources - Siltation
Source Unknown - Cause Unknown
Streambank Modification / Destabilization - Siltation
Municipality Boundary

Figure 9 provides a visual analysis of environmental pressures within the Cornplanter Run - Buffalo Creek watershed, highlighting areas where agricultural practices, acid mine drainage (AMD), natural sources, and other factors contribute to water quality challenges. The source of this data is the PaDEP Non-Attaining Streams (2023) dataset, which provided the polyline streams outlines shown and their respective impairment, depicted in the legend.

PaDEP stream impairments are typically mapped as color-coded polylines. To aid in visual understanding of pollutant sources, these polylines color schemes were expanded to the contributing subwatersheds. This is particularly useful for targeting land cover related impairments in the headwater tributaries, as shown in Figure 9.

Agricultural activities are prevalent contributors to the watershed's health. Nutrient loading, a result of fertilizer use, and siltation from soil erosion are particularly significant in areas with intensive farming. These regions are crucial points for intervention, as they can greatly impact the nutrient dynamics and sediment levels in the watershed, leading to eutrophication and habitat degradation in aquatic systems.

The map also details the locations affected by AMD, indicated by the presence of metals and siltation. These legacy impacts from mining introduce toxic substances and excess sediment into the water, necessitating targeted remediation efforts to restore and protect affected streams and rivers.

Natural sources of siltation are identified, along with areas where on-site treatment systems contribute to algae proliferation and toxicity issues, highlighting the complex interplay between human infrastructure and the natural environment.

Streambank destabilization, often a consequence of both natural processes and human activities such as improper land use or inadequate riparian management, is marked as a source of sediment, which can have far-reaching effects on water clarity and the health of aquatic habitats.

Tree Canopy and Riparian Buffer

Figures 10 and 11 present a compelling visual representation of the Cornplanter Run - Buffalo Creek watershed's current state of tree canopy cover and riparian buffer zones. Figure 10 showcases the tree canopy cover with gradations of green indicating the density of foliage, from dense, bright green areas to lighter shades where the canopy is sparser. Figure 11 delineates the riparian buffer zones along the watercourses, highlighted by the bright green lines snaking through the landscape. Areas in red reflect depleted riparian buffers.

The tree canopy map is a testament to the watershed's forest health, with the green hues symbolizing areas where trees serve as a critical ecological asset. These areas are essential for reducing erosion, improving air and water quality, and providing habitat for countless species. The darker green patches are likely mature forests that offer robust ecosystem services, including moderating the microclimate and sequestering carbon.

The riparian buffer map (Figure 11) underscores the importance of vegetation alongside water bodies. These buffers, essential for maintaining water quality, appear as corridors of green tracing the waterways. They act as natural biofilters, trapping sediment, and nutrients before they enter the streams and rivers, thereby protecting aquatic habitats and enhancing water quality. The presence of riparian buffers is particularly critical in areas where the tree canopy is absent or diminished, as indicated by the lighter green or grey patches on the canopy map.

Notably, the areas devoid of significant green on the tree canopy map align with the absence of riparian buffers on the adjacent map, highlighting regions where watershed management interventions could be prioritized. These areas might correspond to agricultural fields, urban landscapes, or other developed lands, where the implementation of riparian buffers could substantially mitigate environmental impacts.

Together, these maps serve as an integral part of the watershed management plan, providing clear indicators of where conservation efforts can be concentrated. They emphasize the interconnectedness of land cover and water quality and the necessity of maintaining both dense forested areas and strategic riparian vegetation for a healthy watershed. By presenting these maps side by side, the report reinforces the need for an integrated approach to land management that considers the critical roles of tree canopy and riparian zones in sustaining the ecological balance within the watershed.

Figure 10: Tree Canopy Map

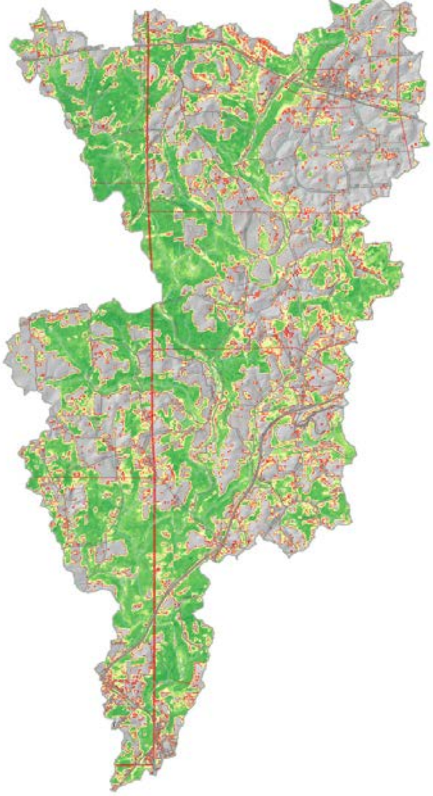
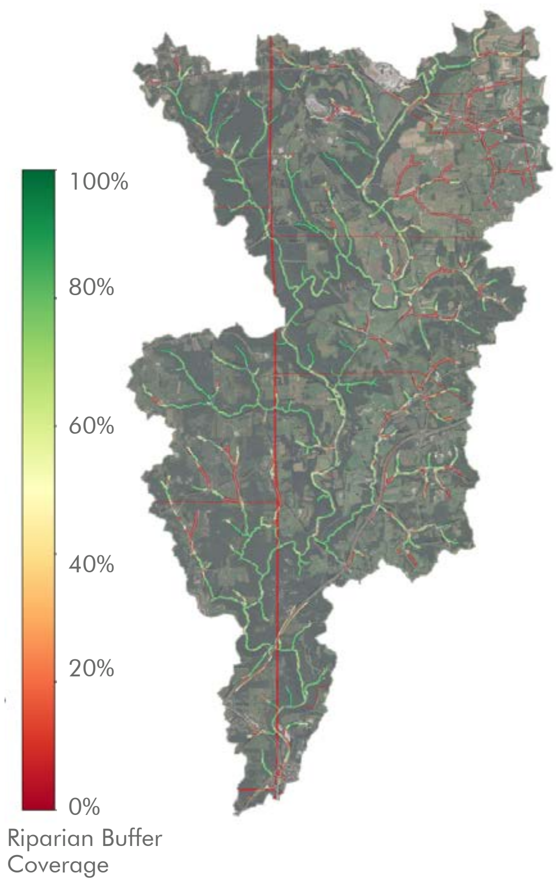


Figure 11: Riparian Buffer Map



Land Cover

Figure 12 provides a detailed depiction of land cover within the Cornplanter Run - Buffalo Creek watershed, with distinct color coding representing various uses: yellow and brown for agricultural areas, as per the legend.

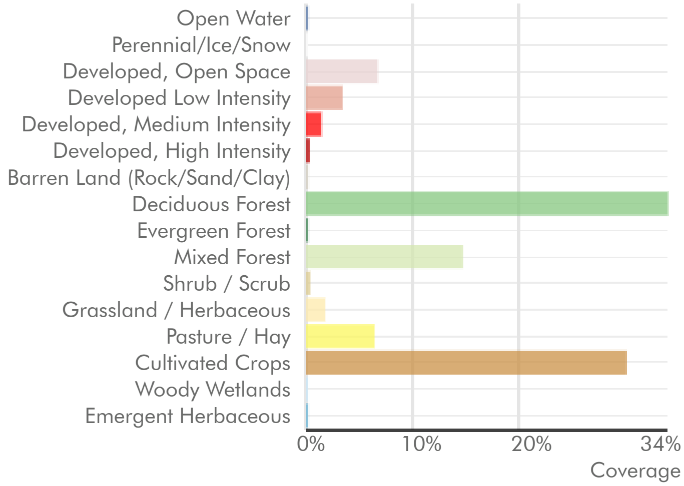
The expanses of yellow and brown signify the agricultural heartlands of the watershed. These areas are critical for food production but also require careful management to prevent potential negative impacts on water quality, such as runoff containing fertilizers and pesticides. Integrating agricultural practices that reduce runoff and enhance soil health is vital for sustaining the watershed's ecological balance.

Forested regions, shown in green, are the watershed's ecological anchors. They provide essential services such as habitat for wildlife, carbon sequestration, soil stabilization, and water regulation. The forested areas form a natural infrastructure that is invaluable for filtering pollutants and moderating water flow, contributing to the health of the watershed's streams and rivers.

Development is indicated by pinks and reds, delineating urban, suburban, and industrial areas. These developed lands are where impervious surfaces are most prevalent, often leading to increased runoff and reduced natural infiltration. Managing stormwater and preserving green spaces within these areas are key for mitigating the effects of urbanization on the watershed.

The juxtaposition of these land uses within the watershed tells a story of diverse human activity and natural processes. The patchwork of agriculture, forest, and development must be managed in a way that supports sustainable practices and conserves natural resources. Recognizing the interconnectedness of these land cover types is essential for watershed management, as actions in one area can have profound effects downstream.

Figure 12: Land Cover



The land cover map serves not only as a visual representation of current land use but also as a planning tool for future land management strategies within the watershed. It highlights the importance of maintaining a balance between development and the natural environment, ensuring that agricultural productivity, urban growth, and ecological integrity can coexist for the benefit of the community and the health of the watershed.

HUC-12 Watershed Analysis

Summary of Analysis Methodology and Tools

The WIP for the Cornplanter Run - Buffalo Creek utilized ModelMyWatershed, an advanced web-based application developed by the Stroud Water Research Center that facilitates detailed watershed analysis through the integration of geographic and hydrologic data. This tool is pivotal in allowing stakeholders to model the effects of land use and management practices on water quality and quantity. A synthesized overview of the methodology and tools is included below:

Geospatial Analysis and Watershed Modeling

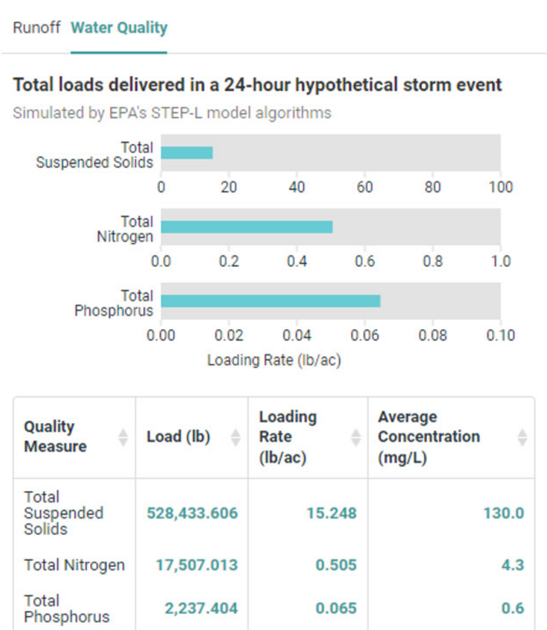
ModelMyWatershed employs geographic information system (GIS) technology to analyze land use, soil composition, and topography within the watershed. By overlaying various data layers, the tool provides a comprehensive visual representation of the watershed's characteristics and enables the identification of areas susceptible to specific environmental challenges.

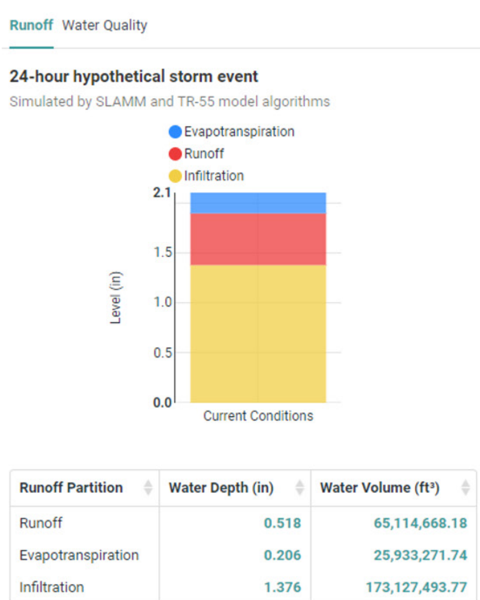
ModelMyWatershed incorporates tools to simulate runoff and estimate water quality impacts based on land cover data. Users can evaluate how changes in land use, conservation efforts, or development will affect runoff volumes and pollution levels, providing a basis for strategic planning and intervention.

Scenario Development

The tool enables users to create and compare scenarios that reflect various land management strategies or changes. This feature is crucial for planning and decision-making, allowing for the exploration of the potential outcomes of different watershed management approaches.

Figure 13: Model My Watershed





Best Management Practices For Agricultural Lands

Based on ModelMyWatershed guidance and generally accepted practices in watershed, agricultural lands, and stormwater management, a number of BMPs were explored for this WIP effort. These are summarized below:

Figure 14: Land Management and Conversion Best Management Practices

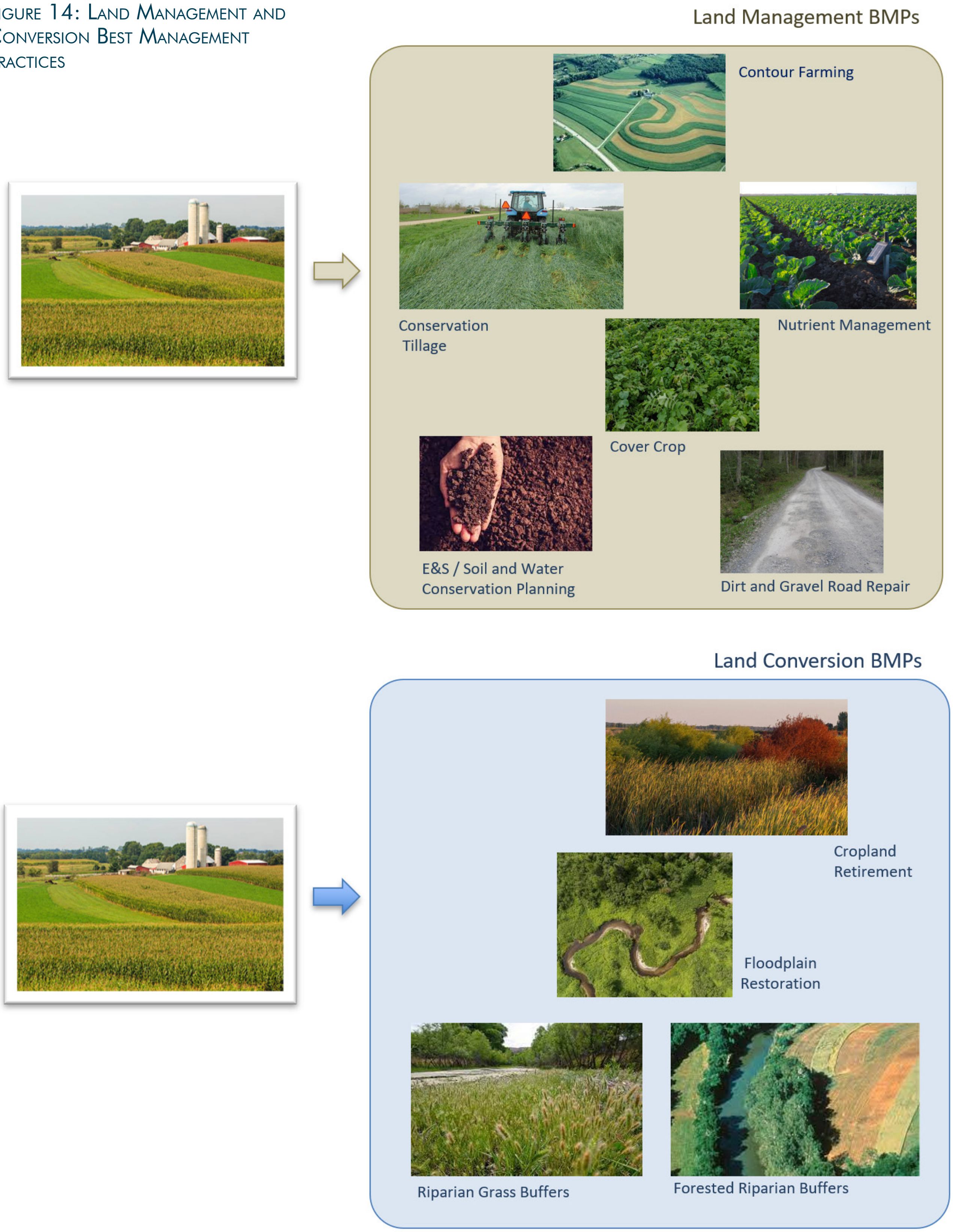
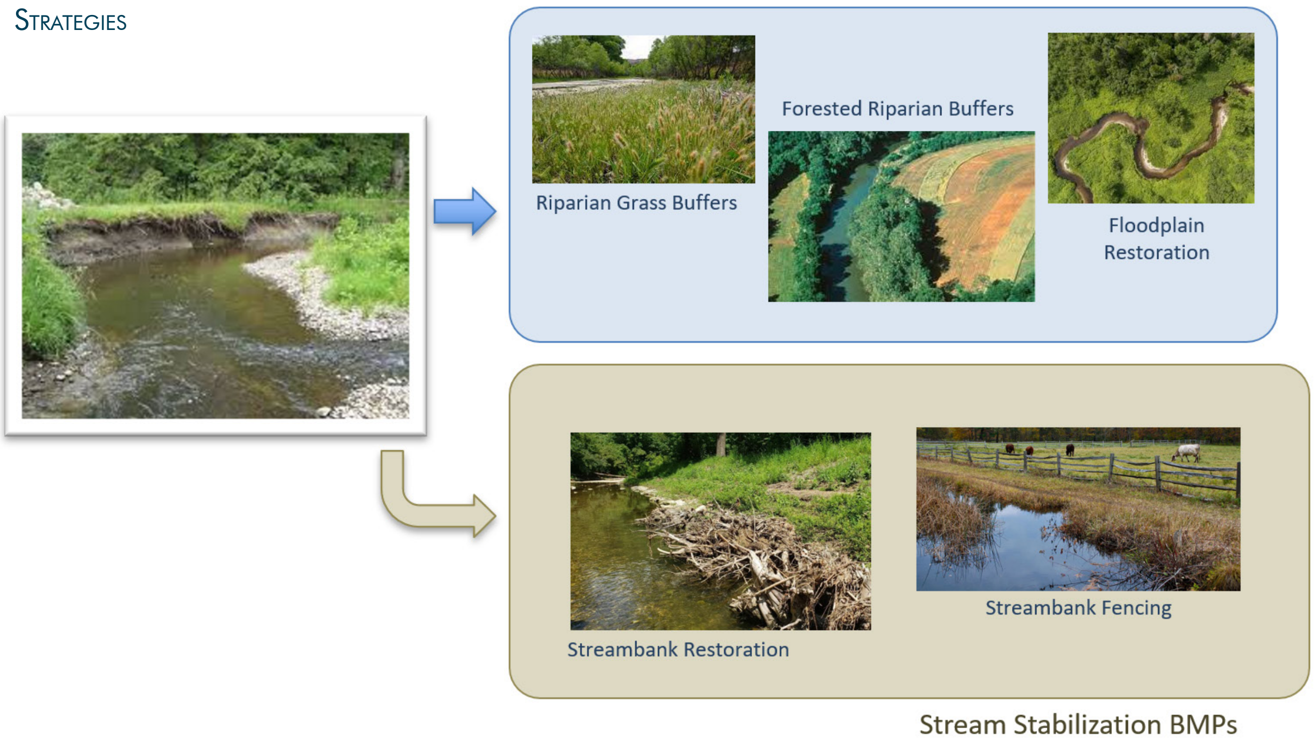
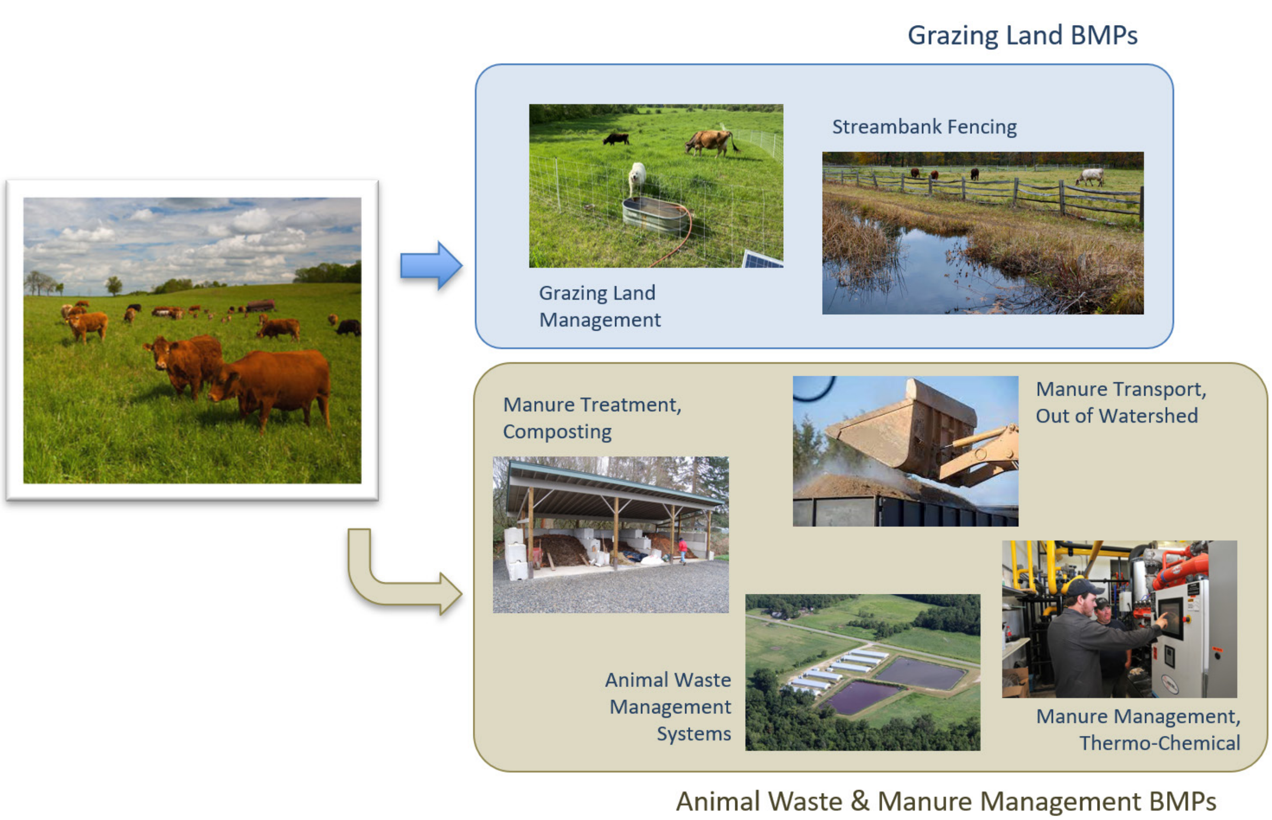


Figure 15: Riparian Restoration and Grazing Land Best Management Strategies





Best Management Practices For Urban and Industrial Lands

The Buffalo Creek Watershed, with its blend of urbanized areas and history of resource extraction, necessitates a comprehensive approach to water quality management that extends beyond agricultural land stewardship. This study delves into the efficacy of BMPs tailored to urban and industrial contexts as means to mitigate the environmental impacts inherent to these landscapes.

Urban BMPs are designed to mitigate the runoff and pollution typically associated with highly developed areas. These practices include, but are not limited to the establishment of rain gardens that naturally filter pollutants and increase groundwater recharge, the installation of filter strips in parking lots to capture and treat runoff before it enters the water system, and additional BMPs that can manage stormwater at its source, reduce the burden on sewer systems, and diminish flood risks.

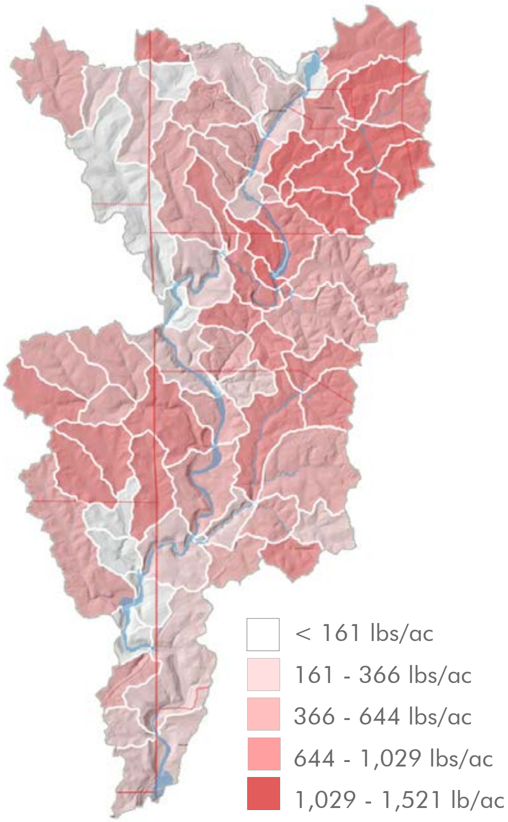
In regions impacted by historic mining and resource extraction, specialized BMPs are required to address the unique challenges posed by such activities. Passive treatment systems, which use natural processes to treat contaminated water from abandoned mines, are a key component of this strategy. These systems are designed to be low-maintenance and sustainable, often utilizing constructed wetlands, limestone drains, and settling ponds to remove pollutants. Additionally, rigorous water quality sampling and testing protocols are implemented to monitor and assess the efficacy of these treatment measures and ensure that they meet or exceed environmental standards.

By integrating a diverse array of BMPs across urban, industrial, and agricultural domains, the Buffalo Creek Watershed Initiative aims to create a resilient and multifaceted strategy for preserving the watershed's ecological integrity. These practices not only address current environmental concerns but also lay the groundwork for sustained stewardship and restoration of the watershed for future generations.

Figure 16: Select Urban and Industrial Lands Best Management Practices

Total Sediment

Figure 17:
Total Sediment, Pollutant Concentration



Total Sediment Loads across numerous subwatershed are shown in Figure 17, and are based on ModelMyWatershed results. The color-coded visual representation identifies zones of varying sediment pollution levels, with the red areas highlighting regions of higher concentration. Such gradations are invaluable in pinpointing sediment pollution hotspots and directing remediation efforts.

Sediment pollution in streams is indicative of the presence of soil, algae, organic remains, and other particulate matter. Elevated sediment levels are known to compromise water clarity, disrupt photosynthesis, and degrade habitats. The map's red zones suggest critical areas where land-based activities, such as agriculture, urban development, and natural erosion, that are contributing to sediment influx. These regions warrant immediate attention to mitigate the detrimental effects on water quality.

Geographically, the hotspots exhibit a discernible pattern, often clustered along steep terrain, agricultural peripheries, and urban runoff pathways. These areas are likely to be significant sediment sources, propelled by soil disturbance and inadequate vegetative cover. Stream bank erosion and the absence of riparian buffers further accentuate the sediment levels, as evidenced by the dense clusters of red along the watercourses.

Urban areas with impervious surfaces exacerbate the issue by funneling stormwater, laden with particulates, directly into the creek system. The confluence of tributaries appears to be a common site for hotspots, where sediment from various sources aggregates due to merging flows.

In the context of the Watershed Implementation Plan, addressing these hotspots is crucial. By deploying BMPs like riparian plantings, construction of sediment basins, and erosion control structures, specifically in these critical areas, the impact on water quality can be significant. The map will guide the strategic placement of such interventions, ensuring that efforts are concentrated where they will yield the most benefit in sediment reduction and water quality improvement.

The implications of these data are significant, affecting not only the health of the watershed's ecosystems but also bearing on human interests such as water treatment, recreation, and property values. Thus, the sediment map is more than a diagnostic tool; it is a foundation for informed action, shaping the efforts of policymakers, conservationists, and community stakeholders in their collective endeavor to safeguard the Cornplanter Run - Buffalo Creek watershed.

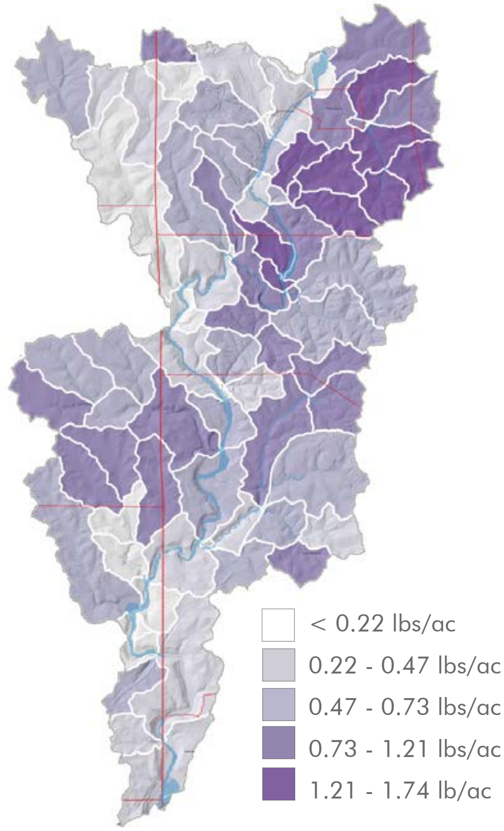
Total Phosphorus (TP)

Total Phosphorus is shown in Figure 18. The TP concentrations, represented by varying shades of purple, indicate regions where phosphorus levels are of particular concern. The darkest areas signal the highest concentrations, suggesting significant phosphorus enrichment, which is often linked to agricultural runoff and the percolation of fertilizers into the watershed.

Unlike sediment, which can be more diffusely distributed due to erosion, phosphorus tends to accumulate in specific areas, frequently associated with agricultural land use. This localized concentration underscores the influence of non-point source pollution – the runoff from fields treated with phosphate fertilizers following rain events, which carries this nutrient into the aquatic ecosystem.

In these highlighted areas, the watershed is at risk of eutrophication, a process that can lead to excessive algal blooms, depleting oxygen in water bodies and harming aquatic life. To address this, the WIP includes nutrient management practices. Examples include establishing or reinforcing buffer zones with vegetation that can absorb and filter out nutrients before they reach waterways, and encouraging soil testing and precision agriculture to minimize fertilizer use.

Figure 18:
Total Phosphorus, Pollutant Concentration



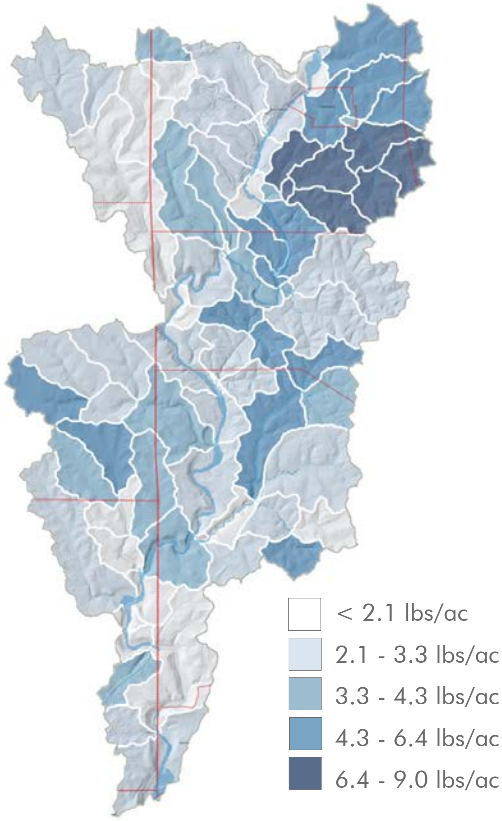
The TP map's indication of nutrient hotspots is integral to directing such interventions. By focusing on these critical zones, the watershed management actions can be tailored to achieve the most effective reduction in phosphorus loading. This approach is expected to not only enhance the water quality but also to benefit the overall health of the aquatic ecosystems within the Cornplanter Run - Buffalo Creek watershed.

In integrating the TSS and TP findings into the watershed's implementation strategy, it becomes evident that while the pollutants differ, the overarching goal remains the same: to identify and target the most affected areas with appropriate and effective management practices. The comprehensive analysis of both sediment and nutrient concentrations will ensure a holistic approach to preserving the watershed's integrity for future generations.

Total Nitrogen (TN)

The Total Nitrogen (TN) map (Figure 19) for the Cornplanter Run - Buffalo Creek watershed reveals a nuanced pattern of nitrogen distribution, differing in key aspects from the sediment and phosphorus data previously discussed. Shades of blue across the map serve as an indicator of TN concentration, with the deepest hues pinpointing regions of heightened nitrogen levels. While nitrogen is an essential element for plant and aquatic life, its excessive presence, indicated by the dark blue areas, signals potential environmental imbalance that could have detrimental effects on the watershed's ecological health.

Figure 19:
Total Nitrogen Pollutant Concentration



Nitrogen's presence in waterways primarily originates from agricultural runoff, encompassing the use of synthetic fertilizers and animal waste, as well as from the natural nitrogen cycle processes including atmospheric deposition and the decomposition of organic materials. The specific concentration areas highlighted on the map correlate with agricultural activity, where nitrogen use is most intensive. The pattern of TN distribution suggests that nitrogen may be entering the watershed through multiple pathways, including overland flow and airborne pathways, complicating the task of managing its levels.

The implications of high TN levels are considerable: nitrogen is a key contributor to eutrophication, which can lead to harmful algal blooms, resulting in oxygen depletion and negative impacts on aquatic organisms. In addition, high nitrogen levels can affect drinking water quality and lead to the formation of nitrites and nitrates, which are concerning for human health.

Consequently, the management strategies outlined in the WIP are multifaceted. Agricultural management practices such as optimizing fertilizer application timing and methods, promoting the use of nitrogen-fixing cover crops, and implementing controlled livestock grazing can significantly mitigate nitrogen runoff. Additionally, the restoration and preservation of natural ecosystems like wetlands can naturally attenuate nitrogen through denitrification processes.

The TN map underscores the critical need for an integrated approach to managing all nutrients within the watershed. Addressing nitrogen alone is not sufficient; the plan must also incorporate measures for controlling phosphorus and sediment. By aligning management practices to tackle the complex interplay of these pollutants, the WIP seeks to address both water quality and the ecological integrity of the Cornplanter Run - Buffalo Creek watershed. The goal is a balanced, sustainable ecosystem where nutrient levels support, rather than hinder, the health of both the environment and the community that depends on it.

Selection of Target Subwatersheds

The selection of the five subwatersheds within the Cornplanter Run - Buffalo Creek watershed for targeted management interventions is informed by a number of factors. The process began with a thorough assessment of past watersheds studies, PaDEP designations for known impairments, TMDL studies, and stakeholder inputs. Per the PaDEP impaired stream lists, several key observations were made and some meaningful patterns were discovered. It was apparent, for example, where agriculture and urban land uses were creating sediment and nutrient impairments, and there were numerous watersheds where PaDEP had labeled the impairments source as "Unknown Source / Cause". These observations, coupled with a thorough analysis of the Total Sediment (TS), Total Phosphorus (TP), and Total Nitrogen (TN) loading watershed wide, illuminated different aspects of the watershed's health. Ultimately, through additional dialogue with PaDEP, it was decided to focus on the subwatershed with more apparent cause-effect impairments, and to avoid those with unknown sources.

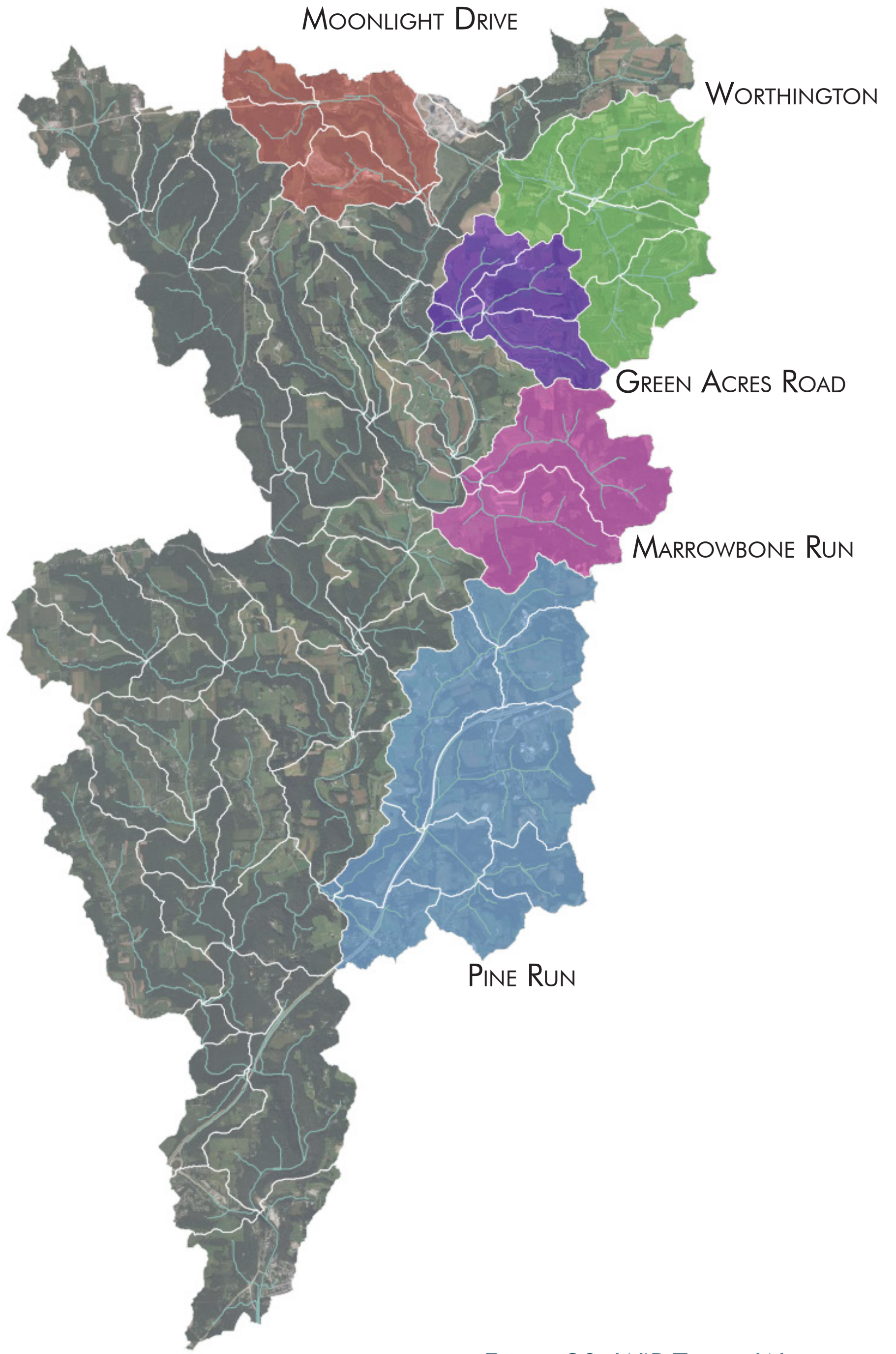


Figure 20: WIP Target Watersheds

The TS analysis reveals areas with significant sediment runoff, indicative of potential soil erosion issues likely caused by land use practices such as agriculture and urban development. Sedimentation not only affects water clarity and quality but also disrupts aquatic habitats and is a vector for other pollutants. The TP analysis provided insight into areas with nutrient over-enrichment, particularly from phosphorus, which is a driving factor behind eutrophication and algal blooms. Similarly, the TN analysis elucidated patterns of nitrogen concentration, another critical nutrient contributing to water quality degradation and ecosystem imbalance.

By integrating these individual analyses, we identified regions that consistently showed high levels of pollutants, pointing to subwatersheds that are both vulnerable to pollution and critical to the overall health of the watershed. The selected subwatersheds - Pine Run, Marrowbone Run, Moonlight Drive, Green Acres

Road, and Worthington - exhibit these characteristics and are hence prioritized for immediate and intensive remediation and conservation actions. These are reflected in Figure 20 above.

Pine Run and Marrowbone Run were selected due to their pronounced TS and nutrient levels, suggesting that they are experiencing significant runoff and nutrient loading, likely from adjacent agricultural lands. The subwatersheds of Moonlight Drive and Green Acres Road, named after local landmarks due to their unnamed tributaries, show similar trends in the pollutant maps, indicating that they are key areas where non-point source pollution can be mitigated through targeted management practices. Worthington, adjacent to a nearby town, represents an area where urban runoff is likely a significant contributor to the watershed's pollutant load, as evidenced by its standout features on all three maps.

The selection of these five subwatersheds is strategic. It allows for focused allocation of resources and implementation of BMPs tailored to the types of land use within each subwatershed. For example, agricultural areas may benefit from cover crops, buffer strips, and precision farming techniques, while urban areas may require green infrastructure and improved stormwater management systems.

In conclusion, the integrative analysis of the TS, TP, and TN was instrumental in identifying these five subwatersheds as critical areas for intervention. Additionally, the historical context of Moonlight Drive and Marrowbone Run, which includes acid mine drainage from past mining activities, has been acknowledged as a factor in their selection. While this factor does not negate the issues indicated by the pollutant maps, it does add a layer of consideration for future remediation efforts. By concentrating efforts on these subwatersheds, we aim to significantly reduce pollutant loads, improve water quality, and enhance the resilience of the Cornplanter Run - Buffalo Creek watershed ecosystem. This targeted approach is a cornerstone of the WIP, aiming for the most impactful environmental improvements and sustainable watershed management.

Water Quality Sampling and Testing

To better characterize target subwatershed issues and solutions, Oikos Ecology was engaged to conduct macroinvertebrate surveys and collect water chemistry data at 6 sites in 2023. Sampling locations are shown in Figures 33, 52, 72, 97, and 123. Section 319(h) Nonpoint Source Management funds were not used for any monitoring efforts. Data collected at these 6 sites was used to supplement a comprehensive water quality sampling program being led by ASWP in 2021-2023 as well as historic PA DEP data available for the priority subwatersheds.

The water quality sampling and testing work for this WIP was informed and guided by previous water quality sampling work performed by PaDEP and Duquesne University.   The work by Duquesne University has been conducted largely in partnership with ASWP and the Buffalo Creek Coalition and has primarily occurred over the past several years, under the academic guidance of Dr. Brady Porter, Associate Professor of Biology at Duquesne University.   The sampling work by PaDEP that was evaluated spans several decades.


Photograph by George Reese

Green Acres Road Subwatershed

Watershed Characteristics

Watershed Analysis

Implementation Plan

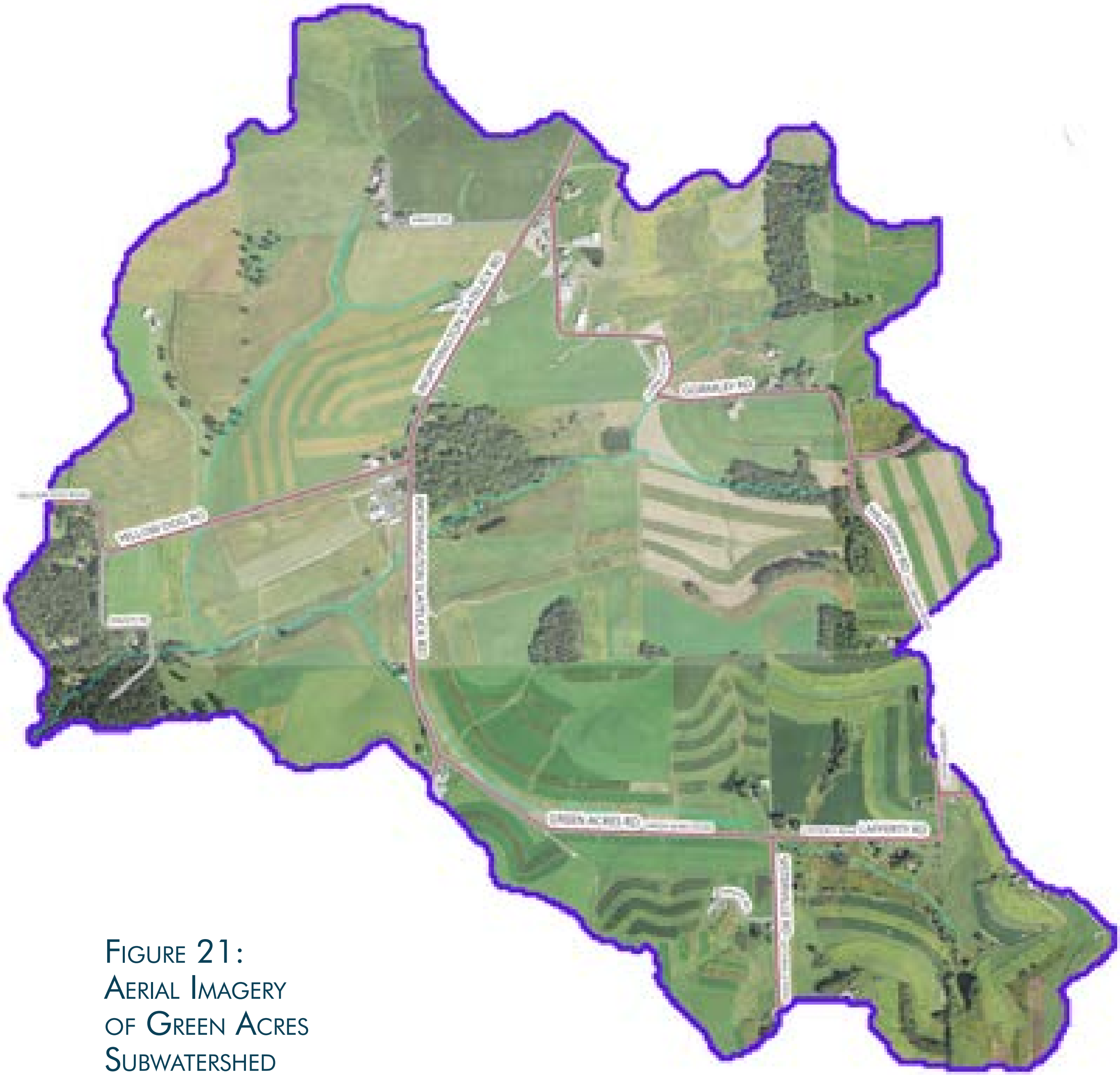


Figure 21:
Aerial Imagery
of Green Acres
Subwatershed

Green Acres Road Subwatershed

Watershed Characteristics

Location and Basin Characteristics

Located within West Franklin Township, immediately south of the Borough of Worthington, the Green Acres Road subwatershed drains generally in the south-west direction to the Buffalo Creek main stem. The three branching tributaries that make up this subwatershed are unnamed per public domain geospatial datasets, and so the 'Green Acres Road' designation was given to the subwatershed for the purpose of this study, reflecting that one of the existing streams largely parallels Green Acres Road along the south watershed boundary.

The Green Acres Road subwatershed area is approximately 1.91 square miles (1,224 acres) in size, and the dominant existing land cover is agriculture. Per the National Hydrography Dataset, the existing streams are generally perennial, transitioning to ephemeral designation within the headwaters. Given the overall agricultural nature of the subwatershed, it is unknown if the ephemeral stream reaches are naturally ephemeral or if they are tile drained to increase the acreage of farmable lands.

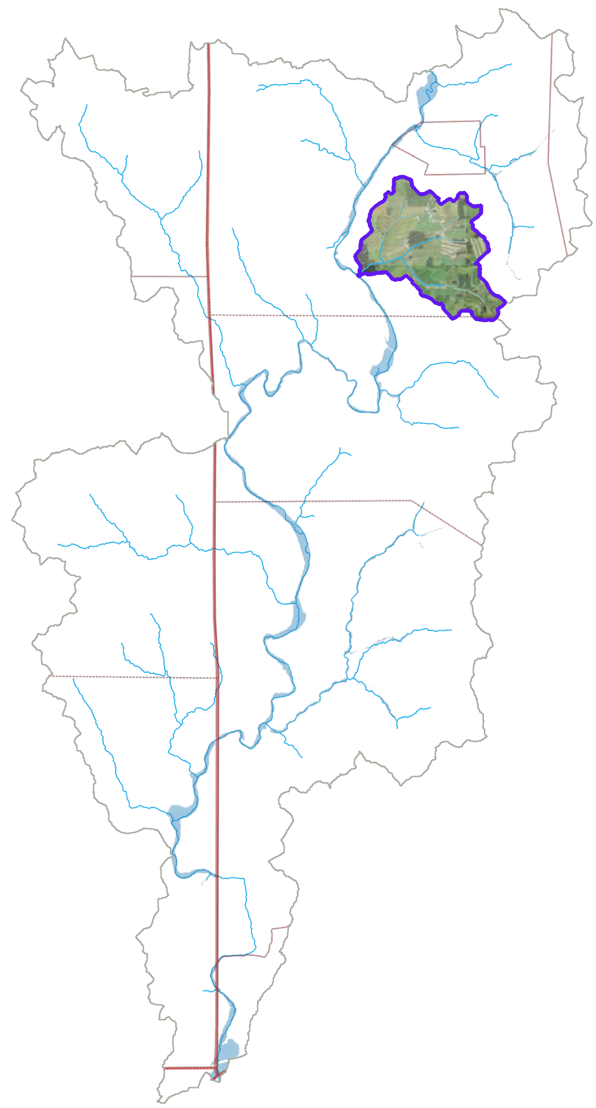


Figure 22 - Green Acres Road Subwatershed, Context Map

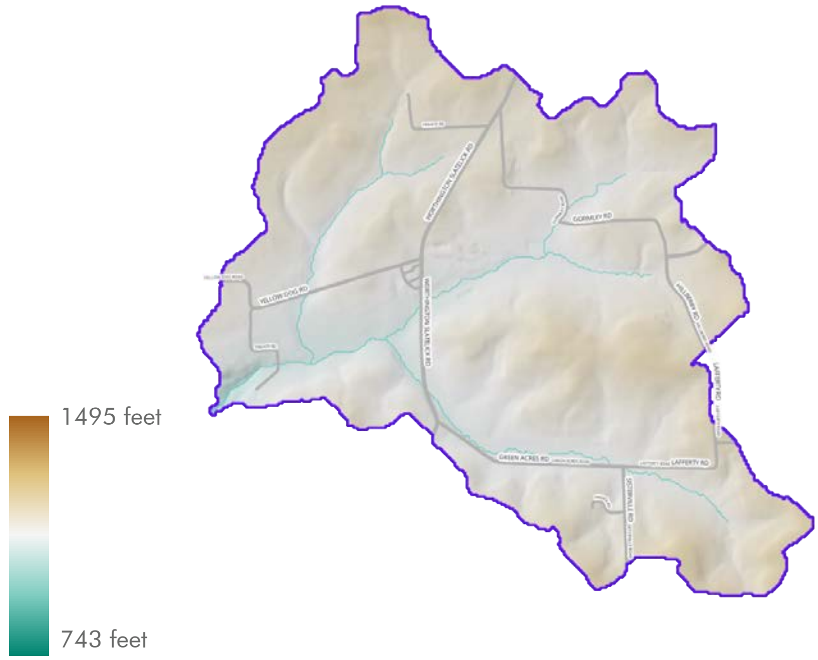
The agricultural parcels within this subwatershed vary in size from approximately ten (10) acres to one hundred (100) acres, with approximately twelve (12) distinct, large-parcel stakeholders. There are no publicly-owned parcels within the subwatershed and very little public right-of-way opportunities. As such, outreach to existing and future landowners will be essential, as their buy-in will ultimately dictate the feasibility and success of any conservation or improvement efforts. Strategies may include educational programs and partnership with environmental organizations to promote sustainable agricultural practices and watershed management.

Terrain and Slope

Based on the NHDPlus V2 NEDSnapshot DEM dataset, elevations vary from approximately 1,292 feet along the ridge line to about 968 feet at the mouth with the Buffalo Creek main stem.

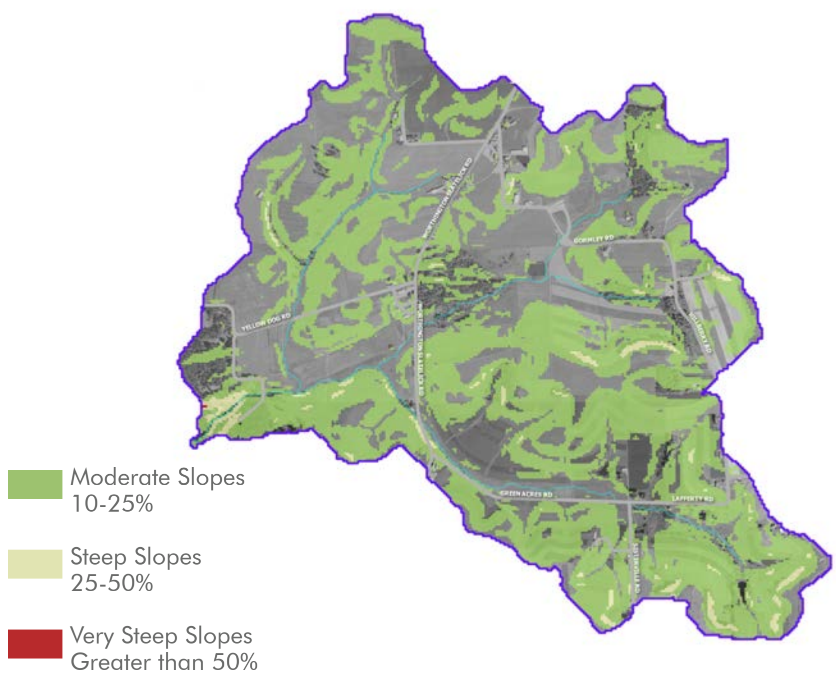
Because the subwatershed has been extensively farmed, the terrain, land cover, and steam reaches have been overwhelmingly impacted by human activities. Except at the mouth and in several select small-acreage areas, very little undeveloped or wooded areas exist within the subwatershed.

Figure 23: Terrain and Elevation Map



As shown in the Slope map (Figure 24), the terrain can be described as gently rolling to moderately steep sloped with an average slope of approximately 8.8% based on 10-m DEM analysis. There is almost no areas where the slopes would be considered particularly steep (>2:1 or 50% slope). There are some areas of minor slope greater or equal to than 5:1 (20%) but less than 4:1 (25%). There are also some moderate slopes, greater or equal to than 4:1 (25%) but less than 2:1 (50%). These minor and moderate slopes are depicted in the slope exhibit to the right as green and yellow areas, respectively.

Figure 24: Steep Slope Map



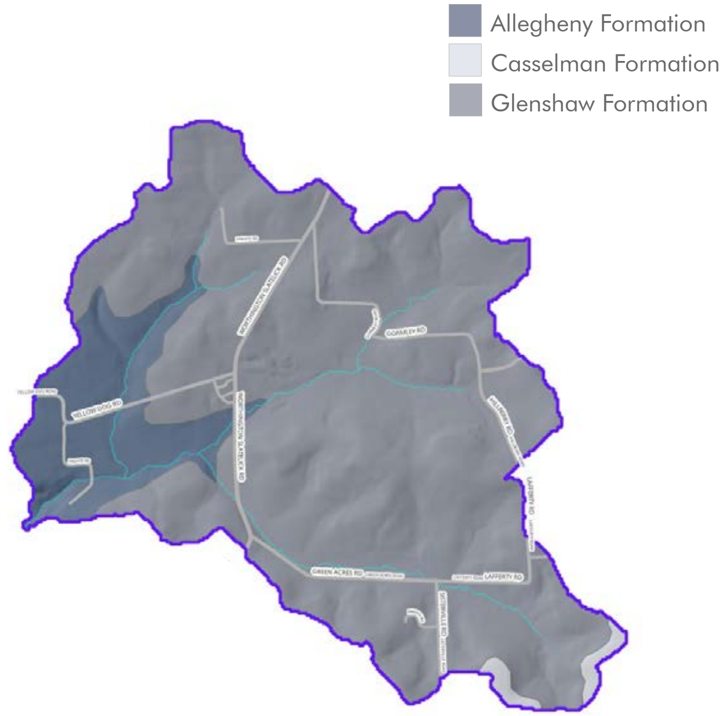
Relative to watershed planning, the gentle slopes within this watershed offers benefit and opportunity. Whereas steep slopes encourage erosion, sedimentation, and rapid pollutant transport and create constructibility challenges for new improvements, gentle slopes are highly conducive to installation of cost-effective and high-performing best management practices for watershed management overall.

Bedrock Geology and Lithology

There are three distinct bedrock geology formations across the Green Acres Road Subwateshed.

Near the mouth and depicted in the figure to the right in dark blue, the bedrock geology is of the Allegheny Formation. The primary lithology of the Allegheny Formation is sandstone, as shown in the figure to the right by the steel blue region. In general, we see this sandstone lithology follow the main stem and major tributaries up and down the entirely of the Buffalo Creek watershed. Sandstone is formed from the cementation of sand particles. In a fluvial environment, the flow along main stem likely acted as a major depositional area for these particles, leading to the formation of sandstone specifically along the stream's course. Secondary and tertiary lithologies within the Allegheny Formation include shale, limestone, clay and coal. These factors include both the suitability of the lands for agricultural use and the drainage characteristics overall.

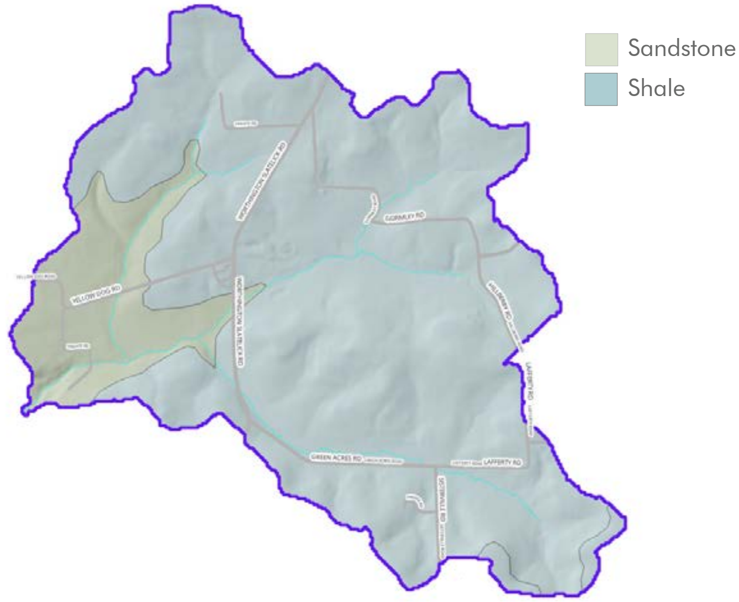
Figure 25: Bedrock Geology Map



Higher up in the subwatershed, the Glenshaw Formation (dark gray) becomes the dominant bedrock geology, and a small portion of the subwatershed is of the Casselman Formation (light gray in Figure 25). Both have a primary lithology of shale, depicted as blue-green in Figure 26. The secondary and tertiary lithologies of the Glenshaw Formation are sandstone, limestone and coal. They are siltstone, sandstone, limestone and coal for the Casselman Formation.

Relative to watershed planning, shale lithologies tend to be less resistant to erosion, meaning increased risk of streambed incision. Shale formations also may contain minerals and organic materials that can leach, leading to decreased water quality downstream and implications for water hardness, alkalinity and heavy metal contamination.

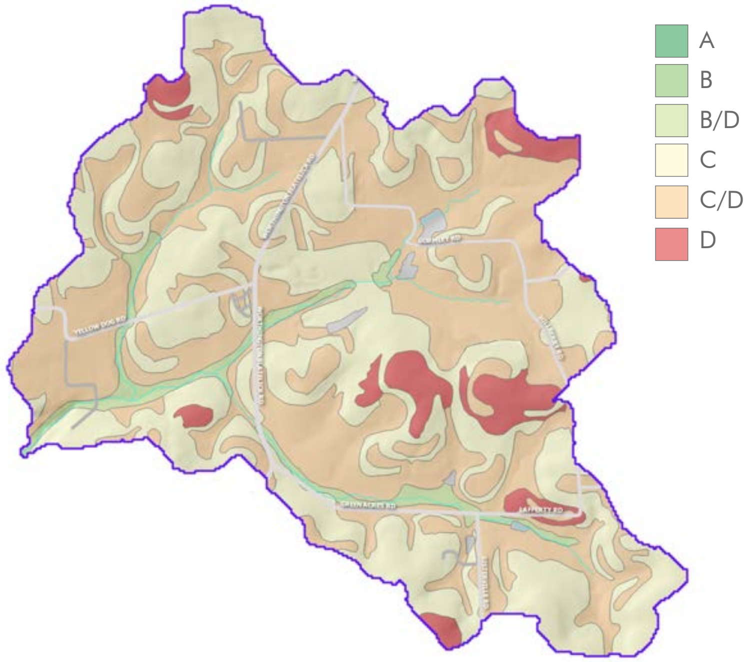
Figure 26: Bedrock Lithology Map

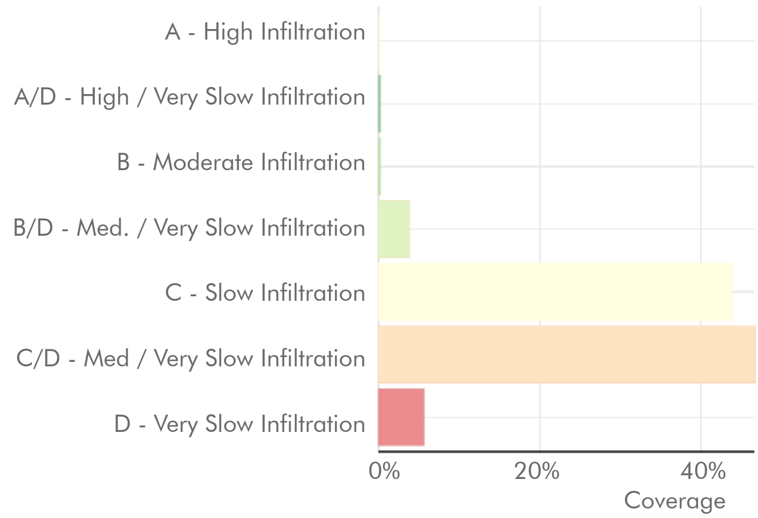


Soils

As shown in the Soils map (Figure 27), the predominant soils (over 90 percent coverage) within the Green Acres Road subwatershed are of hydrologic soils group (HSG) C and C/D, with regions of HSG B soils along the stream tributaries and areas of poorly drained D soils in scattered locations. Soils in the C and C/D hydrological soils group generally exhibit average to poor drainage characteristics, with often limited ability to infiltrate and above average runoff and erosion potential during rain events.

Figure 27: Hydrologic Soils Groups





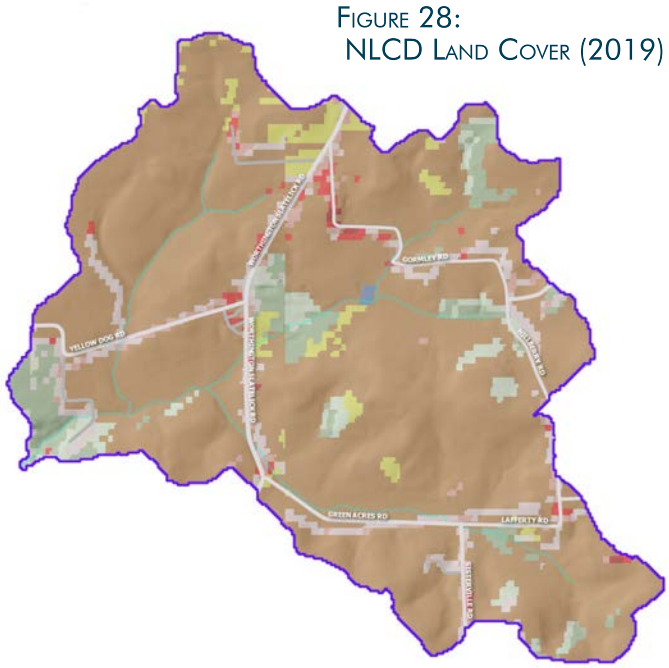
While B soils are generally more suitable for agriculture, C and to a lesser extent C/D are generally suitable for agriculture but only with careful implementation of water management strategies to reduce risks of waterlogging, excessive erosion / soils loss, and drought stress to crops. Generally consisting of sandy clay loams, the moderately fine to fine textures and inherent layering of these soils tend to impede downward movement of water, resulting in above average to excessive surface runoff instead.

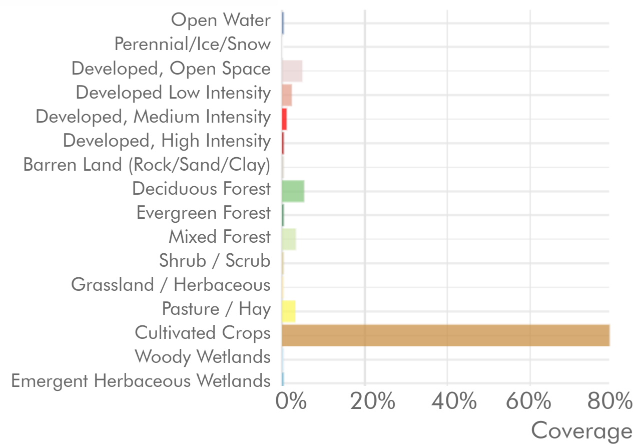
When agricultural lands are well maintained and in the active growing season, the risks of erosion and sediment / nutrient transport within C and C/D soil areas is generally limited through the stabilizing and moisture uptake actions of the vegetation itself. When the fields are fallow, when unchecked livestock grazing is introduced, or if adequate riparian buffers are not maintained, then these types of soils are particularly prone to harmful impacts that can degrade water quality to the receiving waters and downstream ecologies.

Land Cover

As noted previously, the overwhelmingly dominant land cover within the Green Acres Road subwatershed is cultivated cropland, based on the 2019 National Land Cover Dataset (NLCD). In total, cropland comprises 1.51 square miles of the 1.91 square mile subwatershed - more than 79 percent of the overall land cover. Other developed land covers include pasture /hay, as well as various classes of "Developed" space - rural roads, farmsteads, barns, and similar, with no medium-density or high-density residential, commercial or industrial land cover of note. Only about 0.16 square miles fall into the categories of deciduous, evergreen, or mixed forest lands - a mere 8.71% of the overall subwatershed. Increasing these percentages over time though the thoughtful addition of new forested or grassy buffers is paramount to success for any future watershed implementation efforts.

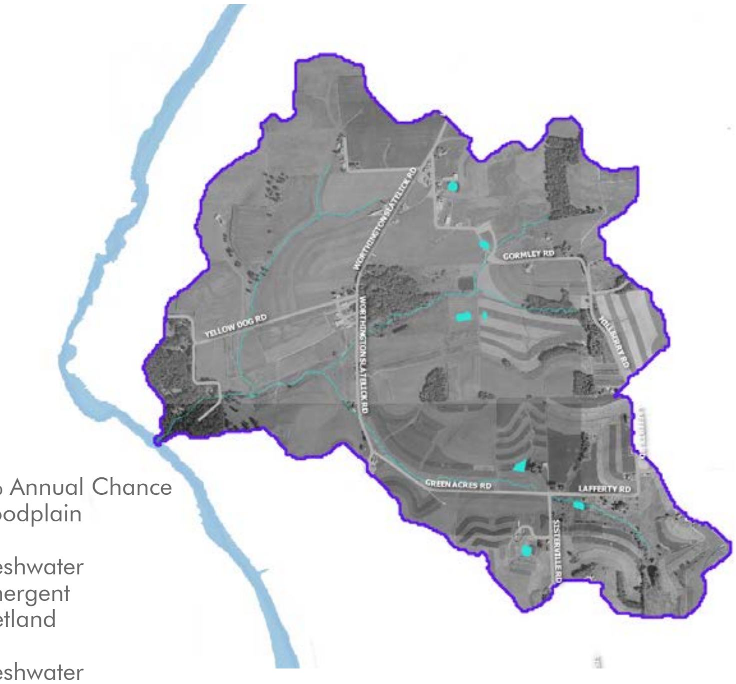
Figure 28: NLCD Land Cover (2019)





Hydrology and Stream Impairments

Figure 29: Floodplains and Wetlands



Based on the NHD High Resolution Stream dataset in ModelMyWatershed, the Green Acres Road length of stream is 3.72 miles, with 2.67 miles within agricultural areas. This includes 3.09 miles (16,315 feet) classified as first order stream at a mean channel slope of 1.49% and 0.63 miles (3,326 feet) designated as second order stream at 3.55% mean channel slope. Except for several common farm ponds, there are no National Wetland Inventory (NWI) delineated wetlands present in the subwatershed. Several of these farm ponds are designated as Palustrine (P) wetlands, using U.S. Fish and Wildlife Services classification system. This designation primarily includes areas dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and often serve as critical habitats for a diverse range of plant and animal species, including both aquatic and terrestrial organisms.

The entire Green Acres Road subwatershed is designated as a High-Quality Trout Stocking Fishery (HQ-TSF). However, as Figure 30 illustrates, all streams within the watershed are listed as impaired and the dominance of active farmland and the severe lack of tree canopy and riparian buffer represents a negative impact to the overall HUC-12 watershed's ability to attain this designation long-term. The length of stream that is impaired by cropland production-related activities per PaDEP is approximately 4.28 miles, exclusive of smaller headwater tributaries.

There are no existing Total Daily Maximum Limit (TMDL) designations within this subwatershed.

Figure 30: Non-Attaining Stream and Documented Causes

Tree Canopy and Riparian Buffer

As the figures to the right and below indicate, the tree canopy across the entire subwatershed is sparse and fragmented significantly. The riparian buffer is similarly impacted and practically non-existing except for a few segments and at the mouth.

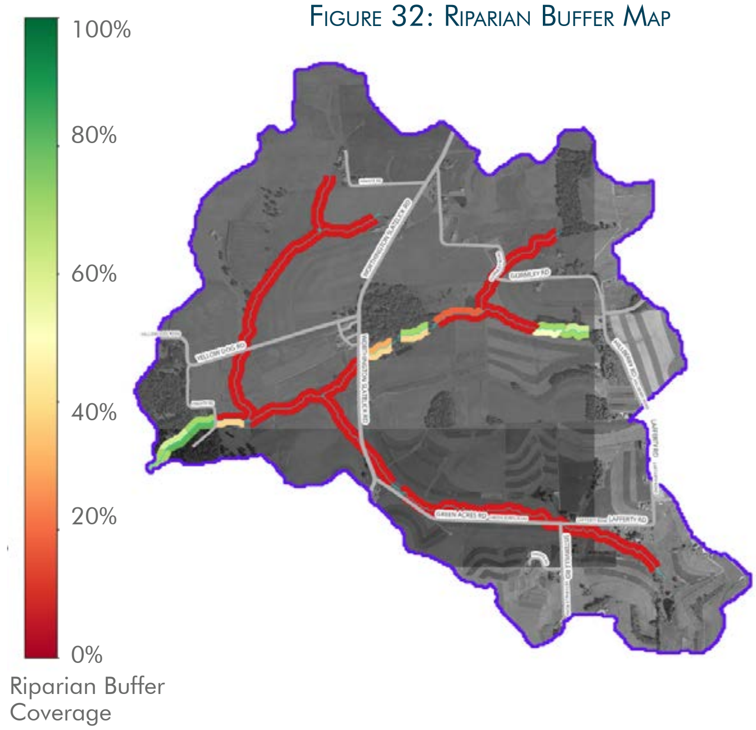
The absence of tree canopy and riparian buffers can have several negative impacts on streams and the ecosystems they support.

Figure 31: Tree Canopy Map

See Riparian Buffer Map for Legend

- Thermal Impacts to Receiving Waters: Without the shade provided by a tree canopy, water temperatures in the stream can rise. Elevated water temperatures can harm aquatic life, especially species like trout that require cold water.
- Increased Runoff: Riparian buffers act as natural filters for pollutants. Their absence can result in more pollutants like pesticides, fertilizers, and sediment entering the stream.
- Nutrient Pollution: Lack of riparian vegetation means fewer plants to uptake excess nutrients, which can lead to nutrient pollution and algal blooms.
- Erosion: Trees and plants in riparian zones have root systems that stabilize the soil, preventing erosion. Without them, the banks of the stream can erode more rapidly.
- Sedimentation: Increased erosion also leads to increased sediment in the stream, which can smother aquatic habitats and contribute to poor water quality.
- Habitat Loss: Riparian zones are often rich in biodiversity. Their absence can mean less habitat for a variety of species.
- Aquatic Life: The reduced water quality and increased temperatures can be inhospitable to sensitive aquatic species, reducing biodiversity in the water as well.
- Altered Flow Regimes: Vegetation acts as a sponge during heavy rain, reducing the speed at which water enters the stream. Without it, streams can experience more rapid changes in water levels, which can be harmful to aquatic life.

Figure 32: Riparian Buffer Map



In summary, the absence of tree canopy and riparian buffers can have a profound impact on stream health, affecting both stream water quality to and ecological biodiversity.

Macroinvertebrate Sampling, Spring 2023

Figure 33: Sampling Location

The macroinvertebrate sampling results from Oikos-3 in the Green Acres Road subwatershed on May 4, 2023, offer an optimistic snapshot of this specific location near the mouth of Buffalo Creek. However, it is important to contextualize these results within the broader landscape and land use practices affecting the subwatershed.

Although the taxa richness at Oikos-3 is satisfactory at 22, and the EPT richness is relatively high at 13, these results may not accurately reflect the conditions throughout the Green Acres Road subwatershed. Due to difficulty with sampling access in a more representative location, the sampling site is under significant tree cover and well connected to the diverse main stem of Buffalo Creek, which likely contributes to the higher water quality and macroinvertebrate diversity observed.

The site's immediate upstream area is characterized by vast expanses of open, unbuffered croplands. The transition from a natural stream to a farm channel and ultimately to a tiledrain in the upper reaches suggests that the subwatershed may be subjected to agricultural runoff, sedimentation, and potential nutrient loading, which are not fully captured by the sampling at Oikos-3. These factors typically reduce water quality and negatively impact macroinvertebrate communities.

Given the changes in land cover and stream channel morphology upstream, the positive indicators such as a lower Hilsenhoff biotic index of 3.76, a Shannon diversity index of 2.04, and an IBI score of 66.00 may not represent the subwatershed's overall health. The results likely represent the buffered conditions near the mouth of Buffalo Creek rather than the impacted upstream areas on private land where sampling could not be conducted.

Detailed monitoring results for all sites are included in Appendix A. It should also be noted across most of the studied subwatersheds that sampling access was difficult to obtain, in part due the lack of public property in the subwatershed.

Figure 34: Sampling Location Photo

Laboratory Water Quality Sampling, Spring 2023

The inclusion of the laboratory results from Green Acres adds another layer of detail to the understanding of the water quality at Oikos 3 in the Green Acres Road subwatershed. These results provide quantitative measurements of various chemical parameters that are critical for assessing the overall health of the aquatic ecosystem.

The pH level recorded at 7.80 falls within the neutral range, which is generally favorable for a wide range of aquatic life. The phosphorus levels were below the detection limit of 0.10 mg/L, indicating a low presence of this nutrient which, at higher levels, can lead to eutrophication. The Total Kjeldahl Nitrogen (TKN) was also below the detection limit, suggesting that nitrogenous compounds from organic sources are not at levels that would typically cause concern. However, the combined Nitrate+Nitrite Nitrogen level was measured at 5.27 mg/L, which is relatively high and could indicate inputs from agricultural runoff or other sources of nutrient pollution. The Total Nitrogen mirrored this at 5.27 mg/L, confirming the presence of nitrogen in the water. Total Suspended Solids (TSS) were measured at 13 mg/L, a moderate level that could reflect land disturbance upstream, but not at a concentration likely to cause immediate harm to aquatic habitats.

The macroinvertebrate community data, alongside the laboratory results, paint a more complete picture of Oikos 3. While the macroinvertebrate indices suggest a community attaining the set ecological standards, the lab results hint at underlying issues. The elevated levels of nitrate and nitrite could be early indicators of nutrient loading, which may not yet have reached a threshold to visibly impact the macroinvertebrate populations or may be mitigated by the buffering effects of the stream's confluence with Buffalo Creek.

Stream Water Quality Findings

The lab results, when considered together with the macroinvertebrate sampling data, suggest that while the immediate area at Oikos 3 appears to be attaining good ecological status, there are signs of potential nutrient enrichment. This could have downstream effects if not addressed, especially in combination with the land use practices observed in the upper reaches of the subwatershed. It is recommended that nutrient management practices be reviewed and potentially enhanced to prevent further increases in nitrogen levels. Additionally, continued and expanded water quality monitoring, including upstream areas, will be essential for early detection of any changes in the water chemistry that could impact the biotic integrity of the stream. Establishing a comprehensive monitoring program that includes both biological and chemical parameters will be crucial for the adaptive management of the Green Acres Road subwatershed.

Watershed Analysis

In order to thoroughly understand the spatial distribution of land cover impacts to the Green Acres Road subwatershed, a higher resolution terrain analysis was performed within the larger study area to create five (5) distinct "microsheds" within the Green Acres Road subwatershed. This higher resolution study was performed using a 20,000 pixel flow accumulation threshold, which equates to a maximum size of approximately 0.77 square miles per microshed using a 10-m Digital Terrain Model.

Current Sediment and Nutrient Loading

Tables 1 and 2 provide a summary of existing pollutant load for Sediment, Total Nitrogen and Total Phosphorus for the entire Green Acres Road subwatershed, aggregated by land cover and summarized overall.

The most significant sources of sediment pollution within the Green Acres Road subwatershed are cropland, hay/pasture, and stream bank erosion. These observations about pollutant sources are consistent across GIS land cover analyses, aerial imagery and site visits.

Table 1: Average Annual Pollutant Loads, by Land Cover

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	45,851.9	130.2	47.1
Cropland	1,532,111.1	6,207.4	1,705.8
Wooded Areas	271.9	8.1	0.6
Wetlands	0.0	0.0	0.0
Open Land	92.4	1.3	0.1
Barren Areas	0.0	0.0	0.0
Low-Density Mixed	297.4	7.8	0.8
Medium-Density Mixed	924.1	17.2	1.7
High-Density Mixed	115.5	2.1	0.2
Low-Density Open Space	620.3	16.3	1.7
Farm Animals	0.0	207.3	49.0
Stream Bank Erosion	26,706.8	17.6	6.6
Subsurface Flow	0.0	2,929.7	60.4
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	42.6	0.0

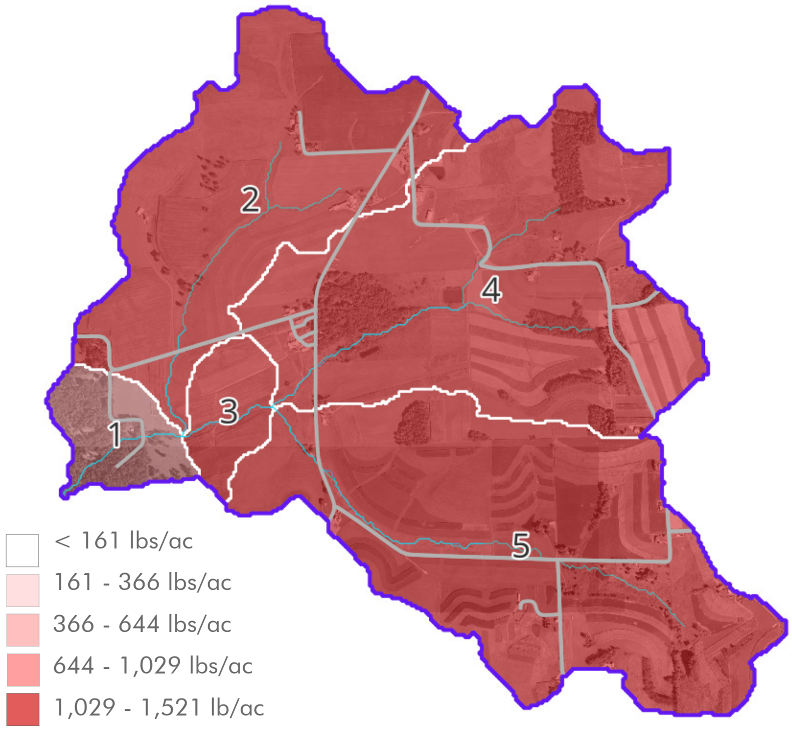
Table 2: Average Annual Loads from 30-years of Daily Fluxes

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	1,606,991.5	9,587.8	1,874.2
Loading Rates (lb/ac)	1,313.79	7.84	1.53
Mean Annual Concentration (mg/L)	386.70	2.31	0.45
Mean Low-Flow Concentration (mg/L)	2,985.51	10.89	3.24

Mean Flow: 66,567,967 (ft^3/year) and 2.11 (ft^3/s)

Figures 35 through 37 on this page reflect the Sediment (red), Total Phosphorus (purple), and Total Nitrogen (blue) loading rates for the various microsheds within the Green Acres Road subwatershed. As the color shades indicate, except for at the tributary mouth where more substantial tree cover is dominant, the loading rates are generally constant across the subwatershed. This is intuitive given the uniformity of the existing agricultural land cover.

