Watershed Implementation Plan for Lower Middle Creek, Snyder County

Prepared by Susquehanna University, Snyder County Conservation District, and Chesapeake Conservancy

Contents

Acknowledgments

The Susquehanna University Freshwater Research Institute (FRI) would like to extend our sincere gratitude to our partners for their valued input to this 319 Watershed Implementation Plan for Middle Creek. Project partners include the Chesapeake Conservancy; Snyder County Conservation District; Susquehanna University; Herbert, Rowland & Grubic, Inc.; and Lancaster Farmland Trust. We would also like to thank the landowners in priority watersheds for their willingness to discuss restoration opportunities on their property. The planning and implementation of this project were made possible by the PA Department of Environmental Protection and US Environmental Protection Agency.

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Acronyms Listing

BMP	Best Management Practice
CAP	Countywide Action Plan
CAST	Chesapeake Assessment Scenario Tool
CBF	The Chesapeake Bay Foundation
COVID-19	Coronavirus Disease 2019
CWF	Cold Water Fishery
DEP	PA Department of Environmental Protection
DCNR	PA Department of Conservation & Natural Resources
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
EV	Exceptional Value Waters
GIS	Geographic Information System
HUC	Hydrologic Unit Code
HQ	High Quality Waters
IBI	Indicator of Biological Integrity
NHD	The National Hydrography Dataset
NRCS	Natural Resources Conservation Service
PA	Pennsylvania
PADEP	Pennsylvania Department of Environmental Protection
TMDL	Total Maximum Daily Load
USDA	The United States Department of Agriculture
USDA ARS	The Agricultural Research Services of the USDA
WIP	Watershed Implementation Plan

Appendices

Appendix 1: Watershed soils.

Appendix 2: BMPs, load reductions, and associated cost estimates.

Appendix 3: Quality Assurance Project Plan (QAPP) for lower Middle Creek watershed implementation.

Executive Summary

This Section 319 Watershed Implementation Plan for the Middle Creek-Penns Creek subwatershed was created in response to the stream's impairment from agricultural activities. This watershed is a HUC-12 tributary to the Susquehanna River (HUC 020503010305) and is located entirely in Snyder County, Pennsylvania. The watershed is within the larger Susquehanna River and Chesapeake Bay watersheds. For clarity in presenting this plan to the general public, it will be referred to as the lower Middle Creek watershed hereafter.

Through discussions between partner organizations and the use of the Chesapeake Conservancy's tools for parcel prioritization, the priority subwatersheds identified for restoration are contained within the Susquehecka watershed, a tributary to Middle Creek. A Total Maximum Daily Load (TMDL) was established by the Pennsylvania Department of Environmental Protection (DEP) in June 2021 with a target maximum load of 2,880,995 pounds of sediment per year, a 12% reduction from the current loading rate. As a result of this TMDL and priority restoration locations, **319 funds will only be used in the Susquehecka Creek watershed**.

This project was led by a diverse team of lower Middle Creek watershed conservation groups and an educational institution with feedback from community members and farmers. To address the impairment of lower Middle Creek and promote a healthier watershed and community, we established these three goals to guide this plan so that priority areas in the lower Middle Creek watershed can be the focal point of restoration efforts, promoting healthier streams and the eventual de-listing of streams that have moved from an impaired status to an attaining status:

- **A decrease in pollutants (sediment, nitrogen, and phosphorus) in streams to match healthy levels in lower Middle Creek and meet sediment goals for the Susquehecka TMDL**.
- **Restore aquatic and riparian habitats in degraded areas for the benefit of water quality, wildlife, and people.**
- **Engage local partners and landowners to foster stewardship of the lower Middle Creek watershed.**

The implementation plan for the lower Middle Creek watershed was guided by our analyses of the watershed as well as community knowledge and interests. Combined, these information sources fed into a parcel prioritization process that is both pragmatic and focused on locations with the highest opportunity for improvement. In order to maintain a recommended 10% safety margin, the goals for Susquehecka Creek as a whole include a 22% decrease in sediment loading to the stream.

This plan sets a realistic timeline to reach our goals using thoughtful solutions to complete outreach and implementation for the lower Middle Creek watershed. Our success will be tracked by the number of BMPs implemented and through stream monitoring efforts to identify and track BMP success using biological, physical, and chemical data. The totality of these efforts is intended to lead to stream attainment and delisting for critical subwatersheds as well as supporting long-term local stewardship of the lower Middle Creek watershed.

Introduction

Project Process

Snyder County Conservation District and the Freshwater Research Institute at Susquehanna University received funding from DEP to create a Section 319 Watershed Management Plan for lower Middle Creek and began working on the project in January 2021. The Freshwater Research Institute (FRI) is a collaborative of scientists, educators, conservationists, and restoration practitioners. Located adjacent to Susquehanna's campus at the 87-acre Center for Environmental Education and Research, the FRI is easily accessible to our undergraduate students. Our objectives are to provide a supportive and student-centered experience that equips Susquehanna University undergraduates with the skills, knowledge, and professional networks to achieve their personal career goals in the research, conservation, and restoration of near- and in-stream habitats. The FRI also strives to serve as a model for innovation and collective impact from a university-community collaborative effort to address challenges in conservation and restoration. To support these objectives, working with the Snyder County Conservation District to develop a restoration plan has heavily involved the support and work of student interns throughout the process. Susquehanna students have been instrumental in the organization and collection of historical information and data, identification of possible BMPs for implementation, map creation, and working on the ground with restoration partners to understand the feasibility of their recommendations.

Project partners involved in the development of this watershed management plan include:

- Susquehanna University
- Snyder County Conservation District
- Chesapeake Conservancy
- Herbert, Rowland & Grubic, Inc.
- Lancaster Farmland Trust

The role of Susquehanna University was to serve as the project coordinator and facilitator, watershed analyst, and plan writer. Project partners came together to identify concerns, voice community values, form project goals, and determine the best restoration strategies. Susquehanna University plan writers met with Snyder County Conservation District; Chesapeake Conservancy; and Herbert, Rowland & Grubic, Inc. staff routinely throughout the creation of this plan to discuss specifics of the watershed and goals for the rapid de-listing and outreach strategies. Chesapeake Conservancy assisted with parcel prioritization and Geographic Information Systems (GIS) mapping.

Clean Water Act

The Clean Water Act (33 U.S.C. §1251 et seq. (1972)) regulates pollutant discharges into United States navigable waterways. It was established to provide for the protection of these waters and the aquatic life within them. Section 303(d) requires states to assess protected uses of surface water. The results of these assessments are labeled as attaining, impaired, or unassessed. Attaining waterways meet the designated use, while impaired waterways have failed to meet a metric required for their designated use.

In accordance with Section 303(d), impaired waters are listed on the state's 303(d) list. They are reported to the United States Environmental Protection Agency (EPA) every other year. A TMDL is created for impaired streams, setting a limit on the amount of pollution allowed into the waterway without interfering with the intended use. Best management practices are employed to maintain or reach state water quality standards.

Sediment Impairment

The lower Middle Creek watershed has 42.0 miles of impaired streams (Category 5, but without a TMDL; 2018 DEP Integrated Water Quality Report). Category five watersheds are waters impaired for one or more uses by a pollutant and require the development of a TMDL. All 42 miles of impairment are the result of siltation, with agriculture as the leading cause. Of these, 2.47 miles are impaired by grazing-related agricultural siltation, 2.22 miles from organic enrichment from animal feeding, and 2.22 miles from residential trash runoff. Of these 42.0 miles, nearly half (20.4 miles) are contained within the Susquehecka watershed where a TMDL was developed in June 2021.

Erosion is a naturally occurring process and is important for aquatic life as it provides substrate for plants and animals in streams. For example, fish require substrate in which to deposit their eggs, but for many local species, including game fish such as smallmouth bass and trout, sediments introduced by erosion are often too fine and unsuitable for the survival of eggs (Castro and Reckendorf 1995). Nutrients are also naturally occurring and essential for aquatic plant growth and aquatic food web integrity, but when artificially concentrated due to human activity, they exacerbate algal growth and are considered pollutants (EPA 2021). Algal blooms caused by nutrient pollution can lower dissolved oxygen (DO), putting aquatic organisms at risk of suffocation, or produce toxins that can make people sick when consumed through water or seafood (EPA 2021). The consequences of long-term sediment and nutrient pollution have harmed the downstream Chesapeake Bay ecosystem by smothering benthic organisms with sediment, lowering dissolved oxygen, and even causing dead zones after algal blooms die off (CBF 2021).

Activities that increase sediment and nutrients in stream systems can include livestock grazing, destruction of riparian buffers, and placing crop fields and lawns next to streams. Streambank destabilization exacerbates this issue when riparian buffers are partially or entirely removed. Because of their porous nature and high infiltration rates, the central bands of limestone and karst features in the lower Middle Creek watershed increase the risk of nutrient overloading as they make sections of lower Middle Creek more prone to accumulating nutrients from far beyond the stream channel. Particularly within Susquehecka Creek, much of the town of Freeburg sits on this limestone band, such that infiltration of nutrients, primarily nitrates, into groundwater is an important issue for its residents. Pollution in drinking water can put residents at risk of health problems (Swistock 2015).

Addressing excess sediment loading requires an approach that accounts for all aspects of the landscape and the watershed. This can be achieved by strategically implementing BMPs including decreasing tillage, increasing soil cover, grazing management, and perennial plantings. Restored riparian buffers, along with stream crossings and fences, can help reduce sediment input from runoff and from erosion due to streambank destabilization. These buffers also provide biotic benefits in the form of shade, biodiversity, food sources, and habitat.

BMPs have already been implemented in lower Middle Creek to keep erosion and nutrient runoff from increasing significantly. However, additional measures, especially the restoration of riparian buffers, the use of no-till agriculture, and the addition of manure-handling systems need to be implemented to combat streambank destabilization and nutrient runoff. To promote a healthier lower Middle Creek watershed, we must prioritize the watershed regions most in need of sediment and nutrient control measures. By working closely with landowners, we will be able to access their knowledge of the area and inspire ownership of the change needed to restore lower Middle Creek.

Project Goals

The team of project partners collectively developed project goals as a part of our implementation plan for the lower Middle Creek watershed. The core goals are:

- **A decrease in pollutants (sediment, nitrogen, and phosphorus) in streams to match healthy levels in lower Middle Creek and meet sediment goals for the Susquehecka TMDL**. We plan to focus on cost-efficient, low-maintenance BMPs that will reduce sediment toward TMDL targets while also benefiting decreases in nitrogen and phosphorus in the watershed.
- **Restore aquatic and riparian habitats in degraded areas for the benefit of water quality, wildlife, and people.** By focusing on BMPs that will create and foster healthy riparian habitat, we can promote a healthy aquatic community. Decreases in sediment loads will allow benthic macroinvertebrate communities to recover. Fish and other stream organisms will respond to healthy benthic macroinvertebrate communities (i.e., food), improved water quality, and riparian buffer restoration. Finally, the downstream Chesapeake Bay ecosystem will benefit from the mitigation of pollution.

- **Engage local partners and landowners to foster stewardship of the lower Middle Creek watershed.** We plan to work with the community through education and outreach programs, which will ensure that our efforts last generations and benefit local farms, families, and communities.

Watershed Characterization

Watershed Context

The lower Middle Creek watershed is located in Snyder County, Pennsylvania and is a tributary of the Susquehanna River. It is a 4th Order stream that flows into Penns Creek before joining the Susquehanna River. The watershed is contained within the Chesapeake Bay watershed, which is more than 64,000 square miles in size (CBP 2020; Figure 1).

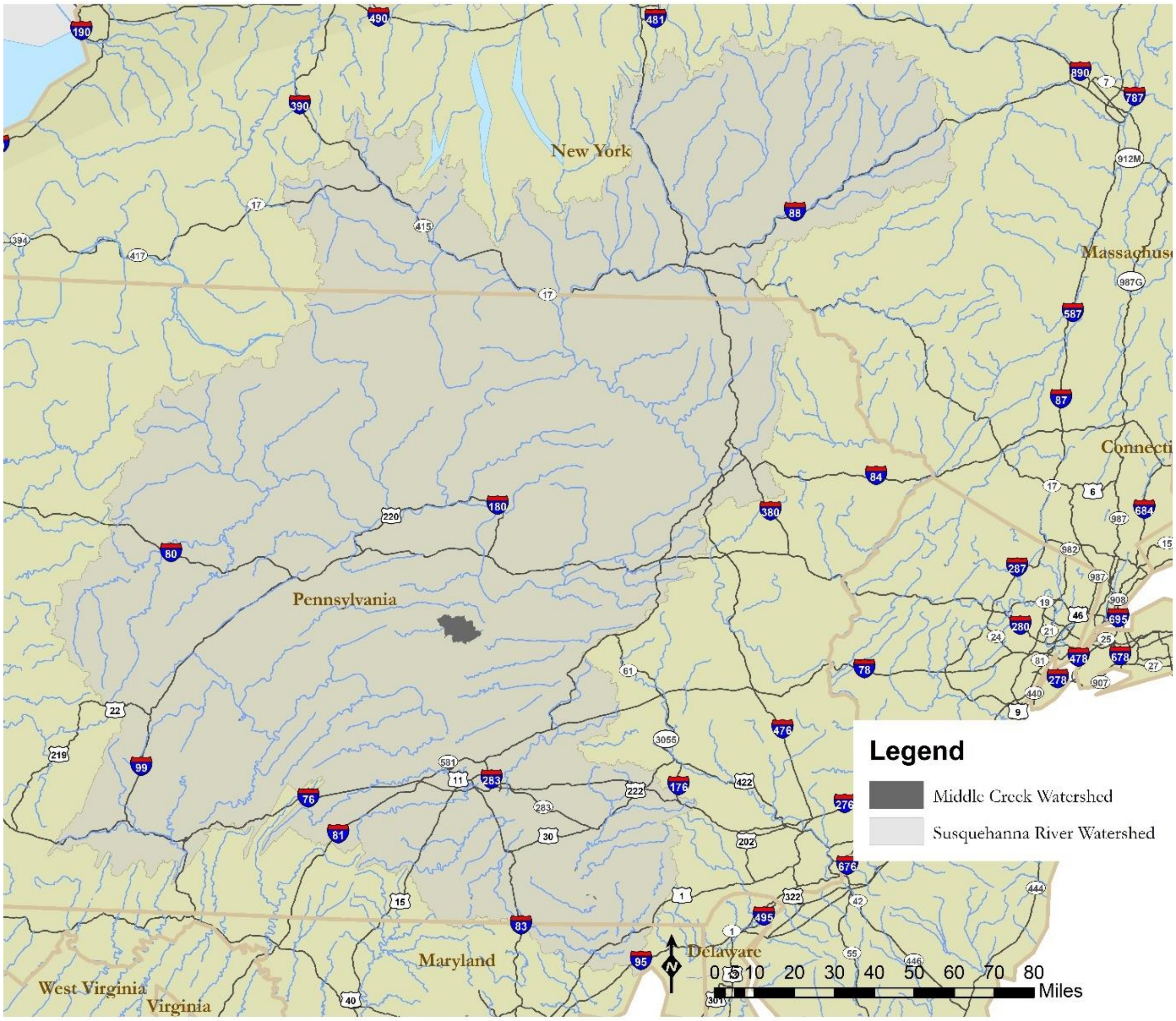


Figure 1: Geography of lower Middle Creek within the broader Chesapeake watershed.

Each watershed in the United States is divided and classified using unique Hydrologic Unit Codes (HUCs). HUC units signify region, subregion, accounting unit, and cataloging units, allowing each stream to be individually identified (USGS 2021). The lower Middle Creek watershed (HUC 02050301) is situated in Region 02 Mid-Atlantic and Subregion Susquehanna. It is cataloged as Susquehanna-Penns with an area of 1430 square miles (USGS 2021). The lower Middle Creek watershed spans 45.67 square miles across parts of Center, Middle Creek, Penn, Washington, and Union Townships as well as Middleburg and Freeburg Boroughs before entering the Susquehanna River. The mouth of Middle Creek (02050301) is located at latitude 40.775463, longitude -76.867458 and sits at 450 feet above sea level (USGS 2021).

Watershed Background

The lower Middle Creek watershed is situated entirely within Snyder County and contains one state game land, State Game Land Number 212. The main roads through the watershed run primarily east west (US 522 and SR 35), connected north south by SR 104 between Middleburg and Mt. Pleasant Mills. More than 90 percent of the landscape was forested when colonists first arrived in the mid-Atlantic in the 1700s. By the mid-1800s, most of the region's trees had been cut down to clear land for cities, towns, and farms or to provide lumber. Once dominated by pine, hemlock, and chestnut forests, the forests regenerated into the second-growth mixed deciduous and evergreen forests present today (DEP 2012). In 1910, Snyder County had 1,845 farms with an average size of 82 acres; and by 1973, the number of farms had decreased to 860 while the average size increased to 130 acres (Housley 1976).

The area was once the home of the Susquehannock people (or the Sas-k-we-an-og; those who live in a place where water is heard grating on the shore), a distinct tribe who spoke an Iroquoian language and were known as the river people because they lived in harmony and balance with the river and land. In the 1680s the territory that is now Snyder County was controlled by the Iroquois Confederacy. The Confederacy included the Kanien'kehá:ka (Mohawks), Onundagaonogas, (Onondaga), Odǫhwęja:deˀ (Cayuga), OnΛyote'a·ká (Oneidas) and the Onöndowa'ga (Senecas). In 1723, the first sizable group of French pioneers began to settle in the Snyder County region. The settlers first attempted to smooth relations through negotiations and treaties, but the French were unsatisfied and ultimately declared war in 1754. The French and Indian War led to genocide of the Susquehannock people by the French and their allies (Housley 1976).

Climate and Weather

The lower Middle Creek watershed has a humid continental climate due to the humid conditions of the East Coast mixing with the dry conditions of the Midwest. This climate is characterized by cold winters with temperatures typically below 0ºC and frequent rainfall (UC Davis 2021). Snyder County averages snowfall of about 30 inches per year, and the lower Middle Creek watershed experiences an average of 42-47 inches of precipitation every year

(DEP 2012). This is greater than the United States average (38 inches of rain per year). The growing season tends to last 140 days between the last spring frost, May 2nd on average, and the first fall frost on October 9th.

Climate change is contributing to changing conditions in the county, directly affecting the lower Middle Creek watershed as well as the Chesapeake Bay as a whole. Weather is now more extreme with more variable winters and longer, hotter growing seasons. There has also been increased precipitation, including a 27% increase in the northeast U.S. since 1901 (IPCC 2019). In conjunction, these climate effects have caused shifts in migration and wildlife habitat, increased flooding, more droughts, and crop damage (IPCC 2019). In addition, an added stressor is that rainfall is becoming more concentrated in heavy storm events that result in higher rates of runoff as well as flashier (higher and faster) peaks in streamflow. Together, these high-energy runoff events result in increased opportunities for erosion and destabilization of stream channels due to the higher force and frequency of flooding events.

Geology

The lower Middle Creek watershed is located entirely within the Ridge and Valley Physiographic Province. The area is primarily composed of sandstone, limestone bedrock, and erosion-susceptible shale soils (Figures 2a and 2b). The most prominent structural features in the watershed are the Montour anticline, Northumberland syncline, the Selinsgrove anticline, and the Shamokin syncline, leading to the characteristic ridge (anticline) and valley (syncline) topography. Additionally, there are noteworthy karst features. Karst features such as sinkholes, sinking streams, caves, and springs are formed as percolating water dissolves the soluble bedrock when traveling through crevices, cracks, joints, and fractures, creating wider cavities and conduits underground (NPS 2021). This makes groundwater more vulnerable to contamination as the soluble bedrock-like limestone dissolves and the sandstone cracks or fractures (2020 Snyder County Watershed Implementation Planning Toolbox). Specifically, the area is more vulnerable to nitrate contamination of groundwater because the geology under the soil makes it easier for nitrogen to enter groundwater and provides less opportunity for its removal to occur naturally. Nitrogen entering streams in Snyder County is estimated to come primarily from agricultural sources (74%), followed by naturally occurring sources (12%) and developed/urban areas (11%) while most phosphorus and sediment in local streams comes from overland runoff or streambank erosion during rain events (2020 Snyder County Watershed Implementation Planning Toolbox).

