Upper Little Swatara Creek Watershed Implementation Plan

February 2024

Prepared by Center for Watershed Protection, Inc.

Prepared for Berks County Conservation District

This report was prepared by the Center for Watershed Protection, Inc.

Julie Schneider
Jordan Fox
Deb Caraco, PE
Lisa Fraley-McNeal
Chris Swann
Emily Trethewey, PE
Ruth Hocker, PE, D.WRE
Sebastian Makrides

11711 East Market Pl, Suite 200
Fulton, MD 20759

This report was prepared for the Berks County Conservation District

1238 County Welfare Road, Suite 200
Leesport, PA 19533

Funded by Pennsylvania Department of Environmental Protection 319 Grant

CONTENTS

LIST OF TABLES

List of Figures

ACRONYM & ABBREVIATION DEFINITIONS

Acronym / Abbreviation	Definition
ACAP	Agricultural Conservation Assistance Program
ACE	Agricultural Conservation Easement
ALA	Adjusted Load Allocation
AVGWLF	ArcView Generalized Watershed Loading Function
AWMS(s)	Animal Waste Management System(s)
BANCS	Bank and Nonpoint Source Consequences of Sediment
BBAP	Berks Bay Action Plan
BCCD	Berks County Conservation District
BCPC	Berks County Planning Commission
BEHI	Bank Erodibility Hazard Index
BMP(s)	Best Management Practice(s)
CAFO(s)	Concentrated Animal Feeding Operation(s)
CAST	Chesapeake Bay Assessment Tool
CFU(s)	Colony Forming Unit(s)
CWOT	Clean Water Optimization Tool
CWP	Center for Watershed Protection, Inc.
GIS	Geographic Information System(s)
gNATSGO	Natural Resource Conservation Service gridded National Soil Survey Geographic Database
GWLF	ArcView Generalized Watershed Loading Function
HOA(s)	Homeowners Association(s)
HSG(s)	Hydrologic Soil Group(s)
HSI	Hotspot Site Investigation
HUC	Hydrologic Unit Code
IBI	Index of Biological Integrity
LA	Load Allocation
LULC	Land Use Land Cover
MMW	Model My Watershed
MOS	Margin of Safety
MS4(s)	Municipal Separate Storm Sewer System(s)
NAIP	National Agriculture Imagery Program
NBS	Near Bank Stress
NFWF MEB	National Fish and Wildlife Foundation Most Effective Basin
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Non-Point Source
NRCS	Natural Resource Conservation Service
NSA	Neighborhood Site Assessment
NWI	National Wetlands Inventory
PA DEP	Pennsylvania Department of Environmental Protection
PFBC	Pennsylvania Fish and Boat Commission
PPCGRS	Petroleum Product Contaminated Groundwater Remediation Systems
QAPP	Quality Assurance Protection Plan
RCPP	Regional Conservation Partnership Program
RRI	Retrofit Reconnaissance Inventory
SSURGO	Natural Resources Conservation Service Soil Survey Geographic Database

Acronym / Abbreviation	Definition
STL	Suburban Testing Labs, Inc.
TMDL(s)	Total Maximum Daily Load(s)
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UNT	Unnamed Tributary
US EPA	U.S. Environmental Protection Agency
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USLE	Unified Soil Loss Equation
USSR	Unified Subwatershed and Site Reconnaissance
WLA	Waste Load Allocation

EXECUTIVE SUMMARY

A Watershed Implementation Plan (WIP) for the Upper Little Swatara Creek watershed was created through coordination with the Berks County Conservation District (BCCD) and stakeholders to provide an action plan to reduce sediment and phosphorus loads to the Little Swatara Creek. The WIP provides a list of projects that, when installed, will improve the water quality in the watershed to meet Pennsylvania Department of Environmental Protection (PA DEP) Total Maximum Daily Load (TMDL) reductions for phosphorus and sediment. This project was funded by a PA DEP 319 grant that can provide funding for project implementation once the WIP is approved by EPA. This WIP is developed for the Upper Little Swatara Creek watershed ("total study watershed"), which drains 59.6 square miles (sq. mi.). The total study watershed includes two subwatersheds: the Little Swatara Creek subwatershed that drains 40.7 sq. mi., and Crosskill Creek subwatershed that drains 18.9 sq. mi. (Figure 1). Both HUC12 subwatersheds are included in this plan because they are hydrologically interrelated and have very similar land use/land cover, topography, water quality problems, and restoration opportunities.

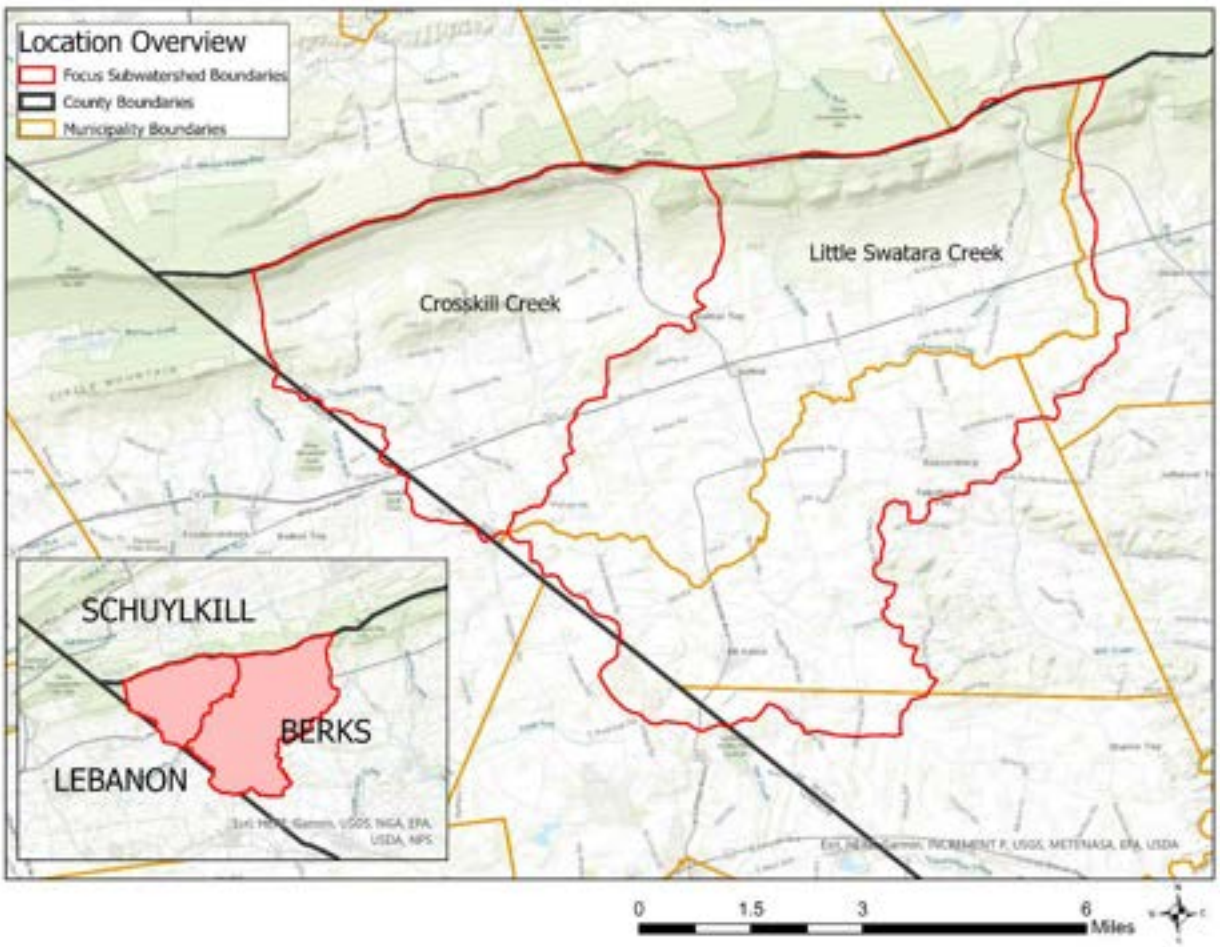

Figure 1. Location overview of the total study watershed

The total study watershed includes portions of Tulpehocken, Upper Tulpehocken, Marion and Bethel Townships in Berks County with a very small portion in Northern Lebanon County. The total study watershed is located in the northwestern corner of Berks County and is a tributary to the Swatara Creek, that drains to the Chesapeake Bay Watershed. The Berks Bay Action Plan (BBAP) was developed in 2021 and provides current and planned clean water actions to meet Chesapeake Bay goals. These actions are incorporated into this report.

Watershed Baseline Assessment

The baseline assessment (Sections 1-4) summarizes watershed characteristics including geology, land use, stream condition, and pollution sources for the total study watershed. The total study watershed land use is dominated by forest and cropland with impervious cover around five percent. The average agricultural operation size is approximately 125 acres and dominant crops include no-till corn grain, soybean, and small grain for silage. Other conventional crop rotations include corn silage, alfalfa hay, and small grains. Livestock operations primarily include dairy and pastured livestock including beef cows, sheep, and horses.

The streams in the total study watershed are designated as protected for aquatic life use as cold-water fishery and recreational use (PA Chapter 93). Most stream miles are impaired for recreational use but support the aquatic life use, and only a small length of stream supports trout reproduction. In the Crosskill Creek subwatershed, 77% of stream miles are impaired for recreational use while 29% of the stream miles are impaired for aquatic life use designation and there is no natural trout reproduction use. In the Little Swatara Creek subwatershed, 33% of stream miles are impaired for recreational use, while 41% are impaired for aquatic life use designation, and 1.5 miles of streams support natural trout reproduction use on Mill Creek. In addition, 5.9 miles of the mainstem is stocked with trout by the Pennsylvania Fish and Boat Commission (PFBC).

A Total Maximum Daily Load (or TMDL) is an estimate of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. When water bodies are too polluted to meet the established water quality criteria, they are added to an “impaired waters list”. In Pennsylvania, the PA DEP develops a TMDL for waterbodies identified as impaired with the goal of “de-listing” or improving the stream so that it can fully support its designated uses. The Crosskill Creek has a sediment TMDL for the entire watershed developed in 2004, while TMDLs for sediment and phosphorus were developed for specific, smaller Unnamed Tributaries (UNTs) of the Little Swatara Creek in 2011 (Section 2).

While TMDLs serve as a guide to determine the amount of implementation to achieve water quality goals, stream health is ultimately used to remove streams from the impaired waters list. Section 2, which focuses on stream quality, provides a summary of ongoing water quality sampling conducted in the study watershed by BCCD and PA DEP. The BCCD data includes recent chemical and biological monitoring data from twelve stations in 2021, while the PA DEP includes only biological monitoring data from 2019 and 2022. Taken together, the data suggest mixed biological health. For example, half of the sites monitored in 2021 by BCCD show poor macroinvertebrate health, and half show moderate health. The water quality data included in this report will serve as a baseline to determine how stream health improves as this plan is implemented.

Field Assessments and Findings

CWP conducted field assessments in Fall 2021 to identify restoration opportunities within the total study watershed. Field assessments included identification of stormwater retrofit projects, pollutant reduction, and restoration opportunities in neighborhoods and commercial, industrial, institutional, municipal, and transport-related operations. In addition, stream assessments were conducted following a rapid BANCS method developed by Rosgen (2009) and an agriculture conservation assessment was conducted. A summary is found in Section 5.

The retrofit inventory identified nineteen total stormwater retrofit opportunities, which cumulatively treat 43 acres of urban land. Stormwater retrofits identified include five permeable pavement practices, one bioswale, one sand filter, one site for additional plantings in an existing pond, and one site for conversion of a dry pond to a wet pond. In addition, several warehouse distribution centers along the I-78 corridor were visited in the field to evaluate potential stormwater retrofit potential. Most of the sites managed stormwater using a dry pond with a few sites using wet ponds. The WIP provides a summary of the estimated pounds of phosphorus,

nitrogen, and TSS the retrofits would remove each year, a planning level cost estimate to design and build the retrofit and maintain it for 1 year, and the cost effectiveness for all retrofits identified.

Neighborhood and commercial inspections resulted in fewer recommendations. No follow-up actions were identified in neighborhoods, while two commercial sites were identified as having pollution producing with follow-up actions of providing a cover for outdoor material storage, keeping dumpster lids closed and inspection of wash water draining to storm drain system.

Stream assessments were conducted along agricultural land to provide an understanding of the degree of streambank erosion and potential for stream restoration projects. This field work identified three potential three restoration sites, including over 12,000 linear feet of stream restoration.

The agriculture conservation assessment included field visits to the watershed with the baseline water quality sampling, stormwater, and streambank assessments. The priority of the field visits was to identify existing farmer practices that includes agricultural operation type (e.g., crop, livestock, or other), existing crop rotations, near stream and field conservation practices, pasture management, and best management practices on farms. This information was used to model pollutant loads to the study watershed.

Pollutant Load Reduction Modeling and Evaluation of BMPs

A simple spreadsheet model, Model My Watershed (MMW), was used to estimate the total phosphorus (TP), total nitrogen (TN), and total sediment (TSS) loads for the Total Study Watershed. MMW is a model developed by Stroud Water Research Center to analyze nationally available landscape, climate and other datasets and model stormwater runoff and water quality impacts (Stroud Water Research Center, 2017). The results are provided in Section 6 and include the potential pollutant load reductions from the implementation of Best Management Practices (BMPs) identified from field assessments.

The modeling compared the TN and TP load in each subwatershed to estimated loads when the TMDLs were developed. The goal in each case was to reduce loads by the amount targeted in each TMDL plan. This was accomplished by determining potential load reduction using the identified stormwater retrofits and stream restoration practices, as well as a combination of agricultural BMPs including conservation tillage practices, nutrient management, and cover crops.

Since the goal was to achieve pollutant reductions in subwatersheds with impaired streams, BMPs were concentrated in the UNTs of the Little Swatara Creek identified in the TMDLs, as well as in the Crosskill Creek Subwatershed. Pollutant reductions are achieved in the overall Little Swatara Creek subwatershed as well, but at a less intense level, resulting in less pollutant reduction (as a percentage) in the overall subwatershed than in the UNTs identified in the TMDL.

Recommended Watershed Management Actions and Implementation Plan

Nine recommendations are provided in Section 8 to achieve the goals of the WIP. These include implementation of agricultural and urban BMPs, stakeholder engagement, business outreach, agricultural land preservation, continued water quality monitoring, review of municipal ordinances specific to warehouse development, and increase staff capacity to support BMP implementation. Section 8.2 provides a summary of the cost for implementation of all identified BMPs at a total of $5.3 million dollars and a list of funding opportunities. A public outreach plan that enhances understanding of the BMPs and provides an opportunity for public involvement is provided in Section 8.3. An implementation table that lists the plan's

recommendations, along with a suggested timeframe for implementation, partners, and milestones is found in Section 8.4. Recommendations include:

- Implement prioritized agricultural BMPs for water quality improvement.
- Continue to engage landowners through outreach to the entire watershed.
- Implement priority stormwater management BMP retrofits for water quality improvement.
- Implement priority streambank restoration projects for water quality improvement.
- Provide outreach to businesses identified as hotspots.
- Review municipal planning model ordinance to address warehouse development.
- Continue to promote preservation of agricultural lands.
- Continue to conduct chemical and biological stream monitoring in the entire watershed.
- Hire additional engineers and trained technicians to increase capacity for BMP implementation.

INTRODUCTION

This watershed implementation plan (the Plan) is developed for the Upper Little Swatara Creek watershed ("total study watershed"), which drains 59.6 square miles (sq. mi.). The total study watershed includes two subwatersheds: the Little Swatara Creek subwatershed that drains 40.7 sq. mi., and Crosskill Creek subwatershed that drains 18.9 sq. mi. (Figure 2). Both HUC12 subwatersheds are included in this plan because they are hydrologically interrelated and have very similar land use/land cover, topography, water quality problems, and restoration opportunities. Developing a single plan that covers both subwatersheds allows for efficiencies in plan development and implementation.

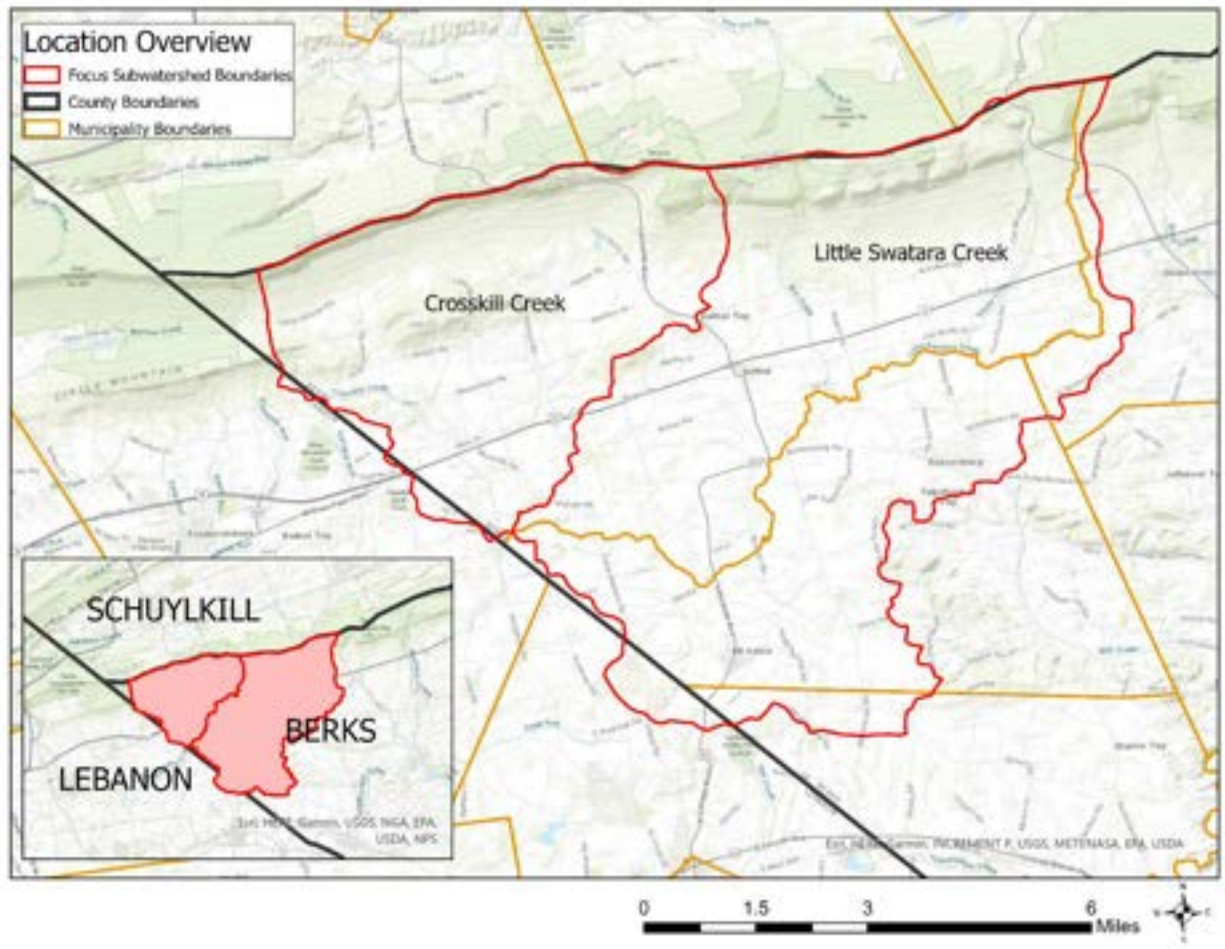

Figure 2. Location overview of the total study watershed

The total study watershed includes portions of Tulpehocken, Upper Tulpehocken, Marion and Bethel Townships in Berks County with a very small portion in Northern Lebanon County. The total study watershed is located in the northwestern corner of Berks County and is a tributary to the Swatara Creek, which drains through Schuylkill, Lebanon, and Dauphin counties before it meets the Susquehanna River at Middletown Borough south of the City of Harrisburg (Figure 3). The total study watershed is the largest portion of Berks County that drains to the Chesapeake Bay and is required to meet the 2010 Chesapeake Bay Total Maximum Daily Load (TMDL). The Berks Bay Action Plan (BBAP) was developed in 2021 and provides current and planned clean water actions to meet Chesapeake Bay goals. This report addresses the two local TMDLs for phosphorus and sediment in the total study watershed and identifies a set of non-point source (NPS) management measures to be implemented to achieve the reductions to meet the local TMDLs.

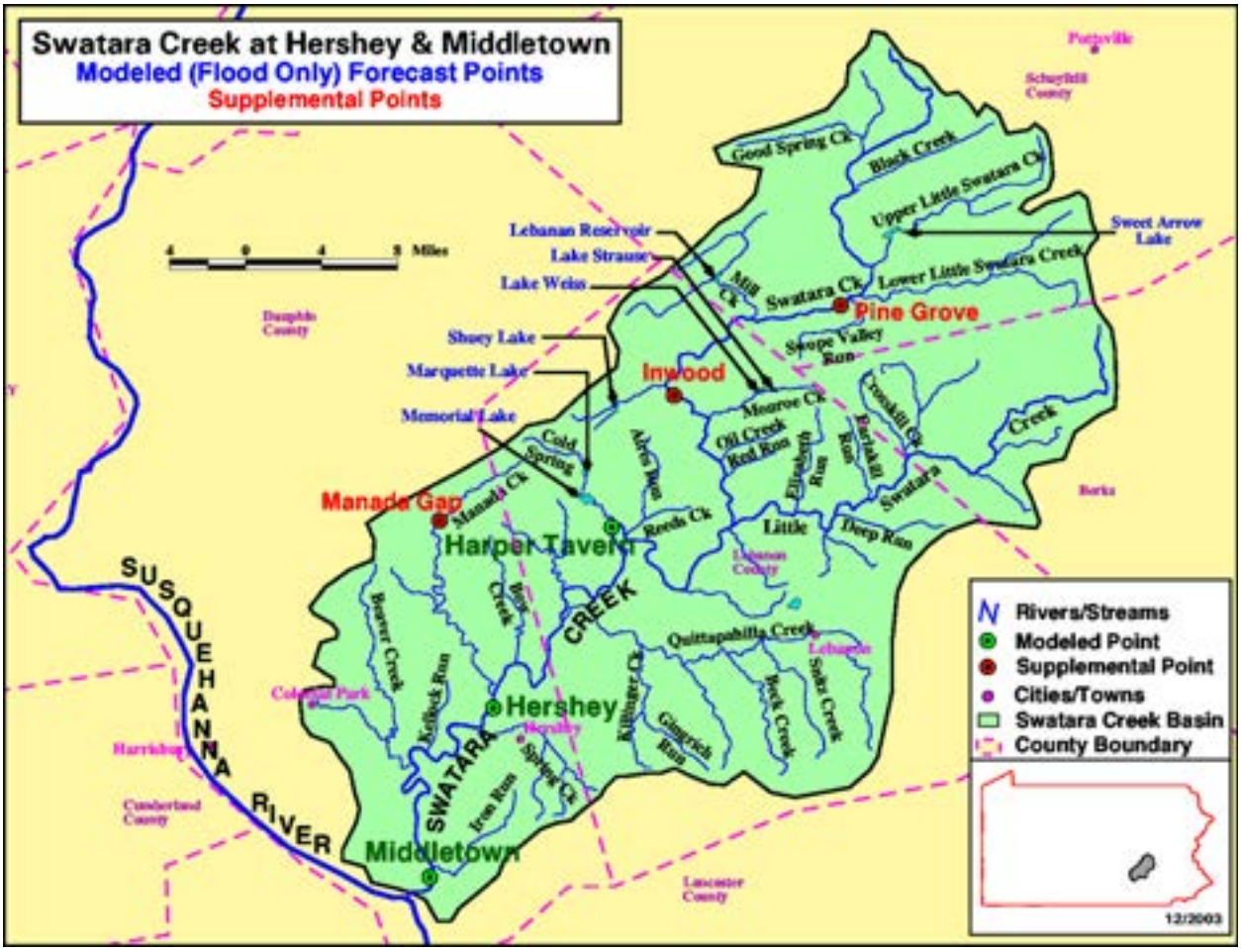

Figure 3. Swatara Creek Watershed (NOAA, National Weather Service, n.d.)

Section 1. Physical and Natural Features

Geology

The geologic map of the total study watershed is found in Figure 4. Table 1 and Table 2 provide areas of the geologic formations in the study watershed and a description of those geologic formations, respectively. The dominant geology is shale and greywacke of Hamburg sequence to the north and Hamburg sequence rocks in the southern half of the total study watershed.

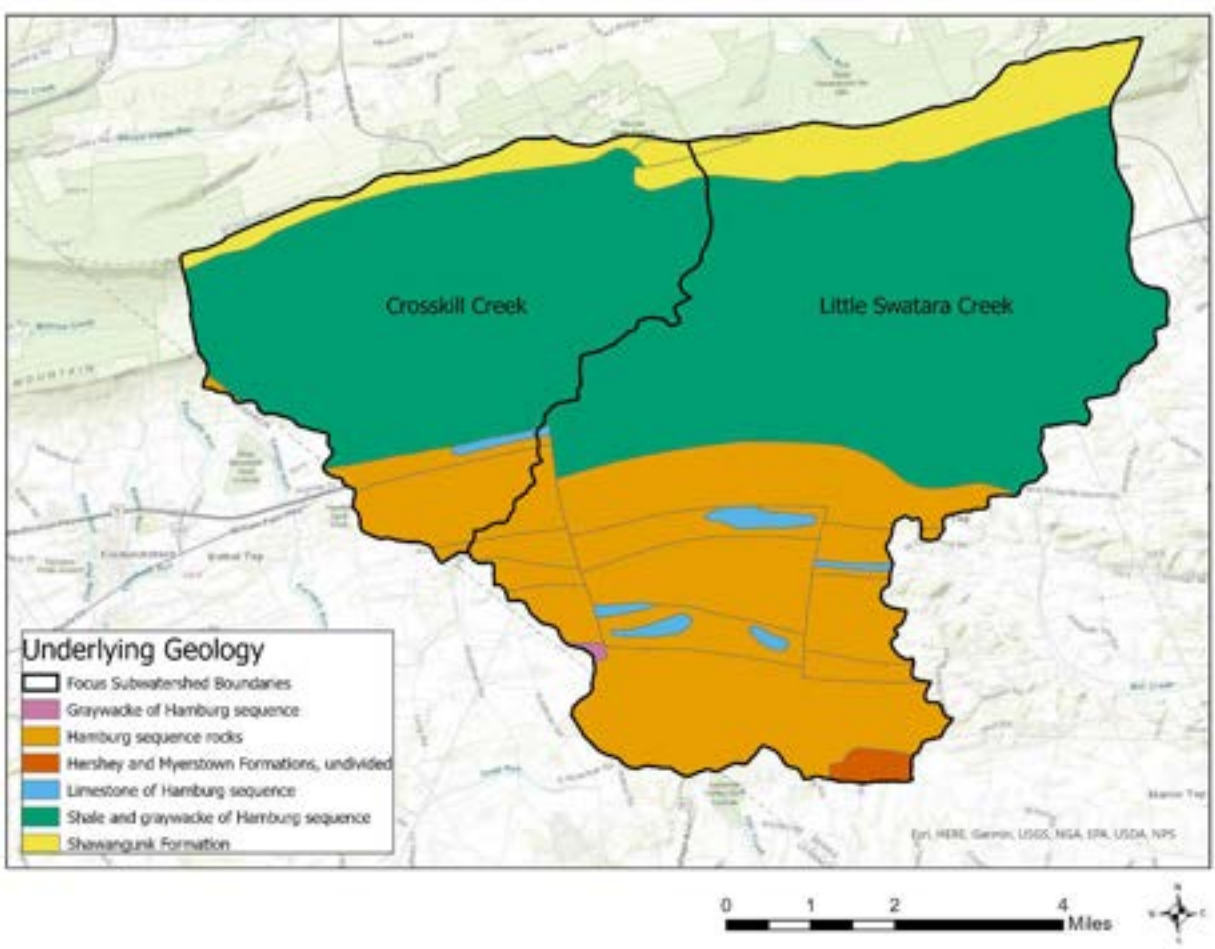

Figure 4. Geology underlying the total study watershed

Table 1. Geology underlying the total study watershed

Underlying Geology	Crosskill Creek		Little Swatara Creek		Total Study Watershed	
	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)
Graywacke of Hamburg sequence	0.0	0.0%	33.4	0.1%	33.4	0.1%
Hamburg sequence rocks	1,403.5	11.6%	10,065.9	38.6%	11,469.4	30.1%
Hershey and Myerstown Formations, undivided	0.0	0.0%	211.5	0.8%	211.5	0.6%

Table 1. Geology underlying the total study watershed

Underlying Geology	Crosskill Creek		Little Swatara Creek		Total Study Watershed	
	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)
Limestone of Hamburg sequence	67.8	0.56%	392.8	1.5%	460.5	1.2%
Shale and graywacke of Hamburg sequence	9,640.0	79.8%	13,294.9	51.0%	22,934.9	60.1%
Shawangunk Formation	967.0	8.0%	2,074.8	8.0%	3041.8	8.0%
Total	12,078.3	100%	26,073.2	100%	38,151.5	100%

Table 2. Definitions of types of underlying geology (Berg et al., 1980)

Underlying Geology	Definition
Graywacke of Hamburg sequence	Predominantly graywacke.
Hamburg sequence rocks (Oh)	Transported rocks of the Hamburg overthrust; gray, greenish-gray, and maroon shale, silty and siliceous in many places; dark-gray impure sandstone; medium-to light-gray, finely crystalline limestone and shaly limestone; total thickness is about 3,000 feet; good surface drainage.
Hershey and Myerstown Formations, undivided	In descending order: Hershey-dark-gray to black, thin-bedded, argillaceous limestone; Myerstown-medium-to dark-gray, platy, medium-crystalline limestone; carbonaceous at base.
Limestone of Hamburg sequence (Ohl)	Hamburg sequence rocks (Oh) with conspicuous limestone.
Shale and graywacke of Hamburg sequence (Ohsg)	Hamburg sequence rock (Oh); shale containing zones of conspicuous greywacke (sandstone).
Shawangunk Formation	Light- to dark-gray, fine to very coarse-grained sandstone and conglomerate containing thin shale interbeds. Includes four members, in descending order: Tammany-conglomerate and sandstone; Lizard Creek- sandstone and red or green shale; Minsi- sandstone and conglomerate: Weiders- conglomerate. Tammany and Lizard Creek Members together are approximately equivalent to Clinton Group to the west; Minsi and Weiders Members together are equivalent to Tuscarora Formation to the west.

Hydrologic Soil Groups (HSGs)

When rain falls over land, a portion runs into streams and the stormwater system while the remaining infiltrates into the soil or evaporates into the atmosphere. The hydrologic soil group (HSG) is a soil property that represents the rate that water infiltrates the soil. Soils are classified into seven soil groups, including four HSGs (A, B, C, and D) based on the soil's infiltration capacity, and three "dual classifications" (A/D, B/D, and C/D) where a soil's infiltration capacity is influenced by a perched water table (Table 3). Data was obtained from the Natural Resource Conservation Service gridded National Soil Survey Geographic Database (gNATSGO), which is developed and maintained by the U.S. Department of Agriculture's Natural Resource Conservation Service (USDA NRCS).

Table 3. Overview of Hydrologic Soil Groups (HSGs)[1]	
Hydrologic Soil Group (HSG)	**Description**
HSG-A	HSG-A soils consist of deep, well-drained sands or gravelly sands with high infiltration and low runoff rates.
HSG-B	HSG-B soils consist of deep, well-drained soils with a moderately fine to moderately coarse texture and a moderate rate of infiltration and runoff.
HSG-C	HSG-C consists of soils with a layer that impedes the downward movement of water or fine-textured soils and a slow rate of infiltration.
HSG-D	HSG-D consists of soils with a very slow infiltration rate and high runoff potential. This group is composed of clays that have a high shrink-swell potential, soils with a high-water table, soils that have a clay pan or clay layer at or near the surface, and soils that are shallow over nearly impervious material.
HSG-A/D	HSG-A/D soils naturally have a very slow infiltration rate due to a high-water table, but they will have high infiltration and low runoff rates if drained.
HSG-B/D	HSG-B/D soils naturally have a very slow infiltration rate due to a high-water table, but they will have a moderate rate of infiltration and runoff if drained.
HSG-C/D	HSG-C/D soils naturally have a very slow infiltration rate due to a high-water table, but they will have a slow rate of infiltration if drained.
No HSG Assigned[2]	Data not available in gNATSGO.

[1] Source: NRCS, 2007 *https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba*
[2] Indicates HSG data was not available within a particular soil boundary.

Figure 5 shows the distribution of HSG within the total study watershed. Table 4 provides a breakdown of the acres and percentage of HSG groups in each subwatershed. Within the total study watershed, HSG-B is dominant at 54.5% indicating that soils are well-drained, and the second dominant soils are HSG-D at 25.45% that are slow to drain.