Figure 35:
Total Sediment, Pollutant Concentration



For watershed planning purposes, this uniformity suggests that water quality improvements anywhere within the subwatershed will provide comparable benefit, and that spatial prioritization has limited value. The loading rates of microsheds 2 and 3 are slightly higher than the average sediment loading of 1,314 lb/acre within the subwatershed, at about 1,460 and 1,530 lb/acre respectively. Microsheds 2 and 3 similarly have slightly higher loading rates for Phosphorus and Nitrogen than microsheds 4 and 5.

Given these factors, a suitable implementation strategy would be one that is simultaneously systematic and opportunistic. Thinking from a systematic perspective, it makes sense to prioritize engagement and collaboration with land owners within microsheds 2 and 3 due to the slightly higher pollutant loading rates. Thinking opportunistically, the loading rate difference between these and microsheds 4 and 5 is minor and investment of time, energy, and capital has the potential to pay dividends wherever opportunity presents itself.

Figure 36:
Total Phosphorus, Pollutant Concentration

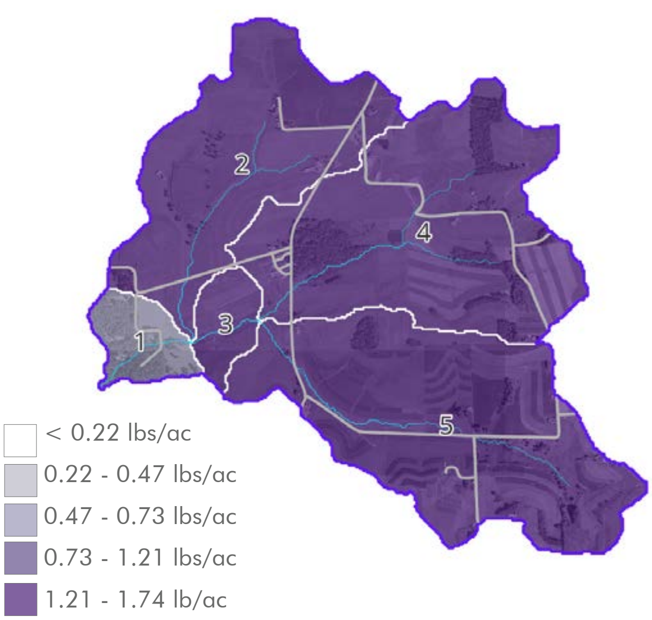
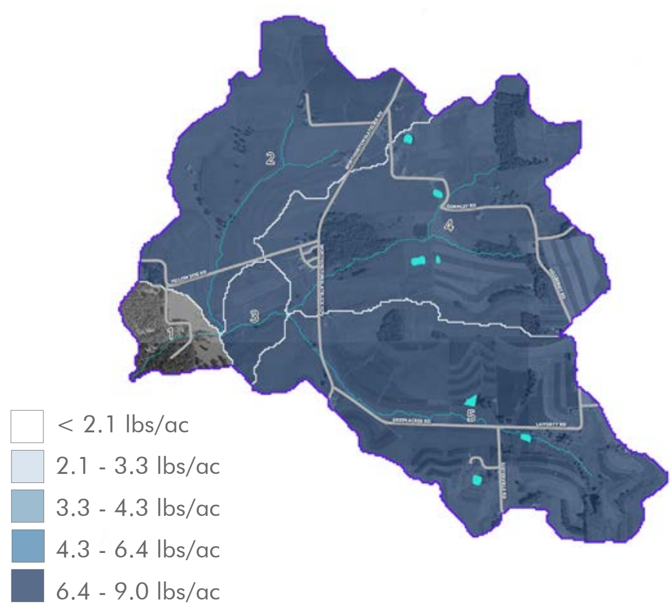


Figure 37:
Total Nitrogen Pollutant Concentration



Summary of Riparian Buffer Opportunities

Per the NHD High Resolution Stream Network dataset, there is a total of 3.72 miles (19,642 feet) of first order and second order streams located within the Green Acres Road watershed. Our more detailed terrain analysis - which tends to reveal perennial, ephemeral, and tile-drained, buried streams that still have drainage path signatures - yielded slightly higher results, indicating that 4.28 miles (22,597 feet) of stream exist. This equates to approximately 108 acres of existing and potential future riparian buffer area, assuming an ideal target buffer width of one hundred (100) feet on each stream bank. Based on the more detailed data set, the following was derived by geospatial analysis:

Table 3: Riparian Buffer Opportunities

Land Cover	Riparian Buffer Coverage (Acres) and Degradation Level			
	0-20%, Critical	20-40%, Severe	40-60%, Moderate	> 60%, Minor
Deciduous Forest *	2.15	1.26	2.25	3.98
Cultivated Crops	77.50	2.25	1.11	1.26
Developed, Open Space	4.95	0.15	-	1.06
Grassland / Herbaceous	0.35	-	-	-
Pasture / Hay	0.72	0.67	-	-
Open Water	1.14	-	-	-
Developed, Low Intensity	2.42	0.19	-	-
Developed, Medium Intensity	0.78	-	-	-
Mixed Forest *	0.54	0.54	0.07	2.59
Total:	90.81	5.06	3.43	8.89
High Priority (Red) **:	80.70	2.44	-	-
Medium Priority (Yellow) ***:	6.02	0.82	-	-

** The categorization of areas as "Deciduous Forest" or "Mixed Forest" may include degraded riparian buffers due to discrepancies between tree canopy and land cover data, especially at canopy edges, but these minor inconsistencies do not impact the main focus of the Watershed Implementation Plan strategy.*

*** The light red shaded cells in Table 3, indicating cultivated crops and developed areas, are key areas for watershed improvement due to their high pollutant loads, with roads and areas near unbuffered, partially incised streams being prime candidates for restoration and stabilization.*

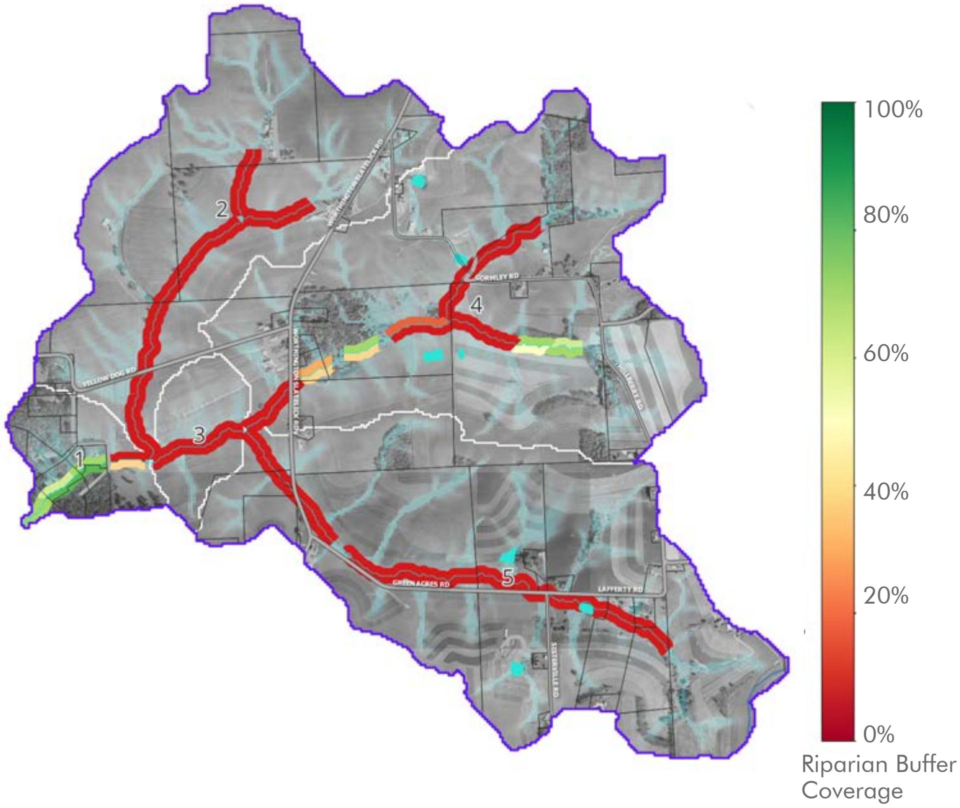
**** Yellow shaded cells in the analysis represent areas where pollution significance is uncertain without further field data. Open spaces, grasslands, and pastures might be high pollutant sources if used for livestock grazing without adequate buffers and fencing, or conversely, could be effectively managed as grass riparian buffers, acting as existing Best Management Practices. Direct engagement with landowners is recommended for accurate assessment.*

Special Consideration for Riparian Buffers

Prioritization of riparian buffers within the Green Acres Road subwatershed requires a nuanced approach in order to maximize benefits and cost effectiveness. Below are two illustrative exhibits.

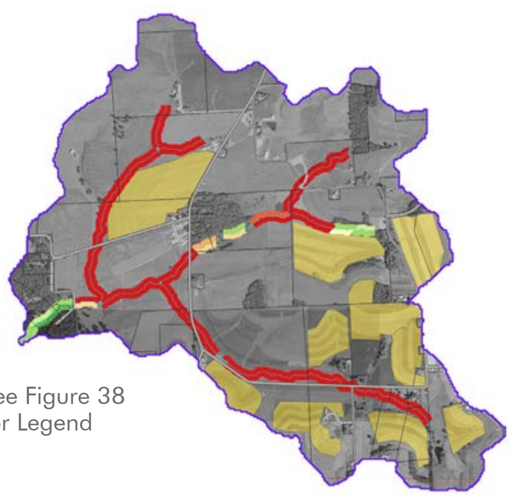
Figure 38 overlays a "flow accumulation" analysis on top of the riparian buffer analysis. As the exhibit shows, not all riparian buffer areas are equal with regard to their pollutant filtering potential. Overland flow tends to concentrate in specific areas - the historic headwaters of the stream tributaries - and riparian buffer replacement projects in these specific areas will be more effective at reducing pollutants than projects at other locations. Consider for example, the last 500-ft segment at the upstream reaches of the northwestern-most tributary. Because of the dendritic pattern of flow in this area, a new riparian buffer has potential to filter from a much larger contributing area than average.

Figure 38: Flow Accumulation Along



Another consideration when prioritizing riparian buffer efforts relates to interplay with existing watershed best management practices already in place. The dark yellow areas in Figure 39 are existing contour farming practices, which happen to be adjacent to degraded riparian buffer areas. In this scenario, it may be more impactful to prioritize riparian buffer projects that are not already protected by contour farming or similar practices. For instance, this may mean prioritizing the west streambank along the microshed 2 tributary, since the east streambank is already partially protected for water quality purposes.

Figure 39: Prioritizing Riparian Buffers Based on Upstream Best Management Practices



See Figure 38 for Legend

Streambank Restoration and Exclusionary Fencing Opportunities

Field visits to the Green Acres Road subwatershed indicated that there are significant streambank restoration and exclusionary fencing opportunities. Based on the watershed analysis, there is over 45,000 linear feet of streambank within the watershed, including ephemeral headwater streams and accounting for both side of the stream. It is estimated that roughly 30% of the existing streambanks are visibly eroded or incised and almost 20% are subject to livestock grazing without exclusionary fencing or appropriate livestock crossing areas. This equates to a potential opportunity for 13,500 linear feet of streambank restoration ranging from minor to moderate in severity, and approximately 9,000 linear feet of streambank fencing.

Implementation Plan, Green Acres Road Subwatershed

Summary of Watershed Implementation Needs and Pollutant Loading Targets

Based in guidance documents for selecting reference watersheds for TMDL assessment and ongoing dialogue with Pennsylvania Department of Environmental Protection (PaDEP), a 1.92 square mile, headwater portion of Cornplanter Run - also within the Cornplanter Run - Buffalo Creek HUC-12 watershed - was chosen for this project as the reference watershed and pollutant loading target for the Green Acres Road subwatershed. Please refer to Appendix C for the more detailed reference watershed assessment. Note that loading rate is used to calculate pollutant targets, rather than total loads. The following summarizes key features of Green Acres Road subwatershed and the selected reference watershed.:

Watershed Area

1,221 acres

Sediment

Loading Rate, Green Acres Road Subwatershed:	0.657 tons/acre
Loading Rate, Reference Watershed:	0.331 tons/acre

Pollutant Reduction Target based on Loading Rate, Sediment: 0.326 tons per year
Pollutant Load Reduction Target, Sediment: 404 tons per year (without safety factor)
Pollutant Load Reduction Target, Sediment: 364 tons per year (with 10% safety factor)

Total Phosphorus

Loading Rate, Green Acres Road Subwatershed:	1.53 lb/acre
Loading Rate, Reference Watershed:	0.79 lb/acre

Pollutant Reduction Target based on Loading Rate, Phosphorus: 904 lbs per year
Pollutant Load Reduction Target, Phosphorus: 965 tons per year (without safety factor)
Pollutant Load Reduction Target, Phosphorus: 869 tons per year (with 10% safety factor)

Total Nitrogen

Loading Rate, Green Acres Road Subwatershed:	7.84 lb/acre
Loading Rate, Reference Watershed:	4.11 lb/acre

Pollutant Reduction Target based on Loading Rate, Nitrogen: 4,554 lbs per year
Pollutant Load Reduction Target, Nitrogen: 5,018 tons per year (without safety factor)
Pollutant Load Reduction Target, Nitrogen: 4,516 tons per year (with 10% safety factor)

Implementation Plans and Projects

As described earlier, the land use within the Green Acres Road subwatershed is largely agricultural in nature. Because several landowners in this area have previously implemented best management practices such as contour farming on their properties, the goal going forward should be to build upon these past successes, focus additional outreach and education on additional priority landowners, showcase exemplary existing BMPs, land conservation through easements, and preservation of the existing land cover types and implemented BMPs that are critical for water quality.

Based on the suite of opportunities described previously and the target pollutant loads that were established using the Reference Watershed process, the following list of BMPs and potential projects were identified for the Green Acres Road subwatershed:

Table 4: Proposed Best Management Practices, Green Acres Road Subwatershed

BMPS	Units	Available	% Proposed	Amount Proposed	Proposed Reduction		
					S (tons)	P (lbs)	N (lbs)
Riparian Buffer & Stream Restoration							
Forested Buffer	acres	108	20%	22	34	65	386
Grass Buffer	acres	108	25%	27	42	82	373
Streambank Stabilization	feet	13,500.0	4%	540	31	94	104
Streambank Exclusionary Fencing	acres	1.4	40%	0.6	1	1	5
Land Conversion							
Cropland Retirement	acres	860	5%	43	33	76	253
Agricultural Land Management							
Water and Soil Conservation Planning	acres	968	50%	484	96	128	248
Cover Crops	acres	860	20%	172	14	12	243
Contour Farming / Strip Cropping	acres	642	10%	64	13	17	33
Conservation Tillage	acres	860	30%	258	161	250	232
Nutrient Management	acres	968	30%	290	-	26	102
Grazing Land Management	acres	40	20%	8	1	2	2
Barnyard Runoff Control	acres	10	25%	3	0	10	584
					S Loading (tons)	P Loading (lbs)	N Loading (lbs)
				Total Proposed Reduction	426	764	2,565
				Current Loading	802	1,869	9,572
				Proposed Loading	376	1,105	7,007
				Target Loading Goal	364	869	4,516
				Percent Above/Below Goal	-3%	-16%	-44%

Table 5: Best Management Practices, Cost Summary (2025 Base Year)

BMPS		Units	Quantity	Unit Cost, Capital	Total Cost, Capital	Unit Cost, O&M	Total Cost, O&M
Riparian Buffer & Stream Restoration							
	Forested Buffer	acres	22	$6,409.19	$138,438.42	$104.89	$2,265.66
	Grass Buffer	acres	27	$1,418.57	$38,301.34	$46.44	$1,253.78
	Streambank Stabilization	feet	540	$809.73	$437,252.51	$82.83	$44,727.61
	Streambank Exclusionary Fencing	acres	1	$21,345.12	$11,867.88	$715.97	$398.08
Land Conversion							
	Cropland Retirement	acres	43	$173.85	$7,474.68	$6.74	$289.74
Agricultural Land Management							
	Water and Soil Conservation Planning	acres	484	$24.91	$12,055.19	$-	$-
	Cover Crops	acres	172	$75.50	$12,984.49	$75.50	$12,984.49
	Contour Farming / Strip Cropping	acres	64	$1.61	$103.35	$1.61	$103.35
	Conservation Tillage	acres	258	$18.73	$4,831.78	$18.73	$4,831.78
	Nutrient Management	acres	290	$27.96	$8,118.55	$10.59	$3,074.17
	Grazing Land Management	acres	8	$81.27	$642.20	$81.27	$642.20
	Barnyard Runoff Control	acres	3	$6,013.28	$15,033.20	$0.77	$1.94
			Total		$687,104		$70,573

10-Year Watershed Implementation Plans for Green Acres Road Subwatershed

Based on the Base Year 2025 values provided below, the proposed 10-year WIP for the Green Acres Road Subwatershed is summarized below in Table 6:

Table 6: Years 1 Through 5 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 1		Year 2		Year 3		Year 4		Year 5	
	2025		2026		2027		2028		2029	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$13,844	$227	$14,366	$470	$14,907	$732	$15,469	$1,013	$16,053	$1,314
Grass Buffer	$3,830	$125	$3,975	$260	$4,124	$405	$4,280	$560	$4,441	$727
Streambank Stabilization	$43,725	$4,473	$45,374	$9,283	$47,084	$14,449	$48,859	$19,992	$50,701	$25,932
Streambank Exclusionary Fencing	$1,187	$40	$1,232	$83	$1,278	$129	$1,326	$178	$1,376	$231
Land Conversion										
Cropland Retirement	$747	$29	$776	$60	$805	$94	$835	$130	$867	$168
Agricultural Land Management										
Water and Soil Conservation Planning	$1,206	$-	$1,251	$-	$1,298	$-	$1,347	$-	$1,398	$-
Cover Crops	$1,298	$1,298	$1,347	$2,695	$1,398	$4,195	$1,451	$5,804	$1,506	$7,528
Contour Farming / Strip Cropping	$10	$10	$11	$21	$11	$33	$12	$46	$12	$60
Conservation Tillage	$483	$483	$501	$1,003	$520	$1,561	$540	$2,160	$560	$2,801
Nutrient Management	$812	$307	$842	$638	$874	$993	$907	$1,374	$941	$1,782
Grazing Land Management	$64	$64	$67	$133	$69	$207	$72	$287	$74	$372
Barnyard Runoff Control	$1,503	$0	$1,560	$0	$1,619	$1	$1,680	$1	$1,743	$1
SUBTOTALS	$68,710	$7,057	$71,301	$14,647	$73,989	$22,798	$76,778	$31,544	$79,673	$40,916
BY YEAR		$75,768		$85,947		$96,787		$108,322		$120,589

Table 7: Years 6 Through 10 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 6		Year 7		Year 8		Year 9		Year 10	
	2030		2031		2032		2033		2034	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$16,658	$1,636	$17,286	$1,980	$17,937	$2,348	$18,614	$2,742	$19,315	$3,161
Grass Buffer	$4,609	$905	$4,782	$1,096	$4,963	$1,300	$5,150	$1,517	$5,344	$1,749
Streambank Stabilization	$52,613	$32,291	$54,596	$39,094	$56,655	$46,363	$58,790	$54,124	$61,007	$62,405
Streambank Exclusionary Fencing	$1,428	$287	$1,482	$348	$1,538	$413	$1,596	$482	$1,656	$555
Land Conversion										
Cropland Retirement	$899	$209	$933	$253	$968	$300	$1,005	$351	$1,043	$404
Agricultural Land Management										
Water and Soil Conservation Planning	$1,451	$-	$1,505	$-	$1,562	$-	$1,621	$-	$1,682	$-
Cover Crops	$1,562	$9,374	$1,621	$11,349	$1,682	$13,459	$1,746	$15,712	$1,812	$18,116
Contour Farming / Strip Cropping	$12	$75	$13	$90	$13	$107	$14	$125	$14	$144
Conservation Tillage	$581	$3,488	$603	$4,223	$626	$5,008	$650	$5,847	$674	$6,741
Nutrient Management	$977	$2,219	$1,014	$2,687	$1,052	$3,187	$1,092	$3,720	$1,133	$4,289
Grazing Land Management	$77	$464	$80	$561	$83	$666	$86	$777	$90	$896
Barnyard Runoff Control	$1,809	$1	$1,877	$2	$1,948	$2	$2,021	$2	$2,097	$3
SUBTOTALS	$82,676	$50,950	$85,793	$61,683	$89,028	$73,153	$92,384	$85,399	$95,867	$98,465
BY YEAR		$133,627		$147,476		$162,180		$177,783		$194,332
10-Year Implementation Cost, Green Acres:										$1,302,812

Table 8: Best Management Practices, Annualized Cost Per Pollutant Reduction

Projects / Opportunities	Net Present Value			Annualized Cost Over 10-Years	Pollutant Reduction		
					Cost / Pound / Year		
	Capital	O&M	Total		S	P	N
Riparian Buffer & Stream Restoration							
Forested Buffer	$138,438	$12,461	$150,900	$15,090	$0.22	$230.91	$39.07
Grass Buffer	$38,301	$6,896	$45,197	$4,520	$0.05	$55.22	$12.10
Streambank Stabilization	$437,253	$246,002	$683,254	$68,325	$1.10	$727.18	$659.00
Streambank Exclusionary Fencing	$11,868	$2,189	$14,057	$1,406	$1.12	$1,230.67	$290.60
Land Conversion							
Cropland Retirement	$7,475	$1,594	$9,068	$907	$0.01	$11.97	$3.59
Agricultural Land Management							
Water and Soil Conservation Planning	$12,055	$-	$12,055	$1,206	$0.01	$9.42	$4.85
Cover Crops	$12,984	$71,415	$84,399	$8,440	$0.31	$696.07	$34.78
Contour Farming / Strip Cropping	$103	$568	$672	$67	$0.003	$3.96	$2.04
Conservation Tillage	$4,832	$26,575	$31,407	$3,141	$0.01	$12.56	$13.56
Nutrient Management	$8,119	$16,908	$25,026	$2,503	$-	$95.12	$24.45
Grazing Land Management	$642	$3,532	$4,174	$417	$0.15	$184.28	$177.94
Barnyard Runoff Control	$15,033	$11	$15,044	$1,504	$1.56	$153.50	$2.58

Worthington Subwatershed

Watershed Characteristics

Watershed Analysis

Implementation Plan

FIGURE 40:
AERIAL IMAGERY
OF WORTHINGTON
SUBWATERSHED

Worthington Subwatershed

Watershed Characteristics

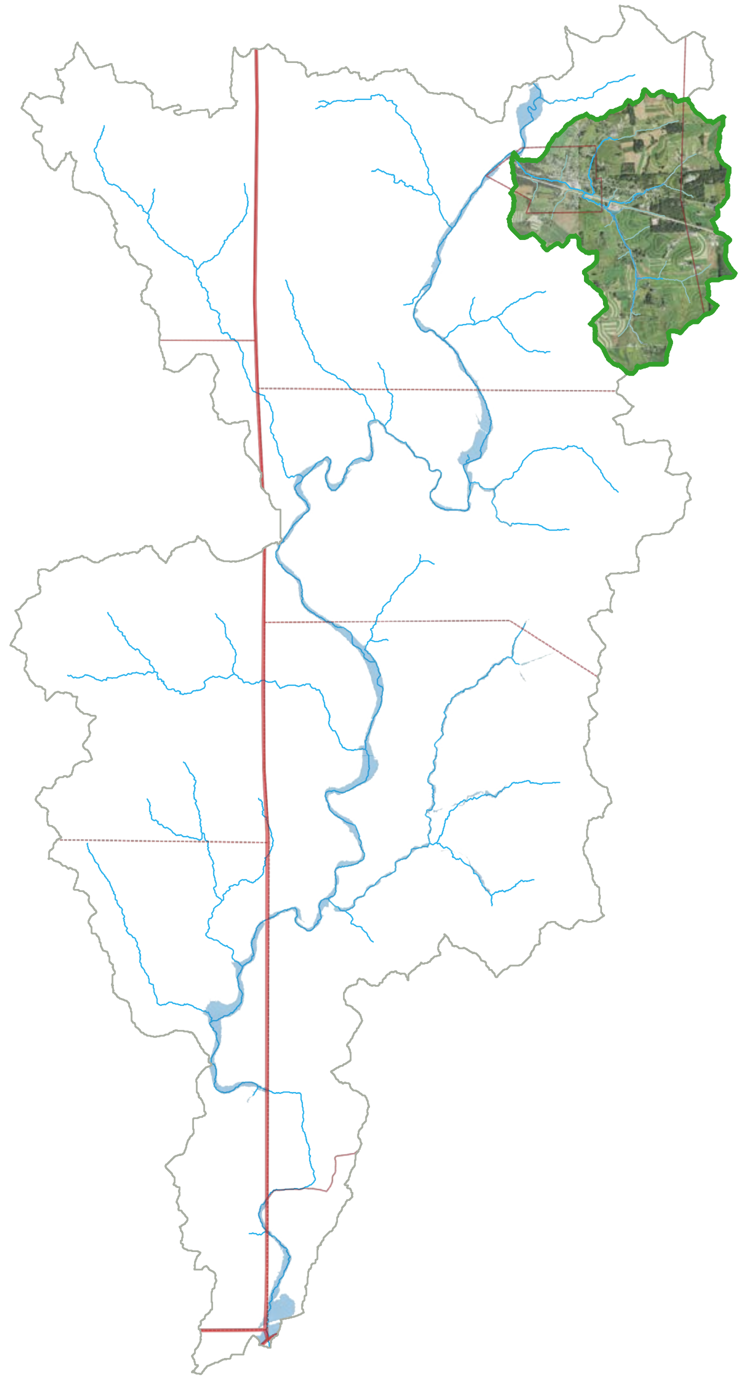
Location and Basin Characteristics

The Worthington subwatershed is 3.93 square miles. This subwatershed includes portions of East Franklin Township and West Franklin Township, with the Worthington Borough situated near the mouth of the subwatershed, where its waters eventually join the Buffalo Creek.

The confluence area is particularly significant for watershed management, serving as a gauge for the health of the watercourses and a checkpoint for mitigating potential contaminants entering Buffalo Creek.

Understanding the spatial layout and water flow within this context is essential for developing comprehensive watershed management strategies. It helps identify priority areas for conservation, potential risks to water quality, and opportunities for restoration and mitigation to ensure the health and sustainability of the aquatic ecosystems within the Worthington subwatershed and the larger Cornplanter Run - Buffalo Creek watershed.

Figure 41: Worthington Subwatershed Context Map



Terrain and Slope

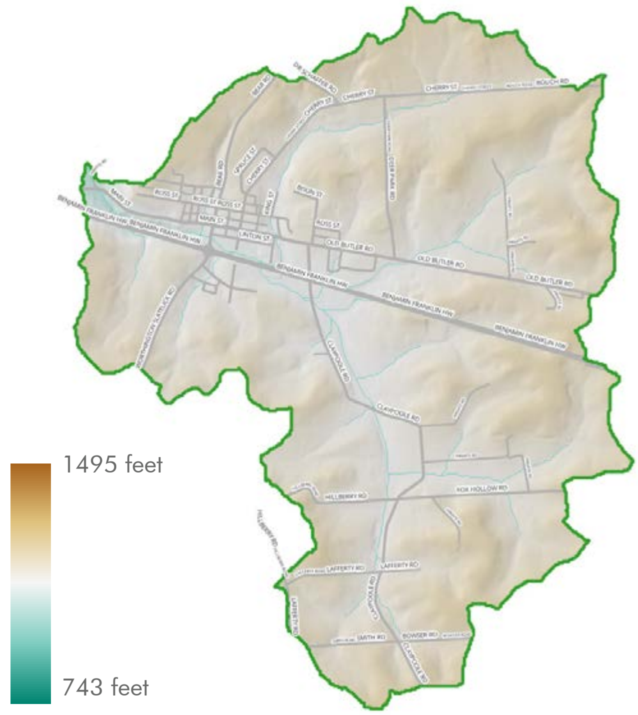


Figure 42: Terrain and Elevation Map

The terrain and elevation map (Figure 42) for the Worthington subwatershed is a crucial element in understanding the area's topography and its implications on water flow and potential erosion risk. Based on the NHDPlus V2 NEDSnapshot DEM dataset, elevations vary from approximately 1,193 feet to about 982 feet at the mouth.

The Steep Slopes map (Figure 43) showcases a variety of slopes, with color gradations indicating the degree of steepness, which has direct implications for land use and watershed management. The subwatershed has an average slope of 8.6%.

Moderate slopes (10-25%), colored in light green and comprising most of the steep slopes in the subwatershed, present opportunities for certain types of land use, such as agriculture, given that they are less prone to soil erosion compared to steeper grades. However, these areas still require attention to soil conservation practices to prevent erosion, especially during heavy rainfall events.

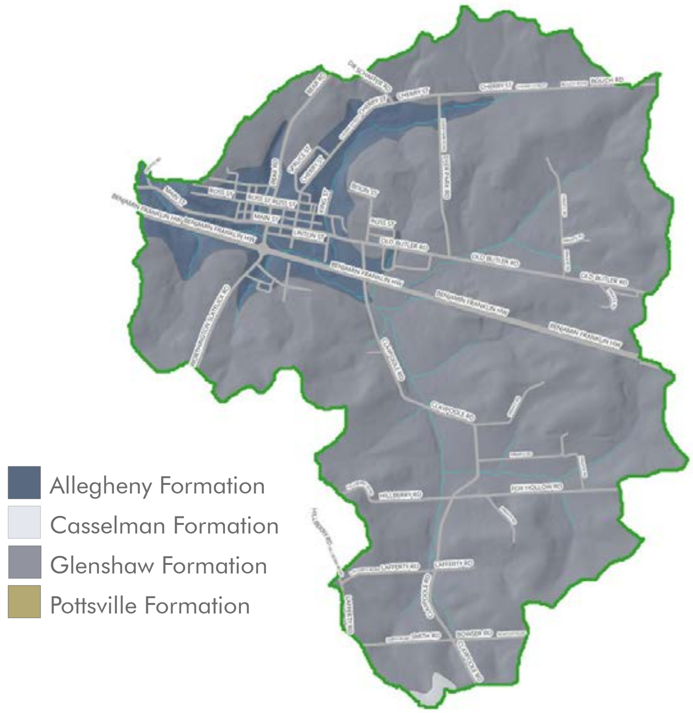
The areas identified with steep slopes, shown in darker green and indicating gradients between 25-50%, are at higher risk for rapid surface runoff, which can lead to significant soil erosion if not properly managed. These slopes are challenging for development and certain types of agriculture due to their susceptibility to erosion and the difficulty in establishing stable land-use practices.

Very steep slopes, marked in red and exceeding 50% grades, are the most critical areas in terms of erosion risk. The map shows some sparse areas in this red color, primarily along the PennDOT Route 422 (Benjamin Franklin Highway). These are likely engineered cut and fill slopes needed to construct the highway through moderately sloped areas, and would not be indicative of increased erosion potential.

Figure 43: Steep Slope Map

Bedrock Geology and Lithology

Figure 44: Bedrock Geology Map

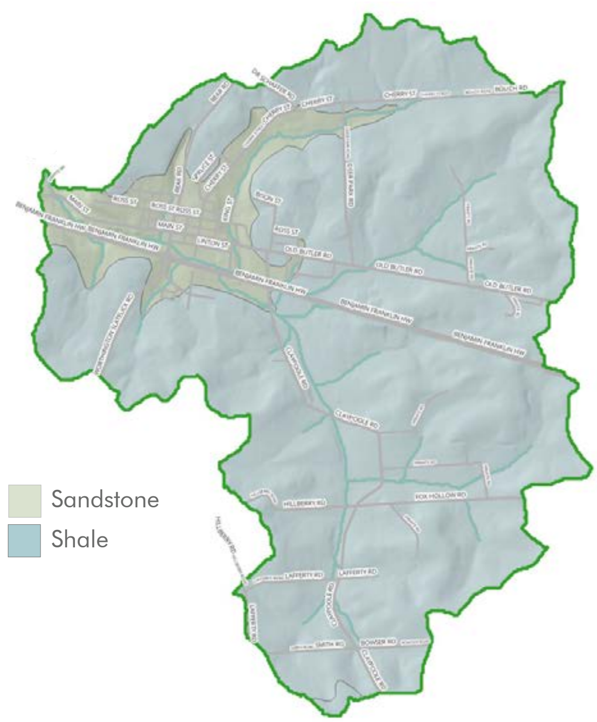


The bedrock geology map (Figure 44) of the Worthington subwatershed prominently displays the Casselman Formation and the extensive presence of shale. These geological features fundamentally shape the hydrological characteristics and management strategies of the area.

The Casselman Formation, typically consisting of sedimentary layers including sandstone, siltstone, and shale, suggests a landscape with mixed water infiltration capacities. Where sandstone is present, we can expect moderate to high water permeability, which benefits groundwater recharge and regulates stream flow by providing a consistent source of water. Conversely, the predominance of shale within the formation indicates areas with considerably reduced permeability. This can lead to surface runoff challenges during rain events, as the water is less able to permeate the ground, increasing the potential for erosion and surface water contamination.

The map's clear indication of shale's dominance, in particular in the agricultural areas, informs the WIP's emphasis on erosion control and stormwater management. Shale areas are likely to experience rapid runoff, which can carry pollutants and sediments into waterways, calling for the implementation of BMPs such as riparian buffers, sediment control structures, and other erosion-prevention strategies.

Figure 45: Bedrock Lithology Map



As mentioned earlier, the geology influences soil development, impacting agricultural practices. The presence of shale suggests that careful soil management is necessary to maintain soil health and prevent degradation, which can be achieved through practices like no-till farming, cover cropping, and careful nutrient management to avoid leaching and runoff issues.

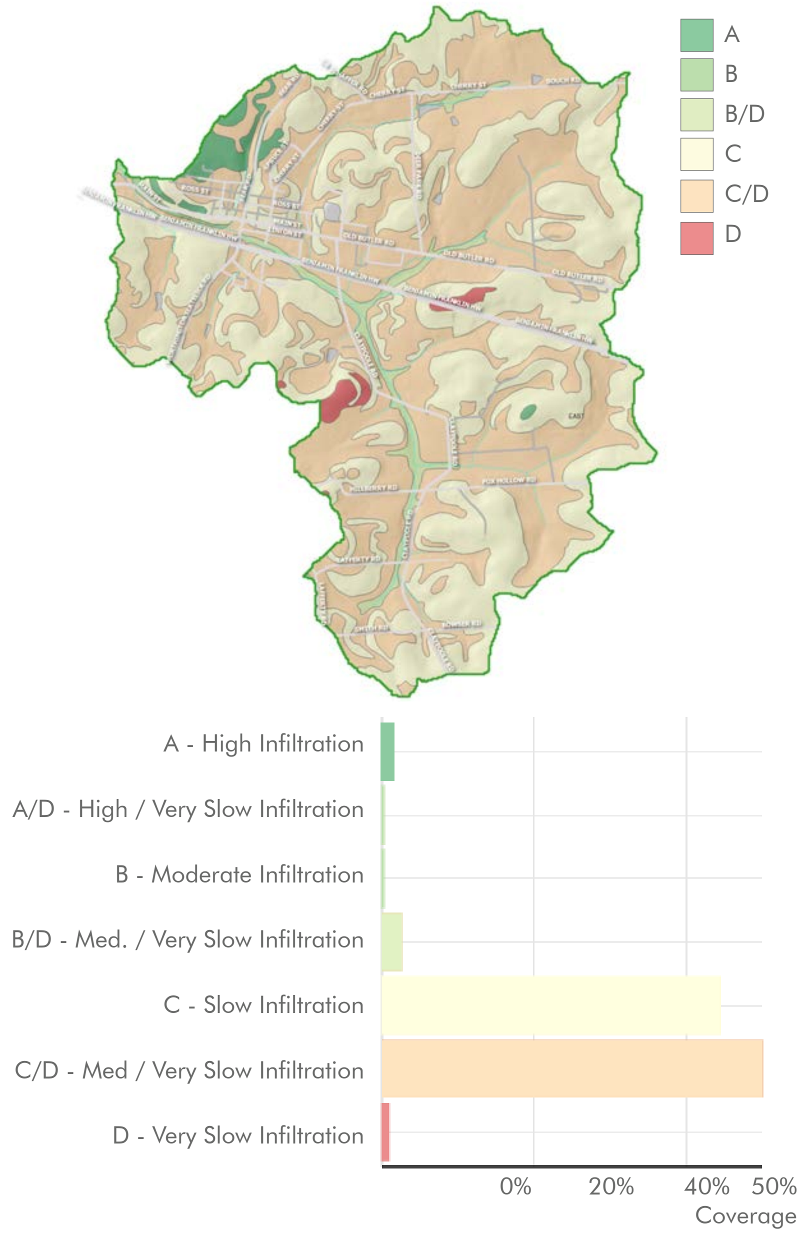
Soils

The hydrologic soil group map (Figure 46) of the Worthington subwatershed was pivotal in shaping the WIP by illustrating the dominant soil infiltration characteristics which govern the movement of water within the landscape.

The map's dominant soil classes, Group C and C/D soils, which show slow to very slow infiltration rates, cover the majority of the subwatershed. These soils, due to their finer textures and higher clay content, are less permeable and more prone to generating runoff, especially after precipitation events. This prevalence of less permeable soils suggests a higher potential for surface water runoff and sediment transport, which could carry pollutants into the watershed's watercourses.

Addressing the challenges posed by Group C and C/D soils will be a focal point of the WIP. Mitigation strategies may include the establishment of extensive riparian buffers to intercept sediments, and the implementation of no-till farming practices to reduce soil compaction and improve infiltration rates.

Figure 46: Hydrologic Soils Group



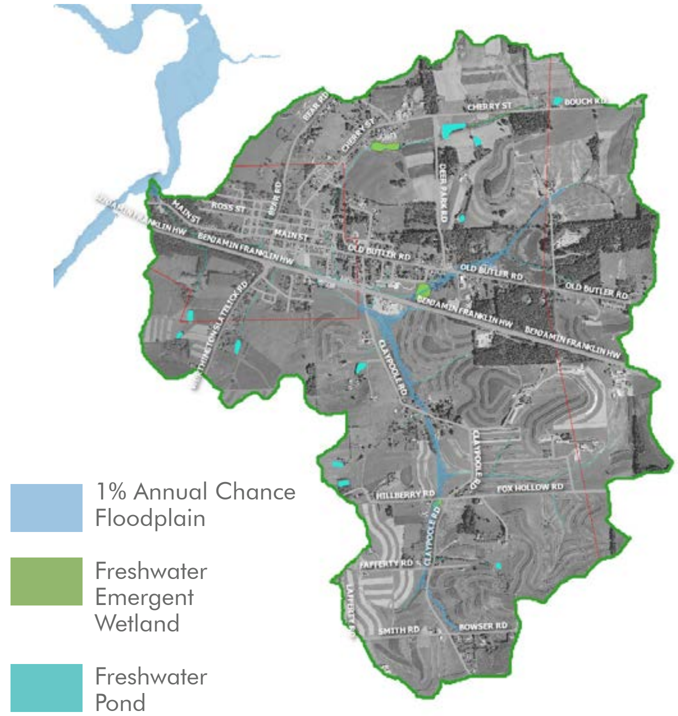
In summary, the WIP manages runoff and enhance infiltration in areas with Group C and C/D soils, while also leveraging the benefits of areas with other, more permeable soils to improve the watershed's overall hydrologic function. Because the more permeable B/D soils follow historical stream channels, emphasis may be placed on riparian restoration solutions. These targeted soil management interventions will be crucial for reducing erosion, managing stormwater, and improving water quality in the Worthington subwatershed.

Hydrology and Stream Impairments

The delineation of floodplains and wetlands (Figure 47) signifies the natural infrastructure for water filtration and habitat conservation. These areas are integral to the subwatershed's ability to handle stormwater surges and maintain biodiversity, serving as a natural buffer and a filter for the landscape.

The Non-attaining Stream and Documented Causes map (Figure 48) depicts impaired streams, impairment causes, and associated land uses., based on previous assessment by PaDEP. The impaired streams shown in red and the corresponding shaded watersheds indicate the potential presence of on-site treatment systems, including septic systems, which are sources of toxicity when they fail or are improperly maintained. These systems may be contributing to the degradation of water quality, necessitating upgrades or replacements to ensure they function efficiently and do not release contaminants.

Figure 47: Floodplains and Wetlands

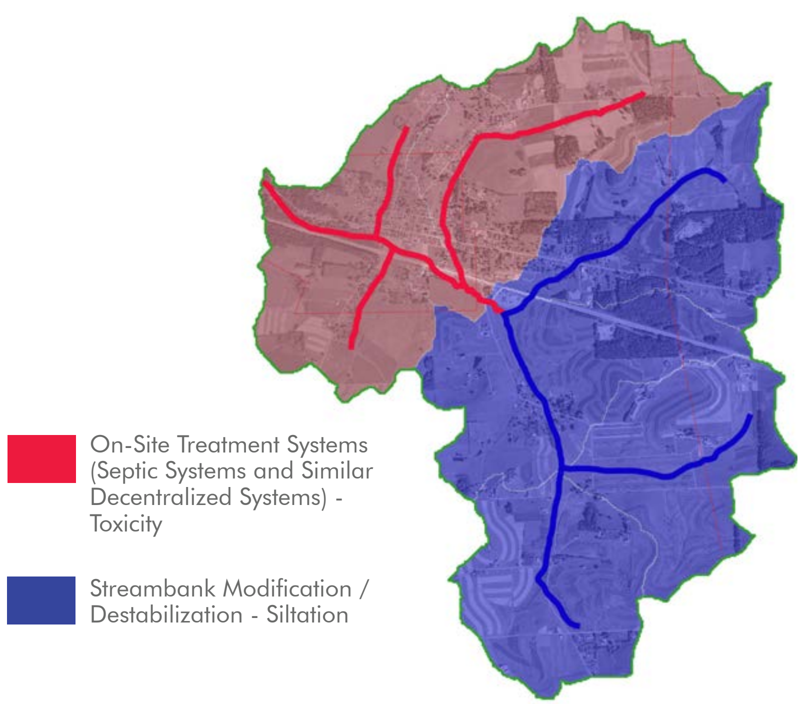


The blue area shown on Figure 48 denotes regions where streambank modification and destabilization has led to siltation to the stream - a process where eroded soil deposits reduce water clarity and quality, affecting aquatic habitats. This informed the WIP's emphasis on streambank stabilization efforts, such as the introduction of vegetation and structural supports to prevent further erosion and siltation, which are essential for the health of aquatic ecosystems and the clarity of water channels.

The length of stream that is impaired by On-Site Treatment Systems and Streambank Modifications per PaDEP is approximately 5.00 and 4.64 miles respectively, exclusive of smaller headwater tributaries.

The WIP, informed by these visual data points, prioritizes the enhancement of existing wetlands and floodplains while addressing the pressing issues of failing septic systems and eroding streambanks. The plan includes strategies that span from technical fixes to ecological restorations—each tailored to the unique challenges presented by the landscape. Through such targeted actions, the goal is to secure the ecological integrity of the Worthington subwatershed, ensuring it sustains its functions as a critical water resource and natural habitat.

Figure 48: Non-Attaining Stream and Documented Causes



Tree Canopy and Riparian Buffer

The tree canopy map (Figure 49) indicates the distribution of wooded areas within the subwatershed. These areas are critical for reducing stormwater runoff, minimizing erosion, and filtering pollutants before they enter the water system. The patches of green signal where these benefits are actively at work. However, the map also reveals significant gaps in the canopy, particularly in areas that are more developed or used for agriculture. These gaps suggest potential areas where restoration efforts should focus on increasing tree cover to enhance the subwatershed's ecological services and resilience.

Figure 49: Tree Canopy Map

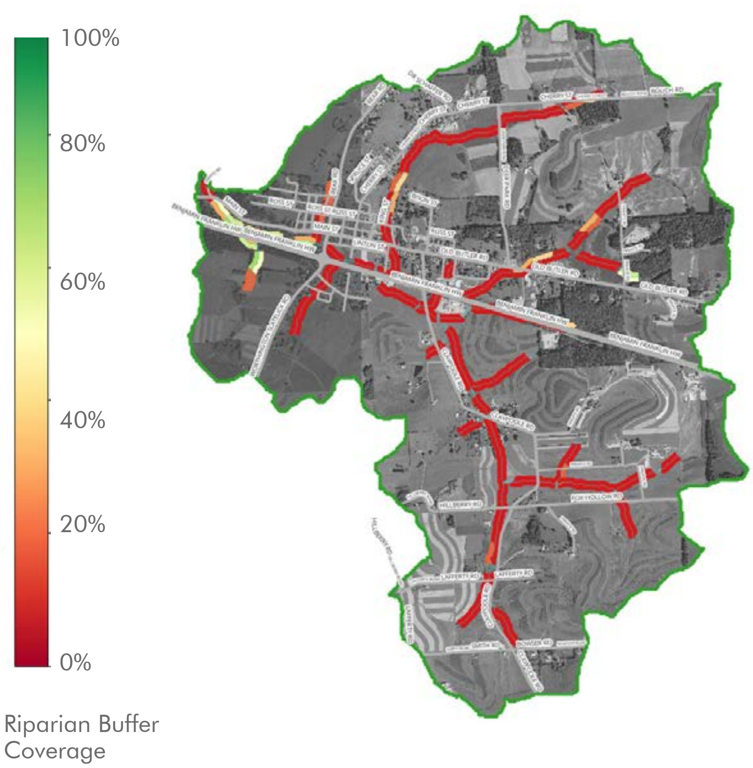
See Riparian Buffer Map for Legend

Figure 50 reveals a critical concern for watershed management—the absence of riparian buffers where they are most needed, shown in red. These missing buffers, ideally composed of native vegetation, are crucial for protecting streams and rivers from runoff, filtering pollutants, and maintaining bank integrity. Their absence along many watercourses leaves these areas vulnerable to the detrimental effects of erosion and pollution, particularly in sections adjacent to agricultural or developed lands.

For the WIP, the implications are clear. First, there are opportunities to augment tree coverage overall, critical in urban or agricultural areas to mitigate the impacts of impervious surfaces and intensive farming practices.

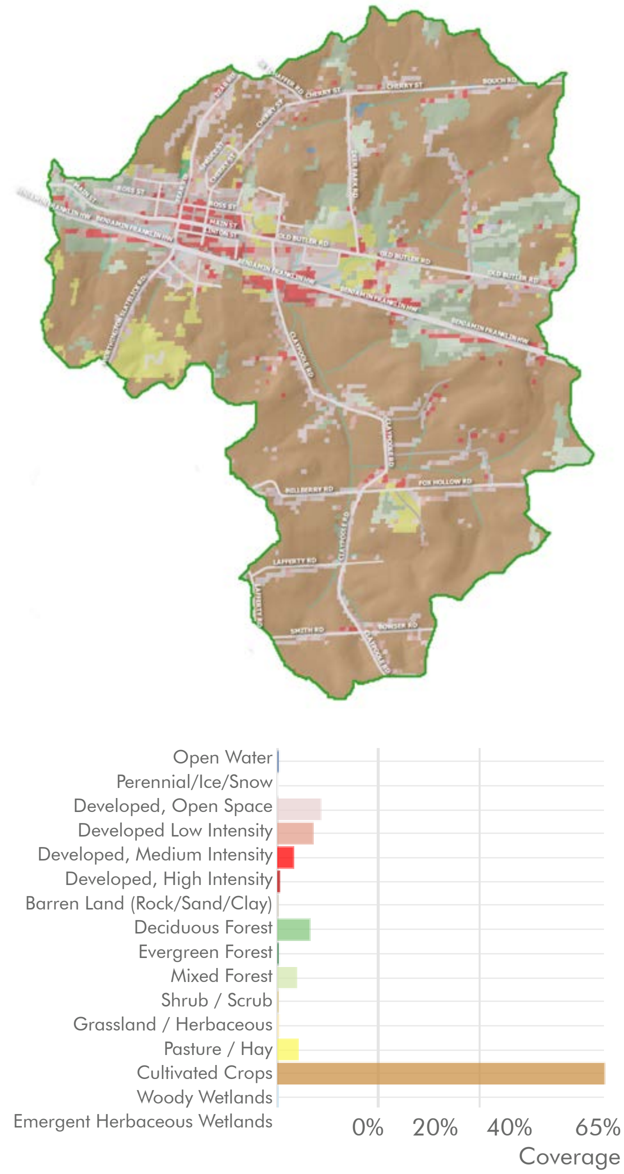
Second, the subwatershed would benefit from expanding and connecting riparian buffers, especially in agricultural areas where runoff is likely to carry sediments and nutrients.

Figure 50: Riparian Buffer Map



Land Cover

Figure 51: NLCD Land Cover (2019)



The Worthington subwatershed's land cover is dominated by agricultural activity (69.16%), with cultivated crops accounting for 64.95% of the subwatershed (NLCD 2019 data) This agricultural dominance shapes the environmental and hydrological patterns within the subwatershed and has substantial implications for watershed management.

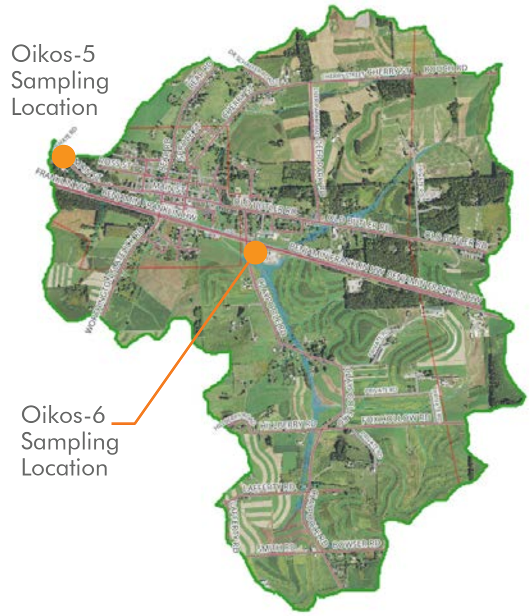
The preponderance of cultivated crops signifies active engagement in tillage, planting, and harvesting cycles, which are essential for the local economy but can also pose environmental challenges. The primary concern is the potential for nutrient runoff, particularly from fertilizers and pesticides, which can lead to eutrophication in nearby water bodies. Soil erosion from these areas, especially without adequate conservation practices like cover crops or no-till farming, can contribute to sedimentation in streams and rivers, impacting water quality and aquatic habitats.

The developed land within Worthington, depicted in shades of red and pink, represents the second most extensive land cover type in the subwatershed. The urban landscape introduces impervious surfaces such as roads, buildings, and parking lots, which reduce infiltration and increase surface runoff. This can exacerbate flooding risks and channel pollutants into the watershed, necessitating the incorporation of urban stormwater management practices to meet water quality standards.

The juxtaposition of intensive agriculture with urban development presents a complex scenario for watershed management. Strategies must balance the need for agricultural productivity with the imperative of protecting and enhancing water quality. Approaches could include promoting precision agriculture to reduce excessive nutrient application, implementing buffer zones between fields and waterways, and establishing green infrastructure within urban areas to absorb and filter runoff.

Macroinvertebrate Sampling, Spring 2023

Figure 52: Sampling Locations



Two locations within the subwatershed were sampled in 2023, including Oikos-5 (downstream of the Borough of Worthington) and Oikos-6 (upstream of the Borough). Sampling results reveal a significant ecological impact, likely influenced by the moderate development and light urbanization in the Borough of Worthington, as well as upstream agricultural activities.

Downstream of the Borough of Worthington, the Oikos-5 sampling data indicates that the taxa richness is at 16, which is below the standard value of 33, indicating a reduced diversity of macroinvertebrate species. EPT richness is at 5, which is significantly lower than the standard of 19, suggesting a stressed environment for pollution-sensitive species. The Beck's index at 4 and the IBI score of 33.61 further affirm the impaired status of the subwatershed. The Shannon diversity index is low at 1.36, pointing to a lack of ecological complexity and resilience. The Hilsenhoff biotic index is high at 5.46, hinting at possible organic pollution. The Percent Sensitive metric is critically low at 10.84, reinforcing the absence of pollution-sensitive organisms. Overall, the data suggests that the downstream environment is impaired and facing ecological stress.

Upstream of the Borough and immediately downstream of a significant agricultural land use area, the situation appears even more severe, based on the Oikos-6 sampling results. The taxa richness here is at 11, and the EPT richness plummets to 2, indicating an even more significant decline in the diversity and presence of sensitive species. The Beck's index at a low 2, the Shannon diversity index at 1.01, and an extremely low IBI score of 22.68 all reflect a highly impaired ecological state, with a very limited presence of stoneflies and mayflies noted in the summary.

Comparing the upstream and downstream sites, it appears that the subwatershed's health is most severely impacted upstream, close to pollutant source and likely attributed to the immediate impacts of agricultural runoff and urbanization. The low presence of sensitive taxa such as mayflies and stoneflies upstream suggests that the water quality issues begin before the water

Figure 53: Oikos-5 Sampling Location Photo

Figure 54: Oikos-6 Sampling Location Photo

reaches the Borough, and these issues continue to be present further downstream, but are somewhat buffered by dilution from the larger stream flows and proximity to the main stem.

The Worthington subwatershed is facing significant ecological challenges, with both sampling locations showing signs of impairment, and 100% of the streams designated as Impaired by PA DEP. It is crucial to implement a comprehensive water quality management plan that includes monitoring of agricultural practices, urban runoff, and point-source pollution control. Restoration efforts should aim to enhance riparian buffers, reduce sedimentation, and improve in-stream habitats to bolster the resilience of the macroinvertebrate communities.

Laboratory Water Quality Sampling, Spring 2023

The Worthington subwatershed's macroinvertebrate sampling provided a biological assessment, and complementary laboratory water quality testing at Oikos-5 and Oikos-6 offers a chemical perspective for 2023.

At Oikos-5, downstream of the Borough of Worthington, the pH level was slightly alkaline at 7.82, which is within the range supportive of most aquatic life. The measured phosphorus concentration was slightly above the detection limit at 0.12 mg/L. While not alarmingly high, it is an indicator of potential nutrient enrichment that could lead to eutrophic conditions if it increases. Total Kjeldahl Nitrogen was below the detection limit, indicating low levels of organic nitrogen. However, Nitrate+Nitrite Nitrogen concentrations were elevated at 3.36 mg/L, which could be attributed to agricultural runoff, a common concern in areas with significant farming activities. This is further substantiated by the Total Nitrogen measurement of 3.36 mg/L. Total Suspended Solids were noted at 20 mg/L, which may reflect land disturbances and could contribute to habitat degradation if not managed properly.

Upstream at Oikos-6, the pH was 7.63, also within a normal range for healthy streams but slightly more acidic than Oikos-5, potentially reflecting different land use impacts. Phosphorus levels were higher at this site, measured at 0.22 mg/L, which could indicate more significant nutrient runoff from the upstream agricultural areas. Total Kjeldahl Nitrogen reached the detection limit of 1.00 mg/L, suggesting a presence of nitrogenous waste. Nitrate+Nitrite Nitrogen levels were also high at 2.84 mg/L, reinforcing concerns about nutrient pollution. The Total Nitrogen content matched the nitrate and nitrite levels, further highlighting potential agricultural influence. Total Suspended Solids were slightly lower than downstream, measured at 16 mg/L, but still indicative of some sediment presence.

Stream Water Quality Findings

The chemical analysis from Oikos-5 and Oikos-6 indicate that the water's pH is generally suitable for aquatic life. However, there are increased levels of phosphorus and nitrogen, likely due to farming and perhaps stormwater runoff from Worthington. While these levels aren't high enough yet to harm the water's ecosystem, as shown by the macroinvertebrate data, they should be monitored to avoid future problems.

The combined data from macroinvertebrate populations and laboratory water quality testing suggest that the Worthington subwatershed, while currently maintaining a balance, is at a critical juncture. Restoration efforts that focus on reducing nutrient runoff, sedimentation, and improving riparian buffers could be effective in maintaining the health of the subwatershed. The water quality indicators point to the need for ongoing monitoring to ensure that

the health of the aquatic ecosystem is not compromised over time. The macroinvertebrate data showing signs of stress, especially upstream, coupled with the laboratory results, indicate areas where focused conservation efforts could be beneficial. By addressing these early signs of stress, the Worthington subwatershed can be preserved for its ecological value and importance to the surrounding community.

Watershed Analysis

A higher resolution terrain analysis was performed within the larger study area to create seven (7) distinct microsheds within the Worthington subwatershed. These microsheds were assigned the labels 6 through 12, so as to be distinct from the previous subwatersheds studied.

Current Sediment and Nutrient Loading

Table 9 and 10 summarize existing pollutant load for Sediment, Total Nitrogen and Total Phosphorus for the entire Worthington subwatershed, aggregated by land cover and summarized overall.

The most significant sources of sediment pollution within the Worthington subwatershed are cropland, hay/pasture, and stream bank erosion. These observations about pollutant sources are consistent across GIS land cover analyses, aerial imagery and site visits.

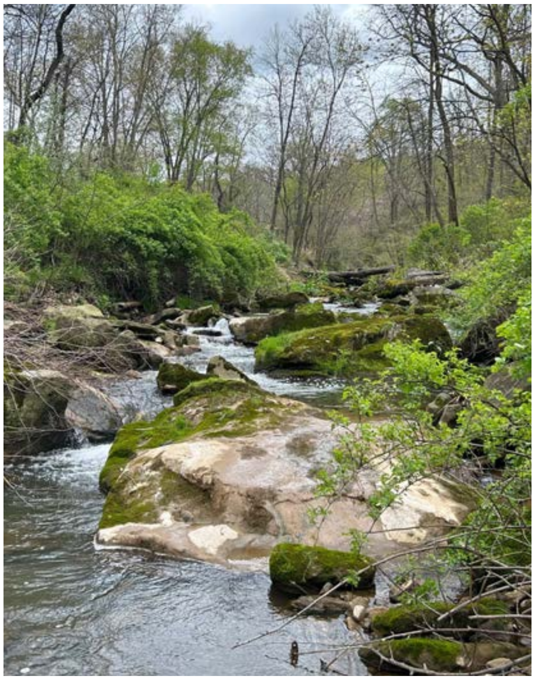


Table 9: Average Annual Pollutant Loads, by Land Cover

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	120,497.7	345.8	125.3
Cropland	2,583,890.1	9,546.4	2,786.4
Wooded Areas	807.9	20.6	1.7
Wetlands	2.2	0.2	0.0
Open Land	526.3	6.4	0.6
Barren Areas	2.3	0.8	0.0
Low-Density Mixed	2,024.6	56.1	5.9
Medium-Density Mixed	5,977.2	113.9	11.6
High-Density Mixed	1,008.2	19.2	2.0
Low-Density Open Space	2,431.2	67.3	7.1
Farm Animals	0.0	455.1	108.8
Stream Bank Erosion	142,531.2	92.6	33.1
Subsurface Flow	0.0	4,972.6	117.2
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	259.3	0.0

Table 10: Average Annual Loads from 30-years of Daily Fluxes

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	2,859,698.8	15,956.4	3,199.6
Loading Rates (lb/ac)	1,132.59	6.32	1.27
Mean Annual Concentration (mg/L)	350.93	1.96	0.39
Mean Low-Flow Concentration (mg/L)	2,841.11	10.79	3.17

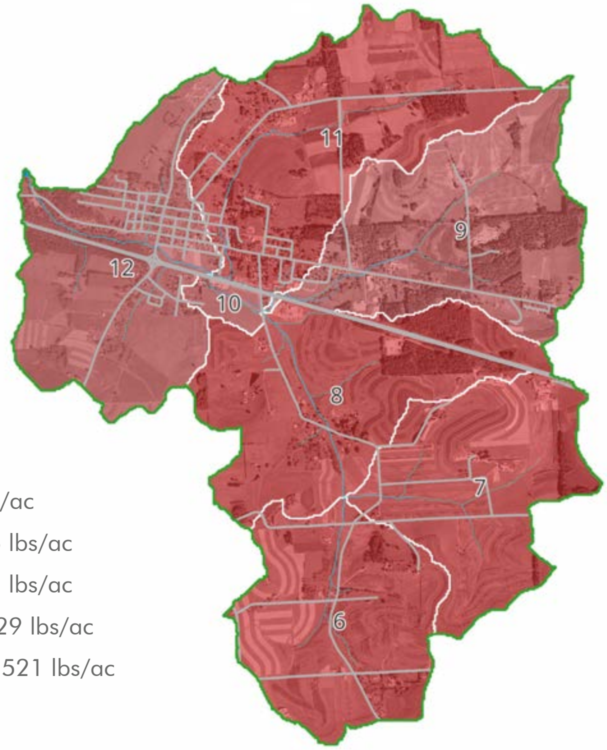
Mean Flow: 130,532,956 (ft^3/year) and 4.14 (ft^3/s)

The Worthington Road subwatershed maps highlight areas of high sediment (Figure 55), phosphorus (Figure 56), and nitrogen (Figure 57) levels, particularly in the southern agricultural regions, evident in microsheds 6 through 8 and 11. These pollutants are likely due to surface runoff and insufficient riparian buffers, which are crucial in filtering and reducing contaminants before they reach waterways. This is reinforced by the riparian buffer maps presented previously, which show significant degradation of these important pollutant management ecologies.

Darker shades of purple and blue on Figure 56 and 57 indicate the most intense concentrations of phosphorus and nitrogen, exceeding 1.21 lbs/ac and 6.4 lbs/ac, respectively. These suggest nutrient overloads from fertilizers, organic waste, and possibly septic systems, which can lead to eutrophication and harmful algal blooms.

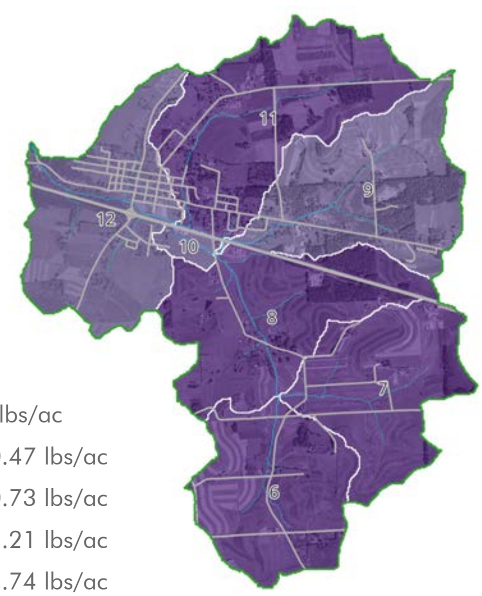
Mitigation strategies such as enhancing riparian buffers and implementing agricultural best management practices are essential. Combined with continued stream monitoring, these efforts aim to improve water quality and ensure the ecological health of the subwatershed.

FIGURE 55:
TOTAL SEDIMENT, POLLUTANT CONCENTRATION



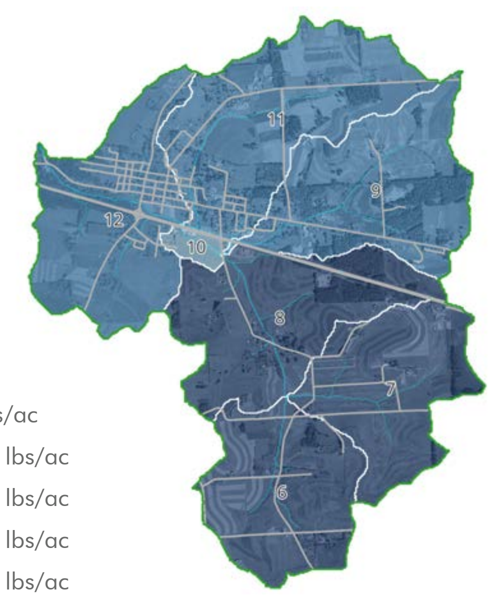
< 161 lbs/ac
161 - 366 lbs/ac
366 - 644 lbs/ac
644 - 1,029 lbs/ac
1,029 - 1,521 lbs/ac

FIGURE 56:
TOTAL PHOSPHORUS, POLLUTANT CONCENTRATION



< 0.22 lbs/ac
0.22 - 0.47 lbs/ac
0.47 - 0.73 lbs/ac
0.73 - 1.21 lbs/ac
1.21 - 1.74 lbs/ac

FIGURE 57:
TOTAL NITROGEN POLLUTANT CONCENTRATION



< 2.1 lbs/ac
2.1 - 3.3 lbs/ac
3.3 - 4.3 lbs/ac
4.3 - 6.4 lbs/ac
6.4 - 9.0 lbs/ac

Summary of Riparian Buffer Opportunities

Per the NHD High Resolution Stream Network dataset, there is a total of 7.15 miles (37,752 feet) of first order and second order streams located within the Worthington subwatershed. Our more detailed terrain analysis - which tends to reveal perennial, ephemeral, and tile-drained, buried streams that still have drainage path signatures - yielded higher results, indicating that 8.77 miles (46,331 feet) of stream exist. This equates to approximately 213 acres of existing and potential future riparian buffer area, assuming one hundred (100) feet of buffer width on each stream bank. Based on the more detailed data set, the following was derived by geospatial analysis:

Table 11: Riparian Buffer Opportunities

Land Cover	Riparian Buffer Coverage (Acres) and Degradation Level			
	0-20%, Critical	20-40%, Severe	40-60%, Moderate	> 60%, Minor
Deciduous Forest	3.26	1.78	2.96	0.94
Cultivated Crops	111.70	3.45	0.10	0.12
Developed, Open Space	24.48	2.32	4.11	0.45
Evergreen Forest	0.69	-	-	-
Woody Wetlands	0.07	-	-	-
Barren Land (Rock / Sand)	0.15	-	-	-
Grassland / Herbaceous	0.99	0.20	0.05	0.05
Pasture / Hay	6.37	0.93	-	-
Open Water	0.89	-	-	-
Developed, Low Intensity	26.90	2.53	2.66	0.94
Developed, Medium Intensity	16.48	0.14	0.62	-
Developed, High Intensity	3.27	0.22	-	-
Mixed Forest	1.28	0.92	1.23	-
Total:	196.53	12.49	11.73	2.50
High Priority (Red) *:	158.35	6.34	-	-
Medium Priority (Yellow) **:	31.99	3.45	-	-

***The light red shaded cells in Table 11, indicating cultivated crops and developed areas, are key areas for watershed improvement due to their high pollutant loads, with roads and areas near unbuffered, partially incised streams being prime candidates for restoration and stabilization.*

*** Yellow shaded cells in the analysis represent areas where pollution significance is uncertain without further field data. Open spaces, grasslands, and pastures might be high pollutant sources if used for livestock grazing without adequate buffers and fencing, or conversely, could be effectively managed as grass riparian buffers, acting as existing Best Management Practices. Direct engagement with landowners is recommended for accurate assessment.*

The finding indicates that there are nearly 200 acres potentially available for restoration of critically to severely degraded riparian buffers throughout the watershed.

Special Consideration for Riparian Buffers

For reasons described in greater detail in the Green Acres Road section of this report, prioritization of future riparian buffer restoration efforts is paramount to meeting water quality standards. Figure 58 depicts areas of high flow concentration within the Worthington subwatershed. Where these pollutant-laden high flows drain to areas of depleted riparian buffer (show in red), there is greater opportunity for stream water quality improvement.

Figure 59 overlays the riparian buffers within the Worthington subwatershed with existing contour farming practices. In this case, the restoration strategy should be to prioritize buffer restorations in areas not already protected by existing BMPs. The farms to the south, for example, employ extensive contour farming, whereas there are less protected agricultural areas to the north and west where future engagement may be more beneficial.

Figure 58: Flow Accumulation Along Riparian Buffers

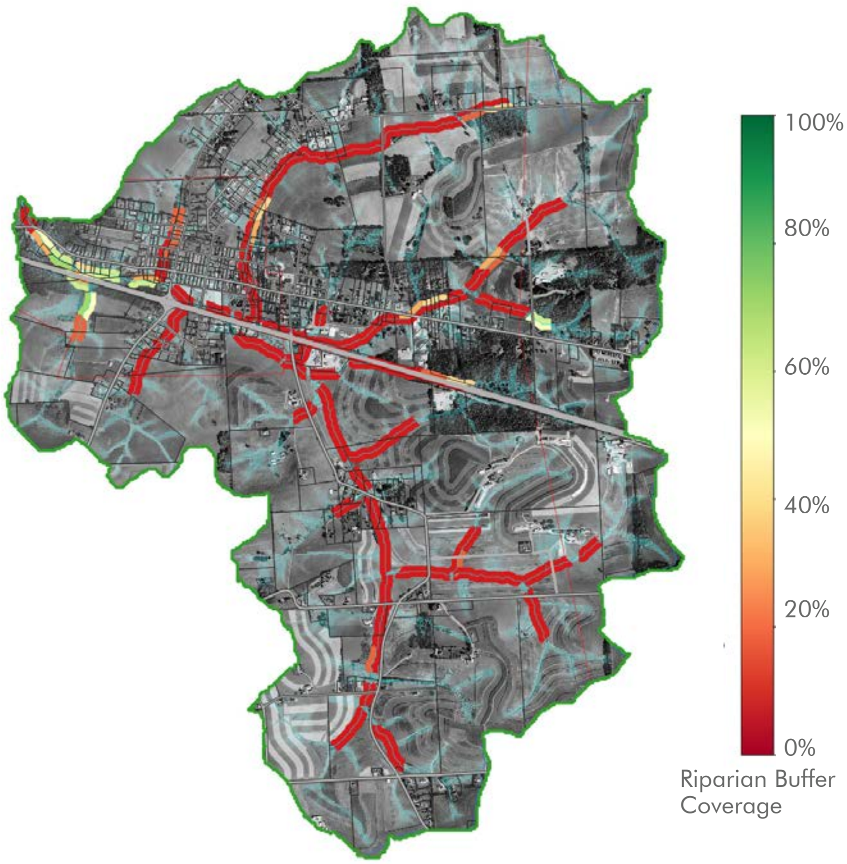
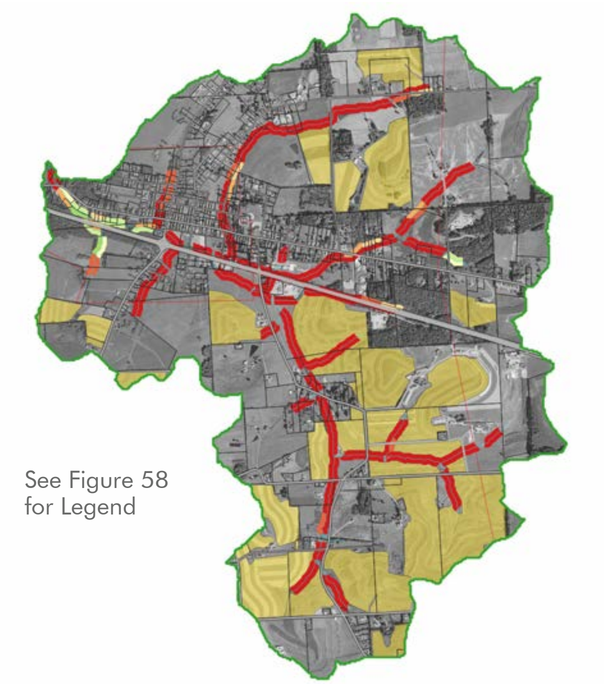


Figure 59: Prioritizing Riparian Buffers Based on Upstream Best Management Practices



See Figure 58 for Legend

Additional riparian buffer opportunities exist within the Borough of Worthington. Priority should be given to areas where paved or gravel areas drain directly to the stream, with limited vegetation to filter. The image below is a good example of a suitable restoration project area.

Streambank Restoration and Exclusionary Fencing Opportunities

Based on field assessments of the Worthington subwatershed, there are significant opportunities for streambank restoration projects, with lesser opportunity for installation of new streambank exclusionary fencing for livestock grazing. Based on the watershed analysis, there is over 92,600 linear feet of streambank within the watershed, including ephemeral headwater streams and considering both side of the stream as separate lengths. It is estimated that 30% of the existing streambanks are visibly eroded or incised and up to 5% are subject to livestock grazing without exclusionary fencing or appropriate livestock crossing areas. This equates to a potential opportunity for 27,800 linear feet of streambank restoration ranging from minor to moderate in severity, and approximately 4,600 linear feet of streambank fencing.

As the photos here indicate, while vegetated in the growing months, the streambank geometries exhibit distinct patterns of cyclical incision and erosion - at times even undercutting the root systems of otherwise lush vegetation at the surface.

Urban Land Management Opportunities

Figure 60 illustrates the density and distribution of impervious surface cover within the Borough of Worthington and in immediately adjacent areas.

The urban landscape within and around the Borough of Worthington presents both challenges and opportunities for improving water quality in the Worthington subwatershed. The high levels of impervious surfaces, as shown in Figure 59, are indicative of urban development that can significantly alter hydrologic processes, leading to increased runoff, reduced infiltration, and heightened potential for pollutant transport into the stream system.

Figure 60: Impervious Surface Coverage, Worthington Borough

The proximity of these impervious areas to the main stem and the dendritic pattern of stream branches signifies potential hotspots for runoff and pollution, especially after rainfall events. This runoff can carry a range of urban pollutants, including sediments, nutrients, heavy metals, and hydrocarbons, directly into the waterways, thereby impacting the aquatic life and water quality downstream. As such, the WIP incorporates strategies that address urban runoff and its management. Green infrastructure practices like rain gardens, bioswales, infiltration beds, and filtration systems can be effective in these urban settings. These measures would help to intercept, treat, and infiltrate runoff close to its source, thereby reducing the volume and improving the quality of water reaching the streams.

Additionally, the WIP considers the restoration of stream buffers and the reconnection of floodplains where feasible to enhance natural filtration and provide additional pollutant removal. Retrofitting existing stormwater management systems with these nature-based solutions could significantly mitigate the impacts of urbanization.

The urban landscape within the Worthington subwatershed, necessitates a nuanced approach. Impervious and gravel surfaces in these areas lead to an accelerated volume of stormwater runoff, which carries pollutants and increases the risk of flash flooding. Additionally, areas with excessive pavement may contribute to localized urban heat island effects, which can further stress local aquatic systems.

Gravel roads and erosion - for instance along unconsolidated roadside cut slopes - pose significant threats to water quality, as these conditions can result in sediment accumulation in streams. The WIP aims to address these challenges by promoting the adoption of erosion and sedimentation measures and green infrastructure techniques that allow water to percolate through the surface and utilize soil and plant life to filter stormwater.

There are also opportunities to re-imagine the developed public areas around civic centers, school, and public building, by transitioning from traditional turf grass to native plant species that require less water and maintenance, while providing greater ecological benefits. Implementing these changes can lead to improved stormwater management, enhanced groundwater recharge, and the creation of urban habitats that support a wider range of biodiversity.

Municipal policies that encourage or mandate the use of low-impact practices and green infrastructure in new developments and redevelopments can also play a crucial role.

Implementation Plan, Worthington Subwatershed

Summary of Watershed Implementation Needs and Pollutant Loading Targets

While a portion of the Worthington subwatershed is listed as impaired due to issues associated with on-site treatment systems (e.g., septic systems), this source is not a primary focus of the proposed BMP implementation strategy. During consultation with PaDEP, it was indicated that the impairment designation may not fully reflect current conditions, and that land use—particularly agricultural runoff and streambank erosion—presents a more actionable and verified source of impairment in this area. Accordingly, the implementation plan prioritizes land cover-based BMPs, which are supported by the Watershed analysis and other datasets reviewed for this WIP. Addressing on-site treatment systems should be seen as a local municipal responsibility and maybe be managed through coordination with the appropriate regulatory agencies and system operators. Therefore, Based on the guidance documents for selecting reference watersheds for TMDL assessment and ongoing dialogue with PaDEP, a 3.95 square mile, headwaters portion of Cornplanter Run - also within the Buffalo Creek watershed - was chosen for this project as the reference watershed and pollutant loading target for the Worthington subwatershed.