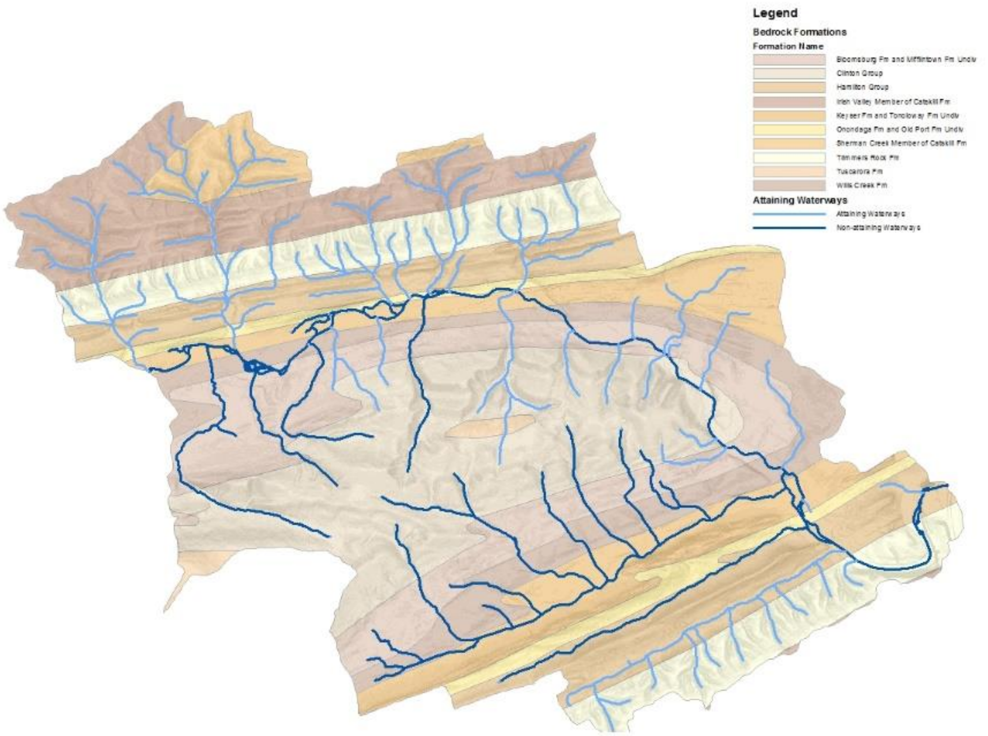


Figure 2a. Bedrock geological formations in the lower Middle Creek watershed.

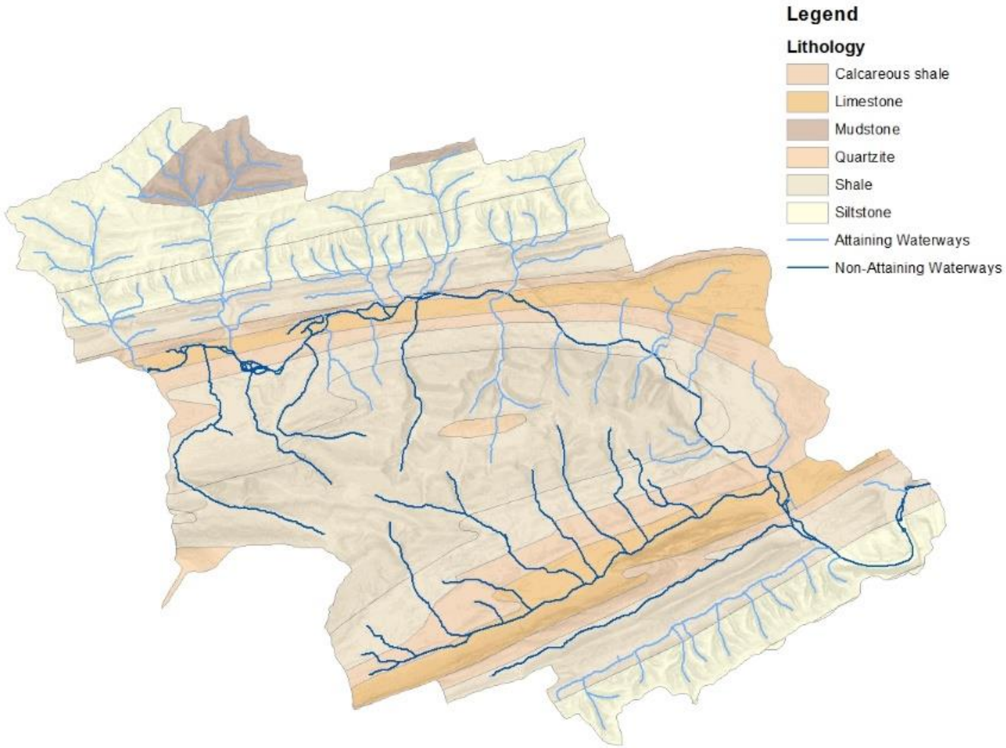


Figure 2b. Bedrock lithology in the lower Middle Creek watershed.

Soils

About 53% of soil in the county is well-drained and is primarily located in steep sloping areas with shallow and moderately deep bedrock. The soils of the lower Middle Creek watershed are largely non-carbonate and carbonate, glacial till, and alluvial (Pennsylvania Natural Heritage Program 2007). The watershed is primarily defined by loamy and silty soils and classified as B and C hydrological soil groups, meaning that they have a slow to moderate infiltration rate when thoroughly wet, allowing more erosion of sediment and other contaminants (NRCS 2019). This makes erosion a top priority in restoration of the lower Middle Creek watershed. A detailed soil characterization for the watershed can be found in Appendix 1, matching Figure 3.

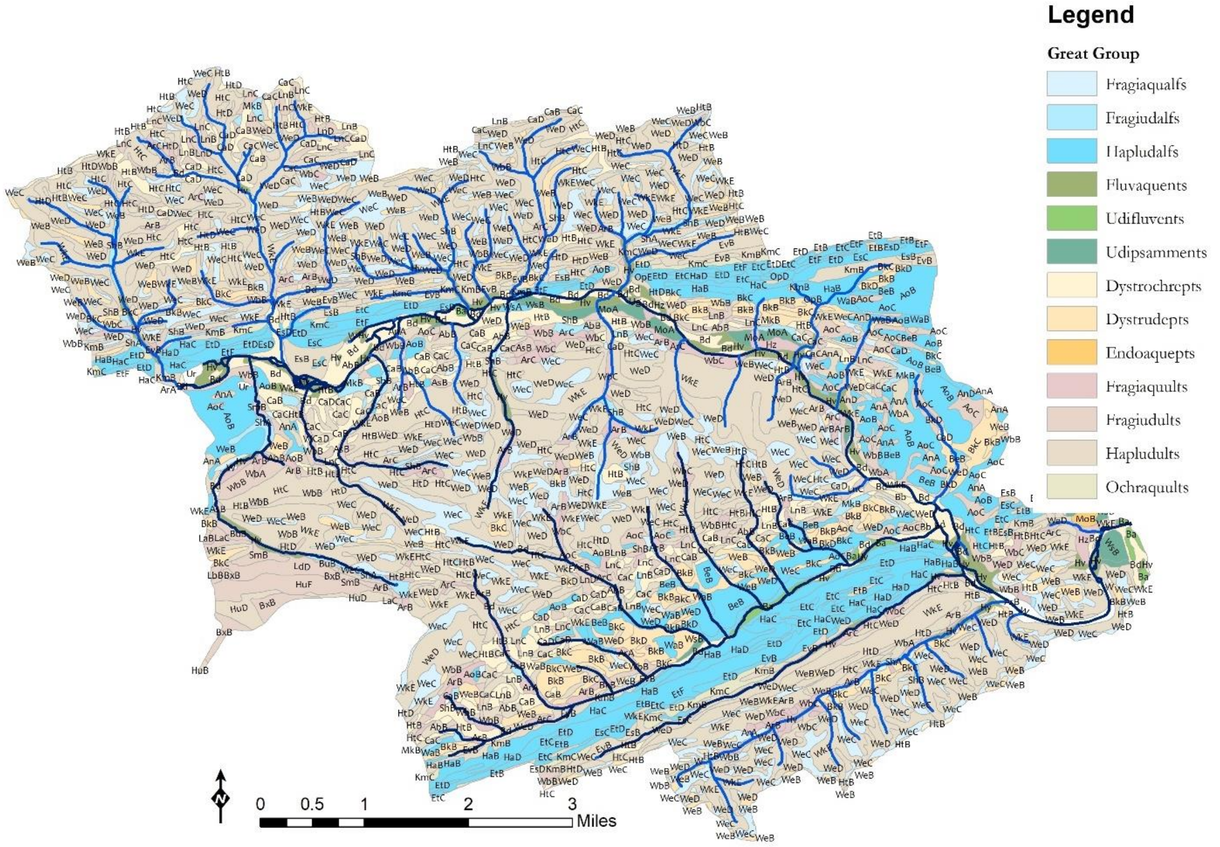


Figure 3: Soil groups in the lower Middle Creek watershed.

Topography and Slope

The topography of the lower Middle Creek watershed is characterized by higher elevations surrounding the tributaries that flow into lower Middle Creek and gradual slopes of 5-25% throughout 61% of the watershed. Lower Middle Creek itself is low gradient with slopes of 5% or less over 16% of the watershed (Figure 4). Steep slopes of about 25% correlate with the

Onondaga and Old Port formations as well as the Hamilton Group and account for a large portion of the watershed. Twenty-one percent of the watershed has a slope greater than 25%. The overall steep slope in the watershed means that the likelihood of erosion is high, leading more opportunity for uncontrolled runoff.

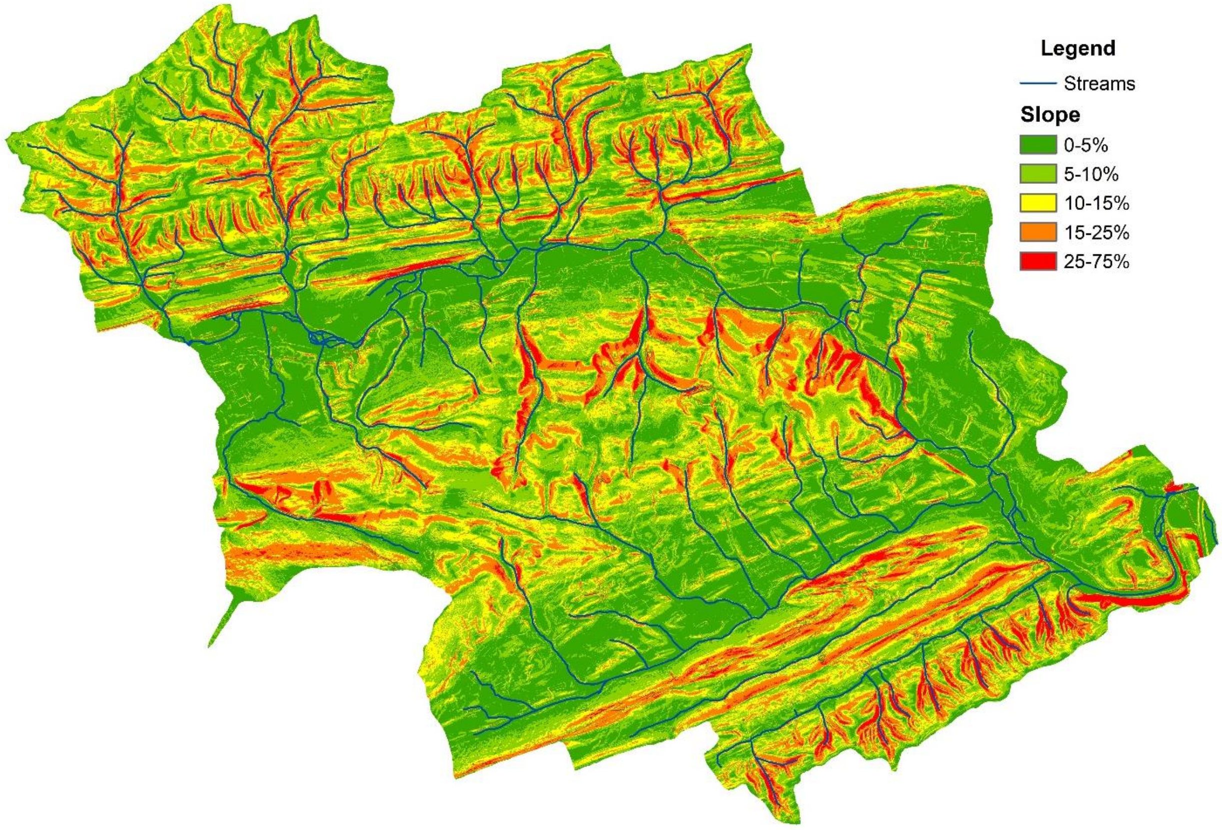


Figure 4: Slopes binned by gradient ranges for the lower Middle Creek watershed.

Hydrology and Aquatic Biota

Many smaller tributaries in the lower Middle Creek watershed are classified as Atlantic coldwater fisheries with a community that includes non-game fish such as slimy sculpin, white suckers, pearl dace, and blacknose dace as well as invasive fathead minnows, golden shiners, and brown trout in some reaches (Pennsylvania Natural Heritage Program 2007; Table 1). The high-quality streams that provide suitable habitat for these fish, especially trout, are cold and relatively small and swift with ridged slopes. They often contain sandstone and have a low buffering capacity. Within the lower Middle Creek watershed there are 73 miles of streams, but only 6.5

miles of naturally reproducing trout streams and 0.3 miles of stocked trout stream (PFBC 2021). All 6.5 miles of naturally reproducing trout waters are contained within the Susquehecka watershed.

Trout reproduction is an important indicator of high water quality. Native brook trout (*Salvelinus fontinalis*) and invasive brown trout (*Salmo trutta*) are the most common trout species in the area, though rainbow trout (*Oncorhynchus mykiss*) are also present. Hatchery brown and rainbow trout are stocked in lower Middle Creek streams. Trout naturally reproduce in only a select number of streams in the southern part of the lower Middle Creek watershed (Figure 5). Trout are important to aquatic ecosystems as predators in the food chain and water quality indicators because they are not tolerant of high water temperatures or high nutrient and sediment loads.

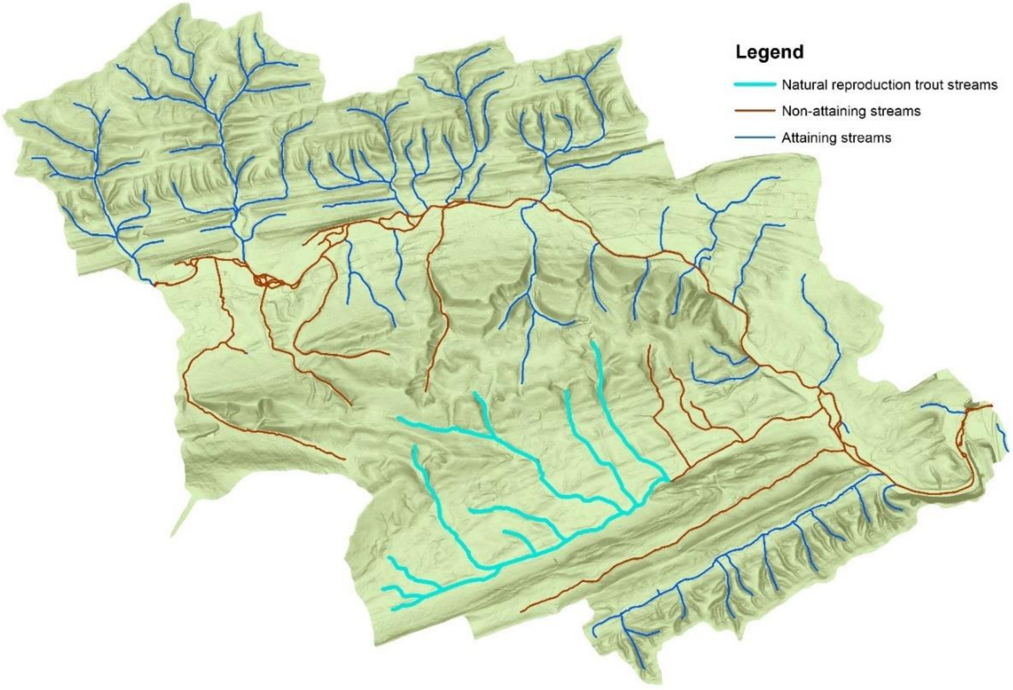


Figure 5: Natural reproduction trout streams in lower Middle Creek.

The mainstem of lower Middle Creek is also classified as a warmwater community consisting of gamefish such as smallmouth and largemouth bass, chain pickerel, and nongame fish such as stonerollers, hogsuckers, chubs, dace, minnows, sculpin, madtoms, shiners, darters, sunfish, bass, and carp (Pennsylvania Natural Heritage Program 2007; Figure 6 and Table 1).

To assess water quality attainment in streams, an Index of Biotic Integrity (IBI) score is often used and typically based on the taxa present in an aquatic macroinvertebrate community. Each taxon (genus or family of invertebrates) has specific water quality needs and/or tolerances that are used to develop pollution tolerance values and, in conjunction with their feeding and movement groups, these features as a whole contribute to the IBI score of a site. The IBI score that determines attainment is also influenced by the underlying geology, i.e., whether the stream is limestone or freestone. Much of the lower Middle Creek watershed is "limestone influenced" meaning that scores for attainment are more challenging to identify as Pennsylvania IBIs are based largely on freestone stream systems and are cautiously applied to limestone streams by requiring higher scores for attainment. With this understanding and knowledge, we will work closely with DEP during the monitoring process to ensure samples are collected and data analyzed in a meaningful way to appropriately assess attainment relative to state standards.

Figure 6: Male creek chub (*Semotilus atromaculatus*) with breeding colors and tubercles for fighting other males.

Table 1: Common coldwater and warmwater species in the lower Middle Creek watershed. Asterisks (*) denote game species and a plus sign (+) denotes invasive species.

Coldwater species	**Warmwater species**
Brook trout (*Salvelinus fontinalis*)*	Rock bass (*Ambloplites rupestris*)
Brown trout (*Salmo trutta*)* +	Smallmouth bass (*Micropterus dolomieu*)* +
Rainbow trout (*Oncorhynchus mykiss*)* +	Largemouth bass (*Micropterus salmoides*)*+
Pearl dace (*Marariscus margarita*)	Chain pickerel (*Esox niger*)*
Blacknose dace (*Rhinichthys atratulus*)	American eel (*Anguilla rostrata*)*
Longnose dace (*Rhinichthys cataractae*)	Hogsucker *(Hypentellium nigricans*)
White sucker (*Cato-stomus commersoni*)	Creek chub (*Semotilus atromaculatus*)
Mottled sculpin (*Cottus bairdii*)	Minnows (e.g., *Exoglossum maxingua*)
Slimy sculpin (*Cottus cognatus*)	Margined madtom (*Noturus insignis*)
Fathead minnow (*Pimephales promelas*)+	Redbreast sunfish (*Lepomis auritus*)
Golden shiner (*Notemi-onus crysoleucas*) +	Pumpkinseed sunfish (*Leponis gibbosus*)
	Green sunfish (*Leponis cyanellus*)+
	Stoneroller (*Campostoma anomalum*)
	Fantail darter (*Etheostoma fabellare,*)
	Greenside darter (*Etheostoma blenniodes*)
	Tessellated darter (*Etheostoma olmstedi*)
	Shield darter (*Percina peltate*)
	Common carp (*Cyprinus carpio*)

Ecology and Terrestrial Biota

The lower Middle Creek watershed includes multiple critical environments and their unique ecologies. In particular, vernal pools, which can be found in the wooded headwater areas of Middle Creek and its tributaries, are essential for amphibians, especially vernal pool obligates like wood frogs (*Rana sylvatica*; Figure 7a) and three species of salamander (Jefferson *Ambystoma jeffersonianum*, marbled *A. opacum*, and spotted *A. maculatum*; Figure 7b), and for other amphibians that are not vernal pool obligates but are frequent visitors. These ephemeral pools areas are also important for wetland plants such as woolgrass, three-way sedge, and Northeastern bulrush (Pennsylvania Natural Heritage Program 2007).

Oak (*Quercus*) and hickory (*Carya*) are the dominant trees in the watershed. American chestnut (*Castanea dentata*) was previously common, however the chestnut blight caused by the fungus *Cryphonectria parasitica* has drastically reduced the population. Mammals across the watershed include muskrat, beaver, mink, white-tailed deer, Virginia opossum, eastern chipmunk, and several bat species. Wetland birds include waterfowl, shorebirds, rails, sparrows, osprey, bald eagle, broad-winged hawk, great blue herons, and great egrets. Common aquatic amphibian and reptiles in the watershed include salamanders, frogs, toads, turtles, and snakes such as the northern black racer, black rat snake, and northern water snake (Pennsylvania Natural Heritage Program 2007; Tables 2, 3, and 4 below).