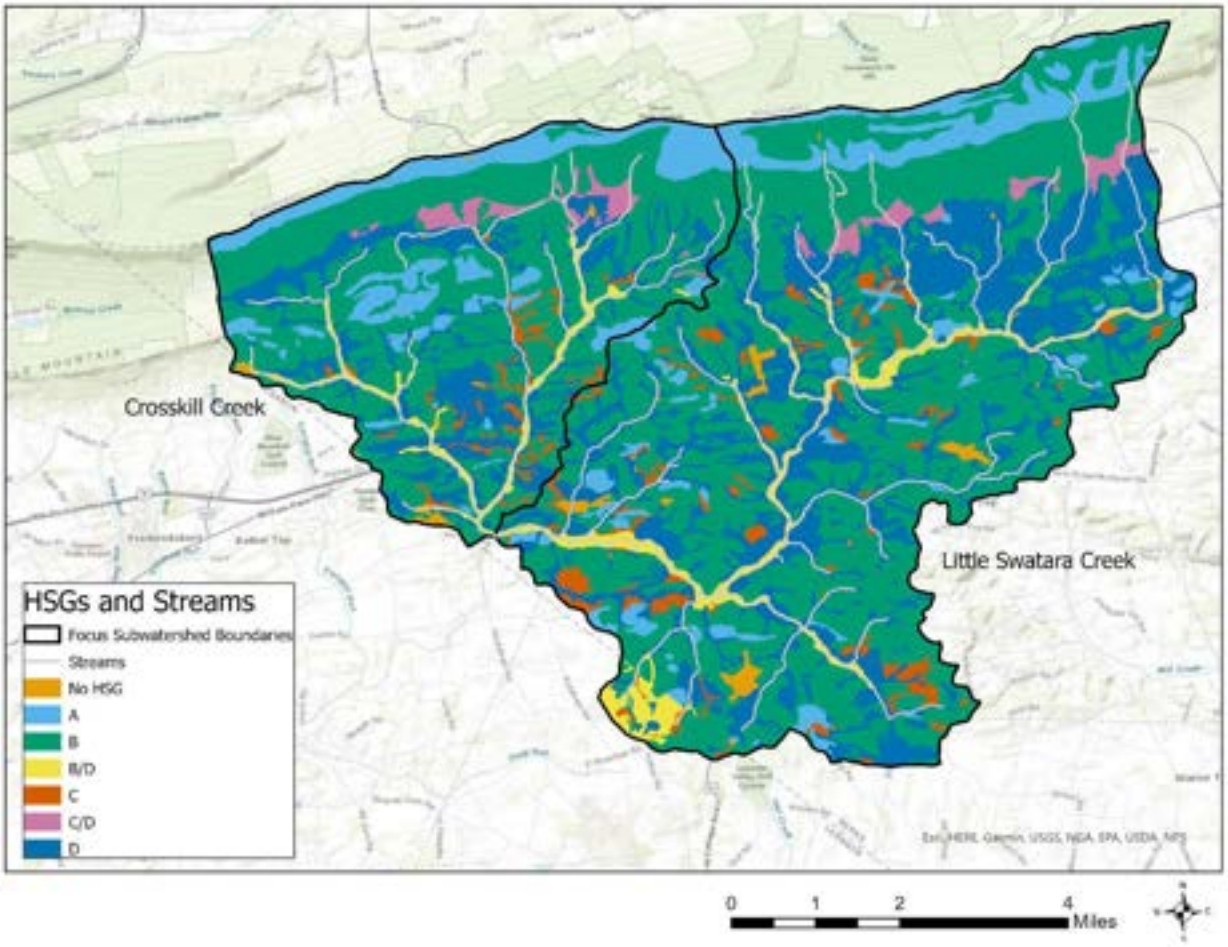

Figure 4. Streams and hydrologic soil groups (HSG) in the total study watershed

Table 4. Hydrologic soil groups (HSG) in the total study watershed

HSG	Crosskill Creek		Little Swatara Creek		Total study watershed	
	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)
A	1,737.9	14.4%	2,155.6	8.3%	3,893.5	10.2%
B	6,715.7	56.0%	14,028.9	53.8%	20,744.6	54.4%
B/D	450.5	3.7%	1,198.8	4.6%	1,649.3	4.3%
C	285.2	2.4%	852.6	3.3%	1,137.8	3.0%
C/D	341.0	2.9%	345.4	1.3%	686.4	1.8%
D	2,452.5	20.3%	7,230.9	27.7%	9,683.4	25.4%
No HSG Assigned	59.3	0.8%	261.1	1.0%	320.4	0.9%
Total	12,078.3	100%	26,073.2	100%	38,115.4	100%

SECTION 2. HYDROLOGY

Annual Precipitation

The average annual precipitation for the City of Reading, PA is 44.77 inches (US Climate Data, 2021).

Surface Water Features

Surface water features are shown in Figure 5 using data from the U.S. Fish and Wildlife Service National Wetlands Inventory (NWI) and summarized in Table 5. The Crosskill Creek subwatershed contains 26.02 miles of streams and the Little Swatara subwatershed contains 58.26 miles of streams for a total of 84.28 miles of stream in the total study watershed. The total study watershed contains less than one percent of freshwater emergent wetlands (0.45%), freshwater forested/shrub wetland (0.68%), and freshwater ponds (0.32%). The wetland acres shown in this section are greater than the wetland acres shown in **SECTION 3. LAND USE LAND COVER**. This variation is due to the differences in the collection methods and analysis of the source data.

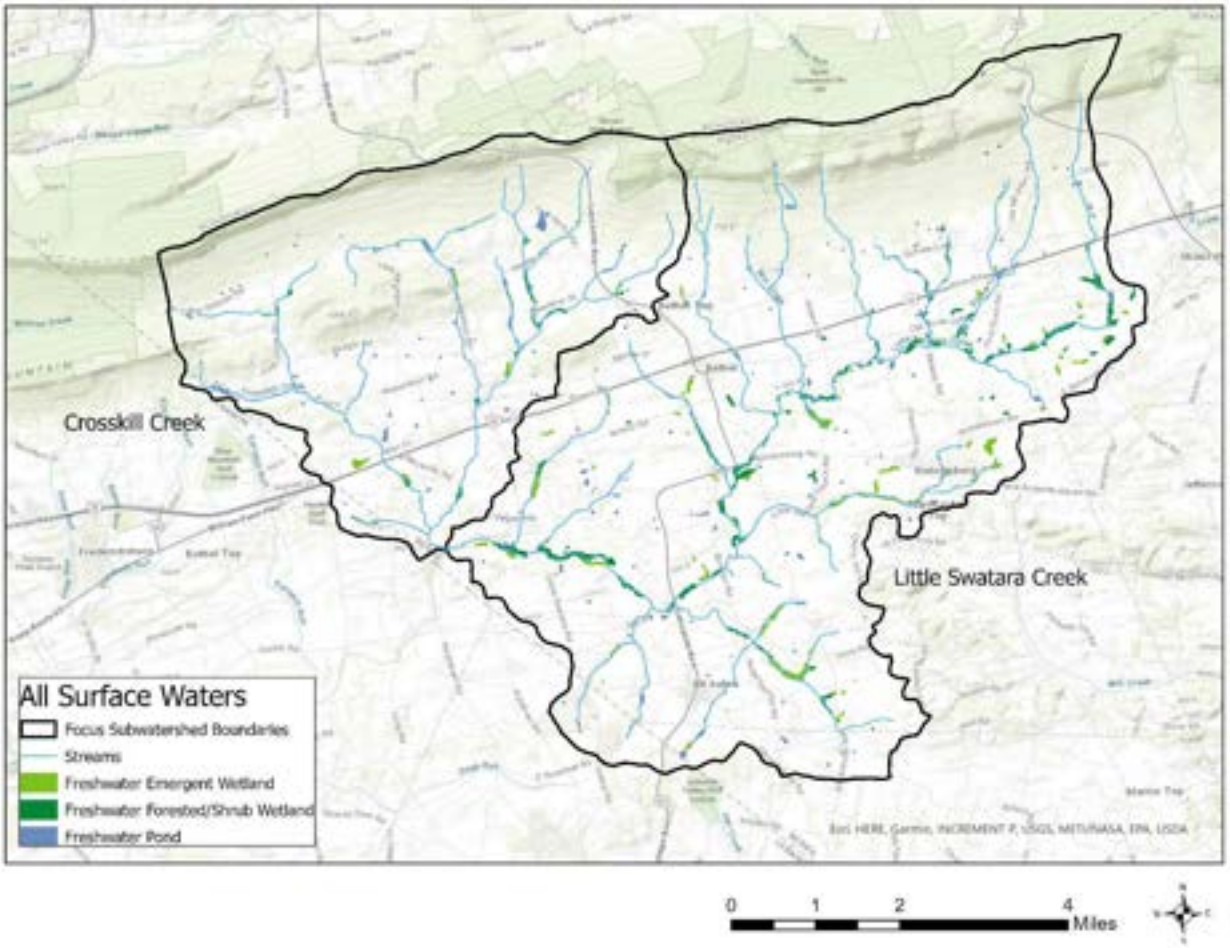

Figure 5. All surface water features within the total study watershed

Table 5. All surface water features and total stream lengths in the total study watershed						
Waterbody Type	**Crosskill Creek**		**Little Swatara Creek**		**Total Study Watershed**	
	Area	Percentage of Total Area (%)	Area	Percentage of Total Area (%)	Area	Percentage of Total Watershed Area (%)
Freshwater Emergent Wetland (acres)	26.8	0.22%	145.4	0.56%	172.2	31.2%
Freshwater Forested/Shrub Wetland (acres)	26.3	0.22%	231.9	0.89%	258.2	46.8%
Freshwater Pond (acres)	45.7	0.38%	75.5	0.29%	121.2	22.0%
Total Wetland Area	98.8	0.82%	452.8	1.74%	551.6	100%
Streams (miles)	26.0	100%	58.3	100%	84.3	100%

Surface Water Conditions

The streams in the total study watershed are designated as protected for aquatic life use as cold-water fishery and recreational use (PA Chapter 93). Cold Water Fishery is defined as, “Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold-water habitat” (PA Chapter 93). Recreation use includes boating, fishing, water contact sports, and esthetics (PA Chapter 93). Fishing is the most likely recreational use in the total study watershed as the Little Swatara mainstem is stocked with trout from the headwaters to the Berks/Lebanon County line (PA Fish and Boat Commission, Trout Streams, 9/13/21). Swimming, wading, and small watercraft may also be other forms of recreational use. (K. Himelright, personal communication, August 31, 2021).

In both subwatersheds, most stream miles are impaired for recreational use but support the aquatic life use (Figure 6, Figure 7, and Table 6). In the Crosskill Creek subwatershed, 77% of stream miles are impaired for recreational use while 29% of the stream miles are impaired for aquatic life use designation and there is no natural trout reproduction use. In the Little Swatara Creek subwatershed, 33% of stream miles are impaired for recreational use, while 41% are impaired for aquatic life use designation, and 1.5 miles of streams support natural trout reproduction use on Mill Creek. Natural reproduction is defined by PFBC as supporting naturally reproducing populations of trout but may also be stocked. In addition, 5.9 miles of the mainstem is stocked with trout by the Pennsylvania Fish and Boat Commission (PFBC) (Figure 8 and Table 6).

The PA DEP recently released their Draft 2024 Integrated Water Quality Report.[1] Not all streams in the subwatersheds were reassessed; however, of those segments that were reassessed, there is only a single, two-mile segment in the Crosskill Creek subwatershed with an impairment change. That segment is an unnamed tributary to Crosskill Creek that was originally impaired for both aquatic life and recreational uses, but its aquatic life impairment was delisted, so it is now only impaired for recreational uses.

In the total study watershed, nutrients, siltation, flow regime modification, organic enrichment, and pathogens are identified as the pollutants causing the impairments and the sources are agricultural land, urban runoff/storm sewers, and pathogens from on-site treatment systems (septic systems and similar decentralized systems) (2020 PA Integrated Waters Report). Potential causes of aquatic life impairment include unrestricted livestock access to streams and lack of riparian buffers in agricultural land uses. The recreational use impairment is from pathogens caused by agricultural land and on-site treatment systems. This Plan addresses the sediment and phosphorus TMDLs that impact aquatic life use and not the recreational use impairment.

[1] See the “2022 to 2024 Changes” section of PA DEP’s Draft 2024 Pennsylvania Integrated Water Quality Report StoryMap: https://storymaps.arcgis.com/stories/7af67824d6924b88b544dbad302ebc4f

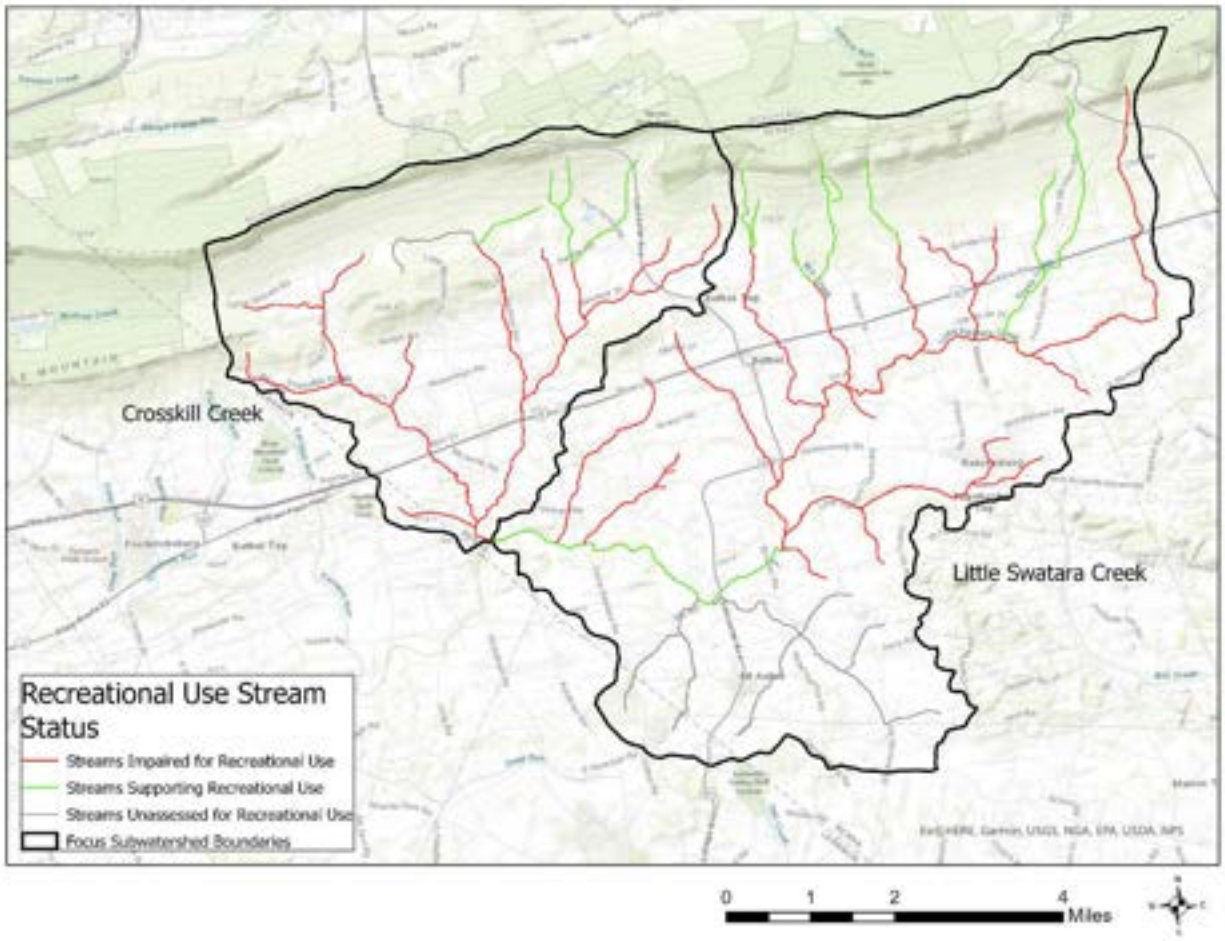

Figure 6. Recreational use status of streams in the total study watershed

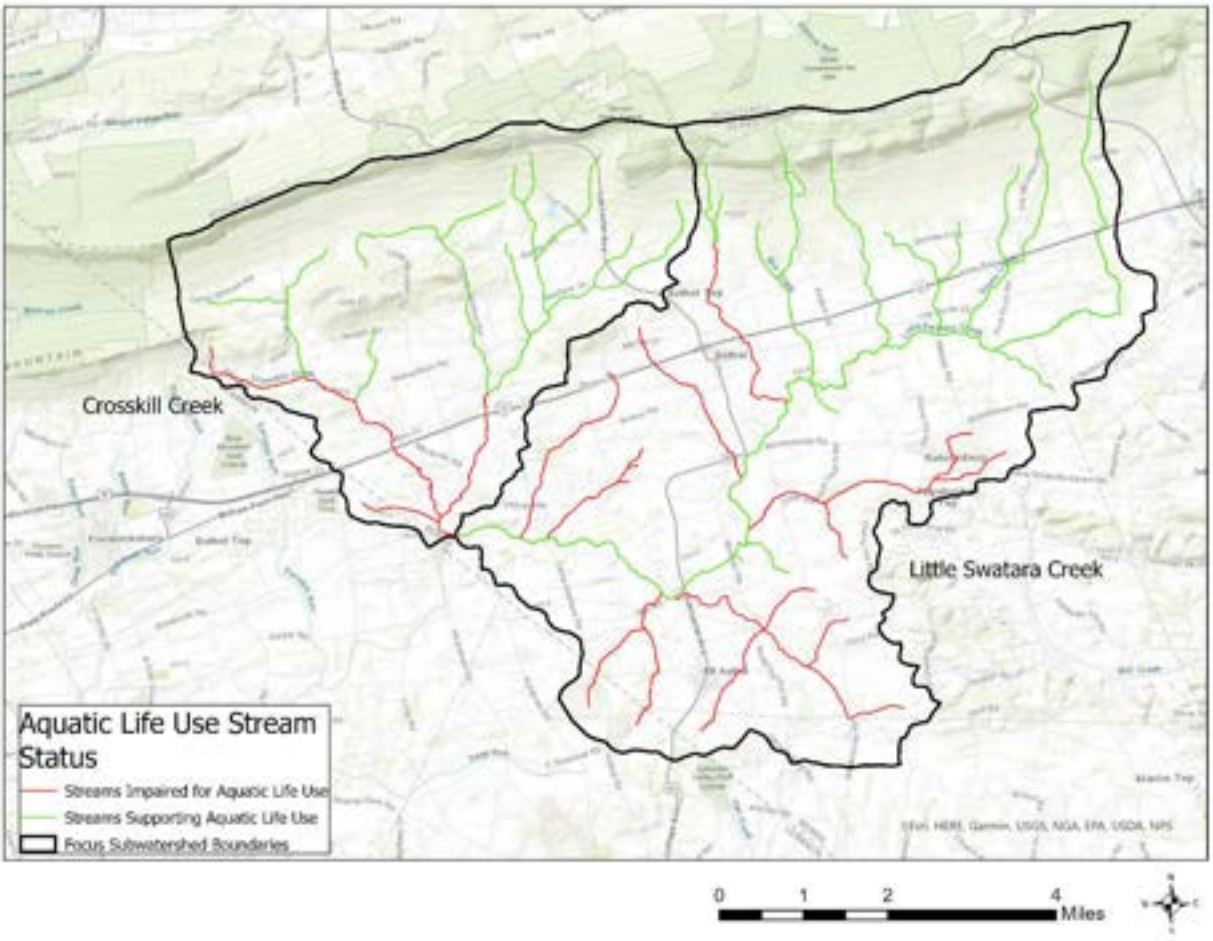

Figure 7. Aquatic life use status of streams in the total study watershed

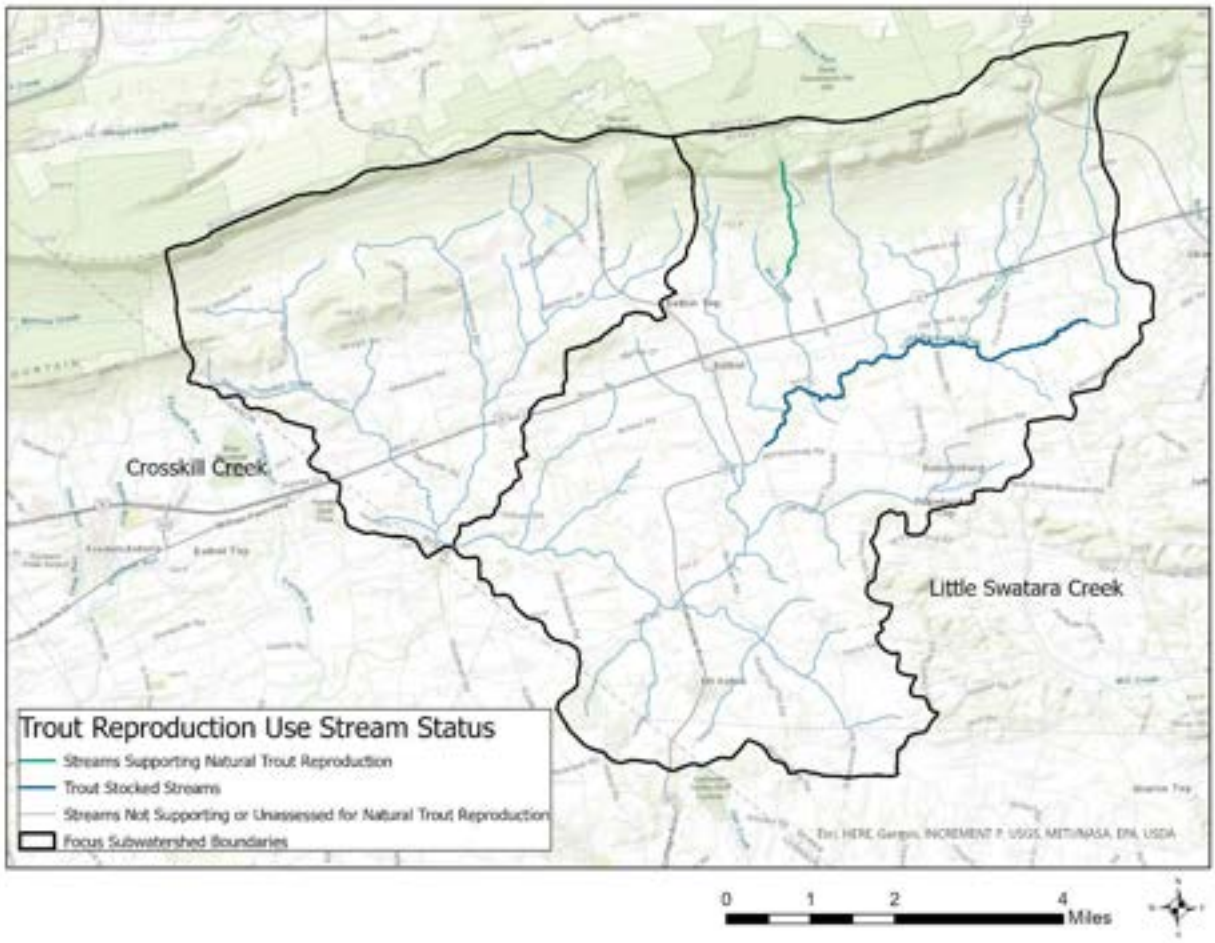

Figure 8. Natural trout reproduction and stocked trout streams in the total study watershed

Table 6. Stream status for designated uses in the total study watershed						
Status for Designated Stream Use	**Crosskill Creek**		**Little Swatara Creek**		**Total Study Watershed**	
	Stream Miles	Percentage of Total Miles (%)	Stream Miles	Percentage of Total Miles (%)	Stream Miles	Percentage of Total Stream Miles (%)
Recreational						
Supporting	4.4	16.9%	14.9	25.6%	19.3	22.8%
Impaired	20.0	76.9%	33.2	56.9%	53.2	63.1%
Unassessed	1.6	6.1%	10.2	17.4%	11.8	13.9%
Aquatic Life[2]						
Supporting	20.3	78.1%	33.2	56.9%	53.5	63.5%
Impaired	7.5	28.8%	25.1	43.1%	32.6	38.7%
Unassessed	0.0	0.0%	0.0	0.0%	0.0	0.0%
Natural Trout Reproduction						
Supporting	0.0	0.0%	1.5	2.5%	1.5	1.8%
Not Supporting or Unassessed	26.0	100.0%	56.8	97.4%	82.8	98.2%
Stocked Trout Streams						
Supporting	0.0	0.0%	5.9	10.1%	5.9	6.9%
Not Supporting or Unassessed	26.0	100.0%	52.4	89.8%	78.4	93.0%
Total Stream Miles	26.0	–	58.3	–	84.3	–

Total Maximum Daily Loads (TMDLs)

Under the Clean Water Act, each state is required to designate uses for each water body and establish water quality criteria that must be met to support those uses. States regularly assess water quality and report on whether the water quality criteria are being met. Where water bodies are too polluted to meet the established water quality criteria, they are added to an "impaired waters list". In Pennsylvania, the PA DEP develops a TMDL for waterbodies identified as impaired with the goal of "de-listing" or improving the stream so that it can fully support its designated uses. A TMDL is a report that calculates the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL consists of a Wasteload Allocation (WLA) that includes point sources, a Load Allocation (LA) that includes non-point sources and natural background conditions, and a Margin of Safety (MOS) to account for uncertainty in the various aspects of TMDL development.

The following TMDLs have been developed to address the water quality impairments in the total study watershed: 1) a 2011 phosphorus and sediment TMDL for the Little Swatara Creek tributaries, and 2) a 2004 sediment TMDL for a portion of Crosskill Creek. Both TMDLs were developed using the reference watershed approach that compares the pollutant loading rate from a watershed attaining its uses to one that is impaired based on biological assessments. This approach is used as both PA DEP and the U.S. Environmental Protection Agency (USEPA) do not provide instream numerical water quality criteria for sediment and nutrients. The reference watershed has similar physical characteristics to the impaired waterbody, including size, land use, geology, and others. The reference watershed meets water quality standards and is used as a benchmark pollutant loading rate to attain designated uses in the impaired waterbody. The ArcView Generalized Watershed Loading Function (AVGWLF) model was used to establish existing loading conditions for the impaired watershed and the reference watershed.

[2] Due to overlap in Pennsylvania's Integrated List Attaining and Integrated List Non-Attaining GIS layers, there is approximately 2.6 miles of unidentifiable overlap in the aquatic life use stream categorizations in Little Swatara Creek subwatershed.

CROSSKILL CREEK SEDIMENT TMDL (PA DEP, 2004)

The Crosskill Creek first appeared on PA's 303d list in 1996 and a TMDL for the upper Crosskill Creek watershed was developed in 2004 to address use impairments caused by turbidity and suspended solids coming from upstream agricultural activities and streambank erosion (nonpoint sources). The upper Crosskill Creek watershed covered in the TMDL encompasses a portion of the total study watershed, consisting of 5.1 miles of streams, including Meck Creek (Figure 9). Unnamed tributary 09929, a subwatershed of Crosskill Creek, was used as the reference watershed for this TMDL (Figure 9). The watershed has no known point sources and therefore does not include a Waste Load Allocation (WLA). Using the AVGWLF model, the TMDL estimates a 24% or 1,611,793 lbs/year reduction of pounds per year of sediment is required to attain water quality standards. The load allocation (LA) land uses where sediment reduction practices will occur include hay/pasture, cropland, transition, and stream bank erosion sources. The TMDL report notes that a future TMDL will be developed to address the pathogen impairment in the Crosskill Creek watershed.

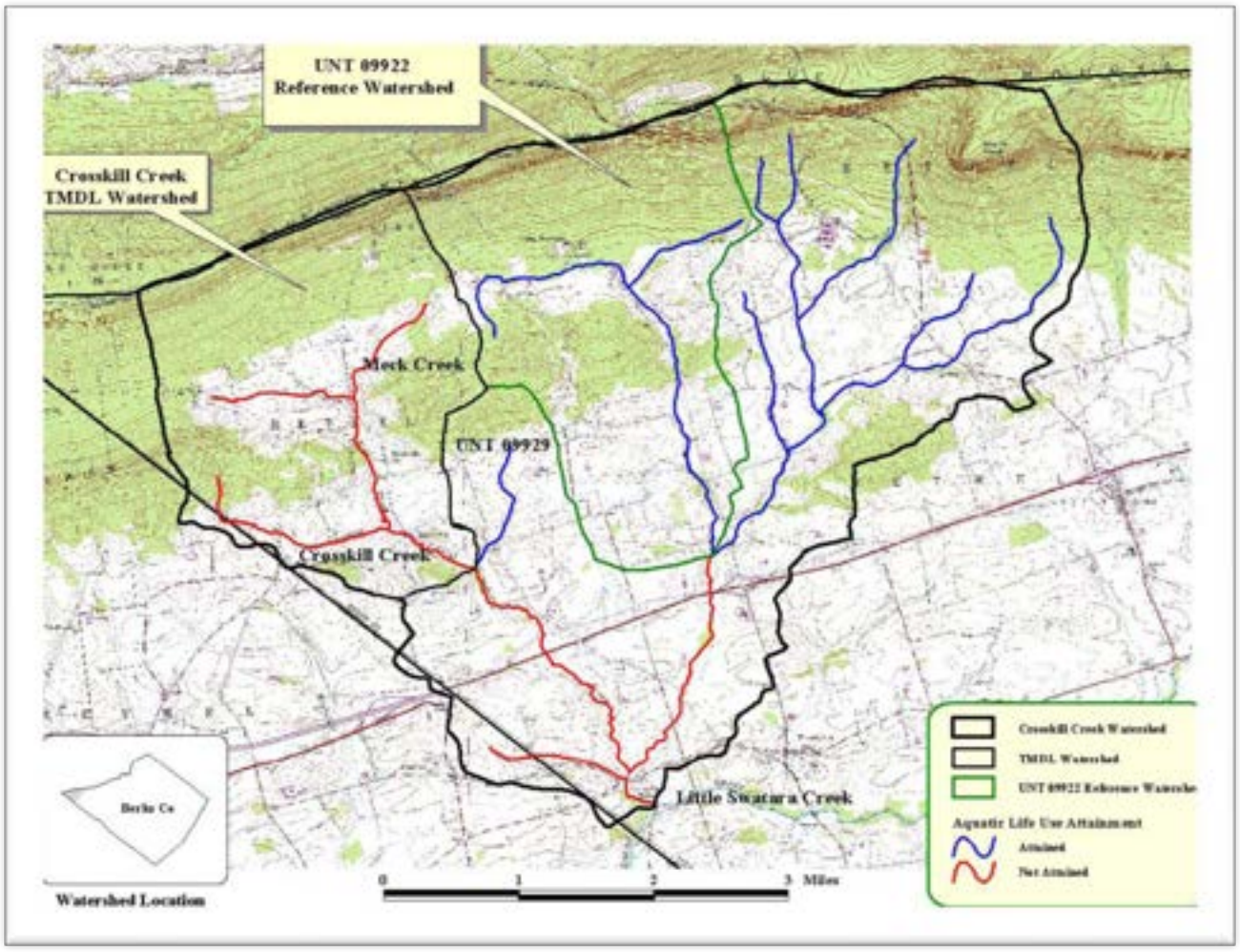

Figure 9. Location of Crosskill Creek TMDL watershed (PA DEP, 2004)

LITTLE SWATARA CREEK TRIBUTARIES TMDL (PA DEP, 2011)

In 2011, a TMDL was developed to address phosphorus and sediment impairments identified in the 2008 303(d) list for seven unnamed tributary watersheds to the Little Swatara Creek. The Little Swatara Creek tributaries in the TMDL includes six unnamed tributary (UNT) subwatersheds located inside and one located outside the total study watershed (Figure 10). Together the seven UNT subwatersheds drain approximately 18.27 square miles and all have an adjusted load allocation (ALA) goal for sediment and phosphorus or only phosphorus (UNT 09933 and UNT 09902) measured in lbs/day. The ALA is defined as the portion of the load

allocation (LA) distributed among nonpoint sources that are considered controllable. These include hay/pasture, cropland, developed lands, and streambanks. The watershed aquatic life existing uses are cold water fisheries upstream of the Berks/Lebanon County line and warm water fisheries downstream of the county line. Identified sources of impairments are from agricultural and residential land use practices. The watershed has no known point sources or WLA. Mill Creek, a tributary to the Little Swatara Creek, is a reference watershed for this TMDL as it is attaining water quality standards to meet the designated use as a cold-water fishery. The TMDL estimates a mean annual loading for sediment will need to be reduced from 1,040.8528 to 2,821.2366 pounds per day (lbs/day) and for phosphorus from 0.6961 to 2.9957 lbs/day to meet water quality standards. The LA land uses where sediment reduction practices will occur include hay/pasture, cropland, developed areas, and stream bank erosion sources.