Note that loading rate is used to calculate pollutant targets, rather than total loads. Please refer to Appendix C for the more detailed reference watershed assessment. The following summarizes key features of Worthington subwatershed and the selected reference watershed:

Watershed Area

2,516 acres

Sediment

Loading Rate, Worthington Subwatershed: 0.567 tons/acre
Loading Rate, Reference Watershed: 0.308 tons/acre

Pollutant Reduction Target based on Loading Rate, Sediment: 652 tons per year
Pollutant Load Reduction Target, Sediment: 774 tons per year
Pollutant Load Reduction Target, Sediment: 697 lbs per year

Total Phosphorus

Loading Rate, Worthington Subwatershed: 1.27 lb/acre
Loading Rate, Reference Watershed: 0.72 lb/acre

Pollutant Loading Target based on Loading Rate, Phosphorus: 1,384 lbs per year
Pollutant Load Reduction Target, Phosphorus: 1,812 lbs per year
Pollutant Load Reduction Target, Phosphorus: 1,631 lbs per year

Total Nitrogen

Loading Rate, Worthington Subwatershed: 6.32 lb/acre
Loading Rate, Reference Watershed: 3.44 lb/acre

Pollutant Loading Target based on Loading Rate,Nitrogen: 7,246 lbs per year
Pollutant Load Reduction Target, Nitrogen: 8,655 lbs per year
Pollutant Load Reduction Target, Nitrogen: 7,790 lbs per year

Implementation Plans and Projects

Based on the suite of opportunities described previously and the target pollutant loads established, the following list of BMPs and potential projects were identified for the Worthington subwatershed:

Table 12: Proposed Best Management Practices, Worthington Subwatershed

BMPS	Units	Available	% Proposed	Amount Proposed	Proposed Reduction		
					S (tons)	P (lbs)	N (lbs)
Riparian Buffer & Stream Restoration							
Forested Buffer	acres	223	30%	67	105	196.3	1,091.9
Grass Buffer	acres	223	30%	67	103	192.2	834.3
Streambank Stabilization (each bank)	feet	27,800	2%	639	37	111.3	122.8
Streambank Exclusionary Fencing	acres	7	10%	0.7	1	1.4	6.2
Land Conversion							
Cropland Retirement	acres	1,409	2%	28	22	46.2	146.6
Agricultural Land Management							
Water and Soil Conservation Planning	acres	1,632	30%	490	97	125.4	229.2
Cover Crops	acres	1,409	40%	564	45	38.5	725.3
Contour Farming / Strip Cropping	acres	822	20%	164	33	42.1	76.9
Conservation Tillage	acres	1,409	30%	423	264	396.9	346.2
Nutrient Management	acres	1,632	25%	408	-	35.8	127.8
Grazing Land Management	acres	106	40%	42	7	12.0	12.4
Barnyard Runoff Control	acres	30	40%	12	2	47.0	2,803.8
Developed Areas							
Bioretention (C/D soils, underdrain)	acres	15	10%	1.5	0.2	0.1	0.5
Bioswales	acres	15	5%	0.7	0.1	0.1	0.7
Filter Strip - Runoff Reduction	acres	15	10%	1.5	0.1	0.2	0.4
Urban Stream Restoration	feet	12,205	7%	903	52	157	173
					S Loading (tons)	P Loading (lbs)	N Loading (lbs)
Total Proposed Reduction					767	1,403	6,699
Current Loading					1,426	3,196	15,901
Proposed Loading					659	1,793	9,202
Target Loading Goal					697	1,631	7,790
Percent Above/Below Goal					17%	1%	-7%

Table 13: Best Management Practices, Cost Summary (2025 Base Year)

BMPS	Units	Quantity	Unit Cost, Capital	Total Cost, Capital	Unit Cost, O&M	Total Cost, O&M
Riparian Buffer & Stream Restoration						
Forested Buffer	acres	67	$6,409.19	$429,255.24	$104.89	$7,025.12
Grass Buffer	acres	67	$1,418.57	$95,008.60	$46.44	$3,110.07
Streambank Stabilization	feet	639	$809.73	$517,739.36	$82.83	$52,960.81
Streambank Exclusionary Fencing	acres	0.7	$21,345.12	$15,581.93	$715.97	$522.66
Land Conversion						
Cropland Retirement	acres	28	$173.85	$4,898.57	$6.74	$189.88
Agricultural Land Management						
Water and Soil Conservation Planning	acres	490	$24.91	$12,196.67	$-	$-
Cover Crops	acres	564	$75.50	$42,547.23	$75.50	$42,547.23
Contour Farming / Strip Cropping	acres	164	$1.61	$264.64	$1.61	$264.64
Conservation Tillage	acres	423	$18.73	$7,916.32	$18.73	$7,916.32
Nutrient Management	acres	408	$27.96	$11,406.92	$5.29	$2,159.67
Grazing Land Management	acres	42	$81.27	$3,451.47	$81.27	$3,451.47
Barnyard Runoff Control	acres	12	$6,013.28	$72,159.36	$0.77	$9.30
Developed Areas						
Bioretention (C/D soils, underdrain)	acres	1.5	$78,301.33	$116,001.98	$2,285.81	$3,386.39
Bioswales	acres	0.7	$27,484.38	$20,358.80	$1,574.68	$1,166.43
Filter Strip - Runoff Reduction	acres	1.5	$18,080.10	$26,785.33	$338.83	$501.97
Urban Stream Restoration	feet	903	$809.73	$731,304.53	$82.83	$74,806.90
		Total		$2,106,877		$200,019

10-Year Watershed Implementation Plans for the Worthington Subwatershed

Based on the Base Year 2025 values provided below, the proposed 10-year WIP for the Worthington Subwatershed is as follows:

Table 14: Years 1 Through 5 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 1		Year 2		Year 3		Year 4		Year 5	
	2025		2026		2027		2028		2029	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$42,926	$703	$44,544	$1,458	$46,223	$2,269	$47,966	$3,140	$49,774	$4,073
Grass Buffer	$9,501	$311	$9,859	$645	$10,231	$1,005	$10,616	$1,390	$11,017	$1,803
Streambank Stabilization	$51,774	$5,296	$53,726	$10,991	$55,751	$17,109	$57,853	$23,672	$60,034	$30,705
Streambank Exclusionary Fencing	$1,558	$52	$1,617	$108	$1,678	$169	$1,741	$234	$1,807	$303
Land Conversion										
Cropland Retirement	$490	$19	$508	$39	$527	$61	$547	$85	$568	$110
Agricultural Land Management										
Water and Soil Conservation Planning	$1,220	$-	$1,266	$-	$1,313	$-	$1,363	$-	$1,414	$-
Cover Crops	$4,255	$4,255	$4,415	$8,830	$4,582	$13,745	$4,754	$19,017	$4,934	$24,668
Contour Farming / Strip Cropping	$26	$26	$27	$55	$28	$85	$30	$118	$31	$153
Conservation Tillage	$792	$792	$821	$1,643	$852	$2,557	$885	$3,538	$918	$4,590
Nutrient Management	$1,141	$216	$1,184	$448	$1,228	$698	$1,275	$965	$1,323	$1,252
Grazing Land Management	$345	$345	$358	$716	$372	$1,115	$386	$1,543	$400	$2,001
Barnyard Runoff Control	$7,216	$1	$7,488	$2	$7,770	$3	$8,063	$4	$8,367	$5
Developed Land										
Bioretention (C/D soils, underdrain)	$11,600	$339	$12,038	$703	$12,491	$1,094	$12,962	$1,514	$13,451	$1,963
Bioswales	$2,036	$117	$2,113	$242	$2,192	$377	$2,275	$521	$2,361	$676
Filter Strip - Runoff Reduction	$2,679	$50	$2,780	$104	$2,884	$162	$2,993	$224	$3,106	$291
Urban Stream Restoration	$73,130	$7,481	$75,887	$15,525	$78,748	$24,166	$81,717	$33,436	$84,798	$43,371
SUBTOTALS	$210,688	$20,002	$218,631	$41,512	$226,873	$64,615	$235,426	$89,402	$244,302	$115,965
BY YEAR		$230,690		$260,143		$291,488		$324,828		$360,267

Table 15: Years 6 Through 10 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 6		Year 7		Year 8		Year 9		Year 10	
	2030		2031		2032		2033		2034	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$51,651	$5,072	$53,598	$6,140	$55,618	$7,282	$57,715	$8,501	$59,891	$9,802
Grass Buffer	$11,432	$2,245	$11,863	$2,718	$12,310	$3,224	$12,774	$3,763	$13,256	$4,339
Streambank Stabilization	$62,297	$38,235	$64,646	$46,290	$67,083	$54,897	$69,612	$64,087	$72,237	$73,893
Streambank Exclusionary Fencing	$1,875	$377	$1,946	$457	$2,019	$542	$2,095	$632	$2,174	$729
Land Conversion										
Cropland Retirement	$589	$137	$612	$166	$635	$197	$659	$230	$683	$265
Agricultural Land Management										
Water and Soil Conservation Planning	$1,468	$-	$1,523	$-	$1,580	$-	$1,640	$-	$1,702	$-
Cover Crops	$5,120	$30,717	$5,313	$37,188	$5,513	$44,103	$5,721	$51,486	$5,936	$59,363
Contour Farming / Strip Cropping	$32	$191	$33	$231	$34	$274	$36	$320	$37	$369
Conservation Tillage	$953	$5,715	$988	$6,919	$1,026	$8,206	$1,064	$9,579	$1,105	$11,045
Nutrient Management	$1,373	$1,559	$1,424	$1,888	$1,478	$2,239	$1,534	$2,613	$1,592	$3,013
Grazing Land Management	$415	$2,492	$431	$3,017	$447	$3,578	$464	$4,177	$482	$4,816
Barnyard Runoff Control	$8,683	$7	$9,010	$8	$9,350	$10	$9,702	$11	$10,068	$13
Developed Land										
Bioretention (C/D soils, underdrain)	$13,958	$2,445	$14,484	$2,960	$15,030	$3,510	$15,597	$4,098	$16,185	$4,725
Bioswales	$2,450	$842	$2,542	$1,019	$2,638	$1,209	$2,737	$1,411	$2,841	$1,627
Filter Strip - Runoff Reduction	$3,223	$362	$3,344	$439	$3,471	$520	$3,601	$607	$3,737	$700
Urban Stream Restoration	$87,995	$54,007	$91,312	$65,384	$94,755	$77,542	$98,327	$90,523	$102,034	$104,373
SUBTOTALS	$253,512	$144,405	$263,069	$174,824	$272,987	$207,331	$283,279	$242,040	$293,958	$279,073
BY YEAR		$397,917		$437,893		$480,318		$525,319		$573,031
10-Year Implementation Cost, Worthington:										$3,881,892

Table 16: Best Management Practices, Annualized Cost Per Pollutant Reduction

Projects / Opportunities	Net Present Value			Annualized Cost Over 10-Years	Pollutant Reduction		
					Cost / Pound / Year		
	Capital	O&M	Total		S	P	N
Riparian Buffer & Stream Restoration							
Forested Buffer	$429,255	$38,638	$467,893	$46,789	$0.22	$238.40	$42.85
Grass Buffer	$95,009	$17,105	$112,114	$11,211	$0.05	$58.33	$13.44
Streambank Stabilization	$517,739	$291,284	$809,024	$80,902	$1.10	$727.18	$659.00
Streambank Exclusionary Fencing	$15,582	$2,875	$18,457	$1,846	$1.15	$1,288.65	$298.48
Land Conversion							
Cropland Retirement	$4,899	$1,044	$5,943	$594	$0.01	$12.86	$4.05
Agricultural Land Management							
Water and Soil Conservation Planning	$12,197	$-	$12,197	$1,220	$0.01	$9.73	$5.32
Cover Crops	$42,547	$234,010	$276,557	$27,656	$0.31	$718.50	$38.13
Contour Farming / Strip Cropping	$265	$1,455	$1,720	$172	$0.003	$4.09	$2.24
Conservation Tillage	$7,916	$43,540	$51,456	$5,146	$0.01	$12.96	$14.86
Nutrient Management	$11,407	$11,878	$23,285	$2,329	$-	$65.06	$18.22
Grazing Land Management	$3,451	$18,983	$22,435	$2,243	$0.16	$186.59	$180.24
Barnyard Runoff Control	$72,159	$51	$72,210	$7,221	$1.56	$153.50	$2.58
Developed Land							
Bioretention (C/D soils, underdrain)	$116,002	$18,625	$134,627	$13,463	$43.42	$100,970.33	$25,242.58
Bioswales	$20,359	$6,415	$26,774	$2,677	$11.87	$24,096.74	$3,585.82
Filter Strip - Runoff Reduction	$26,785	$2,761	$29,546	$2,955	$12.84	$19,438.26	$6,603.86
Urban Stream Restoration	$731,305	$411,438	$1,142,743	$114,274	$1.10	$727.18	$659.00

Marrowbone Run Subwatershed

Watershed Characteristics

Watershed Analysis

Implementation Plan

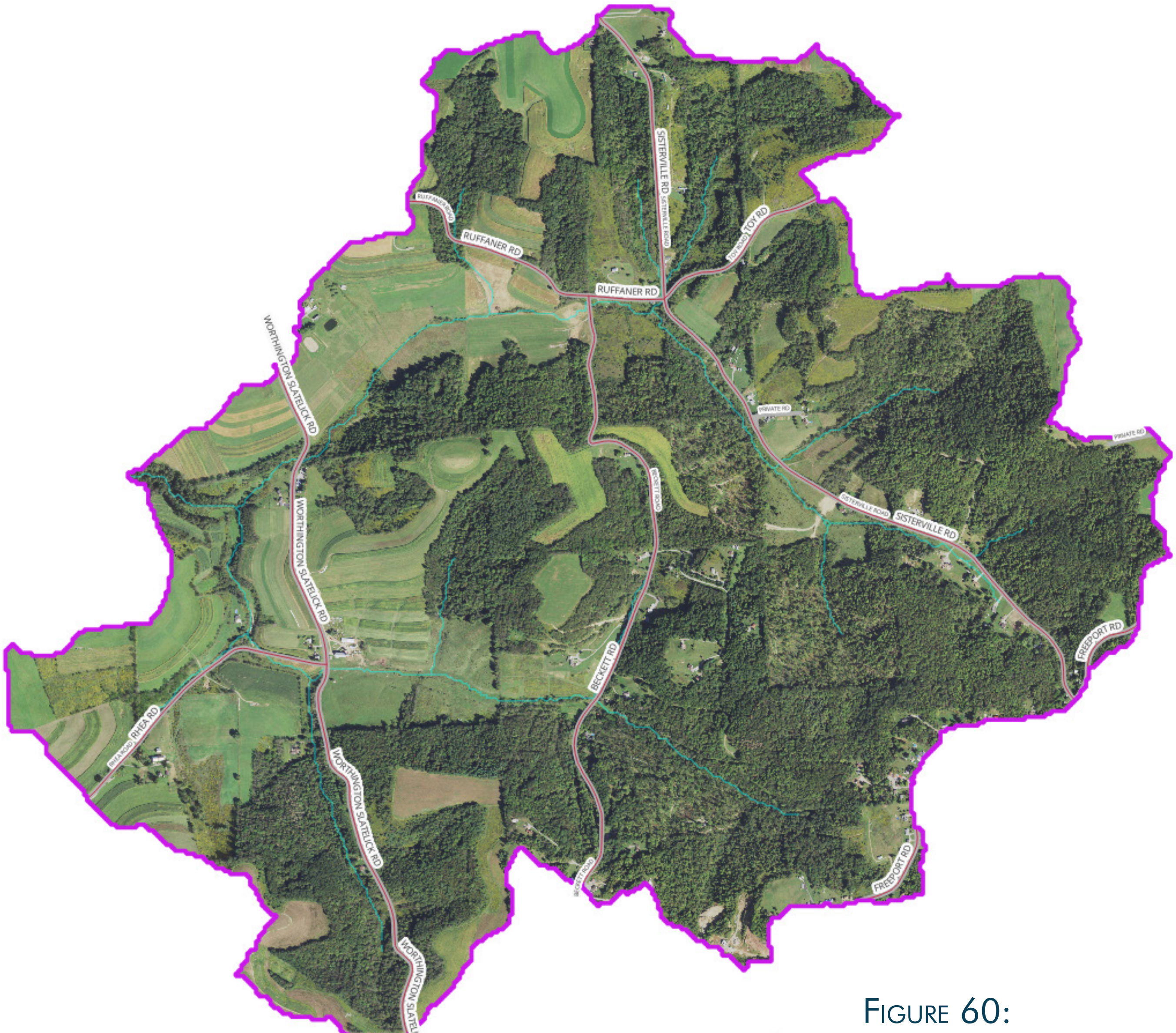


Figure 60:
Aerial Imagery of
Marrowbone Run
Subwatershed

Marrowbone Run Subwatershed

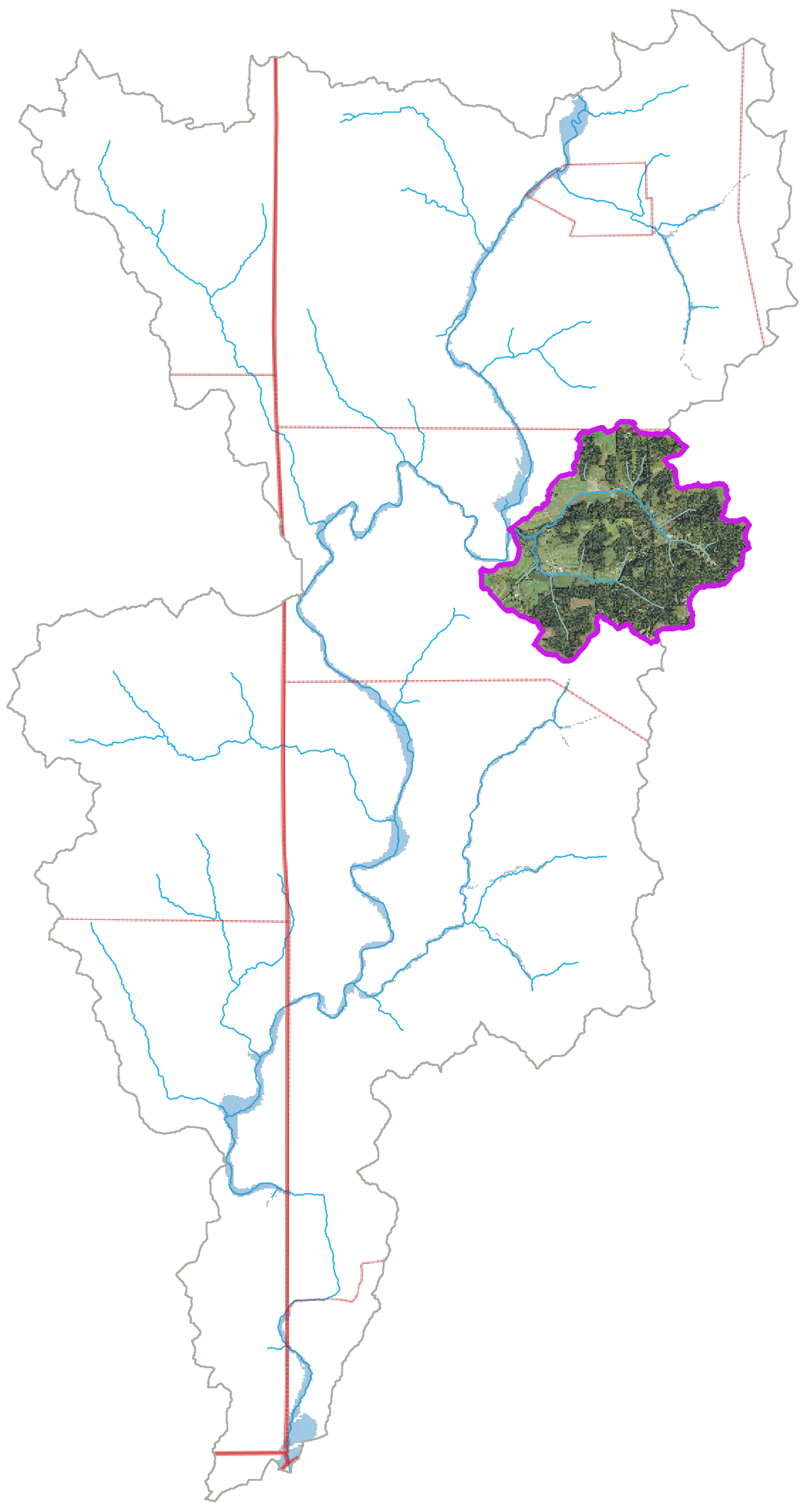
Watershed Characteristics

Location and Basin Characteristics

Marrowbone Run features a diverse array of land uses and natural features. The streams branching within the subwatershed indicate a well-developed drainage system that likely supports a range of aquatic habitats and contributes to the water quality of Buffalo Creek.

Efforts in watershed management would focus on maintaining and enhancing the quality of runoff entering Marrowbone Run. Given its proximity to both rural and potentially developed areas, strategies would need to balance environmental protection with sustainable land use. Riparian buffers, wetland conservation, and effective stormwater management practices would be integral to preserving the subwatershed's ecological integrity.

Figure 61: Marrowbone Run Subwatershed Context Map



Terrain and Slope

The terrain, elevation and slope maps of Marrowbone Run subwatershed (Figures 62 and 63) are vital visual tools that illustrates the complexity of its topography. The areas shaded in green on the slope map (Figure 63) depict moderate slopes ranging from 10-25%, indicating terrain that may support a variety of land uses, including agriculture and development, while still maintaining a degree of water infiltration and soil stability. These areas are generally more suitable for human activity and less prone to severe erosion.

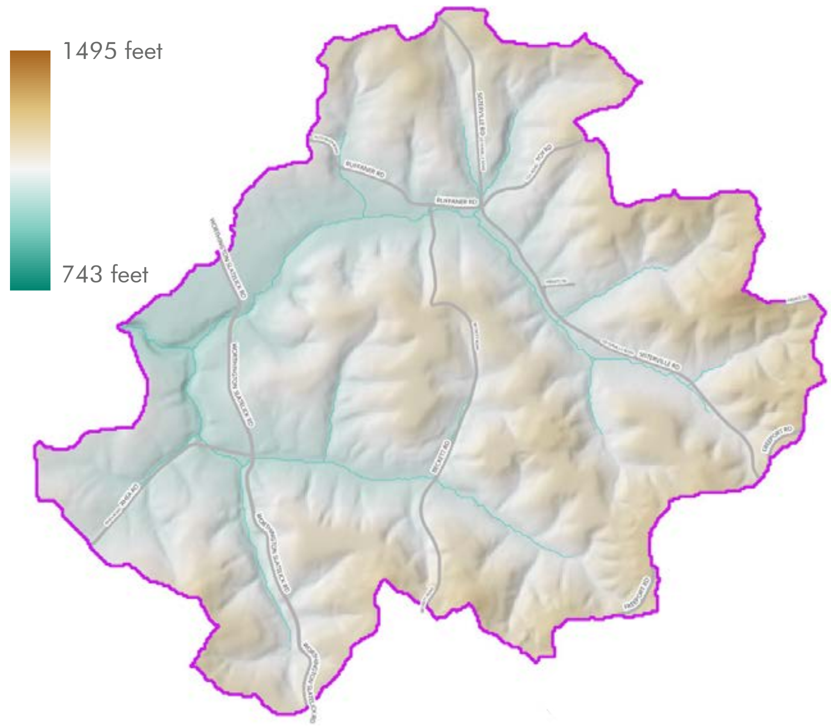


Figure 62: Terrain and Elevation Map

Pale yellow zones on Figure 63 represent steep slopes between 25-50%, which are more susceptible to erosion. They often require specific management practices to prevent soil loss and runoff that could carry pollutants into the water system. Measures might include the planting of ground cover to hold the soil in place and the construction of barriers to slow water flow.

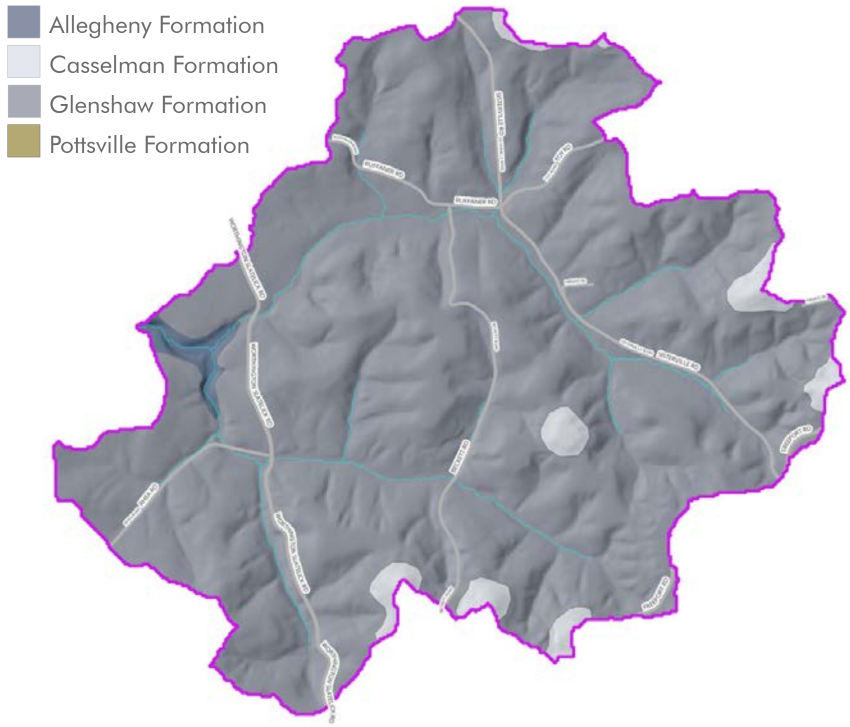
The red areas on Figure 63, highlight very steep slopes greater than 50%, and are the most critical in terms of watershed management. These areas are the most vulnerable to rapid soil erosion and surface runoff, making them less suitable for development or agriculture. Conservation efforts in these zones are paramount, focusing on preserving existing vegetation and introducing erosion control methods such as riprap, terracing, or retention basins.

For the Marrowbone Run subwatershed, the terrain map underscores the necessity of tailored approaches to land management that respect the inherent slope-induced vulnerabilities. By addressing these areas appropriately, the watershed can be managed in a way that supports both ecological integrity and human needs.

Figure 63: Steep Slope Map

Bedrock Geology and Lithology

Figure 64: Bedrock Geology Map



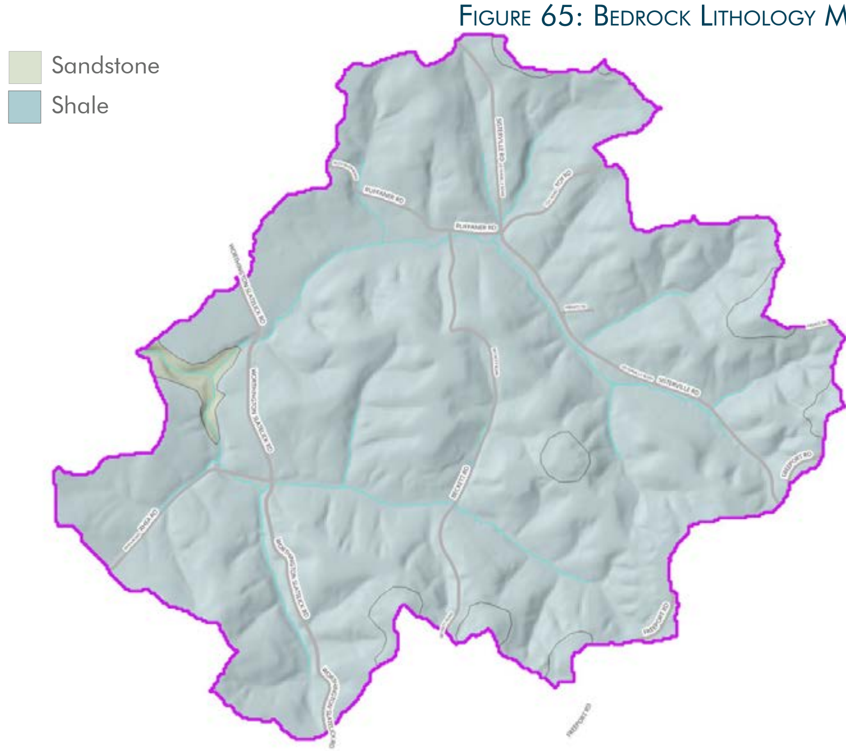
The bedrock geology (Figure 64) of Marrowbone Run is dominantly characterized by the Glenshaw Formation, which primarily consists of shale. Shale is known for its fine-grained texture and is typically associated with lower rates of infiltration, which can lead to increased surface runoff and potential erosion. Its prevalence within the subwatershed suggests that water management strategies need to account for these characteristics to mitigate surface water contamination and soil erosion risks effectively.

The extensive presence of shale, as shown in the Bedrock Lithology Map (Figure 65) also has historical implications, particularly in the context of the area's mining history. Shale layers can act as a barrier to pollutants, but they can also direct the flow of acidic mine drainage or other contaminants along its layers, posing a risk to water quality in streams and rivers.

In managing the Marrowbone Run subwatershed within the framework of a WIP, the dominance of the Glenshaw Formation and shale must be considered. Strategies should include the monitoring of water quality for acidity and metal concentrations, the assessment of erosion risks, and the potential for acid mine drainage impact from historical mining activities.

These geological insights inform a proactive approach to conservation and restoration efforts, guiding the placement of riparian buffers, the design of runoff management systems, and the remediation of impacted soils and waters. Understanding the dominant shale composition aids in anticipating the hydrologic response of the landscape to natural and anthropogenic changes, ensuring the sustainability of the watershed's environmental health.

Figure 65: Bedrock Lithology Map



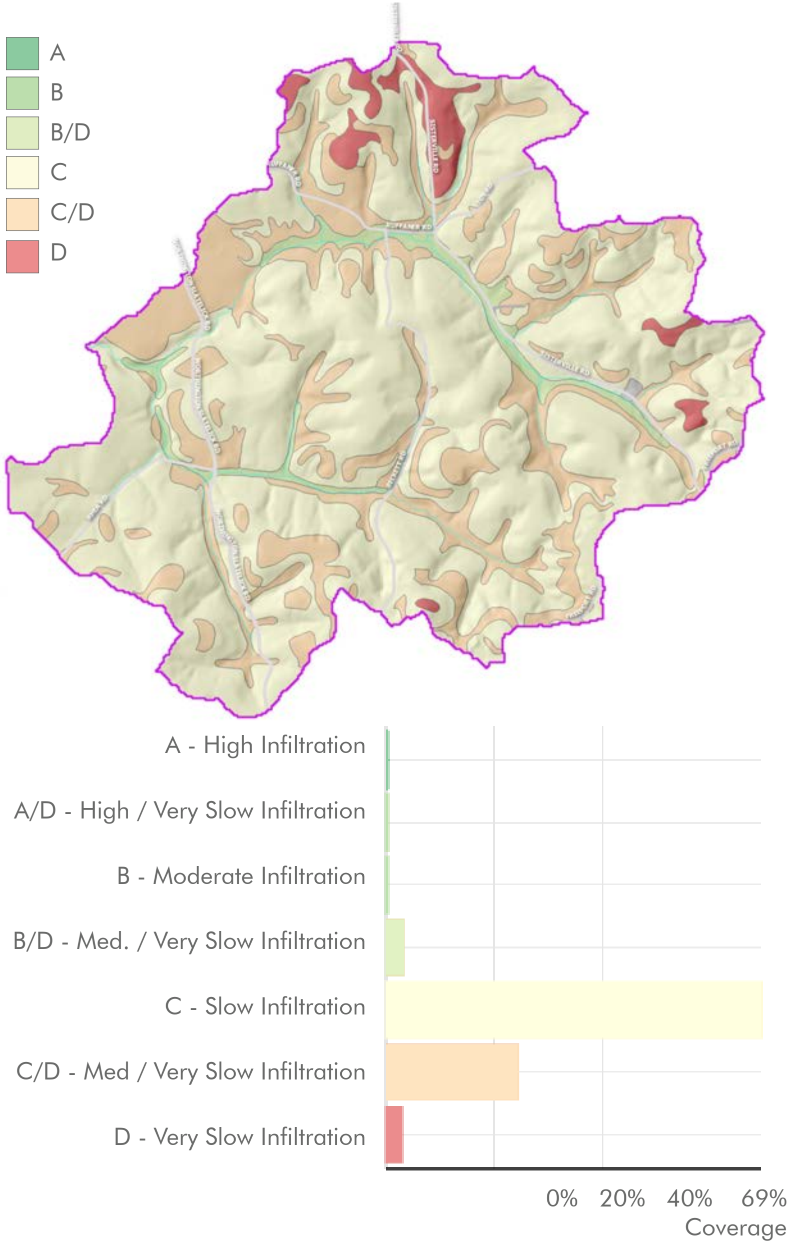
Soils

In the Marrowbone Run subwatershed, the hydrologic soil group C is dominant, characterizing the landscape with soils that have slow infiltration rates when wet. This is indicative of a tighter soil structure that impedes water movement, increasing the potential for runoff during precipitation events.

Adjacent to this predominant group, C/D soils, which exhibit similarly slow infiltration rates, further characterize the subwatershed. These soils require careful consideration, necessitating strategies to enhance infiltration where possible or to manage runoff more effectively. BMPs such as constructed wetlands or bioretention systems can be effective in areas with C and C/D soils, as they provide opportunities for stormwater to infiltrate and be treated by vegetation and soil processes.

Sparse patches of soil group D, especially in steeper terrain, present additional challenges due to their very slow infiltration capacity, which can lead to significant surface runoff and soil erosion. In these areas, erosion control measures like riprap, diversion terraces, or reinforced vegetative areas should be prioritized to stabilize the soil.

Figure 66: Hydrologic Soils Group

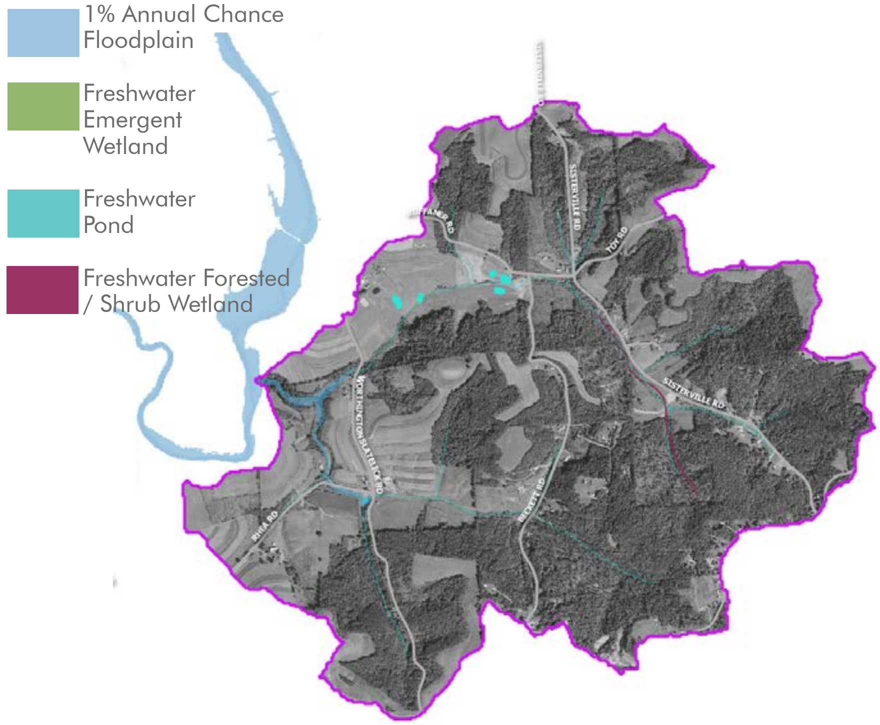


Soil group B/D, which appears along stream paths, represents transitional areas with variable infiltration rates. These areas can benefit from riparian buffers and streambank stabilization efforts to protect water quality and reduce sediment load.

Overall, restoration efforts need to tailor its approach to these hydrologic conditions, emphasizing infiltration enhancement, runoff management, and erosion control in its suite of BMPs to address the specific challenges presented by the dominant soil groups within the Marrowbone Run subwatershed.

Hydrology and Stream Impairments

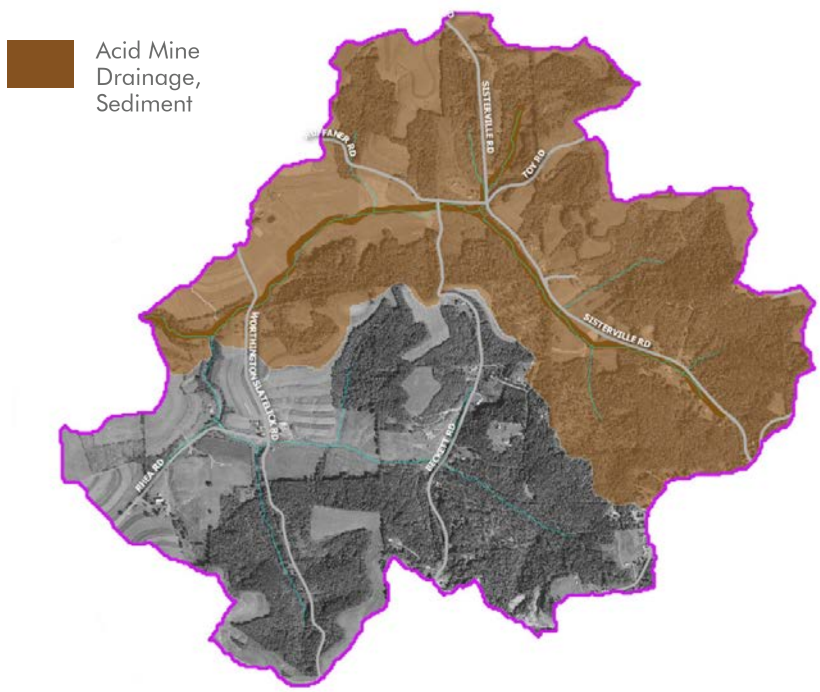
Figure 67: Floodplains and Wetlands



As shown in the Floodplains and Wetlands map (Figure 67) as well as the Non-Attaining Stream Map (Figure 68), Marrowbone Run subwatershed reveal a landscape marked by the interplay of natural resources and historical land use, particularly the impacts of mining activities. The northern branch of Marrowbone Run is designated as Impaired by PA DEP due to acid mine drainage (AMD), a legacy of the region's coal mining past. This impairment is likely exacerbated by a mine seep located upstream and the remnants of strip mining near the stream's confluence with the main water body. The length of stream that is impaired by AMD, Sediment per PaDEP is approximately 3.24 miles, exclusive of smaller headwater tributaries.

The southern branch, though not designated as impaired, exhibits a higher degree of agricultural development. This distinction in land use between the two branches raises important considerations for the restoration and conservation efforts. Future work must address both the immediate concerns of AMD in the north branch and the potential for nonpoint source pollution stemming from agricultural practices in the south.

Figure 68: Non-Attaining Stream and Documented Causes



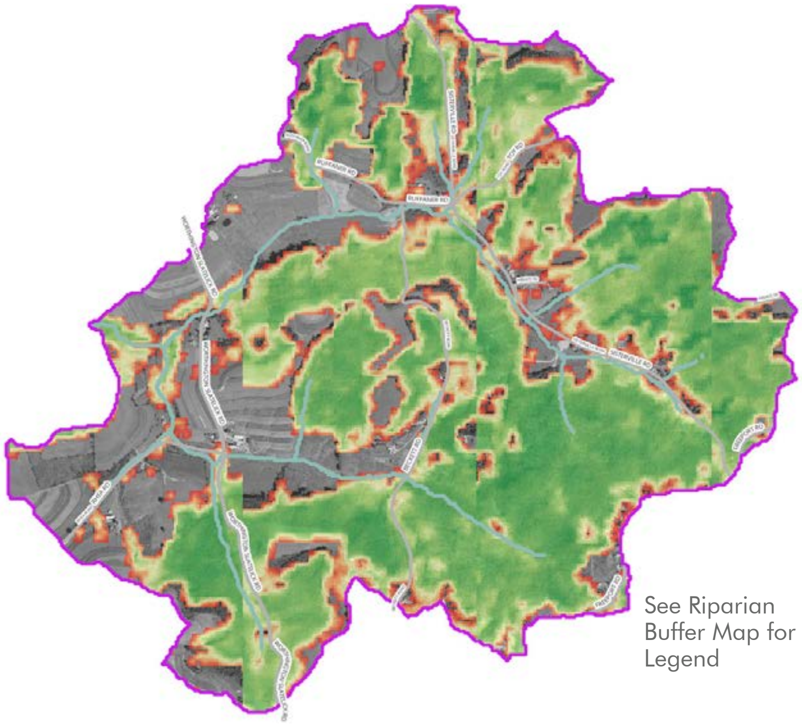
Efforts in the northern branch must address AMD impacts, assuming private land owner cooperation. This could involve the installation of AMD treatment systems that neutralize acidity and remove metallic pollutants, as described in the "Opportunities for Acid Mine Drainage Assessment and Remediation" section on page 96. Additionally, reforestation and the creation of buffer zones along the stream can help filter runoff and restore stream health over time.

In the southern branch, where agriculture is prevalent, BMPs such as controlled livestock access to streams, cover cropping, and nutrient management plans are vital. These practices can reduce runoff and sedimentation, thereby preventing further degradation of water quality.

Tree Canopy and Riparian Buffer

The Marrowbone Run subwatershed displays a significant canopy cover (Figure 69), indicating a predominantly forested landscape. This dense tree canopy is crucial for preventing soil erosion, enhancing groundwater recharge, and supporting a diverse array of wildlife habitats. However, there's a notable fragmentation of this canopy, particularly around developed areas where historical riparian buffers have been cleared to make way for human activities. This deforestation of riparian zones, as shown in Figure 70, is concerning as these areas are critical for the protection and enhancement of water quality, serving as natural filters that trap sediment and pollutants before they enter the waterways.

Figure 69: Tree Canopy Map

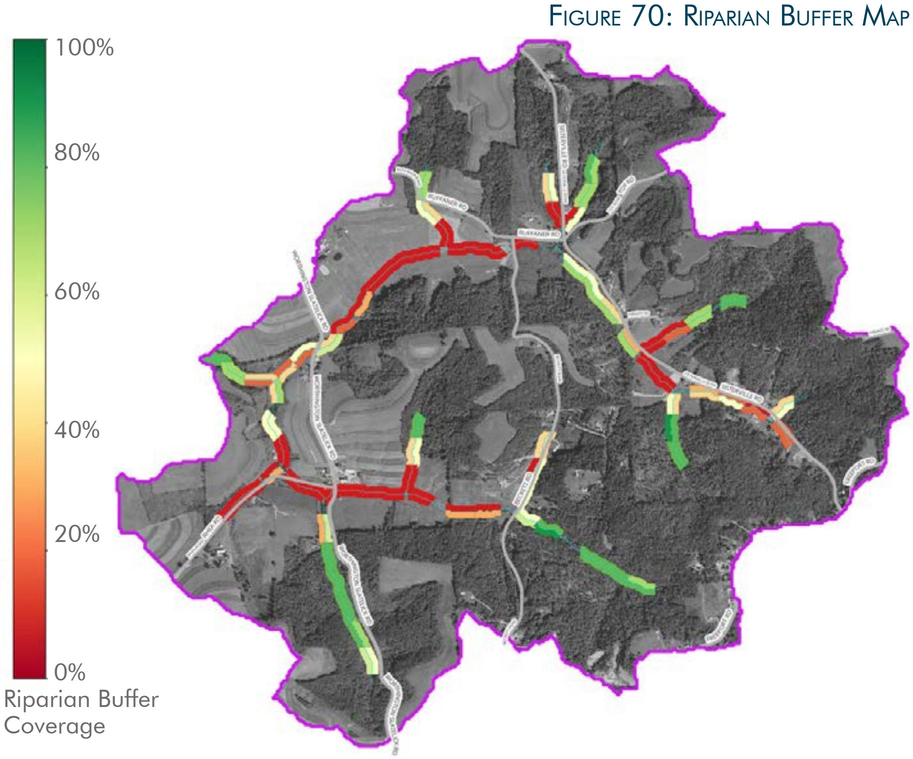


See Riparian Buffer Map for Legend

In the northern branch of the subwatershed, culverting is prevalent. While this may serve immediate human land-use needs, it can have detrimental effects on stream health and biodiversity. Culverts can disrupt the natural flow of streams, impede the movement of aquatic organisms, and alter the sediment transport dynamics. Such changes can lead to increased erosion and affect the quality of fish habitats, potentially resulting in a decline in native fish populations.

To mitigate these human development impacts, the WIP prioritizes the restoration and reestablishment of riparian buffers, in addition to acid mine drainage. Replanting native vegetation along stream banks can reduce the velocity of surface runoff, promote infiltration, and improve the riparian corridor's function as a habitat. Moreover, addressing the culverted sections of the stream with more ecologically sensitive solutions, such as open channels or appropriately designed culverts that facilitate aquatic organism passage, would enhance stream function and resilience.

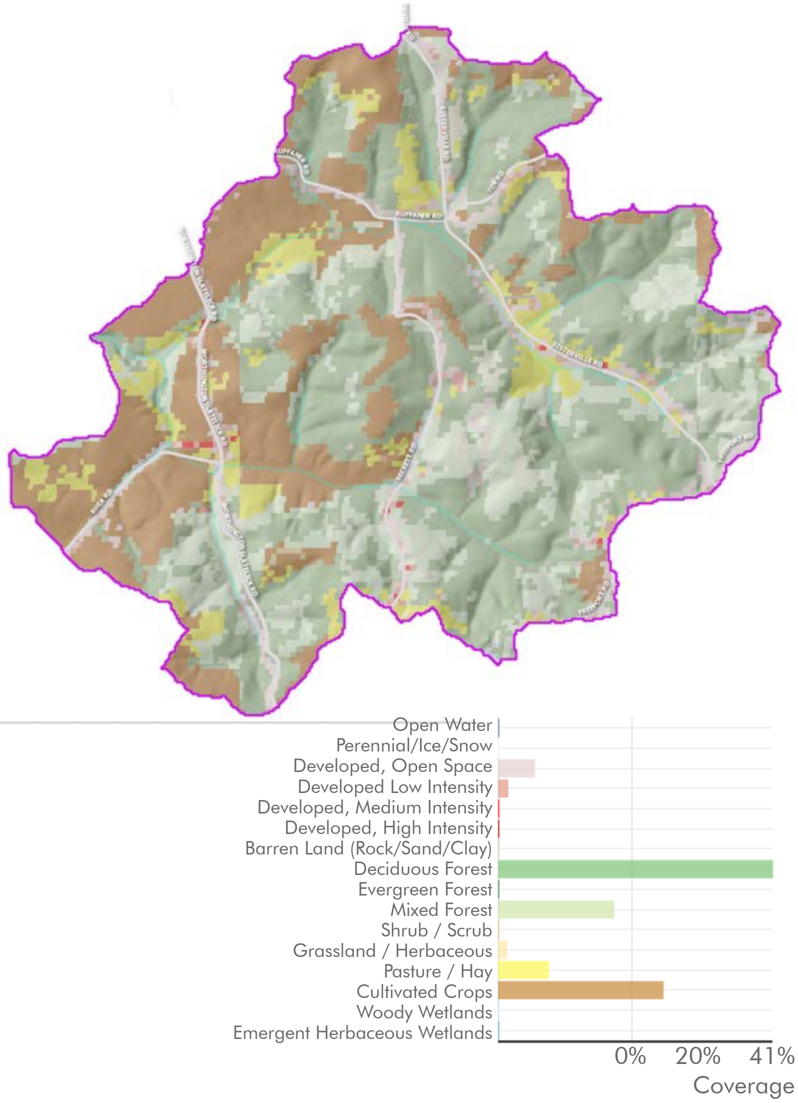
Figure 70: Riparian Buffer Map



Land Cover

The Marrowbone Run subwatershed, as shown in Figure 71, showcases a rural character with significant agricultural activity, predominantly near the mouth of the watershed where the terrain is likely more amenable to cultivation.

Figure 71: NLCD Land Cover (2019)



Higher in the watershed, the land cover transitions to pastures and grazing lands. This type of land use is often adapted to the hilly terrain found in this region, where slopes may be too steep for crop production but can support grazing.

Residential development is sparse, reflecting the challenging nature of the terrain for construction and urban sprawl. This limited development is likely due to the steepness of the area, which naturally restricts large-scale building projects and could potentially act as a protective factor against over-development, preserving the region's ecological integrity and rural heritage.

However, the concentration of agricultural activities, especially near water bodies, raises concerns about nonpoint source pollution, such as runoff carrying nutrients and sediments into streams, which can degrade water quality and aquatic habitats. Effective land management practices, such as the establishment of buffer zones and the implementation of sustainable farming practices, are essential to mitigate these impacts. Conservation effort should incorporate strategies to balance agricultural productivity with environmental conservation, ensuring the sustainability of both the natural ecosystem and the agricultural livelihoods dependent on it.

Community engagement initiatives that encourage the adoption of conservation agriculture practices can prove beneficial. Such practices include cover cropping, reduced tillage, and the maintenance of perennial vegetation strips alongside waterways. Moreover, incentives for farmers to adopt these practices could be explored to foster a cooperative approach to watershed management.

Macroinvertebrate Sampling, Spring 2023

The macroinvertebrate sampling at Marrowbone Run (Oikos-2) conducted in 2022 and 2023 provides a detailed picture of the aquatic ecosystem's health and highlights the trends and changes over the period. The location is shown in Figure 72.

Figure 72: Sampling Locations

The 2022 data set indicated a moderately diverse macroinvertebrate community with a total taxa richness of 23, slightly below the standard value of 33, resulting in a standardized score of approximately 69.70. EPT richness was low at 10 against a standard of 19, showing a limited presence of sensitive taxa. The Shannon diversity index was noted at 1.92, indicating lower ecological complexity compared to the desired standard of 2.86. Furthermore, the Percent Sensitive (PTV 0-3) taxa was at 21.6, a significant drop from the standard of 84.5. The Hilsenhoff biotic index stood at 5.73, pointing towards potential organic pollution issues. The IBI score for the year was critically low at 49.44, marking the subwatershed as impaired.

The following year showed a slight improvement in several metrics. The taxa richness increased marginally to 22, and EPT richness remained steady at 11. The Hilsenhoff biotic index improved to 3.42, suggesting a decrease in organic pollution levels. The Shannon diversity index increased to 2.02, reflecting a slight improvement in the subwatershed's ecological resilience. Notably, the Percent Sensitive taxa score saw a significant rise to 60.54, which is closer to the standard value, indicating a better environment for sensitive taxa. The IBI score increased to 63.26, yet the subwatershed remained in the impaired category.

Comparing the two years, there has been a notable improvement in the Hilsenhoff biotic index and the Shannon diversity index, which are positive signs for the subwatershed's health. However, the consistently low IBI scores across both years underline the impaired status of Marrowbone Run. The 2023 data also suggest signs of year-round acidification with iron precipitate visible on macroinvertebrates, a serious concern that could be contributing to the low IBI scores. As previous studies of Marrowbone Run suggest, this iron precipitate is not prevalent throughout the subwatershed, but is present in particular near to and downstream of the known historic strip mining area referenced on page 96.

Figure 73: Sampling Location Photo

The dominance of taxa like Leuctra and Amphinemura in the 2023 samples, and the decrease in mayfly populations align with the observed signs of acidification. These taxa are known to be more tolerant of such conditions, which may explain their prevalence over more sensitive species like mayflies.

The macroinvertebrate data for Marrowbone Run indicate an aquatic ecosystem that is struggling with issues of acidification and organic pollution, although there have been slight improvements in diversity and habitat conditions. Continuous and targeted monitoring is crucial for identifying sources of impairment and for evaluating the effectiveness of any remediation efforts. Immediate attention towards reducing acidification sources, possibly through improving land use practices and controlling pollution run-off, is essential for the restoration and protection of Marrowbone Run's aquatic life.

Laboratory Water Quality Sampling, Spring 2023

The water quality laboratory results for Marrowbone Run, taken on May 4, 2023, complement the macroinvertebrate sampling data and provide insights into the chemical attributes of the water.

- The pH was measured at 7.22, which is slightly more basic than neutral but still within a range that can support diverse aquatic life.
- Phosphorus levels were recorded at 0.16 mg/L, marginally higher than the detection limit, which could suggest the start of nutrient enrichment but not at alarming levels.
- Total Kjeldahl Nitrogen (TKN) was below the detection limit, suggesting low levels of organic nitrogen pollutants.
- Nitrate+Nitrite Nitrogen was found to be 0.34 mg/L, which is relatively low and indicates that nitrogen from inorganic sources, like fertilizers, is not excessively present in the water.
- Total Nitrogen was also low, which, along with the TKN and nitrate+nitrite measurements, implies controlled nitrogen levels in the stream.
- Total Suspended Solids were considerably high at 122 mg/L, pointing towards significant sedimentation, which could impact habitat quality and aquatic life.

Stream Water Quality Findings

While the macroinvertebrate sampling showed slight improvements in biodiversity and habitat conditions for Marrowbone Run between 2022 and 2023, the water chemistry suggests additional areas of concern. The elevated levels of total suspended solids highlight the need for sediment management, possibly due to land use practices upstream that contribute to runoff.

The lab results indicate that nutrient levels are not yet at levels known to cause eutrophication. However, the presence of iron precipitates on macroinvertebrates and history of acid mine drainage suggest that chemical parameters should be monitored closely, in parallel with biological assessments, to capture the full picture of the subwatershed's health.

Watershed Analysis

In order to thoroughly understand the spatial distribution of land cover impacts to the Marrowbone Run subwatershed, a higher resolution terrain analysis was performed within the larger study area to create three (3) distinct "microsheds". This higher resolution study was performed using a 20,000 pixel flow accumulation threshold, which equates to a maximum size of approximately 0.77 square miles per microshed using a 10-m Digital Terrain Model.

Current Sediment and Nutrient Loading

Tables 17 and 18 provide a summary of existing pollutant load for Sediment, Total Nitrogen and Total Phosphorus for the entire Marrowbone Run subwatershed, aggregated by land cover and summarized overall.

The most significant sources of sediment pollution within the Marrowbone Run subwatershed are cropland, hay/pasture, and stream bank erosion. These observations about pollutant sources are consistent across GIS land cover analyses, aerial imagery and site visits, specifically in the lower reaches where agricultural development is prevalent.

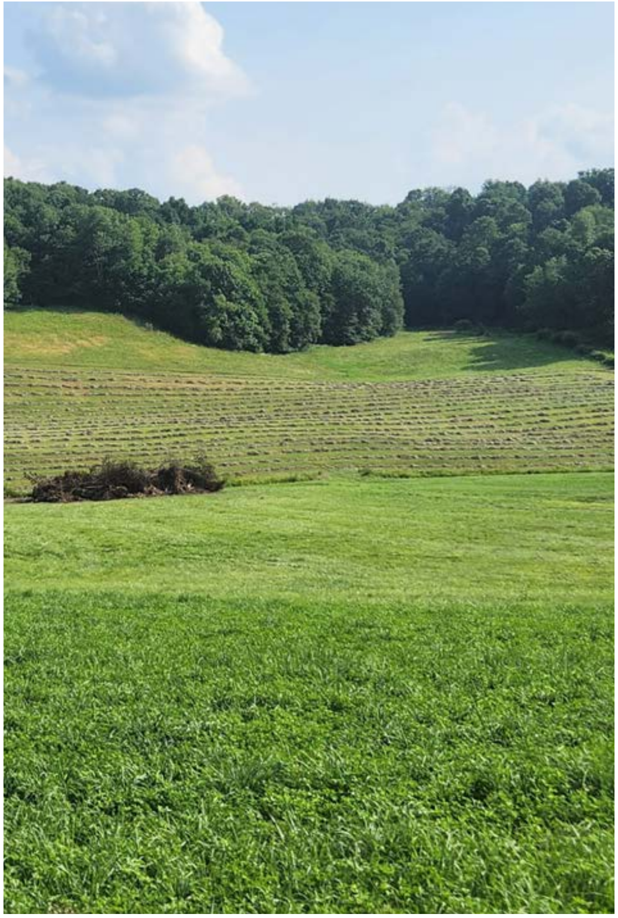


Table 17: Average Annual Pollutant Loads, by Land Cover

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	151,008.4	467.9	160.2
Cropland	699,454.8	2,811.2	770.4
Wooded Areas	7,155.6	93.4	10.6
Wetlands	0.0	0.0	0.0
Open Land	3,294.5	23.1	3.4
Barren Areas	6.2	0.9	0.0
Low-Density Mixed	296.6	7.4	0.8
Medium-Density Mixed	241.3	4.1	0.4
High-Density Mixed	0.0	0.0	0.0
Low-Density Open Space	1,061.5	26.6	2.8
Farm Animals	0.0	346.5	82.9
Stream Bank Erosion	43,179.8	30.9	11.0
Subsurface Flow	0.0	1,916.5	83.3
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	14.2	0.0

Table 18: Average Annual Loads from 30-years of Daily Fluxes

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	905,698.6	5,742.7	1,126.0
Loading Rates (lb/ac)	449.06	2.85	0.56
Mean Annual Concentration (mg/L)	139.70	0.89	0.17
Mean Low-Flow Concentration (mg/L)	1,302.48	5.95	1.67

Mean Flow: 103,853,417 (ft^3/year) and 3.29 (ft^3/s)

The map exhibits on this page reflect the loading rates for Sediment (Figure 74 in reds), Total Phosphorus (Figure 75 in purples), and Total Nitrogen (Figure 76 in blues) for the various microsheds within the Marrowbone Run subwatershed. As the color shades indicate, the loading rates are generally constant across the subwatershed. However, it should be noted that, in the pollutant modeling, the more intensive loading rates associated with the actively-farmed areas are likely moderated by the forested headwater areas.

The emphasis should be placed on strategic intervention points, particularly where developed areas meet the waterways. Initiatives should also, however, focus on reinforcing riparian buffers and expanding filtering measures to reduce the influx of pollutants into the streams. Given the importance of tree canopy in maintaining water quality, preserving existing forested areas is crucial. The WIP should prioritize the protection of these natural buffers to prevent sedimentation and nutrient loading, particularly where development pressure is highest. By coupling preservation efforts with the implementation of advanced stormwater management techniques in developed corridors, the WIP can address the localized sources of pollutants more effectively and maintain the integrity of Marrowbone Run's aquatic ecosystem.

FIGURE 74:
TOTAL SEDIMENT, POLLUTANT CONCENTRATION

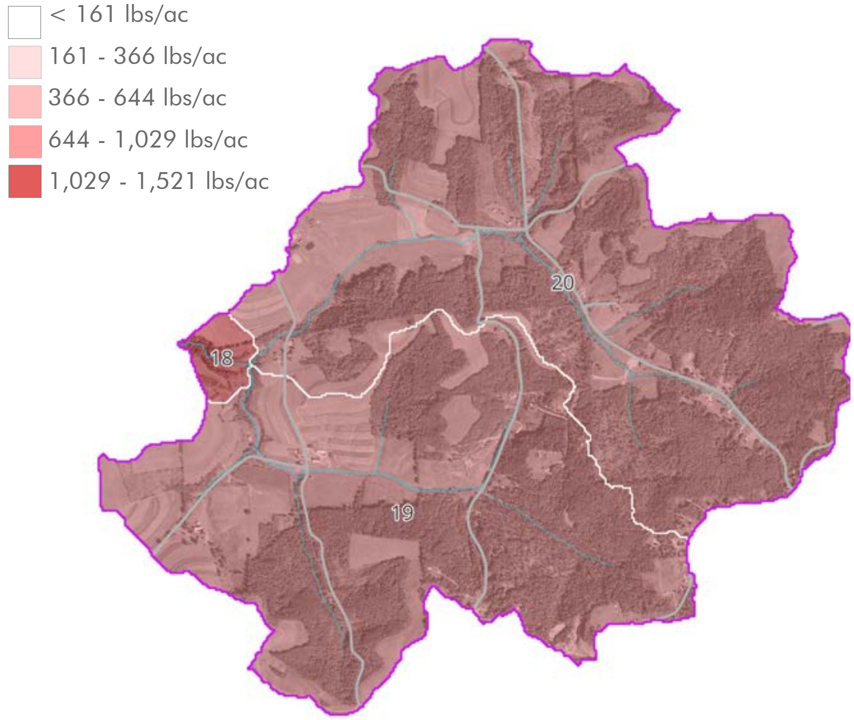


FIGURE 75:
TOTAL PHOSPHORUS, POLLUTANT CONCENTRATION

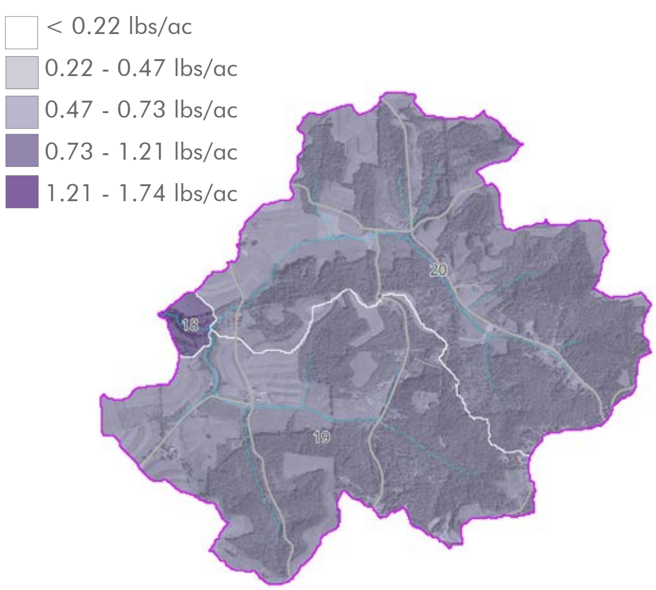
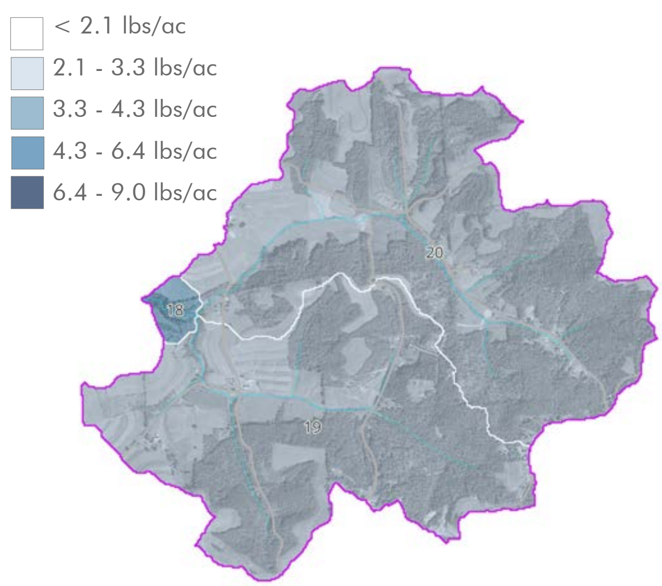


FIGURE 76:
TOTAL NITROGEN POLLUTANT CONCENTRATION



Summary of Riparian Buffer Opportunities

Per the NHD High Resolution Stream Network dataset, there is a total of 5.44 miles (28,723 feet) of first order and second order streams located within the Marrowbone Run watershed. Our more detailed terrain analysis - which tends to reveal perennial, ephemeral, and tile-drained, buried streams that still have drainage path signatures - yielded slightly higher results, indicating that 6.41 miles (33,845 feet) of stream exist. This equates to approximately 155 acres of existing and potential future riparian buffer area, assuming one hundred (100) feet of buffer width on each stream bank. Based on the more detailed data set, the following was derived by geospatial analysis:

Table 19: Riparian Buffer Opportunities

Land Cover	Riparian Buffer Coverage (Acres) and Degradation Level			
	0-20%, Critical	20-40%, Severe	40-60%, Moderate	60-80%, Minor
Deciduous Forest	5.38	7.11	8.69	29.57
Cultivated Crops	25.23	2.67	1.90	0.10
Developed, Open Space	9.69	3.17	4.93	4.04
Grassland / Herbaceous	-	-	-	-
Pasture / Hay	19.34	3.64	2.44	0.07
Open Water	-	-	-	-
Developed, Low Intensity	1.72	1.31	0.92	1.04
Developed, Medium Intensity	0.17	0.17	0.17	-
Mixed Forest	5.15	5.24	4.70	9.63
Total:	66.68	23.31	23.75	44.45
High Priority (Red) *:	27.12	4.15	-	-
Medium Priority (Yellow) **:	29.03	6.81	-	-

** The light red shaded cells in Table 19, indicating cultivated crops and developed areas, are key areas for watershed improvement due to their high pollutant loads, with roads and areas near unbuffered, partially incised streams being prime candidates for restoration and stabilization.*

*** Yellow shaded cells in the analysis represent areas where pollution significance is uncertain without further field data. Open spaces, grasslands, and pastures might be high pollutant sources if used for livestock grazing without adequate buffers and fencing, or conversely, could be effectively managed as grass riparian buffers, acting as existing Best Management Practices. Direct engagement with landowners is recommended for accurate assessment.*

Relative to the other subwatersheds studied, Marrowbone Run is fairly well established with mature tree canopy. This is due largely to the hilly, difficult-to-develop terrain. Where development has occurred, however, it has been generally along riparian corridors where the gradient is lower and historic floodplains created relatively flat areas for building and farming. As such, riparian buffer restoration is a need, specifically in the agricultural areas along Ruffaner Road and along Worthington-Slatelick Road. Additional riparian buffer restoration opportunities exist along Sisterville Road, where the stream traverses active grazing lands. At the upstream reach along Sisterville Road, the stream is culverted over a long stretch through a developed, turf lawn area, and daylighted for a few hundred feet in a landscaped and rock-lined trapezoidal channel. Daylighting and naturalization of the channel is possible here, but would require substantial engagement and coordination with the landowners.

Special Consideration for Riparian Buffers

Figure 77 depicts areas of high flow concentration within the Marrowbone Run subwatershed. Where these pollutant-laden high flows drain to areas of depleted riparian buffer (shown in red), there is greater opportunity for stream water quality improvement. Note the white rectangle and how well the analysis predicts actual drainage patterns in the enlargement image below. These

are indicator of failed tile drains and areas where interventions may potentially be beneficial.

Figure 77: Flow Accumulation Along Riparian Buffers

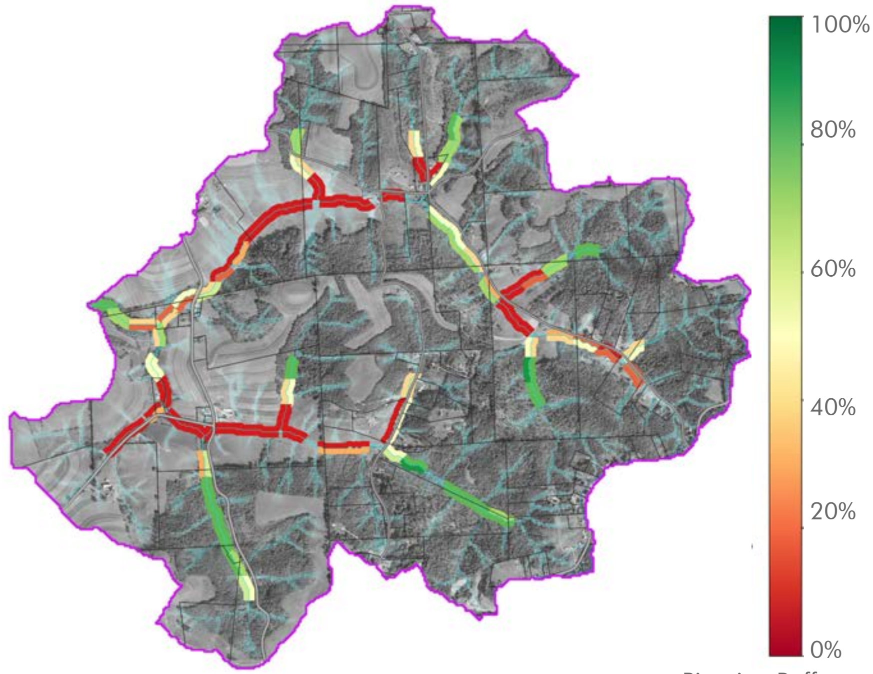
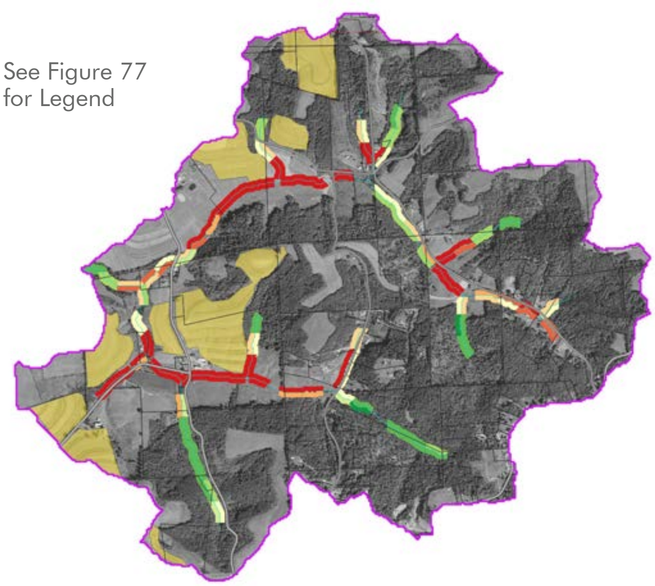


Figure 78 below overlays the riparian buffers with existing contour farming practices. As the map and the adjacent photo indicate, contour farming on several farms within the subwatershed, but several areas of degraded riparian buffers are less protected by BMPs. It is recommended that these less protected areas be prioritized.

Figure 78: Prioritizing Riparian Buffers Based on Upstream Best Management Practices

See Figure 77 for Legend



Streambank Restoration and Exclusionary Fencing Opportunities

Based on NLCD land cover data, there are approximately 23 acres of critically or severely degraded riparian buffer areas within mapped hay / pasture land throughout the Marrowbone Run subwatershed. Based on site observations and an assessment of aerial imagery, much of this area is active grazing land that has a high potential impact on stream health and pollutant load, with little or no provisions for exclusionary fencing.

The aforementioned 23 acres of critically or severely degraded riparian buffer equates to approximately 10,000 linear feet (1.89 miles) of opportunity for new exclusionary fencing within the Marrowbone Run subwatershed, in addition to the 23 acres of potential riparian buffer restoration opportunity.

Given the steeper slopes in the headwaters of the subwatershed, there may be areas of natural streambank erosion that could be addressed with this WIP. The opportunity within actively grazed and human-impacted areas, however, appear to be more critical. The destructive nature of livestock grazing in close proximity to unprotected stream, combined with visual observations of disturbed and eroded banks, warrants swift action.

Daylighting and naturalizing the culverted and manicured stream channels along Sisterville Road represents another restoration opportunity.

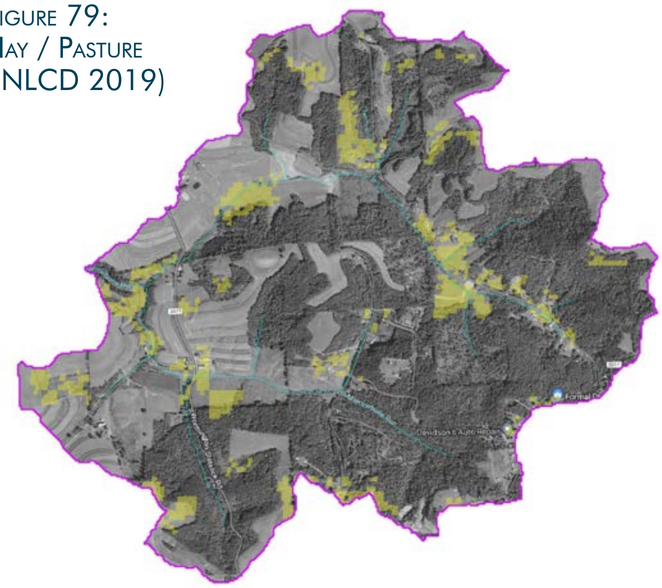


Figure 79: Hay / Pasture (NLCD 2019)

Figure 80: Heavy Use Grazing with Visible Stream Impacts

Opportunities for Acid Mine Drainage Assessment and Remediation

Historical strip mining activities in the Marrowbone Run watershed have left a notable residual mark on the landscape and water quality of the area. These activities served to disrupt the natural terrain and alter the hydrological flow, as well as contributed to the presence of metals associated with acid mine drainage (AMD) detected in the stream.

Figure 81, sourced from the USGS 1958 via the Pennsylvania Mine Map Atlas, provides a detailed topographic view of the terrain before or during the mining activities. The intricate contour lines and shaded areas indicate the excavation and deposition areas associated with strip mining. A much later report (Figure 82) from September 2000, titled "Assessment of Nonpoint Source Pollution for the Buffalo Creek Watershed in Southwest Pennsylvania" and prepared by the Armstrong Conservation District, identified the "Old Stripmine Discharge", suitable for wetland or passive treatment system.

The aerial overlay (Figure 83) locates these features within the subject watershed.

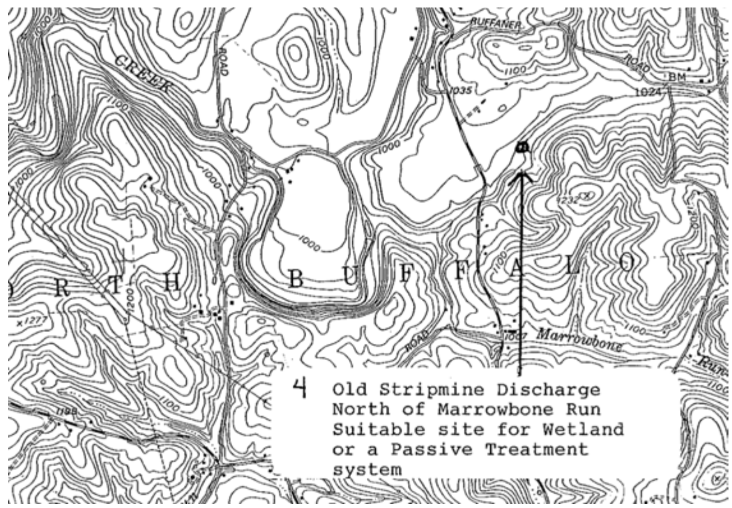
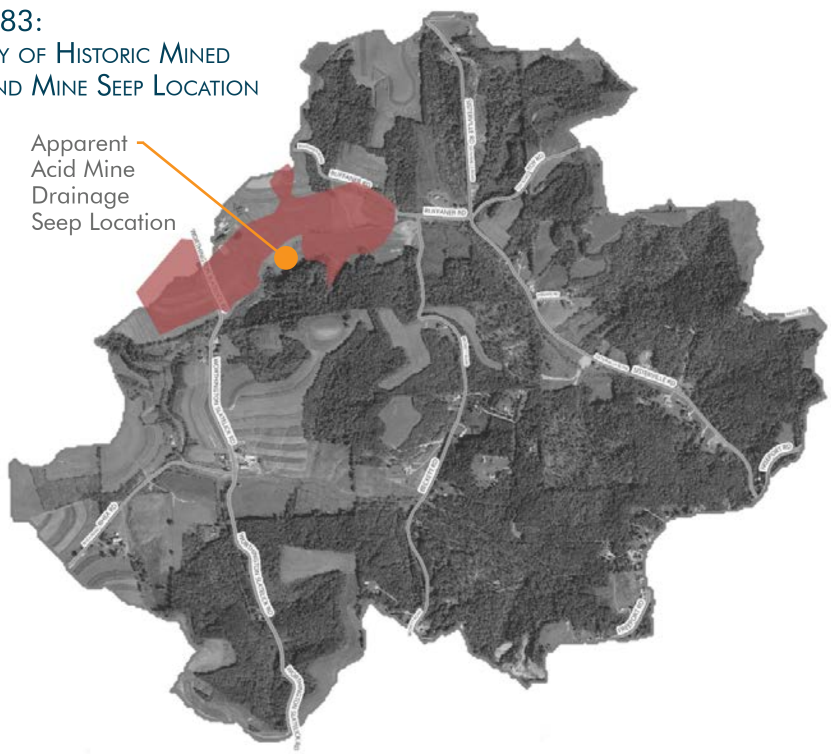


Figure 81 (top) and Figure 82 (bottom): Historic Strip Mine Area within the Marrowbone Run Subwatershed

Figure 83: Overlay of Historic Mined Area and Mine Seep Location



Although no documentation was found of any AMD remediation installation related to this site, an aerial assessment of imagery from 2021 indicates an interesting drainage feature in this same location. Active drainage in this location is clearly visible in aerial imagery (right) from 1993 and likely predates this period. If this is the historic stripmine discharge point referenced in the 2000 report, it is recommended that this be further investigated as part of the future remediation efforts. If it was previously remediated with a passive treatment system, additional water quality testing could be used to assess its effectiveness and any need for system maintenance or restoration. If the seep has not been previously remediated, then activities related to the WIP implementation would provide an opportunity to realize the recommendations of the Armstrong Conservation District report.

Figure 84: Suspected Mine Seep Location from Aerial

The 2008 Buffalo Creek Watershed Conservation Plan 10-Year Update indicated that this drainage is alkaline, containing iron from strip mines. It also indicates that the discharge has "severely impacted Marrowbone Run". This suggests that this discharge point should be monitored and potentially addressed going forward as part of the WIP.

There is no Total Maximum Daily Load (TMDL) specified for Marrowbone Run and the AMD-related impairments are severe, but not at critical levels. However, recent and ongoing detections of metals in the water during a multi-year study by Duquense University signals that the legacy of mining still lingers. Metals typically associated with AMD, such as iron, manganese, and aluminum, can precipitate and accumulate in streambeds, affecting aquatic life and water chemistry.   As such, this WIP includes provisions for future investigation, sampling, and testing for metals, pH, and other AMD-related parameter, in addition to construction of remediation measures.