Figure 7a: Wood frog (*Rana sylvatica*) and **7b:** Spotted salamander (*A. maculatum*).

Terrestrial habitats in the lower Middle Creek watershed have largely been disturbed through fragmentation, when humans create “biological islands” of forests surrounded by agriculture or developed land. Biological communities within these islands are also threatened by soil and water degradation from developments, residences, roads, buildings, mining, and other industry due to runoff. Roads in developed regions contribute to wildlife mortality, habitat fragmentation and loss, alteration of chemical environment, disrupted wildlife dispersal, and the spread of exotic/invasive species (Pennsylvania Natural Heritage Program 2007). Populations can be dramatically affected by human presence, so restoration efforts must find a balance between human activities and ecosystem needs and focus on reconnecting habitat fragments.

Table 2: Wetland bird species found in the lower Middle Creek watershed.

Common Name	**Scientific Name**
Great blue heron	*Ardea herodias*
Red-winged blackbird	*Agelaius phoeniceus*
Great egret	*Ardea alba*
Red-shouldered hawk	*Buteo lineatus*
Osprey	*Pandion haliaetus*
Bald eagle	*Haliaeetus leucocephalus*
Song sparrow	*Melospiza melodia*
Swamp sparrow	*Melospiza georgiana*
Virginia rail	*Rallus limicola*
Marsh wren	*Cistothorus palustris*
American bittern	*Botaurus lentiginosus*

Table 3: Wetland and other common mammals found in the lower Middle Creek watershed.

Common Name	**Scientific Name**
Muskrat	*Ondatra zibethicus*
Beaver	*Castor canadensis*
Mink	*Neogale vison*
White-tailed deer	*Odocoileus virginianus*
Virginia opossum	*Didelphis virginiana*
Eastern chipmunk	*Tamias striatus*
Little brown bat	*Myotis lucifugus*
Big brown bat	*Eptesicus fuscus*

Table 4: Reptiles and amphibians found in the lower Middle Creek watershed.

Common Name	**Scientific Name**
Bull frog	*Rana catesbeiana*
Green frog	*Rana clamitans*
Red-backed salamander	*Plethodon cinereus*
Slimy salamander	*Plethodon glutinosis*
Northern dusky salamander	*Desmognathus fuscus*
Northern two-lined salamander	*Eurycea bislineata*
Northern red salamander	*Pseudotriton ruber*
Long-tailed salamander	*Eurycea longicauda*
Northern spring salamander	*Gyrinophilus porphyriticus*
Wood frog	*Rana sylvatica*
Jefferson salamander	*Ambystoma jeffersonianum*
Marbled salamander	*Ambystoma opacus*
Spotted salamander	*Ambystoma maculatum*
Four-toed salamander	*Hemidactylium scutatum*
Red-spotted newt	*Notopthalmus viridescens*
American toad	*Bufo americanus*
Spring peeper	*Pseudacris crucifer*
Grey tree frog	*Hyla versicolor*
Painted turtle	*Chrysemys picta*
Snapping turtle	*Chelydra serpentina*
Eastern box turtle	*Terrapene Carolina*
Map turtle	*Graptemys geographica*
Wood turtle	*Glyptemys insculpta*
Eastern garter snake	*Thamnophis sirtalis*
Northern water snake	*Nerodia sipedon*
Black rat snake	*Elaphe allegheniensis*
Northern black racer	*Coluber constrictor*
Red-bellied snake	*Storeria occipitomaculata*
Northern brown snake	*Storeria dekayi*
Ring-necked snake	*Diadophis punctatus*
Timber rattlesnake	*Crotalus horridus*
Northern copperhead	*Agkistrodon contortrix*

Land Use

The predominant land cover types for Snyder County are forest (55% of the watershed) followed by agriculture (33%) and developed land (12%; Snyder County Watershed Planning Toolbox 2020; Figure 8). Agriculture and development are located primarily in the central and southern half of the county, meaning that they are also closest to lower Middle Creek and the Susquehanna River. Forested areas are most connected in the north and through the center of the watershed south of Middleburg, with patches scattered throughout the agricultural areas. Approximately 45% of land use in the lower Middle Creek watershed is associated with agricultural activities (26% pasture/hay and 19% cultivated crops; Model My Watershed 2021).

Figure 8: Land cover across the lower Middle Creek watershed.

Eighty-two percent of the lower Middle Creek watershed has a slope greater than 5%, which results in a high probability of erosion. Heavy agricultural use in the area combined with steep slopes makes sediment and nutrient runoff much more likely. Nitrogen, one of the primary nutrients responsible for watershed pollution, enters waterways from agriculture in the form of manure, especially from poultry and swine (Snyder County Toolbox 2020). When excess sediments and nutrients are carried into the stream via runoff, they can cause increased turbidity and artificially high nutrient availability, which can smother benthic organisms and cause harmful algal blooms downstream.

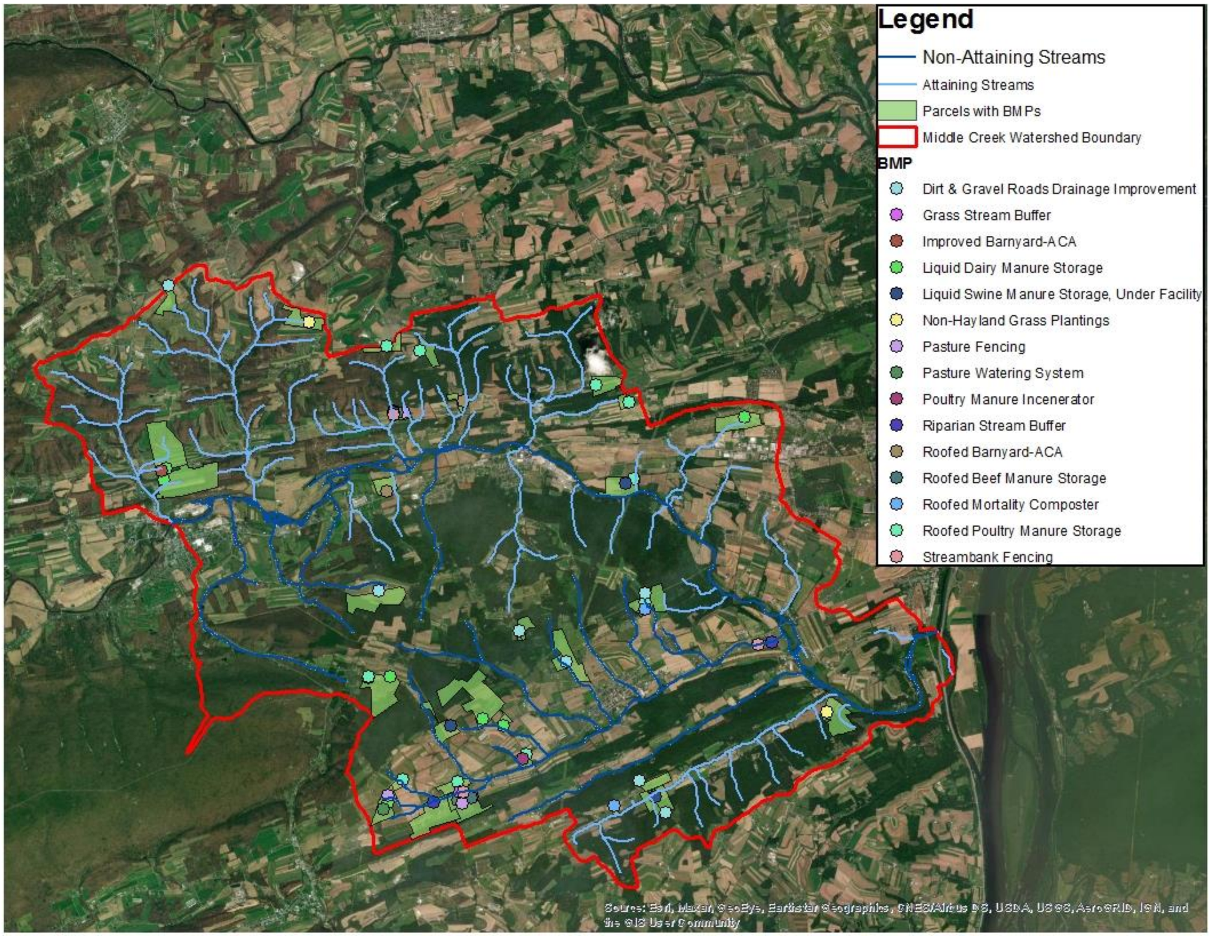
We used 1-meter resolution land cover data developed by the Chesapeake Conservancy to determine how land in the lower Middle Creek watershed is used by the community (CIC and UVM SAL 2021). While these data include 16 distinct land use classes, only the 12 classes listed below are present in the lower Middle Creek watershed (Table 5).

Table 5: Watershed coverage by land cover type according to Chesapeake Conservancy 1-meter resolution data.

Land cover class	Acreage	Percent of watershed
Tree canopy	14600	49.8%
Low vegetation	13200	45.1%
Other paved surface	454	1.6%
Roads	356	1.2%
Structures	252	0.9%
Scrub-Shrub	130	0.4%
Water	112	0.4%
Tree canopy over roads	78.9	0.3%
Barren	54.8	0.2%
Tree canopy over other paved	49.5	0.2%
Tree canopy over structures	18.3	<0.1%
Wetlands (emergent)	1.73	<0.1%

Existing Best Management Practices

Some progress has already been made in the lower Middle Creek watershed, where several BMPs are in place (Table 6). Many existing BMPs are for manure handling, which is important given the agricultural and livestock-raising presence in the area (Figure 9). The manure handling process can involve decomposing organic material in the presence of oxygen, also known as composting, which reduces nitrogen in waste. Manure handling can also involve mechanical separation of manure liquids and solids to stabilize the waste, creating compost. This compost benefits farmers more than untreated manure because it can be used on fields as fertilizer.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 9: BMPs implemented prior to the creation of this plan. Streams not attaining are highlighted in dark blue, while streams that do attain for all uses are highlighted in light blue.

Fences and riparian buffers are both used to prevent livestock from disturbing streambanks, eroding soils, and depositing nutrients in their waste each time they enter and exit the stream. Riparian buffers provide many services to stream ecosystems, such as the uptake and filtration of nutrients, anchoring of banks, and provision of habitat and food to benthic macroinvertebrates and fish. Riparian forest buffers can also be strategically planted to provide production value to the landowner in the form of native fruit- and nut-bearing plants in multifunctional buffers. A demonstration multifunctional buffer has been planted on Susquehanna University's campus and will be used to document methods and benefits as it develops. The addition of fencing and livestock exclusion from the riparian zone can have dramatic effects even over short time periods. Regrowth and bank stabilization is already visible within two years of a fencing project on the lower portion of Susquehecka Creek.

Figure 10: Before (2018) and after (2020) installation of fencing, crossing, and buffer planting at upstream end of Weaver Martin farm, Susquehecka Creek.

Figure 11: Before (2018) and after (2020) installation of fencing, crossing, and buffer planting at downstream end of Weaver Martin farm, Susquehecka Creek.

Dirt and gravel roads, which can lead to sediment and gravel entering waterways during storm events, are also common in the area and will benefit from BMPs designed to keep their sediments and gravel in place (Culpeper 2019). These BMPs can include placing subsurface drains of rock or geotextile fabric under a road to allow water to filter, the strategic use of road shaping, and ditches to direct or disperse runoff (Culpeper 2019).

Water storage facilities, which are structural BMPs used to retain water and prevent runoff, also make up a large fraction of the existing BMPs. Additional BMPs that would further our goals of reducing sediment, nitrogen, and phosphorus loads in priority areas include the implementation of riparian buffers and fitting more livestock-raising operations with pasture or streambank fencing.

Table 6: BMPs established in the watershed prior to the creation of this plan, compiled from Snyder County Conservation District data.

BMP Type	Amount
Wildland food plots	45.5 acres
Established riparian forest buffer protected	6.50 acres
Protection - road, concrete, curbing	0.27 acres
Protection - reinforced stone	0.18 acres
Waste storage facility	30,000 square feet
Pasture fencing	37800 linear feet
Water pipeline	8080 linear feet
Streambank fencing	2600 linear feet
Watering trough facility	22 units
Road improvement	7 units
Poultry manure composter	2 units
Poultry manure incinerator	1 unit

Watershed Analysis

Methods

The selection of priority landowners and parcels for outreach and restoration often results from a cost-benefit analysis of total nutrient and sediment reductions combined with the quantity and complexity of BMPs required to achieve those load reductions. In identifying priority sub-watersheds for restoration, we chose to also be intentional about the landscape surrounding a parcel, upslope area draining toward locations identified for BMP implementation, and integrate local knowledge of the landowner landscape into the selection process. Through this pragmatic approach and the Chesapeake Conservancy's rapid stream de-listing strategy we were able to identify sub-watersheds where multiple willing landowners and high return-on-investment opportunities exist. This integrated approach to co-developing a model of prioritization with local partners also increases the likelihood of collaborative work continuing forward over the life of the plan.

Prioritization Process

The rapid stream de-listing strategy by Chesapeake Conservancy includes a combination of hard science modeling of spatial data mixed with local conservation needs and partner priorities that would not otherwise be captured in the site selection process. The first step in this process was to develop a goal statement for prioritization across partners in the county: "The Snyder County community is focused on improving water quality through implementing cost-effective and low-maintenance projects to benefit local farm operations, families, and communities."

With this focus in mind, we collaboratively developed a scoring rubric to determine the importance of available data sets. Specific parcel scores were generated based on a combination of the "designation score" and "site score". The designation score is created from landscape-scale information on stream impairments, stream order, proximity to protected lands, and proximity to completed projects. The site score is based on a combination of riparian buffer gaps and upslope drainage areas, and the final prioritization score for a parcel is the total of these two groups. Point values for these two groups are outlined in Tables 7 and 8.

Table 7: Designation scoring rubric for parcel prioritization.

Metric	Point designations
Location relative to impaired streams. Yes/No and source	Yes, Ag-impaired= 250 Yes, Other-impaired = 100 No, not impaired but on a stream =50 Upstream of ag-impaired= 150 Upstream of other-impaired=50 No stream = 0
Nutrient and sediment loading: At HUC12 level to compare watersheds for nitrogen, phosphorous, and sediment Points sorted into 5 categories based on percentiles or natural breaks	N:(high to low loading) = 100-80-60-40-20 P:(high to low loading) = 50-40-30-20-10 Sed:(high to low loading) = 50-40-30-20-10
Stream order: Higher points in lower order to prioritize headwaters	1st Order = 100 2nd Order = 80 3rd Order = 60 4th Order = 40 5th Order = 20
Proximity to preserved lands	On preserved land = 50 Adjacent = 25 Not on or adjacent = 0
Proximity to completed projects	On or adjacent = 50 Within 0.5 miles = 25 Within 1 mile = 10 Not on or near = 0
Groundwater Vulnerability: To consider karst formations and issues with nitrate contamination	On or adjacent = 100 Within 0.25 miles = 50 Not on or near = 0

Within the lower Middle Creek watershed, each parcel of land was scored using a combination of the parcel designation score (Table 7) and site score developed by the Chesapeake Conservancy (Table 8). The designation score includes presence or absence and impairment level of the parcel's stream segment; whether the parcel is upstream of an impaired stream; the percentile of nitrogen, phosphorus, and sediment loading; stream order; proximity to preserved lands; proximity to completed projects; and whether a parcel's stream segment is on or near vulnerable groundwater. The site score includes the area that drains to Riparian Opportunity Areas (ROAs), or areas that would benefit from restoring or planting riparian buffers calculated via satellite imagery (Conservation Innovation Center, 2019), on each parcel; the area of agriculture, impervious surfaces, and turf in the drainage area; the length of stream in each parcel; the distance between any barnyards and the nearest stream; whether the barnyard is within area that drains to an ROA; and whether a chicken barn is present in the parcel.

From these parcel-specific scores across the watershed, we overlayed sub-basin polygons to identify small drainage areas for with the highest scores across multiple nearby parcels, indicating an opportunity for improvement across the entire sub-watershed.

Table 8: Site-specific scoring rubric for parcel prioritization.

Metric	Point designation and multiplier
Drainage area to ROAs (in acres)	Acreage multiplied by 0.09
Total area of agriculture, impervious, and turf (AIT) in drainage areas (in acres)	Acreage multiplied by 0.75
Ratio of AIT to ROAs	Multiplied by 0.5
Stream length on parcel	Multiplied by 40
Distance between barnyard and nearest stream	<150 feet = 150 150-250 feet = 100 250-350 feet = 50 >350 feet = 10 No barnyard = 0
Is barnyard within ROA?	Yes = 100 No = 0
Are chicken barns present?	Yes = 50 No = 0

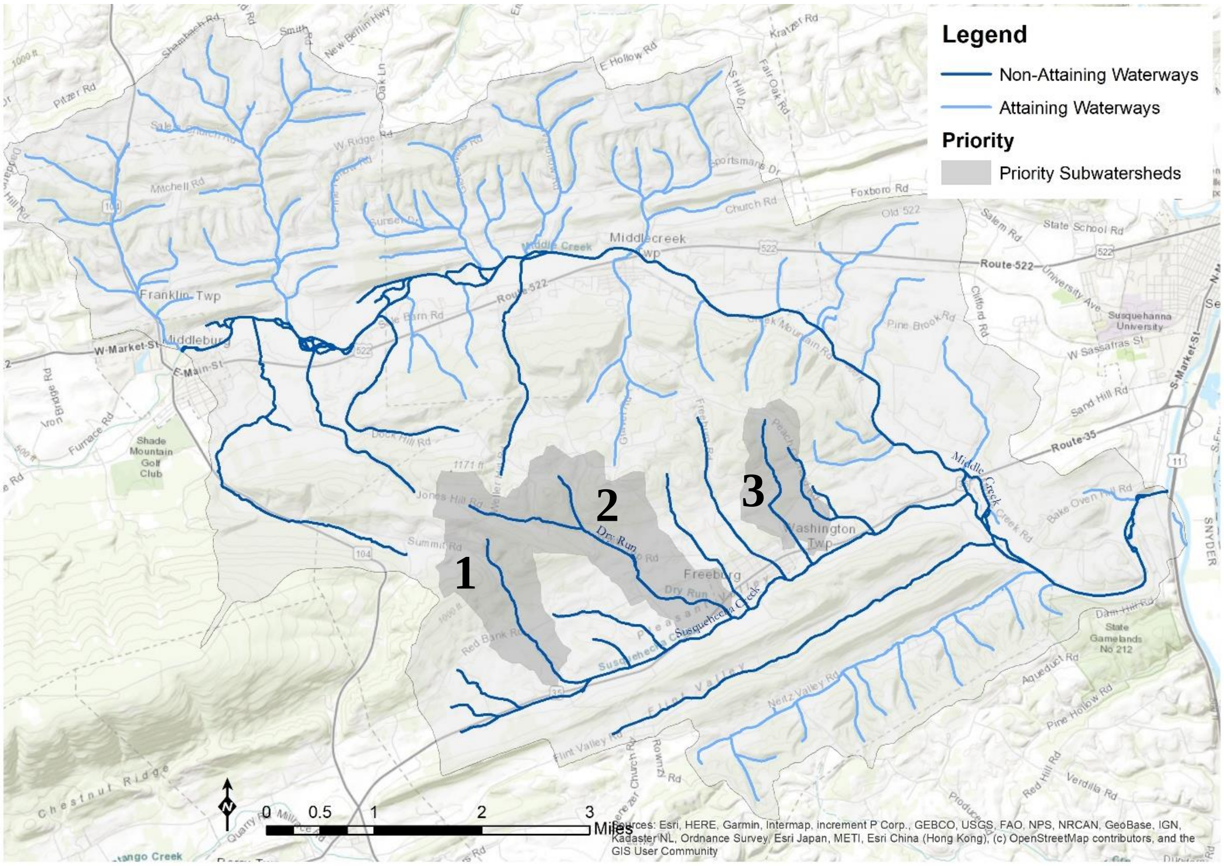
Base Data

The geographic, geological, and hydrological information used in our analyses were primarily derived from publicly-available GIS datasets. We also used the prioritization map pioneered by the Conservation Innovation Center at Chesapeake Conservancy to understand current land use in the watershed and to classify opportunities for riparian restoration and BMP implementation.