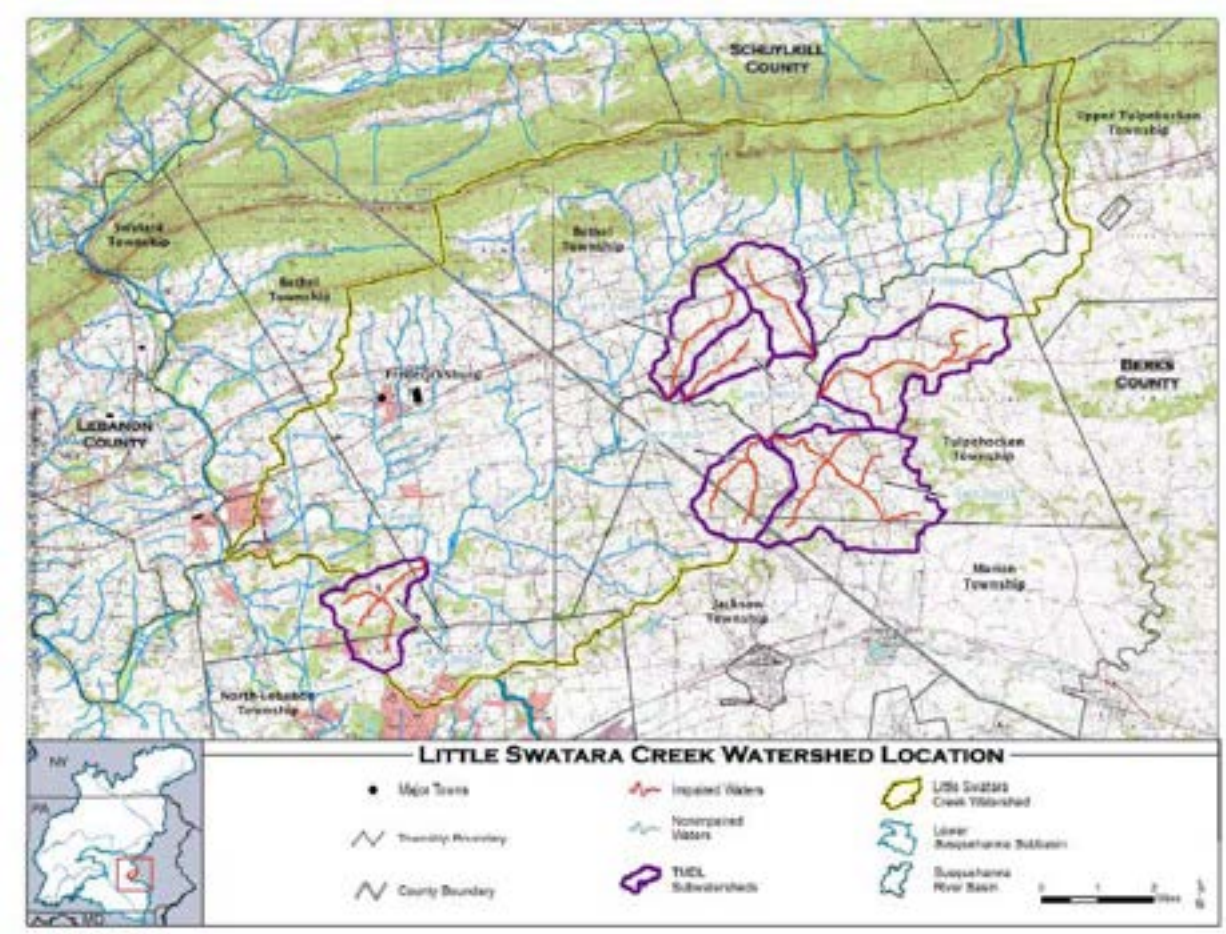

Figure 10. Location of Little Swatara Creek TMDL watershed (PA DEP, 2011)

Water Quality

In the spring of 2021, Berks County Conservation District (BCCD) conducted chemical, biological, and physical habitat assessments at twelve specific stream sites to establish a water quality baseline for development of the Plan. PA DEP water quality monitoring protocols for streams and rivers (PA DEP, 2018) were used for data collection and evaluation. Suburban Testing Labs, Inc. (STL) was utilized for data analysis and JB Ecological Services conducted physical and biological assessments at 10 permanent sites and two floating sites. Sampling and laboratory protocols are provided in the project Quality Assurance Protection Plan (QAPP) (CWP, 2001). Site selection focused on small subwatersheds (less than five sq. mi.) where past and future conservation BMPs have been or will be implemented and near existing PA DEP stream monitoring sites. The water quality data will assist in determining restoration potential, and it will provide a comparison for determining incremental success of future implementation and a long-term monitoring program.

Figure 11 provides the locations of the 12 sites sampled in 2021 by BCCD, nine sites sampled in 2019 by PA DEP, and nine sites sampled in 2022 by PA DEP to reassess the aquatic life use in the Crosskill Creek subwatershed. Table 7 provides an abbreviated version of water quality sampling results for key parameters analyzed using the 2019 PA DEP and 2021 BCCD data. Due to budget constraints, physical and biological assessments were not conducted at sites LSW-05 and LSW-09. This is indicated in Table 7 as 'nd' or no data. Table 8 provides IBI scores from the 2022 PA DEP sampling.

The standard for chloride is a maximum of 250 mg/L for a public water supply. While none of the sites are near this threshold, Table 7 shows chloride concentrations that are comparatively high at sites LSW-05 and LSW-09. The water quality categories for Total Nitrogen (TN) and Total Phosphorus (TP) are color-coded in Table 7. Total Nitrogen concentrations at most sites are in the moderate category and LSW-06 has a high concentration of TN at 9.17 mg/l. Most sites have low (< 0.1 mg/L) Total Phosphorus concentrations with three sites in the moderate category (0.1 – 0.3 mg/L; US EPA, n.d.). The Index of Biological Integrity (IBI) is a general index used to assess stream biological health. The IBI score is categorized as poor, fair, good or excellent. Bacteria was sampled as fecal coliform with a seasonal standard of a geometric mean of 200 per 100 mL during the swimming season (Chapter 93). Five of the sampled locations exceed the fecal coliform seasonal standard. The revised bacteria criteria during the swimming season are a maximum E. coli geometric mean of 126 colony forming units (CFU) per 100 ml (Title 25 Chapter 93. Specific water quality criteria). For the purposes of this report, the fecal coliform standard is used.

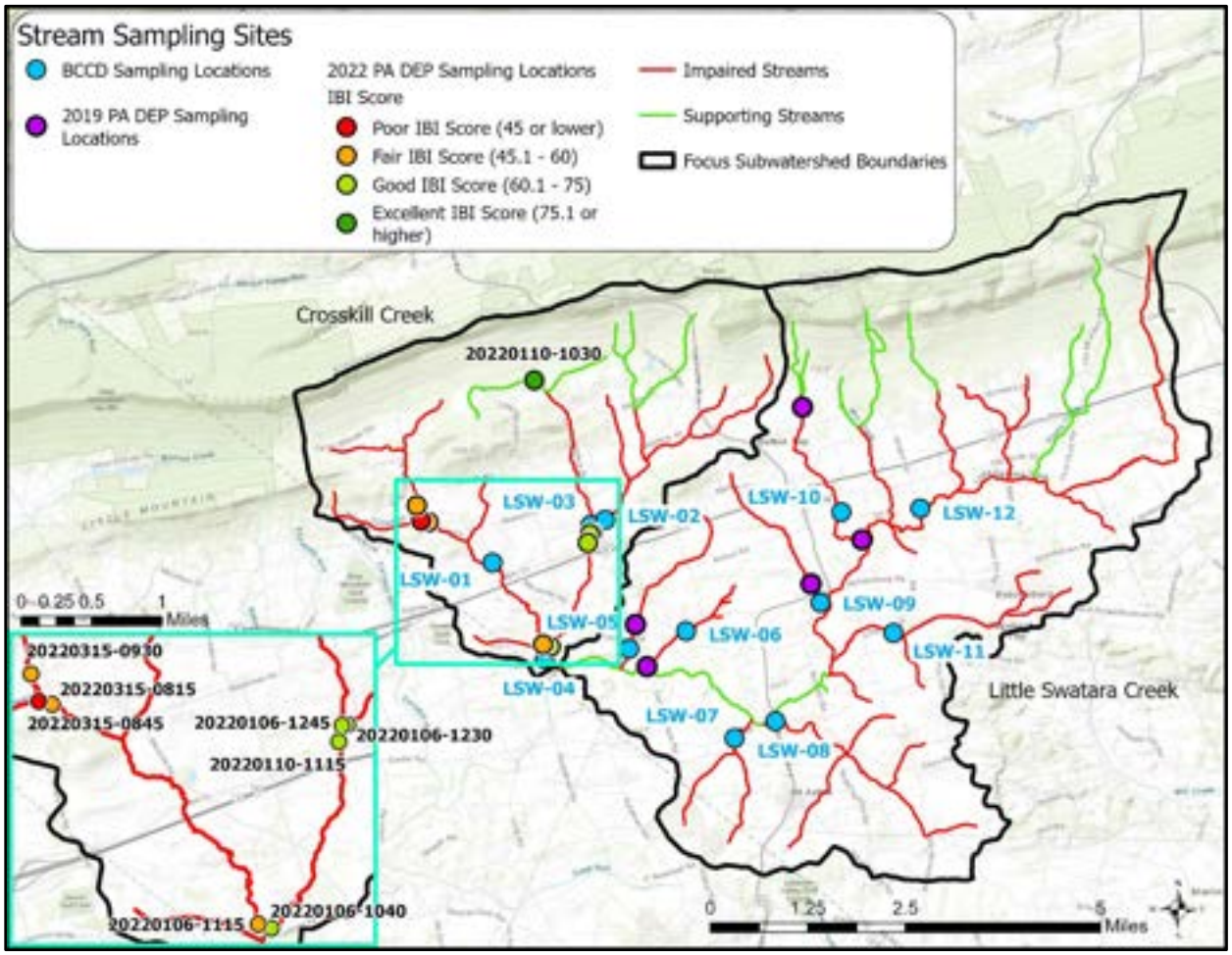

Figure 11. Stream sampling sites (BCCD and PA DEP) in the total study watershed

Table 7. Summary of water quality data from in the total study watershed

Site ID	Chloride (mg/L)	TN (mg/L)	TP (mg/L)	pH	Fecal Coliform /100ml	Habitat Assess-ment Total Score	BCCD 2021 IBI Score	PADEP 2019 IBI Score
LSW-01	6.91	1.75	0.2	7.63	104	153	59.8	nd
LSW-02	9.26	2.10	< 0.10	7.64	124	156	53.1	nd
LSW-03	7.61	1.74	0.12	7.53	132	177	52.8	nd
LSW-04	7.97	2.07	0.14	7.31	88	147	57.5	nd
LSW-05	57.1	3.92	< 0.10	nd	188	nd	nd	42.7
LSW-06	20.5	9.17	0.10	6.82	281	139	32.9	43.3
LSW-07	19.4	5.33	< 0.10	7.62	211	162	38.2	nd
LSW-08	15.6	5.62	< 0.10	7.69	140	148	44.4	nd
LSW-09	80.7	4.69	< 0.10	nd	204	nd	nd	45.8
LSW-10	8.28	1.70	< 0.10	7.4	98	162	42.9	45.2
LSW-11	14.0	5.55	< 0.10	7.07	204	158	41.0	nd
LSW-12	12.0	1.59	< 0.10	6.75	277	178	53.6	nd

Total nitrogen and total phosphorus. Low=blue, moderate=yellow, high=orange, very high=red
Fecal coliform. Above standard=red, at or below standard=blue
IBI score and PA DEP 2019 IBI:

- Poor= 45 or less (red)
- Fair=45.1 – 60 (orange)
- Good= 60.1 – 75 (light green)
- Excellent= 75.1 > (dark green)

Table 8. PA DEP 2022 IBI Scores	
Site ID	**PADEP 2022 IBI Score**
20220315-0845	32.8
20220106-1115	49.4
20220315-0815	52.1
20220315-0930	58.1
20220106-1230	61.8
20220106-1040	64.5
20220110-1115	67.0
20220106-1245	69.8
20220110-1030	87.1

SECTION 3. LAND USE LAND COVER

Land Use Land Cover

The existing land use land cover (LULC) in the total study watershed is predominantly cropland (40.6%), forest (33.2%), and pasture/hay (8.7%), as seen in Figure 12 and Table 9. This cropland is primarily herbaceous, although it does include barren cropland and orchards/vineyards, both of which comprise less than 1% of the total cropland in the total study watershed.

The average agricultural operation size is approximately 125 acres and dominant crops include no-till corn grain, soybean, and small grain for silage. Other conventional crop rotations include corn silage, alfalfa hay, and small grains. Livestock operations primarily include dairy and pastured livestock including beef cows, sheep, and horses. The entire study watershed has access to US Interstate 78 that allows for convenience to getting a product to market and therefore opens the corridor to high density poultry and swine operations including broilers, layers, turkey, and finishing hogs (K. Himelright, personal communication, May 11, 2023). The watershed includes 14 Concentrated Animal Feeding Operations (CAFOs), which are discussed further in Section 4.

The existing LULC dataset has 1-meter resolution and was developed by the Chesapeake Conservancy in partnership with the U.S. Geological Survey (USGS) and the University of Vermont Spatial Analysis Lab. The data represents land cover conditions as evident in NAIP (National Agriculture Imagery Program) imagery for the years 2017/2018 (Chesapeake Conservancy, n.d.).

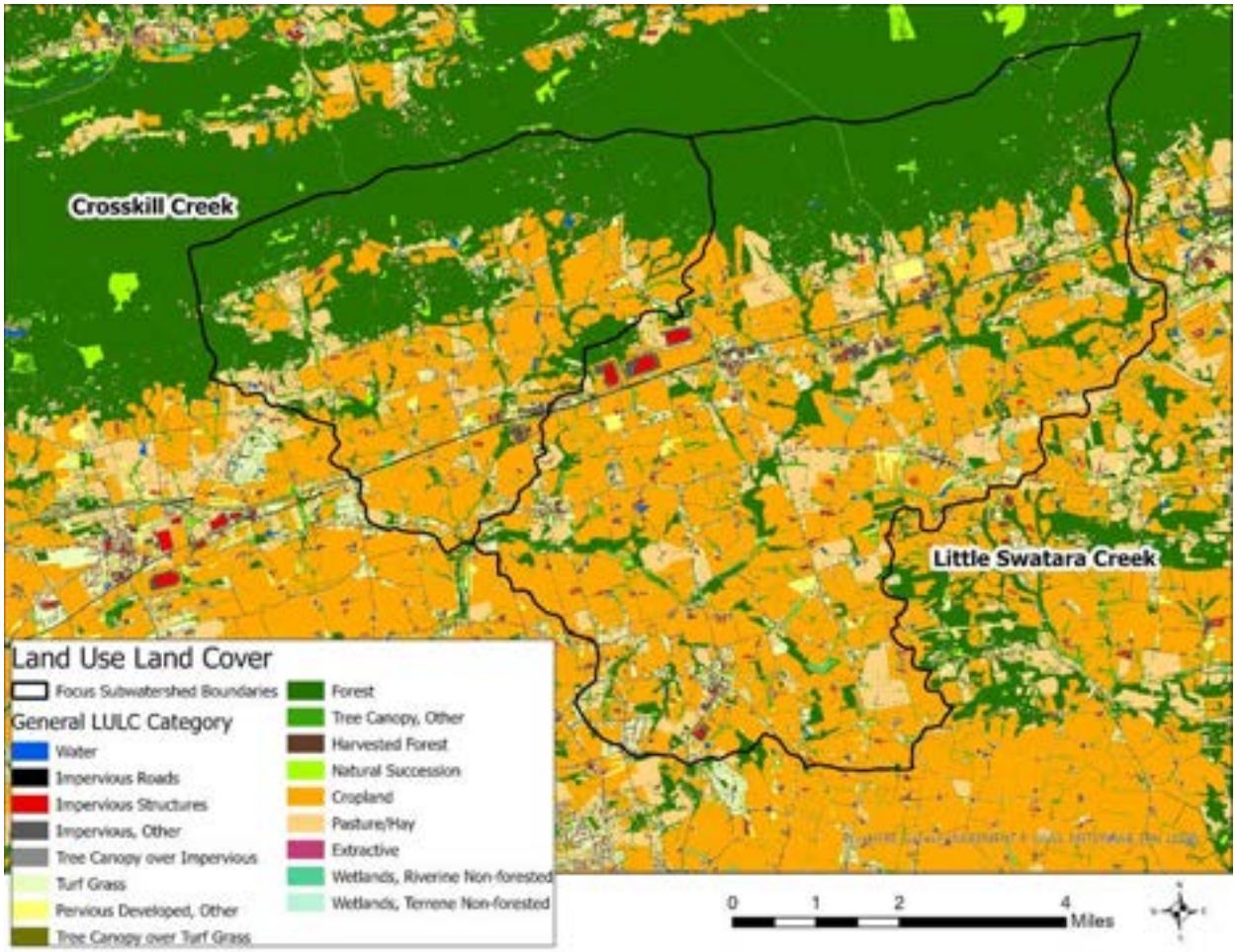

Figure 12. Land use land cover (2017/2018) in the total study watershed

Table 9. Land use land cover (2017/2018) in the total study watershed

Land Cover Classification	Crosskill Creek		Little Swatara Creek		Total Study Watershed	
	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Watershed Area (%)
Water	55.2	0.5%	126.5	0.5%	182.1	0.5%
Impervious Roads	146.4	1.2%	377.8	1.4%	524.2	1.4%
Impervious Structures	79.1	0.7%	331.5	1.3%	410.6	1.1%
Impervious, Other	143.8	1.2%	617.7	2.4%	761.5	2.0%
Tree Canopy over Impervious	57.1	0.5%	68.3	0.3%	125.4	0.3%
Turf Grass	441.5	3.7%	1,341.0	5.1%	1,782.5	4.7%
Pervious Developed, Other	164.0	1.4%	561.5	2.2%	725.5	1.9%
Tree Canopy over Turf Grass	216.4	1.8%	468.6	1.8%	685.0	1.8%
Forest	5,624.2	46.6%	7,033.3	27.0%	12,657.5	33.2%
Tree Canopy, Other	264.5	2.2%	763.8	2.9%	1,028.23	2.7%
Natural Succession	136.2	1.1%	165.6	0.6%	301.7	0.8%
Cropland	3,913.6	32.4%	11,571.4	44.4%	15,485.0	40.6%

Table 9. Land use land cover (2017/2018) in the total study watershed						
Land Cover Classification	**Crosskill Creek**		**Little Swatara Creek**		**Total Study Watershed**	
	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Watershed Area (%)
Pasture/Hay	810.3	6.7%	2,495.8	9.6%	3,306.1	8.7%
Wetlands, Riverine Non-Forested	21.5	0.2%	122.4	0.5%	143.9	0.4%
Wetlands, Terrene Non-Forested	0.05	< 0.01%	11.08	0.04%	11.13	0.03%
Total	12,074.17	–	26,056.05	–	38,130.22	–

The impervious cover is approximately 5.2% for the total study watershed, with similar impervious cover percentages in both the Crosskill Creek (4.9%) and Little Swatara Creek (5.4%) subwatersheds (Table 10). Based on the Impervious Cover Model, the watershed is in the “Sensitive” category defined as impervious cover between 0% and 10%. Within this range, the watershed generally supports its designated use and should apply other metrics such as forest cover, road density, or crop cover to predict stream quality (Schueler et al., 2009). Impervious cover was calculated as the sum of these categories from the land cover data in Table 9: impervious roads, impervious structures, other impervious, and tree canopy over impervious.

Table 10. Impervious cover in the total study watershed		
Watershed Name	**Impervious Cover**	
	Area (acres)	Percentage of Total Area (%)
Crosskill Creek	586.6	4.9%
Little Swatara Creek	1,395.9	5.35%
Total Study Watershed	38,150.2	5.2%

Easements and Managed Lands

Berks County employs two easement programs, the Berks County Agricultural Conservation Easement (ACE) program and Berks Nature conservation easement program. A conservation easement is a legal agreement between a landowner and a land trust government agency that permanently limits uses of the land to protect its conservation values. Within the total study watershed, 24.6% of land is held in a conservation easement with 24.2% in the ACE program and 0.4% in the Berks Nature Conservation Easement program (Figure 13 and Table 11).

Managed lands include Pennsylvania state game lands and State Forest lands along the northern boundary near the Blue Mountains Ridge. Within the total study watershed, 2.4% of land is state game lands and 0.4% is state forest lands (Figure 13 and Table 12).

The Berks County Agricultural Land Preservation Office manages an agricultural conservation easement program (ACE), which is funded by the state and county and has protected over 50,000 acres of farmland since its inception in 1989. In this program, agricultural conservation easements are purchased or donated voluntarily by a landowner to protect farms for agriculture in perpetuity. Land protected by an easement can only be used for agricultural production or commercial equine activity and may not be developed. Protecting groups or clusters of farms helps maintain agriculture as a viable industry, and the goal of the program is to purchase agricultural conservation easements in perpetuity to keep land in agricultural production and help ensure the future of agriculture in Berks County. To qualify for this program, landowners submit an application

to apply to the program and are required to meet minimum criteria including the size of the easement, location within an agricultural security area and others, and properties are selected based on ranking criteria and available funding. Once the easement is finalized, the landowner is compensated based on appraisal values and maximum payments per acre (Berks County, 2021).

Berks Nature is a non-profit conservation organization in Berks County whose primary function is to serve as a land trust. They manage conservation easements that focus on protecting conservation values. Their role is to enforce the restrictions identified in a property's conservation easement document. This enforcement includes monitoring properties to ensure it remains in the condition identified in the conservation easement, long-term stewardship, and defense of the conservation easements (Berks Nature, 2021).

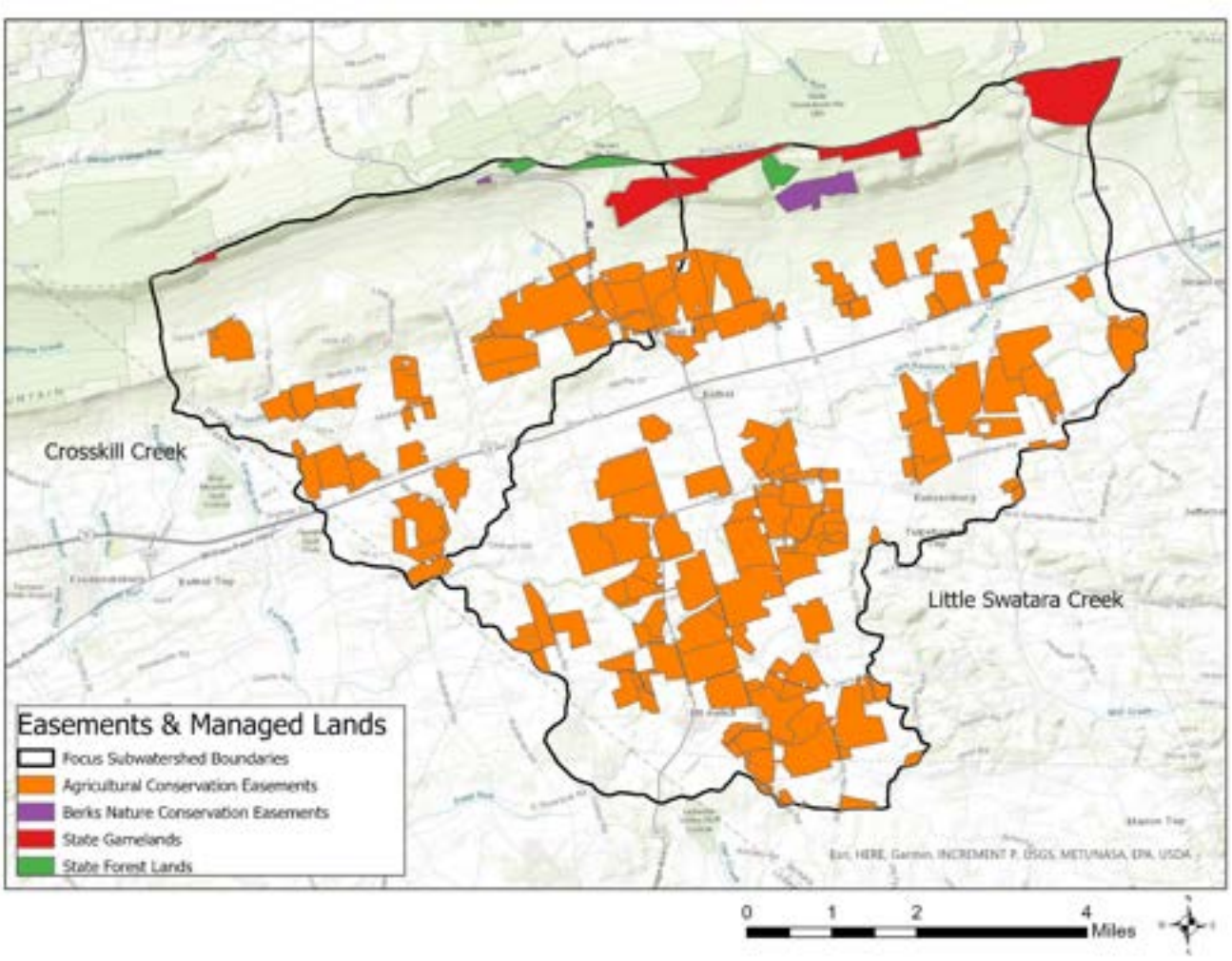

Figure 13. Easements and State managed lands in the total study watershed

Table 11. Easements in the total study watershed

Watershed Name	Agricultural Conservation Easements (ACE)		Berks Nature Conservation Easements		Total Easements	
	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)
Crosskill Creek	2,252.6	18.7%	9.8	0.08%	2,262.4	18.7%
Little Swatara Creek	6,980.8	26.8%	150.3	0.6%	7,131.1	27.3%

Table 11. Easements in the total study watershed

Watershed Name	Agricultural Conservation Easements (ACE)		Berks Nature Conservation Easements		Total Easements	
	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)
Total Study Watershed	9,233.4	24.2%	160.1	0.42%	9,393.5	24.6%

Table 12. Managed lands in the total study watershed

Watershed Name	State Game Lands		State Forest Lands		Total Managed Lands	
	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)	Area (acres)	Percentage of Total Area (%)
Crosskill Creek	183.6	1.5%	75.7	0.6%	259.3	2.1%
Little Swatara Creek	724.6	2.8%	62.2	0.2%	786.8	3.0%
Total Study Watershed	908.3	2.4%	137.9	0.4%	1,046.1	2.8%

SECTION 4. POINT SOURCE POLLUTION

Point sources are summarized using data on biosolid sites, Captive Hazardous Waste Operations and data from the PA DEP permitted facility report that provides information on facilities with National Pollutant Discharge Elimination System (NPDES) permits, and other permits related to water quality. Under the Clean Water Act, the NPDES permit program was created to regulate point sources that discharge pollutants to waters of the US. In general terms, an NPDES permit is a license for a facility to discharge a specified amount of a pollutant into a receiving water under defined conditions.

Biosolids

Biosolids refers to nutrient rich organic material resulting from the solids produced during the wastewater treatment process and solids and liquids from residential septic tanks, holding tanks and other treatment units. Once treatment is conducted, the biosolid product has beneficial uses when applied to mine reclamation sites, forestry, gardening and landscaping, and agricultural land. The PA DEP regulates biosolids under the Pennsylvania permit PAG-08. There are 3 biosolid sites in the Little Swatara creek subwatershed that apply fertilizer on agricultural lands with 2 active and 1 inactive.

Captive Hazardous Waste Operation

A Captive Hazardous Waste Operation is a DEP primary facility type related to the Waste Management Hazardous Waste Program (PA DEP, 2021). The only active site is the Dutch Valley Food Distribution located in the Little Swatara Creek (Table 13).

Table 13. Captive Hazardous Waste Operations in the total study watershed

Name of Operation	Crosskill Creek	Little Swatara Creek	Total Study Watershed
Super SVC Painting & Sandblasting	Out of business		Out of business
WC Mcquaide Inc Bethel Parts Shop		Out of business	Out of business
Dutch Valley Food Distribution		Active	Active

NPDES Permits

NPDES permits are summarized in Table 14 and described below.

Table 14. NPDES permits in the total study watershed

Type of Facility	Crosskill Creek	Little Swatara Creek	Total Study Watershed
Concentrated Animal Feeding Operation	5	9	14
Groundwater Cleanup	1	2	3
Industrial Waste	0	1	1
NPDES Industrial Stormwater Permit	0	3	3
NPDES Municipal Stormwater Permit (MS4)	0	2	2

CONCENTRATED ANIMAL FEEDING OPERATIONS (CAFOS)

Concentrated Animal Feeding Operations (CAFOs) are agricultural operations where animals are kept and raised in confined situations. A CAFO is defined as more than 1,000 animal units confined on a site for more than 45 days during the year. CAFOs are considered point sources as waste is collected at a point, generally in manure lagoons or tanks. They are regulated under the NPDES, PAG-12 general permit (US EPA 2021). Of the 13 operations in the watershed, all in compliance except for the Mountain View Swine Farms discharge point.

Groundwater Cleanup

These facilities for the treatment of petroleum contaminated groundwater are regulated by PA DEP under PAG-05, which provides NPDES permit coverage for the discharge of wastewater from petroleum product contaminated groundwater remediation systems (PPCGRS). The three sites within the total study watershed are all in compliance.

Industrial Waste

The only industrial waste site within the watershed is a Valero service station owned by Exxon Mobile that discharges to an unnamed tributary to the Little Swatara that is in compliance. An industrial waste site is regulated under and is defined as a facility that discharges treated process and utility wastewaters other than sewage, including water treatment plants.

NPDES Industrial Stormwater Permit

Stormwater discharges from industrial activities are regulated by PA DEP as defined at 40 CFR§ 122.26(b)(14) and Pennsylvania's Clean Streams Law. A PAG-03 General Permit is required to provide NPDES permit coverage for discharges of stormwater associated with industrial activity. Within the watershed, there are three NPDES industrial stormwater permits for a lumber mill, auto salvage yard, and truck parts shop.

NPDES Municipal Stormwater Permit (MS4)

Tulpehocken Township and Merion Township in Berks County and Jackson Township in Lebanon County are regulated municipal separate storm sewer systems (MS4s) that all received a waiver for their NPDES MS4 permit. They are regulated under the 2018 PAG-13 general permit that provides NPDES permit coverage for stormwater discharges from the MS4 to surface waters (Figure 14 and Table 15).

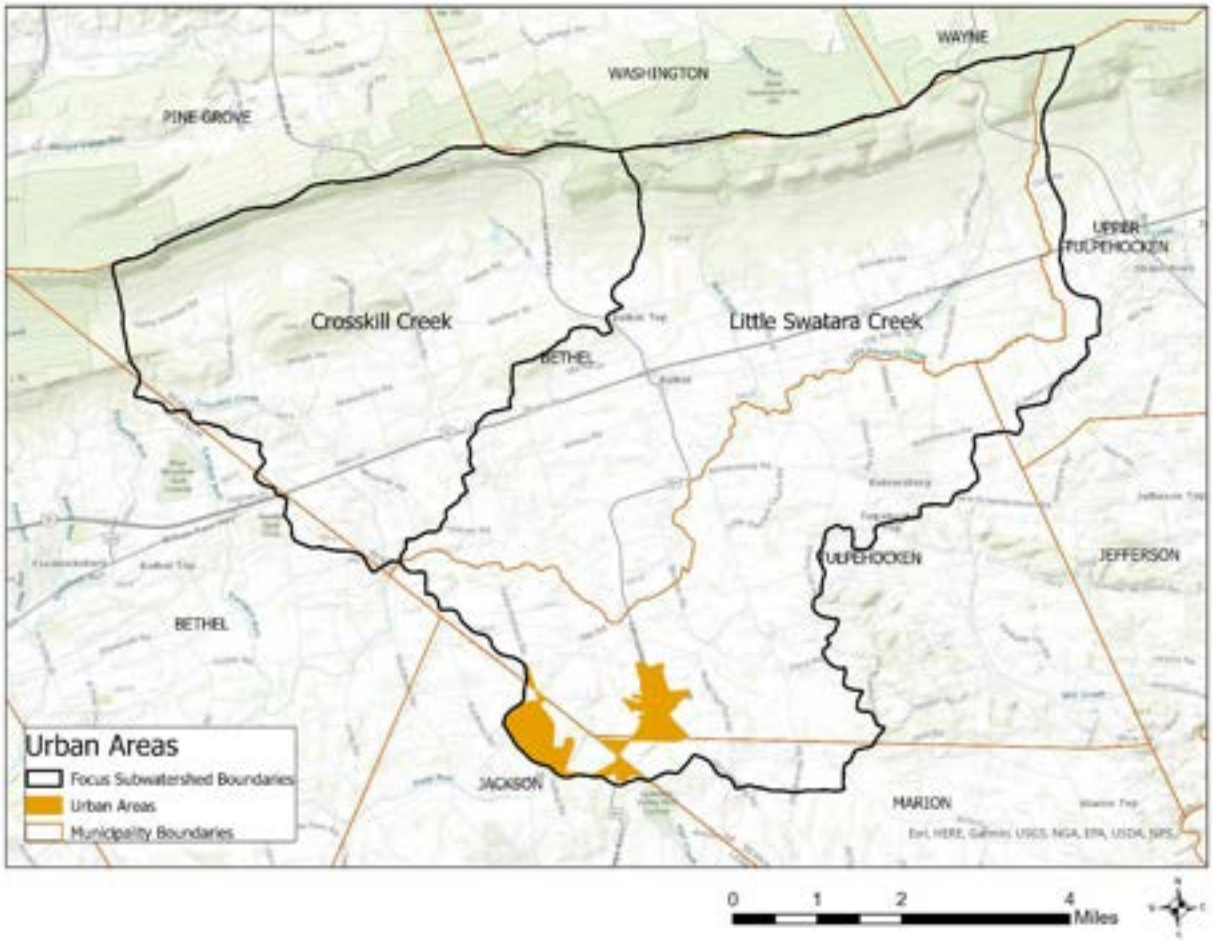

Figure 14. Urban areas in the total study watershed

Table 15. Urban areas within jurisdictions in the total study watershed						
Jurisdiction	**Crosskill Creek**		**Little Swatara Creek**		**Total Study Watershed**	
	Area (acres)	Percentage of Total Subwatershed Area (%)	Area (acres)	Percentage of Total Subwatershed Area (%)	Area (acres)	Percentage of Total Subwatershed Area (%)
Marion Township	0.0	0.0%	37.6	0.1%	37.6	0.1%
Tulpehocken Township	0.0	0.0%	242.3	0.9%	242.3	0.9%
Jackson Township	0.0	0.0%	301.7	1.2%	301.7	1.2%
Total	0.0	0.0%	581.6	2.2%	581.6	2.2%

SECTION 5. FIELD ASSESSMENTS AND FINDINGS

CWP conducted field assessments November 8th – 11th, 2021, to identify restoration opportunities within the total study watershed. Field assessments included identification of stormwater retrofit projects, pollutant reduction, and restoration opportunities in neighborhoods and commercial, industrial, institutional, municipal, and transport-related operations. In addition, stream assessments were conducted following a rapid BANCS method developed by Rosgen (2009) and an agriculture conservation assessment was conducted. This section provides an overview of the field methods for each assessment, field results, and recommendations.