Implementation Plan, Marrowbone Run Subwatershed

Summary of Watershed Implementation Needs and Pollutant Loading Targets

Based in guidance documents for selecting reference watersheds for TMDL assessment and ongoing dialogue with PaDEP, a 3.23 square mile, headwaters portion of North Branch Rough Run - also within the Buffalo Creek watershed but in an upstream HUC-12 - was chosen for this project as the reference watershed and pollutant loading target for the Marrowbone Run Road subwatershed. Note that loading rate is used to calculate pollutant targets, rather than total loads. Please refer to Appendix B for the more detailed reference watershed assessment. A summary of key details of Marrowbone Run and the selected reference watershed are as follows:

Watershed Area

2,011 acres

Sediment

Loading Rate, Marrowbone Run Subwatershed: 0.225 tons/acre
Loading Rate, Reference Watershed: 0.161 tons/acre

Pollutant Reduction Target based on Loading Rate, Sediment: 129 tons per year
Pollutant Load Reduction Target, Sediment: 323 tons per year (without safety factor)
Pollutant Load Reduction Target, Sediment: 290 tons per year (with 10% safety factor)

Total Phosphorus

Loading Rate, Marrowbone Run Subwatershed: 0.56 lb/acre
Loading Rate, Reference Watershed: 0.39 lb/acre

Pollutant Loading Target based on Loading Rate, Phosphorus: 342 lbs per year
Pollutant Load Reduction Target, Phosphorus: 784 lbs per year (without safety factor)
Pollutant Load Reduction Target, Phosphorus: 706 lbs per year (with 10% safety factor)

Total Nitrogen

Loading Rate, Marrowbone Run Subwatershed: 2.85 lb/acre
Loading Rate, Reference Watershed: 2.35 lb/acre

Pollutant Loading Target based on Loading Rate, Nitrogen: 1,006 lbs per year
Pollutant Load Reduction Target, Nitrogen: 4,726 lbs per year (without safety factor)
Pollutant Load Reduction Target, Nitrogen: 4,253 lbs per year (with 10% safety factor)

Implementation Plans and Projects

Based on the suite of opportunities described previously and the target pollutant loads established, the following list of Best Management Practices and potential projects were identified for the Marrowbone Run subwatershed:

Table 20: Proposed Best Management Practices, Marrowbone Run Subwatershed

BMPS	Units	Available	% Proposed	Amount Proposed	Proposed Reduction		
					S (tons)	P (lbs)	N (lbs)
Riparian Buffer & Stream Restoration							
Forested Buffer	acres	158	10%	16	22	41.9	248.4
Grass Buffer	acres	158	10%	16	21	40.1	186.3
Streambank Stabilization (each bank)	feet	29,600	3%	888	51	154.5	170.5
Streambank Exclusionary Fencing	acres	25.5	10%	2.5	2	4.3	19.6
Land Conversion							
Cropland Retirement	acres	341	2%	7	4	9.7	32.6
Agricultural Land Management							
Water and Soil Conservation Planning	acres	499	20%	100	17	45.0	45
Cover Crops	acres	341	20%	68	5	84.5	84
Contour Farming / Strip Cropping	acres	159	15%	24	4	10.7	11
Conservation Tillage	acres	341	20%	68	38	53.8	54
Nutrient Management	acres	499	20%	100	-	26.3	26
Grazing Land Management	acres	153	10%	15	2	4.2	4
Barnyard Runoff Control	acres	5	10%	1	0	116.8	117
Developed Areas							
Passive Acid Mine Drainage Treatment	acres	0.20	100%	0.20	-	-	-

	S Loading (tons)	P Loading (lbs)	N Loading (lbs)
Total Proposed Reduction	167	355	999
Current Loading	451	1,126	5,732
Proposed Loading	284	771	4,733
Target Loading Goal	290	706	4,253
Percent Above/Below Goal	13%	2%	0%

Table 21: Best Management Practices, Cost Summary (Base Year 2025)

BMPS	Units	Quantity	Unit Cost, Capital	Total Cost, Capital	Unit Cost, O&M	Total Cost, O&M
Riparian Buffer & Stream Restoration						
Forested Buffer	acres	16	$6,409.19	$101,386.91	$104.89	$1,659.28
Grass Buffer	acres	16	$1,418.57	$22,440.33	$46.44	$734.58
Streambank Stabilization	feet	888	$809.73	$719,037.46	$82.83	$73,552.08
Streambank Exclusionary Fencing	acres	2.5	$21,345.12	$54,408.70	$715.97	$1,825.02
Land Conversion						
Cropland Retirement	acres	7	$173.85	$1,184.18	$6.74	$45.90
Agricultural Land Management						
Water and Soil Conservation Planning	acres	100	$24.91	$2,484.85	$-	$-
Cover Crops	acres	68	$75.50	$5,142.69	$75.50	$5,142.69
Contour Farming / Strip Cropping	acres	24	$1.61	$38.30	$1.61	$38.30
Conservation Tillage	acres	68	$18.73	$1,275.80	$18.73	$1,275.80
Nutrient Management	acres	100	$27.96	$2,788.74	$5.29	$527.99
Grazing Land Management	acres	15	$81.27	$1,244.13	$81.27	$1,244.13
Barnyard Runoff Control	acres	1	$6,013.28	$3,006.64	$0.77	$0.39
Developed Areas						
Passive Acid Mine Drainage Treatment	acres	0.20	$59,908.21	$11,981.64	$293.49	$58.70
		Total		$926,420		$86,105

10-Year Watershed Implementation Plans for the Marrowbone Run Subwatershed

Based on the Base Year 2025 values provided below, the proposed 10-year WIP for the Marrowbone Run Subwatershed is as follows:

Table 22: Years 1 Through 5 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 1		Year 2		Year 3		Year 4		Year 5	
	2025		2026		2027		2028		2029	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$10,139	$166	$10,521	$344	$10,918	$536	$11,329	$742	$11,756	$962
Grass Buffer	$2,244	$73	$2,329	$152	$2,416	$237	$2,508	$328	$2,602	$426
Streambank Stabilization	$71,904	$7,355	$74,615	$15,265	$77,427	$23,761	$80,347	$32,875	$83,376	$42,643
Streambank Exclusionary Fencing	$5,441	$183	$5,646	$379	$5,859	$590	$6,080	$816	$6,309	$1,058
Land Conversion										
Cropland Retirement	$118	$5	$123	$10	$128	$15	$132	$21	$137	$27
Agricultural Land Management										
Water and Soil Conservation Planning	$248	$-	$258	$-	$268	$-	$278	$-	$288	$-
Cover Crops	$514	$514	$534	$1,067	$554	$1,661	$575	$2,299	$596	$2,982
Contour Farming / Strip Cropping	$4	$4	$4	$8	$4	$12	$4	$17	$4	$22
Conservation Tillage	$128	$128	$132	$265	$137	$412	$143	$570	$148	$740
Nutrient Management	$279	$53	$289	$110	$300	$171	$312	$236	$323	$306
Grazing Land Management	$124	$124	$129	$258	$134	$402	$139	$556	$144	$721
Barnyard Runoff Control	$301	$0	$312	$0	$324	$0	$336	$0	$349	$0
Developed Land										
Passive Acid Mine Drainage Treatment	$599	$-	$1,243	$-	$10,568	$63	$-	$66	$-	$68
SUBTOTALS	$92,043	$8,605	$96,135	$17,858	$109,037	$27,860	$102,181	$38,525	$106,033	$49,955
TOTAL BY YEAR		$100,648		$113,993		$136,897		$140,706		$155,988

Table 23: Years 6 Through 10 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 6		Year 7		Year 8		Year 9		Year 10	
	2030		2031		2032		2033		2034	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$12,199	$1,198	$12,659	$1,450	$13,137	$1,720	$13,632	$2,008	$14,146	$2,315
Grass Buffer	$2,700	$530	$2,802	$642	$2,908	$761	$3,017	$889	$3,131	$1,025
Streambank Stabilization	$86,519	$53,101	$89,781	$64,287	$93,165	$76,241	$96,678	$89,005	$100,322	$102,622
Streambank Exclusionary Fencing	$6,547	$1,318	$6,794	$1,595	$7,050	$1,892	$7,315	$2,208	$7,591	$2,546
Land Conversion										
Cropland Retirement	$142	$33	$148	$40	$153	$48	$159	$56	$165	$64
Agricultural Land Management										
Water and Soil Conservation Planning	$299	$-	$310	$-	$322	$-	$334	$-	$347	$-
Cover Crops	$619	$3,713	$642	$4,495	$666	$5,331	$691	$6,223	$718	$7,175
Contour Farming / Strip Cropping	$5	$28	$5	$33	$5	$40	$5	$46	$5	$53
Conservation Tillage	$154	$921	$159	$1,115	$165	$1,322	$172	$1,544	$178	$1,780
Nutrient Management	$336	$381	$348	$461	$361	$547	$375	$639	$389	$737
Grazing Land Management	$150	$898	$155	$1,087	$161	$1,290	$167	$1,506	$174	$1,736
Barnyard Runoff Control	$362	$0	$375	$0	$390	$0	$404	$0	$419	$1
Developed Land										
Passive Acid Mine Drainage Treatment	$721	$-	$748	$-	$776	$-	$805	$-	$836	$-
SUBTOTALS	$110,752	$62,121	$114,927	$75,207	$119,260	$89,192	$123,756	$104,123	$128,421	$120,054
TOTAL BY YEAR		$172,873		$190,134		$208,451		$227,879		$248,476
10-Year Implementation Cost, Marrowbone Run:										$1,696,045

Table 24: Best Management Practices, Annualized Cost Per Pollutant Reduction

Projects / Opportunities	Net Present Value			Annualized Cost Over Ten Years	Pollutant Reduction		
	Capital	O&M	Total		Cost / Pound / Year		
					S	P	N
Riparian Buffer & Stream Restoration							
Forested Buffer	$101,387	$9,126	$110,513	$11,051	$0.25	$263.76	$44.48
Grass Buffer	$22,440	$4,040	$26,481	$2,648	$0.06	$66.01	$14.22
Streambank Stabilization	$719,037	$404,536	$1,123,574	$112,357	$1.10	$727.18	$659.00
Streambank Exclusionary Fencing	$54,409	$10,038	$64,446	$6,445	$1.38	$1,505.56	$328.11
Land Conversion							
Cropland Retirement	$1,184	$252	$1,437	$144	$0.02	$14.82	$4.41
Agricultural Land Management							
Water and Soil Conservation Planning	$2,485	$-	$2,485	$248	$0.01	$10.75	$5.52
Cover Crops	$5,143	$28,285	$33,427	$3,343	$0.35	$794.04	$39.57
Contour Farming / Strip Cropping	$38	$211	$249	$25	$0.003	$4.52	$2.32
Conservation Tillage	$1,276	$7,017	$8,293	$829	$0.01	$14.33	$15.43
Nutrient Management	$2,789	$2,904	$5,693	$569	$-	$71.94	$21.65
Grazing Land Management	$1,244	$6,843	$8,087	$809	$0.18	$210.20	$192.04
Barnyard Runoff Control	$3,007	$2	$3,009	$301	$1.56	$153.50	$2.58
Developed Land							
Passive Acid Mine Drainage Treatment	$14,607	$176	$14,783	$1,478	$-	$-	$-

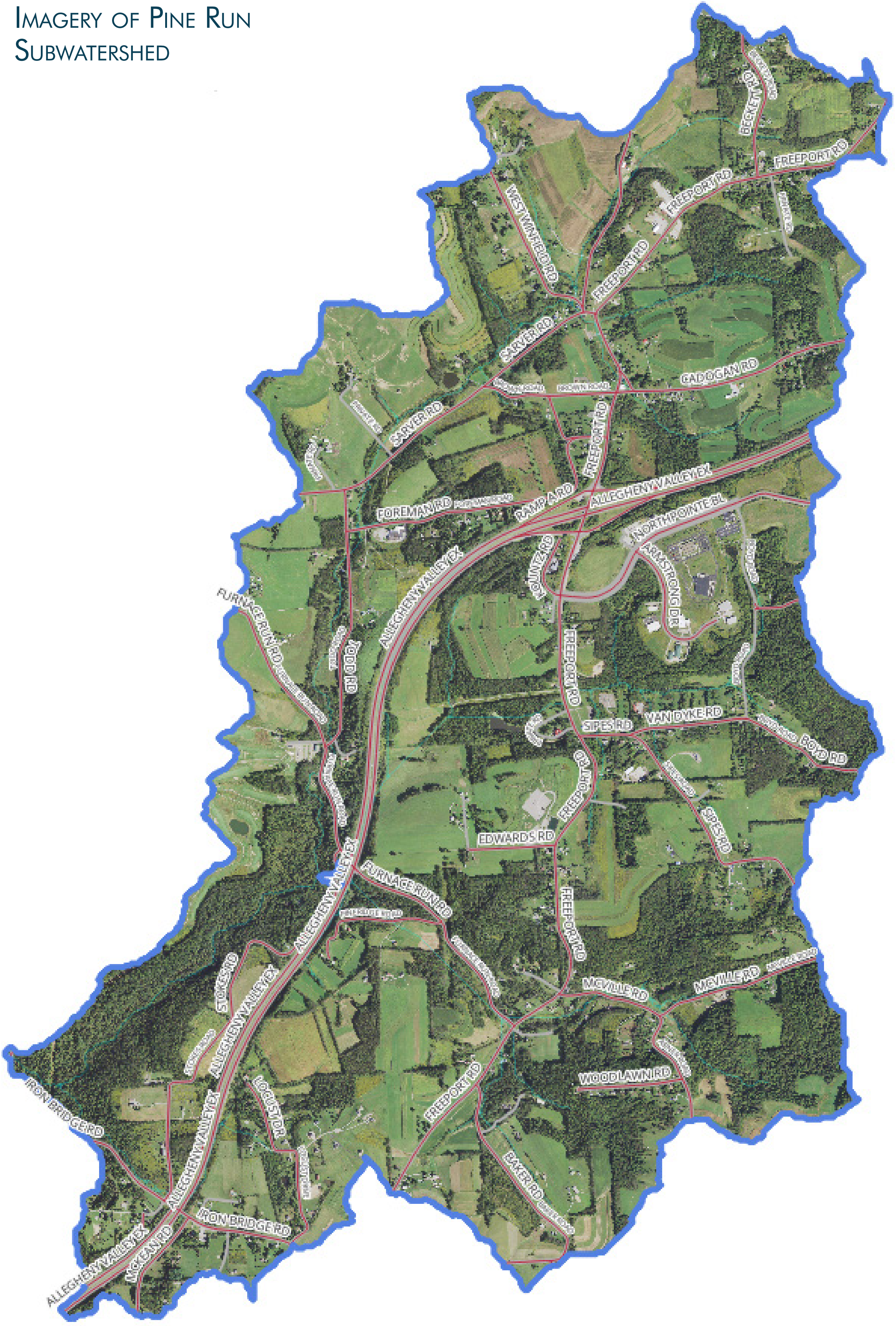
Pine Run Subwatershed

Watershed Characteristics

Watershed Analysis

Implementation Plan

Figure 85: Aerial Imagery of Pine Run Subwatershed



Pine Run Subwatershed

Watershed Characteristics

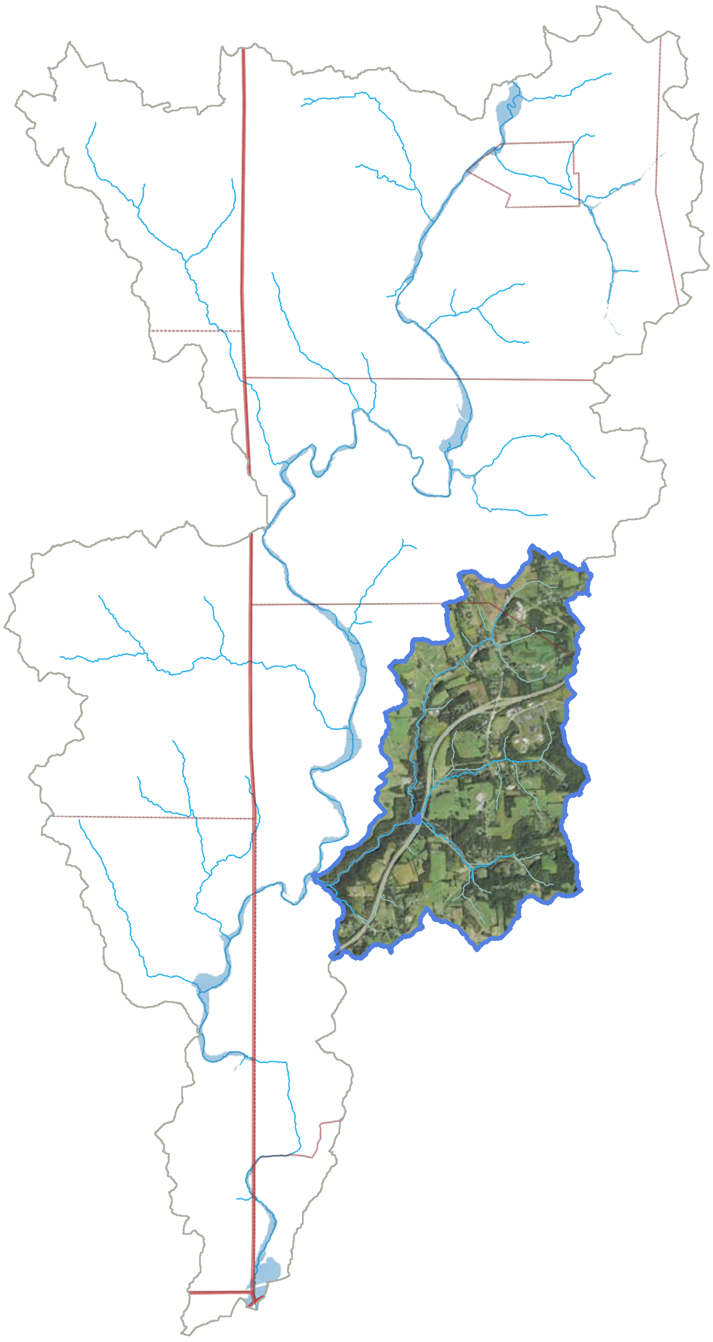
Location and Basin Characteristics

Pine Run is one of the larger subwatersheds within the HUC-10 Buffalo Creek, spanning an impressive 7.16 square miles. Its considerable size amplifies its importance within the WIP, as actions taken here have the potential to exert substantial influence on the health of the downstream environments.

Strategically situated as one of the most downstream segments, Pine Run serves as a significant conduit, channeling water and, consequently, any associated pollutants, sediment, or biological organisms from east to west towards main stem Buffalo Creek. This directional flow underlines the need for effective management at the source – the headwaters. Here, intervention strategies are likely to yield the most significant impact, potentially facilitating the delisting of impaired stream reaches in these areas and further downstream.

The development within Pine Run is more pronounced than in other subwatersheds under study, with a higher prevalence of agricultural, commercial, and industrial land uses. This heightened level of development brings with it increased responsibility and challenges for the WIP. Measures to manage runoff, control pollution, and mitigate habitat disruption will be critical.

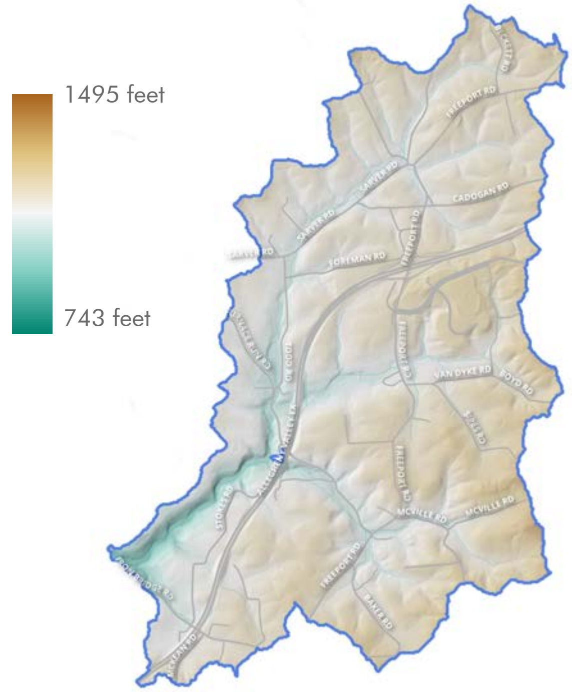
Figure 86: Pine Run Subwatershed Context Map



The subwatershed's development also raises the stakes for restoration and conservation efforts. Conservation efforts must account for the complex interplay between land use and watershed health, aiming to enhance water quality and ecosystem resilience while supporting the socioeconomic fabric of the community.

Terrain and Slope

Figure 87: Terrain and Elevation Map



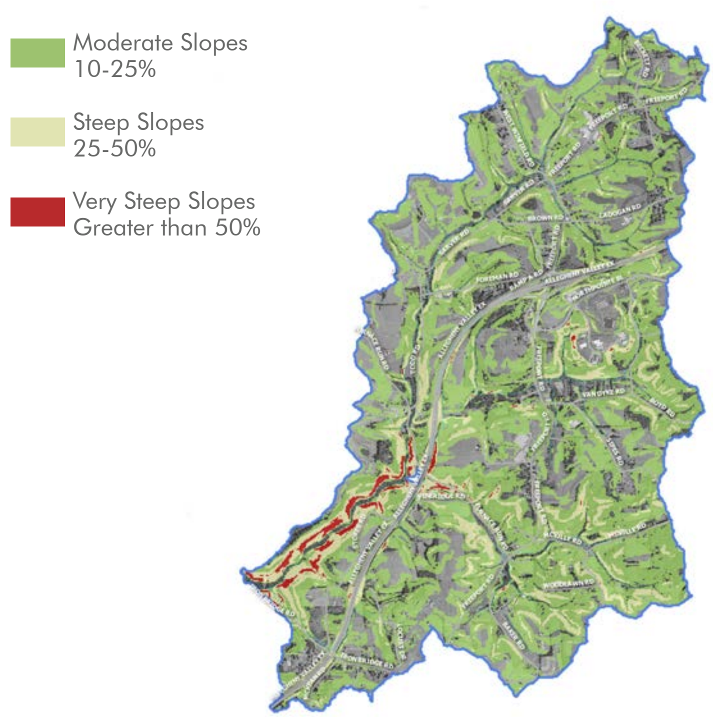
In the Pine Run subwatershed, the terrain presents a mix of moderately steep to very steep slopes, a topographic feature that has not hindered the spread of agricultural and commercial/industrial developments. The moderate slopes have been harnessed effectively for these land uses, demonstrating a fine balance between utilization and preservation.

As Pine Run flows downstream, the slopes adjoining the streambanks become markedly steeper, especially in the most downstream reach before meeting the main stem. This steepness characterizes the lower order streams and is indicative of areas that may hold potential for streambank restoration efforts.

Given the terrain patterns and the PaDEP's recommendation to prioritize headwater areas, the WIP prioritizes upstream interventions. This strategic approach aims to maximize the ecological uplift and water quality improvements in the headwaters, thus exerting a positive downstream effect.

Restoration efforts will need to employ a nuanced understanding of Pine Run's terrain to design interventions that align with the natural landscape and hydrological processes. This will involve a delicate balance between leveraging the land's inherent potential for development and ensuring the integrity and health of the watershed. By doing so, the plan hopes to foster a sustainable relationship between the land's use and its vital water resources.

Figure 88: Steep Slope Map



Bedrock Geology and Lithology

The bedrock geology of Pine Run subwatershed is integral to understanding the hydrological and ecological characteristics that influence the area. The predominance of the Glenshaw Formation, characterized by its durability and resistance to weathering, provides a stable geological foundation for much of the watershed. However, its predominance also implies certain limitations and concerns for watershed management.

The presence of the Allegheny Formation, noted downstream of the confluence with the upper branches, introduces a different set of geological characteristics. Channel incision in the lower reaches where the sandstone of the Allegheny Formation is exposed suggests that overlying shale has been eroded. Despite sandstone's resistance, the confluence of headwater streams likely accelerates its erosion, contributing to sediment load in Buffalo Creek. Effective watershed management must focus on stabilizing these areas to mitigate downstream siltation.

Future management efforts for Pine Run must carefully address the management of sediment and erosion, especially in the lower reaches of the watershed. Interventions may include the stabilization of streambanks, the restoration of native vegetation, and the implementation of BMPs to reduce runoff velocity and enhance infiltration.

Figure 89: Bedrock Geology Map

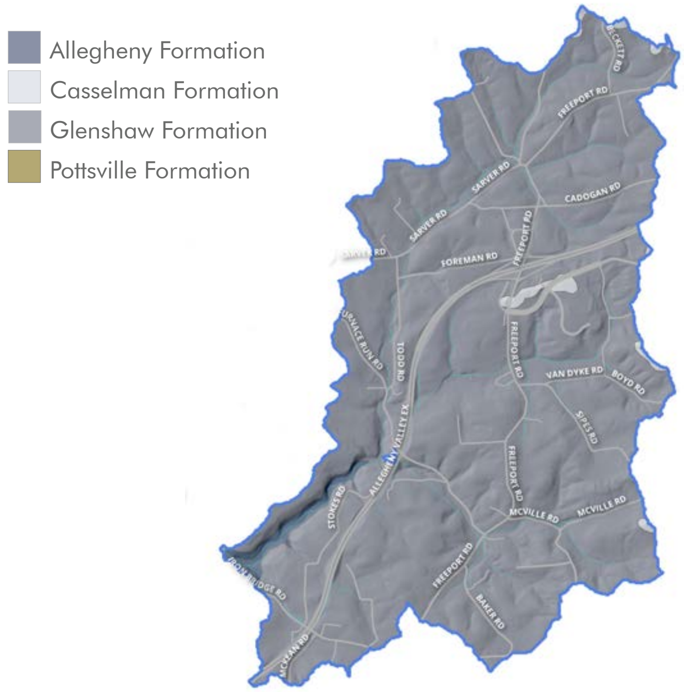
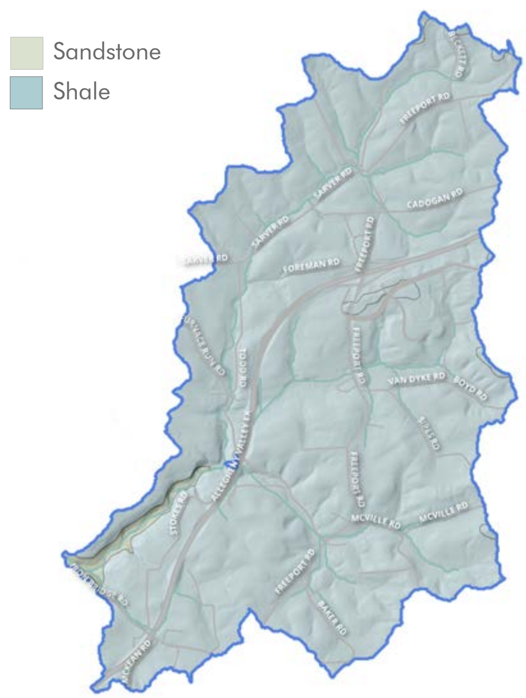


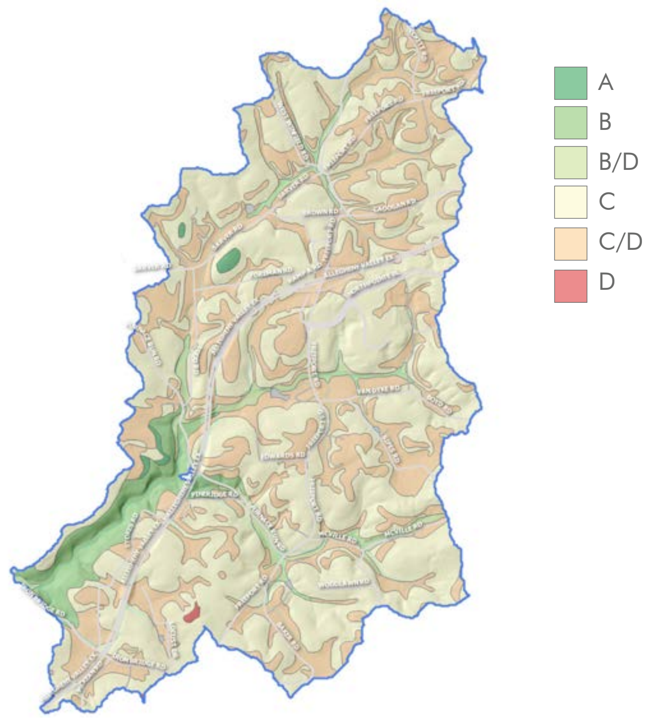
Figure 90: Bedrock Lithology Map

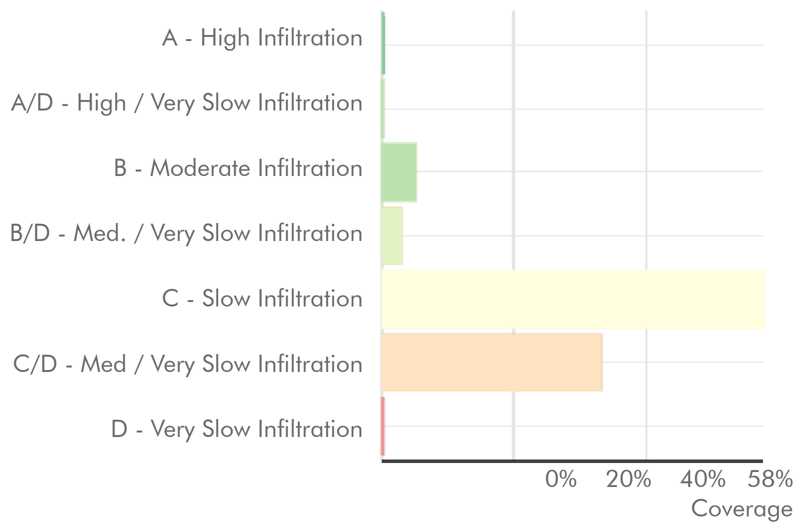


Soils

The hydrologic soil groups of Pine Run subwatershed play a crucial role in shaping the watershed's hydrology and, consequently, its management strategies. The dominance of Group C soils, characterized by their slow infiltration rates when wet, indicates a moderate runoff potential and a lower capacity for groundwater recharge. These soils typically have a finer texture or a layer that impedes water flow, such as clay.

Figure 91: Hydrologic Soils Group





Close behind in prevalence are the C/D soils, which have similar infiltration characteristics to Group C but with a component of very slow infiltration, indicative of the presence of more restrictive layers within the soil profile. These combined soil groups cover a significant portion of the watershed, influencing not only surface water dynamics but also the vegetative and land use patterns.

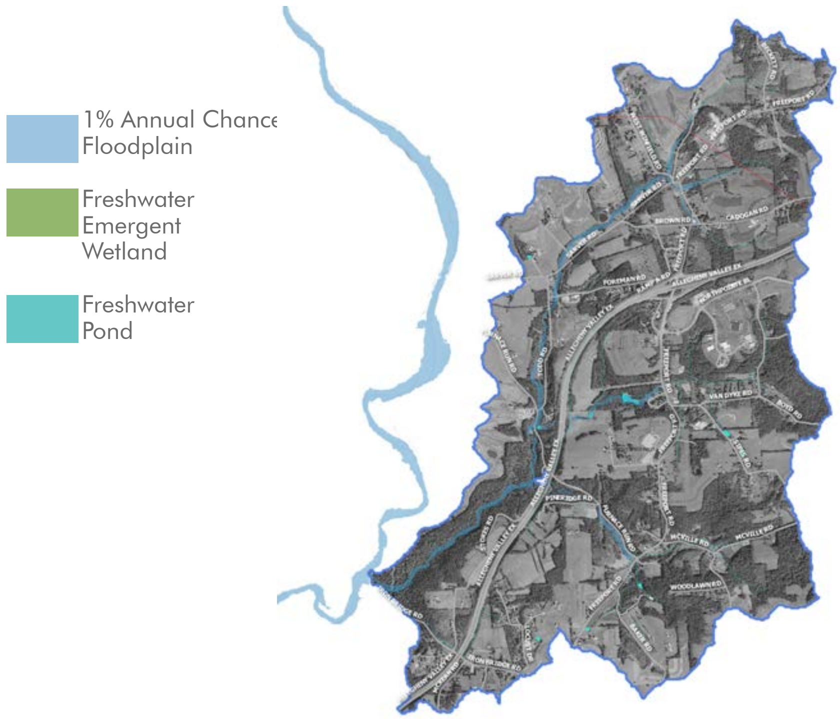
The presence of moderately infiltrating B soils in the lower reaches of the tributary, corresponding to the areas underlain by the sandstone-rich Allegheny Formation, is noteworthy. These B soils, while limited in extent, are crucial for stormwater management as they allow for more significant infiltration and less surface runoff, which can reduce the erosive force on streambanks and decrease the sediment load entering the waterways.

For Pine Run, understanding the interaction between these soil groups and the underlying bedrock geology is essential for devising strategies that effectively address the challenges of managing runoff and preserving water quality. The plan must balance the need for development with the imperative to maintain the hydrologic function of the soils and the integrity of the watershed as a whole.

Hydrology and Stream Impairments

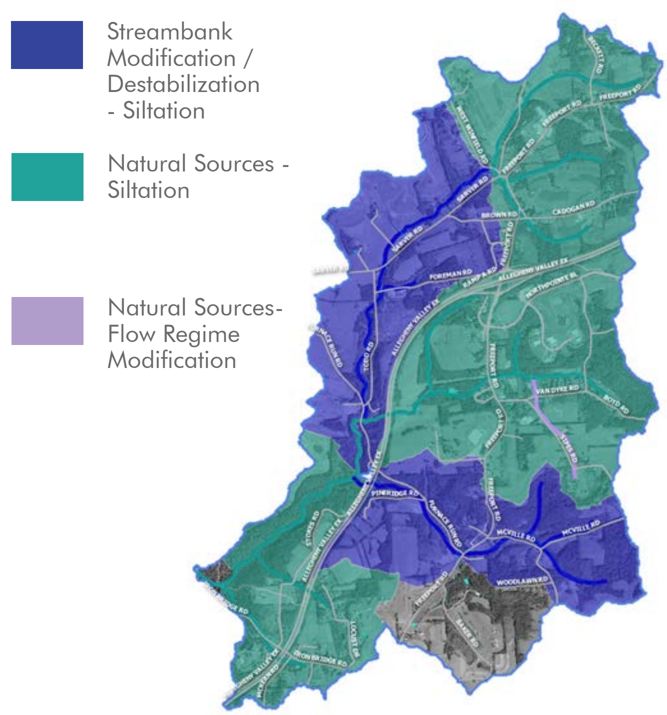
The floodplains and wetlands map of Pine Run subwatershed, Figure 91, delineates the areas subject to flooding and highlights the wetland regions, essential for maintaining hydrological balance and providing wildlife habitats. The 1% annual chance floodplain areas, commonly referred to as the 100-year floodplain, are critical in understanding the risk of significant flood events.

Figure 92: Floodplains and Wetlands



The impairments due to streambank modifications are stark, particularly in the vicinity of the RIDC industrial park Northpointe, where industrial activities have altered the natural stream functions. The labeling of impairments due to "Natural Sources" is ambiguous, especially in a watershed that has experienced extensive anthropogenic disturbances. Based on previous discussion with PaDEP and based on the dominance of this impairment in areas that are largely impacted by agriculture and development, it seems likely that this impairment label is inaccurate. The siltation observed in the tributaries of Pine Run seem much more likely caused by human activities than due to "natural sources".

Figure 93: Non-Attaining Stream and Documented Causes



The reference to impairments from "flow regime modifications" in one stream reach indicates alterations to the natural hydrology, potentially stemming from agricultural practices such as tiling for drainage or the creation of ponds, which can disrupt the natural flow patterns and timing, affecting aquatic ecosystems downstream.

Overall, the ambiguity of "natural sources" as a cause for impairment throughout the Pine Run subwatershed points to a need for further investigation and clarification to ensure that restoration efforts are effectively targeted.

The length of stream that is impaired by Streambank Modification, Siltation (Natural Sources), and Flow Regime Modification per PaDEP is approximately 6.30, 10.98 and 0.80 miles respectively, exclusive of smaller headwater tributaries.

Tree Canopy and Riparian Buffer

Figure 94: Tree Canopy Map

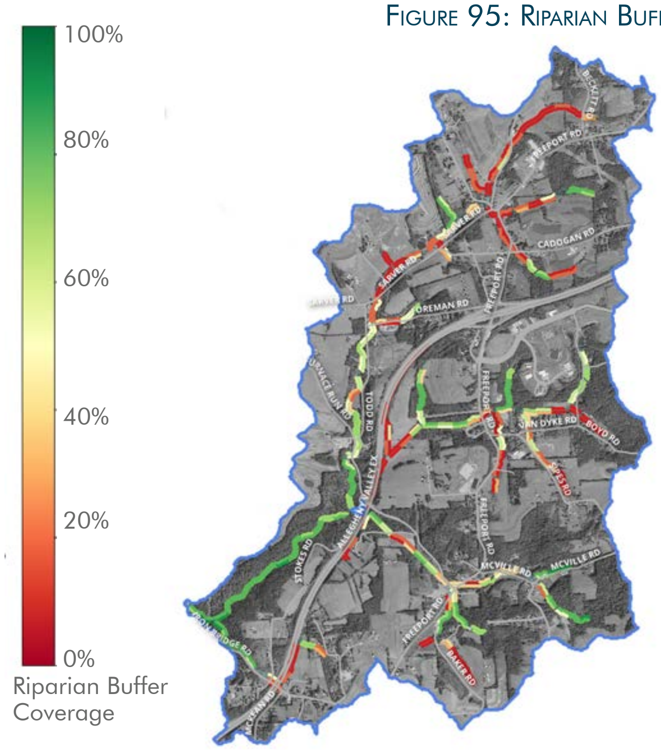
The tree canopy map (Figure 94) and riparian buffer map (Figure 95) of Pine Run subwatershed depict significant ecological disturbances that have implications for watershed health and management.

Figure 94 shows substantial disruption of healthy tree canopy, particularly around high development zones like RIDC Armstrong Innovation Park. The fragmentation of the canopy due to industrial expansion has likely altered local microclimates and reduced the habitat quality for wildlife. It also has potential implications for air quality and carbon sequestration capabilities within the region. The preservation of existing canopy and reforestation efforts in deforested areas is critical to restore ecological balance and enhance the region's natural resilience.

Figure 95 highlights the deterioration of riparian buffers, essential for protecting water quality by filtering runoff and stabilizing streambanks to prevent erosion. The visible degradation, especially in highly developed areas, suggests a need for restoration strategies to re-establish these natural barriers. In contrast, the southern headwater areas display less riparian buffer destruction, with agricultural activities predominantly occurring upgradient. This pattern is a departure from that seen in Marrowbone Run, where the landscape's steep topography inherently limited development.

In Pine Run, the presence of agriculture along the hilltops rather than the valleys may offer opportunities for implementing buffer zones without significant alteration to current land use. WIP strategies focus on enhancing riparian corridors to improve water quality and to provide continuity of habitat for terrestrial and aquatic species.

Figure 95: Riparian Buffer Map



Land Cover

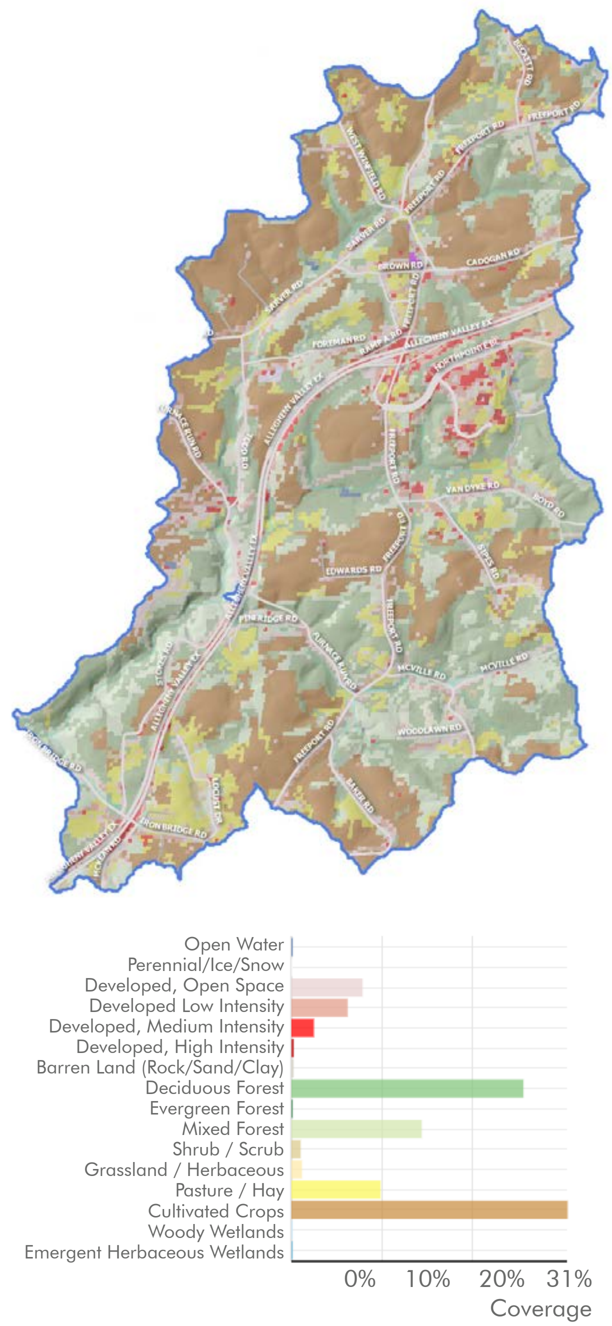
The land cover map (Figure 96) of Pine Run subwatershed reveals a landscape significantly influenced by human activities, notably agriculture and industrial development. The watershed is characterized by a diverse tapestry of land uses, each with distinct implications for watershed health and management strategies.

Agricultural lands, evident in hues of light brown representing cultivated croplands and the lighter green of pasture and grazing lands, signify the rural character of much of the watershed. These areas, while vital for local food production and the economy, are also critical zones for the management of surface runoff and erosion.

The industrialized footprint of the RIDC Armstrong Innovation Park (formerly known as RIDC Northpointe) can be clearly identified on the land cover map, indicated by the red hues indicating low-intensity to high-intensity developed areas. This concentration of development within the watershed presents both challenges and opportunities. It introduces impervious surfaces that alter hydrology and increase runoff but also offers potential partnerships for innovative stormwater management solutions.

The major PennDOT highway, Route 28, snaking through the watershed and paralleling natural drainage courses, underscores the intersection of infrastructure and hydrology. The highway's alignment with stream paths can lead to direct impacts on stream hydrology and water quality, necessitating careful consideration for restoration efforts. Collaborative efforts with PennDOT could lead to infrastructure improvements that benefit both transportation and watershed health.

Figure 96: NLCD Land Cover (2019)



The array of land cover types within Pine Run subwatershed indicates a complex ecological landscape where human land use and natural systems intersect. Efforts to meet water quality standards in Pine Run must navigate these complexities to devise effective strategies that balance developmental pressures with ecological preservation and water quality enhancement.

Stream Water Quality Sampling and Testing

Macroinvertebrate Sampling, Spring 2023

Figure 97: Sampling Locations

The macroinvertebrate sampling data from Pine Run (Oikos 1) over two consecutive years, 2022 and 2023, present a nuanced view of the subwatershed's ecological trends and health. Between 2022 and 2023, the IBI score declined from 75.00 to 64.11, crossing the threshold into a more concerning impaired category. This shift signals potential ecological stress or degradation within the subwatershed. However, such changes to the IBI and other water quality indices can also be explained by varying sampling times, seasonal weather / water conditions, and other factors that are difficult to draw conclusions about from just two samples. As such, the WIP includes additional sampling and an adaptive management strategy to help account for such early planning uncertainties.

Acknowledging this, we can continue to examine the 2023 data in light of the established methodology and comparison with the previous year. Here we observe that taxa richness maintained at 24, indicating a stable variety of macroinvertebrate species present. However, the EPT richness decreased from 12 to 11, hinting at a slight reduction in pollution-sensitive taxa. From 2022 to 2023, the Hilsenhoff biotic index increased from 2.61 to 3.97, which may reflect an uptick in water pollution levels, as this index is inversely proportional to water quality. Furthermore, the Percent Sensitive Individuals metric showed a marked decrease from 63.37 to 38.71, reinforcing concerns about the subwatershed's ability to support sensitive species.

The Shannon diversity index, which provides a measure of community complexity and ecological resilience, showed an increase from 2.197 in 2022 to 2.547 in 2023. This rise usually would suggest an improvement in ecological conditions; however, the other declining metrics imply that while there may be a greater number of taxa present, the community's overall health is facing challenges, particularly among taxa sensitive to pollution.

Figure 98: Sampling Location Photo

In summary, the 2023 macroinvertebrate sampling data from Pine Run, when compared with the data from 2022, point towards a concerning trajectory with regard to water quality and biotic integrity. Despite stable taxa richness and increased Shannon diversity, the decline in IBI score and sensitive species populations warrant attention and action. It is essential to investigate potential causes for these trends, such as habitat changes, pollution sources, or other anthropogenic impacts, and implement targeted restoration and management efforts to improve and protect the aquatic health of Pine Run.

Laboratory Water Quality Sampling, Spring 2023

The laboratory results for Pine Run gathered on May 4, 2023, are reflective of the stream's chemical water quality and provide additional context to the biological data:

- The pH level of 7.73 indicates a stable, near-neutral aquatic environment conducive to a variety of aquatic life forms.
- Phosphorus levels were below the detection limit of 0.10 mg/L, suggesting that phosphorus-induced eutrophication is not a current concern for Pine Run.
- Total Kjeldahl Nitrogen was not detectable, indicating low levels of organic nitrogen compounds, which is a positive sign for water quality.
- Nitrate+Nitrite Nitrogen was measured at 0.53 mg/L, which is above the detection limit but does not signify high levels of these nutrients; however, it's indicative of some level of nitrogen presence.
- The Total Nitrogen, being below the detection threshold, aligns with the low TKN and Nitrate+Nitrite results, suggesting a system not heavily influenced by nitrogen pollution.
- Total Suspended Solids were very low at 5 mg/L, indicative of minimal sedimentation issues and good clarity of the water at the time of sampling.

Stream Water Quality Findings

The macroinvertebrate and water quality analyses collectively offer a window into the ecological dynamics of Pine Run. While the chemical quality of the water appears to be within acceptable limits based on pH, nutrient levels, and suspended solids, the biological assessment points toward ecological stress, as evidenced by the decrease in sensitive species and the uptick in pollution-tolerant taxa.

The decline in the IBI score from 2022 to 2023 raises concerns, despite the overall water chemistry not showing alarming levels of pollutants. The rise in Hilsenhoff biotic index and the drop in Percent Sensitive Individuals from 2022 to 2023 highlight potential issues that are affecting the more vulnerable members of the aquatic community.

Given the findings, it is imperative to delve into potential factors beyond the immediate chemical properties of the water that could be influencing macroinvertebrate populations. Factors such as habitat alteration, the impact of non-chemical pollutants, and subtle changes in water chemistry over time could be contributing to the observed biological trends.

In conclusion, Pine Run's ecological status requires careful observation and possibly proactive management to ensure that the slight deterioration in water quality does not escalate. Continued integrated monitoring that includes both biological assessments and detailed chemical water analyses will be vital in guiding conservation efforts and ensuring the resilience and recovery of the aquatic ecosystem in Pine Run.

Watershed Analysis

In order to thoroughly understand the spatial distribution of land cover impacts to the Pine Run subwatershed, a higher resolution terrain analysis was performed within the larger study area to create five (5) distinct "microsheds" within the Pine Run subwatershed. This higher resolution study was performed using a 20,000 pixel flow accumulation threshold, which equates to a maximum size of approximately 0.77 square miles per microshed using a 10-m Digital Terrain Model.

Current Sediment and Nutrient Loading

Tables 25 and 26 provide a summary of existing pollutant load for Sediment, Total Nitrogen and Total Phosphorus for the entire Pine Run subwatershed, aggregated by land cover and summarized overall.

The most significant sources of sediment pollution within the Pine Run subwatershed are cropland, hay/pasture, and stream bank erosion. These observations about pollutant sources are consistent across GIS land cover / pollutant loading analyses, aerial imagery and site visits.

Table 25: Average Annual Pollutant Loads, by Land Cover

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	448,926.1	1,384.0	478.7
Cropland	1,855,673.5	7,569.2	2,073.6
Wooded Areas	3,302.1	103.1	8.1
Wetlands	0.0	0.0	0.0
Open Land	2,403.5	34.3	2.8
Barren Areas	17.8	4.3	0.2
Low-Density Mixed	3,156.0	87.0	9.2
Medium-Density Mixed	8,585.9	157.6	16.0
High-Density Mixed	927.2	17.0	1.7
Low-Density Open Space	3,990.0	110.0	11.6
Farm Animals	0.0	825.3	197.3
Stream Bank Erosion	370,945.7	255.7	88.2
Subsurface Flow	0.0	4,151.9	181.0
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	362.3	0.0

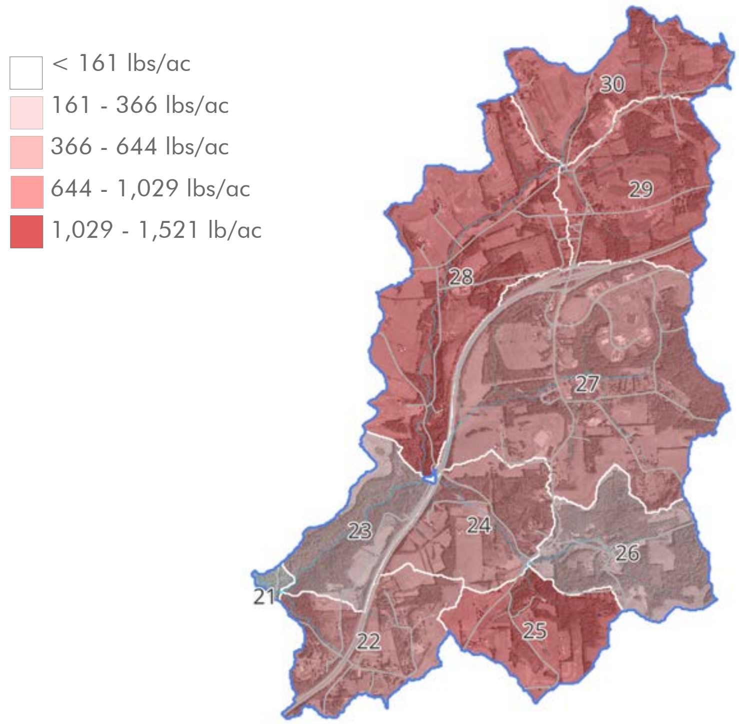
Table 26: Average Annual Loads from 30-years of Daily Fluxes

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	2,697,927.9	15,061.9	3,068.4
Loading Rates (lb/ac)	587.79	3.28	0.67
Mean Annual Concentration (mg/L)	192.87	1.08	0.22
Mean Low-Flow Concentration (mg/L)	1,676.00	7.80	2.11

Mean Flow: 224,073,073 (ft³/year) and 7.11 (ft³/s)

The distribution of pollutant concentrations within the Pine Run subwatershed reflects a significant disparity in environmental impact across the region. The northernmost microsheds - 28 through 30 - exhibit the highest concentrations of sediment (Figure 99 in reds), phosphorus (Figure 100 in purples) , and nitrogen (Figure 101 in blues), suggesting a pronounced impact from intensive land uses. These areas, characterized by the presence of the RIDC Armstrong Innovation Park and extensive agricultural operations, are identified as the most impaired within the subwatershed.

Figure 99:
Total Sediment, Pollutant Concentration



Microshed 25, situated in the south near the mouth of the subwatershed and also dominated by agriculture, displays similarly high pollutant concentrations. This suggests that farming practices in this area are a substantial contributor to the overall loading rates of these critical nutrients and sediments.

The microsheds located south of the Allegheny Valley Expressway exhibit moderate levels of impact. Here, the interplay between agricultural lands and forested areas creates a buffer that mitigates some of the detrimental effects of nutrient and sediment runoff. .

Strategic implementation of BMPs in the northern and southern agricultural hotspots, coupled with the preservation and enhancement of forested buffers in the moderately impacted microsheds, would be vital steps toward restoring and protecting the water quality within Pine Run subwatershed.

Figure 100:
Total Phosphorus, Pollutant Concentration

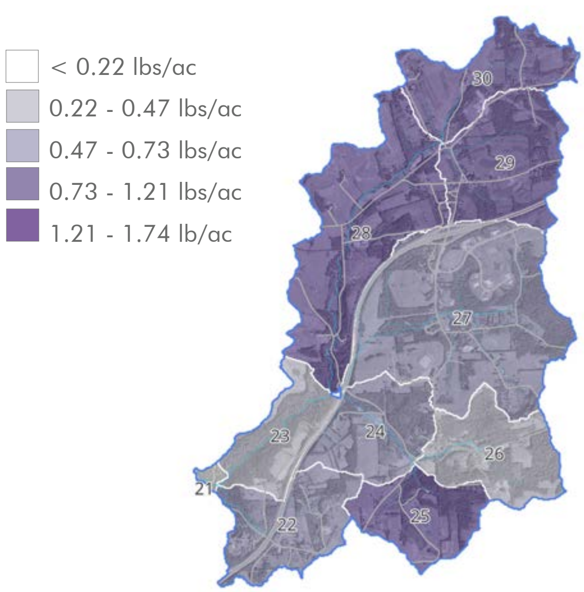
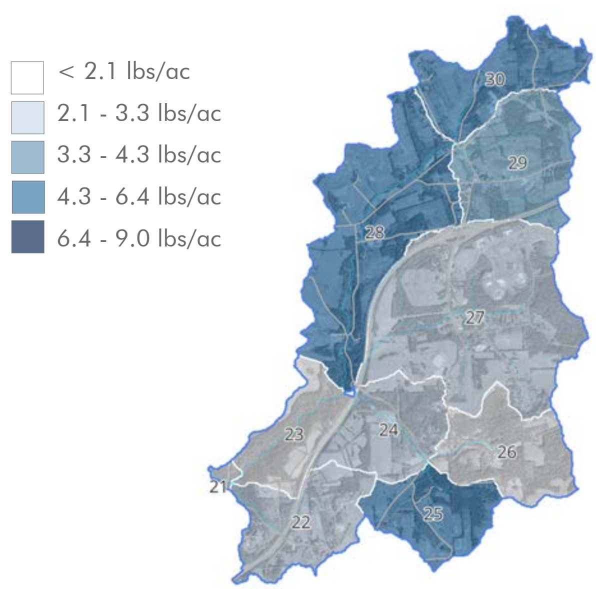


Figure 101:
Total Nitrogen Pollutant Concentration



Summary of Riparian Buffer Opportunities

Per the NHD High Resolution Stream Network dataset, there is a total of 15.68 miles (82,790 feet) of first order through fourth order streams located within the Pine Run watershed. Our more detailed terrain analysis - which tends to reveal perennial, ephemeral, and tile-drained, buried streams that still have drainage path signatures - yielded slightly higher results, indicating that 16.24 miles (85,753 feet) of stream exist. This equates to approximately 394 acres of existing and potential future riparian buffer area, assuming one hundred (100) feet of buffer width on each stream bank. Based on the more detailed data set, the following was derived by geospatial analysis:

Table 27: Riparian Buffer Opportunities

Land Cover	Riparian Buffer Coverage (Acres) and Degradation Level			
	0-20%, Critical	20-40%, Severe	40-60%, Moderate	60-80%, Minor
Deciduous Forest	20.23	21.29	24.35	66.95
Cultivated Crops	44.86	7.58	2.22	1.86
Developed, Open Space	16.70	4.17	9.54	8.39
Grassland / Herbaceous	4.71	2.55	0.38	0.82
Pasture / Hay	30.56	2.34	2.34	1.11
Open Water	0.10	-	0.52	0.19
Woody Wetlands	-	-	0.12	-
Barren Land (Rock/Sand)	-	0.55	-	-
Developed, Low Intensity	27.81	3.43	3.09	0.92
Developed, Medium Intensity	11.01	0.45	0.91	1.20
Developed, High Intensity	0.52	-	0.05	-
Mixed Forest	11.67	8.20	13.62	45.13
Evergreen Forest	0.28	-	-	-
Shrub / Scrub		0.02	-	-
Total:	168.45	50.58	57.14	126.57
High Priority (Red) *:	84.20	12.01	-	-
Medium Priority (Yellow) **:	51.97	9.06	-	-

** The light red shaded cells in Table 27, indicating cultivated crops and developed areas, are key areas for watershed improvement due to their high pollutant loads, with roads and areas near unbuffered, partially incised streams being prime candidates for restoration and stabilization.*

*** Yellow shaded cells in the analysis represent areas where pollution significance is uncertain without further field data. Open spaces, grasslands, and pastures might be high pollutant sources if used for livestock grazing without adequate buffers and fencing, or conversely, could be effectively managed as grass riparian buffers, acting as existing Best Management Practices. Direct engagement with landowners is recommended for accurate assessment.*

The findings indicates that nearly 156 acres are potentially available for restoration of critically to severely degraded riparian buffers throughout the watershed.

Special Consideration for Riparian Buffers

For reasons described in greater detail in the Pine Run section of this report, prioritization of future riparian buffer restoration efforts is paramount to meeting water quality standards in the future. Figure 102 depicts areas of high flow concentration within the Pine Run subwatershed. Where these pollutant-laden high flows drain to areas of depleted riparian buffer (show in red), there is greater opportunity for stream water quality improvement.

Figure 103 overlays the riparian buffers within the Pine Run subwatershed with existing contour farming practices. In this case, the restoration strategy would be to prioritize buffer restorations in areas not already protected by existing BMPs. As this map illustrates, contour farming is not a common practice in the Pine Run subwatershed, and so there are fewer places where existing depleted riparian buffers are already somewhat protected by agricultural BMPs. This is an opportunity for future restoration efforts. Riparian buffers are also largely missing along major highways; this is discussed in more detail in the later sub-section of this chapter, titled "Transportation-Related Opportunities".

Figure 102: Flow Accumulation Along Riparian Buffers

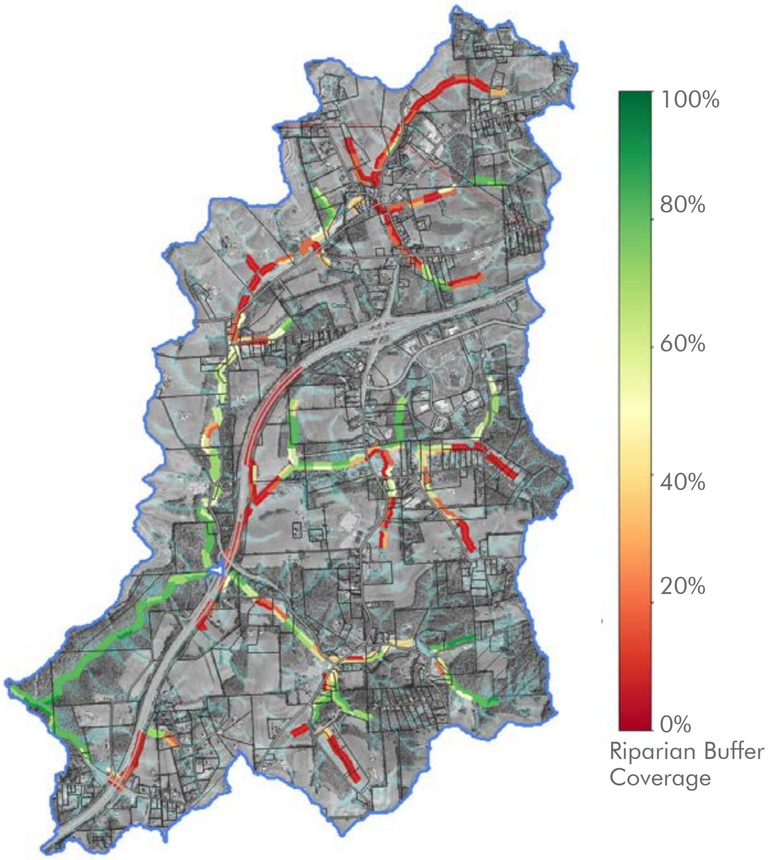
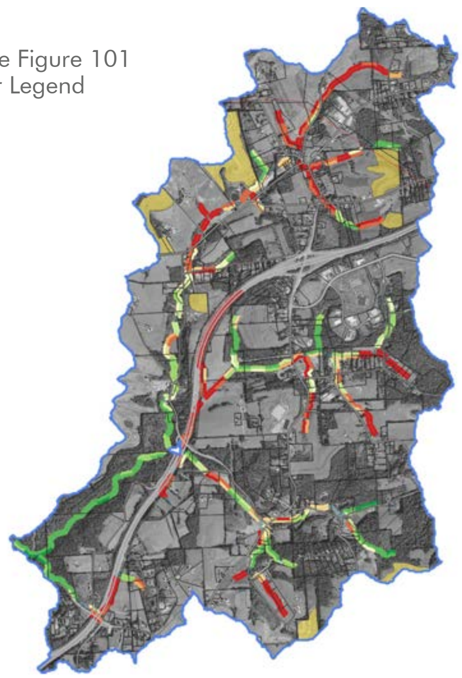


Figure 103: Prioritizing Riparian Buffers Based on Upstream Best Management Practices

See Figure 101 for Legend

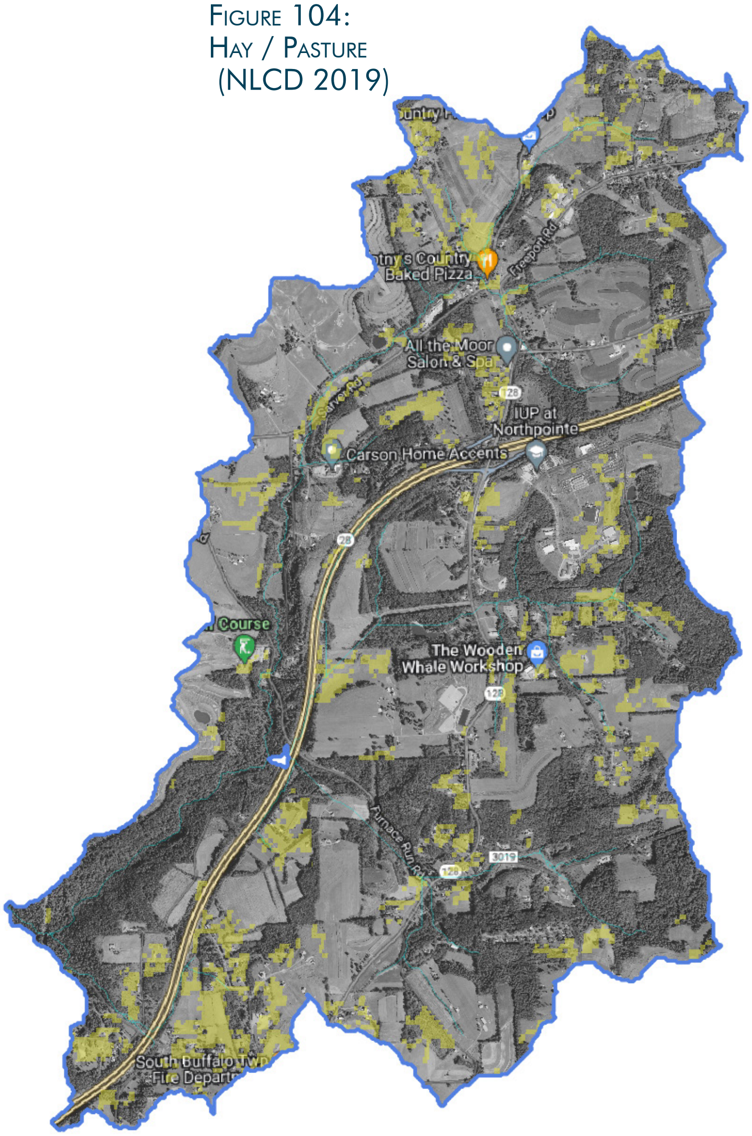


Streambank Restoration and Exclusionary Fencing Opportunities

Based on NLCD land cover data, hay and pasture land (Figure 104) - presumed to be largely for livestock grazing - is one of the dominant land covers in the Pine Run subwatershed. There is approximately 33 acres of critically or severely degraded riparian buffer areas within 452 total acres of mapped pasture land throughout the Pine Run subwatershed. Based on site observations and an assessment of aerial imagery, much of this area is active grazing land that has a high potential impact on stream health and pollutant load, with limited provisions for exclusionary fencing.

The aforementioned 33 acres of critically or severely degraded riparian buffer equates to approximately 14,370 linear feet (2.72 miles) of opportunity for new exclusionary fencing within the Pine Run subwatershed, in addition to the 33 acres of potential riparian buffer restoration opportunity.

Figure 104:
Hay / Pasture
(NLCD 2019)



Urban Land Management Opportunities

Figure 105: Impervious Area Coverage at RIDC Armstrong Innovation Park and Aerial Imagery

Figure 105 illustrates the density and distribution of impervious surface cover in and around the RIDC Armstrong Innovation Park - formerly known as RIDC Northpointe Industrial Park - and in immediately adjacent areas. As indicated in the heatmap and aerial imagery, the extensive impervious surfaces, such as large parking expanses and the ongoing development pressures, pose significant challenges for watershed management.

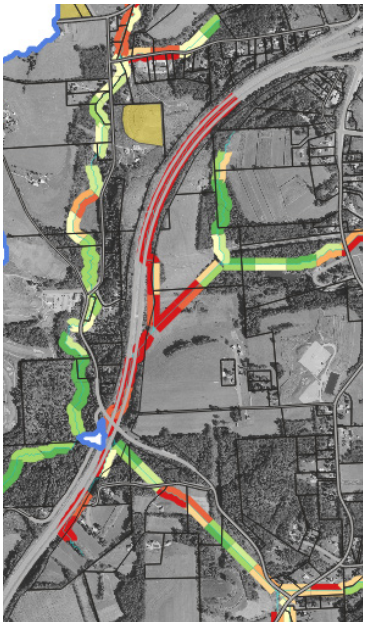
Furthermore, the park's continued expansion intensifies the need for vigilant environmental oversight. Existing greenfields are under the specter of development, which could diminish the area's natural absorption capacity and escalate the risk of pollution to Pine Run and its tributaries.

Based on site observations, it appears that the ponds (Figure 105, aerial) were likely designed under older stormwater regulations which lack the current emphasis on volume control and water quality. No volume or water quality control BMPs were observed at the site. Rather, the existing stormwater management systems consists of large, centralized wet ponds and are presented in RIDC marketing literature as "integrated" and ready for connection for new tenant. This language suggests that any new development would possibly be grandfathered into the previously approved stormwater management controls and would not necessarily be subject to further review by the municipality or the Conservation District under the National Pollution Discharge and Elimination Systems (NPDES) permit, except perhaps on a superficial level to confirm previous calculations. This presents a significant hurdle for meeting and maintaining water quality standards, as these pre-established systems do not well align with contemporary environmental goals.

Retrofitting these systems to comply with modern BMPs for stormwater would be both challenging and costly. There are numerous opportunities, however, for construction of new, distributed stormwater management facilities throughout the Armstrong Innovation Park. Such improvements will likely need to be grant funded or constructed as part of an agency partnership, assuming that the burden would not be on private developers grandfathered into the existing facilities. Such strategies may include the targeted addition of green infrastructure elements, combined with selective naturalization of manicured lawn areas to soften the developed nature of the site overall. The challenge lies in balancing the park's growth with the health of the Pine Run subwatershed, ensuring that economic and industrial progress does not come at the cost of ecological integrity.

Figure 106: Ideas for Incorporating Green Infrastructure into RIDC Armstrong Innovation Park

Figure 107: Riparian Buffers Interrupted by Highway



In the Pine Run subwatershed, the Allegheny Valley Expressway, managed by PennDOT, presents unique opportunities for partnership in the context of watershed restoration. As shown in Figures 107 and 108, the natural and constructed drainage way courses through the median in portions of the expressway - a tangible intersection of infrastructure and watershed health.

Collaborating with PennDOT could open avenues for integrated stormwater management practices that enhance the ecological functionality of the roadway's median and provide added ecological benefit to Pine Run. This could include the implementation of bioswales, rain gardens, or constructed wetlands within the median to filter runoff, reduce pollutant loads, and manage stormwater flow more effectively. These measures not only benefit the watershed by mitigating potential contaminants from the road surface but also contribute to the aesthetic and ecological value of the expressway corridor.

Figure 108: Highway Bioswale Design Concept

In addition, the partnership could explore retrofitting existing drainage systems to incorporate advanced filtration systems, ensuring that runoff from the roadway is treated before it enters Pine Run. PennDOT's maintenance practices could also be aligned with conservation goals, including the use of native plantings in landscaping to promote biodiversity and reduce maintenance needs.

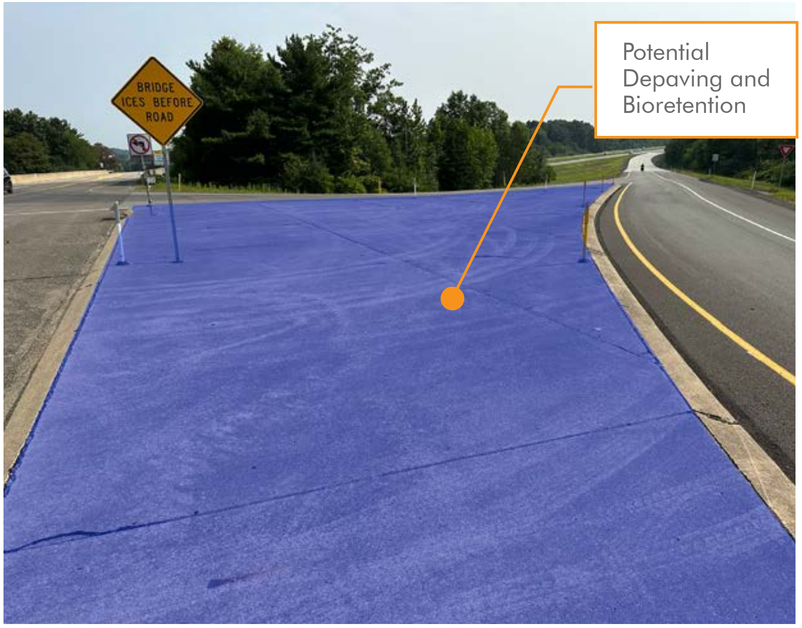


FIGURE 109: HIGHWAY DEPAVING AND BIORETENTION DESIGN CONCEPT

One potential focus area is the optimization of existing stockpile sites adjacent to the Allegheny Valley Expressway. Enhancements could be made to the current stormwater management systems, including creating vegetated swales or bioretention areas around these sites to filter runoff before it reaches the waterways, aligning with hotspot treatment strategies.

The existing Park-and-Ride near the RIDC Armstrong Innovation Park also presents an opportunity for retrofitting with green infrastructure (Figures 109 and 110). Improvements could involve the installation of rain gardens, bioswales, and filtering measures to manage stormwater effectively. These upgrades would not only mitigate surface runoff but also contribute to the reduction of non-point source pollution, a key aspect of PennDOT's MS4 (Municipal Separate Storm Sewer System) obligations. MS4 requirements emphasize the need for municipalities, including state agencies, to address stormwater runoff in urbanized areas.

To further integrate watershed protection measures, PennDOT and watershed partners can utilize the Park-and-Ride as a platform for educational outreach. Informative displays about stormwater management, the benefits of green infrastructure, and PennDOT's commitment to environmental stewardship could engage commuters and local citizens, fostering a sense of collective responsibility for watershed health.

FIGURE 110: PARK-AND-RIDE RAIN GARDEN DESIGN CONCEPT

Implementation Plan, Pine Run Subwatershed

Summary of Watershed Implementation Needs and Pollutant Loading Targets

As mentioned in the narrative above, the downstream reach of Pine Run between the mouth and the confluence of the three headwater subwatershed is a lower order stream that has been more historically impacted by upstream activities. As such, the Pine Run study area focused on the headwater areas, measuring 5.93 square miles.

Based in guidance documents for selecting reference watersheds for TMDL assessment and ongoing dialogue with PaDEP,a 4.53 square mile, headwaters portion of North Branch Rough Run - also within the Buffalo Creek watershed but in an upstream HUC-12 - was chosen for this project as the reference watershed and pollutant loading target for the revised Pine Run subwatershed. Note that loading rate is used to calculate pollutant targets, rather than total loads.

Watershed Area

3,586 acres

Sediment

Loading Rate, Pine Run Subwatershed:	0.307 tons/acre
Loading Rate, Reference Watershed:	0.176 tons/acre

Pollutant Loading Target based on Loading Rate, Sediment: 470 lbs per year
Pollutant Load Reduction Target, Sediment: 629 lbs per year (without safety factor)
Pollutant Load Reduction Target, Sediment: 566 lbs per year (with 10% safety factor)

Total Phosphorus

Loading Rate, Pine Run Subwatershed:	0.70 lbs/acre
Loading Rate, Reference Watershed:	0.42 lbs/acre

Pollutant Loading Target based on Loading Rate, Phosphorus: 1,004 lbs per year
Pollutant Load Reduction Target, Phosphorus: 1,506 lbs per year (without safety factor)
Pollutant Load Reduction Target, Phosphorus: 1,355 lbs per year (with 10% safety factor)

Total Nitrogen

Loading Rate, Pine Run Subwatershed:	3.48 lbs/acre
Loading Rate, Reference Watershed:	2.41 lbs/acre

Pollutant Loading Target based on Loading Rate, Nitrogen: 3,837 lbs per year
Pollutant Load Reduction Target, Nitrogen: 8,642 lbs per year (without safety factor)
Pollutant Load Reduction Target, Nitrogen: 7,778 lbs per year (with 10% safety factor)

Implementation Plans and Projects

Based on the suite of opportunities described previously and the target pollutant loads established, the following list of BMPs and potential projects were identified for the Pine Run subwatershed:

Table 28: Proposed Best Management Practices, Pine Run Subwatershed

BMPS	Units	Available	% Proposed	Amount Proposed	Proposed Reduction S (tons)	Proposed Reduction P (lbs)	Proposed Reduction N (lbs)
Riparian Buffer & Stream Restoration							
Forested Buffer	acres	403	25%	101	132	256.6	1,521.6
Grass Buffer	acres	403	35%	141	182	352.4	1,621.1
Streambank Stabilization (each bank)	feet	83,200	4%	2,995	172	521.2	575.1
Streambank Exclusionary Fencing	acres	36.4	25%	9.1	9	16.1	72.2
Land Conversion							
Cropland Retirement	acres	995	3%	30	19	42.7	142.8
Agricultural Land Management							
Water and Soil Conservation Planning	acres	1,398	30%	419	70	93.3	181.7
Cover Crops	acres	995	20%	199	13	11.8	237.1
Contour Farming / Strip Cropping	acres	863	20%	173	29	38.4	74.8
Conservation Tillage	acres	995	20%	199	104	162.4	150.9
Nutrient Management	acres	1,398	25%	349	-	26.6	88.4
Grazing Land Management	acres	106	40%	42	6	10.8	11.7
Barnyard Runoff Control	acres	30	40%	12	2	47.0	2,803.8
Developed Areas							
Bioretention (C/D soils, underdrain)	acres	12	15%	1.9	0.3	0.2	0.8
Bioswales	acres	12	10%	1.2	0.3	0.3	1.4
Filter Strip - Runoff Reduction	acres	12	15%	1.9	0.2	0.2	0.6

	S Loading (tons)	P Loading (lbs)	N Loading (lbs)
Total Proposed Reduction	740	1,580	7,484
Current Loading	1,281	2,890	15,888
Proposed Loading	541	1,310	8,404
Target Loading Goal	566	1,355	7,778
Percent Above/Below Goal	16%	14%	3%

Table 29: Best Management Practices, Cost Summary (Base Year 2025)

BMPS	Units	Quantity	Unit Cost, Capital	Total Cost, Capital	Unit Cost, O&M	Total Cost, O&M
Riparian Buffer & Stream Restoration						
Forested Buffer	acres	101	$6,409.19	$645,308.90	$104.89	$10,561.02
Grass Buffer	acres	141	$1,418.57	$199,959.95	$46.44	$6,545.62
Streambank Stabilization	feet	2,995	$809.73	$2,425,282.27	$82.83	$248,087.97
Streambank Exclusionary Fencing	acres	9.1	$21,345.12	$193,973.74	$715.97	$6,506.42
Land Conversion						
Cropland Retirement	acres	30	$173.85	$5,188.33	$6.74	$201.11
Agricultural Land Management						
Water and Soil Conservation Planning	acres	419	$24.91	$10,443.75	$-	$-
Cover Crops	acres	199	$75.50	$15,021.34	$75.50	$15,021.34
Contour Farming / Strip Cropping	acres	173	$1.61	$277.82	$1.61	$277.82
Conservation Tillage	acres	199	$18.73	$3,726.49	$18.73	$3,726.49
Nutrient Management	acres	349	$27.96	$9,767.49	$5.29	$1,849.28
Grazing Land Management	acres	42	$81.27	$3,451.47	$81.27	$3,451.47
Barnyard Runoff Control	acres	12	$6,013.28	$72,159.36	$0.77	$9.30
Developed Areas						
Bioretention (C/D soils, underdrain)	acres	1.9	$78,301.33	$145,002.47	$2,285.81	$4,232.99
Bioswales	acres	1.2	$27,484.38	$33,931.33	$1,574.68	$1,944.05
Filter Strip - Runoff Reduction	acres	1.9	$18,080.10	$33,481.66	$338.83	$627.46
Total				$3,796,976		$303,042

10-Year Watershed Implementation Plans for the Pine Run Subwatershed

Based on the Base Year 2025 values provided below, the proposed 10-year WIP for the Pine Run Subwatershed is as follows:

Table 30: Years 1 Through 5 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 1		Year 2		Year 3		Year 4		Year 5	
	2025		2026		2027		2028		2029	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$64,531	$1,056	$66,964	$2,192	$69,488	$3,412	$72,108	$4,720	$74,826	$6,123
Grass Buffer	$19,996	$655	$20,750	$1,358	$21,532	$2,115	$22,344	$2,926	$23,186	$3,795
Streambank Stabilization	$242,528	$24,809	$251,672	$51,488	$261,160	$80,144	$271,005	$110,887	$281,222	$143,834
Streambank Exclusionary Fencing	$19,397	$651	$20,129	$1,350	$20,888	$2,102	$21,675	$2,908	$22,492	$3,772
Land Conversion										
Cropland Retirement	$519	$20	$538	$42	$559	$65	$580	$90	$602	$117
Agricultural Land Management										
Water and Soil Conservation Planning	$1,044	$-	$1,084	$-	$1,125	$-	$1,167	$-	$1,211	$-
Cover Crops	$1,502	$1,502	$1,559	$3,118	$1,618	$4,853	$1,679	$6,714	$1,742	$8,709
Contour Farming / Strip Cropping	$28	$28	$29	$58	$30	$90	$31	$124	$32	$161
Conservation Tillage	$373	$373	$387	$773	$401	$1,204	$416	$1,666	$432	$2,161
Nutrient Management	$977	$185	$1,014	$384	$1,052	$597	$1,091	$827	$1,133	$1,072
Grazing Land Management	$345	$345	$358	$716	$372	$1,115	$386	$1,543	$400	$2,001
Barnyard Runoff Control	$7,216	$1	$7,488	$2	$7,770	$3	$8,063	$4	$8,367	$5
Developed Land										
Bioretention (C/D soils, underdrain)	$14,500	$423	$15,047	$879	$15,614	$1,367	$16,203	$1,892	$16,814	$2,454
Bioswales	$3,393	$194	$3,521	$403	$3,654	$628	$3,792	$869	$3,934	$1,127
Filter Strip - Runoff Reduction	$3,348	$63	$3,474	$130	$3,605	$203	$3,741	$280	$3,882	$364
SUBTOTALS	$379,698	$30,304	$394,012	$62,893	$408,866	$97,897	$424,281	$135,450	$440,276	$175,695
BY YEAR		$410,002		$456,906		$506,763		$559,731		$615,972

Table 31: Years 6 Through 10 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 6		Year 7		Year 8		Year 9		Year 10	
	2030		2031		2032		2033		2034	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$77,647	$7,625	$80,575	$9,231	$83,612	$10,947	$86,765	$12,780	$90,036	$14,735
Grass Buffer	$24,060	$4,726	$24,967	$5,721	$25,909	$6,785	$26,885	$7,921	$27,899	$9,133
Streambank Stabilization	$291,824	$179,108	$302,826	$216,838	$314,243	$257,157	$326,090	$300,208	$338,383	$346,140
Streambank Exclusionary Fencing	$23,340	$4,697	$24,220	$5,687	$25,133	$6,744	$26,081	$7,873	$27,064	$9,078
Land Conversion										
Cropland Retirement	$624	$145	$648	$176	$672	$208	$698	$243	$724	$281
Agricultural Land Management										
Water and Soil Conservation Planning	$1,257	$-	$1,304	$-	$1,353	$-	$1,404	$-	$1,457	$-
Cover Crops	$1,807	$10,845	$1,876	$13,129	$1,946	$15,570	$2,020	$18,177	$2,096	$20,958
Contour Farming / Strip Cropping	$33	$201	$35	$243	$36	$288	$37	$336	$39	$388
Conservation Tillage	$448	$2,690	$465	$3,257	$483	$3,863	$501	$4,509	$520	$5,199
Nutrient Management	$1,175	$1,335	$1,220	$1,616	$1,266	$1,917	$1,313	$2,238	$1,363	$2,580
Grazing Land Management	$415	$2,492	$431	$3,017	$447	$3,578	$464	$4,177	$482	$4,816
Barnyard Runoff Control	$8,683	$7	$9,010	$8	$9,350	$10	$9,702	$11	$10,068	$13
Developed Land										
Bioretention (C/D soils, underdrain)	$17,448	$3,056	$18,105	$3,700	$18,788	$4,388	$19,496	$5,122	$20,231	$5,906
Bioswales	$4,083	$1,404	$4,237	$1,699	$4,396	$2,015	$4,562	$2,352	$4,734	$2,712
Filter Strip - Runoff Reduction	$4,029	$453	$4,181	$548	$4,338	$650	$4,502	$759	$4,671	$875
SUBTOTALS	$456,875	$218,783	$474,099	$264,870	$491,972	$314,120	$510,520	$366,708	$529,766	$422,814
BY YEAR		$675,658		$738,968		$806,093		$877,228		$952,580
10-Year Implementation Cost, Pine Run:										$6,599,900

Table 32: Best Management Practices, Annualized Cost Per Pollutant Reduction

Projects / Opportunities	Net Present Value			Annualized Cost Over 10-Years	Pollutant Reduction		
					Cost / Pound / Year		
	Capital	O&M	Total		S	P	N
Riparian Buffer & Stream Restoration							
Forested Buffer	$645,309	$58,086	$703,394	$70,339	$0.27	$274.15	$46.23
Grass Buffer	$199,960	$36,001	$235,961	$23,596	$0.06	$66.96	$14.56
Streambank Stabilization	$2,425,282	$1,364,484	$3,789,766	$378,977	$1.10	$727.18	$659.00
Streambank Exclusionary Fencing	$193,974	$35,785	$229,759	$22,976	$1.31	$1,428.86	$318.23
Land Conversion							
Cropland Retirement	$5,188	$1,106	$6,294	$629	$0.02	$14.74	$4.41
Agricultural Land Management							
Water and Soil Conservation Planning	$10,444	$-	$10,444	$1,044	$0.01	$11.19	$5.75
Cover Crops	$15,021	$82,617	$97,639	$9,764	$0.37	$826.70	$41.18
Contour Farming / Strip Cropping	$278	$1,528	$1,806	$181	$0.003	$4.70	$2.41
Conservation Tillage	$3,726	$20,496	$24,222	$2,422	$0.01	$14.92	$16.05
Nutrient Management	$9,767	$10,171	$19,939	$1,994	$-	$74.91	$22.55
Grazing Land Management	$3,451	$18,983	$22,435	$2,243	$0.18	$207.76	$191.59
Barnyard Runoff Control	$72,159	$51	$72,210	$7,221	$1.56	$153.50	$2.58
Developed Land							
Bioretention (C/D soils, underdrain)	$145,002	$23,281	$168,284	$16,828	$26.62	$74,792.84	$22,300.20
Bioswales	$33,931	$10,692	$44,624	$4,462	$7.28	$17,849.44	$3,167.84
Filter Strip - Runoff Reduction	$33,482	$3,451	$36,933	$3,693	$8.36	$16,787.59	$6,351.48

Moonlight Drive Subwatershed

Watershed Characteristics

Watershed Analysis

Implementation Plan

Figure 111: Aerial Imagery of Moonlight Drive Subwatershed

Moonlight Drive Subwatershed

Watershed Characteristics

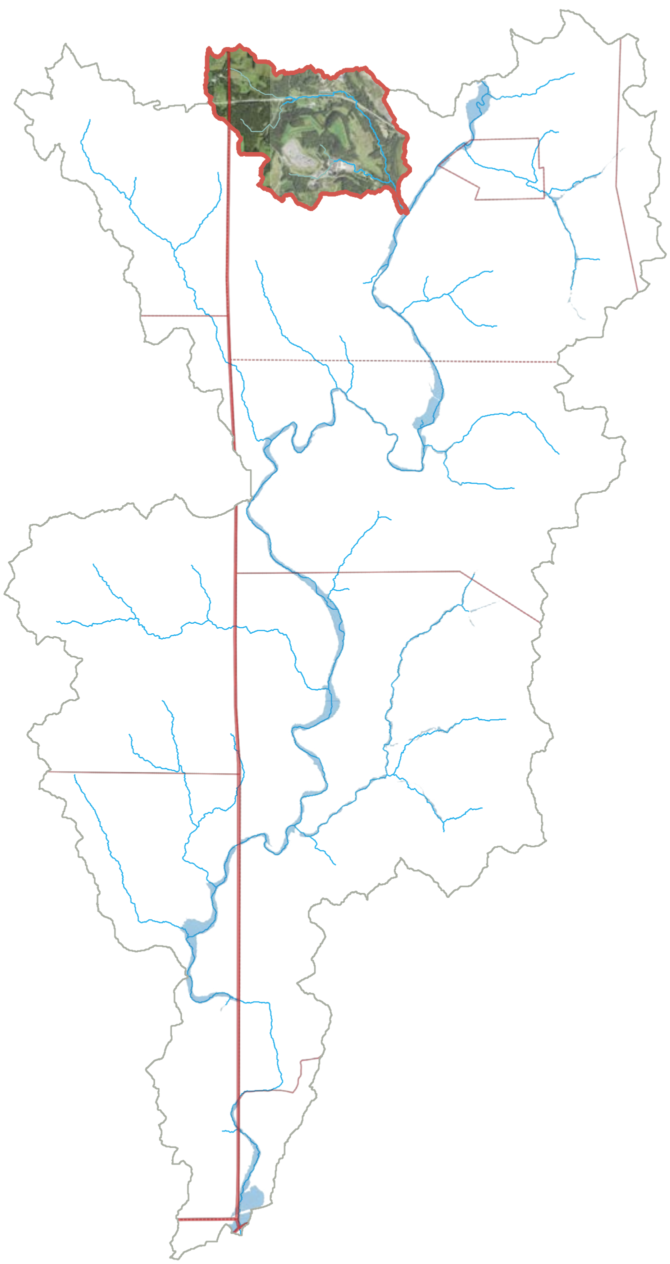
Location and Basin Characteristics

The Moonlight Drive subwatershed is a landscape shaped by its geological past and the human activities that have occurred over the years. The region, characterized by its rolling hills and the branching tributary to Buffalo Creek, shows clear signs of ecological disturbances reflected in the patterns of its tree canopy coverage, clearly visible in the aerial image. (Figure 112).