The locations and types of current BMPs were established from conservation records and ground-truthed via site visits when possible. Data on completed BMPs (Figure 9) were used jointly with Chesapeake Conservancy's prioritization map and prioritization scores to determine the parcels where future restoration or BMP implementation will have the greatest impact.

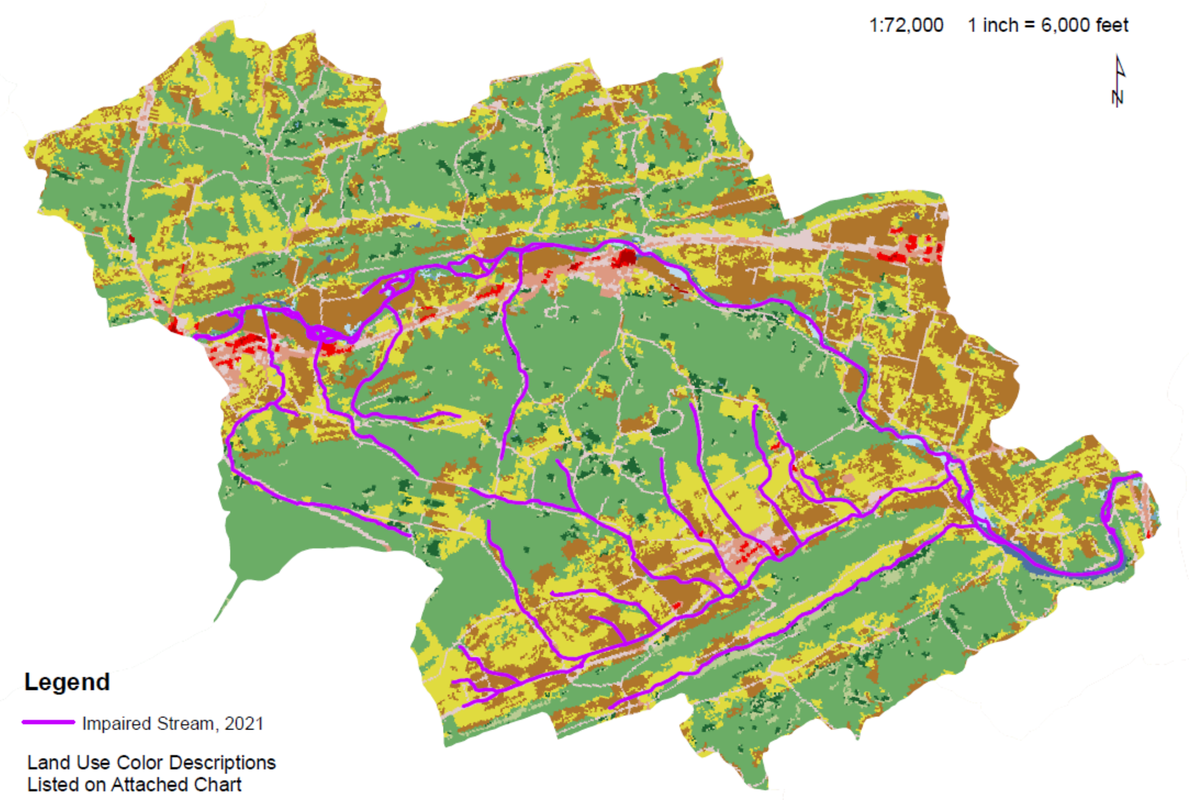
Current sediment and nutrient yields

Through this prioritization process, all sub-watersheds identified for immediate restoration work are contained within the Susquehecka Creek watershed (Figure 12). In the TMDL for Susquehecka Creek current average annual loading of sediment is estimated to be 3,289,958 pounds; and in order to meet water quality objectives with a margin for safety this should be reduced to 2,551,999 pounds per year. A similar reduction for the 99th percentile of daily loading is estimated, decreasing from the current estimate of 129,766 pounds/day to 101,669 pounds/day to be within the margin of safety (DEP 2021). The three priority sub-watersheds we have selected cover 29.3% percent of the Susquehecka Creek watershed (Tables 9-11).



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Figure 12: Priority sub-watersheds for restoration and rapid de-listing. (1) Susquehecka-Freeburg, Peach Orchard Road, (2) Dry Run, Freeburg and (3) Susquehecka- Freeburg, Peach Orchard Road.



Land Use information from USGS 2007 spacial information.

Figure 13: Land use conditions contributing to non-attaining impairment status of streams within the Lower Middle Creek subwatershed. Impairment status of non-attaining streams are solely impaired by various agricultural sources as explained in table 9.

Table 9: According the 2022 DEP Integrated Streams Report, the following segments located in Snyder County and within the three priority subwatersheds for rapid stream de-listing, were assessed and listed as impaired in 2012 for their aquatic life designated use of cold water fishes.

ATTAINS ID:	ATTAINS Name:	Length (miles):	Impairment Source:	Impairment Cause:	Impairment Cause Context:
PA-SCR-54968285	Unnamed Tributary to Susquehecka Creek-54968285	0.01491291	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968671	Unnamed Tributary to Susquehecka Creek-54968671	0.49585421	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968065	Unnamed Tributary to Susquehecka Creek-54968065	0.45795057	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967923	Unnamed Tributary to Susquehecka Creek-54967923	1.08304999	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967629	Susquehecka Creek-54967629	0.19821741	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967631	Dry Run-54967631	1.0028931	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967237	Unnamed Tributary to Dry Run-54967237	0.55550585	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966599	Unnamed Tributary to Susquehecka Creek-54966599	0.53375785	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966315	Unnamed Tributary to Susquehecka Creek-54966315	0.07891414	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967329	Unnamed Tributary to Dry Run-54967329	0.0086992	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968293	Unnamed Tributary to Susquehecka Creek-54968293	0.02299073	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967847	Unnamed Tributary to Susquehecka Creek-54967847	0.00621371	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967523	Dry Run-54967523	0.12800247	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966137	Unnamed Tributary to Susquehecka Creek-54966137	0.00621371	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966329	Unnamed Tributary to Susquehecka Creek-54966329	0.01615565	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966639	Unnamed Tributary to Susquehecka Creek-54966639	0.00932057	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967171	Susquehecka Creek-54967171	0.66113895	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-54967919	Unnamed Tributary to Susquehecka Creek-54967919	0.81026803	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966857	Unnamed Tributary to Susquehecka Creek-54966857	0.94137736	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966961	Unnamed Tributary to Susquehecka Creek-54966961	0.02112662	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968277	Susquehecka Creek-54968277	0.10936133	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968567	Susquehecka Creek-54968567	0.61018651	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968569	Unnamed Tributary to Susquehecka Creek-54968569	0.75745148	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967173	Unnamed Tributary to Susquehecka Creek-54967173	0.41507596	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968261	Unnamed Tributary to Susquehecka Creek-54968261	1.02526247	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968063	Susquehecka Creek-54968063	0.37779369	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967263	Unnamed Tributary to Susquehecka Creek-54967263	1.04328223	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967921	Susquehecka Creek-54967921	0.69282888	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967281	Dry Run-54967281	1.0979629	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966609	Unnamed Tributary to Susquehecka Creek-54966609	0.01491291	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967561	Susquehecka Creek-54967561	0.50144655	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-54966885	Susquehecka Creek-54966885	1.0028931	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-54967563	Unnamed Tributary to Susquehecka Creek-54967563	0.55799133	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967253	Unnamed Tributary to Susquehecka Creek-54967253	1.00475722	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967531	Dry Run-54967531	0.02112662	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966889	Unnamed Tributary to Susquehecka Creek-54966889	0.68723654	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966809	Unnamed Tributary to Susquehecka Creek-54966809	0.3753082	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968651	Susquehecka Creek-54968651	0.23052871	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966949	Unnamed Tributary to Susquehecka Creek-54966949	0.57725384	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967269	Susquehecka Creek-54967269	0.29266583	GRAZING IN RIPARIAN OR SHORELINE ZONES	SILTATION	SEDIMENT
PA-SCR-54967841	Unnamed Tributary to Susquehecka Creek-54967841	0.0279617	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968209	Susquehecka Creek-54968209	0.37655094	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967435	Unnamed Tributary to Dry Run-54967435	0.10190488	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967437	Dry Run-54967437	0.62385668	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54968813	Susquehecka Creek-54968813	0.38525014	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54966887	Unnamed Tributary to Susquehecka Creek-54966887	0.41134773	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-54967855	Unnamed Tributary to Susquehecka Creek-54967855	0.07021495	AGRICULTURE	SILTATION	SEDIMENT

Table 10: Estimated MMW loading from the headwaters of Dry Run (upstream of Short Road).

Land cover type	**% Cover**	**Acres**	**Nitrogen (lb/yr)**	**Phosphorus (lb/yr)**	**Sediment (lb/yr)**
Developed, open space	7.2	64.2	50.1	12.2	49010.0
Developed, low intensity	0.8	7.4	5.8	1.4	5655.0
Deciduous forest	57.6	518.5	165.9	31.1	113163.1
Evergreen forest	3.7	32.1	10.3	1.9	7005.3
Mixed forest	1.2	9.9	3.2	0.6	2155.5
Shrub/Scrub	1.6	14.8	4.7	0.9	3233.2
Pasture/Hay	22.2	200.0	1310.0	410.0	71258.0
Cultivated crops	5.6	51.9	644.5	165.9	72800.5
Totals	**100**	**898.8**	**2194.5**	**624.0**	**324280.6**

Table 11: Estimated MMW loading from the headwaters of Susquehecka Creek (north branch, upstream of Red Bank Road).

Land cover type	**% Cover**	**Acres**	**Nitrogen (lb/yr)**	**Phosphorus (lb/yr)**	**Sediment (lb/yr)**
Developed, open space	3.9	17.3	13.5	3.3	13190.7
Developed, low intensity	0.8	3.3	2.6	0.6	2536.7
Deciduous forest	70.5	311.2	99.6	18.7	67924.1
Evergreen forest	0.4	1.6	0.5	0.1	338.4
Mixed forest	0.05	0.2	0.1	0.01	48.3
Shrub/Scrub	0	-	-	-	-
Pasture/Hay	21.2	93.7	613.7	192.1	33385.0
Cultivated crops	3.1	13.5	168.0	43.2	18971.7
Totals	**100**	**441.3**	**899.0**	**258.3**	**137355.8**

Table 12: Estimated MMW loading from the selected unnamed tributary to Susquehecka Creek (stream mouth at: 40.764452° North, 76.929868° West).

Land cover type	% Cover	Acres	Nitrogen (lb/yr)	Phosphorus (lb/yr)	Sediment (lb/yr)
Developed, open space	5.3	21.3	16.6	4.0	16234.7
Developed, low intensity	1.8	7.3	5.7	1.4	5580.7
Deciduous forest	30.7	123.8	39.6	7.4	27024.6
Evergreen forest	0	-	-	-	-
Mixed forest	0.7	2.9	0.9	0.2	628.5
Shrub/Scrub	0	-	-	-	-
Pasture/Hay	49.1	197.8	1295.7	405.5	70479.2
Cultivated crops	12.3	49.4	614.0	158.1	69355.5
Totals	**100**	**403.2**	**1974.2**	**577.1**	**191026.0**

Stream Monitoring

Understanding the current conditions of the lower Middle Creek watershed was important in the development of this plan. Macroinvertebrate samples were collected in lower Middle Creek between 2004 and 2014 and used to calculate IBI scores at select sites in the watershed (Figure 13). By conducting new monitoring efforts, we will determine how the BMPs implemented as a result of this plan influence water quality and biological communities in the watershed.

It is probable that a delayed response for macroinvertebrate populations to rebound will occur following BMP implementation. As a result, sediment loads will be measured to track increase in pebble/cobble size after significant deposits of fine sediments have been flushed from the streambeds.

Continuous monitoring of stream habitat, pollutant loads, water quality, and aquatic communities will be necessary to understand changes in watershed health throughout plan implementation. Hydrological modeling can be used to predict changes in nitrogen, phosphorus, and sediment loading after BMPs are implemented, but monitoring in-stream conditions throughout the project will be extremely important because aquatic life requires time to respond to stream improvements. There is not a currently-established monitoring program in lower Middle Creek, and monitoring efforts may benefit from partnerships between Susquehanna University and other local conservation and research institutions. If able to secure such partnerships and sufficient funding, we could perform yearly water quality, habitat structure analyses, macroinvertebrate collections, and fish surveys to monitor project success (see the Quality Assurance Project Plan in Appendix 3 for more detail of specific methods).

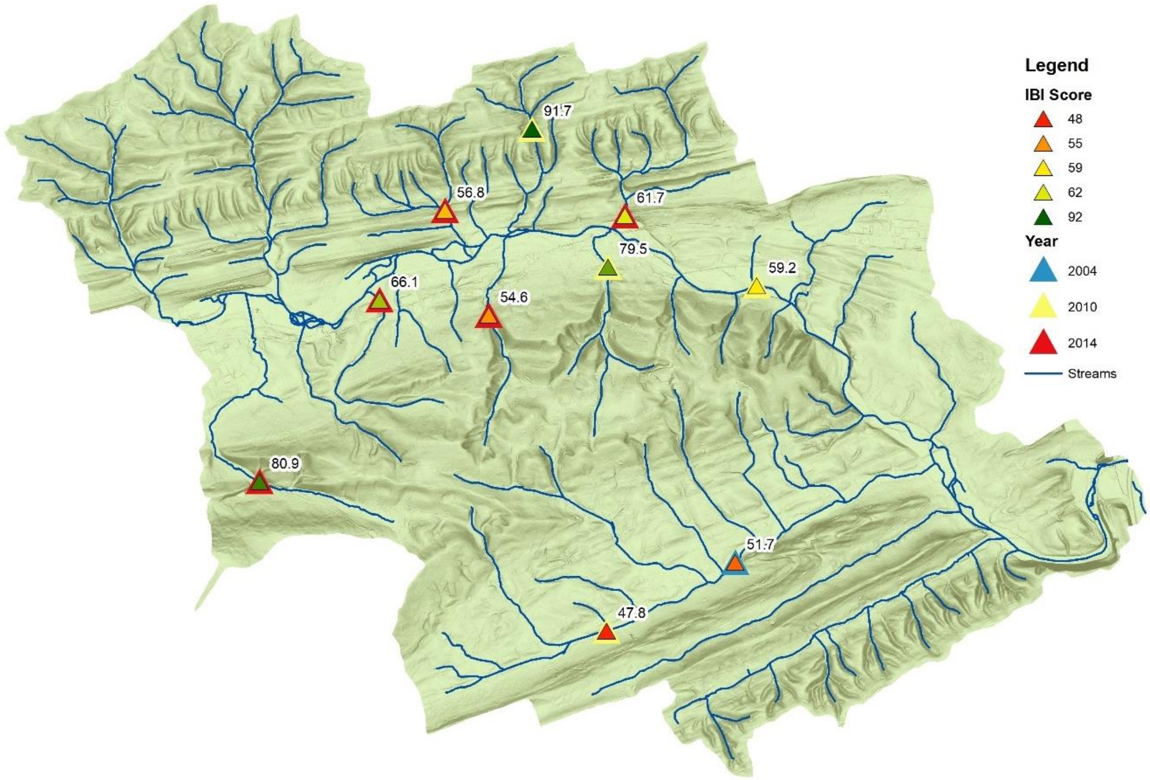


Figure 14: DEP sampling locations and IBI scores by site. The outer triangle indicates the year of sampling and inner triangle indicates IBI score.

Sampling and Evaluating BMPs

Monitoring physical habitat, sedimentation (as a measure of erosion), and biological communities will be integral in assessing the success of restoration and BMPs implemented on lower Middle Creek. This plan includes input and assistance from the lower Middle Creek community as well as other groups and individuals with an interest in local conservation, who will be informed with data and about the watershed via educational and/or outreach events. To measure the effect of BMPs installed on nutrient and sediment loading in the watershed, samples of surface water and benthic sediment will be collected for chemical analysis according to standard methods, beginning in the summer prior to BMP implementation, one year after implementation, and additional future time points as funding permits.

Sampling will be completed regularly to evaluate how instream, riparian, and upslope BMPs for restoration affect stream health. Data from each sampling will be scanned and stored on cloud-based storage with the originals kept at Susquehanna University's Freshwater Research Institute and will be processed to evaluate changes in stream health after implementation of BMPs.

The IBI data collected by DEP in 2004, 2010, and 2014 will also help us understand long-term trends in the lower Middle Creek watershed (Table 12). IBI data were collected at 11 sites throughout the watershed (Figure 13). Seven of the sites had IBI scores of less than 63, indicating that they are impaired for aquatic life. At the conclusion of phase three, the target IBI scores for each of the priority subwatersheds sampling sites within the Susquehecka Creek, would be 63 or greater. Using DEP's IBI data from 2004 and 2014, and to air on the side of caution, it is presumed that current IBI scores for each priority subwatershed will increase from 45 to 63 or greater after the completion of phase 3 implementation. To achieve a score of 63 or greater, targeted IBI scores will need to increase by a minimum of 6 per phase. Proposed interim IBI scores listed per subwatershed, per phase, has been included in table 17

Table 12: IBI scores, richness, and diversity in lower Middle Creek samples collected by DEP.

Metric	Site 1	Site 2	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11
Year	2004	2010	2010	2010	2014	2014	2014	2014	2014	2010
Total Taxa Richness	21	28	21	24	24	33	14	25	26	24
Richness of Intolerant EPT (0-4)	7	16	5	7	10	13	7	10	11	13
% Sensitive Ind. (0-3)	39.8	80.2	17.5	32.3	61.2	58.6	48.5	33.1	19.9	85.9
Shannon Diversity	2.21	2.76	2.50	2.56	2.25	2.78	1.65	2.51	2.03	2.09
IBI Score	51.7	91.7	47.8	59.2	66.1	80.9	54.6	61.7	56.8	79.5

Riparian Buffer Opportunities

Riparian forest buffers are plantings of trees, shrubs, and grasses along a waterway. Restored riparian buffers can be among the most effective and cost-efficient BMPs for reducing pollutants. We used the Chesapeake Conservancy Conservation Innovation Center's prioritization data to determine the areas that would benefit most from BMPs, and where riparian buffer restoration would be most effective. Chesapeake Conservancy's high-resolution land cover and 35-foot flowpath data can be used to determine where intact riparian areas are not present along enhanced flow paths (models flowpaths smaller than and including those in the National Hydrography Dataset). Parcels with more than 0.4 acres of ROA were included in Chesapeake Conservancy's prioritization analysis, so ROAs were automatically factored into our analysis of priority subwatersheds. We augmented the analysis of riparian buffer opportunities included in the parcel prioritization with information from the Snyder County Conservation District regarding landowner willingness to discuss or potentially implement BMPs such as restored riparian buffers. Our priority subwatersheds are those with the most amenable landowners whose parcels are ranked as priority by the Chesapeake Conservancy.

BMP Build-Out Analysis

One of the largest challenges in stream restoration is quantifying project success over time. Overall efficiency will be determined using multivariate redundancy analysis of relationships between individual or grouped BMPs and sediment characteristics or biotic communities. However, overall effectiveness in only one way to measure success and select BMPs for implementation. Cost plays a significant role in this decision process (see Appendix 2 for costs associated with BMPs for Snyder County where data are available; Chesapeake Bay Foundation 2020) and will be considered to maximize return on investment.

To consider water quality benefits, we calculated the total reduction of sediment and nutrients depending on a presence or absence of specific BMPs (Table 13) within the Susquehecka watershed (Table 14). To be consistent with the existing TMDL models, we used Model My Watershed for this analysis. Cost estimates are drawn from available data in the Chesapeake Assessment Scenario Tool (CAST). Based on these analyses, cover crops, conservation tillage, and riparian buffer plantings will be the most cost effective BMPs. *If implemented on a watershed-wide scale, each practice individually has the ability to reduce sediment loading to well within the TMDL goals.*

Table 13: Descriptions of the main BMP types considered in this plan to decrease loading of sediment, nitrogen, phosphorus, and improve aquatic habitat.