5.1 Unified Subwatershed Site Reconnaissance (USSR)

CWP conducted the Unified Subwatershed and Site Reconnaissance (USSR) to evaluate pollution-producing behaviors and restoration potential in upland areas of the total study watershed. The USSR includes the Neighborhood Source Assessment (NSA) and the Hotspot Site Investigation (HSI). The USSR is a "windshield survey" where field crews drive watershed roads to determine specific pollution sources and identify areas where pollution prevention possibilities exist described in Wright et al. (2005). The USSR can be a powerful tool in shaping initial watershed restoration strategies and locating potential stormwater retrofit or restoration opportunities. The goal of the USSR is to quickly identify source areas that are contributing pollutants to the stream, and reduce these pollutant loads through source controls, outreach and change in current practice, and improved municipal maintenance operations.

5.1.1 NEIGHBORHOOD SOURCE ASSESSMENT (NSA)

Residents engage in behaviors and activities that can influence water quality. Some behaviors that negatively influence water quality include over-fertilizing lawns, using excessive amounts of pesticides, and poor housekeeping practices such as inappropriate trash disposal or storage. Alternatively, positive behaviors such as tree planting and using native plants, disconnecting rooftop downspouts, and picking up pet waste can help improve water quality.

The Neighborhood Source Assessment (NSA) was conducted to evaluate pollution source areas, stewardship behaviors, and restoration opportunities within individual residential areas. The assessments focus specifically on yards and lawns, rooftops, driveways and sidewalks, curbs, and common areas. Table 16 provides examples of the types of restoration opportunities that were evaluated for each site.

An NSA field form was used to assess neighborhoods in terms of age, lot size, tree cover, drainage, lawn size, general upkeep, evidence of pollution sources, and evidence of resident stewardship (i.e., storm drain stenciling, pet waste management signage, etc.). Each site was assigned a pollution severity rating of "severe," "high," "moderate," or "low," using a set of benchmarks set forth in Wright et al. (2005). Pollution severity is an index of the amount of non-point source pollution a neighborhood is likely to generate based on easily observable features (i.e., lawn care practices, drainage patterns, oil stains, etc.). A restoration potential rating of "high," "moderate," or "low" was also assigned to each neighborhood. Restoration potential is a measure of how feasible onsite retrofits or behavior changes would be, based on space, number of opportunities, presence of a strong homeowner association (HOA), and other similar factors.

Table 16. Types of projects identified during Neighborhood Source Assessment (NSA)		
Type	**Description**	**Examples**
On-site Retrofits 	Homeowners reduce stormwater runoff generated by their lots	• Rain gardens • Rain barrels • Rooftop disconnection
Lawn and Landscaping Practices 	Better lawn and landscaping practices minimize the use of chemicals and encourage the use of native landscaping, particularly in neighborhoods where high input lawns and extensive turf cover are prevalent.	• Improved buffer protection • Native plantings • Turf reduction • Proper fertilizer and pesticide application
Open Space Management 	Management of neighborhood common areas or courtyards	• Landscaping • Tree planting • Pet waste education • Trash removal
Education and Outreach 	Providing homeowners with additional information to better manage pollution in their residential lots	• Lawn and nutrient management outreach • Rain barrel and rain garden education • Storm drain stenciling

A total of two neighborhoods were visited by the field crews during field assessments (Figure 15). Much of the residential development in the total study watershed is composed of single-family homes and were not in clearly designed neighborhoods with Homeowner Associations (HOAs). In addition, except for the newer neighborhoods that were assessed, other neighborhoods had no visible stormwater management practices. Figure 16 shows a representative photo of a home in each neighborhood.

The two neighborhoods that were assessed were rated low in terms of pollution severity. The Mountain Meadows neighborhood (NSA_01) was rated low for restoration potential with identified opportunities that include installing rain barrels, tree planting, constructing rain gardens, marking stormwater inlets, and providing nutrient and lawn management education. The Apple Creek neighborhood (NSA_02) was rated moderate for restoration potential, with similar opportunities identified for Mountain Meadows, with an added opportunity for downspout disconnection. In general, however, both neighborhoods had limited opportunities for large-scale stormwater retrofits. Table 17 provides a list of the sites visited with their ranked priority, opportunities, and planning-level cost estimates.

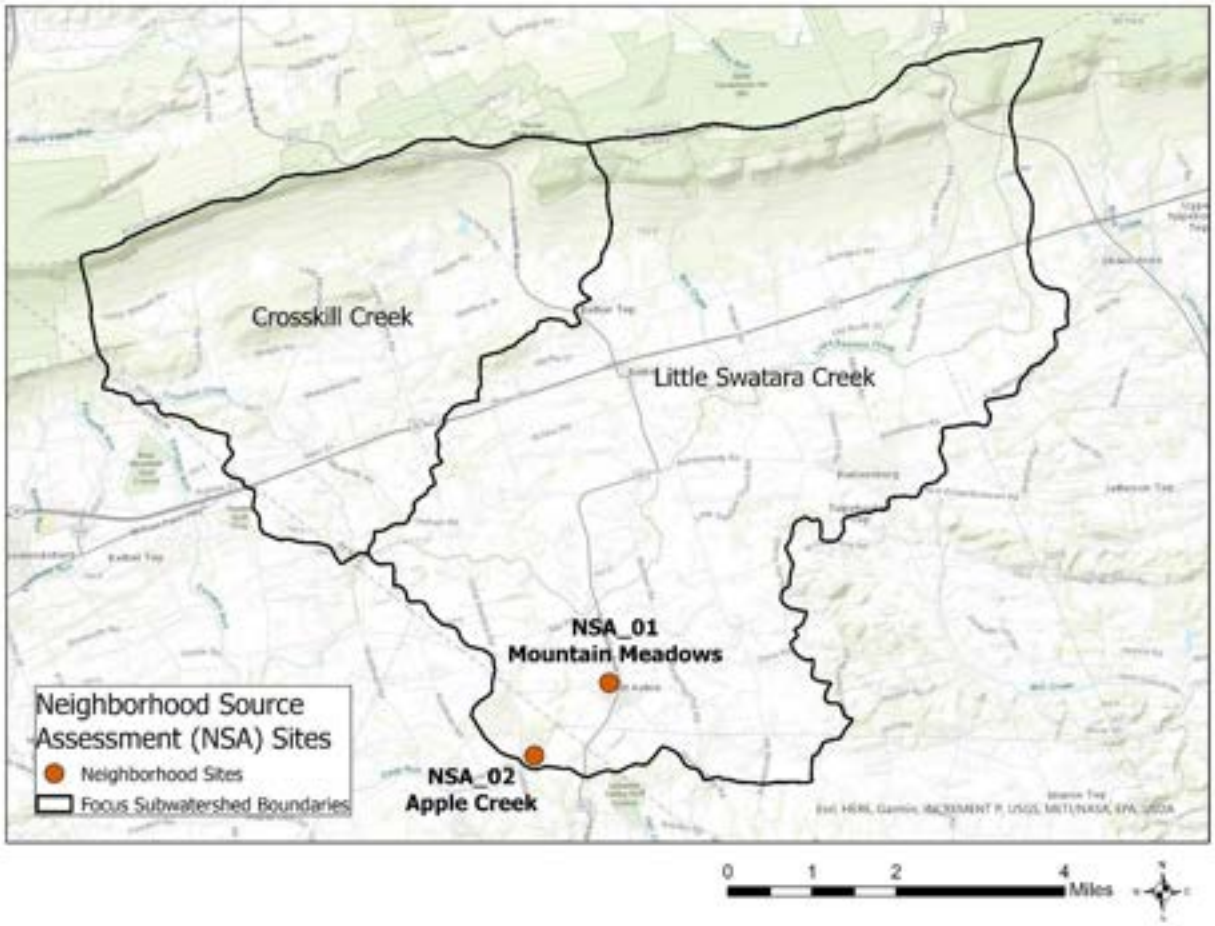

Figure 15. Neighborhood Source Assessment (NSA) sites

Table 17. Neighborhood source control opportunities

Site ID	Neighborhood	Pollution Severity	Restoration Potential	Opportunity	Priority	Cost Assumptions
NSA_01	Mountain Meadows	Low	Low	Rain barrels or rain gardens, Lawn management education, Stormwater inlet markers	Low	Rain barrels for 10% of homes; lawn management advice
NSA_02	Apple Creek	Low	Moderate	Downspout disconnection, Rain gardens, Lawn management education, Stormwater inlet markers	Low	Downspout disconnection or rain barrels for 10% of homes; lawn management advice

NSA_01: Mountain Meadows

NSA_02: Apple Creek

Figure 16. Typical homes in each assessed neighborhood

5.1.2 Hotspot Site Investigation (HSI)

Pollution source control includes the management of potential "hotspots" which are certain commercial, industrial, institutional, municipal, and transport-related operations in the watershed. These hotspots tend to produce higher concentrations of polluted stormwater runoff than other land uses and have a higher risk for spills. They include auto repair shops, restaurants, etc. Specific on-site operations and maintenance combined with pollution prevention practices can significantly reduce the occurrence of "hotspot" pollution problems.

The Hotspot Site Investigation (HSI) is used to evaluate commercial, industrial, municipal, or transport-related sites that have a high potential to contribute contaminated runoff to the storm drain system or directly to receiving water. At hotspot sites, field crews examined vehicle operations, outdoor materials storage, and stormwater infrastructure to evaluate potential pollution sources (Table 18).

Table 18. Potential hotspot pollution sources

Type	Description	Examples
Vehicle Operations	Routine vehicle maintenance and storage practices, as well as vehicle fueling and washing operations	• Vehicle storage and repair • Fueling areas • Vehicle washing practices
Outdoor Materials	Exposure of outdoor materials stored at the site	• Loading and unloading • Outdoor materials • Secondary containment
Waste Management	Housekeeping practices for waste materials generated at the site	• Dumpster practices
Stormwater Infrastructure	Practices used to convey or treat stormwater, including the curb and gutter, catch basins, and any stormwater treatment practices	• Catch basins • Stormwater treatment practices

Based on observations at the site, field crews may recommend enforcement measures, follow-up inspections, illicit discharge investigations, retrofits, or pollution prevention control and education. The overall pollution prevention potential for each hotspot site is assessed based on observed sources of pollution and the potential of the site to generate pollutants that would likely enter the storm drain network. A hotspot designation criterion set forth in Wright et al. (2005) was used to determine the status of each site based on field crew observations. All sites visited for hotspot potential were also assessed for their potential as a stormwater retrofit and are shown in Table 19.

5.1.2.1 Assessment Findings

The field assessments resulted in none of the sites designated as hotspots based on the HSI rating system, defined as the presence of multiple pollution producing behaviors at a site. Pollution producing behaviors were

identified at Sites 115, Best Used Trucks of PA and site 118, Trainer's Midway Diner. Follow-up actions are provided in Table 19 and photographs of the follow-up actions identified at Sites 115 and 118 are shown in Figure 17.

Table 19. Assessed sites for Hotspot Site Investigation (HSI)

Site ID	Location	Hotspot Type	Follow-up Actions
100	Bethel Public Works	Municipal Services	None
101	Onvo Travel Center	Fueling Services	None
102	Bethel Tulpehocken Library and Municipal Office	Municipal Services	None
103	Sheetz	Fueling Services	None
104	Salem Lutheran	Church	None
105	Bethel Elementary School	Educational Institution	None
106	Union Fire Company of Bethel	Fire Station	None
107	Hornings Market	Grocery/Food	None
108	Conservative Baptist	Church	None
109	Frystown Fire Company	Fire Station	None
110	Trinity UCC Rehrersburg	Church	None
111	Mt. Aetna Bible	Church	None
112	Lanita Specialized, LLC	Transportation Services	None
113	Dutch Valley Food Distributor	Food Products Supplier	None
114	Flying J Travel Center	Fueling and Travel Services	None
115	Best Used Trucks of PA	Commercial	Inspect wash water draining to storm drain system and keep dumpster lids closed.
116	Dunkard Brethren Church School	Educational Institution	None
117	Kauffman's BBQ	Food Services	None
118	Trainer's Midway Diner	Food Services	Provide a cover for outside tire storage.
119	Tulpehocken Area School District Administration Offices	Municipal Services	None
120	Frystown Neighborhood Park	Public Park	None

Site 118. Improve Dumpster Siting

Site 118. Cover Tire Storage Area

Site 115. Close Open Dumpster

Site 115. Control Wash Water to Storm Drain

Figure 17. Sites with potential hotspot behaviors in the watershed

5.2 Stormwater Retrofit Inventory

Stormwater retrofits are structural stormwater management practices that can be used to address existing stormwater management problems within a watershed. These practices are installed in upland areas to capture and treat stormwater runoff before it is delivered to the storm drainage system, and ultimately, Crosskill and Upper Little Swatara Creeks. They are an essential element of a holistic watershed restoration program because they can help improve water quality, increase groundwater recharge, provide channel protection, and control overbank flooding. Without using stormwater retrofits to address existing problems and to help establish a stable, predictable hydrologic regime by regulating the volume, duration, frequency, and rate of stormwater runoff, the success of many other watershed restoration strategies—such as stream stabilization and aquatic habitat enhancement—will be threatened. In addition to the stormwater management benefits they offer, stormwater retrofits can be used as demonstration projects, forming visual centerpieces that can be used to help educate residents and build additional interest in watershed restoration.

Potential stormwater retrofit opportunities at several candidate project sites in the total study watershed were assessed during the retrofit inventory using the methods described in Schueler et al. (2007). A Retrofit Reconnaissance Inventory (RRI) field form was used to evaluate retrofit opportunities at candidate sites. Field crews look specifically at drainage patterns, the amount of impervious cover, available space, and other site constraints when developing concepts for a site. Candidate retrofit sites identified for the assessment included the same sites assessed for hotspot potential described in Section 5.1.2 and generally had one or more of the following characteristics:

- Located on commercial, industrial, or institutional sites with large areas of impervious cover
- Could serve as a demonstration project; and
- Located at existing stormwater management facilities.

5.2.1 Water Quality and Pollutant Removal Calculations and cost estimates

The pollutant removal calculations for stormwater retrofits were calculated using the Model My Watershed (MMW) BMP spreadsheet tool. Table 20 provides more detailed information.

5.2.2 Cost Estimates

Cost estimates (including design and construction) were developed for each proposed retrofit using the construction estimates based on Chesapeake Bay Assessment Tool (CAST) Cost Profiles for Pennsylvania. CAST estimates are based on the implementation cost and maintenance cost of the drainage area treated by the BMP practice. The drainage area treated was capped at the 1' storm for water quality to ensure the cost estimates were more accurate to the size of the BMP practice. Additionally, the implementation costs have been increased by 30% to account for the recent inflation. The implementation cost also includes design cost which is based on engineering guideline of about 30% of the construction cost and an additional $5,000 for survey and geotechnical report. These costs do not include the permit fee cost. Please note these are planning

level costs and more in depth and site specifics cost estimates should be developed if/when these projects are designed and constructed.

5.2.3 Desktop Assessment

In preparation for the field assessment, CWP first conducted a desktop analysis using Google Earth Pro, which narrowed down the locations to visit in the watershed. The aerial imagery and the total study watershed boundary were used to identify commercial areas in the census-designated place of Frystown, located in Bethel Township, and the census-designated places of Mt. Aetna and Rehrersburg located in Tulpehocken Township, PA. In addition, locations were identified along Interstate 78 (I-78) that includes commercial operations and warehouse distribution centers. This process identified 19 locations to visit to look for potential retrofits (Figure 18).

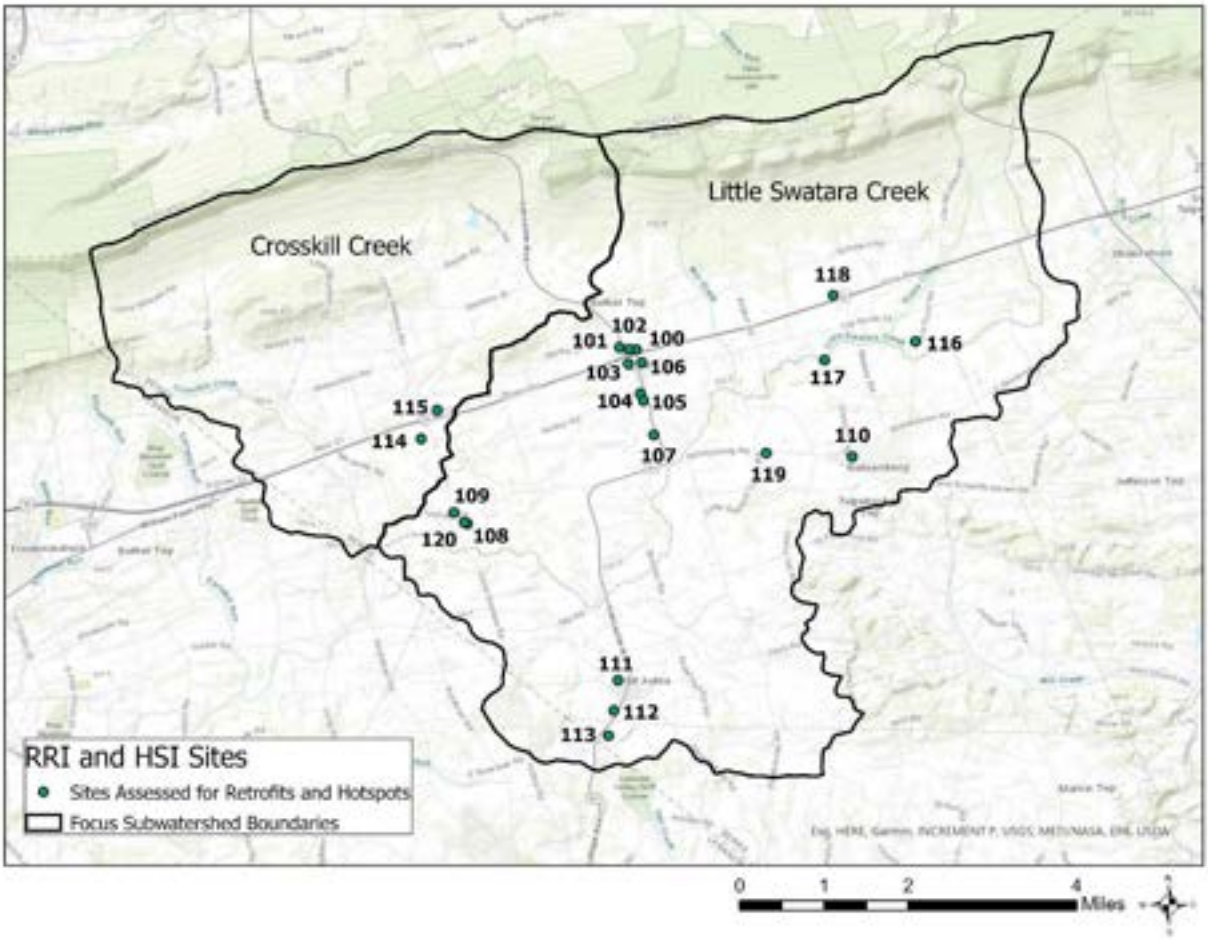

Figure 18. Potential retrofit sites visited during field assessment

5.2.4 Field Assessment

In addition to the 19 sites identified through the desktop analysis, field crews identified 2 additional sites for a total of 21 sites. After visiting all 21 potential RRI locations identified in Figure 18, 16 of these locations were deemed suitable for retrofits. The other 5 locations were deemed unsuitable for a retrofit project due to topography, land use, shallow stormwater inlet depth, or other reasons that would make constructing a stormwater retrofit inherently difficult or expensive. There are a total of 19 retrofits proposed since several sites could accommodate multiple retrofits.

The majority of retrofit opportunities proposed are bioretention practices. In addition, opportunities identified include five permeable pavement practices, one bioswale, one sand filter, one site for additional plantings in an existing pond, and one site for conversion of a dry pond to a wet pond. Approximately 0.12% of the entire study area (44.3 acres) and 1.7% (34.4 acres) of the impervious cover would be treated by the retrofits

identified. For the purposes of this report the retrofits discussed assume an underdrain will be needed, unless otherwise noted.

The total study watershed has seen the development of warehouse distribution centers along the I-78 corridor over the past decade. Several of these sites were visited in the field to evaluate potential stormwater retrofit potential. Most of the sites managed stormwater using a dry pond with a few sites using wet ponds.

The identified retrofits are summarized in Table 20. Table 20 lists the estimated pounds of phosphorus, nitrogen, and TSS the retrofits would remove each year, a planning level cost estimate to design and build the retrofit and maintain it for 1 year, and the cost effectiveness for all retrofits identified.

Table 20. Stormwater retrofits in the Total Study Watershed

Location Name	Retrofit ID	BMP Type	Drainage Area (acres)	% IC	% Water Quality Volume	TSS Removal (lbs/yr)	TP Removal (lbs/yr)	TN Removal (lbs/yr)	Cost $ (Design, Construction)**	Cost Effectiveness ($/lbs TSS Removed)	Cost Effectiveness ($/lbs TP Removed)	Maintenance cost per year***	Public Land
Flying J Travel Center - North	114N	Submerged gravel wetland*	6.3	87%	11%	4005.03	0.794	1.42	$59,922.21	$8.57	$43,243.11	$1,224.62	No
Flying J Travel Center - South	114S	Submerged gravel wetland*	4.23	87%	33%	2689.09	0.533	0.95	$114,828.38	$25.53	$128,790.46	$2,448.87	No
Mt. Aetna Bible Church	111	Bioswale	7.6	87%	45%	7513.07	2.337	11.07	$100,193.59	$7.92	$25,458.28	$4,165.76	No
Bethel Tulpehocken Public Library	102	Bioretention/ raingardens - C/D soils, underdrain	0.65	87%	91%	108.32	0.020	0.05	$51,903.03	$270.62	$1,431,716.46	$1,045.81	Yes
Trainer's Midway Diner/Quality Inn	118	Bioretention/ raingardens - C/D soils, underdrain	0.62	87%	216%	421.37	0.114	0.32	$54,233.73	$73.03	$269,001.52	$1,097.78	No
Dutch Valley Food Distributors	113	Wet Ponds and Wetlands	11.5	87%	112%	3169.32	0.673	1.20	$216,682.98	$41.74	$196,658.29	$4,157.37	No
Frystown Fire Company	109	Filtering Practices	0.85	15%	203%	42.49	0.031	0.16	$40,043.83	$515.48	$715,764.44	$648.93	No
Kauffman's BBQ	117	Permeable Pavement w/o Sand, Veg. - A/B soils, underdrain	2.54	52%	158%	1439.03	0.406	2.22	$677,099.04	$291.91	$1,033,616.88	$29,833.11	No
Salem Lutheran Church - Parking Lot	104 A	Bioretention/rain gardens - C/D soils, underdrain	0.55	87%	498%	91.66	0.017	0.05	$48,675.09	$297.81	$1,575,580.32	$973.84	No
Salem Lutheran Church - Building	104 B	Bioretention/rain gardens - C/D soils, underdrain	0.11	87%	419%	18.33	0.003	0.01	$13,735.02	$297.81	$1,575,580.32	$194.77	No
Bethel School - Permeable Pavement	105 B	Permeable Pavement w/o Sand, Veg. - A/B soils, no underdrain	0.17	87%	466%	43.78	0.010	0.04	$49,983.01	$642.11	$2,953,191.07	$1,996.70	Yes
Frystown Lion Park	120	Bioretention/rain gardens - A/B soils, underdrain	1.35	52%	64%	181.58	0.091	0.67	$232,429.88	$782.81	$1,559,875.73	$2,454.77	Yes

Table 20. Stormwater retrofits in the Total Study Watershed

Location Name	Retrofit ID	BMP Type	Drainage Area (acres)	% IC	% Water Quality Volume	TSS Removal (lbs/yr)	TP Removal (lbs/yr)	TN Removal (lbs/yr)	Cost $ (Design, Construction)**	Cost Effectiveness ($/lbs TSS Removed)	Cost Effectiveness ($/lbs TP Removed)	Maintenance cost per year***	Public Land
Bethel School - Bioretention	105 A	Bioretention/rain gardens - A/B soils, underdrain	0.64	87%	164%	155.14	0.034	0.15	$174,347.79	$682.24	$3,150,070.48	$1,827.86	Yes
Commercial Area in Mt. Aetna	112 N	Bioretention/rain gardens - A/B soils, underdrain	2.9	52%	147%	744.31	0.305	1.91	$772,357.17	$644.35	$1,575,035.24	$8,282.49	No
Trinity UCC Rehrersburg	110	Permeable Pavement w/o Sand, Veg. - A/B soils, underdrain	0.14	87%	113%	42.83	0.008	0.03	$42,044.83	$540.60	$2,756,311.67	$1,644.34	No
Tulpehocken Area School District Administrative Offices	119	Bioretention/rain gardens - A/B soils, underdrain	0.85	15%	1679%	81.46	0.038	0.28	$229,915.03	$1,725.70	$3,675,082.22	$2,427.63	Yes
Onvo Travel Plaza	101	Bioretention/rain gardens - A/B soils, underdrain	0.85	87%	114%	206.04	0.045	0.20	$229,915.03	$682.24	$3,150,070.48	$2,427.63	No
Union Fire Co. of Bethel	106	Permeable Pavement w/o Sand, Veg. - A/B soils, no underdrain	0.41	87%	404%	105.60	0.023	0.10	$113,488.43	$642.11	$2,953,191.07	$4,815.58	No
Sheetz	103	Permeable Pavement w/o Sand, Veg. - C/D soils, underdrain	0.6	87%	214%	99.99	0.008	0.02	$163,763.55	$992.35	$11,812,764.29	$7,047.19	No
Total			**42.86**			**21,158.46**	**5.49**	**20.83**	**$3,385,561.61**			**$78,715.04**	

* While a submerged gravel wetland is proposed, Model My Watershed does not include this practice. The Bioretention/raingardens - C/D soils, underdrain practice was used since it was determined this was the closest practice to a submerged gravel wetland.

**The construction estimates are based on Chesapeake Bay Assessment Tool (CAST) Cost Profiles for Pennsylvania, and the percent of water quality volume per BMP, the costs have been increased by 30% to account for the recent inflation. The cost also includes design cost which is based on engineering guideline of about 30% of the construction cost and an additional $5,000 for survey and geotechnical report. These do not include the permit fee cost

***The maintenance estimates are based on Chesapeake Bay Assessment Tool (CAST) Cost Profiles for Pennsylvania, and the percent of water quality volume per BMP.

5.2.5 Prioritized Ranking of Recommended Actions

Proposed stormwater retrofit practices and their ranking are provided in Table 21. Each proposed practice is ranked based on pollutant removal, cost, cost effectiveness, sediment and nutrient removal, maintenance cost, and land ownership. A description of each ranking factor is provided. The ranking factors are based on criteria important to the BCCD and typical factors found in stormwater grants. This will allow the strongest projects to be proposed for grant funding, while still prioritizing the BCCD's needs.

Cost of the practice

The cost for each practice was calculated and summarized in Table 20. Projects that cost less than $52,500 received a 10, projects that cost between $52,500 to $200,000 received a 5, and projects that cost over $200,000 received a 1.

Total Suspended Solids (TSS) Removal

Nutrient removal was calculated for each site using MMW and summarized in Table 21. The TSS Removal was rated based on how much suspended sediment would be removed each year by this project. Projects above 1,000 lbs/yr received a 10, projects between 1,000 to 100 lbs/yr received a 5, and projects under 100 lbs/yr received a 1.

Total Phosphorus (TP) Removal

Nutrient removal was calculated for each site using MMW and summarized in Table 21. The TP Removal was rated based on how much total phosphorus would be removed each year by this project. Projects above 0.20 lbs/yr received a 10, projects between 0.20 to 0.025 lbs/yr received a 5, and projects under 0.025 lbs/yr received a 1.

Cost Effectiveness for Total Suspended Solids (TSS) Removal

The nutrient removal rankings are based on the calculated nutrient removal efficiencies for each nutrient and the costs of each practice. Projects with a cost effectiveness of $200/lbs/yr received a 10, projects with a cost effectiveness between $200/lbs/yr to $675/lbs/yr received a 5, and projects with a cost effectiveness over $675/lbs/yr received a 1.

Cost Effectiveness for Total Phosphorus (TP) Removal

The nutrient removal rankings are based on the calculated nutrient removal efficiencies for each nutrient and the costs of each practice. Projects with a cost effectiveness of $300,000/lbs/yr received a 10, projects with a cost effectiveness between $300,000/lbs/yr to $2,000,000/lbs/yr received a 5, and projects with a cost effectiveness over $2,000,000/lbs/yr received a 1.

Property Ownership

Publicly owned land is scored higher than privately owned land as the County can install projects easier on land where it has ownership. If the practice is on privately held land it is given a score of 1; while practices on publicly owned land are given a score of 10.

Maintenance Cost

When dealing with rain events, there is rarely any solution that does not have maintenance involved. The maintenance needs are based on the cost per year for each practice. Projects that cost less than $1,500 received a 10, projects that cost between $1,500 to $4,000 received a 5, and projects that cost over $4,000 received a 1.

Table 21. Priority ranking of identified stormwater retrofits

Location Name	Retrofit ID	BMP Type	Cost Ranking	Cost Effectiveness Ranking TSS	Cost Effectiveness Ranking TP	TSS Removal Ranking	TP Ranking	Public Land	Maintenance Ranking	Total Points	Ranking
Flying J Travel Center - North	114N	Submerged gravel wetland*	5	10	10	10	10	1	10	56	1
Flying J Travel Center - South	114S	Submerged gravel wetland*	5	10	10	10	10	1	5	51	2
Mt. Aetna Bible Church	111	Bioswale	5	10	10	10	10	1	1	47	3
Bethel Tulpehocken Public Library	102	Bioretention/ raingardens - C/D soils, underdrain	10	5	5	5	1	10	10	46	4
Trainer's Midway Diner/Quality Inn	118	Bioretention/ raingardens - C/D soils, underdrain	5	10	10	5	5	1	10	46	5
Dutch Valley Food Distributors	113	Wet Ponds and Wetlands	1	10	10	10	10	1	1	43	6
Frystown Fire Company	109	Filtering Practices	10	5	5	1	5	1	10	37	7
Kauffman's BBQ	117	Permeable Pavement w/o Sand, Veg. - A/B soils, underdrain	1	5	5	10	10	1	1	33	8
Salem Lutheran Church - Parking Lot	104 A	Bioretention/raingardens - C/D soils, underdrain	10	5	5	1	1	1	10	33	9
Salem Lutheran Church - Building	104 B	Bioretention/raingardens - C/D soils, underdrain	10	5	5	1	1	1	10	33	10
Bethel School - Permeable Pavement	105 B	Permeable Pavement w/o Sand, Veg. - A/B soils, no underdrain	10	5	1	1	1	10	5	33	11
Frystown Lion Park	120	Bioretention/raingardens - A/B soils, underdrain	1	1	5	5	5	10	5	32	12
Bethel School - Bioretention	105 A	Bioretention/raingardens - A/B soils, underdrain	5	1	1	5	5	10	5	32	13

Table 21. Priority ranking of identified stormwater retrofits

Location Name	Retrofit ID	BMP Type	Cost Ranking	Cost Effectiveness Ranking TSS	Cost Effectiveness Ranking TP	TSS Removal Ranking	TP Ranking	Public Land	Maintenance Ranking	Total Points	Ranking
Commercial Area in Mt. Aetna	112 N	Bioretention/raingardens - A/B soils, underdrain	1	5	5	5	10	1	1	28	14
Trinity UCC Rehrersburg	110	Permeable Pavement w/o Sand, Veg. - A/B soils, underdrain	10	5	1	1	1	1	5	24	15
Tulpehocken Area School District Administrative Offices	119	Bioretention/raingardens - A/B soils, underdrain	1	1	1	1	5	10	5	24	16
Onvo Travel Plaza	101	Bioretention/raingardens - A/B soils, underdrain	1	1	1	5	5	1	5	19	17
Union Fire Co. of Bethel	106	Permeable Pavement w/o Sand, Veg. - A/B soils, no underdrain	5	5	1	5	1	1	1	19	18
Sheetz	103	Permeable Pavement w/o Sand, Veg. - C/D soils, underdrain	5	1	1	1	1	1	1	11	19

5.2.6 Retrofit Description and Proposed Practice for Top Four Projects

Table 22 provides a description and photographs of the top four proposed retrofit practices. The top two ranked proposed retrofit are Site 114N and Site 114S at the Flying J Travel Center. A submerged gravel wetland is proposed at both the northwest (Site 114N) and southwest (Site 114S) corners adjacent to the large parking lot. Therefore, only one project concept was created. The third highest ranked proposed retrofit is Site 111 located at the Mt. Aetna Bible Church and is a bioswale within the existing dry pond. The fourth highest proposed retrofit is Site 102 at the Bethel Tulpehocken Municipal Building and is a bioretention system at the existing catch basin.