Industrial and resource extraction activities, particularly those related to past coal mining operations, have significantly disrupted the natural vegetation. Abandoned deep mines and refuse piles, a testament to the area's mining heritage, have contributed to acid mine drainage (AMD), which has resulted in elevated levels of manganese at certain points and net alkaline water conditions. The legacy of these activities is a patchwork of areas where the tree canopy has been depleted or entirely eradicated, leaving the land exposed and the waterways vulnerable.

The watershed's troubles are compounded by the Kellersburg Anticline, which bisects the tributary. The local geology—with strata gently sloping south and east—has a bearing on the flow and accumulation of pollutants from old mining operations. These pollutants emerge from seeps and discharges, some of which originate from pre-Act mining operations and are thus considered nonpoint sources of pollution.

Figure 112: Moonlight Drive Subwatershed Context Map

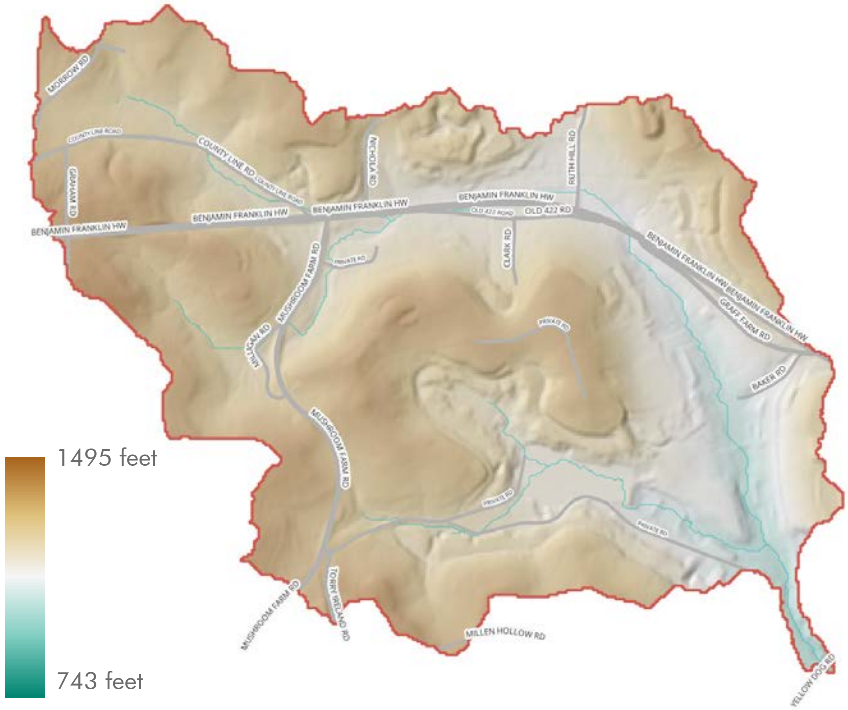


Addressing the challenges and leveraging the opportunities presented by the Moonlight Drive subwatershed requires a multifaceted approach. It calls for a thorough understanding of its location, inherent characteristics, and the historical influences that continue to shape its environmental narrative. The aim is to foster a sustainable coexistence between human activities and the natural environment, ensuring the health and vitality of the Buffalo Creek watershed for generations to come.

Terrain and Slope

The Moonlight Drive subwatershed presents a landscape where the interplay of terrain and slope distinctly influences the hydrological patterns and ecological functions. The terrain map (Figure 113) illustrates a varied topography with elevations that significantly affect water flow and soil distribution. The slope map (Figure 114) provides further insight into the character of the land. Green areas signify moderate slopes, where the incline is gentle enough to support various land uses, including agriculture, without significant risk of erosion. These slopes contribute to a stable environment, where the potential for land slippage and sediment displacement into watercourses is minimized. However, areas marked with red indicate very steep slopes, often exceeding a 50% gradient. These areas pose a higher risk of erosion and require careful management to prevent soil loss and the subsequent degradation of water quality in streams.

Figure 113: Terrain and Elevation Map



The interaction between the terrain's elevation and slope is crucial in defining the subwatershed's vulnerability to environmental stresses. Steeper slopes are more susceptible to the effects of heavy rainfall, leading to increased runoff and potential flooding, while flatter areas may facilitate better infiltration, contributing to groundwater recharge and lessening flood risks.

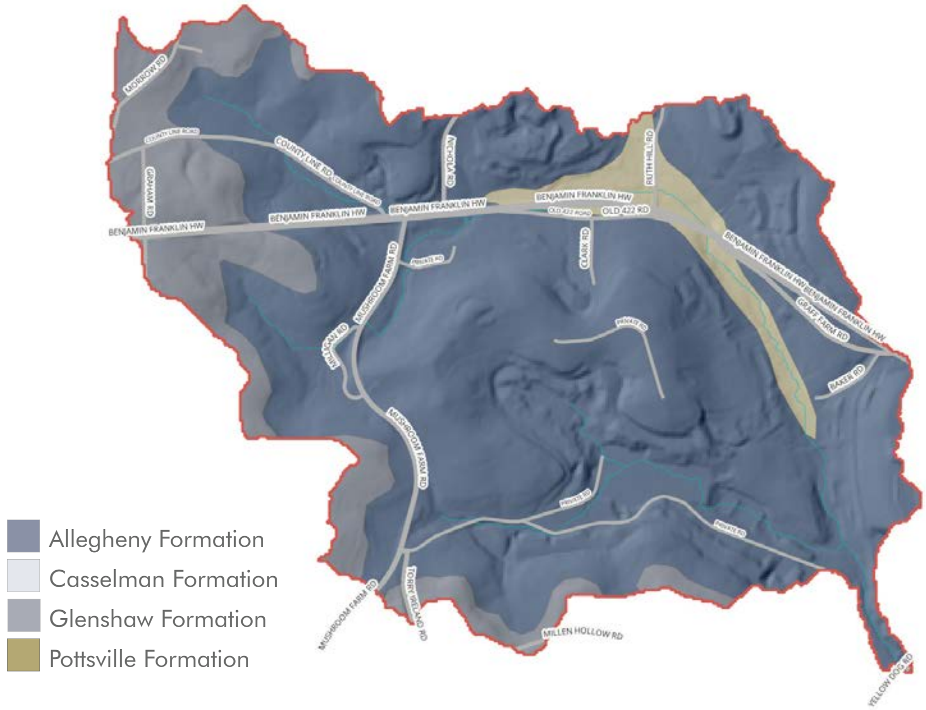
The combination of these factors—the terrain's elevations, the slopes, and the resulting patterns of water flow—shapes the hydrologic dynamics of the Moonlight Drive subwatershed. This understanding is vital for developing land use strategies and watershed management practices that respect the natural contours of the landscape, aiming to mitigate adverse effects on the subwatershed's water resources and overall ecological health.

Figure 114: Steep Slope Map

Bedrock Geology and Lithology

The Moonlight Drive subwatershed presents a varied geological landscape influenced by historical mining activities. The bedrock geology map (Figure 115) suggests the presence of predominant formations of sandstone and shale, which underpin the physical terrain and influence the hydrologic dynamics of the area. These sedimentary rocks, formed from ancient river deposits and marine sediments, are typically known for their permeability and porosity, factors that play a significant role in the movement of water and pollutants through the subwatershed.

Figure 115: Bedrock Geology Map



The historical context reveals that the area has a rich history of deep and surface mining, particularly on coal seams such as Upper Kittanning, Lower Kittanning, Clarion #2, Brookville, and Scrubgrass. The mining legacy has left an environmental footprint, notably in the form of acid mine drainage (AMD), which is a persistent water quality issue within the subwatershed. AMD arises when sulfide minerals in the exposed rock react with oxygen and water, leading to the formation of acidic runoff. This runoff can carry heavy metals like manganese, creating challenges for water quality management.

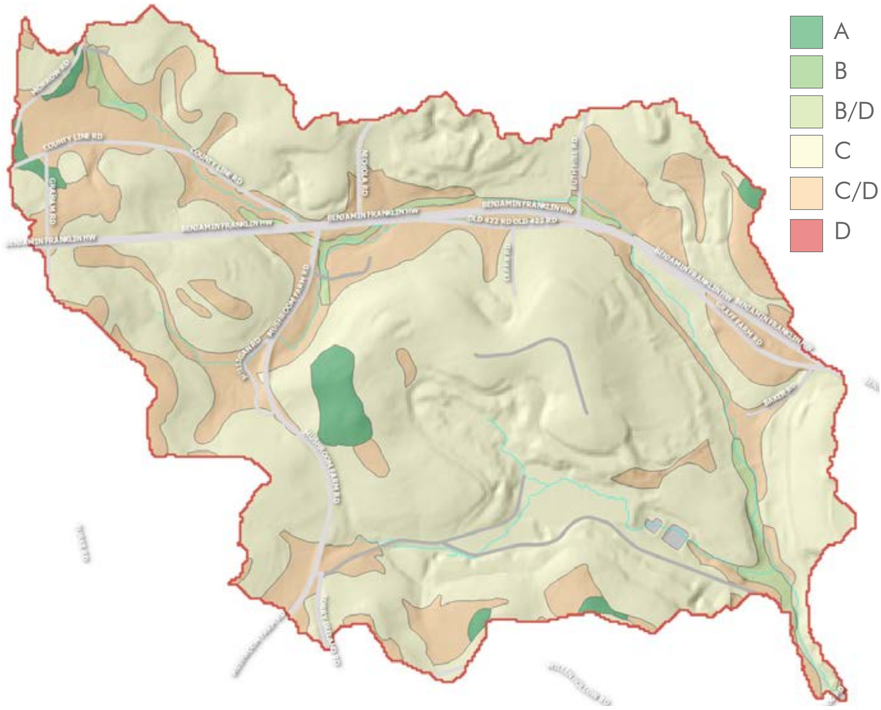
The geological makeup (Figure 116), with its sandstone and shale composition, has a dual influence on these environmental issues. While sandstone may offer pathways for drainage and potentially mitigate some surface water retention, shale can contribute to the formation of impermeable layers that hinder water flow, potentially exacerbating the concentration of pollutants. Furthermore, the presence of Vanport Limestone in the region's stratigraphy can act as a natural buffer to acid generation, providing a modicum of remediation to the AMD impacts if left undisturbed by mining activities.

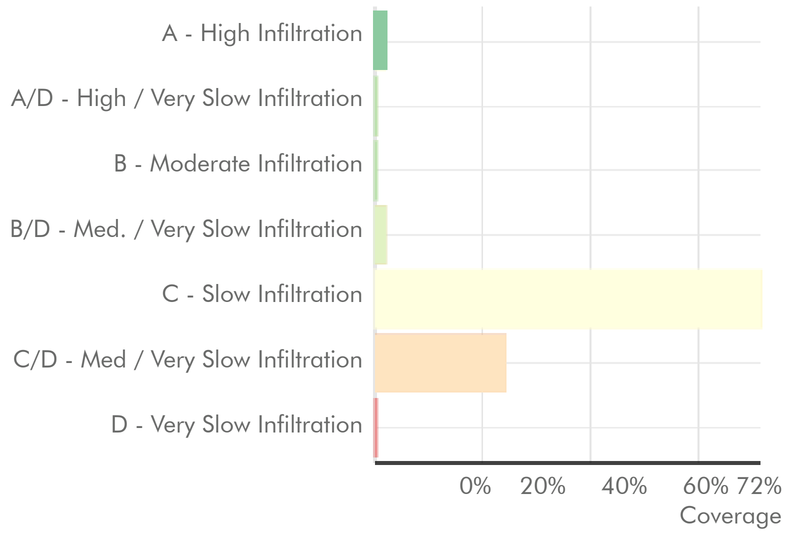
Figure 116: Bedrock Lithology Map

Soils

As shown in Figure 117, the Moonlight Drive subwatershed is characterized predominantly by Hydrologic Soil Group C, indicative of its clay-rich constitution that impedes water's subterranean passage. This slow infiltration capacity is mirrored by the second most prevalent, C/D soils, forming a landscape that is more susceptible to surface runoff and less amenable to water percolation.

Figure 117: Hydrologic Soils Group





The prevalence of these soil types plays a pivotal role in dictating the hydrological response of the watershed to precipitation events. During periods of rainfall, these soils' retentive nature curtails the swift absorption of water, predisposing the area to heightened runoff, which could escalate soil erosion risks and augment the sediment load in the fluvial systems. In the wake of historical mining activities, which have sculpted the region's topography and soil profile, the challenge of managing runoff is accentuated. The remnants of past extraction enterprises, primarily coal, have left an indelible mark on the soil's ability to handle and filter water effectively.

In light of these conditions, the WIP prioritizes interventions aimed at mitigating runoff and bolstering soil retention capacity. Such measures include the establishment of vegetative buffers that not only arrest the flow of sediments into streams but also serve as biofilters to attenuate the migration of potential pollutants. Additionally, the introduction of soil amendments, tailored recontouring efforts, and the strategic deployment of erosion control structures would contribute to soil stabilization and improved water quality.

The historical mining legacy also necessitates the incorporation of acid mine drainage (AMD) mitigation strategies into remediation efforts. Integrating passive treatment systems to neutralize acidity and remove metallic pollutants from water emanating from old mine workings is crucial for rehabilitating aquatic habitats and ensuring the health of the watershed.

Hydrology and Stream Impairments

The mapping of the watershed provides an essential understanding of the terrain's hydrologic characteristics and the impacts of historical industrial activities. Figure 118 illustrated the locations and extents of floodplains and wetlands. It showcases areas subject to a 1% annual chance of flooding, which are vital to consider in regional planning for flood mitigation and ecological conservation.

Figure 118: Floodplains and Wetlands

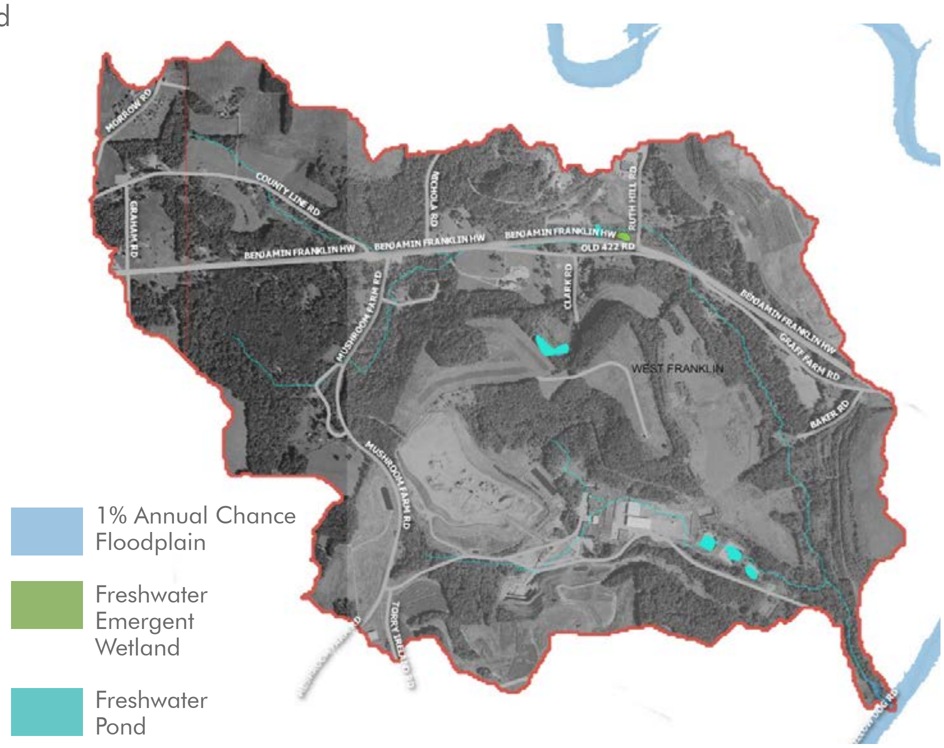
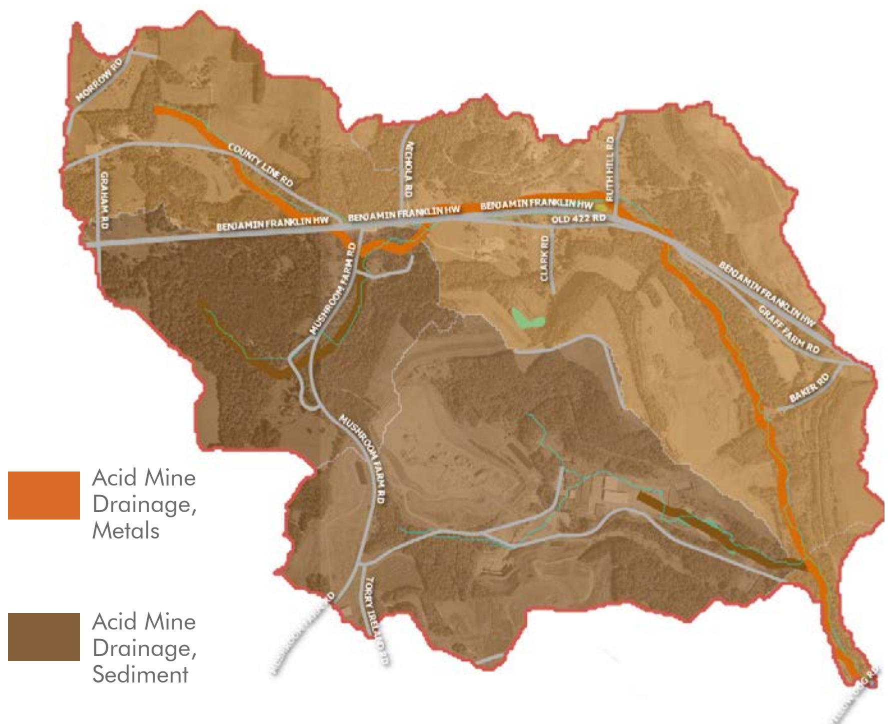


Figure 119 presents a more compelling story, focusing on the impaired streams within the watershed. It visually represents the troubling legacy of AMD, with regions highlighted where streams are failing to meet environmental quality standards. These areas are heavily influenced by the remnants of mining operations, as evidenced by the high levels of manganese and other pollutants. Figure 119 clearly indicates the locations of AMD from seeps and discharges, remnants of a time when mining was prevalent in the region, leaving a lasting mark on the watershed.

The dominant brown areas on the map, representing acid mine drainage and sediment, are a stark reminder of the enduring impact of abandoned mines. This aligns with historical data that identifies multiple abandoned deep mines and surface mining operations that have contributed to the watershed's current state. The identified non-attaining streams reflect the ongoing challenge to address the water quality issues and rehabilitate the watershed. These issues, underscored by the map, necessitate targeted and sustained efforts to remediate the affected areas, improve water quality, and restore the natural balance of the Buffalo Creek ecosystem. The length of stream that is impaired by AMD Metals and AMD Sediment per PaDEP is approximately 3.59 and 1.55 miles respectively, exclusive of smaller headwater tributaries.

Figure 119: Non-Attaining Stream and Documented Causes



Tree Canopy and Riparian Buffer

Figure 120: Tree Canopy Map

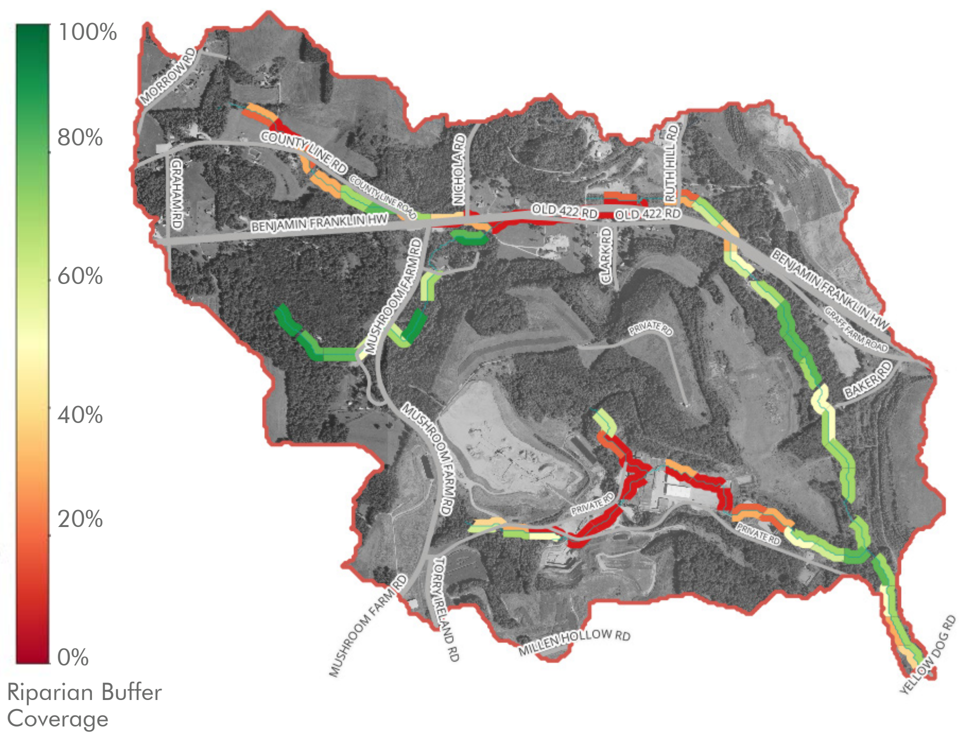
See Riparian Buffer Map for Legend

Current land uses within the watershed contribute to the pressure on the tree canopy and riparian buffers. Agriculture, forestland, and rural residential properties, alongside a few small communities, dominate the landscape. However, the historical impact of extensive strip mining and deep mining on various coal seams has left a lasting scar.

The tree canopy map, with areas of lush green indicating healthy vegetation and stark red areas where the canopy is absent, tells a story of contrast and the need for restoration. These red areas, where riparian buffers are completely depleted, are the most immediate concern for mitigation efforts. Replanting trees and reestablishing vegetation in these areas would not only help to filter pollutants before they reach waterways but also restore the habitat necessary for local wildlife and help to stabilize the soil, preventing further erosion and runoff issues.

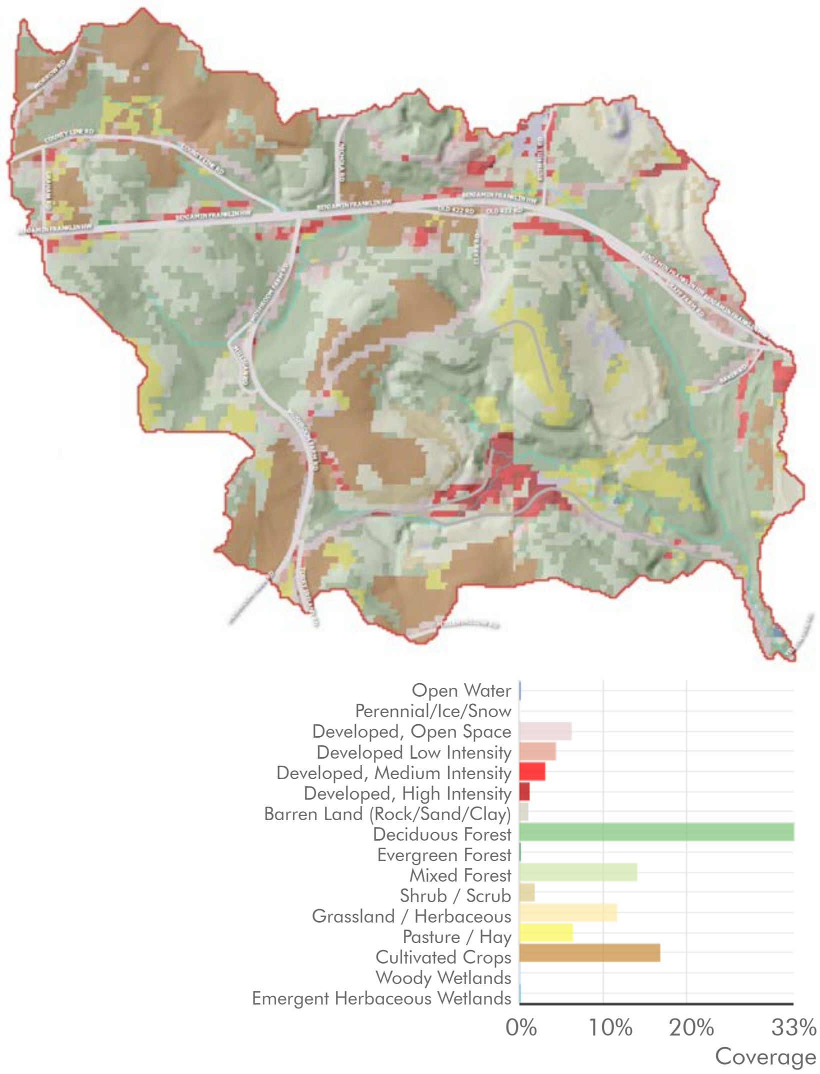
The goal moving forward for the Moonlight Drive subwatershed is to heal the wounds left by its industrial past, balancing the need for productive land use with the imperative of ecological restoration. Efforts will be centered on engaging with local stakeholders, including farmers and property owners, to foster sustainable land management practices that align with the overall health and recovery of the ecosystem.

Figure 121: Riparian Buffer Map



Land Cover

Figure 122: NLCD Land Cover (2019)



The Moonlight Drive subwatershed, depicted in the land cover data from the National Land Cover Database (NLCD) 2019 (Figure 122), presents a mosaic of various land uses. The dominance of cultivated crops, indicated by the expansive yellow areas, reflects the agricultural character of the subwatershed. These lands are pivotal for local food production but also require careful management to mitigate potential impacts on water quality through runoff and sedimentation.

The swathes of deciduous and mixed forests, shown in shades of green, provide essential ecological functions such as habitat for wildlife, carbon sequestration, and natural filtration of water. These forested areas are interspersed with patches of grassland and herbaceous cover, which can be associated with both natural meadows and managed fields or pastures.

Developed areas, rendered in tones of red and pink, mark the presence of human settlement and infrastructure. These areas, particularly those of high and medium intensity, are concentrated around roadways and population centers, creating potential zones of impervious surfaces that can contribute to stormwater runoff challenges.

Effective watershed management within the Moonlight Drive subwatershed will need to address these varied land uses. Conservation practices in agricultural areas, such as implementing cover crops and contour farming, can reduce erosion and nutrient loading. In developed areas, green infrastructure and stormwater management systems can help mitigate the impacts of impervious surfaces. Protecting and expanding forested areas can enhance ecological benefits and improve water quality. This integrated approach is essential for maintaining the balance between land use and water resource sustainability within the subwatershed.

Stream Water Quality Sampling and Testing

Macroinvertebrate Sampling, Spring 2023

Figure 123: Sampling Locations

The macroinvertebrate sampling from Oikos-4 within the Moonlight Drive subwatershed, conducted on May 4, 2023, provides an insight into the aquatic health and the challenges the ecosystem is currently facing. The sampling location is shown in Figure 123.

The data presents a concerning snapshot of the subwatershed's condition. The taxa richness was recorded at 16, which is significantly below the standard value of 33, yielding a standardized score of 48.48. The EPT richness, representing the presence of sensitive taxa, is notably low at 6, which is far from the standard of 19, indicating an environment that is not conducive to sensitive species. The Hilsenhoff biotic index is high at 5.27, suggesting that the water quality may be compromised, possibly due to organic pollution. This is further supported by the Shannon diversity index, which is only 1.33 compared to the standard of 2.86, indicating a low diversity and possible ecological imbalance. Additionally, the Percent Sensitive metric is at a mere 22.12, drastically lower than the standard of 84.5, reflecting the absence of organisms that are sensitive to pollution. The overall IBI score for the subwatershed stands at a mere 40.00, classifying it as impaired.

The dominance of taxa such as Chironomidae, which are typically more tolerant to pollution, and the low numbers of Ephemeroptera, which are more sensitive, point towards a stressed ecosystem. The presence of iron precipitate on the macroinvertebrates is a clear indicator of water quality issues, likely linked to acidification or metal contamination.

The 2023 data for Oikos 4 on Moonlight Drive subwatershed reveals an environment under significant ecological strain. The low IBI score and the associated metrics highlight the need for immediate remedial actions to address the water quality and to protect the biodiversity within the subwatershed. Efforts should include investigating the sources of pollution, especially those contributing to acidification and metal deposits, and implementing measures to mitigate these impacts. Restoration efforts may also be necessary to

Figure 124: Sampling Location Photo

rebuild a healthy, diverse, and resilient macroinvertebrate community. Continued monitoring will be essential to track the effectiveness of these interventions and to make adaptive management decisions.

Laboratory Water Quality Sampling, Spring 2023

The laboratory results from the Moonlight Drive subwatershed reveal several chemical parameters that are key indicators of water quality:

- The pH level was measured at 7.74, which is within the acceptable range for most aquatic organisms, indicating a relatively neutral water environment.
- Phosphorus concentrations were at the detection limit of 0.10 mg/L. While not indicative of excessive levels, consistent monitoring is essential to prevent potential eutrophication.
- Total Kjeldahl Nitrogen was below detectable levels, suggesting minimal input from organic sources.
- Nitrate+Nitrite Nitrogen was recorded at 0.60 mg/L, which is three times the detection limit but not excessively high; however, it warrants attention for potential agricultural runoff influences.
- Total Nitrogen was also below the detection limit, corroborating the lower levels of nitrogen compounds in the water.
- Total Suspended Solids were relatively high at 60 mg/L, which could indicate some level of sediment disturbance affecting the subwatershed.

Stream Water Quality Findings

The integration of macroinvertebrate sampling data with the chemical water quality results from Oikos-4 paints a picture of a subwatershed grappling with environmental stressors. While the pH levels are stable, the presence of iron precipitate on organisms and the low diversity and abundance of sensitive taxa suggest underlying issues with water quality, possibly linked to organic pollution or acidification.

The laboratory results show that, in general, nutrient levels are not alarmingly high, but the higher total suspended solids point towards sedimentation that could be impacting habitat quality. The low IBI score and the corresponding biological metrics underscore the impaired status of the subwatershed, necessitating immediate and strategic intervention.

Remediation efforts should focus on identifying and mitigating sources of pollution, particularly those affecting acidification and sedimentation. Restoration initiatives could include establishing vegetative buffers, improving land use practices, and enhancing water filtration systems to reduce the entry of pollutants into the stream. Ongoing monitoring of both water chemistry and biological communities will be critical to evaluate the impact of these measures and to ensure the recovery and maintenance of the Moonlight Drive subwatershed's ecological integrity.

Watershed Analysis

In order to thoroughly understand the spatial distribution of land cover impacts to the Moonlight Drive subwatershed, a higher resolution terrain analysis was performed within the larger study area to create five (5) distinct “microsheds” within the Moonlight Drive subwatershed. This higher resolution study was performed using a 20,000 pixel flow accumulation threshold, which equates to a maximum size of approximately 0.77 square miles per microshed using a 10-m Digital Terrain Model.

Current Sediment and Nutrient Loading

Table 33 and 34 offer a summary of existing pollutant load for Sediment, Total Nitrogen and Total Phosphorus for the entire Moonlight Drive subwatershed, aggregated by land cover and summarized overall.

The most significant sources of sediment pollution within the Moonlight Drive subwatershed are cropland, hay/pasture, stream bank erosion, and Open Land. These observations about pollutant sources are consistent across GIS land cover analyses, aerial imagery and site visits.

Table 33: Average Annual Pollutant Loads, by Land Cover

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	103,555.6	303.4	103.0
Cropland	405,826.2	1,544.3	417.0
Wooded Areas	2,382.7	46.5	4.2
Wetlands	0.0	0.0	0.0
Open Land	48,563.7	225.3	45.0
Barren Areas	38.2	5.5	0.2
Low-Density Mixed	791.0	21.6	2.3
Medium-Density Mixed	3,563.5	76.1	7.8
High-Density Mixed	1,422.0	30.4	3.1
Low-Density Open Space	1,130.1	30.8	3.2
Farm Animals	0.0	293.1	70.3
Stream Bank Erosion	49,919.3	33.1	11.0
Subsurface Flow	0.0	1,422.8	57.7
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	163.4	0.0

Table 34: Average Annual Loads from 30-years of Daily Fluxes

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	617,192.2	4,196.3	724.9
Loading Rates (lb/ac)	372.07	2.53	0.44
Mean Annual Concentration (mg/L)	121.89	0.83	0.14
Mean Low-Flow Concentration (mg/L)	1,027.49	5.42	1.35

Mean Flow: 81,107,465 (ft^3/year) and 2.57 (ft^3/s)

As depicted in Figures 125 through 127, the Moonlight Drive subwatershed has been segmented into five microsheds to pinpoint the origin and distribution of pollutants across the landscape. Microshed 17, situated at the westernmost boundary, demonstrates notable concentrations of all three pollutants. The dominant agricultural practices in this area are likely contributing to the heightened levels, with runoff carrying both nutrients and soil particles into the waterways. Such patterns call for targeted interventions, possibly including buffer zones and revised farming methods to mitigate runoff.

Also worth noting is Microshed 14, which sits on the grounds of the former mushroom farming venture, now repurposed for limestone extraction by Allegheny Mineral. The pollutant readings here are moderate, but these figures may not paint the full picture. The NLCD 2019 land cover data is based on a snapshot in time when the plant was not yet fully operational and modeling software in use, ModelMyWatershed, lacks the capability to account for the full environmental impact of active mining operations. The classification of this land as a mixture of cropland, grassland, and limited barren land cover does not quite account for the potentially significant soil disturbance and potential sedimentation resulting from the mining processes. Sediment load, in particular, may be underestimated within the microshed.

Figure 125:
Total Sediment, Pollutant Concentration

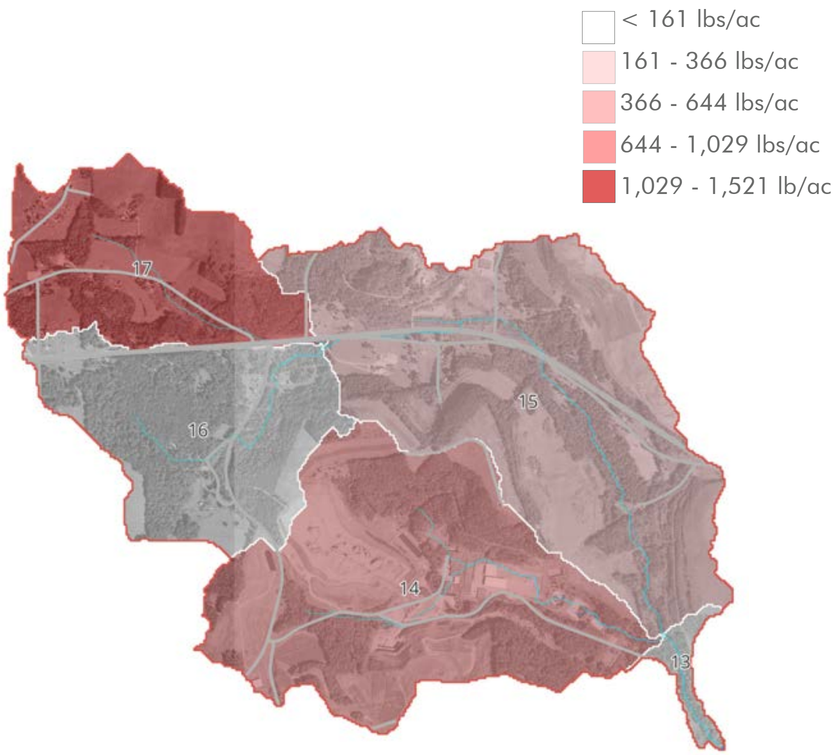


Figure 126:
Total Phosphorus, Pollutant Concentration

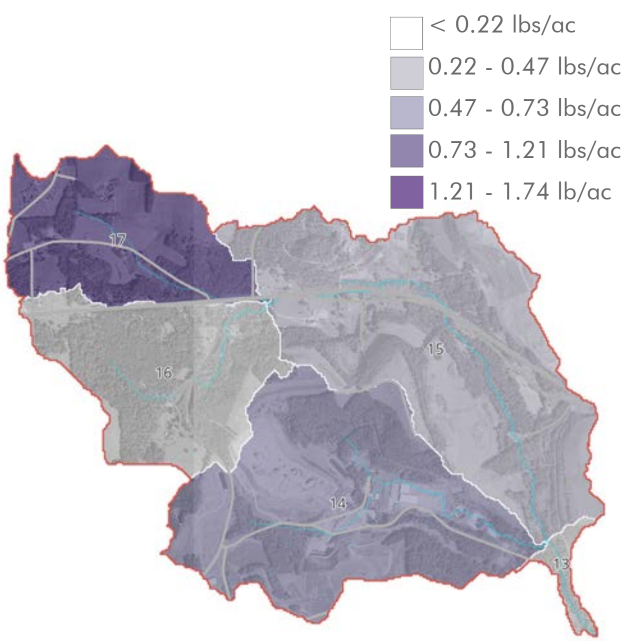
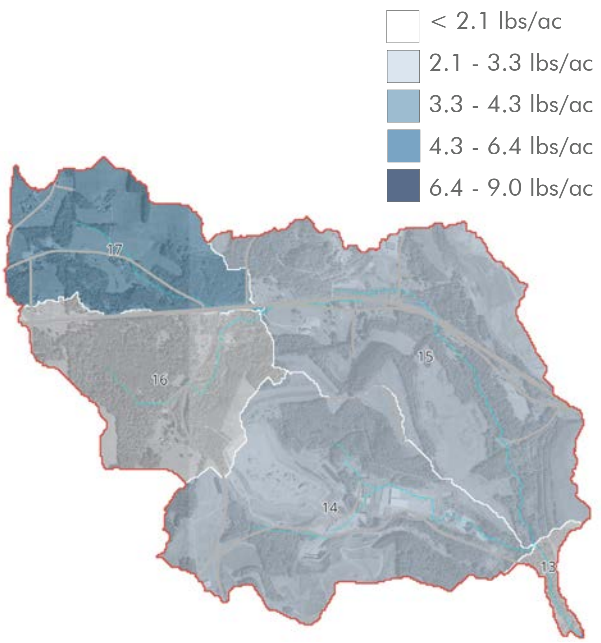


Figure 127:
Total Nitrogen Pollutant Concentration



Summary of Riparian Buffer Opportunities

Per the NHD High Resolution Stream Network dataset, there is a total of 4.32 miles (22,810 feet) of first order and second order streams located within the Moonlight Drive watershed. Our more detailed terrain analysis - which tends to reveal perennial, ephemeral, and tile-drained, buried streams that still have drainage path signatures - yielded slightly higher results, indicating that 5.24 miles (27,691 feet) of stream exist. This equates to approximately 127 acres of existing and potential future riparian buffer area, assuming one hundred (100) feet of buffer width on each stream bank. Based on the more detailed data set, the following was derived by geospatial analysis:

Table 35: Riparian Buffer Opportunities

Land Cover	Riparian Buffer Coverage (Acres) and Degradation Level			
	0-20%, Critical	20-40%, Severe	40-60%, Moderate	60%-80%, Minor
Deciduous Forest	6.30	9.70	12.54	33.90
Cultivated Crops	6.05	1.63	-	-
Developed, Open Space	3.38	2.12	3.60	1.46
Grassland / Herbaceous	4.64	1.45	0.22	0.32
Pasture / Hay	5.78	1.01	2.12	1.07
Open Water	-	0.22	-	0.30
Barren Land (Rock/Sand)	0.07	-	-	-
Developed, Low Intensity	7.80	0.79	0.95	1.20
Developed, Medium Intensity	4.91	2.03	0.22	0.52
Developed, High Intensity	3.74			
Mixed Forest	1.43	1.16	1.75	2.47
Shrub / Scrub	-	0.02	-	-
Total:	44.73	20.13	21.40	41.24
High Priority (Red) *:	22.50	4.45	-	-
Medium Priority (Yellow) **:	13.87	4.58	-	-

** The light red shaded cells in Table 35, indicating cultivated crops and developed areas, are key areas for watershed improvement due to their high pollutant loads, with roads and areas near unbuffered, partially incised streams being prime candidates for restoration and stabilization.*

*** Yellow shaded cells in the analysis represent areas where pollution significance is uncertain without further field data. Open spaces, grasslands, and pastures might be high pollutant sources if used for livestock grazing without adequate buffers and fencing, or conversely, could be effectively managed as grass riparian buffers, acting as existing Best Management Practices. Direct engagement with landowners is recommended for accurate assessment.*

Table 35 indicates that nearly 47 acres are potentially available for restoration of critically to severely degraded riparian buffers throughout the watershed.

Figure 128: Riparian Buffer Restoration Opportunity along Township Road T570 near Thee Punk Road

Special Consideration for Riparian Buffers

Figure 129: Flow Accumulation Along Riparian Buffers

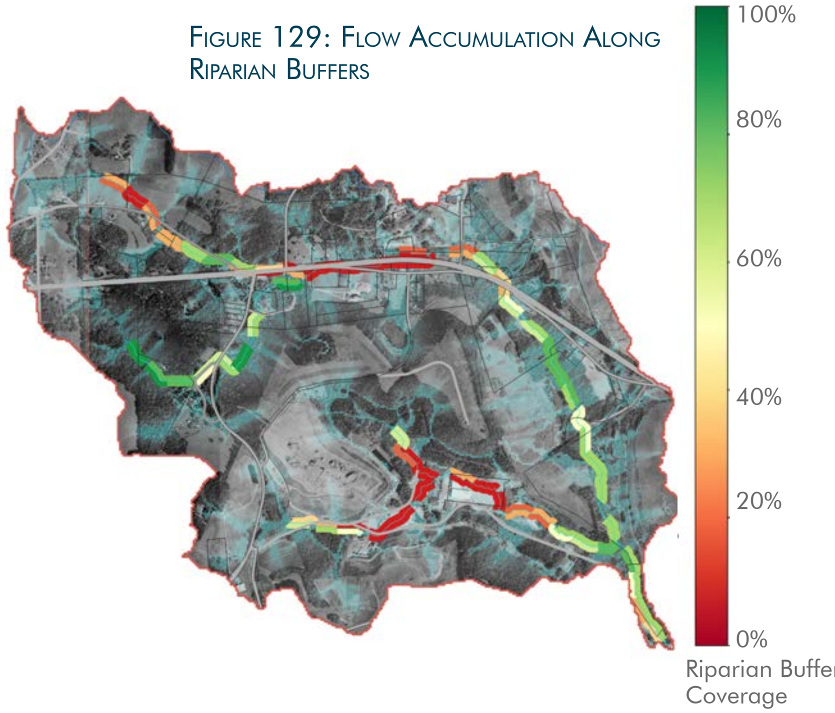


Figure 129 depicts areas of high flow concentration within the Moonlight Drive subwatershed. Where these pollutant-laden high flows drain to areas of depleted riparian buffer (Figure 129, shown in red), there is greater opportunity for stream water quality improvement.

As the image shows, the areas of critically and severely riparian buffer are located in three (3) specific locations - to the south in close proximity to the Bison Plant owned by Allegheny Mineral; directly along the Benjamin Franklin Highway (Route 422) to the north; and within the most western headwaters tributary along Township Road T570. Of these locations, the T570 restoration opportunity (Figure 128) presents the most conventional and feasible model for successful landowner engagement and implementation. This area is primarily cropland and grazing land, with partial grass buffer established and consistently wet, muddy conditions where the natural stream is infringed upon by agricultural activities.

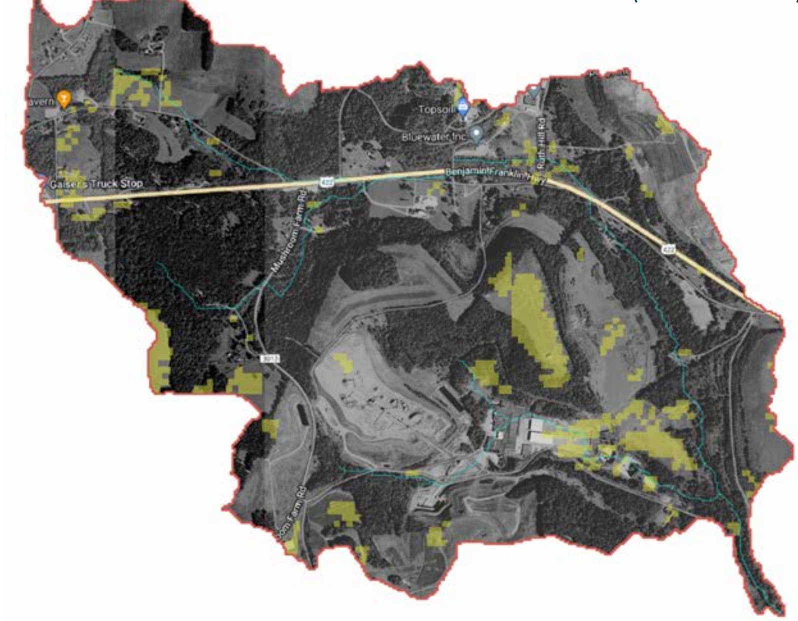
The area along Route 28 also has potential, albeit limited. Although the riparian buffer mapping suggests a substantial disturbance, much of the historic stream is either culverted or substantially displaced by the construction of the highway. There are, however, sparse areas where limited-width riparian buffer could be established and would serve an important ecological function related to reducing sediment, hydrocarbons and other pollutants from transportation infrastructure and vehicles.

The industrial interests and large-scale earth disturbance activities at the Bison Plant would be a substantial barrier to restoring the riparian buffers in this area (Figure 130). When Allegheny Mineral acquired the land holdings from the previous mushroom farming operation and opened the Bison Plant in 2017, substantial earthwork occurred in the tributary headwaters to establish the renewed limestone extraction activities in the previously abandoned mined area. Based on an October 2022 article in Pit & Quarry online magazine, the Bison Plant was built with a capability of producing between 1 and 1.5 million tons per year of extracted limestone aggregate, and is twice the size of their nearby Worthington Plant.

Figure 130: Location of Headwaters Relative to Bison Plant Mine Entrance

Streambank Restoration and Exclusionary Fencing Opportunities

Figure 131: Hay/Pasture (NLCD 2019)



As depicted in Figure 131, there is only about 7 acres of critically or severely degraded riparian buffer areas within mapped hay / pasture land throughout the Moonlight Drive subwatershed, and 10 acres overall. While there is little evidence of exclusionary fencing within these areas based on site observations, the opportunity to substantially improve water quality through the use of grazing land BMPs seems to be limited.

That said, the aforementioned 7 acres of critically or severely degraded riparian buffer equates to approximately 3,050 linear feet (0.55 miles) of opportunity for new exclusionary fencing within the Moonlight Drive subwatershed, in addition to the 7 acres of potential riparian buffer restoration opportunity.

Given that the vast percentage of streams are generally difficult to access due to industrialization, wooded cover, and terrain limitations, the opportunities for streambank restoration appear to be limited for the purposes of the future remediation efforts, except in low- to medium density developed and existing agricultural areas. Based on the riparian buffer study presented previously, this equates there are approximately 9,800 feet (1.85 miles) of unbuffered streambank within low- to medium-density developed or agricultural areas, where streambank restoration may be appropriate. Further site investigation and engagement with landowners would be necessary to identify specific restoration opportunities within the subwatershed.

Opportunities Related to Legacy Acid Mine Drainage

Watershed groups and community stakeholders are the backbone of restoration, providing local knowledge, volunteer support, and a passion for environmental stewardship. Across Pennsylvania and locally, these groups, have a track record of monitoring water quality, funding, and implementing grassroots conservation projects. Their ongoing efforts to educate the community, conduct stream clean-ups, restore native vegetation, and develop remediation projects contribute significantly to reducing AMD impacts.

Continued partnerships with academic institutions, such as Duquesne University, can further bolster remediation efforts through research and the development of innovative yet practical AMD treatment solutions. Engaging students and faculty offers the dual benefit of educational opportunities and continued technical support with regard to water quality sampling and testing.

Local landowners and businesses also play a crucial role in future restoration efforts. By promoting BMPs such as buffer strip planting and proper land management, they can reduce the runoff and sedimentation that exacerbate AMD conditions. This will, of course, require future engagement by watershed stakeholder and funding sources to support new projects and initiatives.

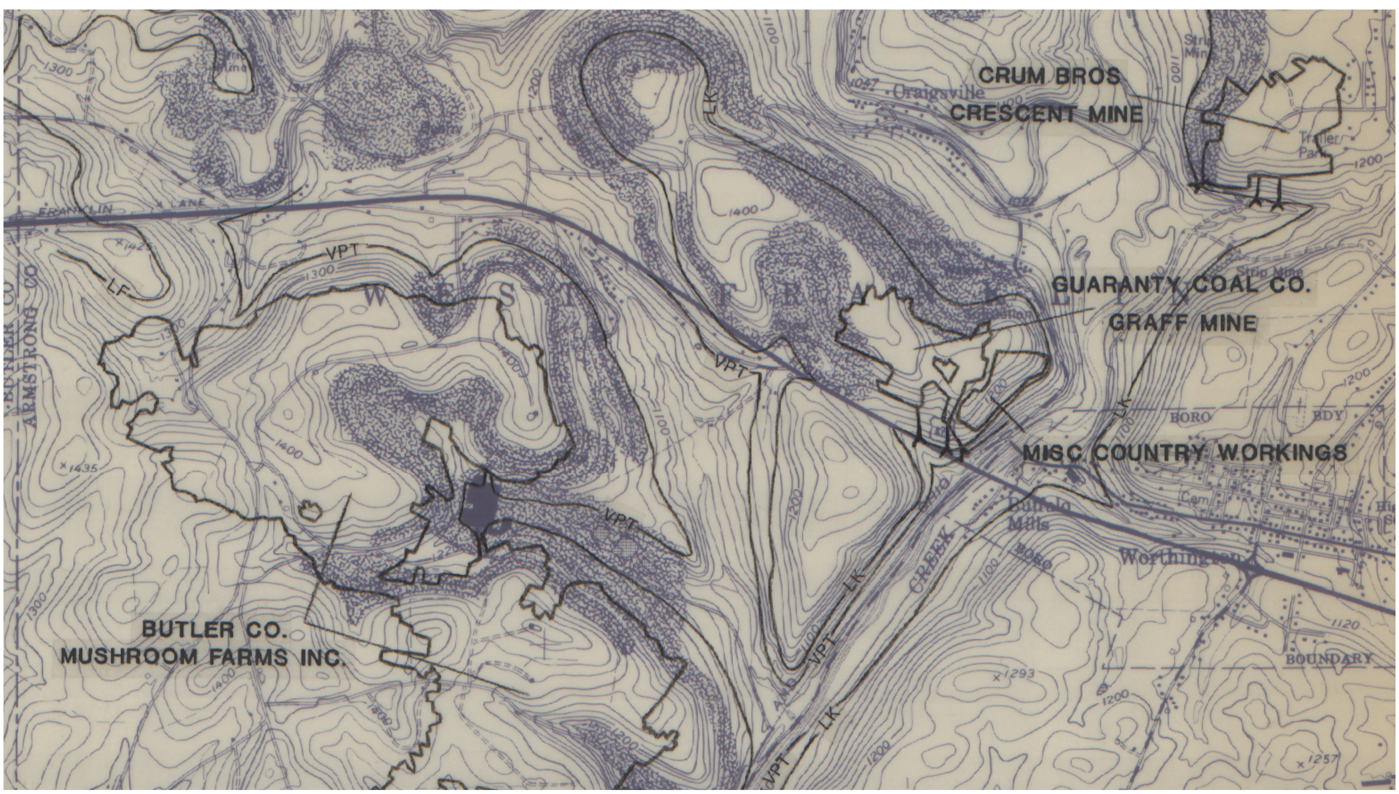
Lastly, collaboration with state and federal agencies can provide access to technical resources and funding opportunities for AMD remediation. Through these partnerships, future remediation efforts can leverage existing programs and resources to implement well-established treatment methods, ensuring that the subwatershed's water quality improves in alignment with state water quality standards and the Clean Water Act.

Collaboration Opportunities with Current Resource Extraction Operations

The environmental health of the Moonlight Drive subwatershed and the larger Buffalo Creek are a substantial concern, particularly due to historical mining activities that have contributed to AMD and stream water quality issues. In alignment with the TMDL recommendations provided by PaDEP, there are potential opportunities for collaborative remediation efforts WIP partners and the active limestone mining operations conducted by Allegheny Mineral at the Bison Plant Mine site.

Notably, there do appear to be several treatment ponds already in operations at the Bison Plant mine. These ponds are in the same locations as legacy treatment ponds that were used during previous operations, but appear to have been refreshed with new limestone material and perhaps otherwise

Figure 132: Historic Mine Map



modified to improve performance when Allegheny Mineral began operations a few years ago. At this time, it is not known if these ponds are effectively improving water quality above the baseline conditions identified in the TMDL, or if they are simply offsetting additional pollutants introduced by the new plant operations. However, PaDEP has indicated to us that these are not operating to improve water quality as part of any TMDL remediation efforts. Because this is still somewhat of a data gap, this WIP proposes both engagement opportunities with the plant operators to foster a future working relationship plus learn more about their operations, and recommends funding for future water quality sampling and testing to assess the AMD-related water quality trends over the next decade. All that said, it is worth noting that there appear to be two significant sources of legacy AMD water quality pollutant sources in this specific location - one from the stream tributary on which the Bison Plant ponds are located and another immediately downstream, from a formally decommissioned mine - an abandoned section of the Graff Mine operations immediately to the north. It is likely that Allegheny Mineral has no land control here, nor responsibility to manage this second potential AMD source. There is also very limited land available in this area for passive AMD treatment systems, as it is located very close to the mouth of the tributary, with little flat open space surrounding.

Assuming that Allegheny Mineral and/or the owner of the Graff Mines are willing partners for later collaboration and assuming that suitable land or a compact design can be identified for future AMD facilities, this WIP includes funding for a significant AMD treatment facility. Additional study of the area is required to understand better the siting and the collaborative relationships, if any. If there is not suitable space on the mining operation properties, it is our assumption that these facilities may be potentially located along Moonlight Drive, or perhaps even outside of the target watershed, immediately downstream and potentially parallel to the main stem of Buffalo Creek. Additional stakeholder engagement and site investigation is needed.

There is also a second potential collaboration opportunity with Allegheny Minerals that seems to exist, with a somewhat unconventional approach. Commercial limestone mining operations typically do not backfill mines with the same high-quality limestone that’s being extracted for sale. Instead, they often use overburden (the rock and soil overlying a mineral deposit) or sometimes lower-quality limestone that is not suitable for commercial use as backfill material within mine sites that they are remediating. If the lower-quality limestone could be preferentially used as backfill in parallel with profitable operations, the efforts would be consistent with environmentally-responsible mining practices and could potentially be part of an effort to address legacy AMD issues in accordance with PaDEP recommendations.

If Allegheny Mineral was amendable to adjusting operations to backfill with the limestone that isn’t suitable for a commercial market but is effective for water quality remediation, this would serve both commercial purposes and also offer a strategic advantage in the realm of environmental stewardship. Furthermore, there is potential for fruitful collaboration with ASWP, other Buffalo Creek Coalition partners, and regional conservation organizations. Such a partnership could provide additional expertise, resources, and community engagement that are critical for the success of the watershed’s restoration efforts. Allegheny Mineral’s active role in this process could serve as a model for integrating commercial activities with environmental remediation efforts. Regular consultations with PaDEP and the mentioned partners would ensure that the mining operations are not only compliant with regulatory standards but also contribute positively to the restoration and preservation of the subwatershed.

Acid Mine Drainage Remediation Adjacent to the Study Area

The image below is a significant AMD discharge through the limestone cliffs, located immediately off Craigsville Road, and adjacent to the Benjamin Franklin Highway overpass. Although this discharge point is not within any of the five (5) WIP study areas, it does discharge to the Buffalo Creek main stem only about 600 feet from the mouth of the Worthington subwatershed and about a mile upstream of the Moonlight Drive mouth. Equally significant, it appears to discharge from the same legacy mine system that contributes to the Moonlight Drive subwatershed AMD impairments and necessitated the TMDL on the unnamed tributaries within. Although addressing this legacy impairment as part of this WIP would not help to delist the target streams, it would have an offsetting positive impact to Buffalo Creek, effectively treating a different discharge from the same AMD source. For this reason, and because the available land appears to be both accessible and feasible for siting of a future passive treatment system, it is recommended that 319(h) funding be pursued to support additional sampling and assessment efforts. These efforts will help better characterize the nature and extent of AMD impacts and build the scientific and technical foundation required to pursue implementation funding from other sources. While AMD remediation is not a primary focus of this WIP and is not proposed for immediate 319 implementation funding, it is included here to guide long-term water quality improvement planning in the Moonlight Drive subwatershed.

One compelling aspect of this potential AMD remediation site is that it already naturally mimics the first few stages of a conventional passive treatment system - a potential cost savings in any future design efforts. The images to the left below are of the Wingfield Pines AMD treatment system - an aerial overview and an image of the first treatment stages, aeration and Settling Pond 1. Located along Chartiers Creek in Upper Saint Clair and South Fayette in Allegheny County, the Wingfield Pines site was a former strip mine and golf club. It was acquired by Allegheny Land Trust in 2001, and the constructed AMD treatment and wetland system has been in operations since 2009, treating approximately 1,500 to 2,000 gallons per minute of iron-laden mine discharge.

Of particular interest to this WIP are the functional similarities between the first treatment stage of Wingfield Pines and the AMD seep photo shown to the following page. The cascading of iron-rich runoff down the limestone cliff at the Buffalo Creek site aerates the drainage in much the same way as the perforated distribution pipes at Wingfield Pines do. There is no settling pond at the Buffalo Creek site, of course. However, at the base of the cliff, the pile-up of precipitate is readily visible, collected and impounded in much the same way as the settling ponds would at Wingfield Pines.

In short, there may be an opportunity to build upon the naturally occurring systems at the Buffalo Creek site to further encourage the AMD precipitate to fall out of solution, sequester the precipitate for regular removal, and buffer the acidic discharge through additional treatment and polishing stages prior to discharge into the Buffalo Creek main step a few hundred yards away.

This WIP includes provisions for additional water quality sampling, for design, and for construction of a new passive treatment system in this location.

Implementation Plan, Moonlight Drive Subwatershed

Summary of Watershed Implementation Needs and Pollutant Loading Targets

Based in guidance documents for selecting reference watersheds for TMDL assessment and ongoing dialogue with PaDEP, a 2.63 square mile, headwaters portion of Long Run - located within the Traverse Creek HUC-12 watershed - was chosen for this project as the reference watershed and pollutant loading target for the Moonlight Drive subwatershed. Note that loading rate is used to calculate pollutant targets, rather than total loads. Please refer to Appendix B for the more detailed reference watershed assessment. The following is a summary of key characteristics of Moonlight Drive subwatershed and the Long Run reference watershed:

Watershed Area

1,198 acres

Sediment

Loading Rate, Moonlight Drive Subwatershed: 0.186 tons/acre
Loading Rate, Reference Watershed: 0.136 tons/acre

Pollutant Loading Target based on Loading Rate, Sediment: 60 tons per year
Pollutant Load Reduction Target, Sediment: 323 tons per year (without safety factor)
Pollutant Load Reduction Target, Sediment, 290 tons per year (with 10% safety factor)

Total Phosphorus

Loading Rate, Moonlight Drive Subwatershed: 0.44 lb/acre
Loading Rate, Reference Watershed: 0.37 lb/acre

Pollutant Loading Target based on Loading Rate, Phosphorus: 84 lbs per year
Pollutant Load Reduction Target, Phosphorus: 784 lbs per year (without safety factor)
Pollutant Load Reduction Target, Phosphorus: 706 lbs per year (with 10% safety factor)

Total Nitrogen

Loading Rate, Moonlight Drive Subwatershed: 2.53 lb/acre
Loading Rate, Reference Watershed: 2.09 lb/acre

Pollutant Loading Target based on Loading Rate, Nitrogen: 527 lbs per year
Pollutant Load Reduction Target, Nitrogen: 4,726 lbs per year (without safety factor)
Pollutant Load Reduction Target, Nitrogen: 4,253 lbs per year (with 10% safety factor)

Implementation Plans and Projects

Based on the suite of opportunities described previously and the target pollutant loads established, the following list of BMPs and potential projects were identified for the Moonlight Drive subwatershed:

Table 36: Proposed Best Management Practices, Moonlight Drive Subwatershed

BMPS	Units	Available	% Proposed	Amount Proposed	Proposed Reduction		
					S (tons)	P (lbs)	N (lbs)
Riparian Buffer & Stream Restoration							
Forested Buffer	acres	128	20%	26	37	65.4	393.8
Grass Buffer	acres	128	30%	38	50	89.4	429.6
Streambank Stabilization (each bank)	feet	25,269	2%	505	29	87.9	97.0
Streambank Exclusionary Fencing	acres	10	10%	1	1	1.4	6.8
Land Conversion							
Cropland Retirement	acres	152	2%	3	2	3.8	13.2
Agricultural Land Management							
Water and Soil Conservation Planning	acres	279	10%	28	5	6.3	12.4
Cover Crops	acres	152	10%	15	1	0.9	18.5
Contour Farming / Strip Cropping	acres	152	10%	15	3	3.4	6.7
Conservation Tillage	acres	152	10%	15	9	12.5	11.7
Nutrient Management	acres	279	10%	28	-	2.1	7.1
Grazing Land Management	acres	106	10%	11	2	2.5	2.7
Developed Areas							
Passive Acid Mine Drainage Treatment	acres	6	100%	6	-	-	-

	S Loading (tons)	P Loading (lbs)	N Loading (lbs)
Total Proposed Reduction	138	276	1,000
Current Loading	451	1,126	5,732
Proposed Loading	314	850	4,732
Target Loading Goal	290	706	4,253
Percent Above/Below Goal	3%	-9%	0%

Table 37: Best Management Practices, Cost Summary (Base Year 2025)

BMPS		Units	Quantity	Unit Cost, Capital	Total Cost, Capital	Unit Cost, O&M	Total Cost, O&M
Riparian Buffer & Stream Restoration							
	Forested Buffer	acres	26	$6,409.19	$163,434.24	$104.89	$2,674.74
	Grass Buffer	acres	38	$1,418.57	$54,260.23	$46.44	$1,776.19
	Streambank Stabilization	feet	505	$809.73	$409,222.29	$82.83	$41,860.34
	Streambank Exclusionary Fencing	acres	1.0	$21,345.12	$21,302.43	$715.97	$714.54
Land Conversion							
	Cropland Retirement	acres	3	$173.85	$526.81	$6.74	$20.42
Agricultural Land Management							
	Water and Soil Conservation Planning	acres	28	$24.91	$695.02	$-	$-
	Cover Crops	acres	15	$75.50	$1,143.92	$75.50	$1,143.92
	Contour Farming / Strip Cropping	acres	15	$1.61	$24.39	$1.61	$24.39
	Conservation Tillage	acres	15	$18.73	$283.78	$18.73	$283.78
	Nutrient Management	acres	28	$27.96	$780.02	$5.29	$147.68
	Grazing Land Management	acres	11	$81.27	$862.87	$81.27	$862.87
Developed Areas							
	Passive Acid Mine Drainage Treatment	acres	6.00	$59,908.21	$359,449.25	$293.49	$1,760.94
			Total		$772,352		$50,096

10-Year Watershed Implementation Plans for the Moonlight Drive Subwatershed

Based on the Base Year 2025 values provided below, the proposed 10-year WIP for the Moonlight Drive Subwatershed is as follows:

Table 38: Years 1 Through 5 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 1		Year 2		Year 3		Year 4		Year 5	
	2025		2026		2027		2028		2029	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$16,343	$267	$16,960	$555	$17,599	$864	$18,262	$1,196	$18,951	$1,551
Grass Buffer	$5,426	$178	$5,631	$369	$5,843	$574	$6,063	$794	$6,292	$1,030
Streambank Stabilization (each bank)	$40,922	$4,186	$42,465	$8,688	$44,066	$13,523	$45,727	$18,710	$47,451	$24,269
Streambank Exclusionary Fencing	$2,130	$71	$2,211	$148	$2,294	$231	$2,380	$319	$2,470	$414
Land Conversion										
Cropland Retirement	$53	$2	$55	$4	$57	$7	$59	$9	$61	$12
Agricultural Land Management										
Water and Soil Conservation Planning	$70	$-	$72	$-	$75	$-	$78	$-	$81	$-
Cover Crops	$114	$114	$119	$237	$123	$370	$128	$511	$133	$663
Contour Farming / Strip Cropping	$2	$2	$3	$5	$3	$8	$3	$11	$3	$14
Conservation Tillage	$28	$28	$29	$59	$31	$92	$32	$127	$33	$165
Nutrient Management	$78	$15	$81	$31	$84	$48	$87	$66	$90	$86
Grazing Land Management	$86	$86	$90	$179	$93	$279	$96	$386	$100	$500
Developed Land										
Passive Acid Mine Drainage Treatment	$35,945	$176	$35,945	$365	$38,706	$569	$40,165	$787	$41,680	$1,021
SUBTOTALS	$101,199	$5,127	$103,659	$10,641	$108,973	$16,563	$113,081	$22,916	$117,344	$29,725
BY YEAR		$106,326		$114,299		$125,535		$135,997		$147,069

Table 39: Years 6 Through 10 (Capital Cost and Operations / Maintenance)

Projects / Opportunities	Year 6		Year 7		Year 8		Year 9		Year 10	
	2030		2031		2032		2033		2034	
	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M	Capital	O&M
Riparian Buffer & Stream Restoration										
Forested Buffer	$19,665	$1,931	$20,407	$2,338	$21,176	$2,773	$21,974	$3,237	$22,803	$3,732
Grass Buffer	$6,529	$1,282	$6,775	$1,552	$7,030	$1,841	$7,296	$2,149	$7,571	$2,478
Streambank Stabilization (each bank)	$49,240	$30,221	$51,096	$36,587	$53,023	$43,391	$55,022	$50,655	$57,096	$58,405
Streambank Exclusionary Fencing	$2,563	$516	$2,660	$625	$2,760	$741	$2,864	$865	$2,972	$997
Land Conversion										
Cropland Retirement	$63	$15	$66	$18	$68	$21	$71	$25	$74	$28
Agricultural Land Management										
Water and Soil Conservation Planning	$84	$-	$87	$-	$90	$-	$93	$-	$97	$-
Cover Crops	$138	$826	$143	$1,000	$148	$1,186	$154	$1,384	$160	$1,596
Contour Farming / Strip Cropping	$3	$18	$3	$21	$3	$25	$3	$30	$3	$34
Conservation Tillage	$34	$205	$35	$248	$37	$294	$38	$343	$40	$396
Nutrient Management	$94	$107	$97	$129	$101	$153	$105	$179	$109	$206
Grazing Land Management	$104	$623	$108	$754	$112	$894	$116	$1,044	$120	$1,204
Developed Land										
Passive Acid Mine Drainage Treatment	$43,251	$1,271	$44,882	$1,539	$46,574	$1,825	$48,329	$2,131	$50,152	$2,457
SUBTOTALS	$121,768	$37,015	$126,359	$44,812	$131,122	$53,144	$136,066	$62,041	$141,195	$71,533
BY YEAR		$158,783		$171,170		$184,266		$198,107		$212,729
10-Year Implementation Cost, Moonlight Drive:								$1,554,280		

Table 40: Best Management Practices, Annualized Cost Per Pollutant Reduction

Projects / Opportunities	Net Present Value			Annualized Cost Over 10-Years	Pollutant Reduction		
	Capital	O&M	Total		Cost / Pound / Year		
					S	P	N
Riparian Buffer & Stream Restoration							
Forested Buffer	$163,434	$14,711	$178,145	$17,815	$0.24	$272.19	$45.24
Grass Buffer	$54,260	$9,769	$64,029	$6,403	$0.06	$71.59	$14.91
Streambank Stabilization	$409,222	$230,232	$639,454	$63,945	$1.10	$727.18	$659.00
Streambank Exclusionary Fencing	$21,302	$3,930	$25,232	$2,523	$1.51	$1,762.36	$370.10
Land Conversion							
Cropland Retirement	$527	$112	$639	$64	$0.02	$16.72	$4.83
Agricultural Land Management							
Water and Soil Conservation Planning	$695	$-	$695	$70	$0.01	$11.11	$5.62
Cover Crops	$1,144	$6,292	$7,435	$744	$0.34	$820.53	$40.29
Contour Farming / Strip Cropping	$24	$134	$159	$16	$0.003	$4.67	$2.36
Conservation Tillage	$284	$1,561	$1,845	$184	$0.01	$14.80	$15.71
Nutrient Management	$780	$812	$1,592	$159	$-	$74.59	$22.30
Grazing Land Management	$863	$4,746	$5,609	$561	$0.18	$226.94	$205.39
Developed Land							
Passive Acid Mine Drainage Treatment	$358,143	$9,685	$367,829	$36,783	$-	$-	$-

Watershed Implementation Plan Summary

- 10-Year Capital Plan Summary
- Implementation Schedule and Milestones
- Adaptive Management Strategy
- Potential Funding Sources
- Stakeholder Engagement and Education
- Long-Term Monitoring Plan
- Conclusion

TABLE 41: 10-YEAR CAPITAL PLAN SUMMARY

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Subwatershed Initiatives										
Green Acres Road Subwatershed	$75,768	$85,947	$96,787	$108,322	$120,589	$133,627	$147,476	$162,180	$177,783	$194,332
Worthington Subwatershed	$230,690	$260,143	$291,488	$324,828	$360,267	$397,917	$437,893	$480,318	$525,319	$573,031
Marrowbone Run Subwatershed	$100,648	$113,993	$136,897	$140,706	$155,988	$172,873	$190,134	$208,451	$227,879	$248,476
Pine Run Subwatershed	$410,002	$456,906	$506,763	$559,731	$615,972	$675,658	$738,968	$806,093	$877,228	$952,580
Moonlight Drive Subwatershed	$106,326	$114,299	$125,535	$135,997	$147,069	$158,783	$171,170	$184,266	$198,107	$212,729
Programmatic Initiatives										
Program Management, Education and Outreach	$45,000	$46,697	$48,457	$50,284	$52,179	$54,147	$56,188	$58,306	$60,504	$62,785
Monitoring and Sampling	$24,000	$24,905	$25,844	$26,818	$27,829	$28,878	$29,967	$31,097	$32,269	$33,486
GRAND TOTALS PER YEAR:	$992,432	$1,102,889	$1,231,772	$1,346,686	$1,479,893	$1,621,881	$1,771,797	$1,930,711	$2,099,089	$2,277,419
TOTAL 10-YEAR WATERSHED IMPLEMENTATION PLAN:										$15,854,569

The WIP Capital Plan Summary for the next decade represents a comprehensive and strategic investment in the health and sustainability of Buffalo Creek. The plan is designed to address the unique needs and challenges of each of the five target subwatersheds: Green Acres Road, Worthington, Marrowbone Run, Pine Run, and Moonlight Drive. These subwatersheds were selected based on observed impairments, pollutant loadings, land use patterns, and feasibility for early engagement.

Key investments will focus on a range of subwatershed initiatives, with a specific emphasis on scaling up efforts in accordance with the environmental needs and the progress of each area. For instance, the Pine Run subwatershed, requiring the highest investment, will see a significant and escalating allocation of resources aimed at tackling its specific challenges. This progressive funding model ensures that as each subwatershed's initiatives mature and expand, they are adequately supported to achieve long-term goals.

First and foremost, WIP progress would be based on the actual progress in implementing the proposed BMPs. Here, it makes sense to track both physical implementation progress - such as the number of acres of riparian buffer restored or linear feet of livestock exclusion fencing installed - but also the anticipated reductions in sediment, nitrogen, and phosphorus, based on assumed loading rates. By accounting for both concurrently, the WIP partners will be able to more easily draw correlations and cause-effect conclusions related to BMPs implemented and IBI scores measured. This is key to successful adaptive management, as described below. For instance, it may not be possible in a given subwatershed to achieve all of the planned riparian buffer restoration due to land owner non-cooperation, but it may be possible to convert a larger area of land than planned to crop retirement from a single cooperating land owners, with similar pollutant loading reductions. Ultimately, the intent is to reduce pollutants

and improve IBI. How we get there may be flexible, as needed.

In addition to the subwatershed-specific initiatives, the plan allocates resources towards programmatic initiatives that cut across all areas. These include Education and Outreach, and Monitoring and Sampling programs, essential for the long-term success of the WIP. Overall, this financial plan is a testament to our commitment to preserving and enhancing our watershed environments. It is an investment not only in the physical landscapes but also in the communities that depend on these vital ecosystems. Through careful planning, targeted initiatives, and ongoing community engagement, this ten-year WIP aims to achieve significant environmental improvements, sustainable management practices, and a healthier, more resilient watershed system.

High Priority, Early Action Watersheds

For the purposes of Section 319 funding and initial implementation, the WIP explicitly identifies Worthington and Marrowbone Run as high priority, early action watersheds. Worthington presents a unique opportunity due to its mix of rural and urban land uses, allowing for diverse BMP demonstrations with broad applicability. Marrowbone Run, while in better ecological condition, offers a high likelihood of early success due to the scale of intervention required and stakeholder readiness.

Other watersheds, such as Green Acres, were also identified as priority area with significant impact potential, but presents short-term challenges due to land ownership concentration.   As such, priority should be given to Worthington and Marrowbone, despite a high-potential area in Green Acres for future implementation. This phased approach allows the WIP to focus early resources where they are most likely to result in measurable water quality improvements and build momentum for broader watershed-scale restoration over time. These funds will be allocated progressively over ten years, reflecting an increasing commitment to momentum grows. The implementation schedule presented prioritizes the Marrowbone Run and Worthington subwatersheds as initial focus areas for BMP implementation. The percentage targets reflect an intentional front-loading of resources in these two areas, with additional phases expanding into other subwatersheds.

WIP Performance Metrics

Progress for this WIP over the decade or so of implementation will be measured and reported to PaDEP relative to three primary metrics: anticipated build-out and pollutant loading reductions from BMPs implemented; level-of-engagement related to the WIP activities; and IBI scores. The following subsections discuss these metrics in detail.

WIP Metric A: Reduction in Anticipated Pollutant Loading

First and foremost, WIP progress would be based on the actual progress in implementing the proposed BMPs.   Here, it makes sense to track both physical implementation progress - such as the number of acres of riparian buffer restored or linear feet of livestock exclusion fencing installed - but also the anticipated reductions in sediment, nitrogen, and phosphorus, based on assumed loading rates. By accounting for both concurrently, the WIP partners will be able to more easily draw correlations and cause-effect conclusions related to BMPs implemented and IBI scores measured.   This is key to successful adaptive management, as described below. For instance, it may not be possible in a given subwatershed to achieve all of the planned riparian buffer restoration due to land owner non-cooperation, but it may be possible to convert a larger area of land than planned to crop retirement from a single cooperating land owners, with similar pollutant loading reductions. Ultimately, the intent is to reduce pollutants and improve IBI. How we get there may be flexible, as needed.

WIP Metric B: WIP-Related Engagement

The success of a well-executed WIP should not only be measured by the physical implementation of

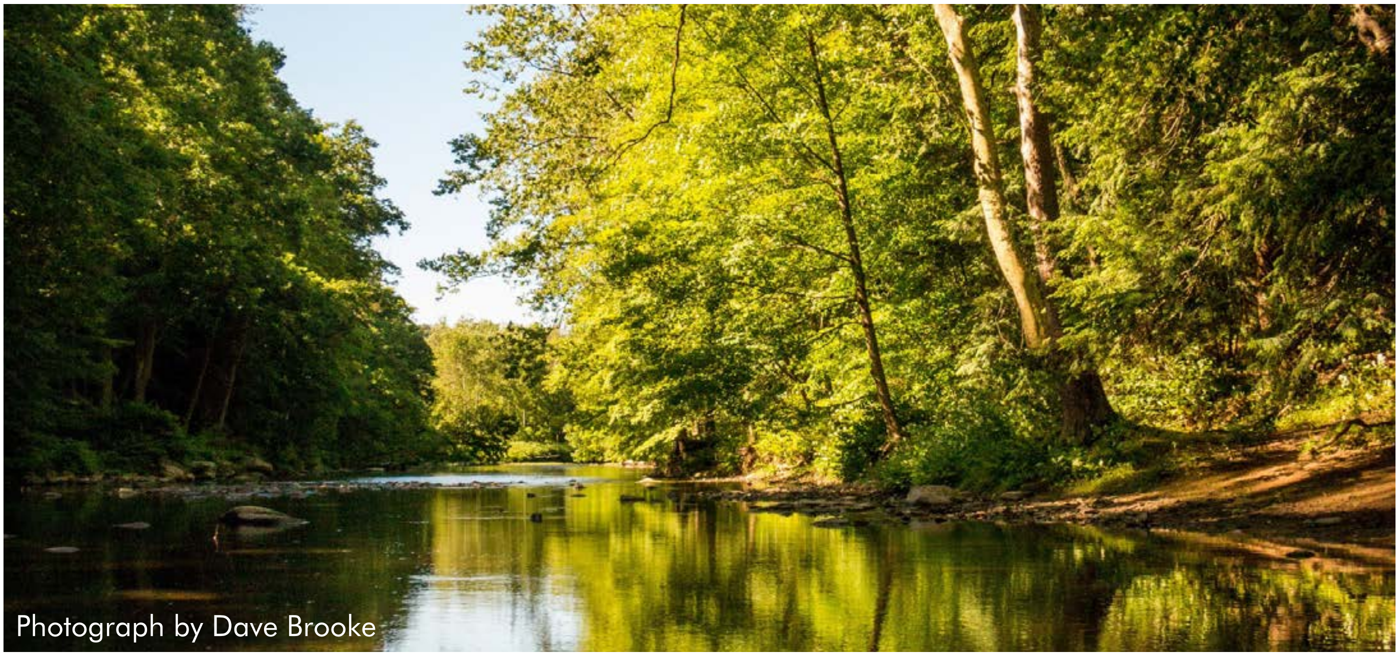
BMPs, but also the positive influences, behavior changes, and environmental messaging these activities have on resident, stakeholders, and the general community. To this end, this WIP includes a second set of metrics related to public and stakeholder engagement. These activities will be funded by the WIP as part of both the "Program Management, Education, and Outreach" line item in the 10-Year Capital Plan Summary (Table 41), and as part of individual project execution over the project horizon. The following table summarizes the WIP-related engagement targets that are proposed:

TABLE 42: PER-YEAR ENGAGEMENT TARGETS

Type of Engagement	Engagement Targets
Buffalo Creek Coalition	Host at least 2 Coalition meetings per year; grow participating landowners, businesses, and organizations annually
Communication and Outreach	Implement a comprehensive communications and outreach campaign annually that includes a combination of social media (at least 12 posts), e-newsletters (quarterly), coordination with traditional media (as needed), and in-person engagement at community and partner-led events
Public Education	Host at least 6 education events for the public annually, including field tours, workshops, and open houses
Watershed Festival	Host 1 watershed festival annually
Local Business and Partnership Exploration	Starting in year 1, host local businesses round table meetings every 2 years
Agency Stakeholder Round Table Meetings	Starting in year 1, host agency stakeholder round table meetings every 2 years
Targeted Landowner Outreach	In alignment with the proposed implementation schedule, annually perform targeted outreach to key landowners through direct mailings, phone calls, in-person meetings, and collaboration with Buffalo Creek Coalition partners

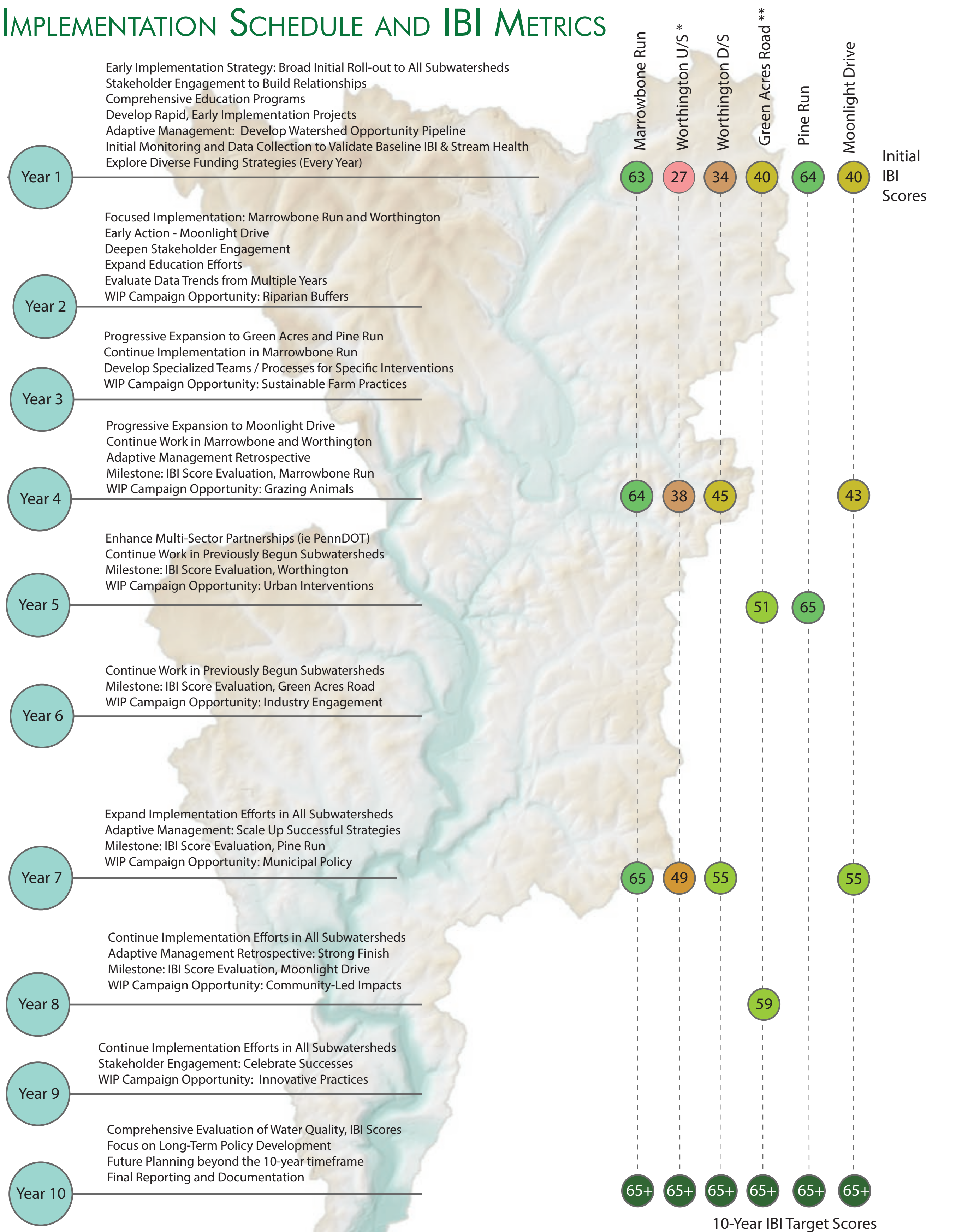
WIP Metric C: Improvement to IBI Score

While the above Metric A (Pollutant Loading Reduction) and Metric B (Engagement) provide quantitative and qualitative measures for WIP success, the ultimate program success will be reflected in improvements to the water quality, as reflected by the IBI scores evaluated for successive years during the study period. Figure 133 on the following page illustrates how the target IBI score will ideally be improved for each subwatershed.