BMP Type	Definition/Function
Cover crops	Annuals planted to cover soil and reduce soil erosion between plantings of harvested crops.
No-till agriculture	A seeding method for crops or pasture that does not disturb the soil.
Conservation tillage	A seeding method that reduces erosion by leaving 30% or more of debris from harvested crops on the fields.
Reduced tillage	A seeding method that reduces erosion by leaving 15-30% of debris from harvested crops on the fields.
Nutrient management	The strategic application of fertilizers, manure, amendments, and organic by-products as a source of plant nutrients.
Waste management	Systems that sequester runoff and/or wastes to break down organics at agricultural operations with livestock.
Riparian buffer	Streamside trees, shrubs, and grasses that minimize bank erosion, channelization, and runoff of nutrients and sediments.
Streambank fencing	Fencing that prevents livestock from damaging bank integrity and riparian plants and decreases sediment and organic waste movement in the stream.
Streambank stabilization	Rip-rap, gabion walls, or engineered plantings intended to protect streambanks and reduce bank erosion during heavy flow events.

Table 14: Total sediment and nutrient reduction estimates (in pounds) from implementation across the Susquehecka watershed at 100% implementation with estimated costs calculated per unit and as a watershed-wide total. Waste and nutrient management will be site-specific and are difficult to generalize. Costs are based on CBF 2020 estimates and Chesapeake Conservancy recent projects in surrounding counties, and do not include any maintenance post-implementation. These BMPs will be installed using 319 funding sources.

BMP	**Cost/unit (acre, linear feet, or square feet)**	**Total cost**	**Sediment**	**Nitrogen**	**Phosphorous**
Cover crops	$79.27	$377,365	1,979,913	9,676	3,625
No-till	$21.62	$102,922	1,697,068	2,669	1,595
Nutrient management	Variable	NA	0	53,713	3,496
Waste management	$30-40	$600,000-800,000	0	43,897	13,693
Riparian buffer	$5,000	$5,950,000	2,119,938	1,729	506
Streambank fencing	$3-5	$268,406-$447,343	228,145	1,789	313
Streambank stabilization	$50-100	$4,473,426-$8,946,851	1,927,216	1,572	460
Total Implementation Cost and Load Reductions		$16,624,481	3,978,477 lbs.	28,874 lbs.	8,370 lbs.

Implementation Plan

Watershed-Wide Goals

Although similar conditions were present in two of our priority subwatersheds, we wanted to ensure our plan took individual landowner and community goals into consideration, so landowner engagement is a focal point of the implementation strategy. The resulting individualized strategies help to achieve the overarching goals of reducing sediment, nitrogen, and phosphorus pollution while keeping BMP implementation cost-efficient and beneficial to local landowners. To achieve the goal of reducing sediment and nutrient pollution to restore sustainable habitat for aquatic life, partners encouraged restoration of riparian buffers and implementation of no-till agriculture across the watershed. Riparian buffers of planted or restored grass or trees and shrubs can help achieve goals for both aquatic habitat and pollution management, so we propose implementing them in every subwatershed. Therefore, a focus of our landowner engagement will be education about riparian buffers.

We will also work with landowners to implement BMPs that reduce erosion from fields, including no-till agriculture and the use of cover crops. Where confined animal operations are present, we suggest manure storage BMPs. We hope to encourage the adoption of as many no-till agriculture practices as possible.

Throughout our outreach and implementation efforts, we will also create strategies for preserving the practices and natural areas conservation which are already in place and are integral to maintaining and furthering water quality improvements. Stewardship of these BMPs and natural systems can be achieved through conservation easements, continued forest management and riparian buffer maintenance, and sustaining our connections and educational outreach within the local community.

Countywide Action Plan

During the creation of this plan, Snyder County Conservation District was simultaneously creating a Countywide Action Plan (CAP) for the Chesapeake Bay Phase 3 Watershed Implementation Plan (Phase 3 WIP) for Pennsylvania. The Susquehecka TMDL and implementation plan for priority subwatersheds takes an initial step toward achieving the nutrient and sediment pollution reductions outlined in the CAP.

The Clean Water Goals in the Snyder County Clean Water Technical Toolbox were used to contextualize goals for the lower Middle Creek watershed within the broader county-wide goals. The reductions goals set by Snyder County are 2,148,000 pounds per year of nitrogen and 125,000 pounds per year of phosphorus by 2025 (Snyder County Toolbox 2020). Phosphorus loading in Snyder County has decreased since 1985, indicating that Snyder County has made some headway in reducing phosphorus loads. Unfortunately, nitrogen loading in Snyder County streams has increased since 1985, so it will be harder to achieve the county nitrogen loading goals (Snyder County Toolbox 2020).

The lower Middle Creek watershed encompasses a large portion of the area in Snyder County that is vulnerable to groundwater contamination due to karst topography, and because of the prevalence of agriculture in the area, the watershed will be an important focus for the county in reducing nutrient pollution (Snyder County Toolbox 2020). In total, if BMPs were to be implemented across 100% of the pasture, hay, and cultivated crops across priority subwatersheds, it would reduce annual loading by 4,646 pounds of nitrogen, 1,375 pounds of phosphorus, and 336,250 pounds of sediment.

Implementation Strategy and Priority Subwatersheds

Overview

The rapid delisting approach combines Chesapeake Conservancy's parcel prioritization system and Snyder County Conservation District's acute knowledge of the lower Middle Creek community to select the regions where our efforts would be the most effective. This allows us to use project resources most efficiently by eliminating areas where outreach is unlikely to be successful or where current landowners have expressed disinterest in the implementation of BMPs. We have targeted the most effective priority subwatersheds for immediately reducing sediment and nutrient loading given the current community preferences and land use in the lower Middle Creek watershed (Figure 12). As a result of the priority restoration locations identified through this process, **319 funds will only be used in the Susquehecka Creek watershed to support TMDL goals**.

Some parcels deemed highest priority by Chesapeake Conservancy are not prioritized in this rapid-delisting plan, but we recognize that these areas will be vital to further reducing sediment and nutrient pollution in the future. These regions include a large section of the southwestern most portion of the Susquehecka headwaters and mainstem approximately halfway between Freeburg and Mount Pleasant Mills, which contributes high nitrogen, phosphorus, and sediment loads and are vulnerable to groundwater pollution due to the nearby band of karst features (Figure 15).

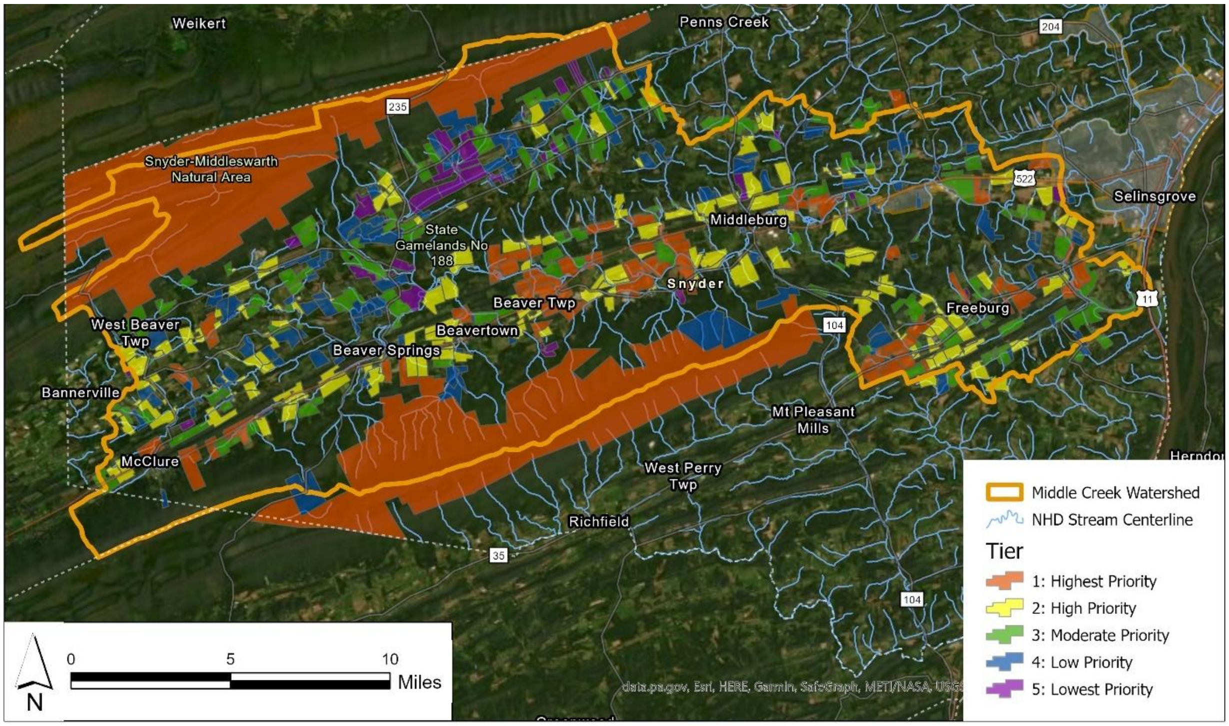


Figure 15: Parcel prioritization across the entire Middle Creek watershed from Chesapeake Conservancy's rapid stream de-listing strategy.

This area should be considered a priority during future conservation efforts in the lower Middle Creek watershed. Like our current priority subwatersheds, the area is predominantly farmland, with little to no riparian tree or shrub cover present. Therefore, implementing riparian buffers on these parcels would benefit landowners and regional water quality immensely. Streambank fencing could be an alternate solution where land is being grazed by cattle. Several farms in the area raise poultry, so manure handling BMPs will be integral to reducing nutrient loading.

Priority BMPs for the Susquehecka Watershed

Across the Susquehecka Creek watershed as a whole, we will work with partners and landowners to reach a 90% implementation rate for agricultural erosion and sedimentation practices, 100% implementation for poultry manure management systems, and an additional 25% implementation rate for cover crops (beyond the subwatershed-specific goals below). These practices collectively will allow us to meet TMDL reduction goals for Susquehecka Creek (total sediment reduction of 942,671 lbs/year). The table below (Table **15**) outlines the specific sediment and nutrient reductions throughout Susquehecka Creek by BMP.

Table **15:** BMPs, available and treated acres, and sediment and nutrient reductions for the Susquehecka Creek watershed.

BMP	***Available Units***	***Acres Treated***	***Sediment Lbs/Year***	***Nitrogen Lbs/Year***	***Phosphorus Lbs/Year***	***Notes***
Riparian Buffers (ac.)	1,723.00	15.40	59,214.17	384.93	60.64	Aggregate, priority subwatersheds
Ag E&S (ac.)	1,723.50	1,551.10	459,049.38	738.72	340.16	90% implementation
Conservation tillage (soil health) (ac.)	1,723.50	282.00	156,483.01	214.89	136.06	Aggregate, priority subwatersheds
Streambank fencing (linear feet)	52,591.87	3,000.00	7,650.00	60.00	10.50	Aggregate, priority subwatersheds
Nutrient management (ac.)	1,723.46	1,551.10	-	2,419.44	252.00	Aggregate, priority subwatersheds
AWMS (%)	NA	90%	-	8,019.66	2,502.11	90% implementation
Streambank Stabilization (linear feet)	52,591.87	20,000.00	967,449.78	837.04	236.82	Aggregate, priority subwatersheds
		Total Reductions	**1,649,846.35**	**12,674.68**	**3,538.28**	

Priority Rapid De-listing Subwatersheds

Dry Run, Freeburg

(Attains ID: PA-SCR-54957237, PA-SCR- 54967329, PA-SCR- 54967435, PA-SCR- 54967631, PA-SCR- 54967523, PA-SCR- 54967281, PA-SCR- 54967531, and PA-SCR- 54967437)
This Tier 1 rapid delisting catchment in Freeburg includes scattered farms, a large forested portion, and a small portion of the residential section of Freeburg along Jones Hill Road. No

BMPs have been implemented in this area to date, but both headwater tributaries to Susquehecka Creek in this region are impaired by siltation connected to current agricultural practices. In both branches, aquatic life is put at risk by high rates of erosion. There is opportunity to expand riparian buffer restoration in the watershed, which is a focus of our strategy since the stream is already partially forested in most of the subwatershed. Enhancing forest buffers in the area will further watershed-wide goals of reducing sediment and nutrient pollution. The implementation of no-till farming will also benefit farmers and the region by mitigating the effects of excessive drainage and helping us achieve our reductions goals. Therefore, educating farmers about the benefits of no-till farming and riparian buffers will be an outreach priority in the region. The stream mouth is located at 40.757221°N, 76.943656°W. The Chesapeake Conservancy prioritization process identified 8 properties with >0.4 acres of restoration opportunity area in the watershed.

Goals and estimated cost:

- 108.5 acres of no-till agriculture and/or cover crops ($10,948)
- 6.85 acres of riparian buffers ($34,250)
- 11,774 linear feet of streambank fencing ($58,872)

Susquehecka—Freeburg (Summit Road)

(Attains ID: PA-SCR-54967919 and PA-SCR- 54968261)

The northernmost third of this subwatershed is largely composed of agricultural land, while most of the bottom portion is forested. Similar to Dry Run, no BMPs have been implemented in the catchment, and aquatic life is also threatened here by siltation due to agriculture. BMPs in this region will be focused in the agricultural portions and will prioritize restoring riparian forest buffers, but we will also educate landowners about other BMPs suited to agriculture and livestock-raising, including no-till farming and nutrient management and erosion control strategies. Each of these strategies will benefit farmers by preventing erosion and excessively-drained soils. This region will also benefit from a manure-handling BMP, because at least one poultry operation is present in the watershed. Furthermore, an underground concrete manure storage unit was implemented very close to the subwatershed and could be used to demonstrate the benefit of manure-handling BMPs. The stream mouth is located at: 40.748350°N, 76.968679°W. The Chesapeake Conservancy prioritization process identified 6 properties with >0.4 acres of restoration opportunity area in the watershed.

Goals and estimated cost:

- 1 manure-handling BMP (cost to be determined)
- 114.6 acres of no-till agriculture and/or cover crops ($11,560)
- 4.6 acres of riparian buffers ($23,000)
- 4,330 linear feet of streambank fencing ($21,648)

Susquehecka—Freeburg (Peach Orchard Road)
(Attains ID: PA-SCR-54966599, PA-SCR-54966137, PA-SCR-54966857, PA-SCR-54966961, PA-SCR-54967173, PA-SCR-5496609, and PA-SCR-54966949)
The easternmost priority subwatershed, this unnamed tributary to Susquehecka Creek starts at Peach Orchard Road, flows through a largely forested stretch, then enters heavy agriculture with minimal riparian buffer for the lower two-thirds of the watershed. BMPs in this subwatershed will focus heavily on riparian buffer implementation, on-field BMPs such as no-till, and manure-handling where appropriate given there are five chicken barns in the watershed. Each of these strategies will benefit farmers by preventing erosion of excessively-drained soils. The stream mouth is located at: 40.764446°N, 76.929857°W. The Chesapeake Conservancy prioritization process identified 3 properties with >0.4 acres of restoration opportunity area in the watershed.

Goals and estimated cost:

- 2 manure-handling BMP (cost to be determined)
- 58.7 acres of no-till agriculture and/or cover crops ($5,921)
- 3.95 acres of riparian buffers ($19,750)
- 3,062 linear feet of streambank fencing ($15,312)

Adaptive Management

As with any successful restoration program, we intend to be flexible and respond to new opportunities (e.g., changes in property ownership) and respond to monitoring of BMP effectiveness. With the simultaneous development of a CAP for Snyder and Union counties, there is likely to become increased awareness and interest in restoration from property owners outside of the priority sub-catchments. We will approach restoration opportunities on additional parcels following the site-specific scoring of Chesapeake Conservancy's delisting strategy as adapted specifically for Snyder County. Within that framework, parcels with willing landowners that fit within scoring Tiers 1 and 2 will be prioritized for additional restoration as funding allows. We will provide technical support to willing landowners in lower tiered parcels to help landowners to lead BMP implementation on their properties.

It is important to note that there could be substantial changes from the proposed BMPs outlined in table 17 for phases one through three. Specific BMPs will be implemented as willing landowners arise and funding is readily available. Other minor BMPs, could be funded and implemented in addition to those already listed in table 17. As time progresses and more BMPs are installed, landowner buy-in is anticipated to increase as neighboring landowners witness the effectiveness and resulting benefits. As requested, the Lower Middle Creek WIP will be updated when new tier 2 subwatersheds are upgraded to tier 1 to continue using 319 funds within the new priority subwatersheds.

Public Outreach

During the planning phase, outreach has focused largely on individual landowners within the priority sub-catchments with support from Herbert, Rowland, and Grubic, Inc. and Lancaster

Farm Trust. We understand that any successful restoration plan relies on the support of the community and engaged landowners who not only allow BMPs to be installed, but are active participants in the process. Maintenance is often most successful when led by landowners because they can act as “first responders” to issues and alert partners when they need support, averting larger and more costly repairs in the future. Through one-on-one meetings and local partners with long-standing knowledge of the community (such as Snyder County Conservation District) we are confident current outreach activities are providing an appropriate groundwork for successful implementation in priority subwatersheds. This plan and opportunities for participation will also be presented the community during the conservation district’s annual farmer meeting in mid-February 2022. Periodic mailings to landowners within the watershed may include items such as an annual report, updates on funding availability, as well as door-to-door visits will be utilized to keep landowners informed about the proposed work, determine interest for future project implementation, and recruit potential new stakeholders. In the future, bi-annual public meetings will be held to engage existing stakeholders and interested landowners. The Freeburg Community building would be the recommended meeting place due to its central location within the Susquehecka subwatershed.

As we begin implementation of projects, continued outreach with supportive landowners will be even more critical to maintain positive relationships. In addition, we recognize that learning about restoration opportunities from supportive neighbors and farmers in the community is the most effective way to improve trust and the likelihood of adding new landowners and projects within a watershed. As projects start, we will gauge interest and work with participating farmers to identify champions for these projects who can help open doors and bring more landowners to the table for conversations about restoration and their vision for their properties. We will also work with partners to publicize participation opportunities at community events in Snyder County.

Our hope is that through multiple outreach avenues we will not only engage new landowners for restoration projects, but we will also increase public awareness of water quality issues and the benefits of healthy watersheds and healthy streams. Toward this end, we will collaborate with the Live Stake Cooperative led by Chesapeake Conservancy to organize and coordinate volunteer events for active restoration on private properties in the area, both supporting the landowner and increasing community engagement.

We will measure success throughout the outreach process in terms of attendance at tables during community events, the number and diversity of volunteers for live staking/restoration events, positive responses to landowner surveys, and the rate that landowners reach out to partners for help initially selecting and implementing BMPs.

Technical and Financial Assistance

Within this watershed implementation plan, many different resources will likely be needed for technical and financial assistance to complete individual projects. While some programs support any and all BMP methods, others are more specific. To best help practitioners and landowners looking for support we have broken these resources into groups based on whether they support all opportunities, no-till or cover crops, more general farm planning, or in-stream and riparian restoration:

- **All opportunities:** Growing Greener; 319 Program, Environmental Quality Incentives Program (EQIP), NRCS Regional Conservation Partnership Program (RCPP), PA Resource Enhancement & Protection Program (REAP), National Fish and Wildlife Foundation Innovative Nutrient and Sediment Reduction Program, National Fish and Wildlife Foundation Small Watershed Grant, Private Foundation Funding.
- **No-till and cover crop support:** PA No-Till Alliance; Snyder County no-till incentive and education program.
- **Farm planning support:** Snyder County Conservation District; Penn State Agriculture & Environment Center; NRCS Conservation Planning, Nutrient Management Plan Implementation Grant Program (NMPIGP).
- **Riparian and in-stream support:** PA Conservation Reserve Enhancement Program (CREP); NRCS Wildlife Habitat Incentive Program (WHIP); Partners for Fish and Wildlife Program; USDA-FSA and NRCS Continuous Conservation Reserve Program (CRP); Chesapeake Bay Financial Assistance Funding Program (FAFP); DEP Stream Bank Fencing Program; CBF and Ducks Unlimited (DU) PA Habitat Stewardship Program; NRCS Conservation Stewardship Program (CSP); Clean Water State Revolving Fund (CWSRF); Keystone 10 Million Tree Partnership; DCNR Riparian Forests and Multifunctional Buffer programs.

Implementation Phase Coordination

In order to be efficient and effective, partner coordination is a critical part of plan implementation. Similar to the structure of roles in our plan-associated QAPP, the organizational roles related to coordination, individual project implementation, public outreach, and stream monitoring and research are outlined below (Table 15).

Table 16: Project roles and responsible parties.