Table 22. Retrofit description and proposed practice for top four projects

Retrofit	Photo Location
RRI-114N – Flying J Travel Center A large amount of runoff from the parking lot currently sheet flows west towards the northwest corner of the large truck stop parking lot. This area then drains through underbrush into the adjacent stream. CWP proposes constructing a submerged gravel wetland due to the presence of high ground water. The submerged gravel wetland would require 5 feet wide strip of the parking lot and use the grassy and underbrush area next to the parking lot. An underdrain would discharge behind the practice and weir overflow would be needed since no drainage system currently exists in this area.	 **Permeable Pavement** (photos taken facing south)

Table 22. Retrofit description and proposed practice for top four projects

Retrofit	Photo Location
RRI-102 – Bethel Tulpehocken Municipal Building A portion of the parking lot, the roof runoff from both the library and municipal building would be captured by the proposed bioretention systems around the existing 3 catch basins. The bioretention would require the use of the grassy area between the parking lot and municipal building. The roof leaders from the municipal building need to be disconnected. The existing catch basins would be used as the overflows and where the underdrain would connect.	   **Bioretention** (photo taken facing northwest and east)

Table 22. Retrofit description and proposed practice for top four projects

Retrofit	Photo Location
RRI-111 – Mt. Aetna Bible Church Stormwater runoff from the paved parking lot and the surrounding residential/commercial area is directed to a large open field/quasi dry pond. The runoff is directed to the north end of this area along the existing berm. CWP proposes to construct a bioswale along the north berm edge at the edge of the parking lot to reduce the erosion to the stream downstream of the existing outfall. The Exiting structure will be used as the overflow and where the underdrain would connect.	 **Bioswale within open space/dry pond area** (photos taken facing west)

5.3 Stream Assessments

The Berks County Conservation District identified three properties to conduct a stream assessment as shown in Figure 19. These properties were identified based on the knowledge that the farms have implemented agricultural BMPs and the property owner's willingness to allow access. All three sites are agricultural land on private property and include the Bicher Farm, Bross Farm and Weaver Farm.

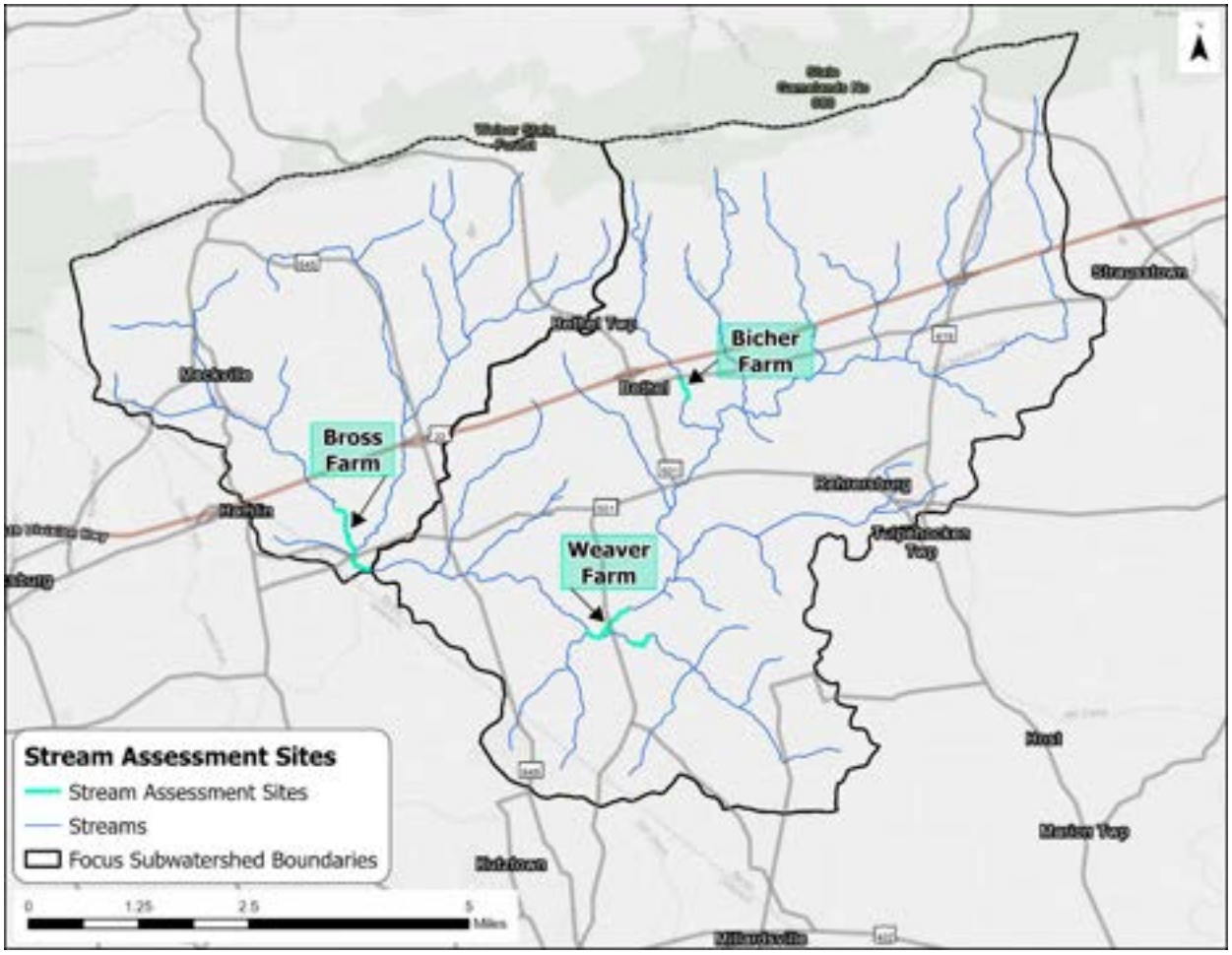

Figure 19. Stream assessment sites

A rapid Bank and Nonpoint Source Consequences of Sediment (BANCS) assessment (Rosgen, 2009) was conducted along reaches at the stream assessment sites to provide an understanding of the degree of streambank erosion. The BANCS assessment uses two measurement methods to predict the potential rate of bank erosion: 1) Bank Erodibility Hazard Index (BEHI), which rates the potential for a bank to erode, and 2) Near Bank Stress (NBS), which rates the shear stress being applied against the bank. Combining the two measurement method ratings results in an estimate of the bank erosion rate. The BEHI and NBS conditions of all eroding banks were rapidly assessed and photographed.

Additionally, preliminary TMDL reduction credits were calculated for each site following the Chesapeake Bay Program Expert Panel to Define Removal Rates for Individual Stream Restoration Projects (Schueler and Stack, 2014) and Consensus Recommendations for Improving the Application of the Prevented Sediment Protocol for Stream Restoration Projects Built for Pollutant Removal Credit (Wood, 2020). Results from the rapid BANCS assessment and planning level estimates of bulk density and soil nutrient concentrations were utilized to estimate the potential sediment and nutrient load reductions due to prevented streambank sediment (Protocol 1 in the crediting guidance) if stream restoration projects were implemented at the assessed sites. A planning level estimate of bulk density was obtained from the U.S. Department of Agriculture Natural Resources

Conservation Service Soil Survey Geographic (SSURGO) database. Soils along all the stream assessment sites are classified as Holly Silt Loam with a bulk density of 1.32 g/cm^3 (82.4 lbs/ft^3). In addition, planning stage estimates of 2.28 lbs TN/ton sediment and 1.05 lbs TP/ton sediment from the Protocol 1 workgroup recommendations (Wood, 2020) were used for soil nutrient concentrations.

Protocol 1 includes a 50 percent reduction efficiency to account for the fact that projects will not be 100 percent effective in preventing streambank erosion and that some sediment transport occurs naturally in a stable stream channel. Efficiencies greater than 50 percent can be achieved if monitoring is conducted pre- and post-restoration for a minimum of 3 years following completion of the project to show that higher rates are justified. Additional information about monitoring methodology can be found in Wood (2020) and Schueler and Stack (2014).

The load reductions included in this report are planning-level estimates only for streambank stabilization based on a rapid assessment. To improve the accuracy and consistency of Protocol 1 application, a more detailed BANCS assessment should be conducted, and the planning level estimates of bulk density and soil nutrient concentrations should be replaced with individual site-specific values. Additional site assessment and analysis will be required if projects are designed, which will result in refinements to the credit calculations. Load reduction credits for denitrification (Protocol 2) and floodplain reconnection (Protocol 3) were not calculated as part of this assessment but may also be applicable depending on the project design selected.

The dominant BEHI/NBS values at Bross Farm are Low/Low, at Weaver Farm are Moderate/Low, and at Bicher Farm are Moderate/High. Although Bicher Farm has the highest dominant BEHI/NBS values of the three assessed sites, it also had the greatest percentage of banks that were not eroding (49.1%). The percentage of eroding banks at the three sites, which includes streambanks on both sides of the stream, ranged between 51 to 70 percent. Overall, Weaver Farm produces the greatest amount of TSS, both in terms of total tons per year and total tons per year per foot. Bicher Farm is producing the least amount of TSS total tons per year as well as total tons per year per foot (Table 23).

Table 23. Bank erosion amounts and rates

Project Site	Predicted Erosion Amount (ft^3/year)	Predicted Erosion Amount (tons/year)	Predicted Average Erosion Amount (tons/year/ft)
Bross Farm	8,701	359	0.07
Weaver Farm	12,095	498	0.09
Bicher Farm	2,172	90	0.06
Total	22,968	948	0.22

Additional details for each of the assessment sites are provided below.

BROSS FARM

The reaches assessed at the Bross Farm are located on Crosskill Creek. The drainage area is approximately 18.9 mi^2 and is 48.5% forested and 1% urban (USGS, 2016). The remaining half of the drainage area is predominantly agricultural. Figure 20 shows the distribution of BEHI ratings across the site and photos of the stream condition are included in Figure 21.

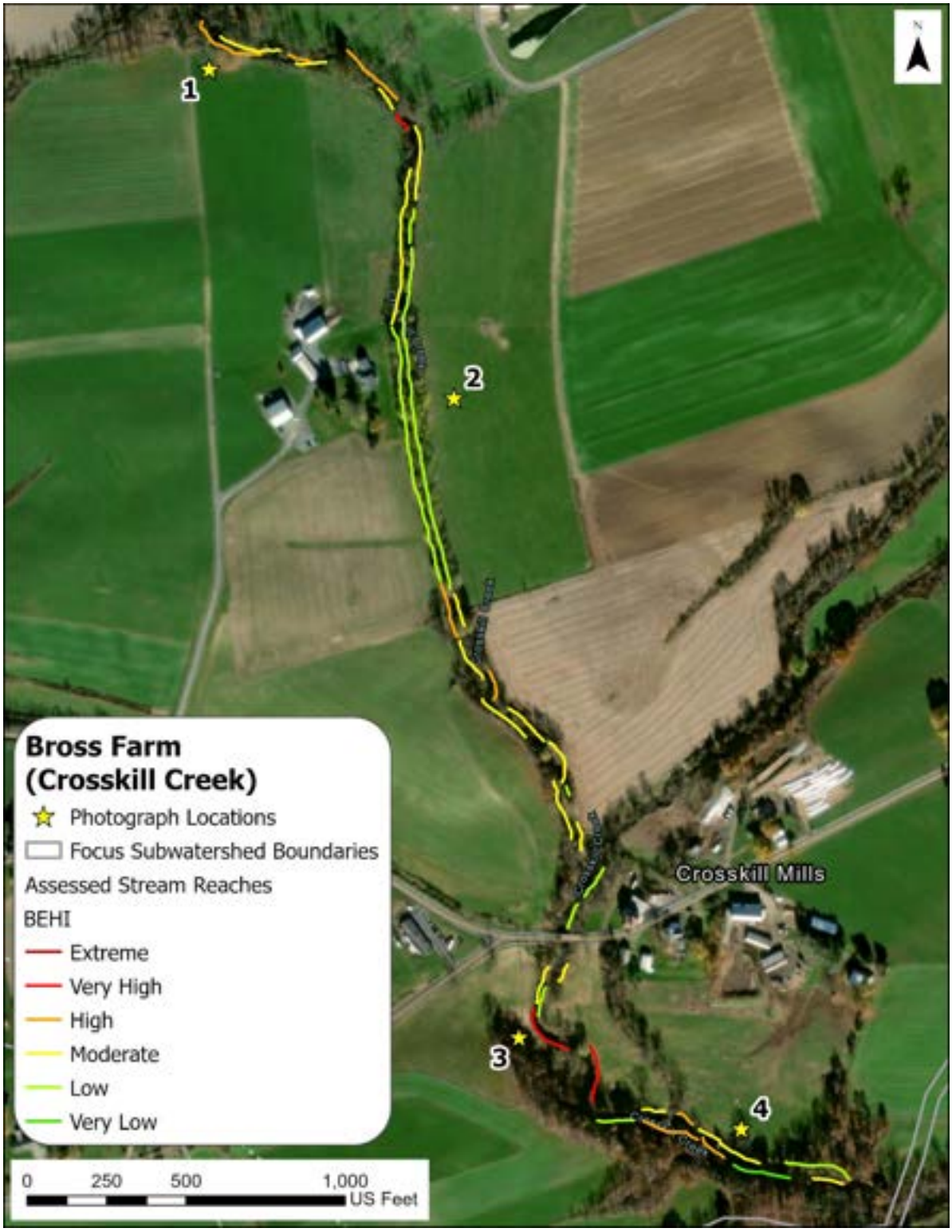

Figure 20. BEHI ratings of assessed reaches at Bross Farm

1. Reach with a High BEHI at the upstream extent of the site.

2. A long portion of the upstream half of the site has a low BEHI and trees along the channel helping to provide stability.

3. Very high BEHI conditions located downstream of Frystown Rd.

4. Reach with a moderate BEHI located at the downstream portion of the site.

Figure 21. Stream conditions at Bross Farm; photo numbers correspond to the numbered locations in the preceding figure

Most of the assessed reach length (73%) has BEHI/NBS ratings that correspond to low erosion rates of 0.13 ft/yr or less. Approximately 11% have moderate erosion rates of 0.3 to 0.4 ft/yr and 16% have high erosion rates of 0.64 ft/yr or greater. The more highly eroding areas are located downstream of Frystown Rd. In

comparison, a large portion of the channel upstream of Frystown Rd has a low BEHI and trees along the channel helping to provide stability. Restoration at this site may be limited due to adjacent pasture and agricultural fields. Table 24 provides a summary of the BEHI and NBS ratings and estimated erosion rates.

Table 24. BEHI and NBS ratings of assessed reaches at Bross Farm

BEHI	NBS	Length (ft)	% of Total Bank Length	BANCS Erosion Rate (ft/yr)
Very High	High	192	1.9%	1.00
High	High	540	5.3%	
Moderate	High	315	3.1%	0.80
Very High	Moderate	246	2.4%	0.64
High	Moderate	338	3.3%	
High	Low	271	2.6%	0.40
Moderate	Moderate	864	8.4%	0.30
Moderate	Low	1,514	14.8%	0.13
Low	Moderate	82	0.8%	0.07
Low	Low	2,590	25.3%	0.03
Very Low	Low	184	1.8%	0.01
N/A – Not Eroding*		3,105	30.3%	0.00

*The total length of left and right banks is estimated as twice the length of the stream centerline length. The length of banks not eroding is the total length of left and right banks minus the total length of all assessed banks.

Table 25. Estimated potential nutrient and sediment load reductions of assessed reaches at Bross Farm

Estimated TN (lbs/yr) Reduction	Estimated TP (lbs/yr) Reduction	Estimated TSS (tons/yr) Reduction
409	188	179

WEAVER FARM

The 5,402 feet of stream reaches assessed at the Weaver Farm are located on the mainstem of the Little Swatara Creek and unnamed tributary 09938. The drainage area is approximately 33.2 mi^2 and is 31.9% forested and 2% urban (USGS, 2016). Most of the drainage area is agricultural. Figure 22 shows the distribution of BEHI ratings across the site, and photos of the stream condition are included in Figure 23.

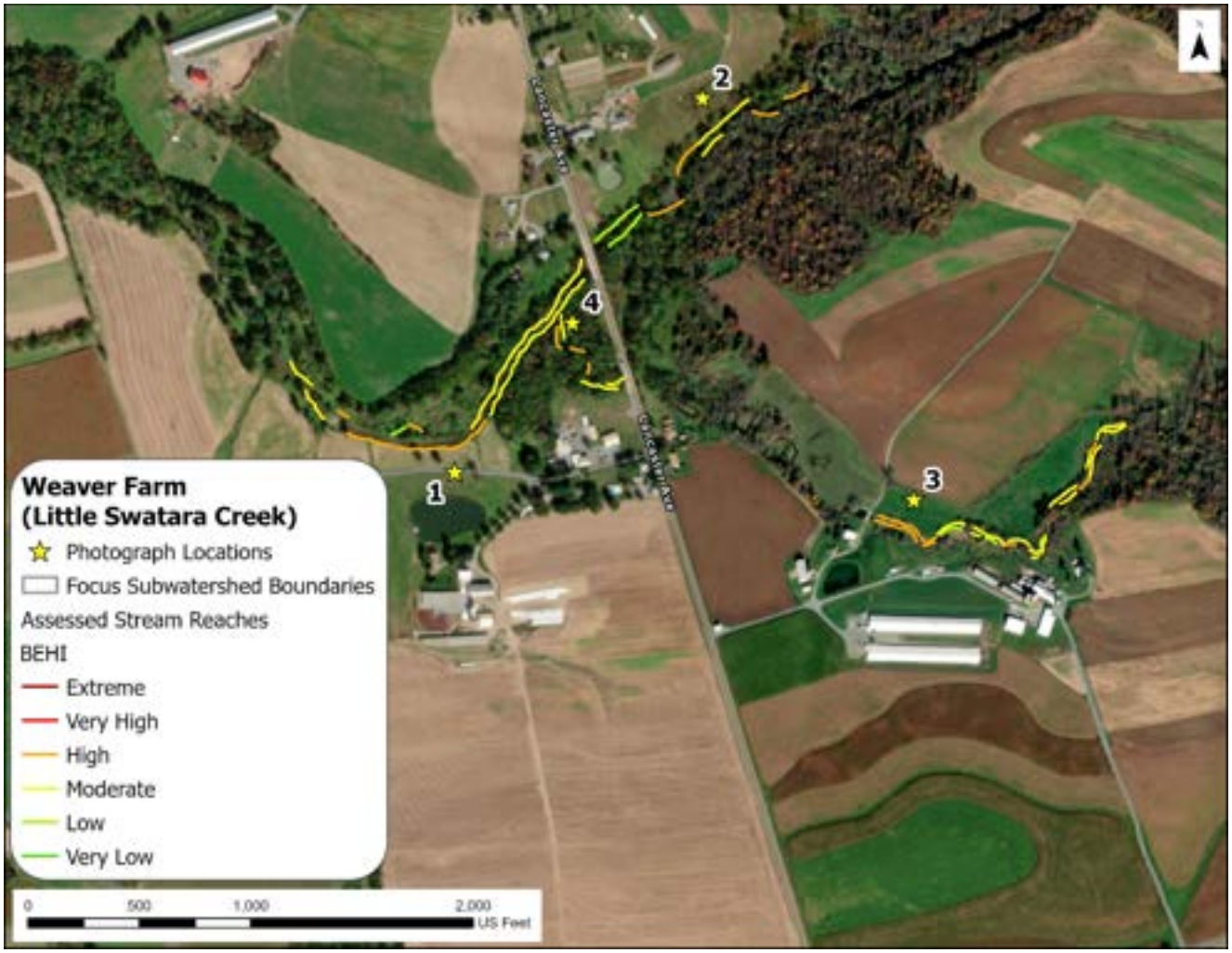

Figure 22. BEHI ratings of assessed reaches at Weaver Farm

1. Reach with a high BEHI at the downstream extent of the site.

2. Reach with a moderate BEHI at the upstream extent of the site.

3. High BEHI conditions located along the tributary.

4. Reach with a moderate BEHI located along the downstream portion of the tributary near the confluence with Little Swatara Creek.

Figure 23. Stream conditions at Weaver Farm; photo numbers correspond to the numbered locations in the preceding figure

Most of the assessed reach length (63.7%) has BEHI/NBS ratings that correspond to low erosion rates of 0.15 ft/yr or less. Approximately 9.2% have moderate erosion rates of 0.3 to 0.4 ft/yr and 27.1% has high erosion rates of 0.64 ft/yr or greater. The more highly eroding areas are located downstream of PA 501 and along

portions of the tributary. Table 26 provides a summary of the BEHI and NBS ratings and estimated erosion rates.

Table 26. BEHI and NBS ratings of assessed reaches at Weaver Farm

BEHI	NBS	Length (ft)	% of Total Bank Length	BANCS Erosion Rate (ft/yr)
High	Very High	152	1.4%	1.75
High	High	797	7.4%	1
Moderate	Very High	63	0.6%	
Moderate	High	770	7.1%	0.8
High	Moderate	1,146	10.6%	0.64
High	Low	240	2.2%	0.4
Moderate	Moderate	753	7.0%	0.3
Low	High	52	0.5%	0.15
Moderate	Low	2,529	23.4%	0.125
Low	Moderate	59	0.5%	0.07
Low	Low	639	5.9%	0.03
N/A - Not Eroding*		3,603	33.4%	0

*The total length of left and right banks is estimated as twice the length of the stream centerline length. The length of banks not eroding is the total length of left and right banks minus the total length of all assessed banks.

Table 27. Estimated potential nutrient and sediment load reductions of assessed reaches at Weaver Farm

Estimated TN (lbs/yr) Reduction	Estimated TP (lbs/yr) Reduction	Estimated TSS (tons/yr) Reduction
568	262	249

BICHER FARM

The 1,567 feet of stream reaches assessed at the Bicher Farm are located on Mill Creek in the Little Swatara subwatershed. The drainage area is approximately 1.8 mi^2 and is 41.1% forested and 2% urban (USGS, 2016). Most of the drainage area is agricultural. Figure 24 shows the distribution of BEHI ratings across the site and photos of the stream condition are included in Figure 25.

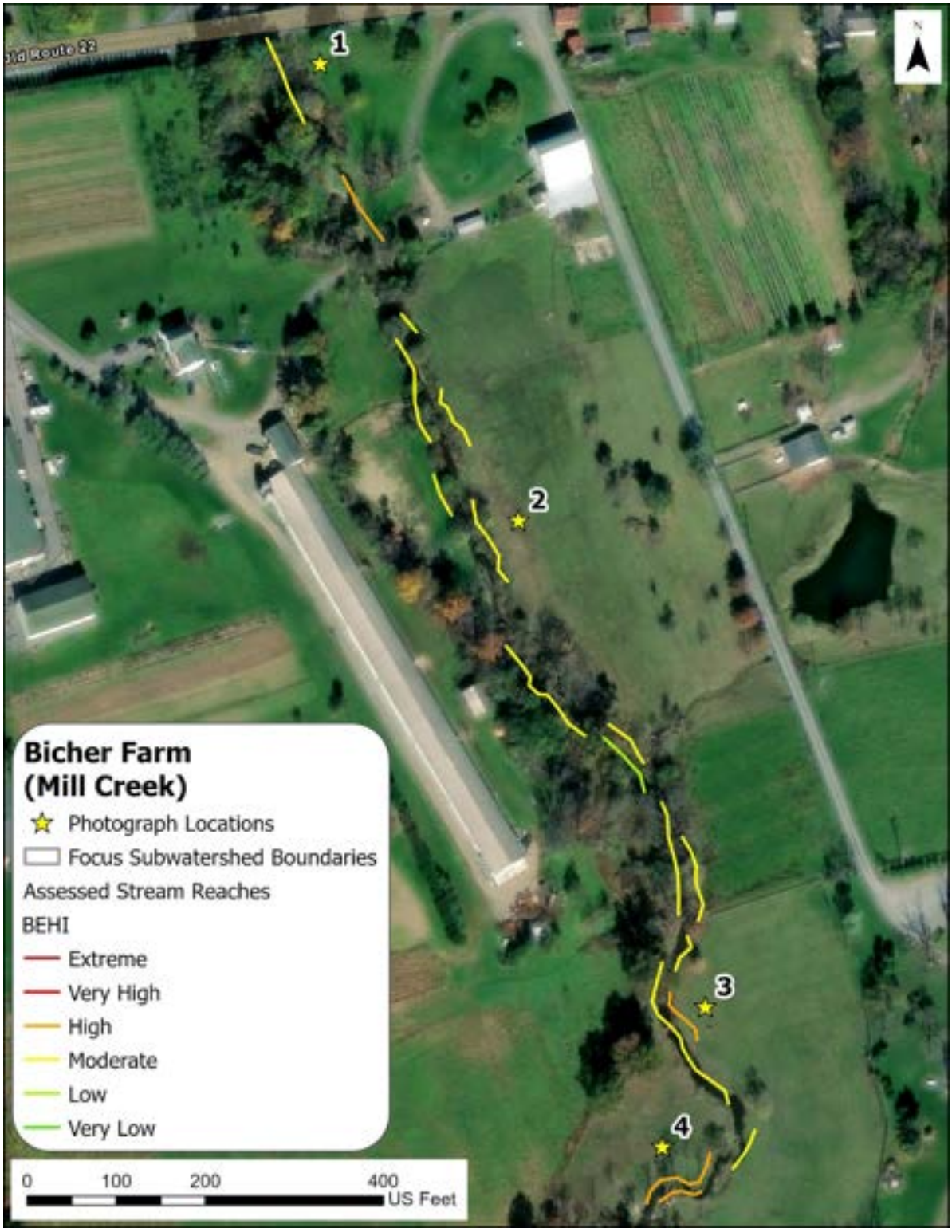

Figure 24. BEHI ratings of assessed reaches at Bicher Farm

1. Reach with a moderate BEHI just downstream of Old Route 22.

2. Reach with a moderate BEHI along the middle portion of the site.

3. High BEHI conditions located along the upstream portion of the site.

4. High BEHI conditions located along the upstream portion of the site.

Figure 25. Stream conditions at Bicher Farm; photo numbers correspond to the numbered locations in the preceding figure

Most of the assessed reach length (66.9%) has BEHI/NBS ratings that correspond to low erosion rates of 0.15 ft/yr or less, with no identified erosion along half of the assessed length. Approximately 6.2% has moderate erosion rates of 0.3 to 0.4 ft/yr and 27% has high erosion rates of 0.64 ft/yr or greater. The more highly eroding areas are located along the downstream portion of the site. Table 28 provides a summary of the BEHI and NBS ratings and estimated erosion rates.

Table 28. BEHI and NBS ratings of assessed reaches at Bicher Farm

BEHI	NBS	Length (ft)	% of Total Bank Length	BANCS Erosion Rate (ft/yr)
High	Very High	112	3.6%	1.75
High	High	137	4.4%	1
Moderate	High	595	19.0%	0.8
High	Low	66	2.1%	0.4
Moderate	Moderate	128	4.1%	0.3
Low	High	79	2.5%	0.15
Moderate	Low	479	15.3%	0.125
N/A - Not Eroding*		1,538	49.1%	0

*The total length of left and right banks is estimated as twice the length of the stream centerline length. The length of banks not eroding is the total length of left and right banks minus the total length of all assessed banks.

Table 29. Estimated potential nutrient and sediment load reductions of assessed reaches at Bicher Farm

Estimated TN (lbs/yr) Reduction	Estimated TP (lbs/yr) Reduction	Estimated TSS (tons/yr) Reduction
102	47	45

5.4 Agriculture Conservation Assessment

Agriculture encompasses nearly half of the land use (49.3%) in the Total Study Watershed, is a driver of economic development in the region, and contributes to the sediment and nutrient impairments. As the dominant land use after forest lands, agricultural lands are the focus for advancing conservation practices to address water quality goals. As such, BCCD and CWP committed significant time assessing the state of agriculture in the Total Study Watershed.

The assessment included field visits to the watershed with the baseline water quality sampling, stormwater, and streambank assessments. The priority of the field visits was to identify existing farmer practices that includes agricultural operation type (e.g., crop, livestock, or other), existing crop rotations, near stream and field conservation practices, pasture management, and best management practices on farms. In addition, BCCD gathered data on agricultural conservation practices already implemented and planned for future implementation through USDA-NRCS and Practice Keeper GIS databases. The data acquired included conservation practices implemented in the last 10 years and future conservation practices planned for the next 5 years. Last, two stakeholder meetings were held, one on August 26, 2021 and the second on February 8, 2024. The first meeting was hosted in the watershed with invitations mailed directly to agricultural land operators (Figure 26). The stakeholder meeting was helpful to understand the local communities' perspective on implementing feasible and cost-effective conservation practices within the watershed (Section 8.3).

Figure 26. First stakeholder meeting at Kauffman's BBQ Restaurant

The second stakeholder meeting was convened virtually using the Zoom platform. There were 26 attendees that represented the agricultural community and implementation partners. The meeting provided an overview of the project timeline, a presentation providing an overview of the Plan, followed by discussion and next steps. The Plan was posted on BCCD's website for stakeholders to provide comments.

These evaluation strategies helped understand the conservation strengths, weaknesses, and needs of the agricultural community in the watershed. Most importantly, the assessment assisted in developing a framework on prioritizing individual subwatersheds based on what conservation practices have already been implemented, and what conservation practices may be needed to further reduce sediment and nutrient loads in accordance with the 2004 TMDL plans.

SECTION 6. POLLUTANT LOADING

Model My Watershed (MMW) was used to estimate the total phosphorus (TP), total nitrogen (TN), and total sediment (TSS) loads for the Total Study Watershed. MMW is a model developed by Stroud Water Research Center to analyze nationally available landscape, climate and other datasets and model stormwater runoff and water quality impacts (Stroud Water Research Center, 2017). MMW estimates loads for three different conditions, representing three different points in time:

- *Baseline conditions* represent loads exported by MMW, without BMPs entered into the model. In this watershed plan, this condition represents the loads in 2012 and assumed equivalent to the TMDL baseline loading.
- *Existing conditions* represent loads with BMPs implemented between 2012 and 2020.
- *Future conditions* represent all of the BMPs implemented in the Existing condition, in addition to BMPs that were planned as of 2020 or identified as a part of this project.

Separate MMW model runs were created to reflect the unique conditions of each of the eight subwatershed target areas: Crosskill Creek, Upper Little Swatara, Unnamed tributary 09944, Unnamed tributary 09947, Unnamed tributary 09932, Unnamed tributary 09933, Unnamed tributary 09936, Unnamed tributary 09938. Section 7. Subwatershed Summaries provides a summary of each subwatershed. For each subwatershed target area, MMW was used to run the Multi-Year Model to provide an estimate of mean annual nutrient and sediment loads and loading rates. The resulting output data is provided in an excel spreadsheet that is then entered into a BMP Spreadsheet Tool (the Tool) developed to evaluate potential pollutant load reductions from the implementation of Best Management Practices (BMPs) in both urban and rural landscapes (Evans et al., 2020). Appendix A provides the MMW BMP spreadsheets for each subwatershed.

Timeframes Modeled

Since the TMDLs were established in 2011 for the Upper Little Swatara Tributaries and 2004 for the Crosskill subwatershed, this Plan documents progress between the baseline year and the existing conditions using BMP Implementation data provided by the BCCD. The pollutant reduction achieved is then used to estimate the required and possible reductions to meet TMDL requirements. As a result, two MMW BMP spreadsheets were completed for each subwatershed:

- Progress runs reflect Baseline Conditions (as reflected in the original TMDLs) and Existing Conditions (reflected by Existing BMPs).
- Future runs reflect Existing Conditions (represented by Existing BMPs) and Future Condition with (reflected by Future Proposed BMPs)

Model Input Data

SUBWATERSHED BOUNDARIES

The MMW model platform requires a drainage area boundary or point of interest from which to delineate the subwatershed. This boundary is then used to summarize both land cover, NLCD 2019 data, and hydrologic soils group (HSG) from the NRCS SSURGO database present in the subwatershed. For this project, the drainage areas for each of the eight subwatersheds were delineated using the tool in MMW to automatically delineate a subwatershed from the outlet point. The eight subwatersheds include Crosskill Creek, Upper Little Swatara Creek, and the six unnamed tributaries (UNT) listed as impaired in the 2011 TMDL for the Upper Little Swatara Watershed. The UNTs include UNT 09932, UNT 09933, UNT 09936, UNT 09938, UNT 09944, and UNT 09947.

URBAN BMP DATA

BASELINE CONDITIONS

No data was available to reflect pre-TMDL urban BMPs implemented, so Baseline (TMDL) conditions did not include any urban BMPs.

EXISTING CONDITIONS (THROUGH 2021)

Existing urban stormwater BMP data was provided by the BCCD and included practices from the Practice Keeper database. This database includes records of BMPs implemented through new development (Chapter 102 permits or NPDES permits). Data was available for the Little Swatara Creek subwatershed, but no urban BMPs were recorded in the Crosskill Creek subwatershed. In addition, urban BMPs in this database included a value for "Volume Treated" but did not include a drainage area or drainage area characteristics. In addition, the equation used to estimate the drainage area or volume treated was slightly different for each BMP, but all calculations assumed that the land use treated is Mixed High Density, which has 87% impervious cover.

Since the last version of PA's stormwater BMP Manual includes an option to treat 2" of stormwater runoff from the drainage area, the area treated for structural stormwater BMPs such as bioretention or wet ponds assumed this treatment depth to normalize the drainage area. The drainage area was calculated using Equation 1, which assumes that BMPs are sized to treat two inches of runoff per impervious acre.

Equation 1

$$DA_{SW-BMP} = \frac{V}{d \times I \times 3630}$$

Where:

DA_{SW-BMP}	=	Drainage Area (acres)
V	=	Treatment Volume (cf)
d	=	Assumed Treatment Depth (2 inches)
I	=	Assumed Impervious Cover Fraction (0.87)
3,630	=	Conversion factor from (ac-in) to cf

FORESTED BUFFERS

Forested buffers were input in the Tool as the "Forest Buffers" Urban BMP Category with required input of the area of the buffer. For this practice, it was important to characterize the actual area of the practice, since MMW uses this area to calculate both a land-conversion and a treatment estimate. Since the last version of PA's stormwater BMP Manual includes an option to treat 2" of stormwater runoff from the drainage area, this treatment depth was used to estimate the forest buffer area. Further, we assumed that the buffer area was 25% of the total drainage area, based on the description of how stream buffers are credited in MMW. The drainage area provided was calculated using Equation 2.