Photograph by Dave Brooke

FIGURE 133 IMPLEMENTATION SCHEDULE AND IBI METRICS



(*) The Worthington subwatershed was monitored in two distinct locations - upstream and downstream of Worthington Borough.

(**) The field-measured IBI Score for the Green Acres Road seemed high. The value provided here is an assumed adjustment, but will be verified in Year 1 testing.

Measuring Progress Towards Load Reduction Goals

In order to meet the quantitative targets set in the Metrics sections above, we propose a robust WIP accounting system that capture implementation details, both at a subwatershed level and per pollutant type. This system can easily be implemented as a series of Excel spreadsheets and simple GIS mapping efforts, or could be implemented as a web-based interface that provided both effective program management and a public-facing map interface. It would be used to capture both capital construction efforts and annual maintenance efforts, thus addressing life cycle implementation needs across the WIP duration. The intent would be to facilitate real-time situational awareness (distance to target towards pollutant reduction goals) for WIP stakeholders, thus informing the adaptive management process. The following subsystems outline the functional requirement of creating a robust WIP accounting system, and will serve as an instruction guide for implementation.

WIP Accounting: Data Fields

Below are the data fields anticipated for capture by the pollutant loading accounting systems:

- BASIC DETAILS OF IMPLEMENTATION
    - Implementation Start Date
    - Implementation Completion Date
    - Designer, Volunteer, and Contractor Information
    - Target Watershed Name
    - Lat / Lon or GIS Polyline / Polygon of Implementation
    - Property Owner / Parcel No.
    - Implementation Notes, Observations, or Details
    - WIP-defined Implementation or Target of Opportunity
    - Future Maintenance Needs
- BEST MANAGEMENT PRACTICES, PHYSICAL IMPLEMENTATION DETAILS
    - BMP Type (Exclusionary Fencing, Streambank Stabilization, Nutrient Management Plan, etc.)
    - Physical Units (Linear Feet, Acres, Each, etc.)
    - Costs Associated with Design, Project Management, Construction, Maintenance Efforts
    - Effective Cost per Physical Units
- BEST MANAGEMENT PRACTICES, POLLUTANT LOADING DETAILS
    - Anticipated Pollutant Loading Reduction per Physical Unit Implemented, Calculated
      - Total Sediment (tons)
      - Total Phosphorus (lbs)
      - Total Nitrogen (lbs)
      - Other pollutants, as appropriate (AMD-related, for example)
    - Remaining Pollutant Reduction Needed to Meet WIP Targets

The WIP accounting system, of course, would be combined with meaningful milestone targets for pollutant reductions. Below is an annual list of pollutant loading targets, listed by subwatershed. In the table below, note also that it is assumed that very little if any progress will be made in Year 1, as this is largely a year for planning and engagement to kick off the WIP efforts. This could change with advanced planning by WIP stakeholders in the years prior to WIP implementation, but are not included here both to be conservative and to acknowledge that funding may be limited prior to the WIP.

WIP Accounting: Pollutant Load Reduction Factors by BMP

This WIP emphasizes a performance-based accounting approach, where pollutant load reduction is directly tied to the scale and type of BMPs implemented. If, for example, 1,000 linear feet of streambank stabilization is realized in any particular year within the Green Acres watershed, then this would equate to 115,000 lbs of sediment reduction, 17 lbs of phosphorus reduction and 19 lbs of nitrogen reduction, per the factors in the table below. As mentioned earlier, the dual accounting of both physical BMP implementation and assumed pollutant reduction is critical to the ultimate success for the WIP overall.

More importantly, this system is flexible by design. It is not overly prescriptive on the physical BMPs specifically - for instance, it does not set a target explicitly of 1,000 linear feet of streambank restoration per year in any specific watershed, where this goal may or may not be attainable due to land use barriers. Instead, it focused on performance-based metrics, allowing WIP planners to both maximize opportunity when it becomes available, and adjust the implementation strategy as needed over the proposed 10-year WIP duration.

Table 43: Pollutant Load Reduction Factors by BMP

Best Management Practice Implemented	Units	Assumed Pollutant Load Reductions per Unit of BMP Implemented		
		S (lbs)	P (lbs)	N (lbs)
Riparian Buffer & Stream Restoration				
Forested Buffer	acres	3132	3.03	17.88
Grass Buffer	acres	3097	3.03	13.83
Streambank Stabilization (each bank)	feet	115	0.17	0.19
Streambank Exclusionary Fencing	acres	2261	2.05	8.70
Land Conversion				
Cropland Retirement	acres	1546	1.76	5.88
Agricultural Land Management				
Water and Soil Conservation Planning	acres	396	0.26	0.51
Cover Crops	acres	158	0.07	1.41
Contour Farming / Strip Cropping	acres	396	0.26	0.51
Conservation Tillage	acres	1251	0.97	0.90
Nutrient Management	acres	0	0.09	0.35
Grazing Land Management	acres	348	0.29	0.30
Barnyard Runoff Control	acres	387	3.92	233.65
Developed Areas				
Bioretention (C/D soils, underdrain)	acres	209	0.09	0.36
Bioswales	acres	304	0.15	1.01
Filter Strip - Runoff Reduction	acres	155	0.10	0.30
Urban Stream Restoration	feet	115	0.17	0.19

References:
Model My Watershed BMP Spreadsheet Tool (Version 2023-08-15 at 5:00pm ET)
Developed by: Barry Evans (Drexel University & Penn State University), Anthony Aufdenkampe (LimnoTech), Mike Hickman (Center for Watershed Protection), and Reid Christianson (Center for Watershed Protection & University of Illinois).
Chesapeake Assessment Scenario Tool (https://cast.chesapeakebay.net/) County Data for Indiana, PA.

WIP Accounting: BMP Implementation Performance-Based Milestones

The table below presents BMP performance-based implementation milestones for the selected priority watersheds. It will be the role of the BMP implementation planner to utilize the WIP accounting system to regularly track BMP installations across the various watershed - both in terms of physical units implemented and costs - as well as to calculate the projected loads reduction based on Table 43. Where the milestone below become critical is in the end-of-year evaluation of the previous year's implementation efforts and continual assessment of progress towards the final WIP goals.

Table 44: 10-Year BMP Performance-Based Implementation Milestones

Implementation Year	Proposed Reduction					
	Total Sediment		Total Phosphorus		Total Nitrogen	
	Percent	Amount (tons)	Percent	Amount (lbs)	Percent	Amount (lbs)
Green Acres Subwatershed						
Year 1	5%	21.30	5%	38.20	5%	128.25
Year 2	5%	21.30	5%	38.20	5%	128.25
Year 3	15%	63.90	15%	114.60	15%	384.75
Year 4	15%	63.90	15%	114.60	15%	384.75
Year 5	10%	42.60	10%	76.40	10%	256.50
Year 6	10%	42.60	10%	76.40	10%	256.50
Year 7	10%	42.60	10%	76.40	10%	256.50
Year 8	10%	42.60	10%	76.40	10%	256.50
Year 9	10%	42.60	10%	76.40	10%	256.50
Year 10	10%	42.60	10%	76.40	10%	256.50
Worthington Subwater						
Year 1	5%	38.35	5%	70.15	5%	334.95
Year 2	15%	115.05	15%	210.45	15%	1,004.85
Year 3	15%	115.05	15%	210.45	15%	1,004.85
Year 4	15%	115.05	15%	210.45	15%	1,004.85
Year 5	10%	76.70	10%	140.30	10%	669.90
Year 6	10%	76.70	10%	140.30	10%	669.90
Year 7	10%	76.70	10%	140.30	10%	669.90
Year 8	10%	76.70	10%	140.30	10%	669.90
Year 9	10%	76.70	10%	140.30	10%	669.90
Year 10	10%	76.70	10%	140.30	10%	669.90
Marrowbone Run Subwatershed						
Year 1	5%	8.35	5%	17.75	5%	49.95
Year 2	15%	25.05	15%	53.25	15%	149.85
Year 3	15%	25.05	15%	53.25	15%	149.85
Year 4	15%	25.05	15%	53.25	15%	149.85
Year 5	10%	16.70	10%	35.50	10%	99.90
Year 6	10%	16.70	10%	35.50	10%	99.90
Year 7	10%	16.70	10%	35.50	10%	99.90
Year 8	10%	16.70	10%	35.50	10%	99.90

	Year 9	10%	16.70	10%	35.50	10%	99.90
	Year 10	10%	16.70	10%	35.50	10%	99.90

Table 44: 10-Year BMP Implementation Milestones (cont)

Implementation Year		Proposed Reduction					
		Total Sediment		Total Phosphorus		Total Nitrogen	
		Percent	Amount (tons)	Percent	Amount (lbs)	Percent	Amount (lbs)
Pine Run Subwatershed							
	Year 1	5%	37.00	5%	79.00	5%	374.20
	Year 2	5%	37.00	5%	79.00	5%	374.20
	Year 3	15%	111.00	15%	237.00	15%	1,122.60
	Year 4	15%	111.00	15%	237.00	15%	1,122.60
	Year 5	10%	74.00	10%	158.00	10%	748.40
	Year 6	10%	74.00	10%	158.00	10%	748.40
	Year 7	10%	74.00	10%	158.00	10%	748.40
	Year 8	10%	74.00	10%	158.00	10%	748.40
	Year 9	10%	74.00	10%	158.00	10%	748.40
	Year 10	10%	74.00	10%	158.00	10%	748.40
Moonlight Drive Subwatershed							
	Year 1	5%	6.90	5%	13.80	5%	50.00
	Year 2	5%	6.90	5%	13.80	5%	50.00
	Year 3	5%	6.90	5%	13.80	5%	50.00
	Year 4	5%	6.90	5%	13.80	5%	50.00
	Year 5	15%	20.70	15%	41.40	15%	150.00
	Year 6	15%	20.70	15%	41.40	15%	150.00
	Year 7	15%	20.70	15%	41.40	15%	150.00
	Year 8	15%	20.70	15%	41.40	15%	150.00

	Year 9	10%	13.80	10%	27.60	10%	100.00
	Year 10	10%	13.80	10%	27.60	10%	100.00

Adaptive Management Strategy

In the context of successfully and cost-effectively executing the proposed WIP for the Cornplanter Run - Buffalo Creek HUC-12, an Adaptive Management approach is crucial. Adaptive Management is a systematic process for continually improving management policies and practices by learning from the outcomes of previously implemented strategies, as well as taking full advantage of unanticipated opportunities when presented. This approach is particularly pertinent to watershed management, where environmental variables, responses to interventions, stakeholder engagement, and specific funding streams can be unpredictable and variable over time.

To support adaptive implementation, this WIP incorporates threshold-based criteria to trigger reassessment and modification of strategies. Specifically, adaptive measures will be considered if: (1) IBI scores do not show measurable improvement within expected timeframes; (2) pollutant reduction targets for sediment, nitrogen, or phosphorus are not being met based on modeled or observed data; or (3) anticipated investments (such as BMP installations or landowner engagement) fail to materialize. An ongoing accounting process should be used to track BMP implementation and pollutant load reductions, to inform whether mid-course corrections are needed.

The Implementation Schedule (Figure 133) provides a high-level overview of the planned 10-year schedule for implementation of the WIP. To the left in this diagram are general guidelines for implementation, including focus areas, campaign themes, and opportunities. To the right are milestones related to IBI score within each of the studied subwatershed.

Evidence-Based Adaptations

The core of Adaptive Management lies in its iterative decision-making process. Using this document as a framework, this involves setting clear objectives, developing management hypotheses, implementing actions, and monitoring the system's response. By comparing actual outcomes with expected results, the management team can discern the effectiveness of their strategies and make informed adjustments. For the Cornplanter Run - Buffalo Creek HUC-12, this could mean altering restoration techniques based on observed changes in water quality, biodiversity, or erosion patterns. Furthermore, future, ongoing stakeholder dialogue and feedback will be an integral part of the process, ensuring that community concerns and local knowledge are

incorporated into management decisions.

A keystone to the evidence-based portion of the adaptive management strategy, the proposed long-term monitoring plan for the watershed is paramount to success. Water quality, macroinvertebrate, and similar stream health data collected from various points along Buffalo Creek and its tributaries will provide insights into the health of the ecosystem and the impact of specific interventions. This data-driven approach ensures that management decisions are not based on conjecture but on tangible evidence of what is working and what is not. Although not explicitly written into the funding plan for this WIP, there may also be opportunities to incorporate emerging technologies such as remote sensing, lidar / geospatial / drone survey, and real-time water quality monitoring to further enhance the precision and efficiency of these efforts.

Opportunity-Based Adaptations

Incorporating an Adaptive Management Strategy into the WIP for the Cornplanter Run - Buffalo Creek HUC-12 also demands a flexible approach to resource allocation, particularly concerning budgetary constraints and opportunity optimization. Consider a planned initial commitment to stabilize 1,500 linear feet of streambank in a specific subwatershed, a notably expensive undertaking, along with the relatively inexpensive action of retiring 10% of farmland into natural meadow. This strategy must be nimble enough to adjust to unexpected changes in opportunities and funding.

If, for example, an unforeseen opportunity arises to retire and convert 30% of the farmland into meadow—tripling the original target—the plan's resource allocation should be reassessed under the Adaptive Management Strategy. If retiring more farmland offers greater environmental benefits at a lower cost, the strategy might suggest reallocating some resources away from streambank stabilization to capitalize on this new opportunity. This shift would not only optimize the use of available funds but also potentially lead to more impactful environmental improvements within the watershed.

While streambank stabilization is recognized as an effective BMP for reducing sedimentation and improving aquatic habitat, its implementation across the Buffalo Creek-Cornplanter Run subwatersheds is constrained primarily by land ownership. The majority of riparian corridors fall within privately owned parcels, many of which are actively farmed. Streambank stabilization efforts in these areas may reduce usable farmland, creating a barrier to participation. As a result, this WIP adopts a measured approach, aiming to balance the ideal of widespread riparian restoration with practical constraints. The current plan presents a range of BMP alternatives while keeping open the potential for increased streambank restoration opportunities as landowner engagement progresses. As part of the adaptive management strategy, targeted efforts may be made to increase the implementation of streambank stabilization practices over time. As restoration dialogues evolve, particularly in agricultural areas, streambank stabilization will remain a priority BMP for future implementation phases.

Opportunity-based adaptations such as this necessitate a dynamic system of continuous record-keeping and periodic auditing of priorities. Such a system would track the progress of each intervention, monitor expenditure against allocated budgets, and evaluate the ecological and financial impacts of implemented actions. By doing so, the management team can quickly identify when an unexpected opportunity, like the increased farmland retirement, offers a more cost-effective path to achieving the plan's environmental objectives. This reallocation not only ensures efficient use of resources but also maximizes the ecological benefit per dollar spent, potentially leading to greater environmental restoration outcomes for the Cornplanter Run - Buffalo Creek HUC-12.

In general, incorporating an Adaptive Management approach allows for a flexible and responsive strategy in watershed management within the target subwatersheds. It acknowledges the complexity and dynamic nature of environmental systems and the need for ongoing learning and adaptation. This approach ensures that the WIP remains effective and relevant over time, adapting to new challenges and information, thus maximizing the ecological and community benefits of the implemented interventions.

Potential Funding Sources

Funding and Technical Resources

There are numerous financial assistance programs and partners which may assist with funding implementation activities within Buffalo Run watershed. Sources represent a range of sectors: government (federal, state, and local), non-profit, foundations and private sectors. Many involve cost sharing, and some may allow the local contribution of materials, land, and in-kind services to cover a portion or the entire local share of the project. For some landowners and local decision makers, the source of the funding by sector may be an important consideration in deciding whether to utilize such resources to implement conservation. The following several pages organize the funding resources

Acronyms List

BMP	Best Management Practice	AMD	Acid Mine Drainage
SW	Stormwater	ARRA	American Recovery and Reinvestment Act
Ag	Agricultural	CWSRF	Clean Water State Revolving Fund
PA DEP	Pennsylvania Department of Environmental Protection	DWSRF	Drinking Water State Revolving Fund
NRCS	Natural Resources Conservation Service	USDA	U.S. Department of Agriculture
NFWF	National Fish and Wildlife Foundation	USEPA	U.S. Environmental Protection Agency
DCNR	Pennsylvania Department of conservation and natural resources	FSA	Farm Service Agency
DCED	Pennsylvania Department of Community and Economic Development		
FPW	Foundation for Pennsylvania Watersheds		
SCC	State Conservation Commission		
PACD	Pennsylvania Association of Conservation Districts		
PENNVEST	Pennsylvania Infrastructure Investment Authority		

Funding Resource	Lead Partner	Practice types funding				Information
		Ag BMPs	SW BMPs	Buffers	Streambank Restoration	
Federal Government						
Conservation Security Program (CSP)	USDA NRCS	X	X		X	NRCS provides technical and financial assistance to help farmers implement conservation practices on working lands.
Environmental Quality Incentives Program (EQIP)	USDA NRCS	X	X	X	X	
Partners for Fish and Wildlife Program (USFWS)	USFWS			X	X	USFWS administers the Partners for Fish and Wildlife Program, which provides technical and financial assistance to private landowners to restore, enhance, and manage private land to improve fish and wildlife habitats. Projects typically include stream restoration, wetland restoration, riparian buffer installation, and stream bank fencing.
Wetland Reserve Easement Program (WRE)	USDA NRCS		X	X	.X	
Conservation Reserve Enhancement Program (CREP)	USDA FSA	X	X		X	FSA provides technical and financial assistance top help farmers implement riparian buffers and other wildlife related conservation practices under the Conservation Reserve Enhancement Program (CREP), and provides a wide variety of other funding and loan opportunities to farmers.
PL-566	USDA NRCS				X	
Wetland Program Development Grants	EPA				X	EPA is a federal agency with the mission of protecting human health and the environment. The Water Division division in EPA Region 3 provides resources to help implement conservation practices in Buffalo Creek Watershed. It manages, among many other Clean Water Act (CWA) programs, the non-point source pollution program (CWA Section 319 Program) and Clean Water State Revolving Loan Fund (SRF).
Regional Conservation Partnership Program (RCPP)	USDA NRCS	X	X	X	X	RCPP provides funds for producers to install and maintain conservation activities. The program is not a grant program, but partners can leverage RCPP funding in their programs.
319 Program	PA DEP	X	X	X	X	Projects addressing non-point sources including AMD restoration (construction projects); watersheds with approved TMDLs and restoration plans considered a priority

Funding Resource	Lead Partner	Practice types funding				Information
		Ag BMPs	SW BMPs	Buffers	Streambank Restoration	
State Government						
Growing Greener Watershed Grants	PA DEP	X	X	X	X	Watershed restoration implementation (construction) projects, O&M, education/ outreach projects, watershed organization and watershed assessment
Ag Planning Reimbursement Program	PA DEP	X				DEP's mission is to protect Pennsylvania's air, land and water from pollution and to provide for the health and safety of its citizens through a cleaner environment. DEP partners with individuals, organizations, governments and businesses to prevent pollution and restore our natural resources.
DCNR Riparian Buffer Grant Program	PA DCNR			X		DCNR provides staff and resources for outreach, technical assistance and funding to implement forested riparian buffers on public and private lands and other conservation implementation, planning and capacity building projects.
Community Conservation Partnerships Program Grants (C2P2)	DCNR		X	X	X	Grants are available for community parks and recreation improvements, land acquisition projects, development and improvement of water trails, and the installation of riparian buffer habitats.
Multifunctional Riparian Buffers	DCNR & PACD			X		Multi-functional riparian forest buffers provide greater flexibility in landowner eligibility, buffer design, width, and plant species: and to include the option of planting some income-producing crop.
Urban and Community Forestry Program (formerly TreeVitalize)	PA DCNR		X	X		
PENNVEST	PENNVEST	X	X	X	X	PENNVEST has been empowered to administer and finance the CWSRF and DWSRF pursuant to the federal Water Quality Act of 1987 as well as administer ARRA funds.
Resource Enhancement & Protection Program (REAP)	SCC	X		X		SCC is a 14-member commission that provides support and oversight for the implementation of conservation programs and is responsible for administering several state conservation programs including the Nutrient Management and Oder Management Program, the Dirt and Gravel Program, Resources Enhancement and Protection (REAP Tax Credit) Program, and the new Conservation Excellence Grant Program.
Clean Water Revolving Fund	PENNVEST	X	X	X	X	
Act 13 Watershed and Flood Mitigation Programs	Common Financing Authority (CFA)			X	X	Provides grants for watershed restoration, AMD abatement, baseline water quality data, orphaned or abandoned well plugging and flood mitigation.

Funding Resource	Lead Partner	Practice types funding				Information
		Ag BMPs	SW BMPs	Buffers	Streambank Restoration	
State Government (Continued)						
Flood Mitigation Program (FMP)	PA DCED		X	X		Act 13 of 2012 establishes the Marcellus Legacy Fund and allocates funds to the Commonwealth Financing Authority (the "Authority") for funding statewide initiatives to assist with flood mitigation projects.
PA Small Water and Sewer Program	PA DCED		.X		X	Funding program to assist municipalities with small water, sewer, storm sewer and flood control infrastructure projects.
Watershed Restoration and Protection Program (WRPP)	PA DCED and PA DEP	X	X	X	X	The program's purpose is to restore and maintain impaired stream reaches impacted by non-point source pollution, and to ultimately remove them from the impaired Waters list. Eligible projects must monitor and track the load reduction impacts resulting from the project.


Photograph by George Reese

Funding Resource	Lead Partner	Practice types funding				Information
		Ag BMPs	SW BMPs	Buffers	Restoration	
County						
Dirt, Gravel and Low Volume Roads	Armstrong and Butler County Conservation District		X			Armstrong and Butler County Conservation Districts work to restore degraded watersheds, promote sustainable farms, healthy forests, and growing vibrant and sustainable communities. The district will work with many private and public partners fro the betterment of their natural resources and the citizens. The Districts can provide technical, administrative, and financial support through many programs as noted on their websites.
Conservation Excellence Grants	Armstrong and Butler County Conservation District	X		X	X	
Nonprofits and Foundations						
BHE GT&S Watershed Mini Grant Program	Western PA Conservancy		X	X	X	Provides financial assistance to watershed groups to support projects in three areas: water quality monitoring, watershed restoration, and organizational promotion and outreach.
Foundation of Pennsylvania Watersheds			X	X	X	FPW awards grants for non-point source pollution, riparian buffer zones, wetland preservation, watershed restoration and preservation projects including AMD.
The Heinz Endowment		X	X	X	X	Restore and protect watersheds, ecosystems and landscapes: decrease human impact (point and non-point) sources; encourage public awareness, empower grassroots organizations, and build partnerships to address environmental preservation and remediation
Richard King Mellon Foundation		X	X	X	X	Watershed restoration, protection and preservation of natural resources
NFWF Grants	National Fish and Wildlife Foundation (NFWF)			X	X	Then NFWF awards competitive grants through their programs to protect and conserve our nation's fish, wildlife, plants and habitats. The Foundation works with the public and private partners in all 50 states and U.S. Territories to solve the most challenging conservation programs.

available in the watershed by the type of source or sector of funding and also indicates the lead partner. In addition, to these programs, partnerships between local governments can also help to leverage funds. Please refer also to the list of acronyms below while navigating the tables of funding resources and partners.

Stakeholder Engagement and Education

BUFFALO CREEK
COALITION
Working together for water, wings and wildlife

Watershed-Based Education

In the realm of watershed management, education emerges as a critical tool, not only in promoting awareness but also in fostering active participation in the preservation and enhancement of Buffalo Creek's environmental health. Integral to this effort is the strategically located Buffalo Creek Nature Park, serving as an Audubon educational center and a local meeting place for Buffalo Creek watershed work.

Stakeholders:

County Governments:

- Armstrong County
- Butler County
- Allegheny County (minor overlap)

Conservation Districts:

- Allegheny County Conservation District
- Armstrong Conservation District
- Butler County Conservation District

Watershed and Environmental Organizations:

- Buffalo Creek Coalition
- Western Pennsylvania Conservancy (WPC)
- Penn Future
- Trout Unlimited

Academic Institutions:

- Duquesne University

Municipal Governments:

- Borough of Worthington
- West Franklin Township
- North Buffalo Township
- South Buffalo Township
- Portions of Washington and Clearfield Townships

Community Partners and Public:

- Local landowners and agricultural producers
- General public participants in ASWP outreach and events

ASWP's long-standing commitment to environmental education provides a solid foundation for engaging the community in watershed stewardship. Through continuous collaboration efforts, ASWP plans to continue providing comprehensive educational programs targeting diverse groups and facilitating meaningful initiatives within the watershed community. These programs and projects will cover a wide range of topics, from the basics of watershed ecology to the specifics of local flora and fauna, pollution sources, and the importance of biodiversity. Buffalo Creek Nature Park plays a crucial role in these endeavors, serving as a hands-on learning environment and a focal point for community engagement.

A significant emphasis will be placed on experiential learning, offering hands-on opportunities for community members to engage with the environment directly. This approach includes guided nature walks, citizen science projects, interactive workshops focused on stream health, water quality testing, volunteer efforts, and wildlife observation at Buffalo Creek Nature Park. The aim is to not only educate but also to instill a sense of connection and responsibility towards Buffalo Creek and its tributaries.

In addition to in-person programs, online resources, virtual tours, and webinars may be developed related to the goals of this WIP, ensuring that watershed education is accessible to all, regardless of geographical or physical constraints. The integration of Buffalo Creek Nature Park into these digital initiatives further enhances the reach and impact of their educational efforts.

Buffalo Creek Coalition: Leveraging Key Partners

The Buffalo Creek Coalition, a collaboration among the Audubon Society of Western Pennsylvania, conservation districts, academic institutions, and other environmental entities, has the potential to play a critical role in WIP implementation. The partnership harnesses the strengths of numerous environmental organizations, advocates and stakeholders. These partners bring specialized skills and resources to the table. The Armstrong, Butler, and Allegheny County Conservation Districts, for example, offer invaluable expertise in sustainable land management and conservation techniques. Duquesne University contributes academic rigor and research capabilities, essential for understanding the complex ecological dynamics of Buffalo Creek. The Western Pennsylvania Conservancy, known for its work in protecting and restoring natural spaces, provides practical experience in habitat restoration and land conservation. As of June 2025, the following members are included in the initiative's rosters: Armstrong Conservancy, Armstrong Conservation District, The Arrowhead Chapter of Trout Unlimited, the Audubon Society of Western Pennsylvania, Butler County Conservation District, the Butler-Freeport Community Trail, Dave Beale (Forestry and Surveyor), Duquesne University, GAI Consultants, Penn State Extension, the Pittsburgh Water Collaboratory, Stream Restoration Incorporated, the Western Pennsylvania Conservancy, and the Worthington-West Franklin Library.

Together, these organizations and individuals form a robust framework for addressing the multifaceted challenges of watershed management. Their collaboration extends beyond technical expertise, embracing community engagement and education. This holistic approach is vital for fostering long-term stewardship and environmental awareness among local residents and stakeholders.

The coalition's strategy revolves around several key areas: water quality monitoring, riparian buffer restoration, streambank stabilization, and public outreach. By pooling their resources and knowledge, the Buffalo Creek Coalition aims to make significant strides in improving the health of the Buffalo Creek ecosystem. Their coordinated efforts ensure that the WIP is not only scientifically sound but also grounded in community needs and priorities.

Engagement with the Agricultural Community

Given the predominance of farming throughout the watershed and the historically negative impacts to the water resources of Buffalo Creek, engaging the agricultural community is essential for the successful implementation of the WIP. The Buffalo Creek Coalition already collaborates frequently with agricultural leaders, practitioners, and facilitating agencies, such as the local conservation districts, the Pennsylvania Department of Agriculture, the Department of Conservation and Natural Resources (DCNR), and the USDA to develop educational materials and workshops tailored to the specific needs of the farming community relative to sound watershed management. These initiatives will be expanded to address the specific needs of Buffalo Creek and the target subwatersheds.

Engagement with the agricultural community, contingent upon mutual interests and collaboration opportunities, could also take various, new forms. One possibility is the organization of farm field days in partnership with local agricultural groups. These events, intended to share best practices in sustainable farming, soil conservation, and water management, would provide a platform for learning about innovative practices and technologies.

A mentorship program, enabling farmers who have successfully adopted sustainable practices to share their experiences with peers, is another concept under consideration. Such peer-to-peer learning approaches would aim to strengthen community bonds and collective responsibility towards Buffalo Creek's health.

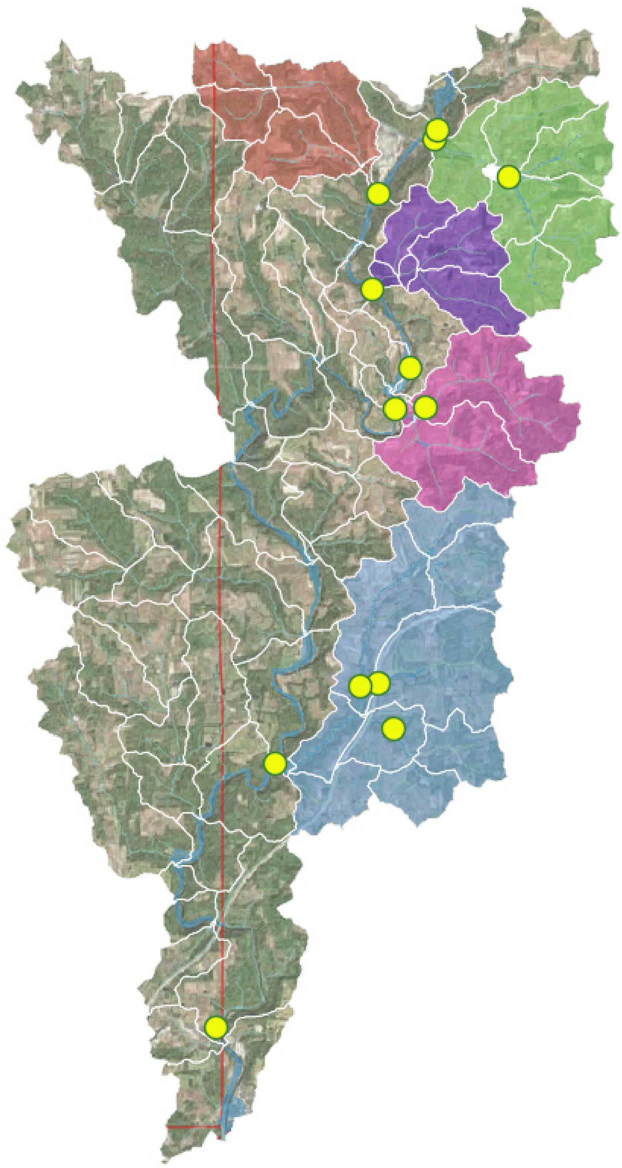
In conclusion, ASWP's approach to Stakeholder Engagement and Education is multi-faceted, aiming to build a knowledgeable, engaged, and proactive community around Buffalo Creek. Through education and collaboration, the intent would be to empower individuals and groups to make informed decisions and take meaningful actions for the sustainability and health of the watershed.

Long-Term Monitoring Plan

Overview of Monitoring Plan

The long-term monitoring plan for the Buffalo Creek WIP is designed to comprehensively assess the health and progress of the watershed. Building upon past efforts by ASWP, Duquesne University, the PaDEP, and other key data collection partners, this plan provides for a strategic network of monitoring and sampling stations across the watershed, ensuring adequate coverage and data collection frequency to effectively measure the evaluation criteria established by this WIP.

Figure 134: Future WIP Monitoring Plan



Monitoring Stations and Frequency

In preparing this WIP, water quality and macroinvertebrate sampling were conducted at six key locations distributed throughout the target subwatersheds. These sites were selected for their representativeness and strategic importance in assessing the overall health of Buffalo Creek. Additionally, ASWP has worked with Duquesne University, Western Pennsylvania Conservancy, and Oikos Ecology on a comprehensive water quality monitoring program for Buffalo Creek HUC-10 that spans several years.

The future WIP entails frequent monitoring of these six primary sites, several sites along the main stem that have been previously monitored by Duquesne University, and supplemental sites as needed to more effectively target subwatershed pollutants, for a total of thirteen (13) sites.

Sampling will be annual, designed to capture seasonal variations and long-term trends, focusing on water quality and macroinvertebrates for consistency with past results. This consistent monitoring frequency is crucial for obtaining reliable data to evaluate the effectiveness of the planned interventions. Figure 134 depicts the preliminary selection of future WIP sampling / monitoring locations.

Data Collection and Analysis

The monitoring strategy involves collecting a standardized set of biological, chemical, and physical data over time. This includes, but is not limited to, measurements of water temperature, pH, dissolved oxygen, nutrients, conductivity, and turbidity. The biological assessments will particularly focus on macroinvertebrate populations, which are key indicators of aquatic ecosystem health.

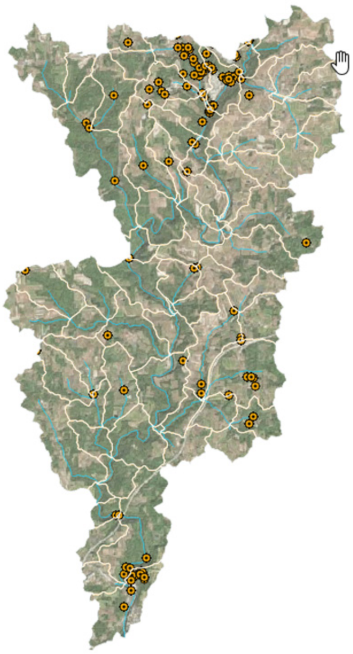


Figure 135:
Previous Monitoring Efforts
By PaDEP

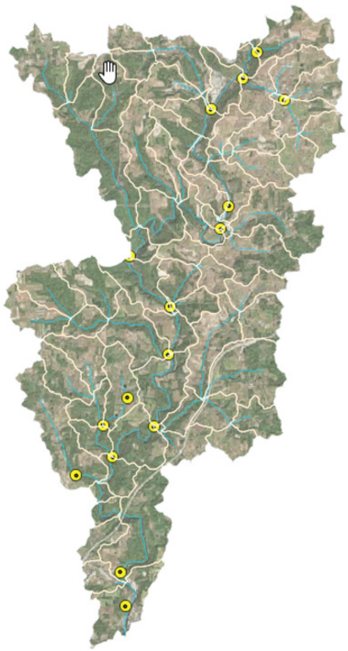


Figure 136:
Previous Monitoring Efforts
By Duquesne University

Figure 137:
Previous Monitoring Efforts
By Oikos Ecology LLC

Progress towards meeting water quality targets will be assessed both with regard to the targets and data set forth in this WIP, and past monitoring, sampling, and testing efforts by PaDEP, Duquesne University, and Oikos Ecology, LLC. Figure 135 through 137 depict the locations of these sites within the Cornplanter Run - Buffalo Creek HUC-12.   As indicated earlier, the Oikos and several of the Duquesne University sites will be incorporated into future WIP-related monitoring efforts.

Adaptive Management and Reporting

The long-term monitoring plan is integral to the adaptive management framework of the WIP. The collected data will be regularly analyzed to assess the effectiveness of implemented measures and inform necessary adjustments in the plan. Regular reporting and communication of findings to stakeholders, including the community and relevant authorities, will ensure transparency and collective decision-making in the ongoing stewardship of Buffalo Creek.

In conclusion, the long-term monitoring plan for the Buffalo Creek

WIP is designed to be robust, comprehensive, and adaptive, ensuring the continuous assessment and improvement of watershed health and the effective implementation of the plan's strategies.

Conclusion

As we embark on this ten-year journey, it's envisioned that the WIP will be more than a financial or environmental endeavor. It will serve as a unifying force, bringing together diverse communities, local governments, and environmental experts with a shared vision of revitalizing and protecting our precious watershed ecosystems. The strategic allocation of impact-driven funding over the next decade underscores our collective commitment to this cause, demonstrating a deep understanding of the intricate balance between human needs and environmental stewardship.

The outcomes of this plan will not only be measured in the improved health of our waterways or the resilience of our ecosystems but also in the strengthened bonds within our communities. Education and outreach programs will foster a greater sense of environmental responsibility, while monitoring and sampling initiatives will keep us informed and prepared to adapt our strategies as needed. This journey will be about cultivating a culture of sustainability, where each stakeholder understands their role in preserving the watershed for future generations.

As we look toward the ten-year horizon, it is anticipated that the foundation laid by this WIP will be robust and enduring. It will serve as a blueprint for continued environmental stewardship, a reminder of our duty to protect and nurture our natural resources. The legacy of this plan will not be just in the waters that flow more cleanly or the landscapes that thrive more abundantly; it will be in the heightened awareness and commitment of our communities to live in harmony with nature.

Appendix A - Water Quality and Macroinvertebrate Sampling Results

Index of Biotic Integrity (IBI) Overview

2023 Macroinvertebrate Results

2022 Macroinvertebrate Results

2023 Water Quality Results

2022 Water Quality Results

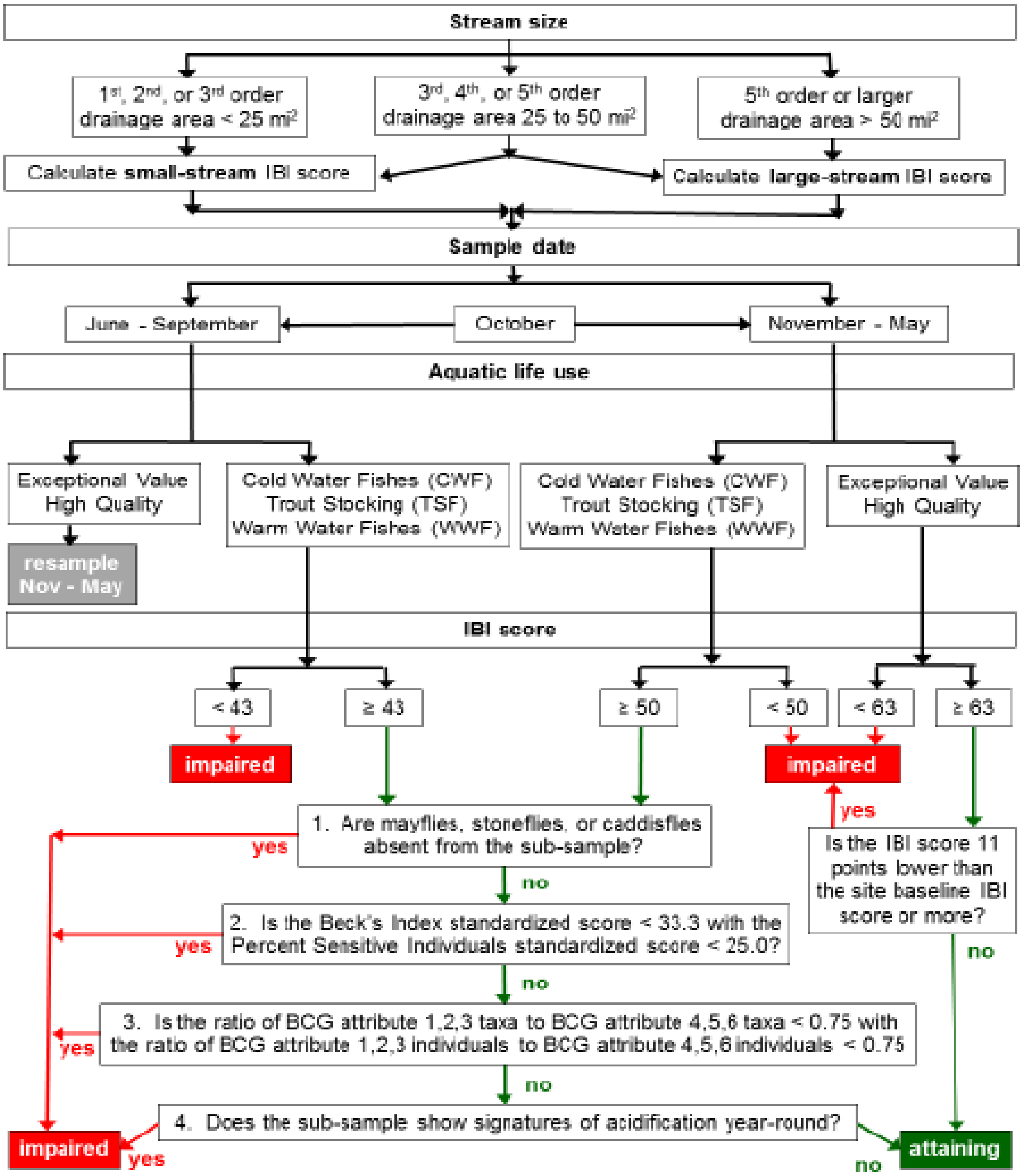


Figure 38. A simplified framework for the aquatic life use assessment process. *** Questions 1 and 3 must be applied to small-stream samples collected from November to May, but do not have to be applied to large-stream samples or samples collected from June to September. Although this simplified decision matrix should guide most assessment decisions for benthic macroinvertebrate samples from Pennsylvania's wadeable, freestone, riffle-run streams using the collection and processing methods discussed above, situations exist where this simplified assessment schematic will not apply exactly as outlined – some such situations are discussed in the following text.

For samples collected between November and May, IBI scores < 50 result in aquatic life use impairment. Samples collected during these months scoring ≥ 50 on the appropriate IBI are subject to four screening questions before the aquatic life use can be considered attaining. **These additional screening questions are:**

1. **Are mayflies, stoneflies, or caddisflies absent from the sub-sample?** Organisms representing these three taxonomic orders are usually found in most healthy wadeable, freestone, riffle-run streams in Pennsylvania. If any or all of these orders are absent from a sample, this strongly suggests some sort of anthropogenic impact. Samples where one of these taxonomic orders is absent due to natural conditions (e.g., mayflies absent from a low-pH tannic stream) should be evaluated accordingly. *This question must be applied to small-stream samples collected between November and May, but does not have to be applied to samples from larger streams and samples collected between June and September.*

2. **Is the standardized metric score for the Beck's Index metric < 33.3 with the standardized metric score for the Percent Sensitive Individuals metric < 25.0?** Although these two metrics go into the IBI calculations, this screening question serves to double check that a sample has substantial richness and abundance of the most sensitive organisms. This question arose from observing that the Beck's Index metric is less sensitive at the lower end of its range and the Percent Sensitive Individuals metric is less sensitive at the upper end of its range. When both these metrics score relatively low, it serves as strong confirmation of impairment. *This question must be applied to all samples.*

3. **Is the ratio of BCG attribute 1,2,3 taxa to BCG attribute 4,5,6 taxa < 0.75 with the ratio of BCG attribute 1,2,3 individuals to BCG attribute 4,5,6 individuals < 0.75?** This screening question evaluates the balance of pollution tolerant organisms with more sensitive organisms in terms of taxonomic richness and organismal abundance. By using the BCG attributes to measure pollution tolerance, this screening question serves as a check against the IBI metrics which account for pollution sensitivity based only on PTVs. *This question must be applied to small-stream samples collected between November and May, but can be relaxed for samples from larger streams and samples collected between June and September.*

4. **Does the sub-sample show signatures of acidification year-round?** The primary acidification signatures in a sub-sample include low mayfly abundance and low mayfly diversity (i.e., scarce mayfly individuals and few mayfly taxa), especially when combined with high abundance of Amphinemura and/or Leuctra stoneflies, occasionally combined with high abundance of Simuliidae and/or Chironomidae individuals. A sub-sample with < 3 mayfly taxa, < 5% mayfly individuals, and > 25% Leuctra and/or Amphinemura stoneflies indicates likely acidification impacts. Acidification effects on benthic macroinvertebrate communities are often most pronounced in small streams with low buffering capacity during the spring months when snowpacks melt and vernal rains are frequent. While it can be difficult to determine if low pH conditions in a stream are natural or more attributable to anthropogenic acidification, sampling of water chemistry and/or fish communities (see Appendix F of PADEP 2009b) in addition to benthic macroinvertebrate communities can help inform assessment of acidic in-stream conditions. With this protocol, PADEP will only impair sites that show persistent acidification signatures year-round. In other words, if a sample has no mayflies and is dominated by Leuctra and Amphinemura in the spring, but a November sample from the same site contains three or more mayfly taxa or over five percent mayfly individuals, the aquatic life use will not be considered impaired because the stream exhibits the ability to recover biological integrity in the fall and winter months. If a spring sample shows acidification signatures, a late fall or early winter sample must be collected before making an aquatic life use assessment decision. *This question must be applied to all samples.*

If the answer to any of the required screening questions is yes for a sample collected between November and May with an IBI score ≥ 50, then the sample is considered impaired without compelling reasons otherwise. If the answer to all of these questions is no for a sample collected between November and May with an IBI score ≥ 50, then the aquatic life use represented by the sample can be considered attaining unless other information (e.g., water chemistry) indicates the aquatic life use may not be fully supported at that location.

2023 Macroinvertebrate Sampling

Overview of Summary Results

The following is a summary of macroinvertebrate sampling results from May 2023

Site Name	Date	Latitude, Longitude	IBI Score	Result	Notes
Pine Run Subwatershed (Oikos 1)	5/4/2023	40°44’45.48”N, 79°39’21.54”W	64.11	impaired	BCG ratios both <0.75
Marrowbone Run Subwatershed (Oikos 2)	5/4/2023	40°47’37.27”N, 79°38’38.99”W	63.26	impaired	see screening question 4 (very few mayflies and many Leuctra/ Amphinemura), shows signs of year-round acidification, iron precipitate visible on macros
Green Acres Road Subwatershed (Oikos 3)	5/4/2023	40°48’51.05”N, 79°39’21.02”W	66.00	attaining	Sampling location may be adjusted in future years, as this sample was taken under riparian canopy near mouth, and may not well represent larger watershed
Moonlight Drive Subwatershed (Oikos 4	5/4/2023	40°49’50.43”N, 79°39’14.88”W	40.00	impaired	iron precipitate visible on macros, very few mayflies
Worthington Subwatershed, Downstream of Borough (Oikos 5)	5/4/2023	40°50’24.15”N, 79°38’27.90”W	33.61	impaired	no stoneflies
Worthington Subwatershed, Upstream of Borough (Oikos 6)	5/4/2023	40°49’59.44”N, 79°37’27.78”W	22.68	impaired	no mayflies

Macroinvertebrate Sampling Results, Pine Creek (2023)
Sample ID: Oikos-1

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Leuctra	2	0	26	0.1405	-1.9623	-0.2758
Rhyacophila	2	1	1	0.0054	-5.2204	-0.0282
Isoperla	2	2	44	0.2378	-1.4362	-0.3416
Leptophlebiidae	2	4	1	0.0054	-5.2204	-0.0282
Haploperla	3	0	2	0.0108	-4.5272	-0.0489
Sweltsa	3	0	3	0.0162	-4.1217	-0.0668
Neophylax	3	3	3	0.0162	-4.1217	-0.0668
Amphinemura	3	3	33	0.1784	-1.7238	-0.3075
Eurylophella	3	4	1	0.0054	-5.2204	-0.0282
Acentrella	3	4	1	0.0054	-5.2204	-0.0282
Gammarus	4	4	1	0.0054	-5.2204	-0.0282
Optioservus	4	4	2	0.0108	-4.5272	-0.0489
Tipulidae	4	4	1	0.0054	-5.2204	-0.0282
Hemerodromia	4	5	2	0.0108	-4.5272	-0.0489
Cambaridae	4	6	1	0.0054	-5.2204	-0.0282
Probezzia	4	6	1	0.0054	-5.2204	-0.0282
Stenelmis	5	5	1	0.0054	-5.2204	-0.0282
Tabanidae	5	6	1	0.0054	-5.2204	-0.0282
Chironomidae	5	6	52	0.2811	-1.2691	-0.3567
Simulium	5	6	3	0.0162	-4.1217	-0.0668
Oligochaeta	5	10	4	0.0216	-3.8341	-0.0829
Hydroptilidae		4	1	0.0054	-5.2204	-0.0282
		TOTAL	217		SHANNON	2.5471

Metric	Value	Standard	Standardized score
Taxa richness	24	33	72.73
EPT richness (PTV 0-4)	11	19	57.89
Beck's index	17	38	44.74
Hilsenhoff biotic index	3.97	1.89	74.35
Shannon diversity	2.55	2.86	89.16
Percent sensitive (PTV 0-3)	38.71	84.5	45.81
		IBI SCORE:	64.11

Macroinvertebrate Sampling Results, Marrowbone Run (2023)
Sample ID: Oikos-2

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Leuctra	2	0	26	0.1405	-1.9623	-0.2758
Rhyacophila	2	1	1	0.0054	-5.2204	-0.0282
Isoperla	2	2	44	0.2378	-1.4362	-0.3416
Leptophlebiidae	2	4	1	0.0054	-5.2204	-0.0282
Haploperla	3	0	2	0.0108	-4.5272	-0.0489
Sweltsa	3	0	3	0.0162	-4.1217	-0.0668
Neophylax	3	3	3	0.0162	-4.1217	-0.0668
Amphinemura	3	3	33	0.1784	-1.7238	-0.3075
Eurylophella	3	4	1	0.0054	-5.2204	-0.0282
Acentrella	3	4	1	0.0054	-5.2204	-0.0282
Gammarus	4	4	1	0.0054	-5.2204	-0.0282
Optioservus	4	4	2	0.0108	-4.5272	-0.0489
Tipulidae	4	4	1	0.0054	-5.2204	-0.0282
Hemerodromia	4	5	2	0.0108	-4.5272	-0.0489
Cambaridae	4	6	1	0.0054	-5.2204	-0.0282
Probezzia	4	6	1	0.0054	-5.2204	-0.0282
Stenelmis	5	5	1	0.0054	-5.2204	-0.0282
Tabanidae	5	6	1	0.0054	-5.2204	-0.0282
Chironomidae	5	6	52	0.2811	-1.2691	-0.3567
Simulium	5	6	3	0.0162	-4.1217	-0.0668
Oligochaeta	5	10	4	0.0216	-3.8341	-0.0829
Hydroptilidae		4	1	0.0054	-5.2204	-0.0282
		TOTAL	185		SHANNON	2.0222

Metric	Value	Standard	Standardized score
Taxa richness	22	33	66.67
EPT richness (PTV 0-4)	11	19	57.89
Beck's index	12	38	31.58
Hilsenhoff biotic index	3.42	1.89	81.13
Shannon diversity	2.02	2.86	70.63
Percent sensitive (PTV 0-3)	60.54	84.5	71.64
		IBI SCORE:	63.26

Macroinvertebrate Sampling Results, Green Acres Road (2023)
Sample ID: Oikos-3

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Dolophilodes	2	0	3	0.01463	-4.22440	-0.06182
Leuctra	2	0	4	0.01951	-3.93672	-0.07681
Diplectrona	2	0	32	0.15610	-1.85727	-0.28992
Ameletus	2	0	1	0.00488	-5.32301	-0.02597
Paraleptophlebia	2	1	5	0.02439	-3.71357	-0.09057
Rhyacophila	2	1	1	0.00488	-5.32301	-0.02597
Diploperla	2	2	2	0.00976	-4.62986	-0.04517
Isoperla	2	2	1	0.00488	-5.32301	-0.02597
Ephemera	3	2	1	0.00488	-5.32301	-0.02597
Prosimulium	3	2	1	0.00488	-5.32301	-0.02597
Amphinemura	3	3	47	0.22927	-1.47286	-0.33768
Maccaffertium	3	3	6	0.02927	-3.53125	-0.10335
Acentrella	3	4	2	0.00976	-4.62986	-0.04517
Stenacron	4	4	4	0.01951	-3.93672	-0.07681
Optioservus	4	4	1	0.00488	-5.32301	-0.02597
Psephenus	4	4	2	0.00976	-4.62986	-0.04517
Cambaridae	4	6	4	0.01951	-3.93672	-0.07681
Baetis	4	6	6	0.02927	-3.53125	-0.10335
Caecidotea	5	6	74	0.36098	-1.01894	-0.36781
Chironomidae	5	6	5	0.02439	-3.71357	-0.09057
Simulium	5	6	1	0.00488	-5.32301	-0.02597
Oligochaeta	5	10	2	0.00976	-4.62986	-0.04517
		TOTAL	205		SHANNON	2.0380

Metric	Value	Standard	Standardized score
Taxa richness	22	33	66.67
EPT richness (PTV 0-4)	13	19	68.42
Beck's index	20	38	52.63
Hilsenhoff biotic index	3.76	1.89	76.94
Shannon diversity	2.04	2.86	71.33
Percent sensitive (PTV 0-3)	50.73	84.5	60.04
		IBI SCORE:	66.00

Macroinvertebrate Sampling Results, Moonlight Drive (2023)
Sample ID: Oikos-4

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Leuctra	2	0	7	0.0337	-3.3916	-0.1141
Dolophilodes	2	0	1	0.0048	-5.3375	-0.0257
Diplectrona	2	0	5	0.0240	-3.7281	-0.0896
Rhyacophila	2	1	1	0.0048	-5.3375	-0.0257
Amphinemura	3	3	29	0.1394	-1.9702	-0.2747
Eurylophella	3	4	3	0.0144	-4.2389	-0.0611
Optioservus	4	4	1	0.0048	-5.3375	-0.0257
Hydropsyche	5	5	3	0.0144	-4.2389	-0.0611
Hemerodromia	4	5	1	0.0048	-5.3375	-0.0257
Stenelmis	5	5	2	0.0096	-4.6444	-0.0447
Calopteryx	4	6	1	0.0048	-5.3375	-0.0257
Polycentropus	4	6	3	0.0144	-4.2389	-0.0611
Cheumatopsyche	5	6	1	0.0048	-5.3375	-0.0257
Caecidotea	5	6	4	0.0192	-3.9512	-0.0760
Chironomidae	5	6	138	0.6635	-0.4103	-0.2722
Oligochaeta	5	10	8	0.0385	-3.2581	-0.1253
		TOTAL	208		SHANNON	1.3340

Metric	Value	Standard	Standardized score
Taxa richness	16	33	48.48
EPT richness (PTV 0-4)	6	19	31.58
Beck's index	11	38	28.95
Hilsenhoff biotic index	5.27	1.89	58.32
Shannon diversity	1.33	2.86	46.50
Percent sensitive (PTV 0-3)	22.12	84.5	26.18
		IBI SCORE:	40.00

Macroinvertebrate Sampling Results, Worthington, Downstream of Borough (2023) Sample ID: Oikos-5

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Paraleptophlebia	2	1	7	0.0422	-3.1661	-0.1335
Rhyacophila	2	1	1	0.0060	-5.1120	-0.0308
Isonychia	3	3	3	0.0181	-4.0134	-0.0725
Maccaffertium	3	3	6	0.0361	-3.3202	-0.1200
Antocha	4	3	1	0.0060	-5.1120	-0.0308
Psephenus	4	4	1	0.0060	-5.1120	-0.0308
Optioservus	4	4	1	0.0060	-5.1120	-0.0308
Chimarra	4	4	2	0.0120	-4.4188	-0.0532
Hydropsyche	5	5	10	0.0602	-2.8094	-0.1692
Stenelmis	5	5	2	0.0120	-4.4188	-0.0532
Baetis	4	6	10	0.0602	-2.8094	-0.1692
Polycentropus	4	6	2	0.0120	-4.4188	-0.0532
Cheumatopsyche	5	6	1	0.0060	-5.1120	-0.0308
Caecidotea	5	6	4	0.0241	-3.7257	-0.0898
Chironomidae	5	6	114	0.6867	-0.3758	-0.2581
Simulium	5	6	1	0.0060	-5.1120	-0.0308
		TOTAL	166		SHANNON	1.3569

Metric	Value	Standard	Standardized score
Taxa richness	16	33	48.48
EPT richness (PTV 0-4)	5	19	26.32
Beck's index	4	38	10.53
Hilsenhoff biotic index	5.46	1.89	55.98
Shannon diversity	1.36	2.86	47.55
Percent sensitive (PTV 0-3)	10.84	84.5	12.83
		IBI SCORE:	31.66

Macroinvertebrate Sampling Results, Worthington, Upstream of Borough (2023) Sample ID: Oikos-6

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Isoperla	2	2	2	0.0095	-4.6540	-0.0443
Optioservus	4	4	1	0.0048	-5.3471	-0.0255
Chimarra	4	4	2	0.0095	-4.6540	-0.0443
Hydropsyche	5	5	6	0.0286	-3.5553	-0.1016
Stenelmis	5	5	30	0.1429	-1.9459	-0.2780
Probezzia	4	6	2	0.0095	-4.6540	-0.0443
Cheumatopsyche	5	6	4	0.0190	-3.9608	-0.0754
Chironomidae	5	6	154	0.7333	-0.3102	-0.2274
Cambaridae	4	6	1	0.0048	-5.3471	-0.0255
Planorbidae	5	6	1	0.0048	-5.3471	-0.0255
Oligochaeta	5	10	7	0.0333	-3.4012	-0.1134
		TOTAL	210		SHANNON	1.0052

Metric	Value	Standard	Standardized score
Taxa richness	11	33	33.33
EPT richness (PTV 0-4)	2	19	10.53
Beck's index	2	38	5.26
Hilsenhoff biotic index	5.9	1.89	50.55
Shannon diversity	1.01	2.86	35.31
Percent sensitive (PTV 0-3)	0.95	84.5	1.12
		IBI SCORE:	22.69

2022 Macroinvertebrate Sampling

Overview of Summary Results

The following is a summary of macroinvertebrate sampling results from April to May 2022

Site Name	Date	Latitude, Longitude	IBI Score	Result	Notes
Headwaters Buffalo Creek	4/15/2022	40.94818, -79.74735	32.42	impaired	
UNT to Little Buffalo Run	4/15/2022	40.88893, -79.7547	50.13	attaining	
Headwaters Little Buffalo Run	4/15/2022	40.85648, -79.76028	40.36	impaired	
Buffalo Run	4/15/2022	40.86472, -79.70507	57.55	attaining	
Pine Run Mouth	4/11/2022	40.732034, -79.679226	75.00	attaining	
Little Buffalo Creek Mouth	4/11/2022	40.708712, -79.704239	47.86	impaired	
Buffalo Creek Lower	4/28/2022	40.70865, -79.70218	60.66	attaining	
Marrowbone Run	4/28/2022	40.79322, -79.65063	49.44	impaired	
Buffalo Creek Middle	4/27/2022	40.85255, -79.64947	46.20	impaired	
Headwaters Little Buffalo Creek	4/26/2022	40.76465, -79.76585	32.79	impaired	
Sarver Run	4/26/2022	40.721, -79.75596	55.53	impaired	Beck's index <33 and percent sensitive <25
Sarver Run- Rough Run	5/11/2022	40.81144, -79.73213	76.76	attaining	

Macroinvertebrate Sampling Results, Headwaters, Buffalo Creek (2022)

Taxon	PTV	Number	n/total	ln(n/total))	E*F
Amphinemura	3	1	0.0055	-5.1985	-0.0287
Maccaffertium	3	1	0.0055	-5.1985	-0.0287
Antocha	3	9	0.0497	-3.0013	-0.1492
Stenacron	4	1	0.0055	-5.1985	-0.0287
Eurylophella	4	1	0.0055	-5.1985	-0.0287
Pycnopschye	4	1	0.0055	-5.1985	-0.0287
Optioservus	4	10	0.0552	-2.8959	-0.1600
Hydropsyche	5	2	0.0110	-4.5053	-0.0498
Stenelmis	5	7	0.0387	-3.2526	-0.1258
Hemerodromia	5	5	0.0276	-3.5891	-0.0991
Caecidotea	6	22	0.1215	-2.1075	-0.2562
Chironomidae	6	105	0.5801	-0.5445	-0.3159
Cheumatopsyche	6	7	0.0387	-3.2526	-0.1258
Hydracrina	7	7	0.0387	-3.2526	-0.1258
Turbellaria	9	1	0.0055	-5.1985	-0.0287
Oligochaeta	10	1	0.0055	-5.1985	-0.0287
	TOTAL	181		SHANNON	1.6086

Metric	Value	Standard	Standardized score
Taxa richness	16	33	48.48
EPT richness (PTV 0-4)	5	19	26.32
Beck's index	0	38	0.00
Hilsenhoff biotic index	5.44	1.89	56.23
Shannon diversity	1.61	2.86	56.29
Percent sensitive (PTV 0-3)	6.08	84.5	7.20
		IBI SCORE:	32.42

Macroinvertebrate Sampling Results, UNT to Little Buffalo Run (2022)

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Acroneuria	0	2	1	0.0049	-5.3230	-0.0260
Suwallia	1	0	6	0.0293	-3.5313	-0.1034
Diplectrona	2	0	6	0.0293	-3.5313	-0.1034
Rhyacophila	2	1	7	0.0341	-3.3771	-0.1153
Perlodidae	2	2	2	0.0098	-4.6299	-0.0452
Ephemerella	3	1	17	0.0829	-2.4898	-0.2065
Prosimulium	3	2	1	0.0049	-5.3230	-0.0260
Amphinemura	3	3	17	0.0829	-2.4898	-0.2065
Maccaffertium	3	3	1	0.0049	-5.3230	-0.0260
Capniidae	3	3	1	0.0049	-5.3230	-0.0260
Optioservus	4	4	1	0.0049	-5.3230	-0.0260
Hemerodromia	4	5	3	0.0146	-4.2244	-0.0618
Probezzia	4	6	2	0.0098	-4.6299	-0.0452
Polycentropus	4	6	1	0.0049	-5.3230	-0.0260
Baetis	4	6	6	0.0293	-3.5313	-0.1034
Tipula	5	4	1	0.0049	-5.3230	-0.0260
Simulium	5	6	19	0.0927	-2.3786	-0.2205
Chironomidae	5	6	110	0.5366	-0.6225	-0.3340
Oligochaeta	5	10	3	0.0146	-4.2244	-0.0618
		TOTAL	205		SHANNON	1.7886

Metric	Value	Standard	Standardized score
Taxa richness	19	33	57.58
EPT richness (PTV 0-4)	9	19	47.37
Beck's index	13	38	34.21
Hilsenhoff biotic index	4.73	1.89	64.98
Shannon diversity	1.79	2.86	62.59
Percent sensitive (PTV 0-3)	28.78	84.5	34.06
		IBI SCORE:	50.13

Macroinvertebrate Sampling Results, Headwaters Little Buffalo Run (2022)

Taxon	PTV	Number	n/total	ln(n/total))	E*F
Ephemerella	1	3	0.0155	-4.1641	-0.0647
Rhyacophila	1	3	0.0155	-4.1641	-0.0647
Amphinemura	3	36	0.1865	-1.6792	-0.3132
Neophylax	3	1	0.0052	-5.2627	-0.0273
Maccaffertium	3	4	0.0207	-3.8764	-0.0803
Eurylophella	4	2	0.0104	-4.5695	-0.0474
Tipula	4	1	0.0052	-5.2627	-0.0273
Optioservus	4	16	0.0829	-2.4901	-0.2064
Stenelmis	5	9	0.0466	-3.0655	-0.1429
Hemerodromia	5	7	0.0363	-3.3168	-0.1203
Cheumatopsyche	6	1	0.0052	-5.2627	-0.0273
Probezzia	6	1	0.0052	-5.2627	-0.0273
Simulium	6	3	0.0155	-4.1641	-0.0647
Chironomidae	6	102	0.5285	-0.6377	-0.3370
Baetis	6	1	0.0052	-5.2627	-0.0273
Hydracrina	7	1	0.0052	-5.2627	-0.0273
Oligochaeta	10	2	0.0104	-4.5695	-0.0474
	TOTAL	193		SHANNON	1.6528

Metric	Value	Standard	Standardized score
Taxa richness	17	33	51.52
EPT richness (PTV 0-4)	6	19	31.58
Beck's index	4	38	10.53
Hilsenhoff biotic index	4.97	1.89	62.02
Shannon diversity	1.65	2.86	57.69
Percent sensitive (PTV 0-3)	24.35	84.5	28.82
		IBI SCORE:	40.36

Macroinvertebrate Sampling Results, Buffalo Run (2022)

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Suwallia	1	0	5	0.02294	-3.77506	-0.08658
Diplectrona	2	0	1	0.00459	-5.38450	-0.02470
Paraleptophlebia	2	1	4	0.01835	-3.99820	-0.07336
Ephemerella	3	1	8	0.03670	-3.30505	-0.12129
Ephemera	3	2	6	0.02752	-3.59274	-0.09888
Prosimulium	3	2	1	0.00459	-5.38450	-0.02470
Micrasema	3	2	1	0.00459	-5.38450	-0.02470
Macronychus	4	2	1	0.00459	-5.38450	-0.02470
Amphinemura	3	3	1	0.00459	-5.38450	-0.02470
Maccaffertium	3	3	28	0.12844	-2.05229	-0.26360
Neophylax	3	3	1	0.00459	-5.38450	-0.02470
Antocha	4	3	1	0.00459	-5.38450	-0.02470
Acentrella	3	4	1	0.00459	-5.38450	-0.02470
Optioservus	4	4	17	0.07798	-2.55128	-0.19895
Chimarra	4	4	10	0.04587	-3.08191	-0.14137
Hemerodromia	4	5	7	0.03211	-3.43858	-0.11041
Gomphus	4	5	1	0.00459	-5.38450	-0.02470
Hydropsyche	5	5	3	0.01376	-4.28588	-0.05898
Stenelmis	5	5	23	0.10550	-2.24900	-0.23728
Baetis	4	6	3	0.01376	-4.28588	-0.05898
Polycentropus	4	6	2	0.00917	-4.69135	-0.04304
Chironomidae	5	6	82	0.37615	-0.97778	-0.36779
Simulium	5	6	8	0.03670	-3.30505	-0.12129
Caenis	5	7	1	0.00459	-5.38450	-0.02470
Oligochaeta	5	10	2	0.00917	-4.69135	-0.04304
		TOTAL	218		SHANNON	2.27184

Metric	Value	Standard	Standardized score
Taxa richness	25	33	75.76
EPT richness (PTV 0-4)	11	19	57.89
Beck's index	13	38	34.21
Hilsenhoff biotic index	4.6	1.89	66.58
Shannon diversity	2.27	2.86	79.37
Percent sensitive (PTV 0-3)	26.61	84.5	31.49
		IBI SCORE:	57.55

Macroinvertebrate Sampling Results, Pine Run Mouth (2022)

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Suwallia	1	0	37	0.1832	-1.6973	-0.3109
Alloperla	1	0	1	0.0050	-5.3083	-0.0263
Diplectrona	2	0	2	0.0099	-4.6151	-0.0457
Epeorus	2	0	2	0.0099	-4.6151	-0.0457
Ameletus	2	0	1	0.0050	-5.3083	-0.0263
Paraleptophlebia	2	1	6	0.0297	-3.5165	-0.1045
Acroneuria	3	0	1	0.0050	-5.3083	-0.0263
Sweltsa	3	0	2	0.0099	-4.6151	-0.0457
Ephemerella	3	1	54	0.2673	-1.3193	-0.3527
Hexatoma	3	2	1	0.0050	-5.3083	-0.0263
Prosimulium	3	2	1	0.0050	-5.3083	-0.0263
Amphinemura	3	3	15	0.0743	-2.6002	-0.1931
Neophylax	3	3	1	0.0050	-5.3083	-0.0263
Eurylophella	3	4	2	0.0099	-4.6151	-0.0457
Baetidae	3	6	1	0.0050	-5.3083	-0.0263
Antocha	4	3	4	0.0198	-3.9220	-0.0777
Optioservus	4	4	18	0.0891	-2.4179	-0.2155
Hemerodromia	4	5	3	0.0149	-4.2097	-0.0625
Polycentropus	4	6	1	0.0050	-5.3083	-0.0263
Hydropsyche	5	5	1	0.0050	-5.3083	-0.0263
Cheumatopsyche	5	6	2	0.0099	-4.6151	-0.0457
Chironomidae	5	6	42	0.2079	-1.5706	-0.3266
Simulium	5	6	3	0.0149	-4.2097	-0.0625
Oligochaeta	5	10	1	0.0050	-5.3083	-0.0263
		TOTAL	202		SHANNON	2.1971

Metric	Value	Standard	Standardized score
Taxa richness	24	33	72.73
EPT richness (PTV 0-4)	12	19	63.16
Beck's index	27	38	71.05
Hilsenhoff biotic index	2.61	1.89	91.12
Shannon diversity	2.2	2.86	76.92
Percent sensitive (PTV 0-3)	63.37	84.5	74.99
		IBI SCORE:	75.00

Macroinvertebrate Sampling Results, Little Buffalo Creek Mouth (2022)

Taxon	PTV	Number	n/total	ln(n/total))	E*F
Alloperla	0	4	0.0242	-3.7197	-0.0902
Suwallia	0	1	0.0061	-5.1059	-0.0309
Diplectrona	0	1	0.0061	-5.1059	-0.0309
Ephemerella	1	5	0.0303	-3.4965	-0.1060
Prosimulium	2	4	0.0242	-3.7197	-0.0902
Amphinemura	3	19	0.1152	-2.1615	-0.2489
Stenacron	4	2	0.0121	-4.4128	-0.0535
Chimarra	4	2	0.0121	-4.4128	-0.0535
Optioservus	4	6	0.0364	-3.3142	-0.1205
Gammarus	4	1	0.0061	-5.1059	-0.0309
Gomphidae	4	1	0.0061	-5.1059	-0.0309
Hydropsyche	5	3	0.0182	-4.0073	-0.0729
Hemerodromia	5	11	0.0667	-2.7081	-0.1805
Simulium	6	29	0.1758	-1.7386	-0.3056
Polycentropus	6	2	0.0121	-4.4128	-0.0535
Chironomidae	6	53	0.3212	-1.1357	-0.3648
Cheumatopsyche	6	4	0.0242	-3.7197	-0.0902
Baetis	6	12	0.0727	-2.6210	-0.1906
Caenis	7	1	0.0061	-5.1059	-0.0309
Hydracrina	7	1	0.0061	-5.1059	-0.0309
Oligochaeta	10	3	0.0182	-4.0073	-0.0729
	TOTAL	165		SHANNON	1.8637

Metric	Value	Standard	Standardized score
Taxa richness	21	33	63.64
EPT richness (PTV 0-4)	7	19	36.84
Beck's index	12	38	31.58
Hilsenhoff biotic index	5.04	1.89	61.16
Shannon diversity	1.99	2.86	69.58
Percent sensitive (PTV 0-3)	20.61	84.5	24.39
		IBI SCORE:	47.86

Macroinvertebrate Sampling Results, Buffalo Creek Lower (2022)

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Diplectrona	2	0	1	0.0048	-5.3423	-0.0256
Acroneuria	3	0	3	0.0144	-4.2437	-0.0609
Haploperla	3	0	2	0.0096	-4.6492	-0.0445
Ephemerella	3	1	7	0.0335	-3.3964	-0.1138
Isoperla	2	2	2	0.0096	-4.6492	-0.0445
Amphinemura	3	3	11	0.0526	-2.9444	-0.1550
Maccaffertium	3	3	23	0.1100	-2.2068	-0.2429
Isonychia	3	3	16	0.0766	-2.5697	-0.1967
Antocha	4	3	2	0.0096	-4.6492	-0.0445
Acentrella	3	4	30	0.1435	-1.9411	-0.2786
Optioservus	4	4	5	0.0239	-3.7329	-0.0893
Psephenus	4	4	8	0.0383	-3.2629	-0.1249
Corydalus	4	4	2	0.0096	-4.6492	-0.0445
Chimarra	4	4	2	0.0096	-4.6492	-0.0445
Hemerodromia	4	5	1	0.0048	-5.3423	-0.0256
Hydropsyche	5	5	1	0.0048	-5.3423	-0.0256
Stenelmis	5	5	31	0.1483	-1.9083	-0.2831
Baetis	4	6	3	0.0144	-4.2437	-0.0609
Polycentropus	4	6	1	0.0048	-5.3423	-0.0256
Chironomidae	5	6	28	0.1340	-2.0101	-0.2693
Cheumatopsyche	5	6	4	0.0191	-3.9560	-0.0757
Simulium	5	6	12	0.0574	-2.8574	-0.1641
Caenis	5	7	10	0.0478	-3.0397	-0.1454
Sphaeriidae		8	1	0.0048	-5.3423	-0.0256
Turbellaria	5	9	1	0.0048	-5.3423	-0.0256
Oligochaeta	5	10	2	0.0096	-4.6492	-0.0445
		TOTAL	209		SHANNON	2.6809

Metric	Value	Standard	Standardized score
Taxa richness	26	33	78.79
EPT richness (PTV 0-4)	10	19	52.63
Beck's index	12	38	31.58
Hilsenhoff biotic index	4.38	1.89	69.30
Shannon diversity	2.68	2.86	93.71
Percent sensitive (PTV 0-3)	32.06	84.5	37.94
		IBI SCORE:	60.66

Macroinvertebrate Sampling Results, Marrowbone Run (2022)

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Leuctra	2	0	15	0.0926	-2.3795	-0.2203
Paraleptophlebia	2	1	1	0.0062	-5.0876	-0.0314
Ephemerella	3	1	1	0.0062	-5.0876	-0.0314
Ephemera	3	2	3	0.0185	-3.9890	-0.0739
Hexatoma	3	2	5	0.0309	-3.4782	-0.1074
Prosimulium	3	2	1	0.0062	-5.0876	-0.0314
Isoperla	2	2	1	0.0062	-5.0876	-0.0314
Amphinemura	3	3	3	0.0185	-3.9890	-0.0739
Neophylax	3	3	3	0.0185	-3.9890	-0.0739
Antocha	4	3	2	0.0123	-4.3944	-0.0543
Stenacron	4	4	2	0.0123	-4.3944	-0.0543
Chimarra	4	4	1	0.0062	-5.0876	-0.0314
Pycnopsyche	3	4	1	0.0062	-5.0876	-0.0314
Optioservus	4	4	2	0.0123	-4.3944	-0.0543
Tipula	5	4	1	0.0062	-5.0876	-0.0314
Stenelmis	5	5	1	0.0062	-5.0876	-0.0314
Hemerodromia	4	5	6	0.0370	-3.2958	-0.1221
Sialis	5	6	1	0.0062	-5.0876	-0.0314
Dubiraphia	4	6	1	0.0062	-5.0876	-0.0314
Baetidae	3	6	1	0.0062	-5.0876	-0.0314
Chironomidae	5	6	74	0.4568	-0.7835	-0.3579
Nematoda		9	2	0.0123	-4.3944	-0.0543
Oligochaeta	5	10	34	0.2099	-1.5612	-0.3277
		TOTAL	162		SHANNON	1.9194

Metric	Value	Standard	Standardized score
Taxa richness	23	33	69.70
EPT richness (PTV 0-4)	10	19	52.63
Beck's index	11	38	28.95
Hilsenhoff biotic index	5.73	1.89	52.65
Shannon diversity	1.92	2.86	67.13
Percent sensitive (PTV 0-3)	21.6	84.5	25.56
		IBI SCORE:	49.44

Macroinvertebrate Sampling Results, Buffalo Creek Middle (2022)

Taxon	PTV	Number	n/total	ln(n/total))	E*F
Acroneuria	0	2	0.0101	-4.6002	-0.0462
Ephemerella	1	5	0.0251	-3.6839	-0.0926
Nigronia	2	1	0.0050	-5.2933	-0.0266
Ephemera	2	2	0.0101	-4.6002	-0.0462
Amphinemura	3	5	0.0251	-3.6839	-0.0926
Maccaffertium	3	4	0.0201	-3.9070	-0.0785
Antocha	3	3	0.0151	-4.1947	-0.0632
Isonychia	3	7	0.0352	-3.3474	-0.1177
Stenacron	4	1	0.0050	-5.2933	-0.0266
Optioservus	4	2	0.0101	-4.6002	-0.0462
Psephenus	4	4	0.0201	-3.9070	-0.0785
Baetisca	4	1	0.0050	-5.2933	-0.0266
Acentrella	4	6	0.0302	-3.5015	-0.1056
Hydropsyche	5	1	0.0050	-5.2933	-0.0266
Stenelmis	5	27	0.1357	-1.9975	-0.2710
Hemerodromia	5	6	0.0302	-3.5015	-0.1056
Chironomidae	6	88	0.4422	-0.8160	-0.3608
Cheumatopsyche	6	5	0.0251	-3.6839	-0.0926
Simulium	6	27	0.1357	-1.9975	-0.2710
Caenis	7	1	0.0050	-5.2933	-0.0266
Ancylidae	7	1	0.0050	-5.2933	-0.0266
	TOTAL	199		SHANNON	2.0280

Metric	Value	Standard	Standardized score
Taxa richness	21	33	63.64
EPT richness (PTV 0-4)	9	19	47.37
Beck's index	7	38	18.42
Hilsenhoff biotic index	5.17	1.89	59.56
Shannon diversity	2.03	2.86	70.98
Percent sensitive (PTV 0-3)	14.57	84.5	17.24
		IBI SCORE:	46.20

Macroinvertebrate Sampling Results, Headwaters Little Buffalo Creek (2022)

Taxon	PTV	Number	n/total	ln(n/total))	E*F
Ephemerella	1	1	0.0047	-5.3566	-0.0253
Antocha	3	6	0.0283	-3.5648	-0.1009
Amphinemura	3	2	0.0094	-4.6634	-0.0440
Eurylophella	4	1	0.0047	-5.3566	-0.0253
Acentrella	4	3	0.0142	-4.2580	-0.0603
Optioservus	4	4	0.0189	-3.9703	-0.0749
Gomphidae	4	1	0.0047	-5.3566	-0.0253
Stenelmis	5	45	0.2123	-1.5499	-0.3290
Hydropsyche	5	3	0.0142	-4.2580	-0.0603
Hemerodromia	5	13	0.0613	-2.7916	-0.1712
Probezzia	6	1	0.0047	-5.3566	-0.0253
Polycentropus	6	1	0.0047	-5.3566	-0.0253
Simulium	6	8	0.0377	-3.2771	-0.1237
Chironomidae	6	112	0.5283	-0.6381	-0.3371
Hydracrina	7	1	0.0047	-5.3566	-0.0253
Caenis	7	1	0.0047	-5.3566	-0.0253
Nematoda	9	3	0.0142	-4.2580	-0.0603
Oligochaeta	10	6	0.0283	-3.5648	-0.1009
	TOTAL	212		SHANNON	1.6393