Overall Coordination	Project Implementation	Public Outreach	Stream Research and Monitoring
• Snyder County Conservation District • Chesapeake Conservancy • Herbert, Rowland, and Grubic • Freshwater Research Institute	• Snyder County Conservation District • Chesapeake Conservancy • Snyder County Natural Resources Conservation Service	• Snyder County Conservation District • Lancaster Farm Trust • Herbert, Rowland, and Grubic	• Freshwater Research Institute • PA Department of Environmental Protection

Monitoring Progress

Implementation Tracking

We will use a phased schedule to maximize the effectiveness of our plan. In developing our phased implementation plan, we created quantifiable milestones for BMPs. Our riparian buffer goals can be used in watershed modeling to produce an estimate of nutrient and sediment reductions expected during and after project implementation. In addition, to effectively track success we will create shared tracking spreadsheets among all partners to follow BMP implementation progress by the specific practice and stage of implementation (from planning to installed and maintenance schedules; Table 16).

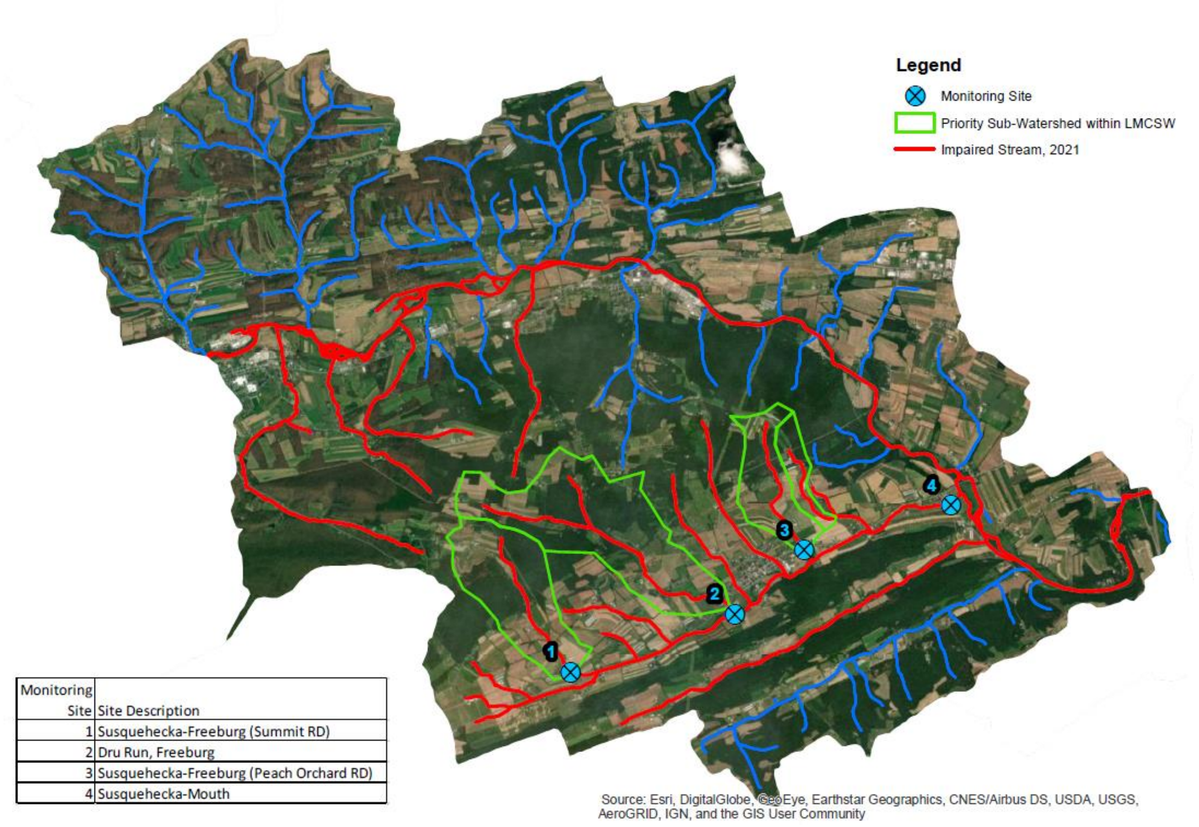
Table 17: Phased project timeline including project milestones and nutrient and sediment reductions estimates for each implementation phase for proposed BMPs.

Phase 1 (Years 1-5)	Phase 2 (Years 6-10)	Phase 3 (Years 11-15)
Milestones: 50% of Tier 1 project target • **Riparian buffers:** 7.7 acres of riparian buffer •**Waste Management:** 4 animal waste storage facility (10,000 sq. ft) •**Streambank fencing:** 1,500 ft •**Streambank Stabilization:** 10,000 ft. • **Outreach:** BMP inventory site visits, door-to-door surveys, follow-up visits post-implementation	**Milestones:** 75% of Tier 1 project target; three additional (Tier 2) priority subwatersheds identified and outreach started • **Riparian buffers:** 11.55 acres of riparian buffer • **Conservation Tillage:** 212 acres is adopted •**Nutrient Management:** 188 acres of manure management or nutrient management planning •**Waste Management:** 6 animal waste storage facility (15,000 sq. ft) •**Streambank fencing:** 2,250 ft. •**Streambank Stabilization:** 15,000 ft. • **Outreach:** continued individualized landowner visits, community event(s)	**Milestones:** 100% of Tier 1 project target, 50% of Tier 2 project target •**Riparian buffers:** >15.4 acres of riparian buffer • **Conservation Tillage:** 282 acres of is adopted •**Ag E&S-** 1,551.10 acres (90%) •**Nutrient Management:** 250 acres of manure management or nutrient management planning •**Waste Management:** 8 animal waste storage facility (20,000 sq. ft) •**Streambank fencing:** 3,000 ft. •**Streambank Stabilization:** 20,000 ft. • **Outreach:** one-on-one BMP follow-up visits
Load Reductions: Sediment 976,206 lbs/yr, 24.3%; TN 5,835 lbs/yr, 5.3%; TP 1,884 lbs/yr, 21.0% **Expected IBI Increases:** Based on scores listed in table 12: Site 1: 53, Site 8: 60 Priority Subwatersheds: #1: 51, #2: 51, #3: 51, #4: 51	**Load Reductions:** Sediment 1,352,425 lbs/yr, 33.7%; TN 10,364 lbs/yr, 9.4%; TP 2,948 lbs/yr, 32.8% **Expected IBI Increases:** (Based on scores listed in table 12: Site 4: 58, Site 8: 65 Priority Subwatersheds: #1: 57, #2: 57, #3: 57, #4: 57	**Load Reductions:** Sediment 1,649,846 lbs/yr, 41.1%; TN 12,675 lbs/yr, 11.4%; TP 3,538 lbs/yr, 39.3% **Expected IBI Increases:** Based on scores listed in table 12: Site 4: 63, Site 8: 65 Priority Subwatersheds: #1: ≥63, #2: ≥63, #3: ≥63, #4: ≥63

Stream monitoring

In addition to tracking physical implementation work, it is critical to monitor BMP effectiveness in achieving stated goals for stream health. While a large focus of restoration will be sediment and nutrient reductions, the ultimate goal of restoration work in most streams is to improve the integrity of the biological communities. These communities, particularly macroinvertebrates, are common indicators of water quality trends over time and can be used for delisting of 303(d) streams from the impaired waterways list when they meet attaining values for intended use. These communities also respond to improvements in water quality, chemistry, physical stream structure, and habitat that allow them to act as proxies for physical and chemical improvements. While macroinvertebrates can act as proxies, the signal-to-noise ratio can sometimes be difficult to interpret, and direct measurements of physical and chemical changes in-stream can greatly improve our understanding of BMP effectiveness. As such, we have developed a detailed Quality Assurance Project Plan for monitoring methods that incorporate physical, chemical, and biological measurements pre- and post-restoration to best understand current states and the rate of improvement after restoration (see associated QAPP in Appendix 3 for more details).

Four sites have been identified for future water quality monitoring on a triennial interval. Each site was carefully selected to adequately assess the water quality within each of the three priority subwatersheds referenced in figure 12, as well as an additional monitoring site located at the mouth of the Susquehecka to assess the water quality and effectiveness of installed BMPs within the Susquehecka’s entirety.



Monitoring Site	Site Description
1	Susquehecka-Freeburg (Summit RD)
2	Dru Run, Freeburg
3	Susquehecka-Freeburg (Peach Orchard RD)
4	Susquehecka-Mouth

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 16: Four monitoring sites, one for each priority subwatershed and one at the mouth of the Susquehecka, have been identified for triennial sampling.

Conclusion

This restoration plan for lower Middle Creek strategically focuses on promoting and implementing the BMPs that will provide the most water quality and habitat benefits now and in the long-term, especially vegetative buffers, no-till agriculture, and manure handling systems. By connecting with landowners and stakeholders, we ensured that this plan incorporates local stakeholder perspectives and the community goals of implementing cost-effective BMPs that will aide in the recovery of aquatic communities and foster long-term community stewardship. This plan guides specific and tangible actions that will help decrease sediment and nutrient pollution entering lower Middle Creek, preserve critical landscapes, and further stewardship by those with the closest ties to the watershed.

Our approach targets select regions within the watershed with the largest potential to implement measures to decrease nonpoint pollution and restore aquatic habitat integrity. By restoring riparian vegetation and reducing runoff of sediment and nutrients into these lower Middle Creek subwatersheds, the community will enjoy a healthier watershed and a brighter future. As we look to the future of lower Middle Creek, we are excited to build upon these connections and to help achieve watershed goals that will benefit aquatic and human communities here and downstream.

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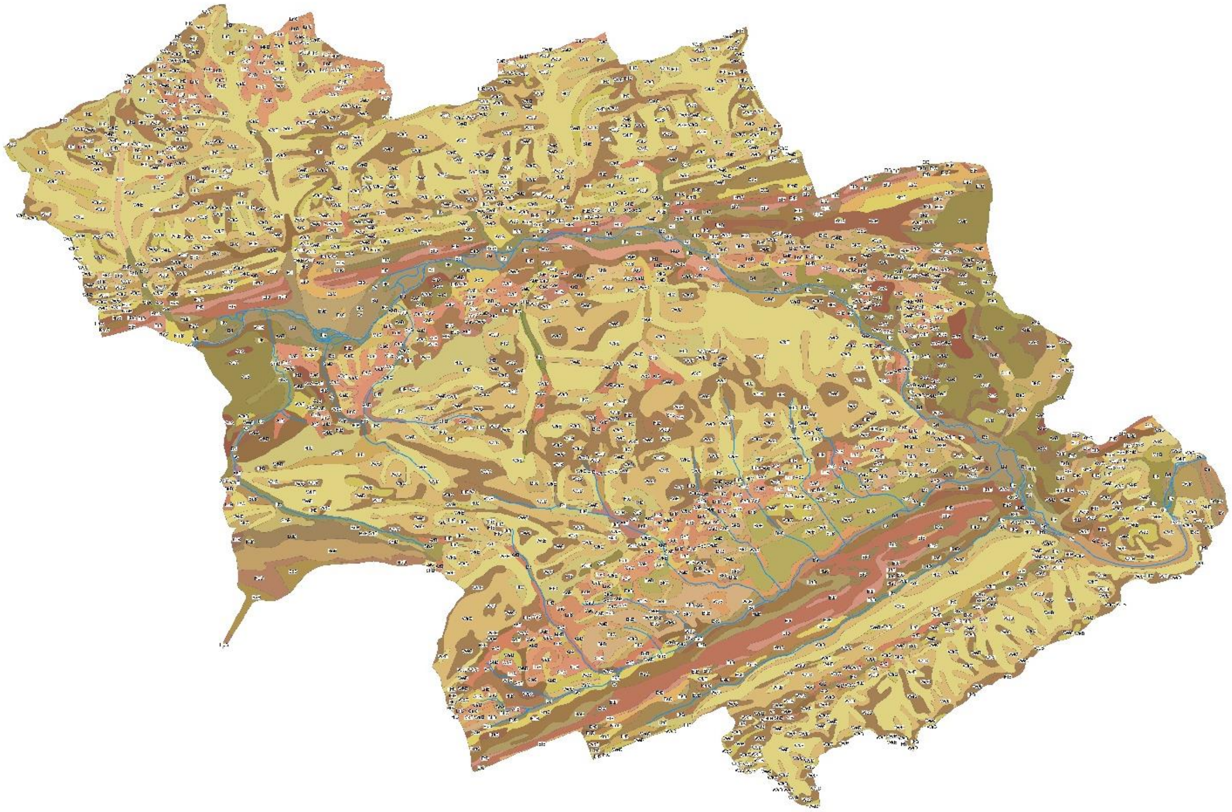
Appendix 1: Watershed soils

Taxonomic soil groups of the lower Middle Creek watershed.



Map Unit Legend

Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent in AOI**
AbB	Albright silt loam, 3 to 8 percent slopes	243.97	0.83
AnA	Allenwood channery silt loam, 0 to 3 percent slopes	143.61	0.49
AnD	Andover channery silt loam, 15 to 25 percent slopes	39.01	0.13
AoB	Allenwood very stony loam, 3 to 8 percent slopes	1026.02	3.50

AoC	Allenwood and Washington soils, 8 to 15 percent slopes	355.28	1.21
ArA	Alvira silt loam, 0 to 3 percent slopes	27.58	0.09
ArB	Alvira silt loam, 3 to 8 percent slopes	436.65	1.49
ArC	Alvira silt loam, 8 to 15 percent slopes	152.24	0.52
AsB	Alvira very stony silt loam, 0 to 8 percent slopes	89.67	0.31
Ba	Barbour soils, frequently flooded	80.28	0.27
Bb	Barbour-Linden complex, rarely flooded	13.70	0.05
Bd	Basher soils, frequently flooded	669.66	2.28
BeB	Bedington silt loam, 3 to 8 percent slopes	514.18	1.75
BkB	Berks channery silt loam, 3 to 8 percent slopes	496.76	1.69
BkC	Berks channery silt loam, 8 to 15 percent slopes	562.42	1.92
BkD	Berks cannery silt loam, 15 to 25 percent slopes	67.27	0.23

BuB	Buchanan gravelly loam, 3 to 8 percent slopes	20.70	0.07
BxB	Buchanan channery loam, 0 to 8 percent slopes, extremely stony	80.09	0.27
CaB	Calvin-Klinesville shaly silt loams, 3 to 8 percent slopes	273.33	0.93
CaC	Calvin-Klinesville shaly silt loams, 8 to 15 percent slopes	443.67	1.51
CaD	Calvin-Klinesville shaly silt loams, 15 to 25 percent slopes	305.05	1.04
DAM	Dams	0.48	0.001
EsB	Elliber cherty silt loam, 3 to 8 percent slopes	162.63	0.55
EsC	Elliber cherty silt loam, 8 to 15 percent slopes	188.86	0.64
EsD	Elliber cherty silt loam, 15 to 25 percent slopes	53.55	0.18
EtB	Elliber very cherty silt loam, 3 to 8 percent slopes	50.51	0.17
EtC	Elliber very cherty silt loam, 8 to 15 percent slopes	159.92	0.55
EtD	Elliber very cherty silt loam, 15 to 25 percent slopes	319.23	1.09

EtF	Elliber very cherty silt loam, 25 to 70 percent slopes	723.05	2.47
EvB	Evendale cherty silt loam, 3 to 8 percent slopes	343.74	1.17
HaB	Hagerstown silt loam, 3 to 8 percent slopes	250.47	0.85
HaC	Hagerstown silt loam, 8 to 15 percent slopes	470.56	1.61
HaD	Hagerstown silt loam, 15 to 25 percent slopes	209.92	0.72
HtB	Hartleton channery silt loam, 3 to 8 percent slopes	778.68	2.66
HtC	Hartleton channery silt loam, 8 to 15 percent slopes	1451.60	4.95
HtD	Hartleton channery silt loam, 15 to 25 percent slopes	355.50	1.21
HuB	Hazleton and Clymer extremely stony sandy loams, 0 to 8 percent slopes	0.86	0.003
HuD	Hazleton and Clymer extremely stony sandy loams, 8 to 25 percent slopes	94.19	0.32
HuF	Hazleton and Clymer extremely stony sandy loams, 25 to 80 percent slopes	159.70	0.54
Hv	Holly silt loam	544.56	1.86

Hy	Holly silt loam, ponded	41.64	0.14
Hz	Holly silt loam, rarely flooded	71.34	0.24
KmB	Kreamer cherty silt loam, 3 to 8 percent slopes	308.05	1.05
KmC	Kreamer cherty silt loam, 8 to 15 percent slopes	193.15	0.66
LaB	Laidig gravelly loam, 0 to 3 percent slopes	6.07	0.02
LaC	Laidig gravelly loam, 3 to 8 percent slopes	28.20	0.10
LbB	Laidig extremely stony loam, 0 to 8 percent slopes	7.02	0.02
LdD	Laidig and Meckesville extremely stony soils, 8 to 25 percent slopes	115.10	0.39
LnB	Leck kill shaly silt loam, 3 to 8 percent slopes	356.30	1.22
LnC	Leck kill shaly silt loam, 8 to 15 percent slopes	302.40	1.03
LnD	Leck kill shaly silt loam, 15 to 25 percent slopes	48.78	0.17
MkB	Meckesville silt loam, 3 to 8 percent slopes	132.63	0.45

MkC	Meckesville silt loam, 8 to 15 percent slopes	5.44	0.02
MoA	Monongahela silt loam, 0 to 3 percent slopes	130.17	0.44
MoB	Monongahela silt loam, 8 to 8 percent slopes	20.43	0.07
OpB	Opequon silty clay loam, 3 to 8 percent slopes	3.25	0.01
OpD	Opequon silty clay loam, 8 to 25 percent slopes	15.97	0.05
OpE	Openquon silty clay loam, 25 to 45 percent slopes	10.64	0.04
ShA	Shelmadine silt loam, 0 to 3 percent slopes	111.80	0.38
ShB	Shelmadine silt loam, 3 to 8 percent slopes	228.06	0.78
SmB	Shlmadine very stony silt loams, 0 to 8 percent slopes	54.53	0.19
Ug	Udifluvents and Fluvaquents, gravelly	2.63	0.01
Ur	Urban Land	19.52	0.07
W	Water	229.36	0.78
WaB	Washington silt loam, wet substratum, 3 to 8 percent slopes	204.63	0.70
WbA	Watson silt loam, 0 to 3 percent slopes	47.66	0.16

WbB	Watson silt loam, 3 to 8 percent slopes	560.51	1.91
WbC	Watson silt loam, 8 to 15 percent slopes	237.07	0.81
WeB	Weikert channery silt loam, 3 to 8 percent slopes	847.44	2.89
WeC	Weikert channery silt loam, 8 to 15 percent slopes	2800.90	9.55
WeD	Weikert channery silt loam, 15 to 25 percent slopes	4336.73	14.79
WkE	Weikert and Klinesville shaly silt loams, steep	5352.41	18.26
WsA	Wheeling soil, 0 to 3 percent slopes	21.68	0.07
WsB	Wheeling soils, 3 to 8 percent slopes	70.49	0.24
WsC	Wheeling soils, 8 to 15 percent slopes	35.18	0.12

Appendix 2: BMP cost-benefit analysis

BMP cost-benefit analysis from Chesapeake Bay Foundation (2020).