Equation 2

$$A_{Buffers} = \frac{V \times 12}{d \times I \times AR}$$

Where:

$A_{Buffers}$	=	Buffer Area (sf)
V	=	Treatment Volume (cf)
d	=	Assumed Treatment Depth (2 inches)
I	=	Assumed Impervious Cover Fraction (0.87)
AR	=	Ratio of Treated Impervious area to Buffer Area (3)
12	=	Conversion factor from feet to inches

Street Sweeping

Street sweeping was assigned the sweeping class "SPC-4", which represents monthly sweeping with advanced sweepers. MMW requires the street length swept, along with the sweeper type. The area swept was derived from the treatment volume reported, using Equation 3.

Equation 3

$$L_{SS} = \frac{V \times 12}{d \times W}$$

Where:

L_{SS}	=	Length of road swept (ft)
V	=	Treatment Volume (cf)
d	=	Assumed Treatment Depth (2 inches)
W	=	Assumed Road with (20')
12	=	Conversion factor from feet to inches

Future Conditions

Future urban BMP data was provided from stormwater BMP opportunities identified during stormwater retrofit field work (Section 5.2 Stormwater Retrofit Inventory). These practices included design information regarding the practice area, design storm and drainage area, and all practice details were entered into the spreadsheets to reflect future urban BMPs (Table 21).

Agricultural BMP Data

Baseline Conditions

The Little Swatara TMDL included appendices describing model runs. While no agricultural BMPs were explicitly modeled, the Practice Factor (P) used in the Unified Soil Loss Equation (USLE) for agricultural land uses was equal to 0.52 (PA DEP 2011). Although the specific values vary, this value is equivalent to Contour Cropping on moderate slopes (Haith et al., 1992; Table B-13 reports values between 0.50 and 0.60 for slopes between 1% and 12%). Consequently, Baseline Conditions assume that Contour Cropping is applied on agricultural lands. The Crosskill TMDL did not state any assumptions regarding baseline management, and it was assumed that the condition was similar (i.e., Contour Cropping was implemented in 2004 on agricultural land).

In addition, based on an estimate provided by BCCD, it was assumed that 75% of livestock and poultry were treated by Animal Waste Management Systems (AWMSs) at the time of TMDL development.

Existing Conditions

Agricultural BMP information was provided from three different sources: the NRCS Database, Practice Keeper, and Berks County RCPP database of Ag BMP contracts currently in place. The first two databases reflect practices already in place as of 2021. The NRCS data were considered more reliable than Practice Keeper data per discussions with BCCD, but location data from Practice Keeper was detailed enough to provide specific subwatershed location of the BMP. This detailed location information was not available for NRCS data and, as a result, it was not possible to use NRCS data at the scale of the TMDL subwatersheds in the Upper Little Swatara. Therefore, Practice Keeper data were used to characterize Agricultural BMPs in the Upper Little Swatara unnamed tributaries, and NRCS Data were used to characterize BMPs in the Crosskill Creek and to reflect implementation across the entire Upper Little Swatara Watershed. Practices in the RCPP database under contract (as of 2021) were also credited and assigned to the subwatershed where they were implemented.

A table was developed to align the agriculture BMP practice types provided from the NRCS database and Practice Keeper with the agricultural BMPs included in MMW for crediting (Table 30). The NRCS Code provided

for Agricultural BMPs was cross referenced to the agriculture BMPs provided in MMW. This allowed for identification of the BMP to credit in the Tool. The area of implementation for each BMP practice type (in acres) was quantified by relating the NRCS Code to MMW BMP practices.

Table 30. Table aligning NRCS codes with agricultural BMPs

NRCS Code	NRCS BMP Name	MMW BMP Name
329	Residue and Tillage Management, No-Till/Strip Till/Direct Seed	Conservation Tillage, >60
330	Contour Farming	Contour Farming
340	Cover Crop	Cover Crops
342	Critical Area Planting	Cropland Retirement
344	Residue Management, Seasonal	Conservation Tillage, 30-59
345	Residue and Tillage Management, Mulch Till	Conservation Tillage, 30-59
386	Field Border	Grass Buffer CBP
391	Riparian Forest Buffer	Forest Buffer
393	Filter Strip	Grass Buffer CBP
528	Prescribed Grazing	Pasture and Grazing Management Practices
590	Nutrient Management	Nutrient Management

Assumptions

Animal Waste Manure Systems (AWMSs) are quantified as a percentage of waste treated for livestock and poultry. This number was not available from existing databases provided by BCCD. As a result, CWP relied on estimates of overall treatment from BCCD staff and made the blanket assumption that the levels of poultry and livestock capture by AWMSs has increased by 20% since TMDLs were initially developed from these watersheds, resulting in 95% of animal waste currently served by AWMSs.

MMW does not allow double counting of certain BMPs on the same land and recommends reducing BMP acreage to ensure that total land covered by BMPs does not exceed the land area in that category. In order to account for this, the Existing Conditions BMPs were included as a reduced amount of contour cropping from the Baseline conditions.

Future Conditions

Stream Restoration

Stream restoration projects identified by CWP during the field assessment were credited as Agricultural BMPs. MMW defines stream restoration as 'streambank stabilization' and applies a pollutant reduction (lbs/ft) value of 44.88 based on the feet of stream stabilized. The CWP conducted a rapid BANCS assessment at three properties along the stream. Pollutant reduction credits were calculated for each site following the Chesapeake Bay Program Expert Panel to Define Removal Rates for Individual Stream Restoration Projects (Schueler and Stack, 2014) and Consensus Recommendations for Improving the Application of the Prevented Sediment Protocol for Stream Restoration Projects Built for Pollutant Removal Credit (Wood, 2020). Results from the rapid BANCS assessment and planning level estimates of bulk density and soil nutrient concentrations were utilized to estimate the potential sediment and nutrient load reductions due to prevented streambank sediment (Protocol 1). The sediment and nutrient load reductions estimated using the Chesapeake Bay Program Expert Panel were used to credit streambank stabilization in the Tool instead of using the default value of 44.88 lbs/ft.

Other Agricultural Practices

Future key practices for implementation identified by the BCCD include nutrient management, conservation tillage with high residue, and cover crops. The process for selecting future implementation levels for these BMPs (Table 31) assumed the following:

- The BBAP proposed BMP implementation levels will be increased in UNT subwatersheds and the Crosskill Creek to meet TMDL load reduction goals.
- In the portion of the Upper Little Swatara subwatershed that is not subject to TMDL requirements, BMP implementation levels will be equal to those proposed in the BBAP.

Table 31. Target implementation levels for agricultural BMPs

NRCS or CBP BMP Name	MMW BMP Name	Implementation Level from BBAP (applied in Upper Little Swatara Subwatershed)[1]	Levels Proposed for UNT Subwatersheds and Crosskill Creek
Nutrient Management Core P[2]	Nutrient Management	25%	40%
Tillage Management – High Residue (No-Till)	Tillage Management (>60% Residue)	48%	90%
Tillage Management – Conservation (Low Residue Tillage)	Tillage Management (30-59% Residue)	42%	0% (Shifted to High Residue/ No-Till)[3]
Cover Crop (Traditional) or Cover Crop with Fall Nutrients	Cover Crop	64%	90%
Contour Farming	Contour Farming	N/A; Assumed 100%	Assumed 100%

[1] Targets may be exceeded in instances where the implementation levels in UNT subwatersheds exceed the total target percentage in the Upper Little Swatara.
[2] "Core P" Nutrient Management is defined in CBP (2016; Table 3) and refers to practices including soil testing and nutrient balancing that achieve phosphorus application rates consistent with Land Grant University Recommendations.
[3] The "0%" application of conservation tillage in the UNT Subwatersheds and the Crosskill Creek are a result of applying high residue (no-till) tillage management in the place of conservation tillage with low residue tillage.

MMW does not allow doble counting of certain practices on the same land parcel, and consequently results in an error if the total area applied exceeds the available acreage for certain BMPs. For example, if only 100 acres of cropland are available, entering 80 acres of conservation tillage (any type) and 30 acres of cover crops will result in an error. As a result, this modeling effort adjusted the acreages reported in the model to avoid this error (e.g., reducing the acres of cover crops reported in the model). This method results in somewhat conservative estimates of pollutant reduction, and the approach is described in the "Read Me" file that accompanies the attached model spreadsheets included in Appendix A.

Results and TMDL Targets

For each subwatershed, the proposed Urban and Agricultural BMPs evaluated in MMW are summarized in Table 32 and Table 33.

Table 32. Proposed MMW urban BMPs by subwatershed

Urban BMP Type	Area (acres)							
	UNT 09932	UNT 09933	UNT 09936	UNT 09938	UNT 09944	UNT 09947	Swatara (Berks)	Crosskill Creek
Bioswale	–	–	–	–	–	–	7.6	–
Bioretention/raingardens - A/B soils, underdrain	1.35	1.46	–	2.9	0.85	–	5.1	–

Table 32. Proposed MMW urban BMPs by subwatershed

Urban BMP Type	Area (acres)							
	UNT 09932	UNT 09933	UNT 09936	UNT 09938	UNT 09944	UNT 09947	Swatara (Berks)	Crosskill Creek
Bioretention/raingardens - C/D soils, underdrain	N/A	1.31	–	–	–	–	0.62	10.5
Filtering Practices	0.85	–	–	–	–	–	–	–
Permeable Pavement w/o Sand, Veg. - A/B soils, underdrain	–	–	–	–	0.14	–	2.54	–
Permeable Pavement w/o Sand, Veg. - A/B soils, no underdrain	–	0.58	–	–	–	–	–	–
Permeable Pavement w/o Sand, Veg. - C/D soils, underdrain	–	0.6	–	–	–	–	–	–
Wet Ponds and Wetlands	–	–	–	11.5	–	–	–	–

Table 33. Proposed Agricultural BMPs by subwatershed

Subwatershed Name	Proposed Additional Nutrient Management (Core P) (acres)	Proposed Additional Tillage Management (High Residue) (acres)	Proposed Additional Cover Crops (acres)	Proposed Streambank Restoration (feet) – Farm Name
UNT 09932	194	493	485	0
UNT 09933	188	422	422	0
UNT 09936	221	493	493	0
UNT 09938	792	1,836	1,831	1,897 – Weaver
UNT 09944	241	1,191	1,162	0
UNT 09947	217	500	509	0
Total Upper Little Swatara Subwatershed[1]	1,853	5,496	7,629	5,072 –Weaver and Bicher
Crosskill Creek Subwatershed	0[2]	2,064	2,805	5,120 –Bross

[1]The Little Swatara Subwatershed also includes an additional 3,901 acres of Conservation Tillage (low residue).

[2] NRCS data indicate that existing levels of Nutrient Management implementation exceeds the target implementation levels in the Crosskill.

The TMDL targets were expressed as a percent reduction from the baseline load, as reported in the TMDL documents, and used to establish target load reductions for each TMDL subwatershed.[3] The UNT subwatersheds in the Upper Little Swatara watershed TMDL have pollutant load reduction target for either sediment, phosphorus, or both. However, the TMDL doesn't assign a pollutant load reduction target for the entire Upper Little Swatara subwatershed, only for the UNTs.

[3] Note that the absolute reduction amount (in pounds) is not the same as the TMDL values reported in Section 2 of this document. This is because MMW's underlying assumptions have changed from the TMDL development (2004 and 2011) to 2024 made it impossible to directly compare the load values calculated.

Based on the MMW results, the TMDL defined percent pollutant load reduction targets for phosphorus that are not achievable even with the very high levels of proposed BMP implementation. Meeting the TMDL load reduction targets is a goal of the Plan but not a regulatory requirement. The MMW results provide achievable reductions of approximately 60% for sediment and 30% for phosphorus. The analysis shows that meeting phosphorus targets could only be achieved by converting large areas of agricultural land to other land uses which is not an approach considered in this plan. In contrast, the MMW results show that the percent pollutant load reduction targets for sediment can be achieved. The proposed sediment and phosphorus pollutant load reductions calculated in MMW are provided in Table 34 and Figure 27, and Table 35 and Figure 28, respectively. The pollutant load reduction estimates will be achieved through implementation of the proposed BMPs (Table 32 and Table 33).

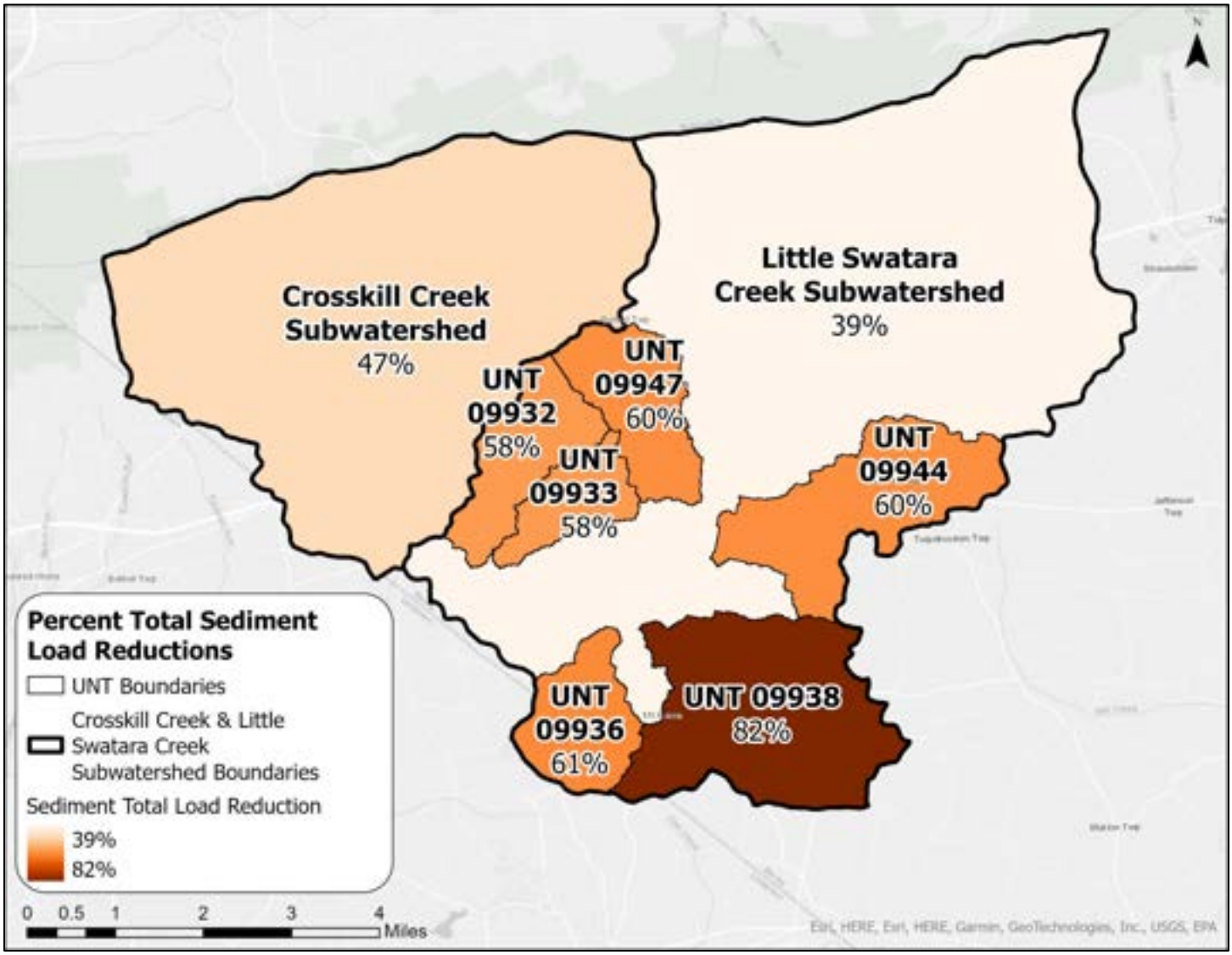

Figure 27. Percent total sediment load reductions. [4]

[4] The Little Swatara Creek Subwatershed includes all of the UNT subwatersheds.

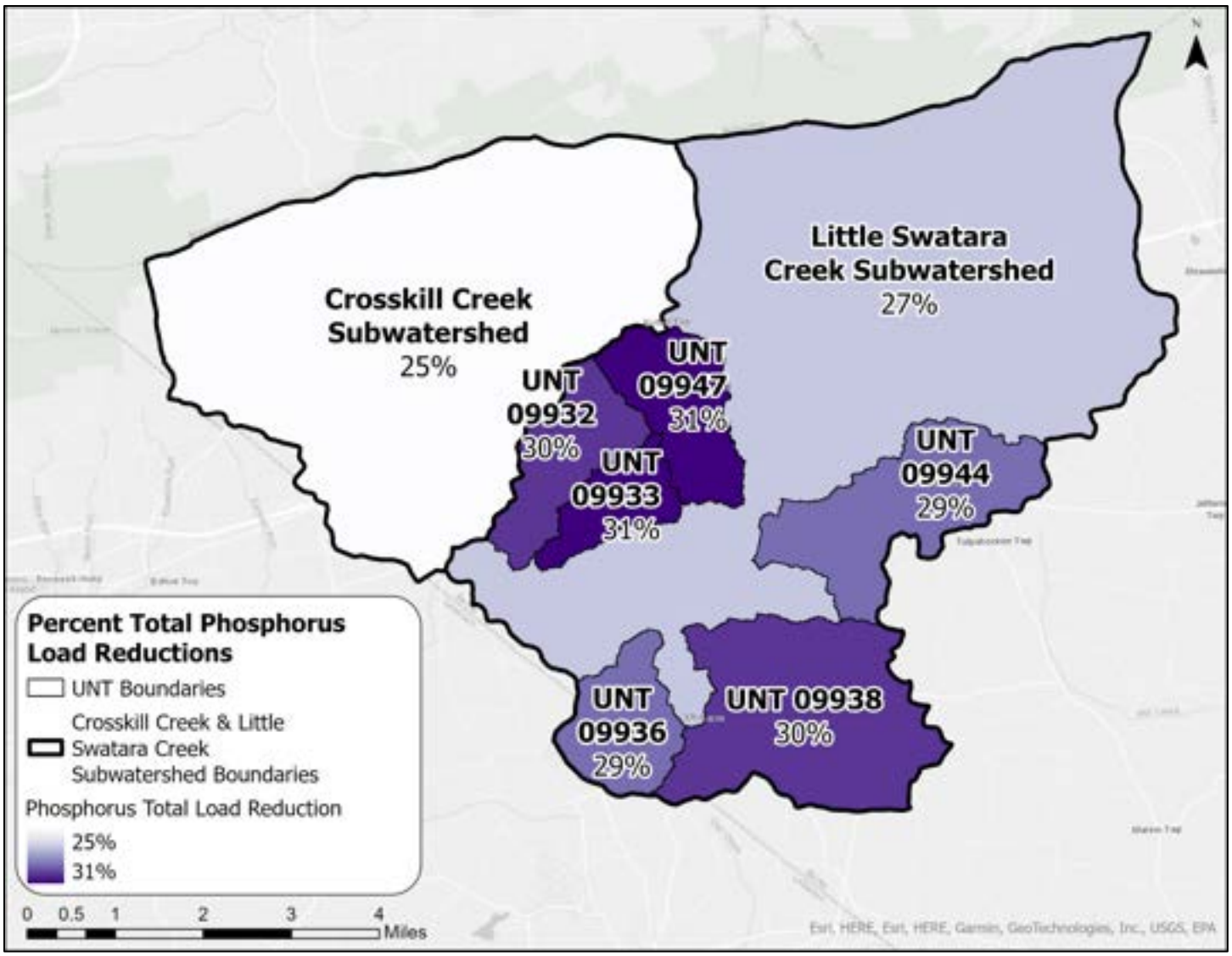

Figure 28. Percent total phosphorus load reductions.[5]

[5] The Little Swatara Creek Subwatershed includes all of the UNT subwatersheds.

Table 34. Sediment TMDL targets and loading in the subwatersheds

Sediment TMDL Target	Loading (tons/year)							
	UNT 09932	UNT 09933	UNT 09936	UNT 09938	UNT 09944	UNT 09947	Swatara (Berks)	Crosskill Creek
Baseline Load	620,812	471,298	568,260	1,660,972	1,127,006	690,519	12,341,678	3,299,962
TMDL Reduction Target	63%	N/A	53%	67%	21%	60%	N/A	24%
Target Load Reduction (Tons/Year)	391,112	N/A	301,178	1,112,851	236,671	414,311	N/A	791,991
2021 Progress Load Reduction (Tons/Year)	28,375	N/A	37,222	85,729	68,722	15,253	1,248,565	329,644
Load Reduction Achieved by Proposed Practices (Tons/Year)	332,356	275,060	310,930	1,270,994	609,249	397,132	3,594,445	1,209,532
Total Load Reduction (Tons/Year)	360,731 (58%)	275,060 (58%)	348,152 (61%)	1,356,732 (82%)	677,971 (60%)	412,385 (60%)	4,843,010 (39%)	1,539,176 (47%)

Table 35. Phosphorus TMDL targets and loading in the subwatersheds

Phosphorus TMDL Target	Loading (lbs/year)							
	UNT 09932	UNT 09933	UNT 09936	UNT 09938	UNT 09944	UNT 09947	Swatara (Berks)	Crosskill Creek
Baseline Load	1,094	803	1,181	3,241	2,196	1,211	22,357	7,309
TMDL Reduction Target	76%	49%	73%	80%	64%	73%	N/A	N/A
Target Load Reduction	831	393	862	2,593	1,405	884	0	0
2021 Progress Load Reduction	57	28	87	185	131	58	2,152	928
Load Reduction Achieved by Proposed Practices	267	221	256	797	516	317	3,907	929
Total Load Reduction	324 (30%)	249 (31%)	343 (29%)	982 (30%)	647 (29%)	375 (31%)	6,059 (27%)	1,857 (25%)

SECTION 7. SUBWATERSHED SUMMARIES

This section provides an overview of the priority subwatersheds in the study area. These subwatersheds are priority for restoration as there is an existing TMDL load allocation for sediment and/or phosphorus. The priority subwatersheds are the six UNT identified in the Upper Little Swatara TMDL (PA DEP 2011) as well as the Crosskill Creek subwatershed. A summary of the subwatershed characteristics, monitoring data collected, and the results of the modeled future phosphorus and/or sediment percent load reduction is provided.

Crosskill Creek Subwatershed

Crosskill Creek originates south of the Berks and Schuylkill County boundary in Bethel Township and flows in a southernly direction before its confluence with Little Swatara Creek near Crosskill Mills (Figure 29). The subwatershed is almost entirely located in Northern Berks County (98%) with the remaining 2% in Lebanon County. The 18.9 square mile watershed contains a total of 26.0 miles of streams (Table 36). The entire basin is currently designated as protected for aquatic life use as cold-water fishery and recreational use (PA Chapter 93). The dominant underlying geology is shale, sandstone, and limestone. The dominant hydrologic soil groups are well-drained soils (HSG B, 56%) and slow to drain soils (HSG D, 20%) are scattered throughout the subwatershed.

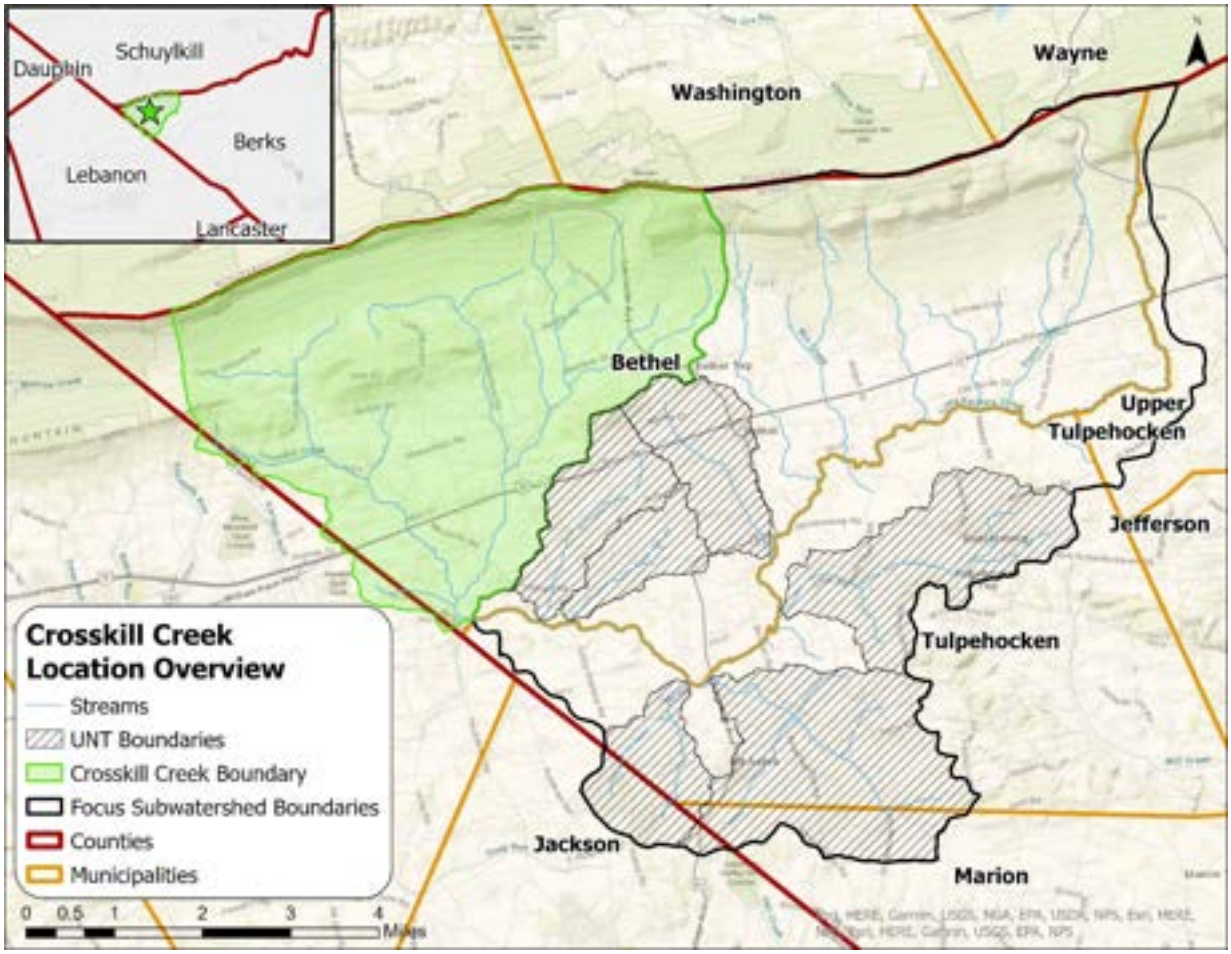

Figure 29. Crosskill Creek location overview

Table 36. Overview facts about the Crosskill Creek subwatershed	
Drainage Area	18.9 mi^2
Existing Impervious Cover	3.5%
TMDL	2004 Sediment
Stream Miles	26.0 mi
Recreational Use	
Impaired	76.9%
Supporting	16.9%
Aquatic Life Use	
Impaired	28.8%
Supporting	78.1%

The subwatershed land use/land cover is dominated by forest cover (46.6%), cropland (32.4%) and pasture hay (6.7%). The forest cover is located mainly in the northern headwaters that drain the Blue Mountain ridge. The creek flows in a southernly direction through a landscape dominated by cropland and pasture/hay. There are five Concentrated Animal Feeding Operations (CAFOs) and one groundwater cleanup site in compliance. Permanent easements are held on 19% of the subwatershed land and ensure the land is used for agricultural production or commercial equine activity and not developed.

A TMDL was developed in 2004 for sediment impairments along 0.6 miles of the Crosskill Creek upstream of unnamed tributary 09929. Siltation and Turbidity/suspended solids were identified as pollutants causing designated use impairments that are predominantly from agricultural activities and streambank erosion.

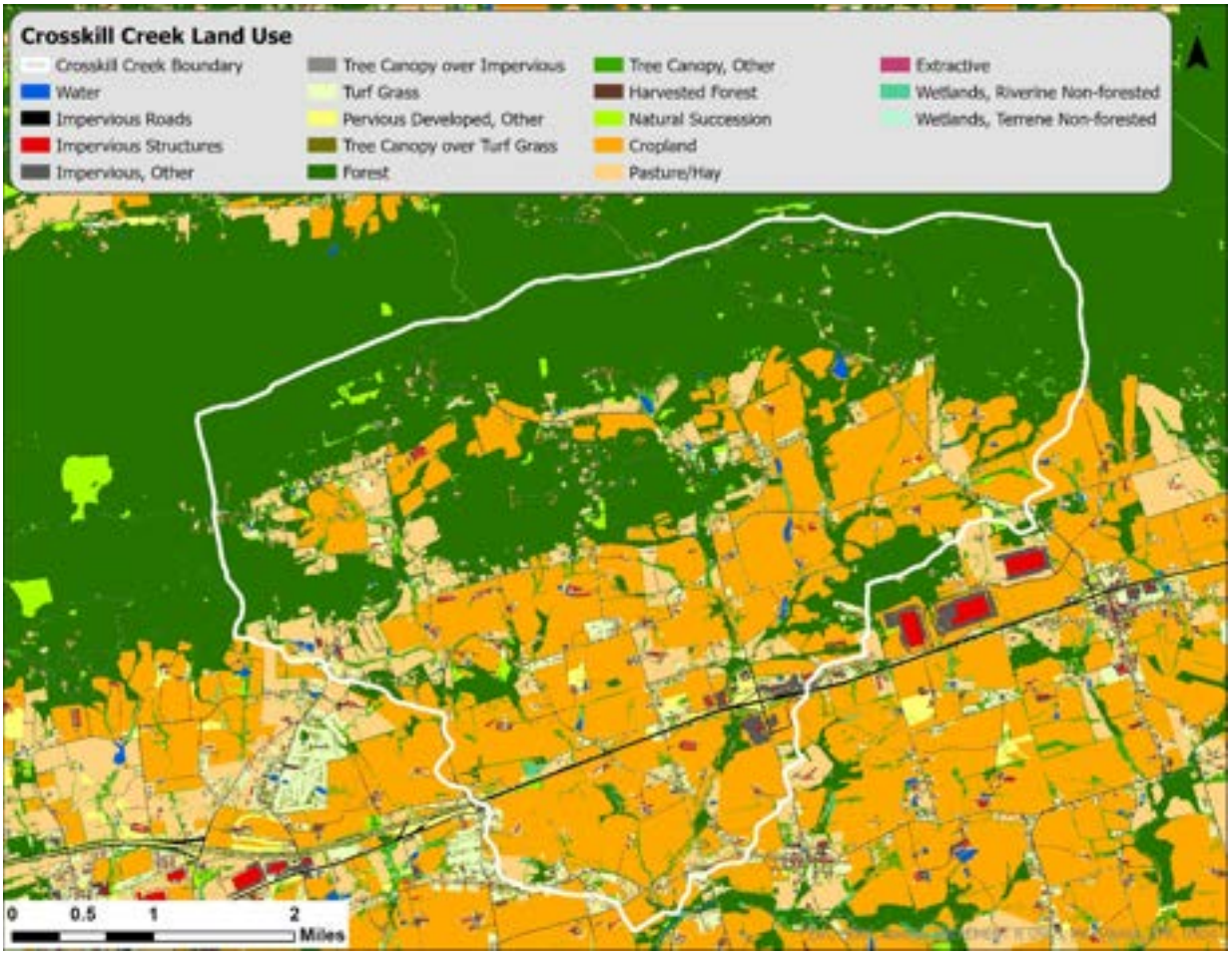

Figure 30. Crosskill Creek land use land cover (LULC)

Biological sampling throughout the watershed was conducted by BCCD in 2021 and PA DEP in 2019 and 2022 along the Crosskill Creek (Figure 31). The forested upper reaches of the Crosskill Creek are attaining their designated uses as shown by the PA DEP sampling site with an excellent IBI score. As the tributaries flow towards the confluence, the streams are impaired for aquatic life use and then impaired for both aquatic life use and recreational use. The IBI scores along the impaired streams range between good to poor IBI scores. At the location where UNT 09929 and a major tributary intersect are several sampling stations from both BCCD and the PA DEP. Sites sampled by BCCD were taken in 2021 and provide a fair IBI score while the sampling conducted in 2022 by the PA DEP show good IBI scores. While these scores represent the water quality monitored once at a specific location, it is worth noting that the IBI scores increased from 2021 to 2022.