Metric	Value	Standard	Standardized score
Taxa richness	18	33	54.55
EPT richness (PTV 0-4)	4	19	21.05
Beck's index	2	38	5.26
Hilsenhoff biotic index	5.66	1.89	53.51
Shannon diversity	1.64	2.86	57.34
Percent sensitive (PTV 0-3)	4.25	84.5	5.03
		IBI SCORE:	32.79

Macroinvertebrate Sampling Results, Sarver Run (2022)

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Suwallia	1	0	3	0.0172	-4.0604	-0.0700
Alloperla	1	0	1	0.0057	-5.1591	-0.0296
Diplectrona	2	0	1	0.0057	-5.1591	-0.0296
Leptophlebiidae	2	4	1	0.0057	-5.1591	-0.0296
Haploperla	3	0	4	0.0230	-3.7728	-0.0867
Ephemerella	3	1	1	0.0057	-5.1591	-0.0296
Amphinemura	3	3	9	0.0517	-2.9618	-0.1532
Eurylophella	3	4	1	0.0057	-5.1591	-0.0296
Acentrella	3	4	40	0.2299	-1.4702	-0.3380
Ectopria	3	5	1	0.0057	-5.1591	-0.0296
Oecetis	3	8	1	0.0057	-5.1591	-0.0296
Stenacron	4	1	1	0.0057	-5.1591	-0.0296
Antocha	4	3	5	0.0287	-3.5496	-0.1020
Psephenus	4	4	5	0.0287	-3.5496	-0.1020
Optioservus	4	4	7	0.0402	-3.2131	-0.1293
Hemerodromia	4	5	4	0.0230	-3.7728	-0.0867
Baetis	4	6	2	0.0115	-4.4659	-0.0513
Hydropsyche	5	5	4	0.0230	-3.7728	-0.0867
Cheumatopsyche	5	6	2	0.0115	-4.4659	-0.0513
Chironomidae	5	6	54	0.3103	-1.1701	-0.3631
Simulium	5	6	4	0.0230	-3.7728	-0.0867
Stenelmis	5	7	19	0.1092	-2.2146	-0.2418
Oligochaeta	5	10	2	0.0115	-4.4659	-0.0513
Hydroptilidae		4	2	0.0115	-4.4659	-0.0513
		TOTAL	174		SHANNON	2.2888

Metric	Value	Standard	Standardized score
Taxa richness	24	33	72.73
EPT richness (PTV 0-4)	11	19	57.89
Beck's index	16	38	42.11
Hilsenhoff biotic index	4.86	1.89	63.38
Shannon diversity	2.29	2.86	80.07
Percent sensitive (PTV 0-3)	14.37	84.5	17.01
		IBI SCORE:	55.53

Macroinvertebrate Sampling Results, Sarver Run- Rough Run (2022)

Taxon	BCG Attribute	PTV	Number	n/total	ln(n/total))	E*F
Goera	1	0	1	0.0053	-5.2417	-0.0277
Diplectrona	2	0	2	0.0106	-4.5486	-0.0481
Drunella	2	1	8	0.0423	-3.1623	-0.1339
Isoperla	2	2	1	0.0053	-5.2417	-0.0277
Leptophlebiidae	2	4	5	0.0265	-3.6323	-0.0961
Acroneuria	3	0	3	0.0159	-4.1431	-0.0658
Haploperla	3	0	28	0.1481	-1.9095	-0.2829
Agapetus	3	0	2	0.0106	-4.5486	-0.0481
Ephemerella	3	1	64	0.3386	-1.0829	-0.3667
Ephemera	3	2	1	0.0053	-5.2417	-0.0277
Hexatoma	3	2	1	0.0053	-5.2417	-0.0277
Amphinemura	3	3	4	0.0212	-3.8555	-0.0816
Maccaffertium	3	3	1	0.0053	-5.2417	-0.0277
Dicranota	3	3	4	0.0212	-3.8555	-0.0816
Acentrella	3	4	17	0.0899	-2.4085	-0.2166
Isonychia	3	7	2	0.0106	-4.5486	-0.0481
Antocha	4	3	2	0.0106	-4.5486	-0.0481
Optioservus	4	4	3	0.0159	-4.1431	-0.0658
Hemerodromia	4	5	1	0.0053	-5.2417	-0.0277
Polycentropus	4	6	1	0.0053	-5.2417	-0.0277
Tipula	5	4	1	0.0053	-5.2417	-0.0277
Hydropsyche	5	5	2	0.0106	-4.5486	-0.0481
Cheumatopsyche	5	6	3	0.0159	-4.1431	-0.0658
Chironomidae	5	6	19	0.1005	-2.2973	-0.2309
Simulium	5	6	10	0.0529	-2.9392	-0.1555
Oligochaeta	5	10	2	0.0106	-4.5486	-0.0481
Gonomyia		4	1	0.0053	-5.2417	-0.0277
		TOTAL	189		SHANNON	2.3815

Metric	Value	Standard	Standardized score
Taxa richness	27	33	81.82
EPT richness (PTV 0-4)	13	19	68.42
Beck's index	22	38	57.89
Hilsenhoff biotic index	2.47	1.89	92.85
Shannon diversity	2.38	2.86	83.22
Percent sensitive (PTV 0-3)	64.55	84.5	76.39
		IBI SCORE:	76.76

2022 Water Quality Sampling

Overview of Summary Results

The following is a summary of water quality sampling results from April to May 2022

Site Name	Date	Lat, Lon	Temp C	DO mg/L	pH	Conduct.	Turb.	TDS	Alk.	PO4	NO3
Buffalo Run	4/15/22	40.90095, -79.70758	11.8	11.12	7.75	97	4	63.6	40	0.06	0.5
Headwaters Buffalo Creek	4/15/22	40.94818, -79.74735	10.8	11.4	7.8	221	7	165	60	0.06	0.5
UNT to Little Buffalo Run	4/15/22	40.88893, -79.7547	10	11.39	7.71	140.3	7	96.8	40	0.6	x
Headwaters Little Buffalo Run	4/15/22	40.85648, -79.76028	7.7	12.68	8.15	231	2	165	60	0.1	2.2
Buffalo Run	4/15/22	40.86472, -79.70507	11.4	11.48	7.66	172	5	122	40	0.03	1.1
Cornplanter Mouth	4/11/22	40.75459, -79.67288	6.3	12.68	8.19	182.2	0	129	40	0	2
Pine Run Mouth	4/11/22	40.732034, -79.679226	7.2	12.36	8.03	248	2	176	60	0.05	1.6
Little Buffalo Creek Mouth	4/11/22	40.708712, -79.704239	6	13.35	8.25	319	0	228	60	0.06	3
Buffalo Creek Lower	4/28/22	40.70865, -79.70218	9.2	13.47	8.47	310	4	217	60	0.06	1.3
Sipes Run	4/28/22	40.76969, -79.672	5.6	13.48	7.9	154.2	3	110	40	0.16	2.7
Marrowbone Run	4/28/22	40.79322, -79.65063	8.7	13.76	7.9	370	2	263	80	0.07	0.5
Headwater fo Patterson Run	4/27/22	40.93166, -79.65656	7.3	13.33	7.69	160.1	0	114	40	0.1	2.7
Long Run	4/27/22	40.86859, -79.63299	8.1	11.98	7.77	432	0	311	60	0.06	1.5
Buffallo Creek Middle	4/27/22	40.85255, -79.64947	8.9	12.46	7.95	264	0	188	60	0.15	0.9
Patterson Run Mouth	4/27/22	40.85229, -79.63796	8.2	12.93	7.79	234	0	169	60	0.23	0.5
Rough Run Mouth	4/26/22	40.78554, -79.68866	13.5	10.5	8.12	289	0	207	60	0	1.5
North Branch Rough Run	4/26/22	40.81106, -79.73204	12.4	10.54	8.09	212	0	151	40	0.08	3.5
Headwaters Little Buffalo Creek	4/26/22	40.76465, -79.76585	12.4	11.06	8.03	317	0	226	60	0.06	1.3
Sarver Run	4/26/22	40.721, -79.75596	13.7	10.43	8.31	302	3	215	80	0.06	1.3
Sarver Run-Rough Run	5/11/22	40.81144, -79.73213	15.4	X	7.64	155.8	0	111	40	0.34	1.4

CWM Environmental
101 Parkview Drive Ext.
Kittanning, Pennsylvania 16201
724-543-3011
Lab # 03-457

Lab Analysis Report

Customer: Ethos Collaborative
Project: Buffalo Creek Testing
Sample: Buffalo Creek Oikos-1
Collection Method: Grab

Sample Number: 23E1322-01
Collection: 05/04/2023 10:00
Received: 05/04/2023 15:33
Matrix: NPW

Cert	Analyte	Result		RL	Units	Prep Date	Analysis Date	Analyst	Method
General Chemistry									
	pH	7.73	H		S.U. @ 25ºC	05/09/2023 10:30	05/09/2023 11:25	EJK	SM 4500-H+B
	Phosphorus	<0.10		0.10	mg/L	05/15/2023 14:23	05/15/2023 14:23	SWB	EPA 365.3
	Total Kjeldahl Nitrogen	<1.00		1.00	mg/L	05/11/2023 15:00	05/15/2023 12:56	POB	EPA 351.2
	Nitrate+Nitrite Nitrogen	0.53		0.20	mg/L	05/11/2023 17:05	05/11/2023 17:05	SWB	SM 4500-NO3 H
	Nitrogen, Total	<1.20		1.20	mg/L	05/11/2023 17:05	05/15/2023 12:56	POB	[CALC]
	Total Suspended Solids	5		3	mg/L	05/08/2023 13:06	05/08/2023 13:06	RLR	SM 2540 D

Paul Bookmyer

Paul Bookmyer, Technical Director

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Reported: 5/17/2023 12:40:51PM

Confidential
Page 1 of 8

CWM Environmental
101 Parkview Drive Ext.
Kittanning, Pennsylvania 16201
724-543-3011
Lab # 03-457

Lab Analysis Report

Customer: Ethos Collaborative
Project: Buffalo Creek Testing
Sample: Buffalo Creek Oikos-2
Collection Method: Grab

Sample Number: 23E1322-02
Collection: 05/04/2023 11:40
Received: 05/04/2023 15:33
Matrix: NPW

Cert	Analyte	Result		RL	Units	Prep Date	Analysis Date	Analyst	Method
General Chemistry									
	pH	7.22	H		S.U. @ 25ºC	05/09/2023 10:30	05/09/2023 11:25	EJK	SM 4500-H+B
	Phosphorus	0.16		0.10	mg/L	05/15/2023 14:23	05/15/2023 14:23	SWB	EPA 365.3
	Total Kjeldahl Nitrogen	<1.00		1.00	mg/L	05/11/2023 15:00	05/15/2023 12:56	POB	EPA 351.2
	Nitrate+Nitrite Nitrogen	0.34		0.20	mg/L	05/11/2023 17:05	05/11/2023 17:05	SWB	SM 4500-NO3 H
	Nitrogen, Total	<1.20		1.20	mg/L	05/11/2023 17:05	05/15/2023 12:56	POB	[CALC]
	Total Suspended Solids	122		3	mg/L	05/08/2023 13:06	05/08/2023 13:06	RLR	SM 2540 D

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CWM Environmental
101 Parkview Drive Ext.
Kittanning, Pennsylvania 16201
724-543-3011
Lab # 03-457

Lab Analysis Report

Customer: Ethos Collaborative
Project: Buffalo Creek Testing
Sample: Buffalo Creek Oikos-3
Collection Method: Grab

Sample Number: 23E1322-03
Collection: 05/04/2023 12:20
Received: 05/04/2023 15:33
Matrix: NPW

Cert	Analyte	Result		RL	Units	Prep Date	Analysis Date	Analyst	Method
General Chemistry									
	pH	7.80	H		S.U. @ 25ºC	05/09/2023 10:30	05/09/2023 11:25	EJK	SM 4500-H+B
	Phosphorus	<0.10		0.10	mg/L	05/15/2023 14:23	05/15/2023 14:23	SWB	EPA 365.3
	Total Kjeldahl Nitrogen	<1.00		1.00	mg/L	05/11/2023 15:00	05/15/2023 12:56	POB	EPA 351.2
	Nitrate+Nitrite Nitrogen	5.27		0.20	mg/L	05/11/2023 17:05	05/11/2023 17:05	SWB	SM 4500-NO3 H
	Nitrogen, Total	5.27		1.20	mg/L	05/11/2023 17:05	05/15/2023 12:56	POB	[CALC]
	Total Suspended Solids	13		3	mg/L	05/08/2023 13:06	05/08/2023 13:06	RLR	SM 2540 D

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Reported: 5/17/2023 12:40:51PM

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CWM Environmental

101 Parkview Drive Ext.
Kittanning, Pennsylvania 16201
724-543-3011
Lab # 03-457

Lab Analysis Report

Customer: Ethos Collaborative
Project: Buffalo Creek Testing
Sample: Buffalo Creek Oikos-4
Collection Method: Grab

Sample Number: 23E1322-04
Collection: 05/04/2023 13:05
Received: 05/04/2023 15:33
Matrix: NPW

Cert	Analyte	Result		RL	Units	Prep Date	Analysis Date	Analyst	Method
General Chemistry									
	pH	7.74	H		S.U. @ 25ºC	05/09/2023 10:30	05/09/2023 11:25	EJK	SM 4500-H+B
	Phosphorus	0.10		0.10	mg/L	05/15/2023 14:23	05/15/2023 14:23	SWB	EPA 365.3
	Total Kjeldahl Nitrogen	<1.00		1.00	mg/L	05/11/2023 15:00	05/15/2023 12:56	POB	EPA 351.2
	Nitrate+Nitrite Nitrogen	0.60		0.20	mg/L	05/17/2023 09:42	05/17/2023 09:42	SWB	SM 4500-NO3 H
	Nitrogen, Total	<1.20		1.20	mg/L	05/17/2023 09:42	05/17/2023 09:42	POB	[CALC]
	Total Suspended Solids	60		3	mg/L	05/08/2023 13:06	05/08/2023 13:06	RLR	SM 2540 D

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CWM Environmental
101 Parkview Drive Ext.
Kittanning, Pennsylvania 16201
724-543-3011
Lab # 03-457

Lab Analysis Report

Customer: Ethos Collaborative
Project: Buffalo Creek Testing
Sample: Buffalo Creek Oikos-5
Collection Method: Grab

Sample Number: 23E1322-05
Collection: 05/04/2023 14:00
Received: 05/04/2023 15:33
Matrix: NPW

Cert	Analyte	Result		RL	Units	Prep Date	Analysis Date	Analyst	Method
General Chemistry									
	pH	7.82	H		S.U. @ 25ºC	05/09/2023 10:30	05/09/2023 11:25	EJK	SM 4500-H+B
	Phosphorus	0.12		0.10	mg/L	05/15/2023 14:23	05/15/2023 14:23	SWB	EPA 365.3
	Total Kjeldahl Nitrogen	<1.00		1.00	mg/L	05/11/2023 15:00	05/15/2023 12:56	POB	EPA 351.2
	Nitrate+Nitrite Nitrogen	3.36		0.20	mg/L	05/17/2023 09:42	05/17/2023 09:42	SWB	SM 4500-NO3 H
	Nitrogen, Total	3.36		1.20	mg/L	05/17/2023 09:42	05/17/2023 09:42	POB	[CALC]
	Total Suspended Solids	20		3	mg/L	05/08/2023 13:41	05/08/2023 13:41	RLR	SM 2540 D

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Paul Bookmyer, Technical Director

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CWM Environmental
101 Parkview Drive Ext.
Kittanning, Pennsylvania 16201
724-543-3011
Lab # 03-457

Lab Analysis Report

Customer: Ethos Collaborative
Project: Buffalo Creek Testing
Sample: Buffalo Creek Oikos-6
Collection Method: Grab

Sample Number: 23E1322-06
Collection: 05/04/2023 14:30
Received: 05/04/2023 15:33
Matrix: NPW

Cert	Analyte	Result		RL	Units	Prep Date	Analysis Date	Analyst	Method
General Chemistry									
	pH	7.63	H		S.U. @ 25ºC	05/09/2023 10:30	05/09/2023 11:25	EJK	SM 4500-H+B
	Phosphorus	0.22		0.10	mg/L	05/15/2023 14:23	05/15/2023 14:23	SWB	EPA 365.3
	Total Kjeldahl Nitrogen	1.00		1.00	mg/L	05/11/2023 15:00	05/15/2023 12:56	POB	EPA 351.2
	Nitrate+Nitrite Nitrogen	2.84		0.20	mg/L	05/17/2023 09:42	05/17/2023 09:42	SWB	SM 4500-NO3 H
	Nitrogen, Total	2.84		1.20	mg/L	05/17/2023 09:42	05/17/2023 09:42	POB	[CALC]
	Total Suspended Solids	16		3	mg/L	05/08/2023 13:41	05/08/2023 13:41	RLR	SM 2540 D

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Paul Bookmyer, Technical Director

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CWM Environmental
101 Parkview Drive Ext.
Kittanning, Pennsylvania 16201
724-543-3011
Lab # 03-457

Lab Analysis Report

Sample Comments

H	Method hold time exceeded.

Paul Bookmyer, Technical Director

PA DEP/TNI Accreditation # 03-00457. All analytes accredited unless otherwise specified.

CHAIN OF CUSTODY
Lab # 03-457
DC#00162 Eff 01-26-22

CWM ENVIRONMENTAL

101 Parkview Drive Ext Kittanning PA 16201 Phone: 724-543-3011 Fax: 724-543-6768

Client Name: Ethos Collaborative	Contact Name: Barton Kirk	PWSID#	NPDES#
Address: 5877 Commerce Street, Suite 222, Pittsburgh, PA 15206	Phone: 802-238-0813 Cell:	Reportable Sample:	RUSH Sample:
	Email:	Check Sample:	See Codes Below

CWM Lab #	Sample Site	Collection Point	DATE Sampled	GRAB Time Sampled	COMPOSITE Start / End	LAB Temps °C	Test/Analysis Requested	Field Data/Comments	Preservative	Matrix	Sample Type	Bottle Type	# of Bottles
01	Buffalo Creek	Oikos-1	5-4-23	10:00	/	4.1	TSS, pH		NA	NPW	G	P	1
⊥		Oikos-1	5-4-23	10:00	/		T.Nitrogen & Phosphorus		S	NPW	G	P	1
02		Oikos-2	5-4-23	11:40	/	5.2	TSS, pH						
⊥		Oikos-2	5-4-23	11:40	/		TN, TP						
03		Oikos-3	5-4-23	12:20	/	4.8	TSS, pH						
⊥		Oikos-3	5-4-23	12:20	/		TN, TP	RECEIVED ON ICE					
04		Oikos-4	5-4-23	1:05	/	4.6	TSS, pH						
⊥		Oikos-4	5-4-23	1:05	/		TN, TP						
05		Oikos-5	5-4-23	2:00	/	5.1	TSS, pH	23E1322					
⊥		Oikos-5	5-4-23	2:00	/		TN, TP						
06		Oikos-6	5-4-23	2:30	/	4.6	TSS, pH						
⊥		Oikos-6	5-4-23	2:30	/		TN, TP						
					/								
					/								

Sampled by Tim Nuttle	Date: 5-4-23	Time: 2:30	**Preservative Key:** ST = Sodium Thiosulfate A = Ascorbic Acid H = HNO3 C = HCL S = H2SO4 OH = NaOH O = Other NA = None
Relinquished by	5-4-23	3:20	**Matrix Key:** DW - Drinking Water Rec - Pool/Recreation Water NPW - Non Potable Water R - Raw S - Soil, Solid, Sludge F - Fuel
Received by			**Sample Type:** C = Composite G = Grab M = Micropurge **Bottles:** P = plastic G = glass O = other
Relinquished by			**Sample Comments:**
Received in Lab by	5/4/23	1520	**Sample Conditions:** Y N COC w/ samples Y N Meets Hold Times Y N Containers Intact Y N Correct bottles for tests Y N Correct # of bottles listed

Rev 000222

Appendix B - TMDL, Moonlight Drive

FINAL

Unt BUFFALO CREEK
Armstrong County, Pennsylvania

Prepared by:

Pennsylvania Department of Environmental Protection

March 5, 2007

TABLE OF CONTENTS

TABLES

ATTACHMENTS

FINAL TMDL
Unt Buffalo Creek Watershed
Armstrong County, Pennsylvania

Introduction

This Total Maximum Daily Load (TMDL) calculation has been prepared for a segment in the Unt (42685) to Buffalo Creek Watershed (Attachment A). It was done to address the impairments noted on the 1996 Pennsylvania 303(d) list, required under the Clean Water Act, and covers the one listed segment shown in Table 1. Metals in acidic discharge water from abandoned coalmines causes the impairment. The TMDL addresses the three primary metals associated with acid mine drainage iron, manganese, and aluminum.

Table 1. 303(d) Sub-List Allegheny River

State Water Plan (SWP) Subbasin: 18F

Year	SWP	Miles	Segment ID	DEP Stream Code	Stream Name	Designated Use	Data Source	Source	EPA 305(b) Cause Code
1996	18F	0.2	-	42685	Unt Buffalo Creek	TSF	303 (d) Report	Resource Extraction	Metals
1998	18F	0.2	-	42685	Unt Buffalo Creek	TSF	SWMP	AMD	Metals
2002	18F	0.2	-	42685	Unt Buffalo Creek	TSF	SWMP	AMD	Metals
2004	18F	3.1	20040930-0900-CLW	42685	Unt Buffalo Creek	TSF	SWMP	AMD	Metals

Trout Stocked Fishes = TSF
Surface Water Monitoring Program = SWMP
Abandoned Mine Drainage = AMD

Directions to the Unt (42685) Buffalo Creek Watershed

The Unnamed Tributary (42685) to Buffalo Creek Watershed is located in South Western Pennsylvania, occupying a west-central portion of Armstrong County and a small piece of Butler County. The watershed area is found on the Worthington 7.5-Minute Quadrangle United States Geological Survey map. The area within the watershed consists of 2.83 square miles. The headwaters of the watershed lie mostly around Route 422 at the Armstrong-Butler County line. The unnamed tributary to Bufflo Creek almost parallels Route 433 as it flows to the main Buffalo Creek stream. This Unnamed Tributary to Buffalo Creek can be accessed by taking route 66 north from Greensburg, PA to Route 422 west just south of Kittanning, PA. After traveling approximately 7.7 miles west on Route 422 the Unnamed Tributary to Buffalo Creek Passes under Route 422.

Segments addressed in this TMDL

The Unnamed Tributary to Buffalo Creek is affected by pollution from AMD. This pollution has caused high levels of manganese (at one sample point). The waterbody is net alkaline. The sources of the AMD are seeps and discharges from abandoned deep mines or refuse piles. Some of the discharges are considered to be nonpoint sources of pollution because they are from abandoned Pre-Act mining operations or from coal companies that have settled their bond forfeitures with the Pennsylvania Department of Environmental Protection (PADEP).

The designation for this stream segment can be found in PA Title 25 Chapter 93.

Clean Water Act Requirements

Section 303(d) of the 1972 Clean Water Act requires states, territories, and authorized tribes to establish water quality standards. The water quality standards identify the uses for each waterbody and the scientific criteria needed to support that use. Uses can include designations for drinking water supply, contact recreation (swimming), and aquatic life support. Minimum goals set by the Clean Water Act require that all waters be “fishable” and “swimmable.”

Additionally, the federal Clean Water Act and the U.S. Environmental Protection Agency’s (USEPA) implementing regulations (40 CFR 130) require:

- States to develop lists of impaired waters for which current pollution controls are not stringent enough to meet water quality standards (the list is used to determine which streams need TMDLs);

- States to establish priority rankings for waters on the lists based on severity of pollution and the designated use of the waterbody; states must also identify those waters for which TMDLs will be developed and a schedule for development;

- States to submit the list of waters to USEPA every four years (April 1 of the even numbered years);

- States to develop TMDLs, specifying a pollutant budget that meets state water quality standards and allocate pollutant loads among pollution sources in a watershed, e.g., point and nonpoint sources; and

- USEPA to approve or disapprove state lists and TMDLs within 30 days of final submission.

Despite these requirements, states, territories, authorized tribes, and USEPA have not developed many TMDLs since 1972. Beginning in 1986, organizations in many states filed lawsuits against the USEPA for failing to meet the TMDL requirements contained in the federal Clean Water Act and its implementing regulations. While USEPA has entered into consent agreements with the plaintiffs in several states, many lawsuits still are pending across the country.

In the cases that have been settled to date, the consent agreements require USEPA to backstop TMDL development, track TMDL development, review state monitoring programs, and fund studies on issues of concern (e.g., AMD, implementation of nonpoint source Best Management Practices (BMPs), etc.).

303(d) Listing Process

Prior to developing TMDLs for specific waterbodies, there must be sufficient data available to assess which streams are impaired and should be on the Section 303(d) list. With guidance from the USEPA, the states have developed methods for assessing the waters within their respective jurisdictions.

The primary method adopted by the Pennsylvania Department of Environmental Protection (Pa. DEP) for evaluating waters changed between the publication of the 1996 and 1998 303(d) lists. Prior to 1998, data used to list streams were in a variety of formats, collected under differing protocols. Information also was gathered through the 305(b) reporting process. Pa. DEP is now using the Unassessed Waters Protocol (UWP), a modification of the USEPA Rapid Bioassessment Protocol II (RPB-II), as the primary mechanism to assess Pennsylvania's waters. The UWP provides a more consistent approach to assessing Pennsylvania's streams.

The assessment method requires selecting representative stream segments based on factors such as surrounding land uses, stream characteristics, surface geology, and point source discharge locations. The biologist selects as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment can vary between sites. All the biological surveys included kick-screen sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Benthic macroinvertebrates are identified to the family level in the field.

After the survey is completed, the biologist determines the status of the stream segment. The decision is based on the performance of the segment using a series of biological metrics. If the stream is determined to be impaired, the source and cause of the impairment is documented. An impaired stream must be listed on the state's 303(d) list with the documented source and cause. A TMDL must be developed for the stream segment. A TMDL is for only one pollutant. If a stream segment is impaired by two pollutants, two TMDLs must be developed for that stream segment. In order for the process to be more effective, adjoining stream segments with the same source and cause listing are addressed collectively, and on a watershed basis.

Basic Steps for Determining a TMDL

Although all watersheds must be handled on a case-by-case basis when developing TMDLs, there are basic processes or steps that apply to all cases. They include:

1. Collection and summarization of pre-existing data (watershed characterization, inventory contaminant sources, determination of pollutant loads, etc.);
2. Calculate TMDL for the waterbody using USEPA approved methods and computer models;

3. Allocate pollutant loads to various sources;
4. Determine critical and seasonal conditions;
5. Submit draft report for public review and comments; and
6. USEPA approval of the TMDL.

This document will present the information used to develop the Unnamed Tributary (42685) of Buffalo Creek Watershed TMDL.

Watershed History

The Unnamed Tributary (42685) of Buffalo Creek is part of the Allegheny River Basin in Armstrong County and drains to the main stem of Buffalo Creek, which then flows south to the Allegheny River near Freeport, PA. The watershed area is located in the Allegheny Plateau Physiographic Province. The plateau is characterized by gently rolling hills with a maximum elevation of 1357 feet and a minimum elevation of 980 feet where the unnamed tributary flows into the main stem of Buffalo Creek.

The watershed is located on the Kellersburg Anticline which bi-sects the tributary roughly in the middle as the anticline runs north to south and the tributary flows west to east. Rocks of the local structure generally slope to the south and east with a dip of 2.0 degrees SE. The axis of the Kellersburg Anticline forms a gentle arching of the strata in an east-west direction and plunges S 15 degrees 30 minutes W into the ground at 0 degrees 40 minutes from horizontal.

Land uses within the watershed include agriculture, forestland, abandoned mine lands, and rural residential properties with a few small communities stretched mostly along Route 422. Route 422 passes through the north two-thirds of the watershed area from west to east. The unnamed tributary then flows south through abandoned mine land areas before entering into the main stem of Buffalo Creek.

Several abandoned deep mines underlie the watershed on the following coal seams: Upper Kittanning, Lower Kittanning, Clarion #2, Brookville and Scrubgrass. West Freedom Mining Co, George Ambrosia, Bauldoff & Somerville did the deep coal mining. An abandoned underground noncoal deep mine into the Vanport Limestone lies in the northern watershed area mined by the Graff-Kittanning Clay Products Co., Inc. Surface mining occurred on the following coal seams: Upper and Lower Freeports, Upper, Middle and Lower Kittannings, Scrubgrass, clarion, and Brookville. Strip mining done in the 1950's was by West Freedom Mining Co, John Heffelfinger, Ivywood Coal Co., Smith Contracting, North Star Coal, J. Russel Cravener, and Black Limestone Co. M & M Lime Co., Inc. surfaced mined coal in the early 1980's and Allegheny Mineral Corp operated surface and auger mining in the watershed during the 1990's. Deep mining on the Lower Freeport coal seam causes acid mine drainage in the watershed. Surface mining doesn't cause discharge problems as long as the Vanport Limestone is encountered and left to neutralize the acid producing materials. There is one active mining permit in the watershed, Allegheny Minerals Graff mine Surface Permit No. 03840105, that is addressed in this TMDL.

AMD Methodology

A two-step approach is used for the TMDL analysis of AMD impaired stream segments. The first step uses a statistical method for determining the allowable instream concentration at the point of interest necessary to meet water quality standards. This is done at each point of interest (sample point) in the watershed. The second step is a mass balance of the loads as they pass through the watershed. Loads at these points will be computed based on average annual flow.

The statistical analysis describes below can be applied to situations where all of the pollutant loading is from non-point sources as well as those where there are both point and non-point sources. The following defines what are considered point sources and non-point sources for the purposes of our evaluation; point sources are defined as permitted discharges, non-point sources are then any pollution sources that are not point sources. For situations where all of the impact is due to nonpoint sources, the equations shown below are applied using data for a point in the stream. The load allocation made at that point will be for all of the watershed area that is above that point. For situations where there are point-source impacts alone, or in combination with nonpoint sources, the evaluation will use the point-source data and perform a mass balance with the receiving water to determine the impact of the point source.

Allowable loads are determined for each point of interest using Monte Carlo simulation. Monte Carlo simulation is an analytical method meant to imitate real-life systems, especially when other analyses are too mathematically complex or too difficult to reproduce. Monte Carlo simulation calculates multiple scenarios of a model by repeatedly sampling values from the probability distribution of the uncertain variables and using those values to populate a larger data set. Allocations were applied uniformly for the watershed area specified for each allocation point. For each source and pollutant, it was assumed that the observed data were log-normally distributed. Each pollutant source was evaluated separately using @Risk[1] by performing 5,000 iterations to determine the required percent reduction so that the water quality criteria, as defined in the *Pennsylvania Code. Title 25 Environmental Protection, Department of Environmental Protection, Chapter 93, Water Quality Standards*, will be met instream at least 99 percent of the time. For each iteration, the required percent reduction is:

PR = maximum {0, (1-Cc/Cd)} where (1)

PR = required percent reduction for the current iteration

Cc = criterion in mg/l

Cd = randomly generated pollutant source concentration in mg/l based on the observed data

Cd = RiskLognorm(Mean, Standard Deviation) where (1a)

[1] @Risk – Risk Analysis and Simulation Add-in for Microsoft Excel, Palisade Corporation, Newfield, NY, 1990-1997.

Mean = average observed concentration

Standard Deviation = standard deviation of observed data

The overall percent reduction required is the 99th percentile value of the probability distribution generated by the 5,000 iterations, so that the allowable long-term average (LTA) concentration is:

LTA = Mean * (1 – PR99) where (2)

LTA = allowable LTA source concentration in mg/l

Once the allowable concentration and load for each pollutant is determined, mass-balance accounting is performed starting at the top of the watershed and working down in sequence. This mass-balance or load tracking is explained below.

Load tracking through the watershed utilizes the change in measured loads from sample location to sample location, as well as the allowable load that was determined at each point using the @Risk program.

There are two basic rules that are applied in load tracking; rule one is that if the sum of the measured loads that directly affect the downstream sample point is less than the measured load at the downstream sample point it is indicative that there is an increase in load between the points being evaluated, and this amount (the difference between the sum of the upstream and downstream loads) shall be added to the allowable load(s) coming from the upstream points to give a total load that is coming into the downstream point from all sources. The second rule is that if the sum of the measured loads from the upstream points is greater than the measured load at the downstream point this is indicative that there is a loss of instream load between the evaluation points, and the ratio of the decrease shall be applied to the load that is being tracked (allowable load(s)) from the upstream point.

Tracking loads through the watershed gives the best picture of how the pollutants are affecting the watershed based on the information that is available. The analysis is done to insure that water quality standards will be met at all points in the stream. The TMDL must be designed to meet standards at all points in the stream, and in completing the analysis, reductions that must be made to upstream points are considered to be accomplished when evaluating points that are lower in the watershed. Another key point is that the loads are being computed based on average annual flow and should not be taken out of the context for which they are intended, which is to depict how the pollutants affect the watershed and where the sources and sinks are located spatially in the watershed.

In Low pH TMDLs, acidity is compared to alkalinity as described in Attachment B. Each sample point used in the analysis of pH by this method must have measurements for total alkalinity and total acidity. Statistical procedures are applied, using the average value for total alkalinity at that point as the target to specify a reduction in the acid concentration. By maintaining a net alkaline stream, the pH value will be in the range between six and eight. This method negates the need to specifically compute the pH value, which for streams affected by low pH may not be a true reflection of acidity. This method assures that Pennsylvania's standard for pH is met when the acid concentration reduction is met.

Information for the TMDL analysis performed using the methodology described above is contained in the "TMDLs by Segment" section of this report.

Method to Quantify Treatment Pond Pollutant Load

Surface Coal Mines remove soil and overburden materials to expose the underground coal seams for removal. After removal of the coal, the overburden is replaced as mine spoil and the soil is replaced for revegetation. In a Typical surface mining operation the overburden materials are removed and placed in the previous cut where the coal has been removed. In this fashion, an active mining operation has a pit that progresses through the mining site during the life of the mine. The pit may have water reporting to it, as it is a low spot in the local area. Pit water can be the result of limited shallow groundwater seepage, direct precipitation into the pit, and surface runoff from partially regarded areas that have been backfilled but not yet revegated. Pit water is pumped to nearby treatment ponds where it is treated to the required treatment pond effluent limits. The standard effluent limits are as follows, although stricter effluent limits may be applied to a mining permit's effluent limits to insure that the discharge of treated water does not cause instream limits to be exceeded.

Standard Treatment Pond Effluent Limits:
Alkalinity > Acidity
6.0 <= pH <= 9.0
Al < 2.0
Fe < 3.0 mg/l
Mn < 2.0 mg/l

When a treatment plant has an NPDES permit a Waste Load Allocation (WLA) must be calculated. When there is flow data available this is used along with the permit Best Available Technology (BAT) limits for one or more of the following: aluminum, iron, and manganese. The following formula is used:

Flow (MGD) X BAT limit (mg/l) X 8.34 = lbs/day

When site specific flow data is unavailable to determine a waste load allocation for an active mining operation, an average flow rate must be determined. This is done by investigating and quantifying the hydrology of a surface mine site. The following is an explanation of the quantification of the potential pollution load reporting to the stream from permitted pit water treatment ponds that discharge water at established effluent limits when site specific flow data is unavailable.

The total water volume reporting to ponds for treatment can come from two primary sources: direct precipitation to the pit and runoff from the unregraded area following the pit's progression through the site. Groundwater seepage reporting to the pit is considered negligible compared to the flow rates resulting from precipitation.

In an active mining scenario, a mine operator pumps pit water to the ponds for chemical treatment. Pit water is often acidic with dissolved metals in nature. At the treatment ponds, alkaline chemicals are added to increase the pH and encourage dissolved metals to precipitate and settle. Pennsylvania averages 40 inches of precipitation per year. A maximum pit dimension without special permit approval is 1500 feet long by 300 feet wide. Assuming 100 percent runoff of the precipitation to be pumped to the treatment ponds results in the following equation and average flow rates for the pit area.

40 in. precip./yr x 1 ft/12/in. x 1500'x 300'/pit x 7.48 gal/ft3 x 1yr/365days x 1day/24hr. x 1hr/60mins. = 21.3

21.3 gal/min average discharge from direct precipitation into the open mining pit area.

Pit water can also result from runoff from the unregraded and revegetated area following the pit. DEP compliance efforts encourage that backfilling, topsoiling, and revegetation be as prompt and concurrent as mining conditions and weather conditions allow. Generally the revegatation follows about three pit widths behind the active mining area.

In the case of roughly backfilled land highly porous spoil; there is very little surface runoff. It is estimated that 80 percent of precipitation on the roughly regraded mine spoil infiltrates, 5 percent evaporates, and 15 percent may run off to the pit for pumping and potential treatment. The following equation represents the average flow reporting to the pit from the unregraded and unrevegatated spoil area.

40 in. precip./yr x 3 pit areas x 1 ft/12/in. x 1500'x 300'/pit x 7.48 gal/ft3 x 1yr/365days x 1day/24hr. x 1hr/60mins. x 15 in. runoff/100 in. precipitation =

= 9.6 gal/min average discharge from spoil runoff into the pit area.

The total average flow to the pit is represented by the sum of the direct pit precipitation and the water flowing to the pit from the spoil area as follows:

Total Average Flow = Direct Pit Precipitation + Spoil Runoff

Total Average Flow = 21.3 gal./min. + 9.6 gal./min. = 30.9 gal./min.

The resulting average load from a permitted treatment pond area as follows.

Allowable Aluminum Waste Load Allocation:
30.9 gal./min. x 2 mg/l x 0.01202 = 0.7 lbs./day

Allowable Iron Waste Load Allocation:
30.9 gal./min. x 3 mg/l x 0.01202 = 1.1 lbs./day

Allowable Manganese Waste Load Allocation:
30.9 gal./min. x 2 mg/l x 0.01202 = 0.7 lbs./day

(Note: 0.01202 is a conversion factor to convert from a flow rate in gal./min. and a concentration in mg/l to a load in units of lbs./day.)

Field experience shows that the average flow rate of 30.9 gal./min. is excessively high. It is common for many mining sites to have very “dry” pits that rarely accumulate water that would require pumping and treatment. Also, it is the goal of DEP’s permit review process to not issue mining permits that would cause negative impacts to the enviroment. As a step to insure that a mine site does not produce acid drainage, it is common to require the addition of alkaline materials (limestone, alkaline shale or other rocks) may produce alkaline pit water with very low metals concentrations that does not require treatment. Also, while most mining operations are permitted to have a standard, 1500’ x 300’ pit, most are well below that size and have a corresponding decreased flow and load. Where pit dimensions are greater that the standard size is present, the calculations to define the potential pollution load are adjusted accordingly. Hence, the above calculated Waste Load Allocation is very generous and likely high compared to actual conditions that are generally encountered.

TMDL Endpoints

One of the major components of a TMDL is the establishment of an instream numeric endpoint, which is used to evaluate the attainment of acceptable water quality. An instream numeric endpoint, therefore, represents the water quality goal that is to be achieved by implementing the load reductions specified in the TMDL. The endpoint allows for comparison between observed instream conditions and conditions that are expected to restore designated uses. The endpoint is based on either the narrative or numeric criteria available in water quality standards.

Because of the nature of the pollution sources in the watershed, the TMDLs component makeup will be load allocations that are specified above a point in the stream segment. All allocations will be specified as long-term average daily concentrations. These long-term average daily concentrations are expected to meet water quality criteria 99 percent of the time. Pennsylvania Title 25 Chapter 96.3(c) specifies that a minimum 99 percent level of protection is required. All metals criteria evaluated in this TMDL are specified as total recoverable. Pennsylvania does have dissolved criteria for iron; however, the data used for this analysis report iron as total recoverable. Table 2 shows the water quality criteria for the selected parameters.

Table 2 Applicable Water Quality Criteria

Parameter	***Criterion Value (mg/l)***	***Total Recoverable/Dissolved***
Aluminum (Al)	0.75	Total Recoverable
Iron (Fe)	1.50 0.3	Total Recoverable Dissolved
Manganese (Mn)	1.00	Total Recoverable
pH *	6.0-9.0	N/A

*The pH values shown will be used when applicable. In the case of freestone streams with little or no buffering capacity, the TMDL endpoint for pH will be the natural background water quality. These values are typically as low as 5.4 (Pennsylvania Fish and Boat Commission).

TMDL Elements (WLA, LA, MOS)

A TMDL equation consists of a wasteload allocation, load allocation and a margin of safety. The wasteload allocation is the portion of the load assigned to point sources. The load allocation is the portion of the load assigned to nonpoint sources. The margin of safety is applied to account for uncertainties in the computational process. The margin of safety may be expressed implicitly (documenting conservative processes in the computations) or explicitly (setting aside a portion of the allowable load).

TMDL Allocations Summary

There was not enough paired data available to Analyze for critical flow conditions for pollutant sources.

Allocation Summary

This TMDL will focus remediation efforts on the identified numerical reduction targets for each watershed. The reductions in Table 3 for each segment are based on the assumption that all upstream allocations are achieved and take into account all upstream reductions. Attachment C contains the TMDLs by segment analysis for each allocation point in a detailed discussion. As changes occur in the watershed, the TMDL may be re-evaluated to reflect current conditions. Table 3 presents the estimated reductions identified for all points in the watershed. An implicit MOS based on conservative assumptions in the analysis is included in the TMDL calculations.

The allowable LTA concentrations in each segment is calculated using Monte Carlo Simulation as described previously. The allowable load is then determined by multiplying the allowable concentration by the flow and a conversion factor at each sample point. The allowable load is the TMDL.

Each permitted discharge in a segment is assigned a waste load allocation and the total waste load allocation for each segment is included in this table. There is one active mining permit in the watershed which requires a WLA, Allegheny Minerals Graff mine Surface Permit No. 03840105, that is addressed in this TMDL. This site has one treatment pond in operation. The difference between the TMDL and the WLA at each point is the load allocation at the point. The LA at each point includes all loads entering the segment, including those from upstream allocation points. The percent reduction is calculated to show the amount of load that needs to be reduced within a segment in order for water quality standards to be met at the point.

In some instances, instream processes, such as settling are taking place within a stream segment. These processes are evidenced by a decrease in measured loading between consecutive sample points. It is appropriate to account for these losses when tracking upstream loading through a segment. The calculated upstream load lost within a segment is proportional to the difference in the measured loading between the sampling points.

Table 3. Summary Table–Unnamed (42685) Tributary to Buffalo Creek

Station	Parameter	Existing Load (lbs/day)	TMDL Allowable Load (lbs/day)	WLA (lbs/day)	LA (lbs/day)	Load Reduction (lbs/day)	Percent Reduction %
BC6	Mouth of Unt (42687) Upstream of Confluence with Unt (42685) of Buffalo Creek						
	Al	0.3	0.2	0.0	0.2	0.1	51
	Fe	0.8	0.3	0.0	0.3	0.5	66
	Mn	0.1	0.1	0.0	0.1	0.0	0
	Acidity	0	0	0.0	0.0	0.0	0
BC5	Most Upstream Sample Point on Unt (42685) of Buffalo Creek						
	Al	0.4	0.4	0.0	0.4	0.0	0
	Fe	0.8	0.7	0.0	0.7	0.1	17
	Mn	5.7	0.6	0.0	0.6	5.1	90
	Acidity	0	0	0.0	0.0	0.0	0
BC4	Unt (42685) of Buffalo Creek Upstream of Confluence with Unt (42686) of Buffalo Creek						
	Al	9.3	0.7	0.103	0.597	8.5	93
	Fe	7.1	1.4	0.620	0.78	5.2	79
	Mn	8.2	1.8	0.207	1.593	1.3	42
	Acidity	0	0	0.0	0.0	0.0	0
BC3	Mouth of Unt (42686) of Buffalo Creek Upstream with Confluence with Unt (42685) of Buffalo Creek						
	Al	1.7	1.5	0.0	1.5	0.2	10
	Fe	2.1	2.1	0.0	2.1	0.0	0
	Mn	2.2	2.2	0.0	2.2	0.0	0
	Acidity	0	0	0.0	0.0	0.0	0
BC2	Mouth of Unt (42685) of Buffalo Creek Upstream of Confluence with Buffalo Creek						
	Al	5.7	1.5	0.0	1.5	0.0	0
	Fe	8.2	3.1	0.0	3.1	0.0	0
	Mn	12.4	2.6	0.0	2.6	3.0	54
	Acidity	0	0	0.0	0.0	15.8	0

All waste load allocations were calculated using the methodology explained previously in the Method to Quantify Treatment Pond Pollutant Load section of the report.

Wasteload allocations for the existing mining operations were incorporated into the calculations at CBR1. This is the first downstream monitoring point that receives all the potential flow of treated water from the treatment site. No required reductions of this permits is necessary at this time because there are upstream non-point sources that when reduced will met the TMDL or there is available assimilation capacity. All necessary reductions are assigned to non-point sources.

The Allegheny Mineral Corp., Graff Mine (SMP#03840105) has a non-standard pit size of 1000 feet in length and a width of 125 feet. In addition there are two pits of this size. This pit size was used in the Method to Quantify Treatment Pond Pollutant Load calculation example shown below:

40 in. precip./yr x 1 ft/12/in. x 1000’x 125’/pit x 7.48 gal/ft3 x 1yr/365days x 1day/24hr. x 1hr/60mins. = 5.93 gal/min average discharge from direct precipitation into the open mining pit area. There are two pits of this size so the total is 11.86 gal/min.

40 in. precip./yr x 3 pit areas x 1 ft/12/in. x 1000'x 125'/pit x 7.48 gal/ft3 x 1yr/365days x 1day/24hr. x 1hr/60mins. x 15 in. runoff/100 in. precipitation = 2.67 gal/min average discharge from spoil runoff into the pit area. There are two pits of this size so the total is 5.34 gal/min

The total average flow to the pit is represented by the sum of the direct pit precipitation and the water flowing to the pit from the spoil area as follows:

Total Average Flow = Direct Pit Precipitation + Spoil Runoff

Total Average Flow = 11.86 gal./min. + 5.34 gal./min. = 17.19 gal./min.

The resulting average load from a permitted treatment pond area as follows.

Allowable Aluminum Waste Load Allocation:
17.19 gal./min. x 0.5 mg/l x 0.01202 = 0.103 lbs./day

Allowable Iron Waste Load Allocation:
17.19 gal./min. x 3 mg/l x 0.01202 = 0.620 lbs./day

Allowable Manganese Waste Load Allocation:
17.19 gal./min. x 1 mg/l x 0.01202 = 0.207 lbs./day

Table 5. Waste Load Allocation of Permitted Discharges

Parameter	Allowable Average Monthly Conc. (mg/l)	Calculated Average Flow (MGD)	WLA (lbs/day)
Allegheny Mineral Corp., Graff Mine, SMP03840105			
T1			
Al	0.5	0.025	0.103
Fe	3	0.025	0.620
Mn	1	0.025	0.207

Recommendations

Two primary programs that provide reasonable assurance for maintenance and improvement of water quality in the watershed are in effect. The PADEP's efforts to reclaim abandoned mine lands, coupled with its duties and responsibilities for issuing NPDES permits, will be the focal points in water quality improvement.

Additional opportunities for water quality improvement are both ongoing and anticipated. Historically, a great deal of research into mine drainage has been conducted by PADEP's Bureau of Abandoned Mine Reclamation, which administers and oversees the Abandoned Mine Reclamation Program in Pennsylvania, the United States Office of Surface Mining, the National Mine Land Reclamation Center, the National Environmental Training Laboratory, and many other agencies and individuals. Funding from EPA's 319 Grant program, and Pennsylvania's Growing Greener program have been used extensively to remedy mine drainage impacts. These many activities are expected to continue and result in water quality improvement.

The PA DEP Bureau of Mining and Reclamation administers an environmental regulatory program for all mining activities, mine subsidence regulation, mine subsidence insurance, and coal refuse disposal; conducts a program to ensure safe underground bituminous mining and protect certain structures form subsidence; administers a mining license and permit program; administers a regulatory program for the use, storage, and handling of explosives; provides for training, examination, and certification of applicants for blaster's licenses; and administers a loan program for bonding anthracite underground mines and for mine subsidence. Administers the EPA Watershed Assessment Grant Program, the Small Operator's Assistance Program (SOAP), and the Remining Operators Assistance Program (ROAP).

Mine reclamation and well plugging refers to the process of cleaning up environmental pollutants and safety hazards associated with a site and returning the land to a productive condition, similar to DEP's Brownfields program. Since the 1960's, Pennsylvania has been a national leader in establishing laws and regulations to ensure reclamation and plugging occur after active operation is completed.

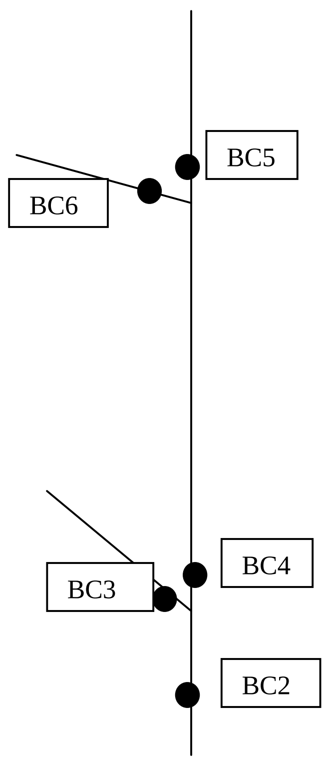
Pennsylvania is striving for complete reclamation of its abandoned mines and plugging of its orphaned wells. Realizing this task is no small order, DEP has developed concepts to make abandoned mine reclamation easier. These concepts, collectively called Reclaim PA, include legislative, policy land management initiatives designed to enhance mine operator, volunteer land DEP reclamation efforts. Reclaim PA has the following four objectives.

- To encourage private and public participation in abandoned mine reclamation efforts
- To improve reclamation efficiency through better communication between reclamation partners
- To increase reclamation by reducing remining risks
- To maximize reclamation funding by expanding existing sources and exploring new sources.

Remining of the deep mines where possible with inclusion of the Vanport Limestone backfill would alleviate some acid mine drainage production. Also, partnering with existing watershed groups to explore treatment options of acid mine drainage problems would be a good avenue for watershed remediation.

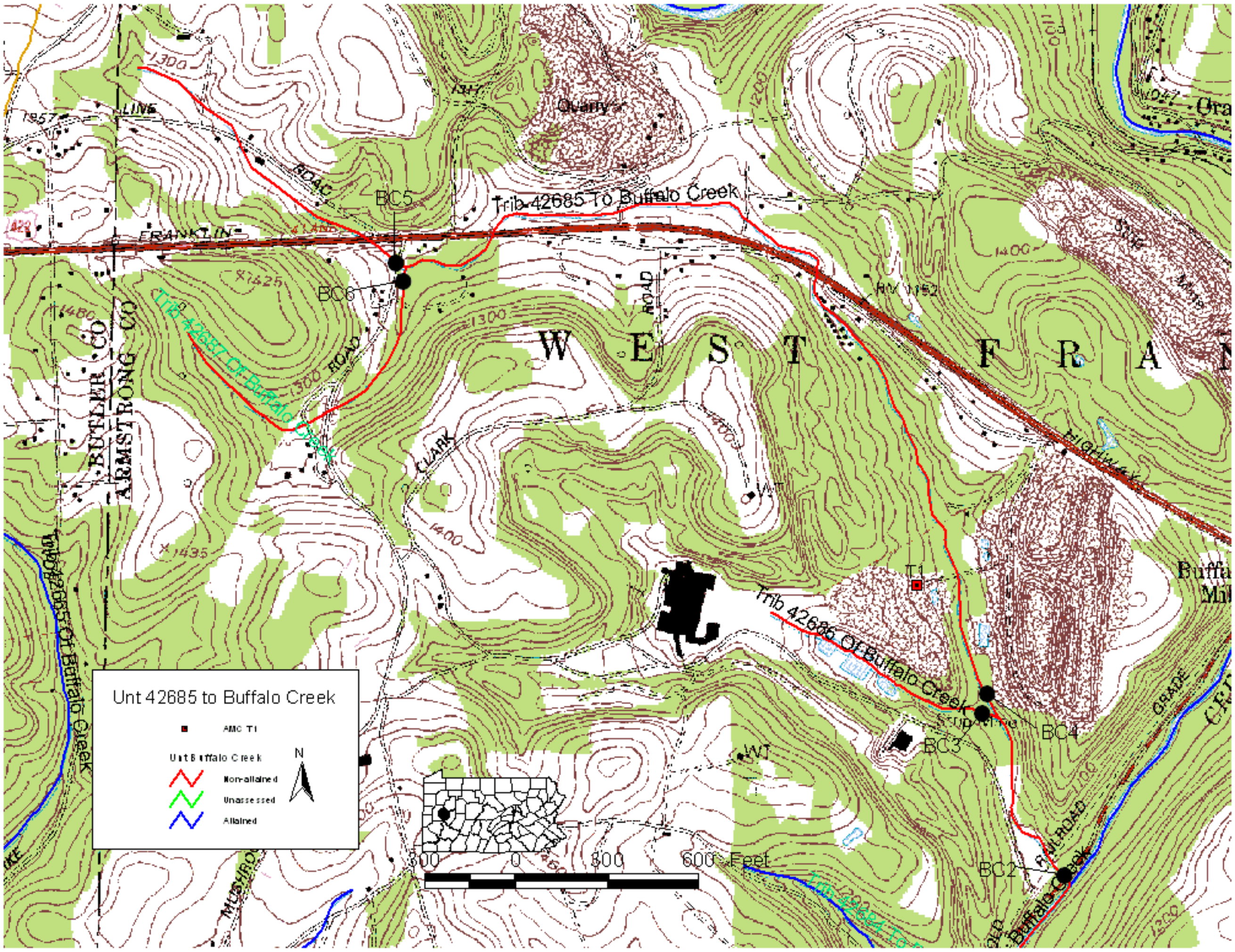
Public Participation

Public notice of the draft TMDL was published in the *Pennsylvania Bulletin* on January 20, 2007 and the Leader Times, Kittanning, PA on January 17, 2007 to foster public comment on the allowable loads calculated. A public meeting was held on January 31, 2007 beginning at 1:00 p.m., at the Greensburg District Mining Office, Armbrust Building, 8205 Route 819, Greensburg, PA, to discuss the proposed TMDL.

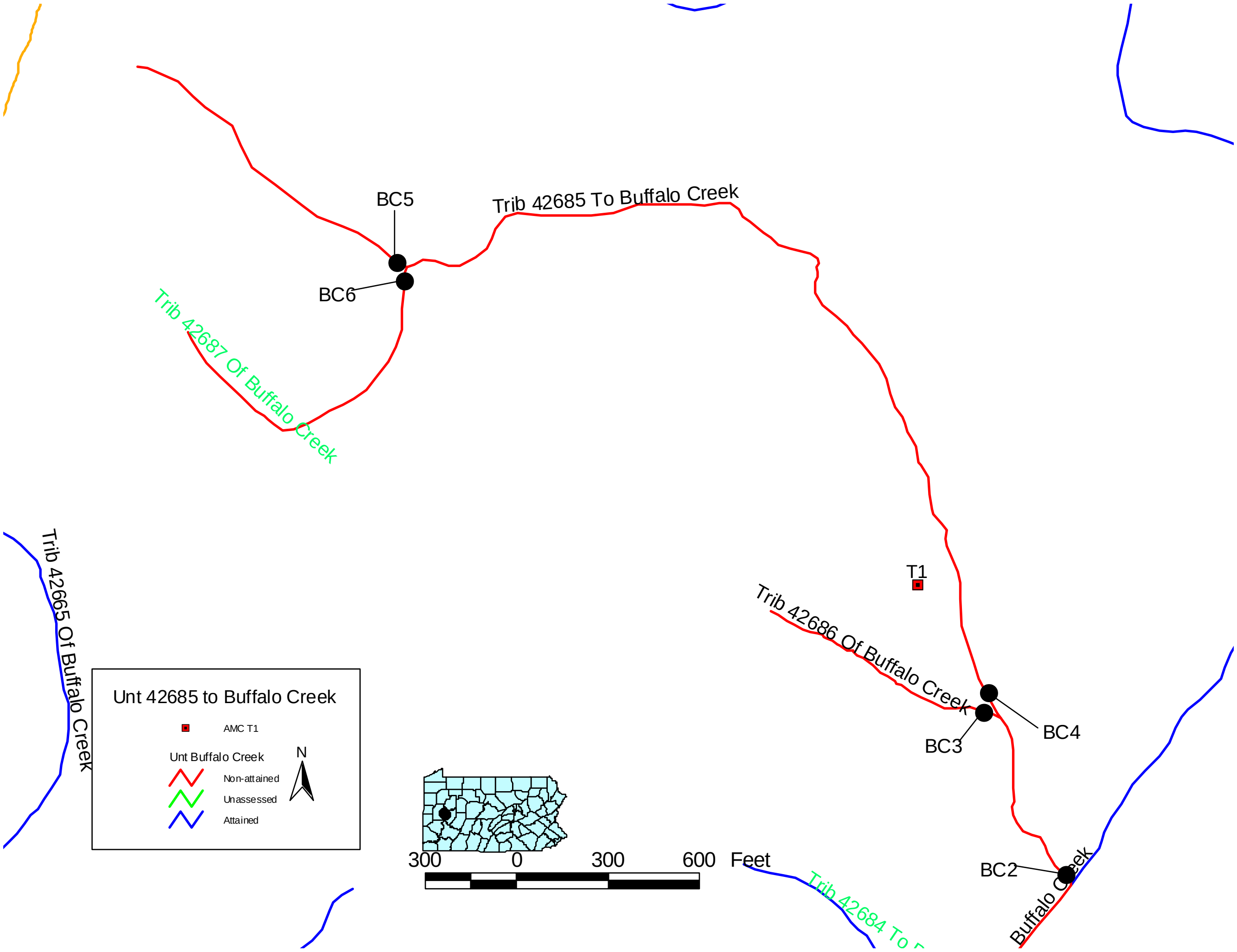

BC5
BC6
BC4
BC3
BC2

Attachment A

Unt (42685) of Buffalo Creek Watershed Maps



Unt 42685 to Buffalo Creek
AMD T1
Unt Buffalo Creek
Non-attained
Unassessed
Attained
N
300
0
300
600 Feet
Trib 42685 To Buffalo Creek
Trib 42686 Of Buffalo Creek
Trib 42687 Of Buffalo Creek
Buffalo Creek
BC2
BC3
BC4
BC5
BC6
T1
Quarry
W E S T F R A N
BUTLER CO
ARMSTRONG CO
FRANKLIN
CLARK
ROAD



BC5
Trib 42685 To Buffalo Creek
BC6
Trib 42687 Of Buffalo Creek
T1
Trib 42686 Of Buffalo Creek
BC4
BC3
Trib 42665 Of Buffalo Creek
Unt 42685 to Buffalo Creek
AMC T1
Unt Buffalo Creek
N
Non-attained
Unassessed
Attained
300
0
300
600
Feet
Trib 42684 To
BC2
Buffalo Creek

Attachment B

Method for Addressing Section 303(d) Listings for pH

Method for Addressing 303(d) Listings for pH

There has been a great deal of research conducted on the relationship between alkalinity, acidity, and pH. Research published by the Pa. Department of Environmental Protection demonstrates that by plotting net alkalinity (alkalinity-acidity) vs. pH for 794 mine sample points, the resulting pH value from a sample possessing a net alkalinity of zero is approximately equal to six (Figure 1). Where net alkalinity is positive (greater than or equal to zero), the pH range is most commonly six to eight, which is within the USEPA's acceptable range of six to nine and meets Pennsylvania water quality criteria in Chapter 93.

The pH, a measurement of hydrogen ion acidity presented as a negative logarithm, is not conducive to standard statistics. Additionally, pH does not measure latent acidity. For this reason, and based on the above information, Pennsylvania is using the following approach to address the stream impairments noted on the 303(d) list due to pH. The concentration of acidity in a stream is at least partially chemically dependent upon metals. For this reason, it is extremely difficult to predict the exact pH values, which would result from treatment of abandoned mine drainage. Therefore, net alkalinity will be used to evaluate pH in these TMDL calculations. This methodology assures that the standard for pH will be met because net alkalinity is a measure of the reduction of acidity. When acidity in a stream is neutralized or is restored to natural levels, pH will be acceptable. Therefore, the measured instream alkalinity at the point of evaluation in the stream will serve as the goal for reducing total acidity at that point. The methodology that is applied for alkalinity (and therefore pH) is the same as that used for other parameters such as iron, aluminum, and manganese that have numeric water quality criteria.

Each sample point used in the analysis of pH by this method must have measurements for total alkalinity and total acidity. The same statistical procedures that have been described for use in the evaluation of the metals is applied, using the average value for total alkalinity at that point as the target to specify a reduction in the acid concentration. By maintaining a net alkaline stream, the pH value will be in the range between six and eight. This method negates the need to specifically compute the pH value, which for mine waters is not a true reflection of acidity. This method assures that Pennsylvania's standard for pH is met when the acid concentration reduction is met.

Reference: *Rose, Arthur W. and Charles A. Cravotta, III 1998. Geochemistry of Coal Mine Drainage. Chapter 1 in Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania. Pa. Dept. of Environmental Protection, Harrisburg, Pa.*

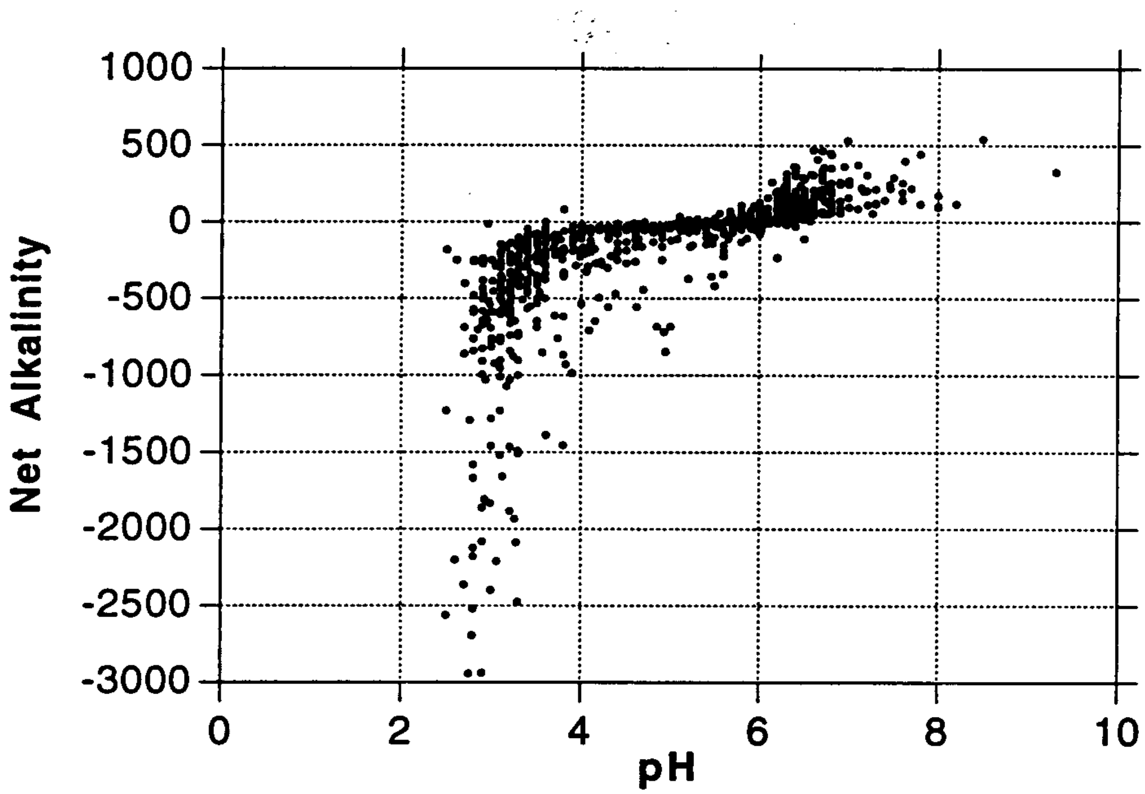


Figure 1. Net Alkalinity vs. pH. Taken from Figure 1.2 Graph C, pages 1-5, of Coal Mine Drainage Prediction and Pollution Prevention in Pennsylvania

Attachment C

TMDLs By Segment

Unnamed (42685) Tributary to Buffalo Creek

The TMDL for Unt (42685) of Buffalo Creek consists of load allocations for five sampling sites along Unt (42685) of Buffalo Creek and two unnamed tributaries

Unt (42685) of Buffalo Creek is listed for metals from AMD as being the cause of the degradation to the stream. The method and rationale for addressing pH is contained in Attachment B.

An allowable long-term average in-stream concentration was determined at the points below for aluminum, iron, manganese and acidity. The analysis is designed to produce an average value that, when met, will be protective of the water-quality criterion for that parameter 99% of the time. An analysis was performed using Monte Carlo simulation to determine the necessary long-term average concentration needed to attain water-quality criteria 99% of the time. The simulation was run assuming the data set was lognormally distributed. Using the mean and standard deviation of the data set, 5000 iterations of sampling were completed, and compared against the water-quality criterion for that parameter. For each sampling event a percent reduction was calculated, if necessary, to meet water-quality criteria. A second simulation that multiplied the percent reduction times the sampled value was run to insure that criteria were met 99% of the time. The mean value from this data set represents the long-term average concentration that needs to be met to achieve water-quality standards.

BC6 Mouth of Unt (42687) Upstream of Confluence with Unt (42685) of Buffalo Creek

The TMDL for this sample point on the Unt (42685) of Buffalo Creek consists of a load allocation to the segment upstream. The load allocation for this segment was computed using water-quality sample data collected at point BC6. The average flow, measured at the sampling point BC6 (0.15 MGD), is used for these computations.

There currently is no entry for this segment on the Pa Section 303(d) list for impairment due to pH. Sample data at point LUB05 shows pH ranging between 6.7 and 7.6, pH will not be addressed in this TMDL because this segment is net alkaline.

Table C1. Load Allocations for Point BC6

	Measured Sample Data		Allowable	
Parameter	Conc. (mg/l)	Load (lbs/day)	Conc. mg/l	Load Lbs/day
Aluminum	0.21	0.3	0.11	0.1
Iron	0.52	0.7	0.20	0.3
Manganese	0.07	0.1	0.07	0.1
Acid	0.00	0.0	0.00	0.0
Alkalinity	33.75	42.9		

Table C2. Calculation of Load Reduction Necessary at Point BC6				
	Al	Fe	Mn	Acidity
	(lbs/day)	(lbs/day)	(lbs/day)	(lbs/day)
Existing Load	0.3	0.7	0.1	0.0
Allowable Load=TMDL	0.1	0.3	0.1	0.0
Load Reduction	0.2	0.5	0.0	0.0
Total % Reduction	46	62	0	0

BC5 Most Upstream Sample Point on Unt (42685) of Buffalo Creek

The TMDL for this segment of Unt (42685) of Buffalo Creek consists of a load allocation to all of the watershed area upstream of sample point BC5. The load allocation for this segment was computed using water-quality sample data collected at point BC5. The average flow, measured at the sampling point BC5 (0.28 MGD), is used for these computations.

There currently is no entry for this segment on the Pa Section 303(d) list for impairment due to pH. Sample data at point BC5 shows pH ranging between 7.2 and 8.0, pH will not be addressed in this TMDL because the segment is net alkaline.

Table C3. Load Allocations at Point BC5				
	Measured Sample Data		**Allowable**	
Parameter	Conc. (mg/l)	Load (lbs/day)	Conc. (mg/l)	Load (lbs/day)
Aluminum	0.16	0.4	0.16	0.4
Iron	0.29	0.7	0.25	0.6
Manganese	2.44	5.7	0.24	0.6
Acid	0.00	0.0	0.00	0.0
Alkalinity	97.35	225.9		

Table C4. Calculation of Load Reduction Necessary at Point BC5				
	Al	Fe	Mn	Acidity
	(#/day)	(#/day)	(#/day)	(#/day)
Existing Load	0.4	0.7	5.7	0.0
Allowable Load=TMDL	0.4	0.6	0.6	0.0
Load Reduction	0.0	0.1	5.1	0.0
Total % Reduction	0	12	90	0

Waste Load Allocations– Permitted Discharges

The Allegheny Mineral Corporation SMP 03840105, Graff Mine has one permitted treatment pond, T1, that discharges to Unt 42685 to Buffalo Creek. The waste load allocation for the discharge is calculated with average monthly permit limits and average flow, which is estimated with permitted pit areas and average rainfall. There is one permitted pits in the permit with a total combined pit area of 250,000 square feet. Included in the permit are limits for aluminum, iron and manganese. The WLA for T1 is evaluated at point CBR1.

Table C5. Waste Load Allocations for Permitted Discharges

Parameter	Allowable Average Monthly Conc. (mg/l)	Calculated Average Flow (MGD)	WLA (lbs/day)
Allegheny Mineral Corp., Graff Mine, SMP03840105			
T1			
Al	0.5	0.025	0.103
Fe	3	0.025	0.620
Mn	1	0.025	0.207

BC4 Unt (42685) of Buffalo Creek Upstream of Confluence with Unt (42686) of Buffalo Creek

The TMDL for sampling point BC4 consists of a load allocation to the area between sample points BC06, BC05 and BC04. The load allocation for this tributary was computed using water-quality sample data collected at point BC4. The average flow, measured at the sampling point BC4 (0.91 MGD), is used for these computations.

There currently is no entry for this segment on the Pa Section 303(d) list for impairment due to pH. Sample data at point BC4 shows pH ranging between 7.4 and 7.8, pH will not be addressed in this TMDL because this segment is net alkaline.

Table C6. Load Allocations at Point BC4

	Measured Sample Data		**Allowable**	
Parameter	Conc. (mg/l)	Load (lbs/day)	Conc. (mg/l)	Load (lbs/day)
Aluminum	1.22	9.3	0.09	0.7
Iron	0.93	7.1	0.19	1.4
Manganese	1.08	8.2	0.24	1.8
Acid	0.00	0.0	0.00	0.0
Alkalinity	95.83	728.1		

The calculated load reductions for all the loads that enter point BC4 must be accounted for in the calculated reductions at sample point BC4 shown in Table C6. A comparison of measured loads between points BC6, BC5, and BC4 shows that there is an increase in aluminum, iron and manganese loading within the segment. The total segment load for aluminum, iron and manganese is the sum on the upstream allocated loads and any additional loading within the segment.

Table C7. Calculation of Load Reduction at Point BC4				
	Al	Fe	Mn	Acidity
Existing Load	9.3	7.1	8.2	0.0
Difference in Existing Load between BC6, BC5 & BC4	8.7	5.8	2.5	0.0
Load tracked from BC6 & BC5	0.5	0.8	0.7	0.0
Percent loss due to instream process	-	-	-	-
Percent load tracked from BC6 & BC5	-	-	-	-
Total Load tracked from BC6 & BC5	9.2	6.6	3.1	0.0
Allowable Load at BC4	0.7	1.4	1.8	0.0
Load Reduction at BC4	8.5	5.2	1.3	0.0
% Reduction required at BC4	93	79	42	0

BC3 Mouth of Unt (42686) of Buffalo Creek Upstream with Confluence with Unt (42685) of Buffalo Creek

The TMDL for this segment of Unt (42685) of Buffalo Creek consists of a load allocation to all of the watershed area upstream of sample point BC3. The load allocation for this segment was computed using water-quality sample data collected at point BC3. The average flow, measured at the sampling point BC3 (0.53 MGD), is used for these computations.

There currently is no entry for this segment on the Pa Section 303(d) list for impairment due to pH. Sample data at point BC3 shows pH ranging between 7.7 and 8.3, pH will not be addressed in this TMDL because this segment is net alkaline.

Table C8. Load Allocations for Point BC3				
	Measured Sample Data		Allowable	
Parameter	Conc. (mg/l)	Load (lbs/day)	Conc. (mg/l)	Load (lbs/day)
Aluminum	0.38	1.7	0.34	1.5
Iron	0.48	2.1	0.48	2.1
Manganese	0.40	1.8	0.34	1.5
Acid	0.00	0.0	0.00	0.0
Alkalinity	59.78	263.0		

Table C9. Calculation of Load Reduction Necessary at Point BC3				
	Al	Fe	Mn	Acidity
	(#/day)	(#/day)	(#/day)	(#/day)
Existing Load	1.7	2.1	1.8	0.0
Allowable Load=TMDL	1.5	2.1	1.5	0.0
Load Reduction	0.2	0.0	0.3	0.0
Total % Reduction	10	0	17	0

BC2 Mouth of Unt (42685) of Buffalo Creek Upstream of Confluence with Buffalo Creek

The TMDL for this Unt (42685) of Buffalo Creek consists of a load allocation to all of the watershed area between sample points BC4, BC3 and BC2. The load allocation for this segment was computed using water-quality sample data collected at point BC2. The average flow, measured at the sampling point BC2 (1.61 MGD), is used for these computations.

There currently is no entry for this segment on the Pa Section 303(d) list for impairment due to pH. Sample data at point BC2 shows pH ranging between 6.9 and 7.9, pH will not be addressed in this TMDL because this segment is net alkaline.

Table C10. Load Allocations at Point BC2				
	Measured Sample Data		**Allowable**	
Parameter	Conc. (mg/l)	Load (lbs/day)	Conc. (mg/l)	Load (lbs/day)
Aluminum	0.42	5.7	0.11	1.5
Iron	0.61	8.2	0.23	3.1
Manganese	0.92	12.4	0.19	2.6
Acid	0.00	0.0	0.00	0.0
Alkalinity	82.96	1116.5		

The calculated load reductions for all the loads that enter point BC2 must be accounted for in the calculated reductions at sample point BC2 shown in Table C10. A comparison of measured loads between points BC4, BC3, and BC2 shows that there is an increase in aluminum, iron and manganese loading within the segment. The total segment load for aluminum, iron and manganese is the sum on the upstream allocated loads and any additional loading within the segment.

Table C11. Calculation of Load Reduction at Point BC2				
	Al	Fe	Mn	Acidity
Existing Load	5.7	8.2	12.4	0.0
Difference in Existing Load between BC4, BC3 & BC2	-5.3	-1.0	2.3	0.0
Load tracked from BC4 & BC3	2.2	3.5	3.3	0.0
Percent loss due to instream process	48	10	-	-
Percent load tracked from BC4 & BC3	52	90	-	-
Total Load tracked from BC4 & BC3	1.1	3.15	5.6	0.0
Allowable Load at BC3	1.5	3.13	2.6	0.0
Load Reduction at BC2	0.0	0.02	3.0	0.0
% Reduction required at BC2	0	1	54	0

Margin of Safety (MOS)

PADEP used an implicit MOS in these TMDLs derived from the Monte Carlo statistical analysis. The Water-Quality standard states that water-quality criteria must be met at least 99% of the time. All of the @Risk analyses results surpass the minimum 99% level of protection. Another margin of safety used for this TMDL analysis results from:

- Effluent variability plays a major role in determining the average value that will meet water-quality criteria over the long-term. The value that provides this variability in our analysis is the standard deviation of the dataset. The simulation results are based on this variability and the existing stream conditions (an uncontrolled system). The general assumption can be made that a controlled system (one that is controlling and stabilizing the pollution load) would be less variable than an uncontrolled system. This implicitly builds in a margin of safety.

- A MOS is added when the calculations were performed with a daily iron average instead of the 30-day average.

Seasonal Variation

Seasonal variation is implicitly accounted for in these TMDLs because the data used represent all seasons.

Critical Conditions

The reductions specified in this TMDL apply at all flow conditions. A critical flow condition could not be identified from the data used for this analysis.

Attachment D

Excerpts Justifying Changes Between the 1996, 1998, 2002, and 2004 Section 303(d) Lists

The following are excerpts from the Pennsylvania DEP 303(d) narratives that justify changes in listings between the 1996, 1998, 2002, and 2004 list. The 303(d) listing process has undergone an evolution in Pennsylvania since the development of the 1996 list.

In the 1996 303(d) narrative, strategies were outlined for changes to the listing process. Suggestions included, but were not limited to, a migration to a Global Information System (GIS), improved monitoring and assessment, and greater public input.

The migration to a GIS was implemented prior to the development of the 1998 303(d) list. As a result of additional sampling and the migration to the GIS, some of the information appearing on the 1996 list differed from the 1998 list. Most common changes included:

1. mileage differences due to recalculation of segment length by the GIS;
2. slight changes in source(s)/cause(s) due to new EPA codes;
3. changes to source(s)/cause(s), and/or miles due to revised assessments;
4. corrections of misnamed streams or streams placed in inappropriate SWP subbasins; and
5. unnamed tributaries no longer identified as such and placed under the named watershed listing.

Prior to 1998, segment lengths were computed using a map wheel and calculator. The segment lengths listed on the 1998 303(d) list were calculated automatically by the GIS (ArcInfo) using a constant projection and map units (meters) for each watershed. Segment lengths originally calculated by using a map wheel and those calculated by the GIS did not always match closely. This was the case even when physical identifiers (e.g., tributary confluence and road crossings) matching the original segment descriptions were used to define segments on digital quad maps. This occurred to some extent with all segments, but was most noticeable in segments with the greatest potential for human errors using a map wheel for calculating the original segment lengths (e.g., long stream segments or entire basins).

The most notable difference between the 1998 and Draft 2000 303(d) lists are the listing of unnamed tributaries in 2000. In 1998, the GIS stream layer was coded to the named stream level so there was no way to identify the unnamed tributary records. As a result, the unnamed tributaries were listed as part of the first downstream named stream. The GIS stream coverage used to generate the 2000 list had the unnamed tributaries coded with the DEP's five-digit stream code. As a result, the unnamed tributary records are now split out as separate records on the 2000 303(d) list. This is the reason for the change in the appearance of the list and the noticeable increase in the number of pages. After due consideration of comments from EPA and PADEP on the Draft 2000 Section 303(d) list, the Draft 2002 Pa Section 303(d) list was written in a manner similar to the 1998 Section 303(d) list.