BMP	**Unit**	**Cost per Unit**	**N reduced per unit**	**N Cost per lb per year**	**P reduced per unit**	**P Cost per lb per year**	**Sed reduced per unit**	**Sed Cost per lb per year**
Filter Strip Runoff Reduction	Acres Treated	15416.6	1.11614	13812.39	0.26584	57991.73	570.90648	27
Filtering Practices	Acres Treated	5799.7	2.23423	2595.83	0.29516	19649.26	815.57957	7.11
Forest Buffer	Acres in Buffers	178.46	5.88184	30.34	1.11194	160.49	932.00098	0.19
Forest Planting	Acres	71.61	4.09442	17.49	0.83136	86.14	421.02938	0.17
Nutrient Management Plan	Acres	1.99	0.39533	5.03	0.03389	58.73	0	0
Tree Planting - Canopy	Acres	80.65	-0.12218	-660.09	0.02656	3036.4	19.33822	4.17
Wet Ponds and Wetlands	Acres Treated	3235.63	1.11614	2898.95	0.22284	14520.16	611.6837	5.29
Wetland Enhancement	Acres	223.97	0	0	0	0	0	0
Wetland Rehabilitation	Acres	403.79	0	0	0	0	0	0
Non Urban Stream Restoration	Feet	105.34	0.06766	1556.84	6.08E-02	1731.77	190.72285	0.55
Urban Stream Restoration	Feet	105.34	0.06766	1556.84	0.06083	1731.77	190.72285	0.55
Cover Crop Commodity Early	Acres	79.27	1.25966	62.93	0	0	0	0
Cover Crop Commodity Late	Acres	79.27	3.76451	21.06	0	0	0	0
Cover Crop Traditional Annual Legume Early Aerial	Acres	79.27	1.0773	73.58	0.01278	6202.99	16.50833	4.8
Cover Crop Traditional Annual Legume Early Drilled	Acres	79.27	1.79549	44.15	0.01278	6202.99	16.50833	4.8

Cover Crop Traditional Annual Legume Early Other	Acres	79.27	1.79422	44.18	0.01278	6202.99	16.50833	4.8
Cover Crop Traditional Annual Legume Normal Drilled	Acres	79.27	1.79422	44.18	0.00639	12405.98	8.25289	9.6
Cover Crop Traditional Annual Legume Normal Other	Acres	79.27	1.4364	55.19	0.00639	12405.98	8.25289	9.6
Cover Crop Traditional Annual Ryegrass Early Aerial	Acres	79.27	4.4881	17.66	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional Annual Ryegrass Early Drilled	Acres	79.27	7.90146	10.03	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional Annual Ryegrass Early Other	Acres	79.27	6.82288	11.62	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional Annual Ryegrass Normal Drilled	Acres	79.27	7.18326	11.04	0.01022	7753.74	14.44447	5.49
Cover Crop Traditional Annual Ryegrass Normal Other	Acres	79.27	6.46378	12.26	0.01022	7753.74	14.44447	5.49
Cover Crop Traditional Barley Early Aerial	Acres	79.27	5.74558	13.8	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Barley Early Drilled	Acres	79.27	10.41515	7.61	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Barley Early Other	Acres	79.27	8.97747	8.83	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Barley Normal Drilled	Acres	79.27	7.90146	10.03	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional Barley Normal Other	Acres	79.27	6.82288	11.62	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional Brassica Early Aerial	Acres	79.27	4.84848	16.35	0.02172	3648.82	26.82636	2.96
Cover Crop Traditional Brassica Early Drilled	Acres	79.27	8.61965	9.2	0.02172	3648.82	26.82636	2.96
Cover Crop Traditional Brassica Early Other	Acres	79.27	7.18326	11.04	0.02172	3648.82	26.82636	2.96

Cover Crop Traditional Forage Radish Early Aerial	Acres	79.27	3.95009	20.07	0.01278	6202.99	18.57347	4.27
Cover Crop Traditional Forage Radish Early Drilled	Acres	79.27	7.18198	11.04	0.01278	6202.99	18.57347	4.27
Cover Crop Traditional Forage Radish Early Other	Acres	79.27	6.10468	12.99	0.01278	6202.99	18.57347	4.27
Cover Crop Traditional Forage Radish Plus Early Aerial	Acres	79.27	4.30919	18.4	0.01661	4771.53	24.76249	3.2
Cover Crop Traditional Forage Radish Plus Early Drilled	Acres	79.27	7.90146	10.03	0.01661	4771.53	24.76249	3.2
Cover Crop Traditional Forage Radish Plus Early Other	Acres	79.27	6.82288	11.62	0.01661	4771.53	24.76249	3.2
Cover Crop Traditional Forage Radish Plus Normal Drilled	Acres	79.27	5.74686	13.79	0.00895	8861.41	12.38061	6.4
Cover Crop Traditional Forage Radish Plus Normal Other	Acres	79.27	5.02739	15.77	0.00895	8861.41	12.38061	6.4
Cover Crop Traditional Legume Plus Grass 25-50% Early Aerial	Acres	79.27	2.87279	27.59	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional Legume Plus Grass 25-50% Early Drilled	Acres	79.27	5.38648	14.72	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional Legume Plus Grass 25-50% Early Other	Acres	79.27	4.66829	16.98	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional Legume Plus Grass 25-50% Normal Drilled	Acres	79.27	5.02866	15.76	0.01022	7753.74	14.44447	5.49
Cover Crop Traditional Legume Plus Grass 25-50% Normal Other	Acres	79.27	4.30919	18.4	0.01022	7753.74	14.44447	5.49

Cover Crop Traditional Legume Plus Grass 50% Early Aerial	Acres	79.27	3.95009	20.07	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional Legume Plus Grass 50% Early Drilled	Acres	79.27	7.18198	11.04	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional Legume Plus Grass 50% Early Other	Acres	79.27	6.10468	12.99	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional Legume Plus Grass 50% Normal Drilled	Acres	79.27	6.82288	11.62	0.01022	7753.74	14.44447	5.49
Cover Crop Traditional Legume Plus Grass 50% Normal Other	Acres	79.27	5.74558	13.8	0.01022	7753.74	14.44447	5.49
Cover Crop Traditional Oats, Winter Hardy Early Aerial	Acres	79.27	3.77118	21.02	0.01917	4135.33	28.88894	2.74
Cover Crop Traditional Oats, Winter Hardy Early Drilled	Acres	79.27	6.82288	11.62	0.01917	4135.33	28.88894	2.74
Cover Crop Traditional Oats, Winter Hardy Early Other	Acres	79.27	5.74558	13.8	0.01917	4135.33	28.88894	2.74
Cover Crop Traditional Oats, Winter Hardy Normal Drilled	Acres	79.27	6.10596	12.98	0.00895	8861.41	14.44447	5.49
Cover Crop Traditional Oats, Winter Hardy Normal Other	Acres	79.27	5.38648	14.72	0.00895	8861.41	14.44447	5.49
Cover Crop Traditional Oats, Winter Killed Early Aerial	Acres	79.27	2.87279	27.59	0.01278	6202.99	16.50833	4.8
Cover Crop Traditional Oats, Winter Killed Early Drilled	Acres	79.27	5.02739	15.77	0.01278	6202.99	16.50833	4.8
Cover Crop Traditional Oats, Winter Killed Early Other	Acres	79.27	4.30919	18.4	0.01278	6202.99	16.50833	4.8
Cover Crop Traditional Rye Early Aerial	Acres	79.27	6.82288	11.62	0.03195	2481.2	41.26827	1.92

Cover Crop Traditional Rye Early Drilled	Acres	79.27	12.21064	6.49	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Rye Early Other	Acres	79.27	10.41515	7.61	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Rye Late Drilled	Acres	79.27	5.38648	14.72	0	0	0	0
Cover Crop Traditional Rye Late Other	Acres	79.27	4.30919	18.4	0	0	0	0
Cover Crop Traditional Rye Normal Drilled	Acres	79.27	11.13335	7.12	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional Rye Normal Other	Acres	79.27	9.69567	8.18	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional Triticale Early Aerial	Acres	79.27	5.92449	13.38	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Triticale Early Drilled	Acres	79.27	10.41643	7.61	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Triticale Early Other	Acres	79.27	8.97875	8.83	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Triticale Late Drilled	Acres	79.27	4.66701	16.99	0	0	0	0
Cover Crop Traditional Triticale Late Other	Acres	79.27	3.59227	22.07	0	0	0	0
Cover Crop Traditional Triticale Normal Drilled	Acres	79.27	9.69567	8.18	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional Triticale Normal Other	Acres	79.27	8.25928	9.6	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional Wheat Early Aerial	Acres	79.27	4.8472	16.35	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Wheat Early Drilled	Acres	79.27	8.61838	9.2	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Wheat Early Other	Acres	79.27	7.18326	11.04	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional Wheat Late Drilled	Acres	79.27	3.59099	22.07	0	0	0	0
Cover Crop Traditional Wheat Normal Drilled	Acres	79.27	7.90146	10.03	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional Wheat Normal Other	Acres	79.27	6.82288	11.62	0.01534	5169.16	20.6335	3.84

Cover Crop Traditional with Fall Nutrients Annual Ryegrass Early Drilled	Acres	79.27	5.74686	13.79	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional with Fall Nutrients Annual Ryegrass Early Other	Acres	79.27	4.66956	16.98	0.02172	3648.82	30.95535	2.56
Cover Crop Traditional with Fall Nutrients Annual Ryegrass Normal Drilled	Acres	79.27	5.02866	15.76	0.01022	7753.74	14.44447	5.49
Cover Crop Traditional with Fall Nutrients Annual Ryegrass Normal Other	Acres	79.27	4.31047	18.39	0.01022	7753.74	14.44447	5.49
Cover Crop Traditional with Fall Nutrients Barley Early Drilled	Acres	79.27	7.18326	11.04	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional with Fall Nutrients Barley Early Other	Acres	79.27	6.46378	12.26	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional with Fall Nutrients Barley Normal Drilled	Acres	79.27	5.38776	14.71	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional with Fall Nutrients Barley Normal Other	Acres	79.27	4.66956	16.98	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional with Fall Nutrients Brassica Early Drilled	Acres	79.27	6.10596	12.98	0.02172	3648.82	26.82636	2.96
Cover Crop Traditional with Fall Nutrients Brassica Early Other	Acres	79.27	5.02866	15.76	0.02172	3648.82	26.82636	2.96
Cover Crop Traditional with Fall Nutrients Forage Radish Plus Early Drilled	Acres	79.27	5.38776	14.71	0.01661	4771.53	24.76249	3.2
Cover Crop Traditional with Fall Nutrients Forage Radish Plus Early Other	Acres	79.27	4.66956	16.98	0.01661	4771.53	24.76249	3.2

Cover Crop Traditional with Fall Nutrients Forage Radish Plus Normal Drilled	Acres	79.27	4.30919	18.4	0.00895	8861.41	12.38061	6.4
Cover Crop Traditional with Fall Nutrients Forage Radish Plus Normal Other	Acres	79.27	3.59099	22.07	0.00895	8861.41	12.38061	6.4
Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Early Drilled	Acres	79.27	4.66956	16.98	0.01917	4135.33	28.88894	2.74
Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Early Other	Acres	79.27	3.95137	20.06	0.01917	4135.33	28.88894	2.74
Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Normal Drilled	Acres	79.27	4.31047	18.39	0.00895	8861.41	14.44447	5.49
Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Normal Other	Acres	79.27	3.59227	22.07	0.00895	8861.41	14.44447	5.49
Cover Crop Traditional with Fall Nutrients Rye Early Drilled	Acres	79.27	8.61965	9.2	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional with Fall Nutrients Rye Early Other	Acres	79.27	7.18326	11.04	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional with Fall Nutrients Rye Late Drilled	Acres	79.27	3.95009	20.07	0	0	0	0
Cover Crop Traditional with Fall Nutrients Rye Late Other	Acres	79.27	2.87407	27.58	0	0	0	0
Cover Crop Traditional with Fall Nutrients Rye Normal Drilled	Acres	79.27	7.90146	10.03	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional with Fall Nutrients Rye Normal Other	Acres	79.27	6.82416	11.62	0.01534	5169.16	20.6335	3.84

Cover Crop Traditional with Fall Nutrients Triticale Early Drilled	Acres	79.27	7.18326	11.04	0.02556	3101.49	35.07924	2.26
Cover Crop Traditional with Fall Nutrients Triticale Early Other	Acres	79.27	6.10596	12.98	0.02556	3101.49	35.07924	2.26
Cover Crop Traditional with Fall Nutrients Triticale Late Drilled	Acres	79.27	3.23189	24.53	0	0	0	0
Cover Crop Traditional with Fall Nutrients Triticale Late Other	Acres	79.27	2.51497	31.52	0	0	0	0
Cover Crop Traditional with Fall Nutrients Triticale Normal Drilled	Acres	79.27	6.82416	11.62	0.01278	6202.99	16.50833	4.8
Cover Crop Traditional with Fall Nutrients Triticale Normal Other	Acres	79.27	5.74686	13.79	0.01278	6202.99	16.50833	4.8
Cover Crop Traditional with Fall Nutrients Wheat Early Drilled	Acres	79.27	6.10596	12.98	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional with Fall Nutrients Wheat Early Other	Acres	79.27	5.02866	15.76	0.03195	2481.2	41.26827	1.92
Cover Crop Traditional with Fall Nutrients Wheat Late Drilled	Acres	79.27	2.51369	31.54	0	0	0	0
Cover Crop Traditional with Fall Nutrients Wheat Normal Drilled	Acres	79.27	5.38776	14.71	0.01534	5169.16	20.6335	3.84
Cover Crop Traditional with Fall Nutrients Wheat Normal Other	Acres	79.27	4.66956	16.98	0.01534	5169.16	20.6335	3.84
Manure Incorporation High Disturbance Early	Acres	20.23	2.96646	6.82	0.12774	158.37	0	0
Manure Incorporation High Disturbance Late	Acres	20.23	2.94794	6.86	0.12774	158.37	0	0
Manure Incorporation Low Disturbance Early	Acres	20.23	2.20988	9.15	0.21194	95.45	0	0
Manure Injection	Acres	85.28	3.31953	25.69	0.31794	268.22	0	0

Tillage Management-Continuous High Residue	Acres	0	5.01972	0	0.62746	0	868.30389	0
Tillage Management-Low Residue	Acres	0	1.79294	0	0.08051	0	197.8367	0
Advanced Sweeping Technology - 1 pass/12 weeks	Acres	152.04	0	0	0	0	28.09879	5.4
Advanced Sweeping Technology - 1 pass/2 weeks	Acres	919.32	0.37026	2482.89	0.02057	44691.99	154.54337	5.95
Advanced Sweeping Technology - 1 pass/4 weeks	Acres	459.66	0.18513	2482.89	0.02057	22346	84.31695	5.45
Advanced Sweeping Technology - 1 pass/8 weeks	Acres	229.83	0.12342	1862.17	0	0	56.19759	4.09
Advanced Sweeping Technology - 1 pass/week	Acres	1838.64	0.53482	3437.85	0.02057	89383.98	224.8315	8.18
Advanced Sweeping Technology - 2 pass/week	Acres	3677.28	0.71995	5107.66	0.04114	89383.98	295.09906	12.46
Advanced Sweeping Technology - fall 1 pass/1-2 weeks else monthly	Acres	848.61	0.37026	2291.92	0.02057	41254.48	140.49397	6.04
Advanced Sweeping Technology - spring 1 pass/1-2 weeks else monthly	Acres	636.45	0.18513	3437.83	0.02057	30940.5	98.34578	6.47
Bioretention/raingardens - A/B soils, no underdrain	Acres Treated	2689.97	9.72735	276.54	0.25978	10354.77	674.07101	3.99
Bioretention/raingardens - A/B soils, underdrain	Acres Treated	5906.15	8.50979	694.04	0.22829	25871	599.18065	9.86
Erosion and Sediment Control Level 2	Acres	6342.38	0	0	0	0	8476.0812	0.73
Erosion and Sediment Control Level 3	Acres	7927.97	0	0	0	0	8995.02495	0.86

Filter Strip Stormwater Treatment	Acres Treated	1941.77	0	0	0	0	164.77192	11.79
Floating Treatment Wetland 20% Coverage of Pond	Acres Treated by Wet Pond	3187.05	0.19156	16637.73	0.0105	303638.55	31.13697	102.32
Floating Treatment Wetland 30% Coverage of Pond	Acres Treated by Wet Pond	4780.58	0.2834	16868.83	0.01574	303638.87	46.3722	103.1
Floating Treatment Wetland 40% Coverage of Pond	Acres Treated by Wet Pond	6374.11	0.37261	17106.42	0.01837	347016.03	60.94879	104.57
Floating Treatment Wetland 50% Coverage of Pond	Acres Treated by Wet Pond	7967.63	0.46446	17154.73	0.02362	337376.38	76.1814	104.59
Infiltration Practices w/ Sand, Veg. - A/B soils, no underdrain	Acres Treated	2602.06	10.33351	251.81	0.25978	10016.36	711.52407	3.66
Mechanical Broom Technology - 1 pass/week	Acres	3309.9	0	0	0	0	6.97327	473.26
Mechanical Broom Technology - 2 pass/week	Acres	6619.82	0	0	0	0	14.00826	473.26
Nutrient Management Maryland Commercial Applicators	Acres	1.99	0	0	0	0	0	0
Nutrient Management Maryland Do It Yourself	Acres	1.99	0	0	0	0	0	0
Nutrient Management Plan High Risk Lawn	Acres	1.99	1.88048	1.06	0.02665	74.68	0	0
Nutrient Management Plan Low Risk Lawn	Acres	1.99	0.56338	3.53	0.00761	261.39	0	0
Permeable Pavement w/ Sand, Veg. - A/B soils, no underdrain	Acres Treated	19358.3	9.72735	1990.09	0.24404	79325.53	636.62583	30.41

Permeable Pavement w/ Sand, Veg. - A/B soils, underdrain	Acres Treated	25285.2	6.07992	4158.8	0.15219	166137.09	524.27979	48.23
Permeable Pavement w/ Sand, Veg. - C/D soils, underdrain	Acres Treated	25285.2	2.43249	10394.77	0.06035	418954.4	411.93374	61.38
Permeable Pavement w/o Sand, Veg. - A/B soils, no underdrain	Acres Treated	19358.3	9.11857	2122.96	0.24404	79325.53	636.62583	30.41
Permeable Pavement w/o Sand, Veg. - A/B soils, underdrain	Acres Treated	25285.2	5.47114	4621.56	0.15219	166137.09	524.27979	48.23
Vegetated Open Channels - C/D soils, no underdrain	Acres Treated	9533.19	1.21756	7829.76	0.02886	330273.39	374.48856	25.46
Septic Denitrification - Advanced	Number of Systems	5980.97	4.13931	1444.92	0	0	0	0
Septic Denitrification - Enhanced	Number of Systems	6346.67	3.80803	1666.65	0	0	0	0
Septic Effluent - Advanced	Number of Systems	2972.99	2.75935	1077.42	0	0	0	0
Septic Effluent - Enhanced	Number of Systems	2138.65	2.09736	1019.69	0	0	0	0
Septic Pumping	Number of Systems	114	0.27588	413.23	0	0	0	0
Septic Secondary Treatment - Advanced	Number of Systems	3969.82	3.31168	1198.73	0	0	0	0
Septic Secondary Treatment - Conventional	Number of Systems	2454.32	1.10351	2224.1	0	0	0	0
Septic Secondary Treatment - Enhanced	Number of Systems	3135.47	2.75935	1136.31	0	0	0	0
Broiler Mortality Freezers	dry tons	2506.78	3.40404	736.41	0.11163	22455.25	0	0

Manure Compost Forced Aeration High CN	dry tons	11.47	8.74249	1.31	0.38556	29.75	0	0
Manure Compost Forced Aeration Low CN	dry tons	11.47	8.48148	1.35	0.38556	29.75	0	0
Manure Compost Static Pile Windrow	dry tons	-11.4	8.87299	-1.28	0.38556	-29.57	0	0
Manure Compost Static Pile Windrow High CN	dry tons	-11.4	8.67728	-1.31	0.38556	-29.57	0	0
Manure Compost Static Pile Windrow Low CN	dry tons	-11.4	8.41628	-1.35	0.38556	-29.57	0	0
Manure Compost Turned Pile Windrow	dry tons	-10.78	8.93828	-1.21	0.38556	-27.96	0	0
Manure Compost Turned Pile Windrow High CN	dry tons	-10.78	8.74249	-1.23	0.38556	-27.96	0	0
Manure Compost Turned Pile Windrow LowCN	dry tons	-10.78	8.48148	-1.27	0.38556	-27.96	0	0
Manure Treatment Combustion	dry tons	150.06	10.36819	14.47	0.38556	389.2	0	0
Manure Treatment Fast Pyrolysis	dry tons	49.3	10.49835	4.7	0.38556	127.87	0	0
Manure Treatment Forced Aeration	dry tons	11.47	8.93828	1.28	0.38556	29.75	0	0
Manure Treatment High Heat Combustion	dry tons	150.06	10.34459	14.51	0.38556	389.2	0	0
Manure Treatment High Heat Gasification	dry tons	138.36	10.48893	13.19	0.38556	358.85	0	0
Manure Treatment Low Heat Gasification	dry tons	138.36	10.54573	13.12	0.38556	358.85	0	0
Manure Treatment Rotating Bin	dry tons	133.7	9.91691	13.48	0.38556	346.77	0	0
Manure Treatment Rotating Bin High CN	dry tons	133.7	9.85171	13.57	0.38556	346.77	0	0
Manure Treatment Rotating Bin Low CN	dry tons	133.7	9.7212	13.75	0.38556	346.77	0	0

Manure Treatment Slow Pyrolysis	dry tons	94.36	10.54573	8.95	0.38556	244.73	0	0

Appendix 3: Quality Assurance Project Plan (QAPP) For Lower Middle Creek Watershed Improvement Plan

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Quality Assurance Project Plan Approval Signatures

_______________________________________ Date: ____________________

Project Lead,
Jason Winey
District Manager
Snyder County Conservation District

_______________________________________ Date: ____________________

Designated Project Manager
Lauren Cheran
Watershed Specialist
Snyder County Conservation District

_______________________________________ Date: ____________________

Project Lead,
Matt Wilson
Director, Freshwater Research Institute
Susquehanna University

_______________________________________ Date: ____________________

Delegated Approving Official
Scott Heidel
Water Program Specialist
Pennsylvania Department of Environmental Protection

27 May 2022; Revision 1.

Project Management

Distribution List

Snyder County Conservation District
10541 US-522, Middleburg, PA 17842

Freshwater Research Institute, Susquehanna University
514 University Ave. Selinsgrove, PA 17870

Chesapeake Conservancy
514 University Ave. Selinsgrove, PA 17870

Herbert, Rowland & Grubic, Inc.
776 Bull Run Crossing, Suite 200, Lewisburg, PA 17837

Pennsylvania Department of Environmental Protection, Northcentral Region
208 West Third Street, Suite 101, Williamsport, PA 17701-6448

United States Environmental Protection Agency, Region 3
1650 Arch St, Philadelphia, PA 19103

Project/Task Organization

Partner	Affiliation	Project Role
Matt Wilson	Susquehanna University	Project Manager Quality Assurance Officer Monitoring and Data Management Leader Restoration Plan & Implementation Leader
Jason Winey	Snyder County Conservation District	Project Manager
Adrienne Gemberling	Chesapeake Conservancy	Project Manager GIS and Information Technology Leader Restoration Plan & Implementation Leader

Project managers will provide general direction and oversee the project, including directing field work associated with implementation of the restoration plan, public outreach, and data coordination. Project managers will also maintain applicable financial and project records.