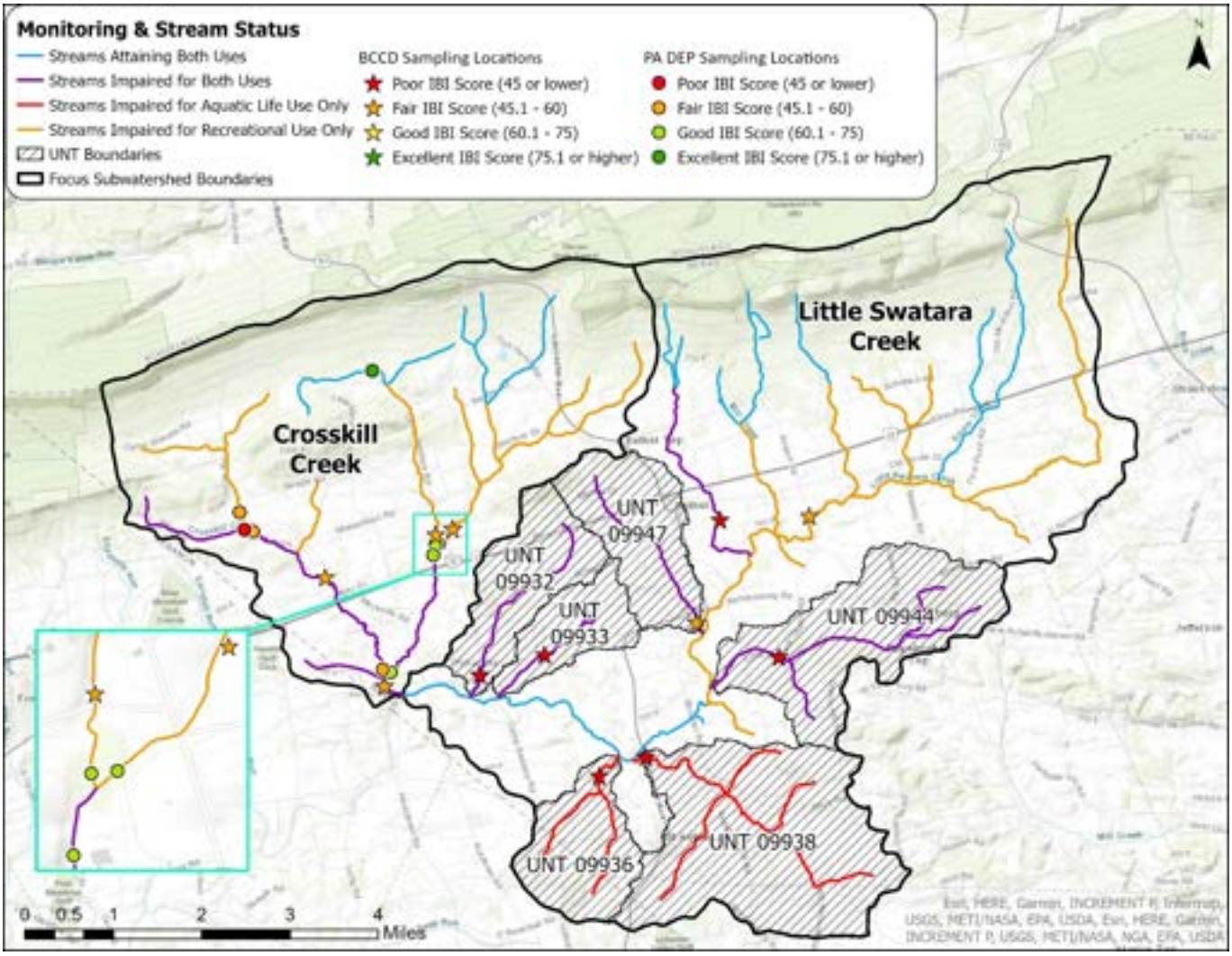

Figure 31. Crosskill Creek monitoring and stream status

NUTRIENT MODELING RESULTS

MMW was used to estimate the reduction in sediment and phosphorus achieved through proposed urban and agricultural BMPs in each subwatershed. Table 37 provides a summary of sediment and phosphorus reductions starting from the initial baseline load of 3,299,962 pounds/year and 7,309 pounds/year respectively. Crosskill Creek has a sediment TMDL target reduction of 24% or 791,991 pounds/year. There is no TMDL for phosphorus in this subwatershed. The total load reduction achieved through current and future proposed BMP implementation results in a 47% reduction for sediment and 25% reduction for phosphorus which exceed meet the TMDL target reductions. Proposed BMPs are provided in Table 38 and Section 8.2 provides information on cost of BMP implementation.

Table 37. Crosskill Creek TMDL targets and loading		
TMDL Target	**Loading (lbs/year)**	
	Sediment	**Phosphorus**
Baseline Load[1]	3,299,962	7,309
TMDL Reduction Target	24%	N/A
Target Load Reduction	791,991	0
2021 Progress Load Reduction	329,644	928
Load Reduction Achieved by Proposed Practices	1,209,532	929
Total Load Reduction	1,539,176 (47%)	1,857 (25%)
Modeled load reduction meets TMDL target reduction	Yes, exceeded by 23%	N/A

Table 38. Crosskill Creek Proposed BMPs		
Proposed BMP	**Unit**	**Amount**
Bioretention	Acres of DA	10.5
Cover Crops	Acres	2,805
Nutrient Management (Core P)	Acres	797
Streambank Restoration	Linear Feet	5,120
Tillage Management (high residue)	Acres	2,064

Little Swatara Creek Subwatershed

Little Swatara Creek has many tributaries draining Bethel and Tulpehocken Township and into the mainstem. The mainstem Little Swatara Creek follows the border of the two townships and flows in a southwesterly direction to reach the confluence with Swatara Creek (Figure 32). The subwatershed is almost entirely located in Northern Berks County (98%) with the remaining 2% in Jackson Township, Lebanon County. The 40.7 square mile watershed contains a total of 38.5 miles of streams (Table 39). The entire subwatershed is currently designated as protected for aquatic life use as cold-water fishery and recreational use (PA Chapter 93). In the subwatershed, 33% of stream miles are impaired for recreational use, while 41% are impaired for aquatic life use designation, and 1.5 miles of streams support natural trout reproduction use on Mill Creek. The dominant underlying geology is shale, sandstone, and limestone. The dominant hydrologic soil groups are well drained soils (HSG B, 58%) and slow to drain soils (HSG D, 28%) are scattered throughout the subwatershed.

Table 39. Overview facts about the Little Swatara Creek subwatershed

Drainage Area	40.7 mi^2
Existing Impervious Cover	5.4%
TMDL	2011 Sediment and Phosphorus
Stream Miles	38.5 mi
Recreational Use	
Impaired	56.9%
Supporting	25.6%
Aquatic Life Use	
Impaired	43.1%
Supporting	56.9%
Natural Trout Population	
Supporting	2.5%

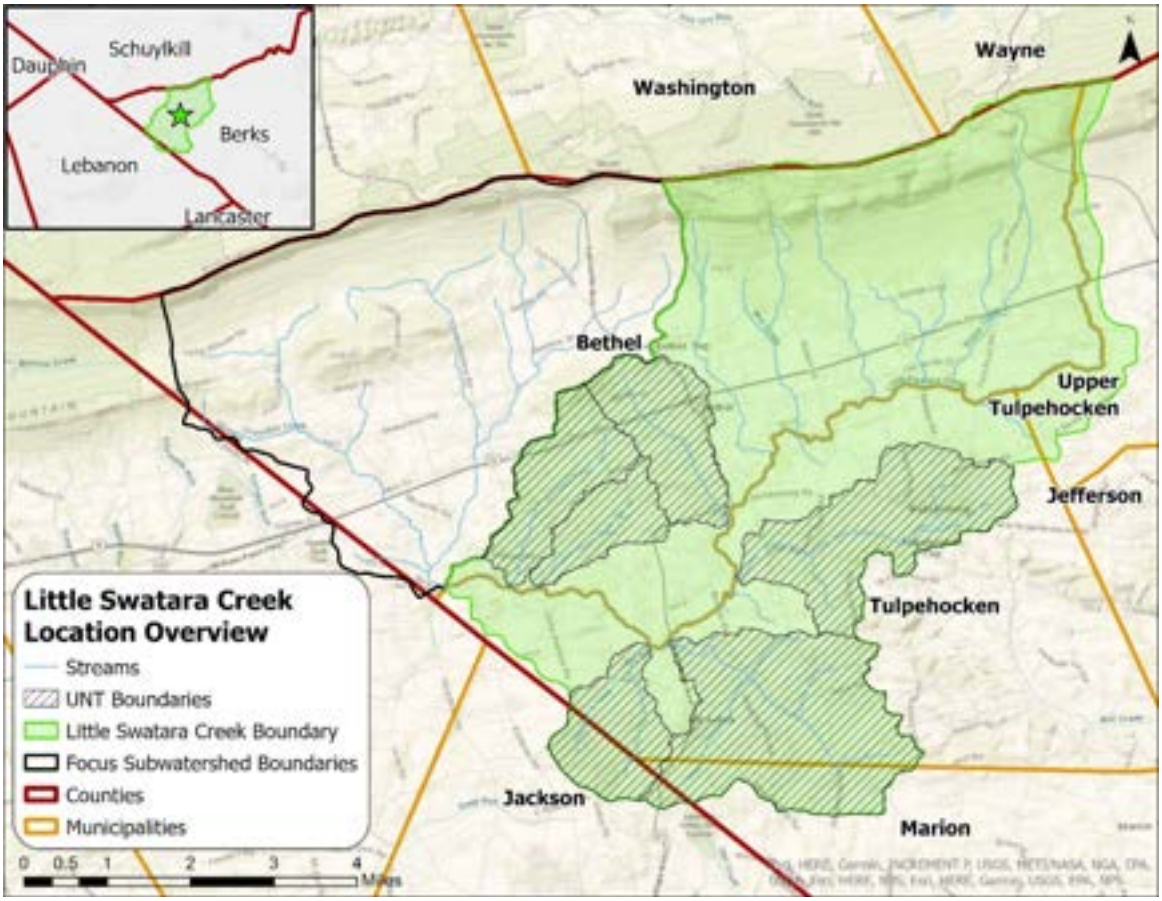

Figure 32. Little Swatara Creek location overview

The subwatershed land use/land cover is dominated by forest cover (27.0%), cropland (44.4%) and pasture hay (9.6%). The forest cover is located mainly in the northern headwaters that drain the Blue Mountain ridge. The creek flows in a southernly direction through a landscape dominated by cropland and pasture/hay (Figure 33). There are 17 NPDES permits, nine CAFOs, two active biosolid operations and one active Captive Hazardous Waste Operation. Permanent easements are held on 27.3% of the subwatershed land and ensure the land is used for agricultural production or commercial equine activity and not developed.

In 2011, a TMDL was developed to address phosphorus and sediment impairments identified in the 2008 303(d) list for seven tributary watersheds to the Little Swatara Creek (PA DEP, 2011). The Little Swatara Creek tributaries in the TMDL include six tributary subwatersheds located inside the total study watershed as shown in Figure 32. The TMDL also includes a tributary subwatershed located outside the total study watershed in Lebanon County. Identified sources of impairments are from agricultural and residential land use practices.

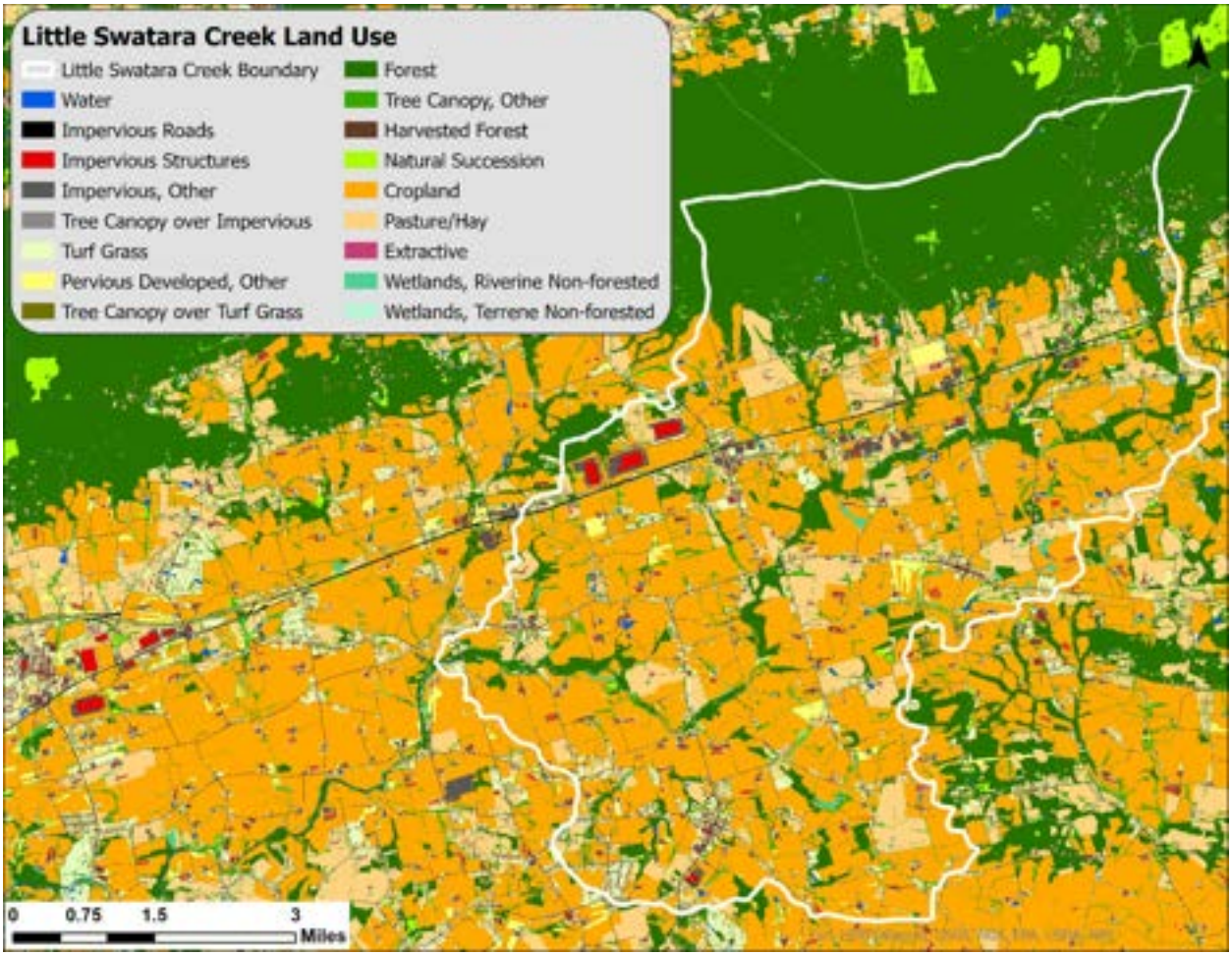

Figure 33. Little Swatara Creek land use land cover (LULC)

Biological sampling within the subwatershed was conducted by BCCD in 2021; however, there are no PA DEP sampling sites. The forested northern tributaries of the Little Swatara Creek are attaining their designated uses and become impaired as they flow south to the mainstem. The two IBI scores in the northern portion of the subwatershed are poor and fair. Only UNT 09938 was sampled and has a poor IBI score. The other UNT subwatersheds were not sampled for IBI due to budget constraints. Interestingly, the Little Swatara mainstem is not impaired from the confluence with UNT 09944 to the confluence. These monitoring stations are illustrated in Figure 34.

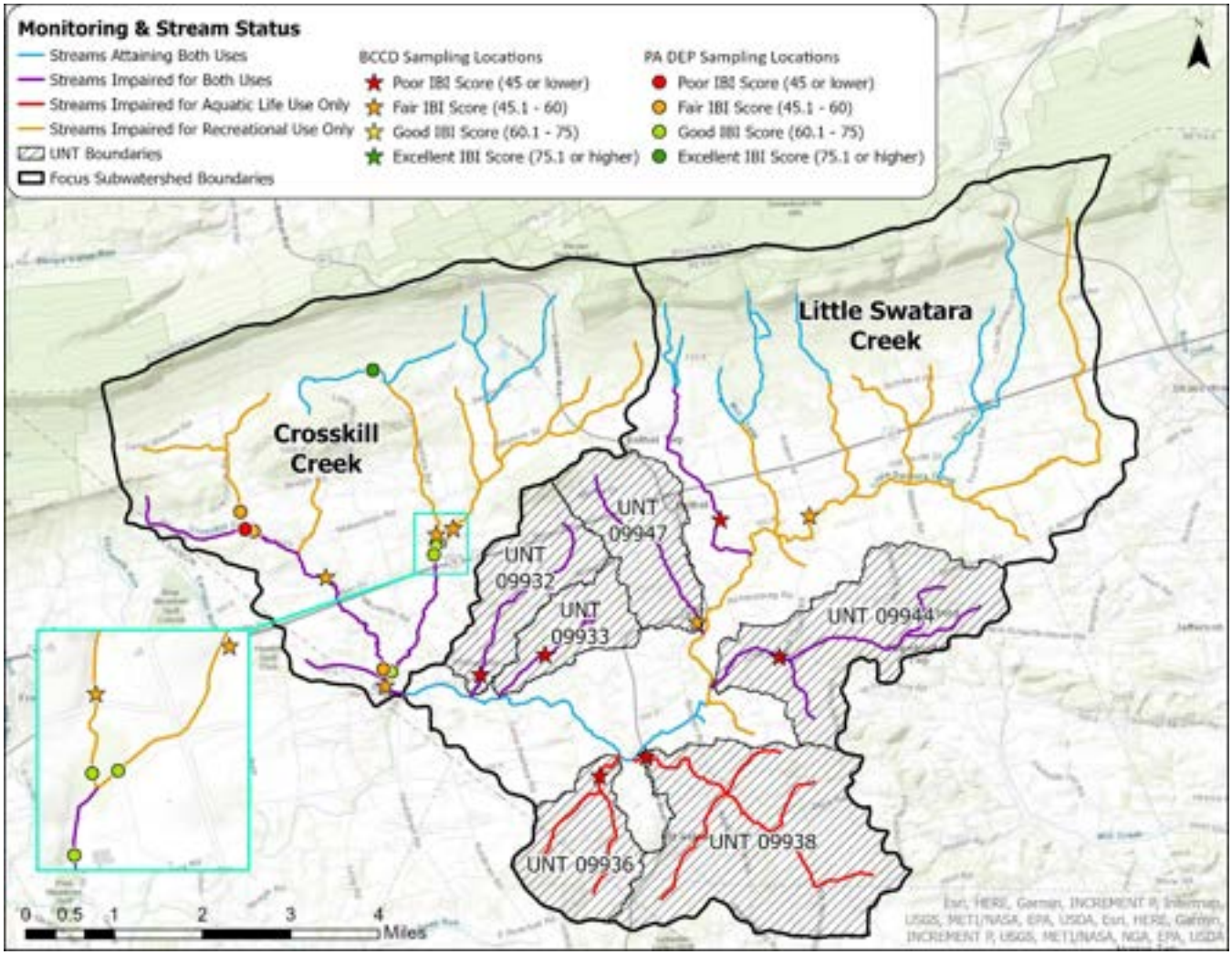

Figure 34. Little Swatara Creek monitoring and stream status

Nutrient Modeling Results

MMW was used to estimate the reduction in sediment and phosphorus achieved through proposed urban and agricultural BMPs in each subwatershed. Table 40 provides a summary of sediment and phosphorus reductions starting from the initial baseline load of 12,341,678 pounds/year and 22,357 pounds/year respectively. The Upper Little Swatara Creek has a sediment and phosphorus TMDL for the UNT but not for the remaining watershed, so no TMDL target was provided. The total load reduction achieved through current and future proposed BMP implementation results in a 39% reduction for sediment and 27% reduction for phosphorus. Proposed BMPs are provided in Table 41 and Section 8.2 Implementation Cost Estimates and Funding Sources provides information on cost of BMP implementation.

Table 40. Little Swatara Creek TMDL targets and loading

TMDL Target	Loading (lbs/yr)	
	Sediment	Phosphorus
Baseline Load	12,341,678	22,357
TMDL Reduction Target	N/A	N/A
Target Load Reduction	N/A	N/A
2021 Progress Load Reduction	1,248,565	2,152
Load Reduction Achieved by Proposed Practices	3,595,445	3,907
Total Load Reduction	4,843,010 (39%)	6,059 (27%)

Table 40. Little Swatara Creek TMDL targets and loading		
TMDL Target	**Loading (lbs/yr)**	
	Sediment	**Phosphorus**
Modeled load reduction meets TMDL target reduction	N/A	N/A

Table 41. Little Swatara Creek Proposed BMPs		
Proposed BMP	**Unit**	**Amount**
Bioretention	Acres of DA	5.7
Bioswale	Acres of DA	7.6
Permeable Pavement	Acres of DA	2.5
Cover Crops	Acres	7,629
Nutrient Management (Core P)	Acres	1,853
Streambank Restoration	Linear Feet	5,072
Tillage Management (high residue/no till)	Acres	5,496
Tillage Management (low residue)	Acres	3,901

Unnamed Tributary 09932 Subwatershed

The Unnamed Tributary 09932 begins just north of Interstate 78 and flows in a southwesterly direction to the Little Swatara Creek mainstem. The tributary receives drainage from a Samsung distribution center located north of I-78 in the Northern portion of the subwatershed (Figure 35) and flows through the census-designated place of Frystown, located in Bethel Township. The 1.9 square mile watershed contains a total of 2.6 miles of streams (Table 42). The entire subwatershed is currently designated as protected for aquatic life use as cold-water fishery and recreational use (PA Chapter 93). In the subwatershed, 100% of stream miles are impaired for recreational use and aquatic life use designation. The dominant underlying geology is shale, sandstone, and limestone. The dominant hydrologic soil groups are well drained soils (HSG B, 57.9%) and slow to drain soils (HSG D, 28.8%) are scattered throughout the subwatershed.

Table . Overview facts about the UNT 09932 subwatershed

Drainage Area	1.9 mi^2
Existing Impervious Cover	10.6%
TMDL	2011 Sediment and Phosphorus
Stream Miles	2.6 mi
Recreational Use	
Impaired	100.0%
Supporting	0.0%
Aquatic Life Use	
Impaired	100.0%
Supporting	0.0%

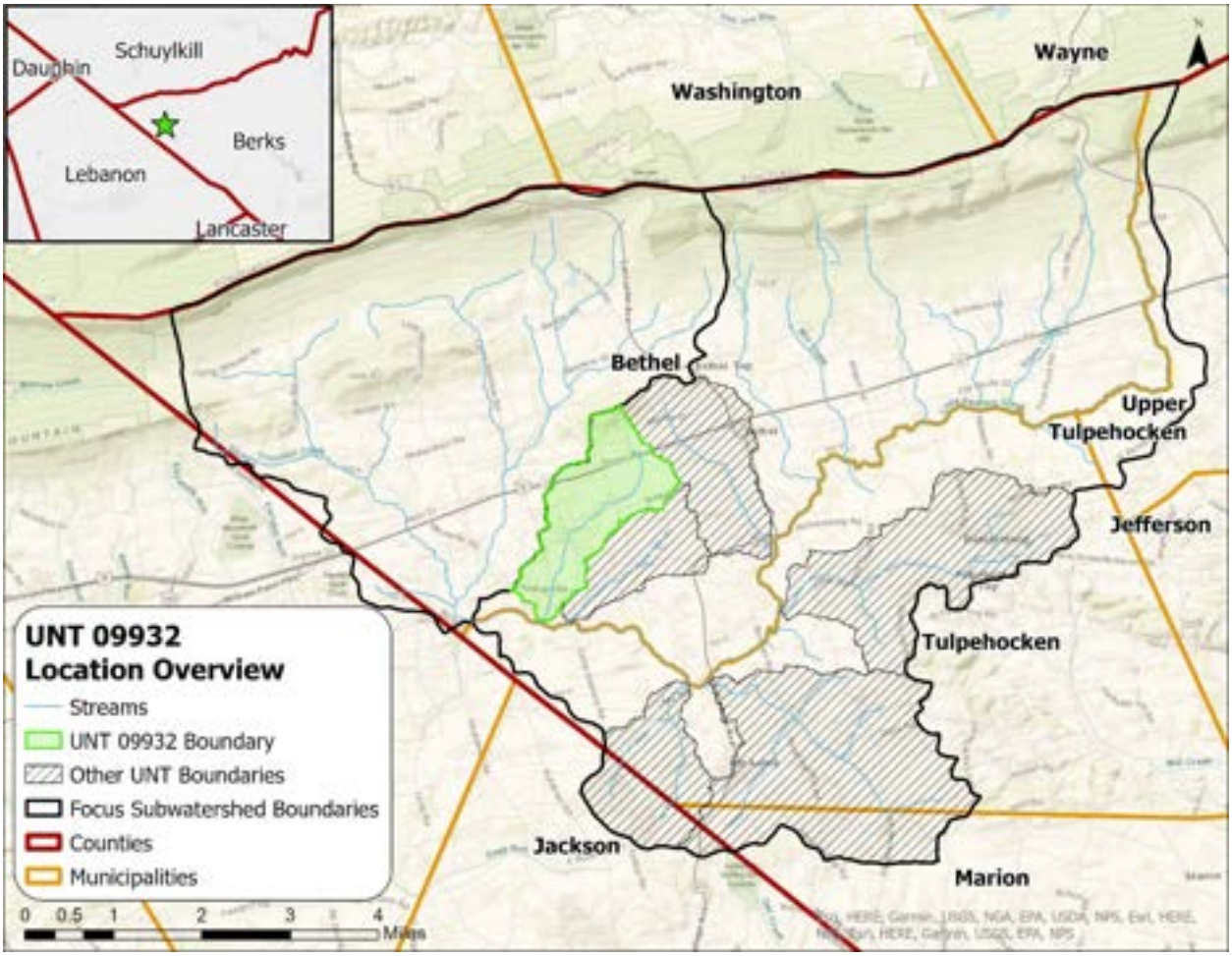

Figure 35. UNT 09932 location overview

The subwatershed land use/land cover is dominated by pasture hay (10.4%), cropland (50.4%) and forest cover (9.8%). The forest cover is located mainly in the northern portion of the subwatershed, just north of the distribution center. The creek flows in a southernly direction through a landscape dominated by cropland and pasture/hay and through Frystown just before it meets the mainstem (Figure 36). There are no NPDES permits, biosolid operations or Captive Hazardous Waste Operation. Permanent easements are held on 2.1% of the subwatershed land and ensure the land is used for agricultural production or commercial equine activity and not developed.

In 2011, a TMDL was developed to address phosphorus and sediment impairments identified in the 2008 303(d) list for seven tributary watersheds to the Little Swatara Creek (PA DEP, 2011). The Little Swatara Creek tributaries in the TMDL include UNT 09932 and five other tributary subwatersheds located inside the total study watershed as shown in Figure 35. The TMDL also includes a tributary subwatershed located outside the total study watershed in Lebanon County. Identified sources of impairments are from agricultural and residential land use practices.

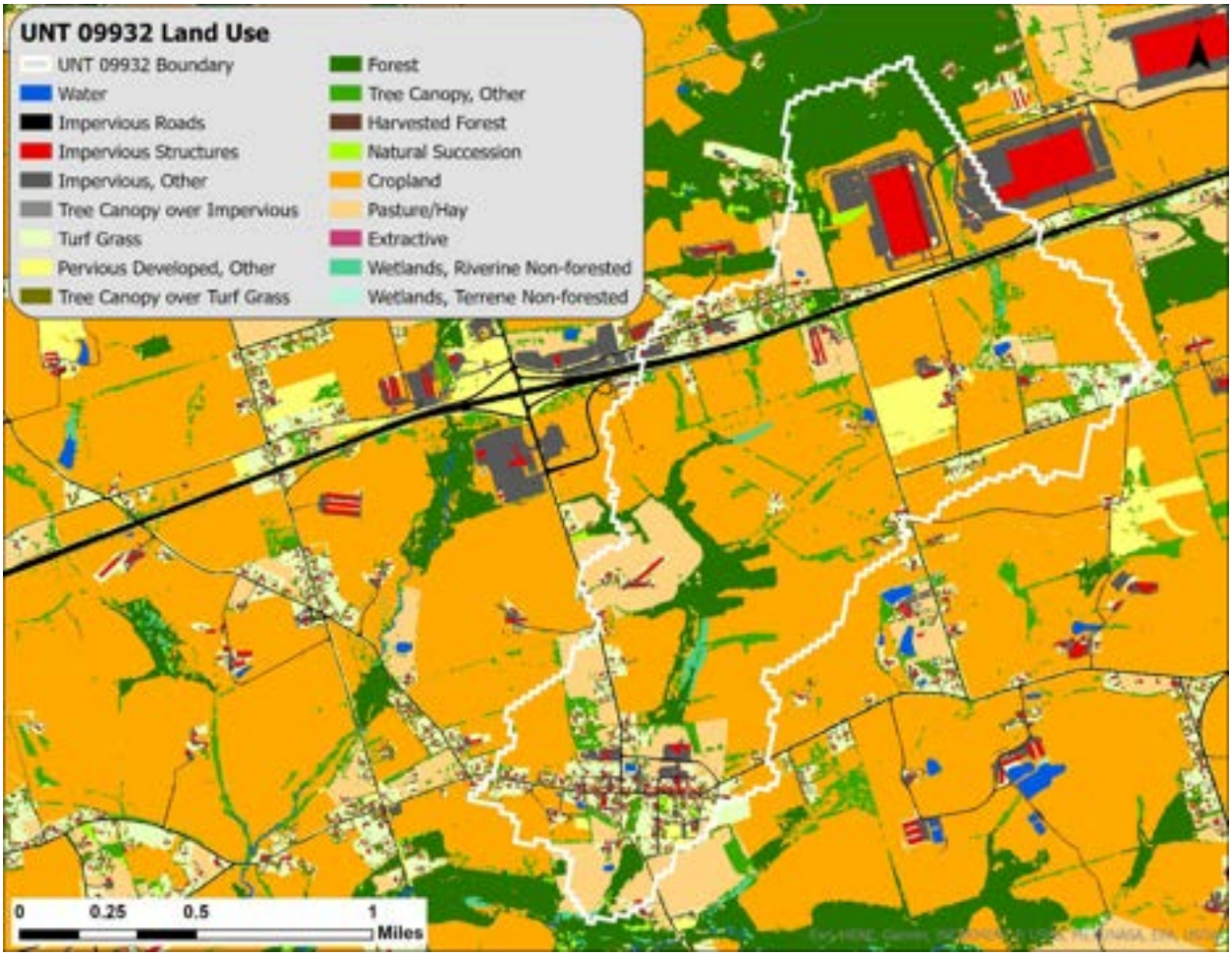

Figure 36. UNT 09932 land use land cover (LULC)

Biological sampling data within the subwatershed is available from BCCD in 2021. The sampling site is located near the confluence with the mainstem Little Swatara and has an IBI value of 42.7 based on 2019 PADEP sampling (Figure 37). The entire unnamed tributary is impaired for both Aquatic Life Use and Recreational Use.

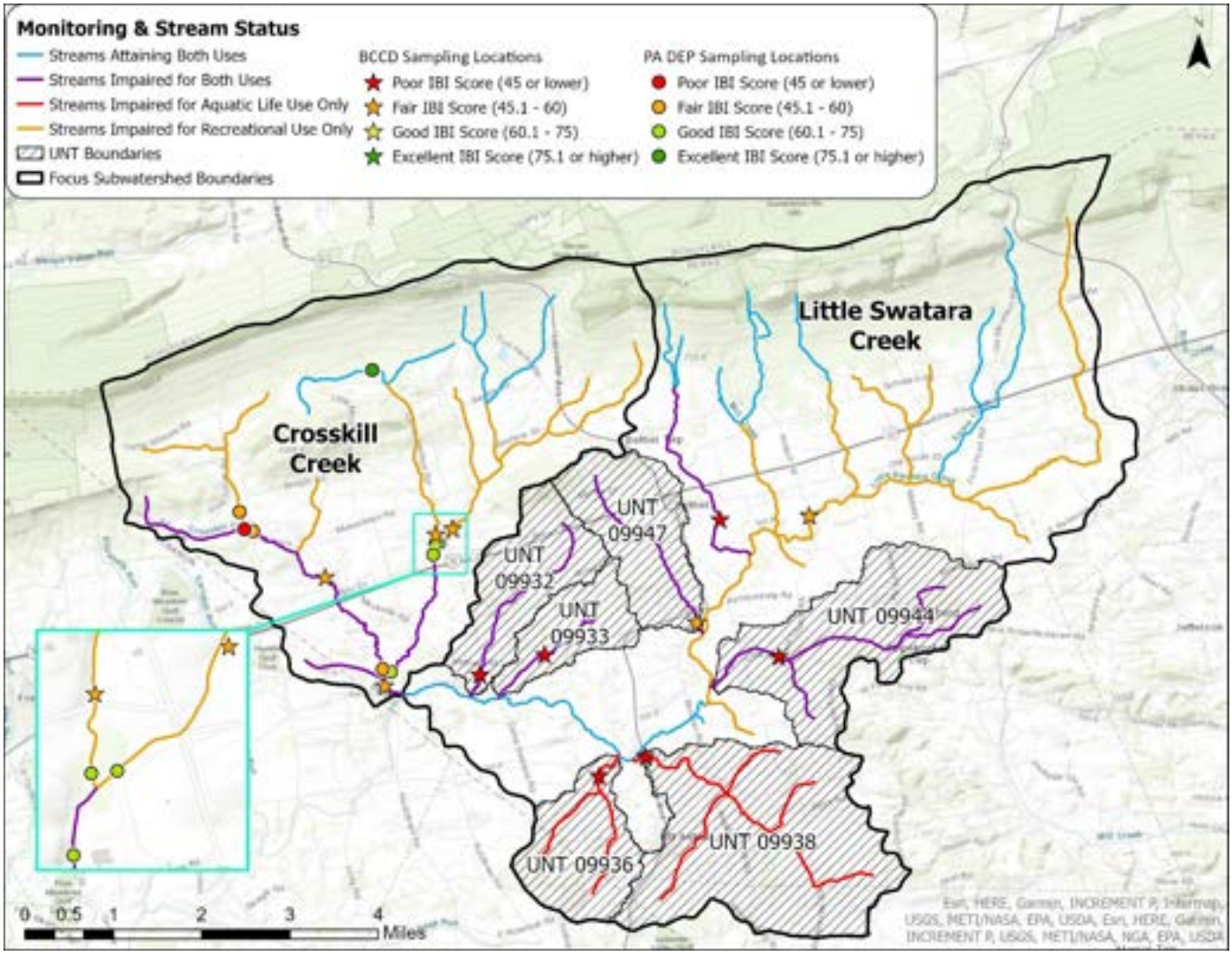

Figure 37. UNT 09932 monitoring and stream status

NUTRIENT MODELING RESULTS

MMW was used to estimate the reduction in sediment and phosphorus achieved through proposed urban and agricultural BMPs in each subwatershed. Table 43 provides a summary of sediment and phosphorus reductions starting from the initial baseline load of 620,812 pounds/year and 1,094 pounds/year respectively. The Upper Little Swatara has a sediment and phosphorus TMDL target reduction of 63% or 391,112 pounds/year and 76% or 831 pounds/year respectively. The total load reduction achieved through current and future proposed BMP implementation results in a 58% reduction for sediment and 30% reduction for phosphorus which do not meet the TMDL target reductions. Proposed BMPs are provided in Table 44 and Section 8.2 Implementation Cost Estimates and Funding Sourcesprovides information on cost of BMP implementation.