Attachment E

Water Quality Data Used In TMDL Calculations

Site	Site Name	Bottle ID	Date-time	Flow (gpm)	pH	Acidity (mg/L)	Alkalinity (mg/L)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
6	Buffalo Creek	44A	12/13/2005	-	6.87	-9.01	33.74	0.02	0.0	0
6	Buffalo Creek	8B	2/24/2006	73.3	6.77	-18.74	19.49	0.24	0.11	0.0
6	Buffalo Creek	-	4/7/2006	139						
6	Buffalo Creek	25D	6/2/2006	183	6.79	-33.59	38.93	0.72	2.1	0.25
6	Buffalo Creek	24E	8/1/2006	95	7.57	-36.64	43.51	0.0	0.24	0.04
6	Buffalo Creek	7F	9/22/2006	39	7.46	-29.23	33.08	0.06	0.14	0.04
BC6			avg=	105.86	7.09	-25.44	33.75	0.26	0.65	0.08
			stdev=			11.41		0.32	0.97	0.11

Site	Site Name	Bottle ID	Date-time	Flow (gpm)	pH	Acidity (mg/L)	Alkalinity (mg/L)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
5	Buffalo Creek	27A	12/13/2005	-	7.77	-110.61	125.38	0.20	0.0	5.4
5	Buffalo Creek	17B	2/24/2006	-	7.5	-85.82	88.91	0.23	0	3.7
5	Buffalo Creek	20C	4/7/2006	243	7.77	-75.00	78.79	0.13	0.39	1.8
5	Buffalo Creek	4D	6/2/2006	354	7.20	-86.36	90.91	0.33	0.97	2.70
5	Buffalo Creek	18E	8/1/2006	97	7.77	-87.35	91.67	0.0	0.15	0.87
5	Buffalo Creek	38F	9/22/2006	79	7.98	-102.31	108.46	0.06	0.16	0.17
BC5			avg=	193.25	7.67	-91.24	97.35	0.19	0.34	2.44
			stdev=			12.88		0.10	0.37	1.92

Site	Site Name	Bottle ID	Date-time	Flow (gpm)	pH	Acidity (mg/L)	Alkalinity (mg/L)	Al (mg/l)	Fe (mg/l)	Mn (mg/l)
			9/14/1995		7.1	0	64	0.55	1.02	0.864
			11/15/1995							
			2/7/1996		6.8	0	56	1.35	0	1.57
			4/3/1996		7.4	0	88	0	0	0.572
			10/15/1996		7.8	0	286	0	0	0.993
			1/6/1997		6.8	0	54	0.975	0.752	1.06
			4/3/1997		7	0	70	1.53	1.6	1.18
			5/15/1997		7.2	0	90	0	0.549	0.6
			7/2/1997		7.6	0	176	1.14	1.51	0.166
			6/25/1998		7.1	0	64	0.719	0	0.632
			4/7/1999		7	0	80	10.5	7.23	4.19
			11/30/1999		7.3	0	71.8	0.813	0	0.686
			5/21/2003							
4	Buffalo Creek	41B	2/25/2006	443	7.68	-64.18	69.40	0.62	0.38	0.71
4	Buffalo Creek	14C	4/7/2006	1082	7.78	-69.23	73.85	0.59	0.77	0.40
4	Buffalo Creek	49D	6/6/2003	840	7.41	-70.92	78.31	0.53	0.54	0.90
4	Buffalo Creek	36E	8/1/2006	360	7.81	-77.85	83.08	0.2	0.44	1.0
4	Buffalo Creek	16F	9/22/2006	438	7.77	-122.19	128.91	0.07	0.16	1.8
BC4			avg=	632.60	7.35	-25.27	95.83	1.22	0.93	1.08
			stdev=			40.59		2.52	1.76	0.92

Site	Site Name	Bottle ID	Date-time	Flow (gpm)	pH	Acidity (mg/L)	Alkalinity (mg/L)	Al	Fe	Mn
3	Buffalo Creek	19B	2/25/2006	583	8.26	-44.01	50.08	0.60	0.39	0.51
3	Buffalo Creek	31C	4/7/2006	362	8.07	-55.64	54.14	0.45	0.61	0.0
3	Buffalo Creek	5D	6/6/2006	242	7.70	-64.09	71.21	0.3	0.31	0.53
3	Buffalo Creek	29E	8/1/2006	168	7.80	-61.71	66.20	0.23	0.56	0.42
3	Buffalo Creek	27F	9/22/2006	477	7.91	-53.79	57.27	0.32	0.51	0.56
BC3			avg=	366.40	7.95	-55.85	59.78	0.38	0.48	0.51
			stdev=			7.85		0.15	0.12	0.06

Site	Site Name	Bottle ID	Date-time	Flow (gpm)	pH	Acidity (mg/L)	Alkalinity (mg/L)	Al	Fe	Mn
			9/14/1995		7.1	0	64	0.551	1.04	0.874
			2/7/1996		7.7	0	86	0	<.3	0.583
			10/15/1996		6.4	0	88	0	2.72	1.33
			1/6/1997		6.9	0	54	0.995	0.523	1.08
			4/3/1997		6.9	0	70	0.629	0.436	0.881
			5/15/1997		7.1	0	90	0.603	0.934	0.644
			7/2/1997		6.9	0	60	0	0	0.577
			11/24/1997		6.8	0	54	0.601	0.4	0.714
			2/25/1998		6.9	0	84	0	0	0.398
			12/22/1998		7.1	0	48	1.14	0.64	0.727
			1/27/1999		7.3	0	118	0	0	0.09
			9/23/1999		7	0	60	1.77	2.66	0.647
			2/23/2000		7.6	0	122	0	0	0.674
			9/13/2000		7.3	0	88	0	0	0.35
			12/8/2000		7.4	0	58	0.508	0.385	0.592
			2/21/2001		7.6	0	96	0	0	0.395
			5/24/2001		7.2	0	84	0	0	0.265
			12/10/2001		7	0	56	0	0.39	0.474
			3/21/2002		6.8	0	72	1.94	2.2	0.597
			5/28/2002		7.9	0	118	0	0	0.081
			7/25/2002		7.6	0	80	0	0	0.298
			12/12/2002		7.7	0	124.4	0	0.381	4.27
			1/30/2003		7.6	0	74.4	2.31	3.41	0.76
			11/19/2003		7.4	13.4	40.4	0.944	1.11	0.721
			4/14/2004		7.9	-110	152.6	0	0	4.87
			8/17/2004		7.8	-46.4	81	0.923	0.902	1.85
			12/15/2004		7.6	-36.4	69.8	0.938	0.569	1.45
			1/25/2005		8	-51	86.8	0	0	0.264
			5/26/2005		7.7	-70.6	93.6	0.699	0.899	0.319
			8/31/2005		7.8	-45.6	89	0	0	0.306
			11/21/2005		7.8	-38.2	69.2	0	0	0.647
			1/17/2006		7.5	-69.4	83.2	0	0.391	0.446
			5/16/2006		7.9	-102	122.6	0	0	1.615
			8/9/2006		7.9	-68.4	83.6	0	0.63	1.07
2	Buffalo Creek	43A	12/13/2005	716	6.90	-70.55	94.57	0.37	0.20	0.6
2	Buffalo Creek	18B	2/24/2006	725	7.58	-54.92	63.08	0.22	0.14	0.12
2	Buffalo Creek	15C	4/7/2006	1896	7.81	-69.39	73.94	0.79	1.1	0.39
2	Buffalo Creek	47D	6/2/2006	1222	7.48	-74.77	76.92	0.55	0.99	0.66
2	Buffalo Creek	1E	8/1/2006	1384	7.60	-85.93	94.81	0.28	0.55	2.9
2	Buffalo Creek	45F	9/22/2006	778	7.88	-90.08	94.66	0.14	0.26	1.2
BC2			avg=	1120.17	7.41	-26.76	82.96	0.42	0.61	0.92
			stdev=			36.53		0.59	0.83	1.00

Attachment F
Comment and Response

Comment: Darrel Lewis, of C.H. Snyder Associates (State Industries, Allegheny Minerals) submitted additional sampling data he requested to be added to the tmdl report.

Response: The submitted data was included at sample points BC4 BC2 and appear in the report.

Appendix C - Reference Watershed Selection

Green Acres Road
Worthington
Marrowbone Run
Pine Run
Moonlight Drive

Reference Watershed Selection, Green Acres Subwatershed

Selection Criteria and Rationale

The Green Acres Road subwatershed, draining southwest towards Buffalo Creek's main stem, is primarily defined by its agricultural landscape. The subwatershed, approximately 1.91 square miles in size, consists of three unnamed tributaries. It is identified as the 'Green Acres Road Subwatershed' for the study, with one stream closely paralleling the Green Acres Road along the southern boundary.

The evolution of this watershed from forestland to predominantly agricultural with parcel sizes ranging from 10 to 100 acres, has altered its ecological balance and influenced the water quality, evidenced by increased sediment, nitrogen, and phosphorus levels.

The Cornplanter Run subwatershed, covering 1.92 square miles, was identified as an ideal reference due to its similarity in area, slope, and geological features to Green Acres Road. Cornplanter Run's exceptional water quality exemplifies the impact of effective land management.

Cornplanter Run not only offers a model for what Green Acres Road could achieve but also highlights the importance of stakeholder engagement in this predominantly privately-owned area. Outreach to landowners will be crucial for implementing sustainable agricultural practices and watershed management. This comprehensive approach, blending the lessons from Cornplanter Run with a deep understanding of Green Acres Road's specific conditions, paves the way for a restoration strategy that is both ecologically sound and agriculturally viable. It underscores the importance of aligning contemporary environmental methodologies with community engagement to foster a sustainable and thriving ecosystem in the Green Acres Road subwatershed.

Chosen Reference Watershed and Characteristics

Cornplanter Run stands out as an optimal choice for a reference watershed when considered against the backdrop of Green Acre’s current state and challenges. Both watersheds share many similarities, but there are also noteworthy differences which, rather than being seen as impediments, can offer fresh perspectives and insights for the restoration of Green Acres.

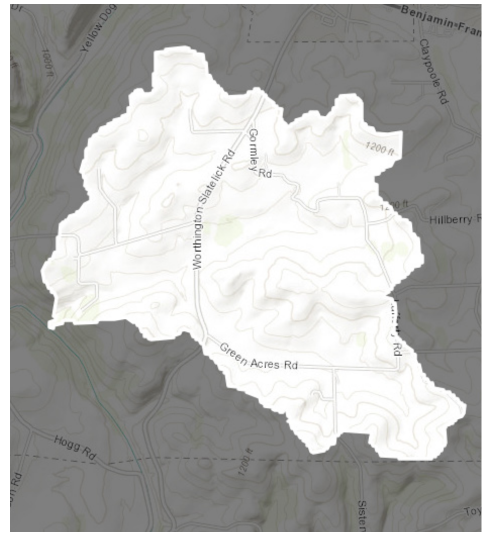


Figure 1: *Green Acres Subwatershed*

Watershed Similarities

Area: The areas of the two watersheds are nearly identical, with Cornplanter Run covering 1.92 square miles and Green Acres 1.91 square miles. This close match in size ensures that hydrological and land use patterns observed in Cornplanter Run can be scaled appropriately for Green Acres.

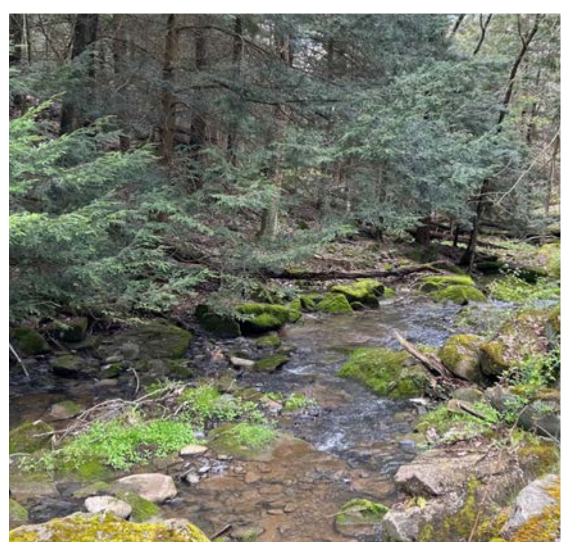
Physiographic Context: Both watersheds are situated within the Appalachian Plateau, specifically in the Pittsburgh Low Plateau section. This ensures that any geological or topographical recommendations derived from Cornplanter Run are directly applicable to Green Acres.

Hydrological Characteristics: Both watersheds exhibit similar precipitation patterns, ensuring that water budget components like evapotranspiration, surface runoff, and subsurface flow are comparable.

Figure 2: *Cornplanter Run Subwatershed*

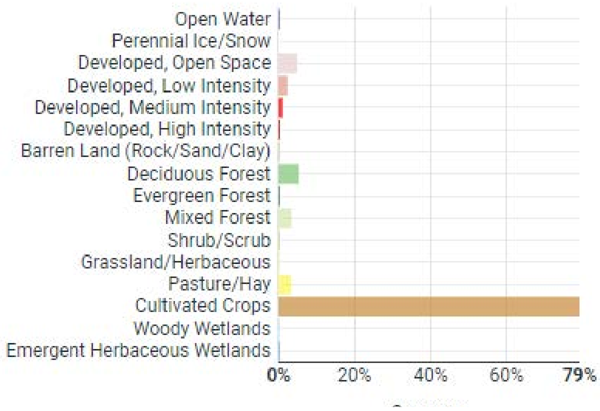
Distinctive Features of Cornplanter Run

Land Cover: Cornplanter Run boasts a significantly higher deciduous forest cover (31.37% compared to Green Acres’ 5.35%) as well as forested buffer. Forests play a pivotal role in reducing surface runoff, enhancing groundwater recharge, and filtering pollutants. On the flip side, Green Acres has a higher percentage of cultivated crops and developed lands, which can contribute to its water quality challenges.



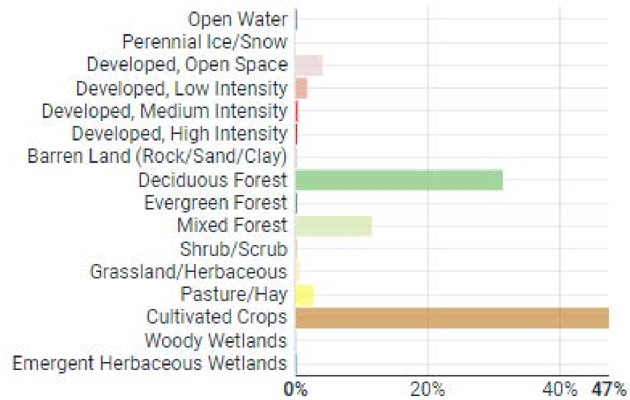
Land Cover Comparison

Green Acres Subwatershed



Type	Area (mi²)	Coverage (%)	Active River Area (mi²)
Open Water	0.00	0.11	0.00
Perennial Ice/Snow	0.00	0.00	0.00
Developed, Open Space	0.09	4.92	0.03
Developed, Low Intensity	0.05	2.36	0.01
Developed, Medium Intensity	0.02	1.13	0.00
Developed, High Intensity	0.00	0.15	0.00
Barren Land (Rock/Sand/Clay)	0.00	0.00	0.00
Deciduous Forest	0.10	5.35	0.05
Evergreen Forest	0.00	0.00	0.00
Mixed Forest	0.06	3.36	0.02
Shrub/Scrub	0.00	0.00	0.00
Grassland/Herbaceous	0.00	0.15	0.00
Pasture/Hay	0.06	3.25	0.02
Cultivated Crops	1.51	79.24	0.32
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00
Total	1.91	100.00	0.46

Cornplanter Run Subwatershed



Type	Area (ft²)	Coverage (%)	Active River Area (ft²)
Open Water	0.00	0.00	0.0
Perennial Ice/Snow	0.00	0.00	0.0
Developed, Open Space	2,201,741.72	4.11	299,359.6
Developed, Low Intensity	956,019.43	1.79	125,537.9
Developed, Medium Intensity	173,821.71	0.32	9,656.7
Developed, High Intensity	28,970.29	0.05	0.0
Barren Land (Rock/Sand/Clay)	0.00	0.00	0.0
Deciduous Forest	16,783,452.20	31.37	7,667,468.9
Evergreen Forest	0.00	0.00	0.0
Mixed Forest	6,161,014.10	11.51	2,375,563.4
Shrub/Scrub	57,940.57	0.11	38,627.0
Grassland/Herbaceous	318,673.14	0.60	0.0
Pasture/Hay	1,448,514.29	2.71	86,910.8
Cultivated Crops	25,377,970.30	47.43	2,578,355.4
Woody Wetlands	0.00	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.00	0.0
Total	53,508,117.74	100.00	13,181,480.0

Slope and Terrain: Cornplanter Run has slightly shallower average and maximum slopes. While shallower terrains can often lead to slower surface runoff and less opportunity for erosion, Cornplanter Run's superior water quality suggests effective land management practices that could be beneficial for Green Acres.

Water Quality: Cornplanter Run outperforms Green Acres in several water quality metrics, including lower sediment, nitrogen, and phosphorus loads. This is a testament to its effective land use patterns and management practices.

Addressing the Contrasts

While the differences between the two watersheds are evident, these contrasts offer valuable lessons:

Land Use Patterns: The disparity in land cover, especially the higher forest cover in Cornplanter Run, underscores the importance of reforestation and sustainable land management. Green Acres can aim to strategically increase its forested areas, which will not only enhance water quality but also provide ecological and recreational benefits.

Water Quality Goals: Cornplanter Run's superior water quality metrics serve as a tangible benchmark for Green Acres. By studying the practices and interventions in place at Cornplanter Run, Green Acres can formulate targeted strategies to reduce its pollutant loads.

Slope Management: The shallower slopes of Cornplanter Run can be seen as an advantage. They demonstrate that with appropriate land management and erosion control measures, it's possible to maintain excellent water quality with similar terrains.

In conclusion, while no two watersheds are identical, the similarities between Cornplanter Run and Green Acres, coupled with the lessons gleaned from their differences, make Cornplanter Run an ideal reference. Its attributes offer a vision of what Green Acres can achieve and a roadmap to guide its restoration journey.

Target Water Quality Goals for Green Acres

The disparities in water quality between Green Acres and Cornplanter Run provide a clear directive for the targets Green Acres should aspire to achieve. By leveraging the insights from Cornplanter Run, we can set ambitious yet feasible water quality goals for Green Acres. Deriving data from the ModelMyWatershed platform, below is a summary comparison of the average annual pollutant loads from 30-years of daily fluxes between the Green Acres and Cornplanter Run watershed. The full water quality data for both watersheds is provided immediately following this summary.

Sediment Reduction

Green Acres currently has a sediment loading rate of 1,313.79 lb/ac, significantly higher than Cornplanter Run's 662.06 lb/ac. This stark contrast underscores the urgent need to address sediment issues in Green Acres.

Objective: Reduce the sediment load to approach Cornplanter Run's levels, aiming for a significant reduction over the next 5-10 years. Emphasizing practices that minimize soil erosion and enhance sediment capture will be pivotal.

Nutrient Management

Nitrogen: Green Acres' current loading rate for total nitrogen is 7.84 lb/ac, nearly double that of Cornplanter Run's 4.11 lb/ac.

Objective: Work towards matching the nitrogen loading rates of Cornplanter Run by promoting practices that reduce nitrogen inputs and enhance nitrogen uptake in the watershed.

Phosphorus: With a phosphorus loading rate of 1.53 lb/ac in Green Acres compared to Cornplanter Run's 0.79 lb/ac, there's evident room for improvement.

Objective: Aim to approximate Cornplanter Run's phosphorus levels by mitigating sources of phosphorus and optimizing its natural cycling in the ecosystem.

Land Use Adjustments

A closer examination of Cornplanter Run reveals the intrinsic benefits of maintaining a balanced land use pattern. For Green Acres, this implies exploring avenues to enhance natural cover and regulate land practices that contribute heavily to sediment and nutrient loads. Strategic land use planning will be essential in moving towards the desired water quality targets.

Stream Health and Rehabilitation

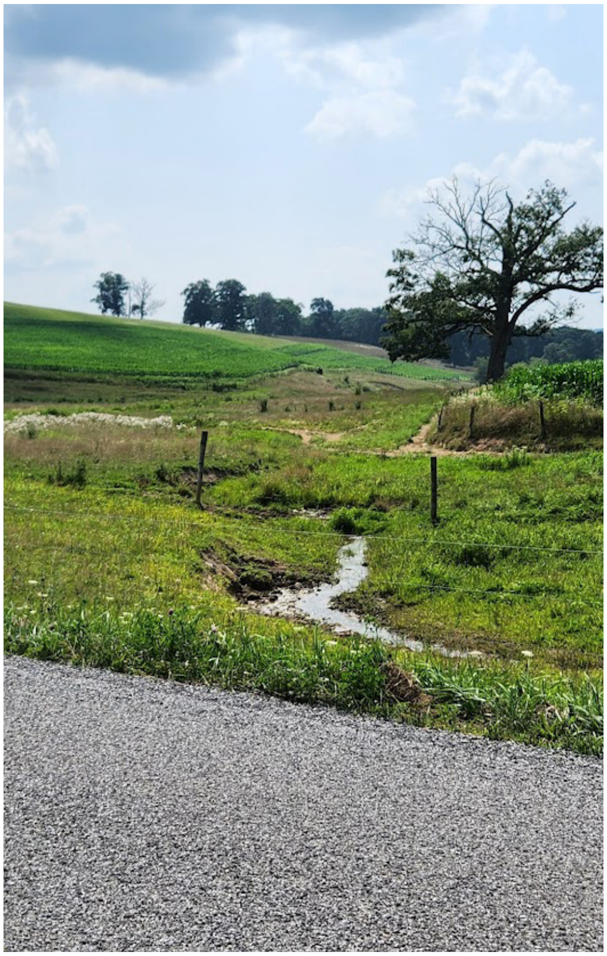
While numerical targets for stream health are set later in the report, it's worth noting that the integrity of stream channels, riparian zones, and aquatic habitats plays a significant role in determining water quality. Efforts to restore and maintain these ecological assets will be central to achieving the outlined sediment and nutrient goals.

Continuous Monitoring and Adaptive Management

To ensure the efficacy of our efforts, a rigorous monitoring framework will be established. This will not only track progress but also offer insights to refine and adapt strategies to the evolving needs of the Green Acres watershed.

Average Annual Pollutant Loads, Green Acres

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	1,606,991.5	9,587.8	1,874.2
Loading Rates (lb/ac)	1,313.79	7.84	1.53
Mean Annual Concentration (mg/L)	386.70	2.31	0.45
Mean Low-Flow Concentration (mg/L)	2,985.51	10.89	3.24



Average Annual Pollutant Loads, Cornplanter Run

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	815,868.3	5,062.7	974.5
Loading Rates (lb/ac)	662.06	4.11	0.79
Mean Annual Concentration (mg/L)	210.36	1.31	0.25
Mean Low-Flow Concentration (mg/L)	1,810.56	7.34	2.09

Mean Flow: 62,128,026 (ft³/year) and 1.97 (ft³/s)

Average Annual Pollutant Loads per Land Cover Source

Green Acres Subwatershed

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	45,851.9	130.2	47.1
Cropland	1,532,111.1	6,207.4	1,705.8
Wooded Areas	271.9	8.1	0.6
Wetlands	0.0	0.0	0.0
Open Land	92.4	1.3	0.1
Barren Areas	0.0	0.0	0.0
Low-Density Mixed	297.4	7.8	0.8
Medium-Density Mixed	924.1	17.2	1.7
High-Density Mixed	115.5	2.1	0.2
Low-Density Open Space	620.3	16.3	1.7
Farm Animals	0.0	207.3	49.0
Stream Bank Erosion	26,706.8	17.6	6.6
Subsurface Flow	0.0	2,929.7	60.4
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	42.6	0.0

Cornplanter Run Subwatershed

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	70,702.5	220.1	74.9
Cropland	1,422,225.7	5,620.6	1,525.9
Wooded Areas	2,180.7	78.8	5.8
Wetlands	0.0	0.0	0.0
Open Land	1,022.2	10.7	1.1
Barren Areas	1.6	0.5	0.0
Low-Density Mixed	304.5	7.5	0.8
Medium-Density Mixed	541.9	10.1	1.0
High-Density Mixed	70.7	1.3	0.1
Low-Density Open Space	1,276.3	31.6	3.4
Farm Animals	0.0	398.2	101.0
Stream Bank Erosion	59,291.2	39.7	13.2
Subsurface Flow	0.0	2,286.7	101.7
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	17.8	0.0

Reference Watershed Selection, Worthington Subwatershed

Selection Criteria and Rationale

The Worthington watershed has experienced significant shifts over time, particularly in its land use and hydrological dynamics. The growth of low-density residential areas, industrial operations, and agricultural endeavors have disrupted the watershed's natural equilibrium, leading to challenges in maintaining its ecological integrity. The repercussions of these changes are evident in the water quality, as sediment, nitrogen, and phosphorus levels have surged to worrisome heights. Changes in land cover, such as the decline of forest areas and an increase in impervious surfaces, have further complicated the watershed's hydrology, altering surface runoff and stream flow behaviors.

In our quest to identify an ideal reference watershed for Worthington, the goal was to find one that closely resembled Worthington's topographical and geological nuances but showcased superior land use patterns and water quality indicators. This would serve as a beacon for Worthington's potential future, providing insights into the practices and attributes that contribute to better water quality and ecological well-being.

The upper 3.95 square mile Cornplanter Run stands out as a prime candidate in this context. Its watershed characteristics, spanning area, slope, and geology, are strikingly similar to Worthington, ensuring the relevance and applicability of any insights drawn. A standout feature of Cornplanter Run is its expansive forest cover, known for its natural pollutant filtering capabilities and hydrological regulation. When it comes to water quality, Cornplanter Run sets a commendable standard, especially in terms of sediment, nitrogen, and phosphorus loads, underscoring the advantages of effective land management.

In essence, Cornplanter Run offers a vision of what Worthington could potentially realize. By understanding and adopting the best practices from Cornplanter Run, we're better positioned to navigate Worthington's restoration journey, aiming for enduring ecological vitality and balance.

In framing this narrative, the emphasis remains on Worthington's specific challenges and the rationale behind choosing Cornplanter Run as a reference, integrating key insights from the shared communication, without direct attributions. Adjustments might be needed based on further data or specific nuances related to Worthington.

Chosen Reference Watershed and Characteristics

Cornplanter Run stands out as an optimal choice for a reference watershed when considered against the backdrop of Worthington's current state and challenges. Both watersheds share many similarities, but there are also noteworthy differences which, rather than being seen as impediments, can offer fresh perspectives and insights for the restoration of Worthington.

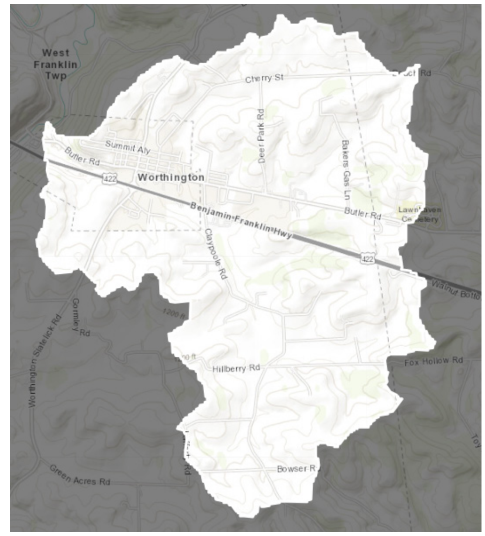


Figure 3: *Worthington Subwatershed*

Watershed Similarities

Area: The areas of the two watersheds are nearly identical, with Cornplanter Run covering 3.95 square miles and Worthington 3.93 square miles. This close match in size ensures that hydrological and land use patterns observed in Cornplanter Run can be scaled appropriately for Worthington.

Physiographic Context: Both watersheds are situated within the Appalachian Plateau, specifically in the Pittsburgh Low Plateau section. This ensures that any geological or topographical recommendations derived from Cornplanter Run are directly applicable to Worthington.

Hydrological Characteristics: Both watersheds exhibit similar precipitation patterns, ensuring that water budget components like evapotranspiration, surface runoff, and subsurface flow are comparable.

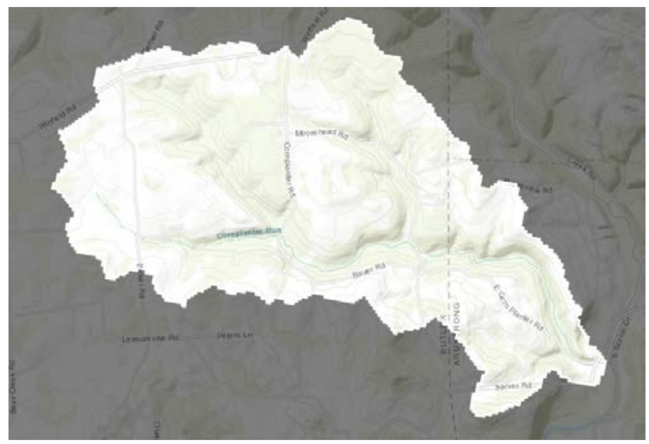


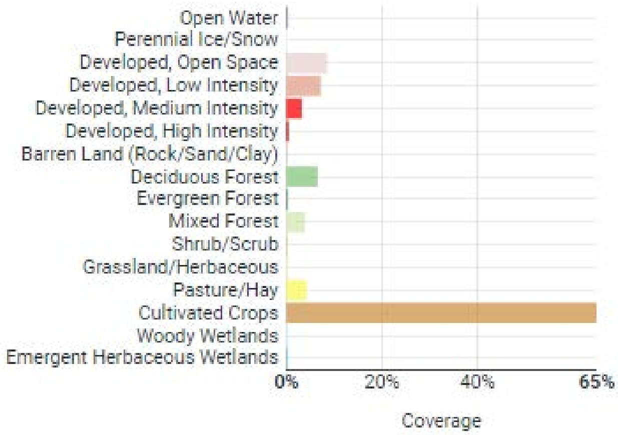
Figure 4: *Cornplanter Run Subwatershed*

Distinctive Features of Cornplanter Run

Land Cover: Cornplanter Run boasts a significantly higher deciduous forest cover (35.56% compared to Worthington's 6.53%) as well as forested buffer. Forests play a pivotal role in reducing surface runoff, enhancing groundwater recharge, and filtering pollutants. On the flip side, Worthington has a higher percentage of cultivated crops and developed lands, which can contribute to its water quality challenges.

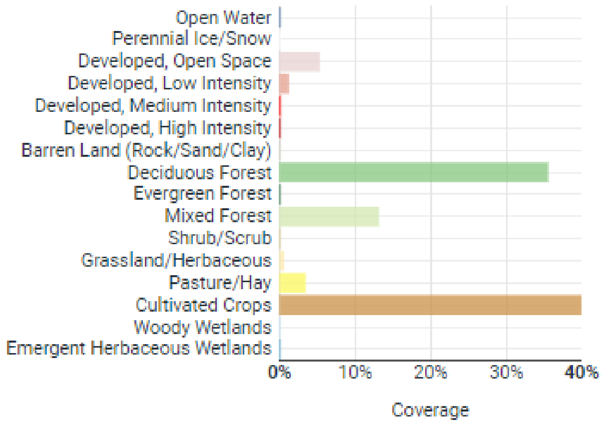
Land Cover Comparison

Worthington Watershed



Type	Area (mi²)	Coverage (%)	Active River Area (mi²)
Open Water	0.00	0.09	0.00
Perennial Ice/Snow	0.00	0.00	0.00
Developed, Open Space	0.34	8.65	0.11
Developed, Low Intensity	0.28	7.21	0.11
Developed, Medium Intensity	0.13	3.25	0.07
Developed, High Intensity	0.02	0.55	0.02
Barren Land (Rock/Sand/Clay)	0.00	0.11	0.00
Deciduous Forest	0.26	6.53	0.05
Evergreen Forest	0.00	0.05	0.00
Mixed Forest	0.15	3.89	0.01
Shrub/Scrub	0.00	0.09	0.00
Grassland/Herbaceous	0.02	0.39	0.00
Pasture/Hay	0.17	4.21	0.04
Cultivated Crops	2.55	64.95	0.45
Woody Wetlands	0.00	0.02	0.00
Emergent Herbaceous Wetlands	0.00	0.02	0.00
Total	3.93	100.00	0.86

Cornplanter Run



Type	Area (mi²)	Coverage (%)	Active River Area (mi²)
Open Water	0.00	0.01	0.00
Perennial Ice/Snow	0.00	0.00	0.00
Developed, Open Space	0.21	5.35	0.04
Developed, Low Intensity	0.05	1.28	0.01
Developed, Medium Intensity	0.01	0.23	0.00
Developed, High Intensity	0.00	0.03	0.00
Barren Land (Rock/Sand/Clay)	0.00	0.05	0.00
Deciduous Forest	1.40	35.56	0.61
Evergreen Forest	0.01	0.15	0.00
Mixed Forest	0.52	13.21	0.17
Shrub/Scrub	0.00	0.05	0.00
Grassland/Herbaceous	0.02	0.61	0.00
Pasture/Hay	0.14	3.51	0.00
Cultivated Crops	1.58	39.96	0.09
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00
Total	3.95	100.00	0.91

Slope and Terrain: Cornplanter Run has steeper average and maximum slopes. While steeper terrains can often lead to faster surface runoff and potential erosion, Cornplanter Run's superior water quality suggests effective land management practices that could be beneficial for Worthington.

Water Quality: Cornplanter Run outperforms Worthington in several water quality metrics, including lower sediment, nitrogen, and phosphorus loads. This is a testament to its effective land use patterns and management practices.

Addressing the Contrasts

While the differences between the two watersheds are evident, these contrasts offer valuable lessons:

Land Use Patterns: The disparity in land cover, especially the higher forest cover in Cornplanter Run, underscores the importance of reforestation and sustainable land management. Worthington can aim to strategically increase its forested areas, which will not only enhance water quality but also provide ecological and recreational benefits.

Water Quality Goals: Cornplanter Run's superior water quality metrics serve as a tangible benchmark for Worthington. By studying the practices and interventions in place at Cornplanter Run, Worthington can formulate targeted strategies to reduce its pollutant loads.

Slope Management: The steeper slopes of Cornplanter Run can be seen as an advantage. They demonstrate that with appropriate land management and erosion control measures, it's possible to maintain excellent water quality even in terrains that are naturally predisposed to faster runoff.

In conclusion, while no two watersheds are identical, the similarities between Cornplanter Run and Worthington, coupled with the lessons gleaned from their differences, make Cornplanter Run an ideal reference. Its attributes offer a vision of what Worthington can achieve and a roadmap to guide its restoration journey.

Target Water Quality Goals for Worthington

The disparities in water quality between Worthington and Cornplanter Run provide a clear directive for the targets Worthington should aspire to achieve. By leveraging the insights from Cornplanter Run, we can set ambitious yet feasible water quality goals for Worthington. Deriving data from the ModelMyWatershed platform, below is a summary comparison of the average annual pollutant loads from 30-years of daily fluxes between the Worthington and Cornplanter Run watershed. The full water quality data for both watersheds is provided immediately following this summary.

Sediment Reduction

Worthington currently has a sediment loading rate of 1,132.59 lb/ac, significantly higher than Cornplanter Run's 614.49 lb/ac. This stark contrast underscores the urgent need to address sediment issues in Worthington.

Objective: Reduce the sediment load to approach Cornplanter Run's levels, aiming for a significant reduction over the next 5-10 years. Emphasizing practices that minimize soil erosion and enhance sediment capture will be pivotal.

Nutrient Management

Nitrogen: Worthington's current loading rate for total nitrogen is 6.32 lb/ac, nearly double that of Cornplanter Run's 3.44 lb/ac.

Objective: Work towards matching the nitrogen loading rates of Cornplanter Run by promoting practices that reduce nitrogen inputs and enhance nitrogen uptake in the watershed.

Phosphorus: With a phosphorus loading rate of 1.27 lb/ac in Worthington compared to Cornplanter Run's 0.72 lb/ac, there's evident room for improvement.

Objective: Aim to approximate Cornplanter Run's phosphorus levels by mitigating sources of phosphorus and optimizing its natural cycling in the ecosystem.

Land Use Adjustments

A closer examination of Cornplanter Run reveals the intrinsic benefits of maintaining a balanced land use pattern. For Worthington, this implies exploring avenues to enhance natural cover and regulate land practices that contribute heavily to sediment and nutrient loads. Strategic land use planning will be essential in moving towards the desired water quality targets.

Stream Health and Rehabilitation

While numerical targets for stream health are set later in the report, it's worth noting that the integrity of stream channels, riparian zones, and aquatic habitats plays a significant role in determining water quality. Efforts to restore and maintain these ecological assets will be central to achieving the outlined sediment and nutrient goals.

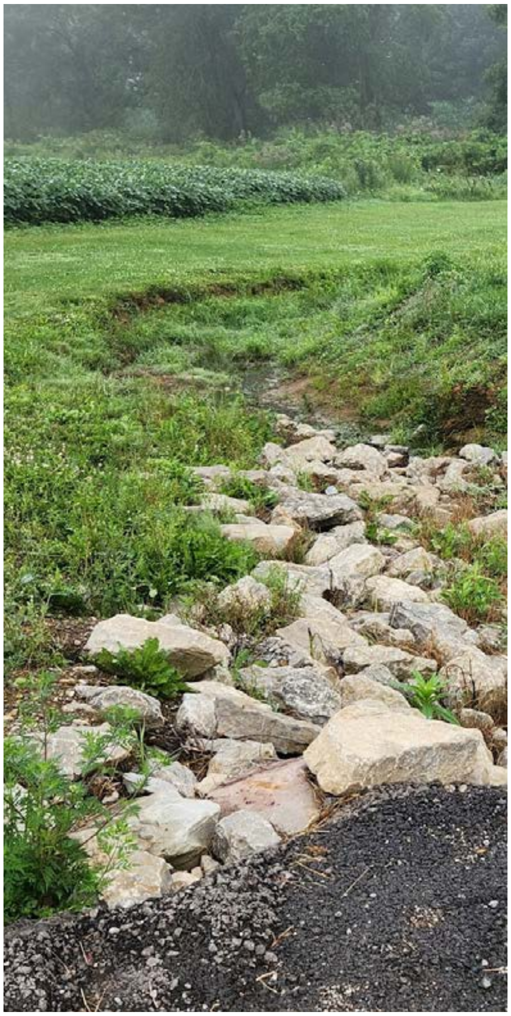
Continuous Monitoring and Adaptive Management

To ensure the efficacy of our efforts, a rigorous monitoring framework will be established. This will not only track progress but also offer insights to refine and adapt strategies to the evolving needs of the Worthington watershed.

Average Annual Pollutant Loads, Worthington Watershed

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	2,859,698.8	15,956.4	3,199.6
Loading Rates (lb/ac)	1,132.59	6.32	1.27
Mean Annual Concentration (mg/L)	350.93	1.96	0.39
Mean Low-Flow Concentration (mg/L)	2,841.11	10.79	3.17

Mean Flow: 130,532,956 (ft³/year) and 4.14 (ft³/s)



Average Annual Pollutant Loads, Cornplanter Run

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	1,557,617.3	8,723.6	1,829.0
Loading Rates (lb/ac)	614.49	3.44	0.72
Mean Annual Concentration (mg/L)	198.03	1.11	0.23
Mean Low-Flow Concentration (mg/L)	1,712.97	7.06	2.01

Mean Flow: 125,993,405 (ft³/year) and 4 (ft³/s)

Average Annual Pollutant Loads per Land Cover Source

Worthington Watershed

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	120,497.7	345.8	125.3
Cropland	2,583,890.1	9,546.4	2,786.4
Wooded Areas	807.9	20.6	1.7
Wetlands	2.2	0.2	0.0
Open Land	526.3	6.4	0.6
Barren Areas	2.3	0.8	0.0
Low-Density Mixed	2,024.6	56.1	5.9
Medium-Density Mixed	5,977.2	113.9	11.6
High-Density Mixed	1,008.2	19.2	2.0
Low-Density Open Space	2,431.2	67.3	7.1
Farm Animals	0.0	455.1	108.8
Stream Bank Erosion	142,531.2	92.6	33.1
Subsurface Flow	0.0	4,972.6	117.2
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	259.3	0.0

Cornplanter Run

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	70,702.5	220.1	74.9
Cropland	1,422,225.7	5,620.6	1,525.9
Wooded Areas	2,180.7	78.8	5.8
Wetlands	0.0	0.0	0.0
Open Land	1,022.2	10.7	1.1
Barren Areas	1.6	0.5	0.0
Low-Density Mixed	304.5	7.5	0.8
Medium-Density Mixed	541.9	10.1	1.0
High-Density Mixed	70.7	1.3	0.1
Low-Density Open Space	1,276.3	31.6	3.4
Farm Animals	0.0	398.2	101.0
Stream Bank Erosion	59,291.2	39.7	13.2
Subsurface Flow	0.0	2,286.7	101.7
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	17.8	0.0

Reference Watershed Selection, Marrowbone Run Subwatershed

Selection Criteria and Rationale

In the search for a comparative watershed to guide the rehabilitation of Marrowbone Run, the primary aim was to find a watershed with similar geographical and geological features but with superior environmental management and water quality. Such a comparison would illuminate the potential path forward for Marrowbone Run, highlighting successful practices and desirable environmental attributes.

North Branch Rough Run, encompassing an area of 3.23 square miles, emerged as an ideal reference point. Its similarities with Marrowbone Run in terms of size, slope, and geological characteristics make it a relevant model. North Branch Rough Run is distinguished by its extensive forest cover, which plays a crucial role in filtering pollutants and stabilizing water flow. In terms of water quality, North Branch Rough Run excels, particularly in managing sediment, nitrogen, and phosphorus levels. This underscores the positive impact of well-managed land use.

North Branch Rough Run serves as an exemplar for what Marrowbone Run could achieve. By emulating the effective strategies observed in North Branch Rough Run, there is an opportunity to guide Marrowbone Run towards a more ecologically stable and healthy state.

This narrative focuses on the unique challenges faced by Marrowbone Run and the reasons for selecting North Branch Rough Run as a benchmark. It integrates key findings while maintaining a focus on Marrowbone's specific situation. This approach may require adjustments as new data emerges or as more nuances of Marrowbone Run's condition are understood.

Chosen Reference Watershed and Characteristics

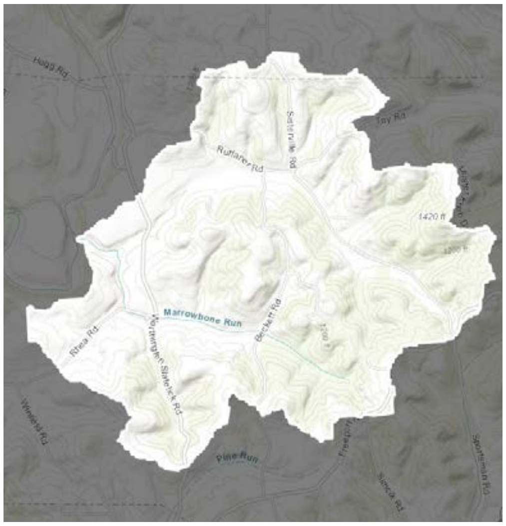


Figure 5: *Marrowbone Run Subwatershed*

North Branch Rough Run stands out as an optimal choice for a reference watershed when considered against the backdrop of Marrowbone Run's current state and challenges. Both watersheds share many similarities, but there are also noteworthy differences which, rather than being seen as impediments, can offer fresh perspectives and insights for the restoration of Marrowbone Run.

Watershed Similarities

<u>Area:</u> The areas of the two watersheds are nearly identical, with N Branch Rough Run covering 3.23 square miles and Marrowbone 3.14 square miles. This close match in size ensures that hydrological and land use patterns observed in N Branch Rough Run can be scaled appropriately for Marrowbone Run.

<u>Physiographic Context:</u> Both watersheds are situated within the Appalachian Plateau, specifically in the Pittsburgh Low Plateau section. This ensures that any geological or topographical recommendations derived from N Branch Rough Run are directly applicable to Marrowbone Run.

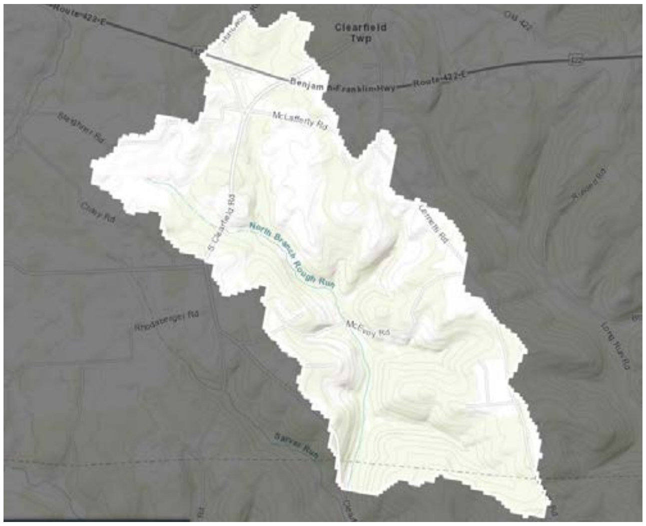


Figure 6: *North Branch Rough Run Subwatershed*

<u>Hydrological Characteristics:</u> Both watersheds exhibit similar precipitation patterns, ensuring that water budget components like evapotranspiration, surface runoff, and subsurface flow are comparable.

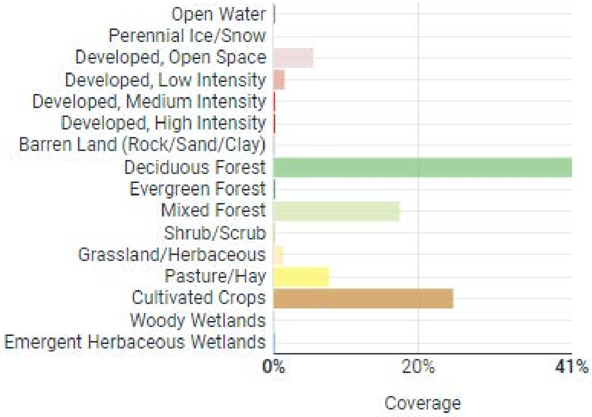
Distinctive Features of N Branch Rough Run

Land Cover: N Branch Rough Run has a higher deciduous forest cover (45.64% compared to Marrowbone's 41.21%). Forests play a pivotal role in reducing surface runoff, enhancing groundwater recharge, and filtering pollutants. On the flip side, Marrowbone has a

higher percentage of cultivated crops and developed lands, which can contribute to its water quality challenges.

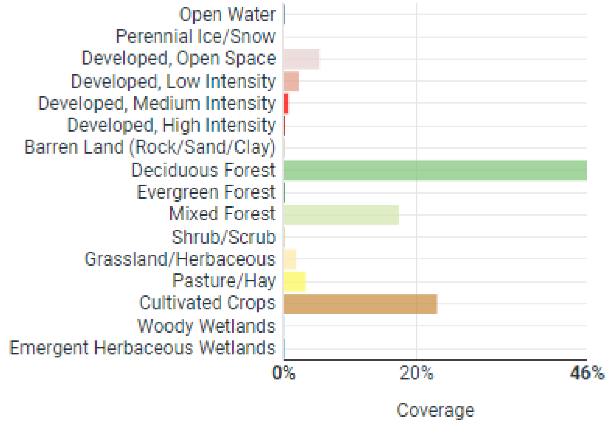
Land Cover Comparison

Marrowbone Run Subwatershed



Type	Area (mi²)	Coverage (%)	Active River Area (mi²)
Open Water	0.00	0.00	0.00
Perennial Ice/Snow	0.00	0.00	0.00
Developed, Open Space	0.17	5.52	0.05
Developed, Low Intensity	0.05	1.54	0.02
Developed, Medium Intensity	0.01	0.20	0.00
Developed, High Intensity	0.00	0.00	0.00
Barren Land (Rock/Sand/Clay)	0.00	0.14	0.00
Deciduous Forest	1.29	41.21	0.19
Evergreen Forest	0.00	0.00	0.00
Mixed Forest	0.55	17.42	0.08
Shrub/Scrub	0.00	0.14	0.00
Grassland/Herbaceous	0.04	1.36	0.01
Pasture/Hay	0.24	7.64	0.11
Cultivated Crops	0.78	24.81	0.18
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00
Total	3.14	100.00	0.64

North Branch Rough Run Subwatershed



Type	Area (mi²)	Coverage (%)	Active River Area (mi²)
Open Water	0.00	0.00	0.00
Perennial Ice/Snow	0.00	0.00	0.00
Developed, Open Space	0.18	5.44	0.01
Developed, Low Intensity	0.07	2.32	0.00
Developed, Medium Intensity	0.02	0.74	0.00
Developed, High Intensity	0.00	0.08	0.00
Barren Land (Rock/Sand/Clay)	0.00	0.09	0.00
Deciduous Forest	1.47	45.64	0.43
Evergreen Forest	0.00	0.00	0.00
Mixed Forest	0.56	17.31	0.08
Shrub/Scrub	0.00	0.06	0.00
Grassland/Herbaceous	0.06	1.91	0.00
Pasture/Hay	0.11	3.36	0.01
Cultivated Crops	0.74	23.06	0.11
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00
Total	3.23	100.00	0.65

Slope and Terrain: N Branch Rough Run has shallower average and maximum slopes. While steeper terrains can often lead to faster surface runoff and potential erosion, N Branch Rough Run's superior water quality suggests effective land management practices that could be beneficial for Marrowbone.

Water Quality: N Branch Rough Run outperforms Marrowbone in several water quality metrics, including lower sediment, nitrogen, and phosphorus loads. This is a testament to its effective land use patterns and management practices.

Addressing the Contrasts

While the differences between the two watersheds are evident, these contrasts offer valuable lessons:

Land Use Patterns: The disparity in land cover, especially the higher forest cover in N Branch Rough Run, underscores the importance of reforestation and sustainable land management. Marrowbone Run can aim to strategically increase its forested areas, which will not only enhance water quality but also provide ecological and recreational benefits.

Water Quality Goals: N Branch Rough Run's superior water quality metrics serve as a tangible benchmark for Marrowbone. By studying the practices and interventions in place at N Branch Rough Run, Marrowbone Run can formulate targeted strategies to reduce its pollutant loads.

Slope Management: The shallower slopes of N Branch Rough Run can be seen as an advantage. They still demonstrate that with appropriate land management and erosion control measures, it's possible to maintain excellent water quality.

In conclusion, while no two watersheds are identical, the similarities between N Branch Rough Run and Marrowbone Run, coupled with the lessons gleaned from their differences, make N Branch Rough Run an ideal reference. Its attributes offer a vision of what Marrowbone Run can achieve and a road map to guide its restoration journey.

Target Water Quality Goals for Marrowbone Run

The disparities in water quality between Marrowbone and N Branch Run provide a clear directive for the targets Marrowbone Run should aspire to achieve. By leveraging the insights from N Branch Rough Run, we can set ambitious yet feasible water quality goals for Marrowbone. Deriving data from the ModelMyWatershed platform, below is a summary comparison of the average annual pollutant loads from 30-years of daily fluxes between the Marrowbone and N Branch Rough Run watershed. The full water quality data for both watersheds is provided immediately following this summary.

Sediment Reduction

Marrowbone Run currently has a sediment loading rate of 449.06 lb/ac, significantly higher than N Branch Rough Run's 321.15 lb/ac. This stark contrast underscores the urgent need to address sediment issues in Marrowbone.

Objective: Reduce the sediment load to approach N Branch Rough Run's levels, aiming for a significant reduction over the next 5-10 years. Emphasizing practices that minimize soil erosion and enhance sediment capture will be pivotal.

Nutrient Management

Nitrogen: Marrowbone Run's current loading rate for total nitrogen is 2.85 lb/ac, greater then that of N Branch Rough Run's 2.35 lb/ac.

Objective: Work towards matching the nitrogen loading rates of N Branch Rough Run by promoting practices that reduce nitrogen inputs and enhance nitrogen uptake in the watershed.

Phosphorus: With a phosphorus loading rate of 0.56 lb/ac in Marrowbone compared to N Branch Rough Run's 0.39 lb/ac, there's evident room for improvement.

Objective: Aim to approximate N Branch Rough Run's phosphorus levels by mitigating sources of phosphorus and optimizing its natural cycling in the ecosystem.

Land Use Adjustments

A closer examination of N Branch Rough Run reveals the intrinsic benefits of maintaining a balanced land use pattern. For Marrowbone this implies exploring avenues to enhance natural cover and regulate land practices that contribute heavily to sediment and nutrient loads. Strategic land use planning will be essential in moving towards the desired water quality targets.

Stream Health and Rehabilitation

While numerical targets for stream health are set later in the report, it's worth noting that the integrity of stream channels, riparian zones, and aquatic habitats plays a significant role in determining water quality. Efforts to restore and maintain these ecological assets will be central to achieving the outlined sediment and nutrient goals.

Continuous Monitoring and Adaptive Management

To ensure the efficacy of our efforts, a rigorous monitoring framework will be established. This will not only track progress but also offer insights to refine and adapt strategies to the evolving needs of the Marrowbone subwatershed.

Average Annual Pollutant Loads, Marrowbone Run

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	905,698.6	5,742.7	1,126.0
Loading Rates (lb/ac)	449.06	2.85	0.56
Mean Annual Concentration (mg/L)	139.70	0.89	0.17
Mean Low-Flow Concentration (mg/L)	1,302.48	5.95	1.67

Mean Flow: 103,853,417 (ft^3/year) and 3.29 (ft^3/s)

Average Annual Pollutant Loads, N Branch Rough Run

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	665,582.4	4,868.9	811.4
Loading Rates (lb/ac)	321.15	2.35	0.39
Mean Annual Concentration (mg/L)	97.49	0.71	0.12
Mean Low-Flow Concentration (mg/L)	892.45	4.18	1.14

Mean Flow: 109,359,295 (ft^3/year) and 3.47 (ft^3/s)

Average Annual Pollutant Loads per Land Cover Source

Marrowbone Run Subwatershed

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	151,008.4	467.9	160.2
Cropland	699,454.8	2,811.2	770.4
Wooded Areas	7,155.6	93.4	10.6
Wetlands	0.0	0.0	0.0
Open Land	3,294.5	23.1	3.4
Barren Areas	6.2	0.9	0.0
Low-Density Mixed	296.6	7.4	0.8
Medium-Density Mixed	241.3	4.1	0.4
High-Density Mixed	0.0	0.0	0.0
Low-Density Open Space	1,061.5	26.6	2.8
Farm Animals	0.0	346.5	82.9
Stream Bank Erosion	43,179.8	30.9	11.0
Subsurface Flow	0.0	1,916.5	83.3
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	14.2	0.0

North Branch Rough Run Subwatershed

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	32,708.8	97.0	35.1
Cropland	573,547.9	2,143.4	585.3
Wooded Areas	3,536.7	26.7	4.0
Wetlands	0.0	0.0	0.0
Open Land	3,080.1	19.2	2.9
Barren Areas	0.9	0.3	0.0
Low-Density Mixed	483.9	12.6	1.3
Medium-Density Mixed	1,112.7	20.3	2.1
High-Density Mixed	107.7	2.0	0.2
Low-Density Open Space	1,137.3	29.6	3.1
Farm Animals	0.0	305.0	79.7
Stream Bank Erosion	49,866.4	28.7	11.0
Subsurface Flow	0.0	2,134.3	86.7
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	49.7	0.0

Reference Watershed Selection, Pine Run Subwatershed

Selection Criteria and Rationale

Pine Run's watershed has witnessed considerable transformations due to changes in land use and hydrological patterns. The construction of highways, industrial areas surrounding RIDC Armstrong Innovation Park, and considerable agricultural development has unsettled the natural balance of the ecosystem, resulting in deteriorating water quality. This is particularly evident in the elevated levels of sediment, nitrogen, and phosphorus. Additionally, the shift from forested areas to impervious surfaces has altered the watershed's hydrological dynamics, affecting surface runoff and stream flows.

In addressing the challenges facing the Pine Run watershed, the search for a suitable reference watershed was primarily driven by the need to find a watershed that not only mirrored Pine Run's geographical and geological features but also demonstrated healthier land use practices and superior water quality. Moreover, given the historical impacts on Pine Run's downstream section between its mouth and the convergence of its three headwater tributaries. it was decided to focus the study on the headwater regions of Pine Run, an area encompassing 5.93 square miles. By concentrating on this area, the intention was to gain a deeper understanding of the watershed's dynamics, with the goal of applying lessons learned from the reference watershed to enhance Pine Run's ecological health and water quality.

The North Branch Rough Run, covering an upper region of 4.53 square miles, emerged as an ideal reference. This watershed shares similar characteristics with Pine Run in terms of area, slope, and geology, making it a relevant comparison. Notably, North Branch Rough Run boasts extensive forest cover, which enhances its ability to naturally filter pollutants and manage water flow. In terms of water quality, it excels, particularly in the management of sediment, nitrogen, and phosphorus levels, highlighting the benefits of sound land stewardship.

North Branch Rough Run thus serves as a potential blueprint for Pine Run's restoration. By studying and implementing best practices from North Branch Rough Run, there is an opportunity to guide Pine Run towards a more balanced and ecologically healthy state. This narrative underscores Pine Run's unique issues and the reasoning behind selecting North Branch Rough Run as a benchmark. It incorporates key findings from our analysis and ongoing discussions, although adjustments may be necessary as new information or specific details about Pine Run become available.

Chosen Reference Watershed and Characteristics

Figure 7: *Pine Run Subwatershed*

North Branch Rough Run stands out as an optimal choice for a reference watershed when considered against the backdrop of Pine Run's current state and challenges. Both watersheds share many similarities, but there are also noteworthy differences which, rather than being seen as impediments, can offer fresh perspectives and insights for the restoration of Pine Run.

Watershed Similarities

<u>Area:</u> The areas of the two watersheds are similar, with North Branch Rough Run covering 4.53 square miles and Pine Run 5.93 square miles. This close match in size ensures that hydrological and land use patterns observed in North Branch Rough Run can be scaled appropriately for Pine Run.

<u>Physiographic Context:</u> Both watersheds are situated within the Appalachian Plateau, specifically in the Pittsburgh Low Plateau section. This ensures that any geological or topographical recommendations derived from North Branch Rough Run are directly applicable to Pine Run.

<u>Hydrological Characteristics:</u> Both watersheds exhibit similar precipitation patterns, ensuring that water budget components like evapotranspiration, surface runoff, and subsurface flow are comparable.

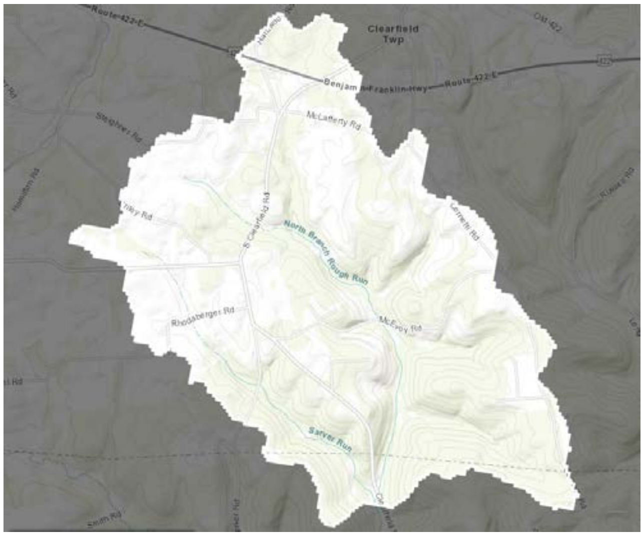


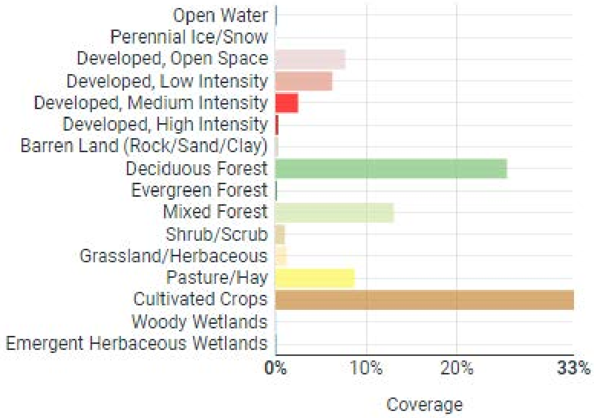
Figure 8: *N Branch Rough Run Subwatershed*

Distinctive Features of North Branch Rough Run

Land Cover: North Branch Rough Run boasts a significantly higher deciduous forest cover (45.5% compared to Pine Run's 25.57%) as well as forested buffer. Forests play a pivotal role in reducing surface runoff, enhancing groundwater recharge, and filtering pollutants. On the flip side, Pine Run has a higher percentage of cultivated crops and developed lands, which can contribute to its water quality challenges.

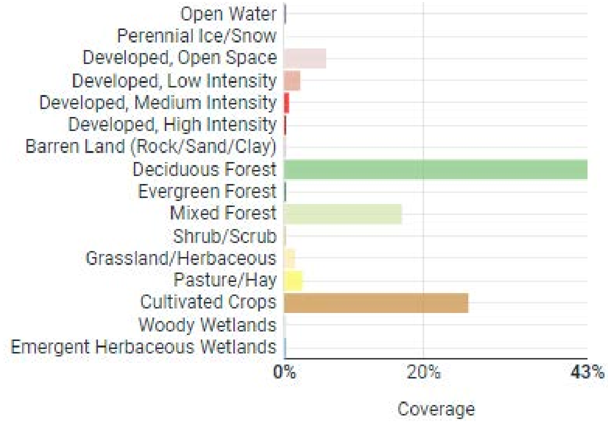
Land Cover Comparison

Pine Run Subwatershed



Type	Area (mi²)	Coverage (%)	Active River Area (mi²)
Open Water	0.01	0.10	0.00
Perennial Ice/Snow	0.00	0.00	0.00
Developed, Open Space	0.46	7.70	0.15
Developed, Low Intensity	0.38	6.30	0.11
Developed, Medium Intensity	0.15	2.48	0.03
Developed, High Intensity	0.02	0.32	0.00
Barren Land (Rock/Sand/Clay)	0.02	0.35	0.01
Deciduous Forest	1.53	25.57	0.49
Evergreen Forest	0.01	0.10	0.00
Mixed Forest	0.78	13.06	0.21
Shrub/Scrub	0.06	1.06	0.00
Grassland/Herbaceous	0.08	1.26	0.03
Pasture/Hay	0.52	8.76	0.14
Cultivated Crops	1.97	32.94	0.28
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00
Total	5.97	100.00	1.46

North Branch Rough Run Subwatershed



Type	Area (mi²)	Coverage (%)	Active River Area (mi²)
Open Water	0.00	0.05	0.00
Perennial Ice/Snow	0.00	0.00	0.00
Developed, Open Space	0.27	6.04	0.03
Developed, Low Intensity	0.10	2.24	0.01
Developed, Medium Intensity	0.03	0.62	0.00
Developed, High Intensity	0.00	0.06	0.00
Barren Land (Rock/Sand/Clay)	0.00	0.06	0.00
Deciduous Forest	1.97	43.50	0.67
Evergreen Forest	0.00	0.00	0.00
Mixed Forest	0.76	16.87	0.11
Shrub/Scrub	0.00	0.05	0.00
Grassland/Herbaceous	0.07	1.55	0.00
Pasture/Hay	0.12	2.58	0.01
Cultivated Crops	1.19	26.37	0.21
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00
Total	4.53	100.00	1.03

Slope and Terrain: North Branch Rough Run has similar average and maximum slopes. While steeper terrains can often lead to faster surface runoff and potential erosion, North Branch Rough Run's superior water quality suggests effective land management practices that could be beneficial for Pine Run.

Water Quality: North Branch Rough Run outperforms Pine Run in several water quality metrics, including lower sediment, nitrogen, and phosphorus loads. This is a testament to its effective land use patterns and management practices.

Addressing the Contrasts

While the differences between the two watersheds are evident, these contrasts offer valuable lessons:

Land Use Patterns: The disparity in land cover, especially the higher forest cover in North Branch Rough Run, underscores the importance of reforestation and sustainable land management. Pine Run can aim to strategically increase its forested areas, which will not only enhance water quality but also provide ecological and recreational benefits.

Water Quality Goals: North Branch Rough Run's superior water quality metrics serve as a tangible benchmark for Pine Run. By studying the practices and interventions in place at North Branch Rough Run, Pine Run can formulate targeted strategies to reduce its pollutant loads.

Slope Management: The similar slopes of North Branch Rough Run can be seen as an advantage. They demonstrate that with appropriate land management and erosion control measures, it's possible to maintain excellent water quality even in terrains are the same.

In conclusion, while no two watersheds are identical, the similarities between North Branch Rough Run and Pine Run, coupled with the lessons gleaned from their differences, make North Branch Rough Run an ideal reference. Its attributes offer a vision of what Pine Run can achieve and a roadmap to guide its restoration journey.

Target Water Quality Goals for Pine Run

The disparities in water quality between Pine Run and North Branch Rough Run provide a clear directive for the targets Pine Run should aspire to achieve. By leveraging the insights from North Branch Rough Run, we can set ambitious yet feasible water quality goals for Pine Run.   Deriving data from the ModelMyWatershed platform, below is a summary comparison of the average annual pollutant loads from 30-years of daily fluxes between the Pine Run and North Branch Rough Run watershed. The full water quality data for both watersheds is provided immediately following this summary.

Sediment Reduction

Pine Run currently has a sediment loading rate of 613.08 lb/ac, significantly higher than North Branch Rough Run's 351.07 lb/ac. This stark contrast underscores the urgent need to address sediment issues in Pine Run.

Objective: Reduce the sediment load to approach North Branch Rough Run's levels, aiming for a significant reduction over the next 5-10 years. Emphasizing practices that minimize soil erosion and enhance sediment capture will be pivotal.

Nutrient Management

Nitrogen: Pine Run's current loading rate for total nitrogen is 3.48 lb/ac, significantly higher then that of North Branch Rough Run's 2.41 lb/ac.

Objective: Work towards matching the nitrogen loading rates of North Branch Rough Run by promoting practices that reduce nitrogen inputs and enhance nitrogen uptake in the watershed.

Phosphorus: With a phosphorus loading rate of 0.70 lb/ac in Pine Run compared to North Branch Rough Run's 0.42 lb/ac, there's evident room for improvement.

Objective: Aim to approximate North Branch Rough Run's phosphorus levels by mitigating sources of phosphorus and optimizing its natural cycling in the ecosystem.

Land Use Adjustments

A closer examination of North Branch Rough Run reveals the intrinsic benefits of maintaining a balanced land use pattern. For Pine Run, this implies exploring avenues to enhance natural cover and regulate land practices that contribute heavily to sediment and nutrient loads. Strategic land use planning will be essential in moving towards the desired water quality targets.

Stream Health and Rehabilitation

It is worth noting that the integrity of stream channels, riparian zones, and aquatic habitats plays a significant role in determining water quality. Efforts to restore and maintain these ecological assets will be central to achieving the outlined sediment and nutrient goals.

Continuous Monitoring and Adaptive Management

To ensure the efficacy of our efforts, a rigorous monitoring framework will be established. This will not only track progress but also offer insights to refine and adapt strategies to the evolving needs of the Pine Run watershed.

Average Annual Pollutant Loads, Pine Run Watershed

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	2,347,858.9	13,334.3	2,695.0
Loading Rates (lb/ac)	613.08	3.48	0.70
Mean Annual Concentration (mg/L)	199.75	1.13	0.23
Mean Low-Flow Concentration (mg/L)	1,730.07	7.95	2.16

Mean Flow: 188,276,749 (ft^3/year) and 5.97 (ft^3/s)

Average Annual Pollutant Loads, North Branch Rough Run

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	1,019,577.3	6,998.3	1,229.1
Loading Rates (lb/ac)	351.07	2.41	0.42
Mean Annual Concentration (mg/L)	111.18	0.76	0.13
Mean Low-Flow Concentration (mg/L)	1,099.46	4.99	1.39

Mean Flow: 146,891,793 (ft^3/year) and 4.66 (ft^3/s)

Average Annual Pollutant Loads per Land Cover Source

Pine Run Subwatershed

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	334,363.6	1,029.3	356.2
Cropland	1,718,447.1	6,940.2	1,911.4
Wooded Areas	2,725.7	83.2	6.6
Wetlands	0.0	0.0	0.0
Open Land	2,106.2	30.5	2.5
Barren Areas	22.1	4.1	0.2
Low-Density Mixed	2,675.0	74.0	7.8
Medium-Density Mixed	7,130.8	132.8	13.5
High-Density Mixed	926.1	17.2	1.8
Low-Density Open Space	3,269.2	90.4	9.5
Farm Animals	0.0	693.9	166.1
Stream Bank Erosion	276,193.1	189.6	66.1
Subsurface Flow	0.0	3,747.1	153.4
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	302.0	0.0

North Branch Rough Run Subwatershed

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	34,576.1	102.4	37.4
Cropland	886,928.2	3,349.7	914.1
Wooded Areas	4,564.0	35.5	5.2
Wetlands	0.0	0.0	0.0
Open Land	3,659.0	22.2	3.4
Barren Areas	0.9	0.3	0.0
Low-Density Mixed	649.5	16.7	1.8
Medium-Density Mixed	1,347.6	24.5	2.5
High-Density Mixed	129.2	2.4	0.2
Low-Density Open Space	1,746.9	45.0	4.8
Farm Animals	0.0	451.2	117.8
Stream Bank Erosion	85,975.9	48.5	17.6
Subsurface Flow	0.0	2,843.1	124.2
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	56.8	0.0

Reference Watershed Selection, Moonlight Drive Subwatershed

Selection Criteria and Rationale

The Moonlight Drive subwatershed presents a landscape deeply influenced by its geological history and human activities, particularly evident in its altered ecological state. The region's past, marked by intensive industrial and coal mining activities, has left a significant imprint on its natural environment and health of the receiving waters. The remnants of these activities, including abandoned mines and refuse piles, are stark reminders of the area's mining legacy, contributing to acid mine drainage (AMD). This has led to increased manganese levels and net alkaline water conditions and imposition of a TMDL on the streams within the subwatershed.

In selecting a reference watershed, the goal was to find one that closely resembled Moonlight Drive's topographical and geological nuances but showcased superior land use patterns and water quality indicators. Long Run was identified as a fitting comparison. Its watershed attributes, including area, slope, and geological composition, align closely with those of Moonlight Drive. Long Run's extensive forest cover, which aids in filtering pollutants and regulating water flow, and its commendable water quality, particularly in terms of sediment, nitrogen, and phosphorus levels, highlight the positive impacts of effective land management.

However, a unique challenge in Moonlight Drive is the historic and ongoing mining activities, along with the resultant acid mine drainage (AMD) impairments. These issues set Moonlight Drive apart from typical reference watersheds used in methodologies recommended by the Pennsylvania Department of Environmental Protection (PaDEP) and exceed the analytical capabilities of tools like ModelMyWatershed. Therefore, the selection of Long Run as a reference watershed was based primarily on relative land cover and pollutant loading, excluding considerations of mining activity and AMD impairment.

Chosen Reference Watershed and Characteristics

Long Run stands out as an optimal choice for a reference watershed when considered against the backdrop of Moonlight Drive's current state and challenges. Both watersheds share many similarities, but there are also noteworthy differences which, rather than being seen as impediments, can offer fresh perspectives and insights for the restoration of Moonlight Drive.

Watershed Similarities

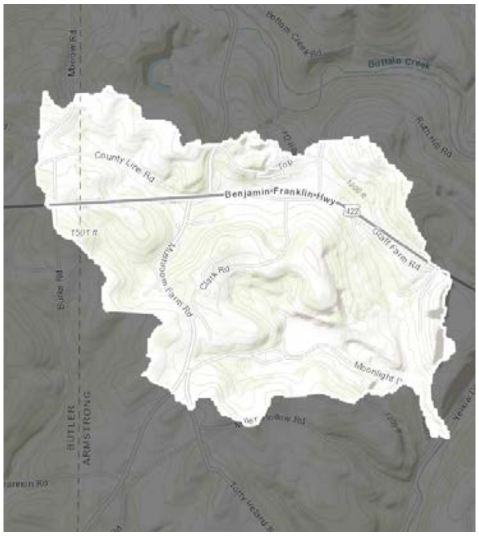


Figure 9: *Moonlight Subwatershed*

Area: The areas of the two watersheds are nearly identical, with Long Run covering 2.63 square miles and Moonlight Drive 2.58 square miles. This close match in size ensures that hydrological and land use patterns observed in Long Run can be scaled appropriately for Moonlight Drive.

Physiographic Context: Both watersheds are situated within the Appalachian Plateau, specifically in the Pittsburgh Low Plateau section. This ensures that any geological or topographical recommendations derived from Long Run are directly applicable to Moonlight Drive.

Hydrological Characteristics: Both watersheds exhibit similar precipitation patterns, ensuring that water budget components like evapotranspiration, surface runoff, and subsurface flow are comparable.

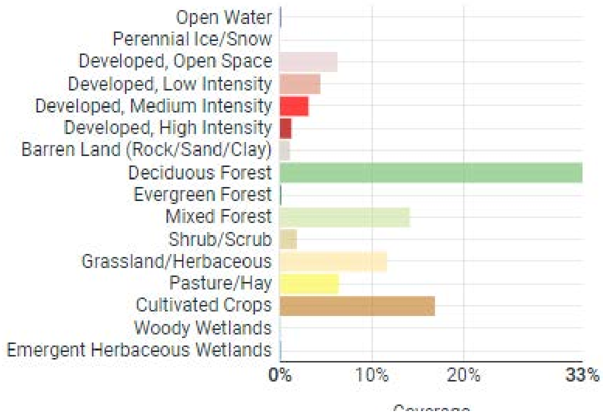
Distinctive Features of Long Run

Land Cover: Long Run boasts a significantly higher deciduous forest cover (58.69% compared to Moonlight's 32.95%) as well as forested buffer. Forests play a pivotal role in reducing surface runoff, enhancing groundwater recharge, and filtering pollutants. On the flip side, Moonlight has a higher percentage of cultivated crops and developed lands, which can contribute to its water quality challenges.

Figure 10: *Long Run Subwatershed*

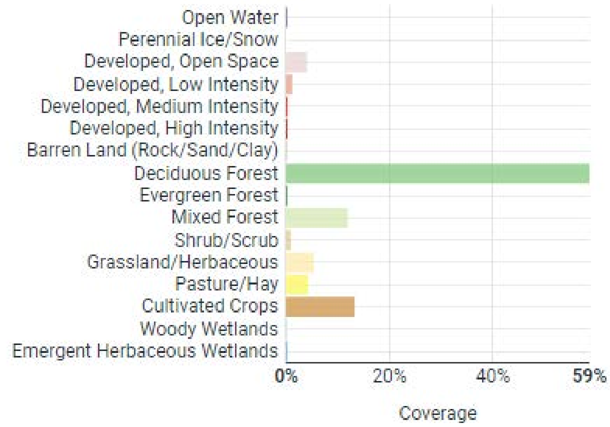
Land Cover Comparison

Moonlight Subwatershed



Type	Area (ft²)	Coverage (%)	Active River Area (ft²)
Open Water	9,656.66	0.01	0.0
Perennial Ice/Snow	0.00	0.00	0.0
Developed, Open Space	4,509,658.40	6.26	965,665.6
Developed, Low Intensity	3,157,726.54	4.38	1,062,232.1
Developed, Medium Intensity	2,230,687.56	3.10	830,472.4
Developed, High Intensity	888,412.36	1.23	19,313.3
Barren Land (Rock/Sand/Clay)	772,532.49	1.07	19,313.3
Deciduous Forest	23,736,060.68	32.95	6,750,002.6
Evergreen Forest	19,313.31	0.03	0.0
Mixed Forest	10,178,115.52	14.13	627,682.6
Shrub/Scrub	1,322,961.88	1.84	96,566.5
Grassland/Herbaceous	8,430,260.77	11.70	589,056.0
Pasture/Hay	4,615,881.61	6.41	791,845.8
Cultivated Crops	12,167,386.68	16.89	1,564,378.2
Woody Wetlands	0.00	0.00	0.0
Emergent Herbaceous Wetlands	0.00	0.00	0.0
Total	72,038,654.46	100.00	13,316,528.7

Long Run Subwatershed



Type	Area (mi²)	Coverage (%)	Active River Area (mi²)
Open Water	0.00	0.13	0.00
Perennial Ice/Snow	0.00	0.00	0.00
Developed, Open Space	0.11	4.04	0.02
Developed, Low Intensity	0.03	1.16	0.00
Developed, Medium Intensity	0.01	0.25	0.00
Developed, High Intensity	0.00	0.05	0.00
Barren Land (Rock/Sand/Clay)	0.00	0.04	0.00
Deciduous Forest	1.55	58.69	0.51
Evergreen Forest	0.00	0.01	0.00
Mixed Forest	0.31	11.87	0.08
Shrub/Scrub	0.02	0.87	0.00
Grassland/Herbaceous	0.14	5.38	0.02
Pasture/Hay	0.11	4.25	0.01
Cultivated Crops	0.35	13.27	0.00
Woody Wetlands	0.00	0.00	0.00
Emergent Herbaceous Wetlands	0.00	0.00	0.00
Total	2.63	100.00	0.65

Slope and Terrain: Long Run has steeper average and maximum slopes. While steeper terrains can often lead to faster surface runoff and potential erosion, Long Run's superior water quality suggests effective land management practices that could be beneficial for Moonlight Drive.

Water Quality: Long Run outperforms Moonlight in several water quality metrics, including lower sediment, nitrogen, and phosphorus loads. This is a testament to its effective land use patterns and management practices.

Addressing the Contrasts

While the differences between the two watersheds are evident, these contrasts offer valuable lessons:

Land Use Patterns: The disparity in land cover, especially the higher forest cover in Long Run, underscores the importance of reforestation and sustainable land management. Moonlight Drive can aim to strategically increase its forested areas, which will not only enhance water quality but also provide ecological and recreational benefits.

Water Quality Goals: Long Run's superior water quality metrics serve as a tangible benchmark for Moonlight. By studying the practices and interventions in place at Long Run, Moonlight can formulate targeted strategies to reduce its pollutant loads.

Slope Management: The steeper slopes of Long Run can be seen as an advantage. They demonstrate that with appropriate land management and erosion control measures, it's possible to maintain excellent water quality even in terrains that are naturally predisposed to faster runoff.

In conclusion, while no two watersheds are identical, the similarities between Long Run and Moonlight Drive, coupled with the lessons gleaned from their differences, make Long Run an ideal reference. Its attributes offer a vision of what Moonlight Drive can achieve and a roadmap to guide its restoration journey.

Target Water Quality Goals for Moonlight Drive

The disparities in water quality between Moonlight Drive and Long Run provide a clear directive for the targets Moonlight should aspire to achieve. By leveraging the insights from Long Run, we can set ambitious yet feasible water quality goals for Moonlight. Deriving data from the ModelMyWatershed platform, below is a summary comparison of the average annual pollutant loads from 30-years of daily fluxes between the Moonlight and Long Run watershed. The full water quality data for both watersheds is provided immediately following this summary.

Sediment Reduction

Moonlight Drive currently has a sediment loading rate of 372.07 lb/ac, significantly higher than Long Run's 272.3 lb/ac. This stark contrast underscores the urgent need to address sediment issues in Moonlight

Objective: Reduce the sediment load to approach Long Run's levels, aiming for a significant reduction over the next 5-10 years. Emphasizing practices that minimize soil erosion and enhance sediment capture will be pivotal.

Nutrient Management

Nitrogen: Moonlight's current loading rate for total nitrogen is 2.53 lb/ac, is significantly larger than that of Long Run's 2.09 lb/ac.

Objective: Work towards matching the nitrogen loading rates of Long Run by promoting practices that reduce nitrogen inputs and enhance nitrogen uptake in the watershed.

Phosphorus: With a phosphorus loading rate of 0.44 lb/ac in Moonlight compared to Long Run's 0.37 lb/ac, there's evident room for improvement.

Objective: Aim to approximate Long Run's phosphorus levels by mitigating sources of phosphorus and optimizing its natural cycling in the ecosystem.

Land Use Adjustments

A closer examination of Long Run reveals the intrinsic benefits of maintaining a balanced land use pattern. For Moonlight, this implies exploring avenues to enhance natural cover and regulate land practices that contribute heavily to sediment and nutrient loads. Strategic land use planning will be essential in moving towards the desired water quality targets.

Stream Health and Rehabilitation

While numerical targets for stream health are set later in the report, it's worth noting that the integrity of stream channels, riparian zones, and aquatic habitats plays a significant role in determining water quality. Efforts to restore and maintain these ecological assets will be central to achieving the outlined sediment and nutrient goals.

Continuous Monitoring and Adaptive Management

To ensure the efficacy of our efforts, a rigorous monitoring framework will be established. This will not only track progress but also offer insights to refine and adapt strategies to the evolving needs of the Moonlight Drive watershed.

Average Annual Pollutant Loads, Moonlight

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	617,192.2	4,196.3	724.9
Loading Rates (lb/ac)	372.07	2.53	0.44
Mean Annual Concentration (mg/L)	121.89	0.83	0.14
Mean Low-Flow Concentration (mg/L)	1,027.49	5.42	1.35

Mean Flow: 81,107,465 (ft^3/year) and 2.57 (ft^3/s)

Average Annual Pollutant Loads, Long Run

Sources	Sediment	Total Nitrogen	Total Phosphorus
Total Loads (lb)	459,969.5	3,530.0	618.6
Loading Rates (lb/ac)	272.30	2.09	0.37
Mean Annual Concentration (mg/L)	87.04	0.67	0.12
Mean Low-Flow Concentration (mg/L)	856.86	4.33	1.25

Mean Flow: 84,653,246 (ft^3/year) and 2.68 (ft^3/s)

Average Annual Pollutant Loads per Land Cover Source

Moonlight Subwatershed

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	103,555.6	303.4	103.0
Cropland	405,826.2	1,544.3	417.0
Wooded Areas	2,382.7	46.5	4.2
Wetlands	0.0	0.0	0.0
Open Land	48,563.7	225.3	45.0
Barren Areas	38.2	5.5	0.2
Low-Density Mixed	791.0	21.6	2.3
Medium-Density Mixed	3,563.5	76.1	7.8
High-Density Mixed	1,422.0	30.4	3.1
Low-Density Open Space	1,130.1	30.8	3.2
Farm Animals	0.0	293.1	70.3
Stream Bank Erosion	49,919.3	33.1	11.0
Subsurface Flow	0.0	1,422.8	57.7
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	163.4	0.0

Long Run Subwatershed

Sources	Sediment (lb)	Total Nitrogen (lb)	Total Phosphorus (lb)
Hay/Pasture	85,792.2	246.8	94.8
Cropland	337,994.2	1,206.4	366.5
Wooded Areas	1,805.9	48.0	4.0
Wetlands	0.0	0.0	0.0
Open Land	9,899.7	70.2	10.3
Barren Areas	0.5	0.2	0.0
Low-Density Mixed	184.8	4.6	0.5
Medium-Density Mixed	315.6	6.2	0.6
High-Density Mixed	74.3	1.5	0.1
Low-Density Open Space	645.8	16.2	1.7
Farm Animals	0.0	293.2	70.3
Stream Bank Erosion	23,256.6	13.2	4.4
Subsurface Flow	0.0	1,609.2	65.3
Point Sources	0.0	0.0	0.0
Septic Systems	0.0	14.2	0.0