Quality assurance officers will review quality assurance guidelines on a regular basis to ensure that quality control procedures are being followed. Duties include: review data and data entry procedures, review field monitoring and laboratory analysis procedures, conduct trainings and direct corrective actions, document changes made to QAPP.

Monitoring and data management leader will oversee sampling and data management for development and implementation of the restoration plan. Specific duties include: oversee and assist in monitoring and data collection; compile, analyze, and evaluate data; review lab and field procedures; verify collection of data according to the guidelines in the QAPP.

GIS and information technology leader will oversee GIS and IT required for implementation. Duties include: oversee and develop GIS mapping associated with the development and implementation of the restoration plan, and maintain spatial databases.

Personnel Qualifications

Tasks will initially be completed by qualified persons who already possess the training, understanding, and experience of the practices described in this document. The Project Managers and Leaders are environmental professionals with advanced degrees in a scientific discipline. If necessary, training will be provided by the Project Managers to any individuals who conduct work but do not have previous experience in the required skills to successfully complete methods outlined in this QAPP.

Problem Definition and Background

This document identifies and details the sampling methods required to monitor and assure efficacy of restoration projects implemented through the Middle Creek – Penns Creek Watershed Implementation Plan (WIP). These methods will follow a combination of accepted sampling and analysis procedures from state (Pennsylvania Department of Environmental Protection) and federal (U.S. Environmental Protection Agency) organizations where supported by the most recent peer-reviewed literature. Additional methods that have been identified through peer-reviewed research but are not yet adopted by state and federal agencies are also included where appropriate.

Project and Task Descriptions

A Watershed Implementation Plan (WIP) for the lower Middle Creek watershed was completed in 2021. The monitoring of water chemistry and biological communities will be integral in assessing the success of restoration and Best Management Practices (BMPs) implemented on lower Middle Creek, and will require use of this QAPP. Project implementation will also include input and assistance from the lower Middle Creek watershed community and other groups and individuals with an interest in local conservation, who will be informed with data and other information about the watershed via educational and/or outreach events. This plan describes the primary tasks that will be conducted with funding provided through current and future grants. Primary tasks upon approval of the WIP and secured implementation funding include:

BMP Implementation: Project implementation will be carried out with willing landowners on private parcels where the likelihood of stream delisting is highest. Project managers will be responsible for coordinating with landowners and determining site-specific BMPs for implementation.

Mapping: Based on values agreed upon by project partners, parcels will be ranked and selected for targeted restoration based on restoration opportunity and rapid delisting scores generated by Chesapeake Conservancy spatial analyses.
Public Participation: In addition to the landowners at implementation sites, all landowners upstream and downstream with restoration opportunity areas will be contacted to assess feasibility of larger projects and/or restoration continuity throughout a watershed.
BMP efficacy monitoring: All proposed sites for BMP implementation will be monitored via the protocols outlined in this QAPP both before and after implementation in order to assess effectiveness of implementation and recovery trajectory of the site.

Monitoring Program

Overview of Goals, Procedures, and Approach

Methods to be employed at each individual sampling event may include a subset of the following methods. At a minimum, they must include physical habitat mapping and water quality measures. The remaining methods will be used when applicable to generate baseline/pre-implementation data, document implementation and as-built conditions, and/or generate post-implementation/response data. This tiered approach is intended to both recognize limited habitat/water availability at the most upstream reaches for implementation and allow for a cost-effective approach to monitoring while collecting robust data.

Data Quality Objectives and Criteria

Specific measures to be included are:

Parameter	Method/Device	Range	Accuracy	Resolution
Primary water quality measures				
Flow	Flow meter, wading rod and tape measure, transect with 10 stations	>0.01 m/s	0.01 m/s	0.01 m/s
pH	Yellow Springs Institute Multimeter	0-14	± 0.1	0.01
Temperature	Yellow Springs Institute Multimeter	-5 to +100°C	± 0.1°C	0.01°C
Dissolved oxygen	Yellow Springs Institute Multimeter	-5 to 550% saturation	± 0.1 mg/L	0.1 mg/L
Specific conductance	Yellow Springs Institute Multimeter	0-0.9999 µS	± 0.30%	0.0001 µS
Secondary water quality measures				
Total suspended solids	Standard methods for water and wastewater	>0.1 mg/L	± 0.76-33% (range-dependent)	0.1 mg/L

Chlorophyll *a*	Standard methods for water and wastewater	>0.11 µg/L	7.5%	0.01 µg/L
Biological measures				
Fish species	Triple-pass depletion sampling protocol/backpack electrofishing unit	NA	NA	Species
Game fish length	Fish board	>1 mm	± 1 mm	1 mm
Game fish weight	Ohaus Scout scale	>0.1 g	± 0.01 g	0.1 g
Benthic macroinvertebrates	Composite Surber sampling	NA	NA	Family or genus
Abiotic measures				
Physical habitat mapping	As outlined below	NA	NA	NA
Substrate size	Gravelometer	0 to -8 φ	± 1 φ	1 φ
Carbon:Nitrogen ratio	16 hrs at 550°C	>0.1 mg/L	0.4-1.9%	0.1 mg/L

Special Training/Certification

Training for all water quality and abiotic measures will be provided on-site and in-lab by project managers or qualified scientists appointed by project managers. All participants in fish sampling will be required to complete the US Department of the Interior electrofishing safety training course online and demonstrate species-level identification competency to project managers. Surber sampling training will be provided on-site and macroinvertebrate identifications will be performed by certified taxonomists. A copy of all standard operating procedures will be kept on-site at the Freshwater Research Institute.

Documents & Records

All sampling records generated by this project will be stored at the Freshwater Research Institute at Susquehanna University. Records stored for this project will include all laboratory records pertinent to this project. Copies of records held by the laboratory will be provided to project manager and maintained in the project file.

Project Managers will ensure all organizations in the Distribution List have a digital copy of the current version of the QAPP. Any revisions to the original document will include a revision date and sequential revision number. Project managers will be responsible for maintaining all financial and project documentation for future grants and deliverables when their organization is the lead applicant.

Data Generation and Acquisition

Sampling Process Design

Methods for sample collection in the field will be done according to standard procedures or EPA Protocols for Wadeable Streams and Rivers, where appropriate (Barbour et al. 1999, Baird et al. 2017, PADEP 2006). Appropriate sampling techniques (systematic and/or random) will be used to ensure that a representative sample is collected.

Fish samples, benthic macroinvertebrate samples, and in-stream habitat measurements will be completed according to standard procedures outlined below.

All samples will be identified with a unique number and labeled with the following information.

- Sample ID
- Stream ID
- Station ID
- Time/date
- Sample type (normal or QC)
- Preservative method (if any)

Fish and macroinvertebrates will be identified to the lowest possible taxonomic level based on quality and size of the specimen, following current taxonomy (Brigham et al. 1982, Wiggins 1996, Stauffer et al. 2016, Merritt et al. 2019). All identifications will be completed by, or under the direct supervision of, trained professionals for field identification of fishes and by a certified taxonomist for aquatic macroinvertebrates.

Sampling Methods

During field sampling events, we will measure temperature, dissolved oxygen, pH, and specific conductance with a YSI probe in the thalweg of the channel. Visual assessments and sediment samples will be collected for three riffles at each site. Discharge will be estimated by pulling a tape measure across the stream at location where the channel is a straight with relatively homogeneous depth and velocity. Depth and velocity will be measured at 10 evenly spaced intervals. Velocity readings will be taken at 6/10ths depth following standard practice. All biologic and sediment sampling will be completed in one day and collected in order of least-to-most disruptive (generally macroinvertebrates, then fish, then sediment).

Benthic macroinvertebrates
Benthic macroinvertebrate samples will be collected with quantitative (1ft^2) Surber samplers to assess absolute changes in populations over time. Samples will be collected as three individual Surbers combined with 1/3 of the material kept for processing at each site and preserved in 95% EtOH. Sample QA/QC and identification will be completed by a certified aquatic entomologist following current taxonomy and methods.

Fish
Fish will be collected through backpack electrofishing at each site. A 100-meter reach, representing multiple habitats, will be electrofished using a triple pass method, collecting all possible individuals during the effort, which will be identified to species, counted, measured to the nearest millimeter, and weighed to the nearest 0.1 g. All fish will then be allowed to recover in holding tanks and redistributed throughout the 100 m reach.

Sediment

Five sediment samples will be collected along the same 100-meter reach as fish and benthic macroinvertebrates. Samples will be collected in a riffle, pool, run, glide, and eddy using either a sharpshooter spade or a handheld bucket dredge. Each sample will be split into coarse and fine earth fractions to quantify grain size characteristics. Grain size classes of sediment samples will be determined using USDA standard sieves for coarse fraction and hydrometer tests for fine earth fraction according to the Udden-Wentworth scale. Carbon to nitrogen ratios will be determined with a total organic carbon/total nitrogen analyzer and organic content of samples through loss on ignition in a muffle furnace (550 ºC for 16 hours).

Habitat and BMP Identification
Best Management Practices are commonly installed in slightly different configurations than proposed based on unexpected differences in stream morphology and "as-built" descriptions are not always consistent between restoration planners or locations. To ensure consistency and accuracy in our analyses, we will ground truth BMPs as implemented at each site as well as the appropriate analogs in reference streams (e.g. log jams, root wads, boulders) following standard BMP terminology and measures as listed by the Chesapeake Bay Program's cost profiles for Pennsylvania.

Sample Handling & Chain of Custody

For relevant chemical analysis, sampling devices and sample bottles will be acid washed in 20% HCl and will be rinsed three times with deionized water and then with sample water prior to collecting each sample. Sterile bottles, whirl-paks, and sample bottles which do contain preservatives/fixing agents (e.g., acids, etc.) will not be rinsed with sample water prior to collecting the sample. When preservatives/fixing agents are used samples will be collected with a secondary device (e.g. net, sieve, etc.) prior to transferring the sample into the bottle.

The following table describes sample holding container, sample preservation method and maximum holding time for each parameter.

Parameter	Sample bottle	Typical sample volume	Preferred procedure and maximum holding time
Temperature, dissolved oxygen, pH, specific conductance (YSI sonde)	n/a	n/a	Check calibration weekly
Total suspended solids	Plastic bottle	500 mL	7 days at 4°C, dark
Fish species	n/a	n/a	Methods as outlined in QAPP; released live immediately
Benthic macroinvertebrates	Whirl-pak or plastic bottle	500 mL	Methods as outlined in QAPP; ten years
In-stream habitat	n/a	n/a	Methods as outlined in QAPP
Sediment samples	Whirl-pak	500 mL	Dried samples; ten years

All water samples that do not include preservatives will be stored on ice in the field and processed or refrigerated within 12-24 hours.

Sample chain of custody will be traceable from the time of sample collection until results are reported.

The following sample control activities will be conducted at the laboratory:

- Verify sample preservation (e.g., temperature, ethanol, etc.)
- Notify the project manager if any problems or discrepancies are identified
- Proper samples storage, including daily refrigerator temperature monitoring and sample security

Documentation procedures

The primary field sampler will be responsible for ensuring that the field sampling team adheres to proper custody and documentation procedures. A master sample logbook or field datasheets will be maintained for all samples collected during each sampling event.

Analytical Methods

Prior to the analyses of any environmental samples, the laboratory must have demonstrated the ability to meet the minimum performance requirements for each analytical method. Initial demonstration of laboratory capabilities includes the ability to meet the project specified quantitation limits (QL), the ability to generate acceptable precision and recoveries, and other analytical and quality control parameters as stated in this QAPP. Analytical methods used for chemistry analyses will follow a published method (US EPA or Standard Method for the Examination of Water and Wastewater) and document the procedure for sample analyses in a laboratory Standard Operating Procedure (SOP) for review and approval.

Quality Control

Field

Field quality control (QC) measures will include samples used to assess the influence of sampling procedures and equipment used in sampling. For basic water quality analyses, QC samples in the field will consist of equipment blanks, field duplicates, and matrix spikes (when applicable).

Equipment blanks
Equipment blanks will be collected and analyzed for all analytes of interest along with the associated environmental samples. Equipment blanks will consist of laboratory-prepared blank water processed through the sampling equipment using the same procedures used for environmental samples.

Field duplicates
One field duplicate will be collected per water sampling event, collected at the same time as environmental samples, and will be analyzed along with the associated environmental samples. If the relative percent difference (RPD) of field duplicate results in greater than 25% and the absolute difference is greater than the reporting limit (RL), both samples will be reanalyzed.

Laboratory

For water analyses, QC samples prepared in the laboratory may consist of method blanks, laboratory control samples, and laboratory duplicates.

Method blanks
Method blanks will be prepared and analyzed with each batch of samples. If any analyte is detected in the blank, the blank and the associated samples must be reanalyzed.

Laboratory control samples and surrogate
Two laboratory control samples (LCS) will be analyzed per sample batch. Surrogates may be added to samples for organic analyses.

Instrument/Equipment Testing, Inspection, & Maintenance
All instrument and equipment testing will be performed according to manufacturer recommendations. Laboratory instrument and equipment testing will be as prescribed under the laboratory operating manual.

Inspection/Acceptance of Supplies & Consumables

All consumables and supplies will be ordered from nationally recognized suppliers with internal quality control measures (e.g., VWR, Carolina Biologic, Forestry Suppliers, etc.).

Non-Direct Measurements

Implementation of restoration projects will largely be based on non-direct measures, primarily from geospatial data. All geospatial data used for parcel prioritization and project decisions is currently housed by the Chesapeake Conservancy. Should, for any reason, the Chesapeake Conservancy choose or be unable to continue hosting these data, the Freshwater Research Institute will house all project-relevant data on Susquehanna University servers and/or through ESRI-hosted online storage.

Data Management

Copies of field logs, original reports, and electronic media will be kept for review by the Freshwater Research Institute at Susquehanna University. The field crew will retain original field logs.

Original fish, macroinvertebrate, and habitat data sheets will be scanned and uploaded to cloud- or server-based storage. Original data sheets will be kept for review at the FRI.

Concentrations of chemicals, toxicity endpoints, and all numerical biological parameters will be calculated as described in the referenced method document for each analyte or parameter, or a laboratory operating procedure. The data generated will be converted to a standard database format maintained by Dr. Dan Ressler (Earth and Environmental Sciences Department Chair) and Matt Wilson (FRI Director) and available for DEP/EPA staff review when requested. This review is for QA/QC purposes only and will not be used for any other purpose. All project information will remain confidential.

After data entry and data transfer procedures are completed for each sample event, data will be inspected for data transcription errors, and corrected as appropriate. After the final QA checks for errors are completed, the data will be added to the final database.

Assessment and Oversight

Assessments & Response Actions

Data will be consistently assessed and documented to determine whether project quality assurance objectives have been met by assessing data quality, and identify potential limitations on data use.

Reports to Management

The following table summarizes the types of data to be reported and the method in which that information will be delivered to DEP/EPA staff.

Data	Data Description	Reporting Method	Frequency
BMP as-built data	Raw data from project reports in units of miles, linear feet, acres, individuals, etc.	Reports submitted to the PA DEP and kept on file at the FRI	Annually
Pre- and post-implementation data	Raw data for water chemistry, habitat, fish, and macroinvertebrate sampling	Reports submitted to the PA DEP and kept on file at the FRI	Annually
Geospatial data	Google polygon maps, latitude/longitude info, watershed segment	Reports submitted to the PA DEP and kept on file at the FRI	Upon request

Data Validation and Usability

Data Review, Validation, & Verification

Data collected in the field will be cross-checked before exiting the site to verify its completeness. Any data collected in the field or laboratory will be reviewed and validated. The laboratory quality assurance manual will be used to accept, reject, or qualify the data generated by the laboratory. The laboratory management will be responsible for validating the data generated by the laboratory.

Only data which have met data quality objectives, or which have acceptable deviations clearly noted, will be integrated into the final database. When QA requirements have not been met, the samples will be reanalyzed when possible and only the results of the reanalysis will be submitted, provided they are acceptable

Reconciliation with Data Quality Objectives

To analyze BMP efficiency, cost-effectiveness, and prioritization we will employ several statistical methods. To quantify the overall efficiency of BMPs in improving stream conditions we will use multivariate redundancy analyses first to understand the relationships between individual or grouped BMPs and sediment characteristics or biotic communities. Based on the results of these analyses we will use generalized additive modeling techniques to narrow down which specific BMPs have the largest effect on improving targeted in-stream conditions. As a result of our BACI (before-after controlimpacted) study design, it will be possible to estimate improvements to sediment and biotic conditions before and after restoration for individual sites, combine these results with the effects of specific BMPs, multiply by standard costs to estimate the overall value of a BMP for stream improvements, and determine how that value analysis changes over time post-restoration. In addition to on-farm improvements, it is also valuable to document downstream benefits from BMP implementation, particularly in the context of TMDL goals for Chesapeake Bay. Where possible, we will sample sites downstream of BMP implementation. By sampling sites multiple times post-restoration we will be able to use principal response curves and multiple regression to quantify response trajectories and determine whether sites are continuing to recover through time or plateau before meeting de-listing requirements. Data that depart from the assumption that BMPs will decrease sediment and benefit biotic communities may indicate the necessity of BMP maintenance.

Outliers or anomalies in the data will be check through multiple detection processes including visual inspection of scatter plots for variables that should be associated (e.g., dissolved oxygen and temperature). Entry into the database also requires all data to be within a biologically feasible range or will be rejected to prevent transcription errors. Any data which are identified by these methods will first be checked against original paper data forms for accurate transcription, then points discussed by a project manager and the original author of the data to determine whether values were written incorrectly (errors) or simply outside expected values (true outliers).

References

Baird, R.B., A.D. Eaton, and E.W. Rice (editors). 2017. Standard methods for the examination of water and wastewater. 23rd edition. Washington, D.C.: American Public Health Association.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish. 2nd edition. Office of Water, US Environmental Protection Agency, Washington, DC.

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Merritt, R. W., K. W. Cummins, and M. B. Berg (editors). 2019. An introduction to the aquatic insects of North America. 5th edition. Kendall/Hunt, Dubuque, Iowa.

PADEP (Pennsylvania Department of Environmental Protection). 2006. Standardized biological field collection and laboratory methods. Document Number 391-3200-015. Pennsylvania Department of Environmental Protection, Harrisburg, Pennsylvania.

Stauffer, J. R., R.W. Criswell, and D.P. Fischer. 2016. The fishes of Pennsylvania (p. 556). El Paso, Texas: Cichlid Press.

Wiggins, G. B. 1996. Larvae of the North American caddisfly genera (Trichoptera). University of Toronto Press, Toronto, Ontario.