Table 43. UNT 09932 targets and loading

TMDL Target	Loading (lbs/yr)	
	Sediment	Phosphorus
Baseline Load	620,812	1,094
TMDL Reduction Target	63%	76%
Target Load Reduction	391,112	831
2021 Progress Load Reduction	28,375	57
Load Reduction Achieved by Proposed Practices	332,356	267

Table 43. UNT 09932 targets and loading

TMDL Target	Loading (lbs/yr)	
	Sediment	Phosphorus
Total Load Reduction	360,731 (58%)	324 (30%)
Modeled load reduction meets TMDL target reduction	No, 5% less than goal	No, 46% less than goal

Table 44. UNT 09932 Proposed BMPs

Proposed BMP	Unit	Amount
Bioretention	Acres of DA	1.35
Filtering practices	Acres of DA	0.85
Cover Crops	Acres	485
Nutrient Management (Core P)	Acres	194
Tillage Management (high residue)	Acres	493

Unnamed Tributary 09933 Subwatershed

The Unnamed Tributary 09933 begins below Interstate 78 and flows in a southwesterly direction to the Little Swatara Creek mainstem. The tributary receives drainage primarily from agricultural areas (Figure 38) and meets the Little Swatara just below the Bethel Township building. The 1.1 square mile subwatershed contains a total of 1.9 miles of streams (Table 45). The entire subwatershed is currently designated as protected for aquatic life use as a cold-water fishery and for recreational use (PA Chapter 93). In the subwatershed, all of the stream miles are impaired for recreational use and aquatic life use designation. The dominant underlying geology is shale, sandstone, and limestone. The dominant hydrologic soil groups are well drained soils (HSG B, 52.9%) and slow to drain soils (HSG D, 30.8%) are scattered throughout the subwatershed.

Table 45. Overview facts about the UNT 09933 subwatershed

Drainage Area	1.1 mi^2
Existing Impervious Cover	4.7%
TMDL	2011 Sediment and Phosphorus
Stream Miles	1.9 mi
Recreational Use	
Impaired	100.0%
Supporting	0.0%
Aquatic Life Use	
Impaired	100.0%
Supporting	0.0%

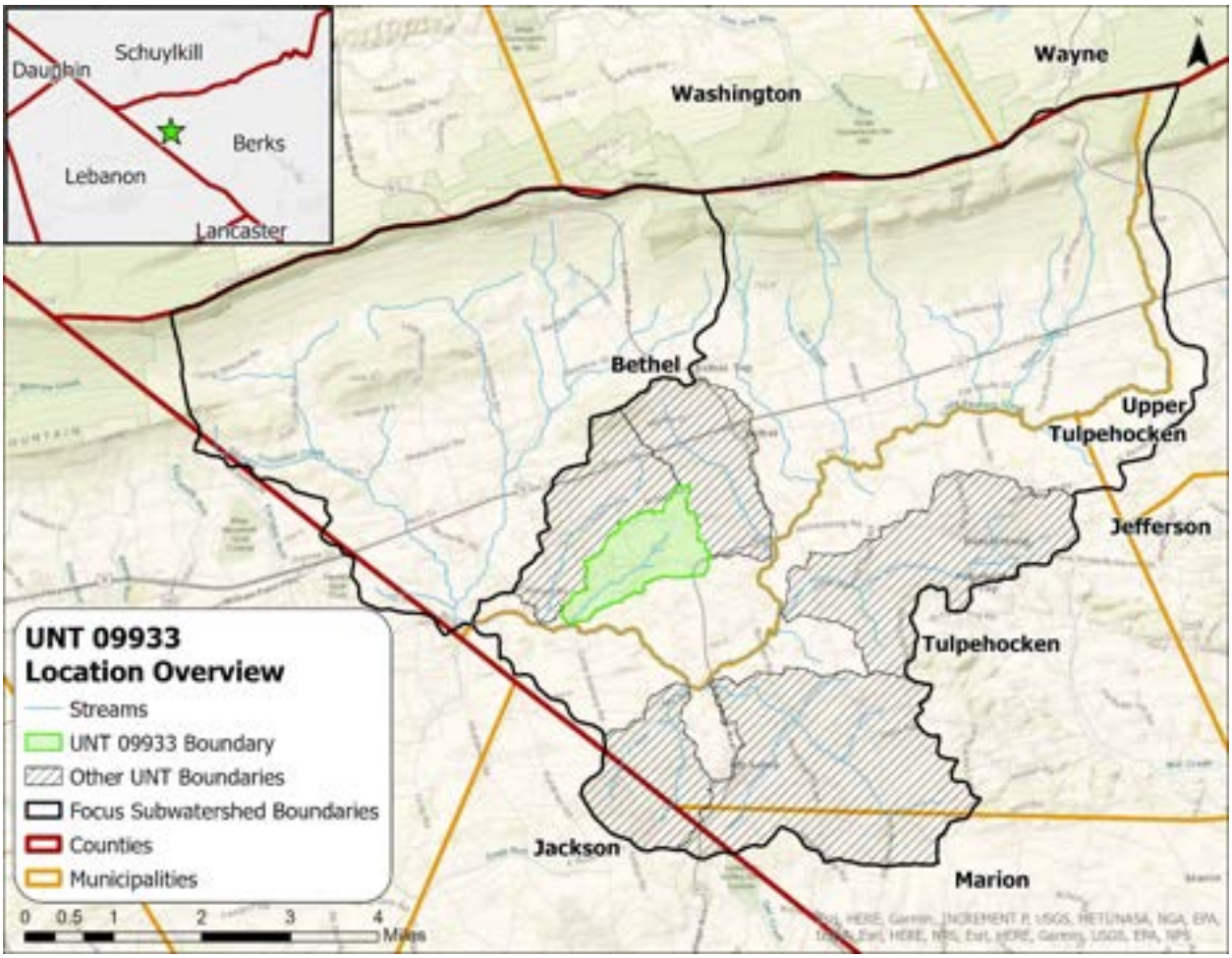

Figure 38. UNT 09933 location overview

The subwatershed land use/land cover is dominated by pasture hay (4.7%), cropland (72.9%) and turf cover (4.9%). The creek flows in a southernly direction through a landscape dominated by cropland and pasture/hay (Figure 39). There are two Concentrated Animal Feeding Operation (CAFO) permits and no biosolid operations or Captive Hazardous Waste Operation. Permanent easements are held on 57.0% of the subwatershed land and ensure the land is used for agricultural production or commercial equine activity and not developed.

In 2011, a TMDL was developed to address phosphorus and sediment impairments identified in the 2008 303(d) list for seven tributary watersheds to the Little Swatara Creek (PA DEP, 2011). The Little Swatara Creek tributaries in the TMDL include UNT 09933 and five other tributary subwatersheds located inside the total study watershed as shown in Figure 38. The TMDL also includes a tributary subwatershed located outside the total study watershed in Lebanon County. Identified sources of impairments are from agricultural and residential land use practices.

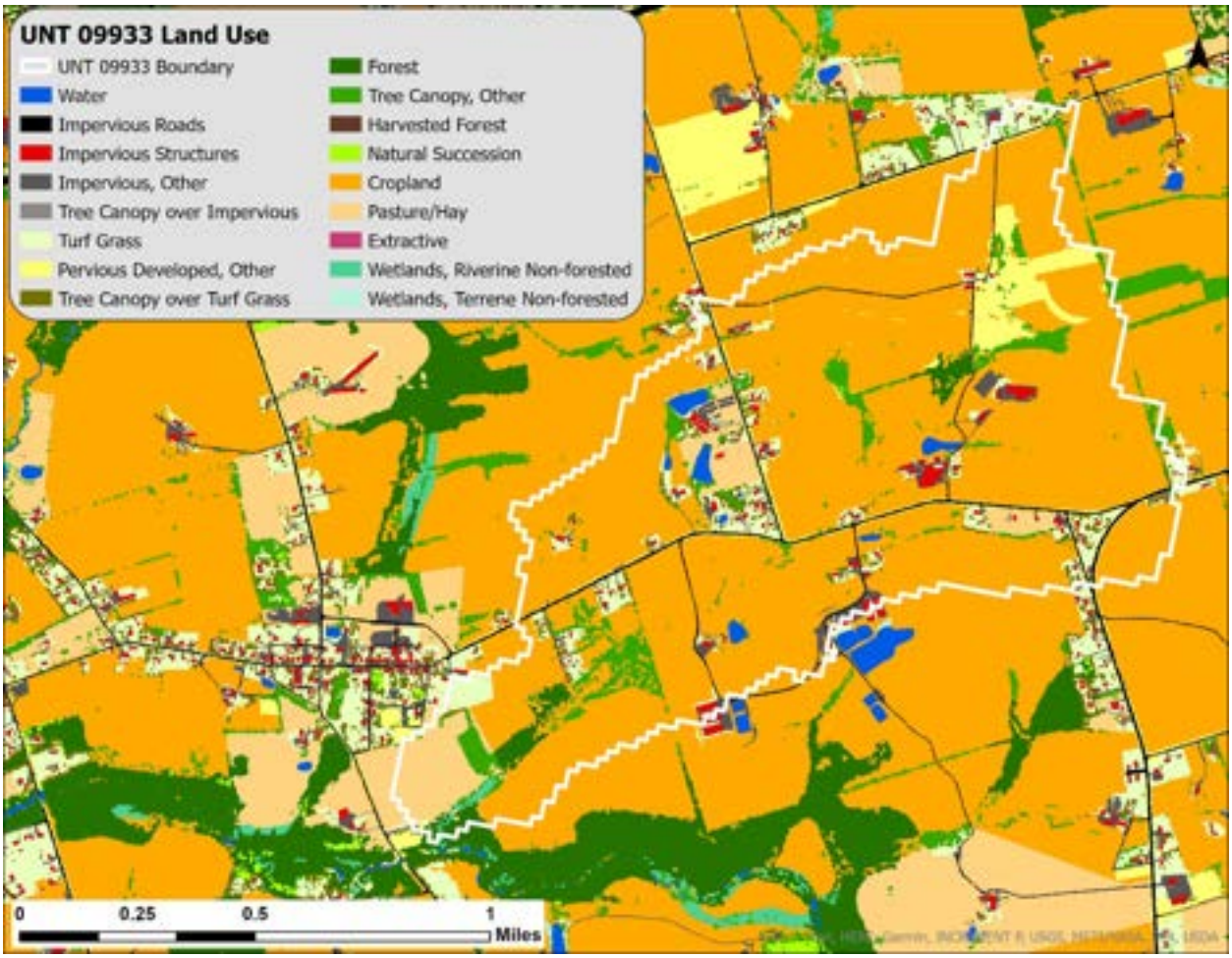

Figure 39. UNT 09933 land use land cover (LULC)

Biological sampling within the subwatershed was conducted by BCCD in 2021; however, there are no PA DEP sampling sites. The sampling site is located about halfway down the tributary from its headwaters to the confluence with the mainstem Little Swatara and does not have an IBI value (Figure 40). The entire unnamed tributary is impaired for both Aquatic Life Use and Recreational Use. Interestingly, the Little Swatara mainstem is not impaired where the tributary meets the confluence.

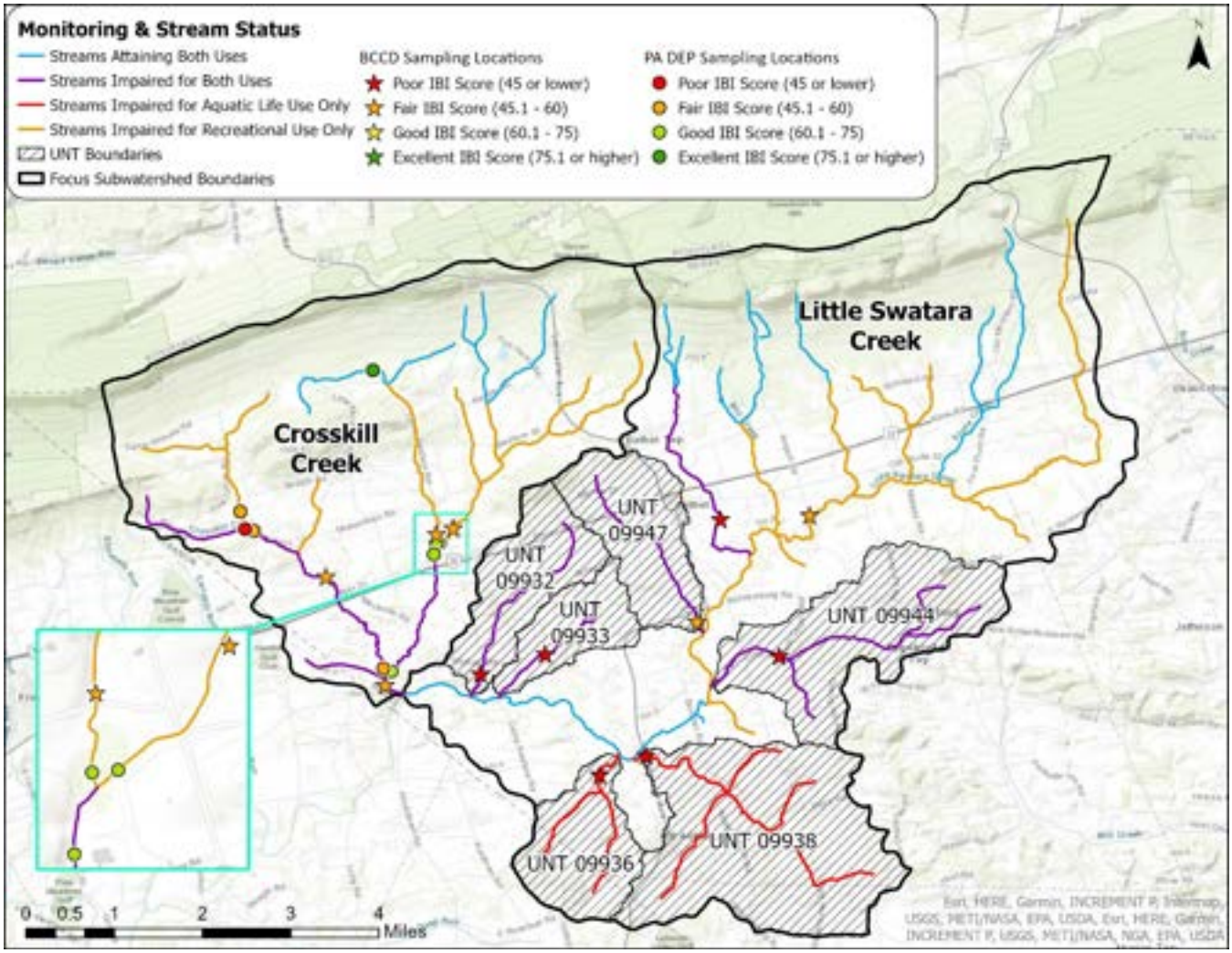

Figure 40. UNT 09933 monitoring and stream status

Nutrient Modeling Results

MMW was used to estimate the reduction in sediment and phosphorus achieved through proposed urban and agricultural BMPs in each subwatershed. Table 46 provides a summary of sediment and phosphorus reductions starting from the initial baseline load of 471,298 pounds/year and 803 pounds/year respectively. UNT 09933 has a phosphorus TMDL target reduction of 49% or 393 pounds/year and no TMDL for sediment. The total phosphorus load reduction achieved through current and future proposed BMP implementation results in a 29% reduction for phosphorus which does not meet the TMDL target reductions. Proposed BMPs are provided in Table 47 and 8.2 Implementation Cost Estimates and Funding Sources provides information on cost of BMP implementation.

Table 46. UNT 09933 targets and loading

TMDL Target	Loading (lbs/yr)	
	Sediment	Phosphorus
Baseline Load	471,298	803
TMDL Reduction Target	N/A	49%
Target Load Reduction	N/A	393
2021 Progress Load Reduction	0	28
Load Reduction Achieved by Proposed Practices	275,060	211

Table 46. UNT 09933 targets and loading		
TMDL Target	**Loading (lbs/yr)**	
	Sediment	**Phosphorus**
Total Load Reduction	275,060 (58%)	249 (31%)
Modeled load reduction meets TMDL target reduction	N/A	No, 18% less than goal

Table 47. UNT 09933 Proposed BMPs		
Proposed BMP	**Unit**	**Amount**
Bioretention	Acres of DA	2.20
Permeable Pavement	Acres of DA	1.18
Cover Crops	Acres	422
Nutrient Management (Core P)	Acres	188
Tillage Management (high residue)	Acres	422

Unnamed Tributary 09936 Subwatershed

The Unnamed Tributary 09936 is located in the southwest corner of the watershed in Jackson Township, Lebanon County and flows in a northeasterly direction into Berks County to join the Little Swatara Creek mainstem. The tributary receives drainage from agricultural areas as well as some small schools and commercial locations (Figure 41). The 1.7 square mile subwatershed contains a total of 3.1 miles of streams (Table 48). The subwatershed is currently designated as protected for aquatic life use as a cold-water fishery (PA Chapter 93). In the subwatershed, all of the stream miles are impaired for aquatic life use designation. The dominant underlying geology is shale, sandstone, and limestone. The dominant hydrologic soil groups are well drained soils (HSG B, 46.5%) and slow to drain soils (HSG B/D, 24.6%) are scattered throughout the subwatershed.

Table 48. Overview facts about the UNT 09936 subwatershed

Drainage Area	1.7 mi^2
Existing Impervious Cover	6.9%
TMDL	2011 Sediment and Phosphorus
Stream Miles	3.1 mi
Aquatic Life Use	
Impaired	100.0%
Supporting	0.0%

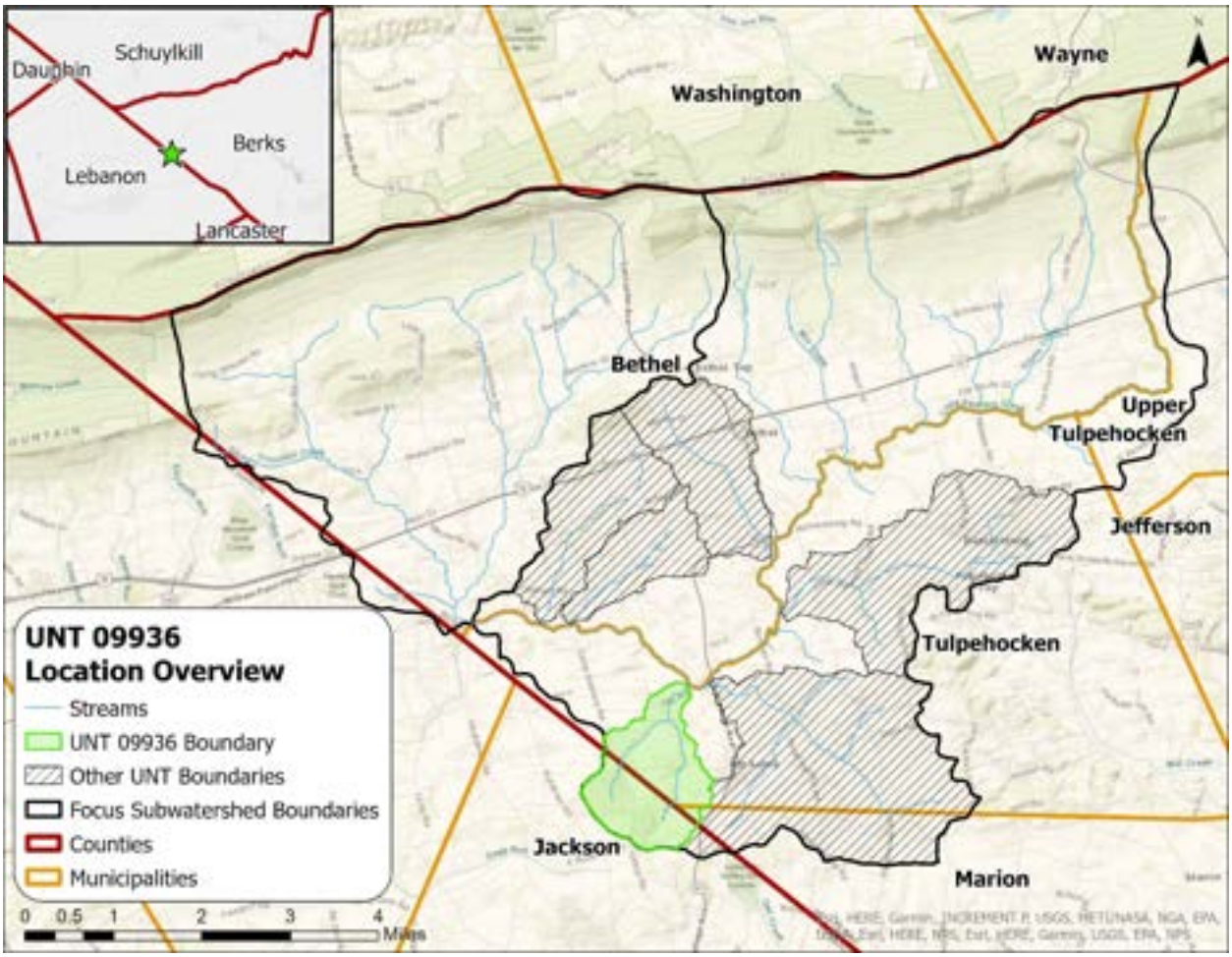

Figure 41. UNT 09936 location overview

The subwatershed land use/land cover is dominated by pasture hay (10.5%), cropland (50.7%) and turf cover (12.9%). The creek flows in a northerly direction through a landscape dominated by cropland and pasture/hay before it meets the mainstem (Figure 42). There are no biosolid operations or Captive Hazardous Waste Operations, but there is one NPDES MS4 permit for Jackson Township in Lebanon County for which they received a waiver. Permanent easements are held on 13.6% of the subwatershed land and ensure the land is used for agricultural production or commercial equine activity and not developed.

In 2011, a TMDL was developed to address phosphorus and sediment impairments identified in the 2008 303(d) list for seven tributary watersheds to the Little Swatara Creek (PA DEP, 2011). The Little Swatara Creek tributaries in the TMDL includes UNT 09936 and five other tributary subwatersheds located inside the total study watershed as shown in Figure 41. The TMDL also includes a tributary subwatershed located outside the total study watershed in Lebanon County. Identified sources of impairments are from agricultural and residential land use practices.

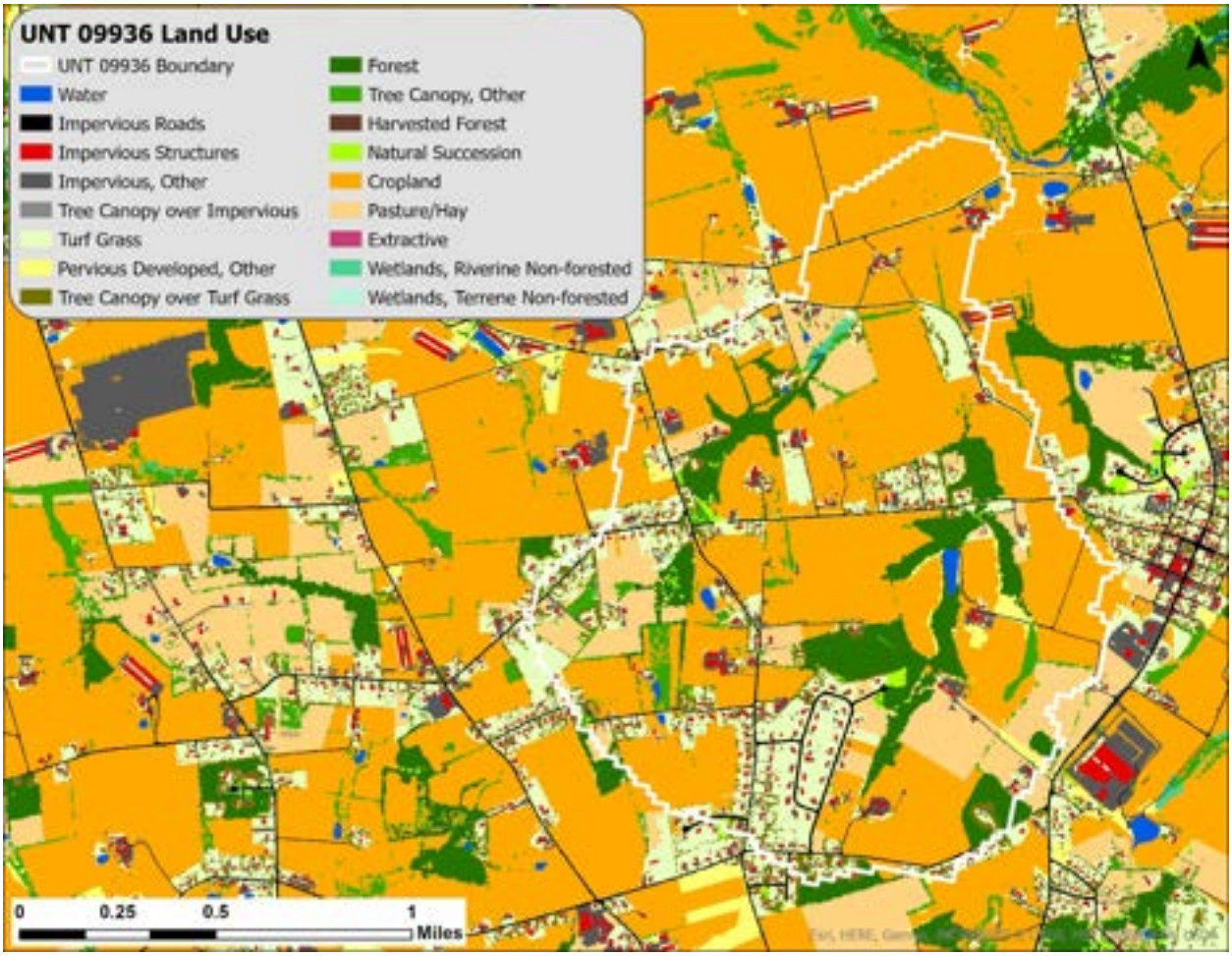

Figure 42. UNT 09936 land use land cover (LULC)

Biological sampling within the subwatershed was conducted by BCCD in 2021 and had an IBI score of 38.2. The sampling site is located near the confluence with the mainstem Little Swatara (Figure 43). The entire unnamed tributary is impaired for both Aquatic Life Use and Recreational Use. Interestingly, the Little Swatara mainstem is not impaired where the tributary meets the mainstem.

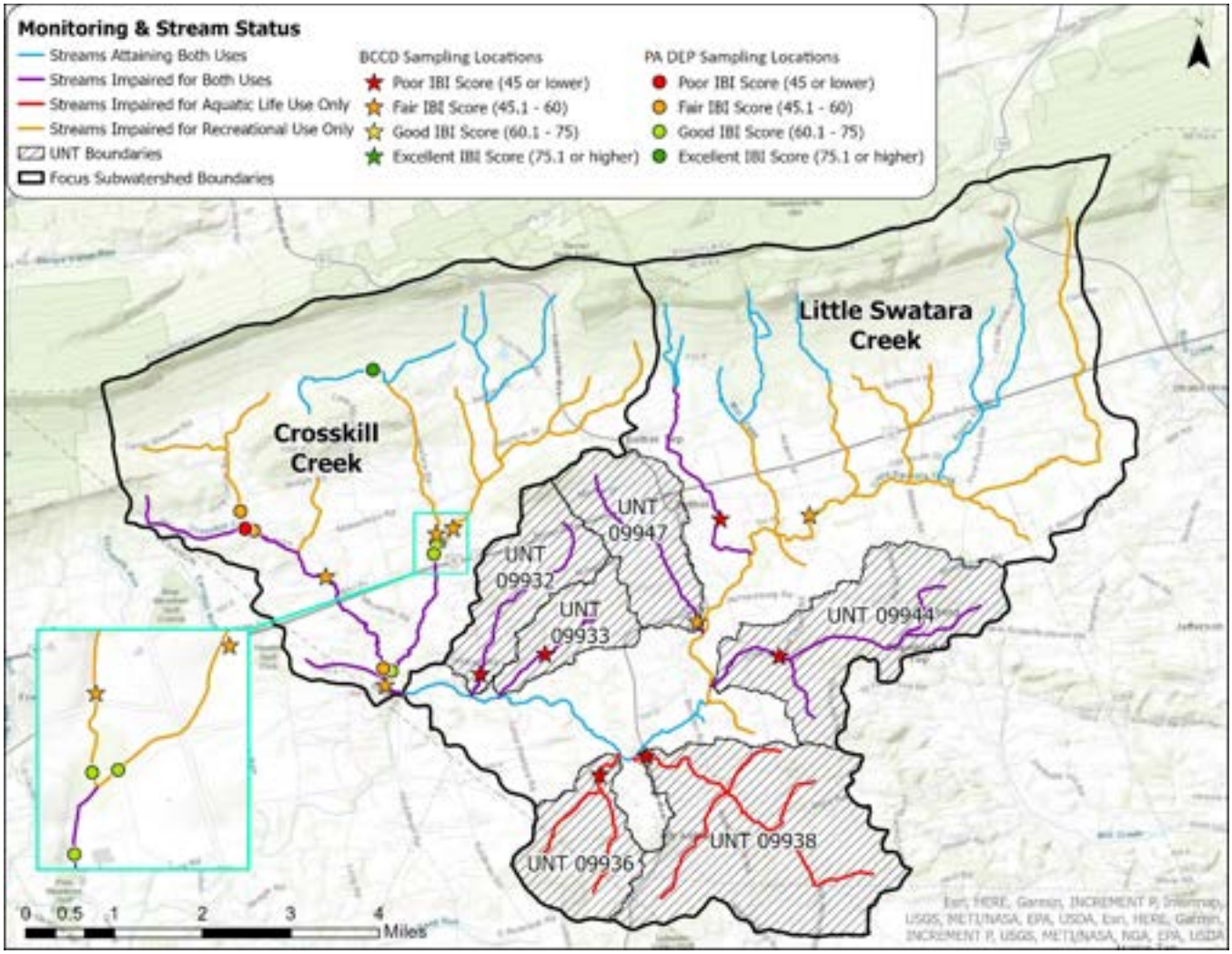

Figure 43. UNT 09936 monitoring and stream status

NUTRIENT MODELING RESULTS

MMW was used to estimate the reduction in sediment and phosphorus achieved through proposed urban and agricultural BMPs in each subwatershed. Table 49 provides a summary of sediment and phosphorus reductions starting from the initial baseline load of 568,260 pounds/year and 3,241 pounds/year respectively. UNT 09936 has a phosphorus and sediment TMDL target reduction of 53% or 301,178 pounds/year and 73% or 862 pounds/year respectively. The total phosphorus load reduction achieved through current and future proposed BMP implementation results in a 29% reduction for phosphorus which does not meet the TMDL target reductions. The total sediment load reduction achieved through current and future proposed BMP implementation results in a 61% reduction for sediment which exceeds the TMDL target reduction by 8%. Proposed BMPs are provided in Table 50 and Section 8.2 Implementation Cost Estimates and Funding Sources provides information on cost of BMP implementation.

Table 49. UNT 09936 targets and loading

TMDL Target	Loading (lbs/yr)	
	Sediment	Phosphorus
Baseline Load	568,260	1,181
TMDL Reduction Target	53%	73%
Target Load Reduction	301,178	862
2021 Progress Load Reduction	37,222	87

Table 49. UNT 09936 targets and loading		
TMDL Target	**Loading (lbs/yr)**	
	Sediment	**Phosphorus**
Load Reduction Achieved by Proposed Practices	310,930	256
Total Load Reduction	348,152 (61%)	343 (29%)
Modeled load reduction meets TMDL target reduction	Yes, exceeds by 8%	No, 44% less than goal

Table 50. UNT 09936 Proposed BMPs		
Proposed BMP	**Unit**	**Amount**
Cover Crops	Acres	498
Nutrient Management (Core P)	Acres	221
Tillage Management (high residue)	Acres	493

Unnamed Tributary 09938 Subwatershed

The Unnamed Tributary 09938 is located in the southern portion of the watershed in Merion Township and flows in a northwesterly direction to the Little Swatara Creek mainstem in Tulpehocken Township. The tributary receives drainage from agricultural lands, the Dutch Valley Foods distribution center located along Lancaster Avenue (PA-501) (Figure 44) and includes Mt. Aetna, a census-designated place in Tulpehocken Township. The 5.2 square mile watershed contains a total of 6.8 miles of streams (Table 51). The entire subwatershed is currently designated as protected for aquatic life use as cold-water fishery (PA Chapter 93). In the subwatershed, all stream miles are impaired for aquatic life use designation. The dominant underlying geology is shale, sandstone, and limestone. The dominant hydrologic soil groups are well drained soils (HSG B, 59.8%) and slow to drain soils (HSG D, 26.9%) are scattered throughout the subwatershed.

Table 51. Overview facts about the UNT 09938 subwatershed	
Drainage Area	5.2 mi^2
Existing Impervious Cover	5.4%
TMDL	2011 Sediment and Phosphorus
Stream Miles	6.8 mi
Aquatic Life Use	
Impaired	100.0%
Supporting	0.0%

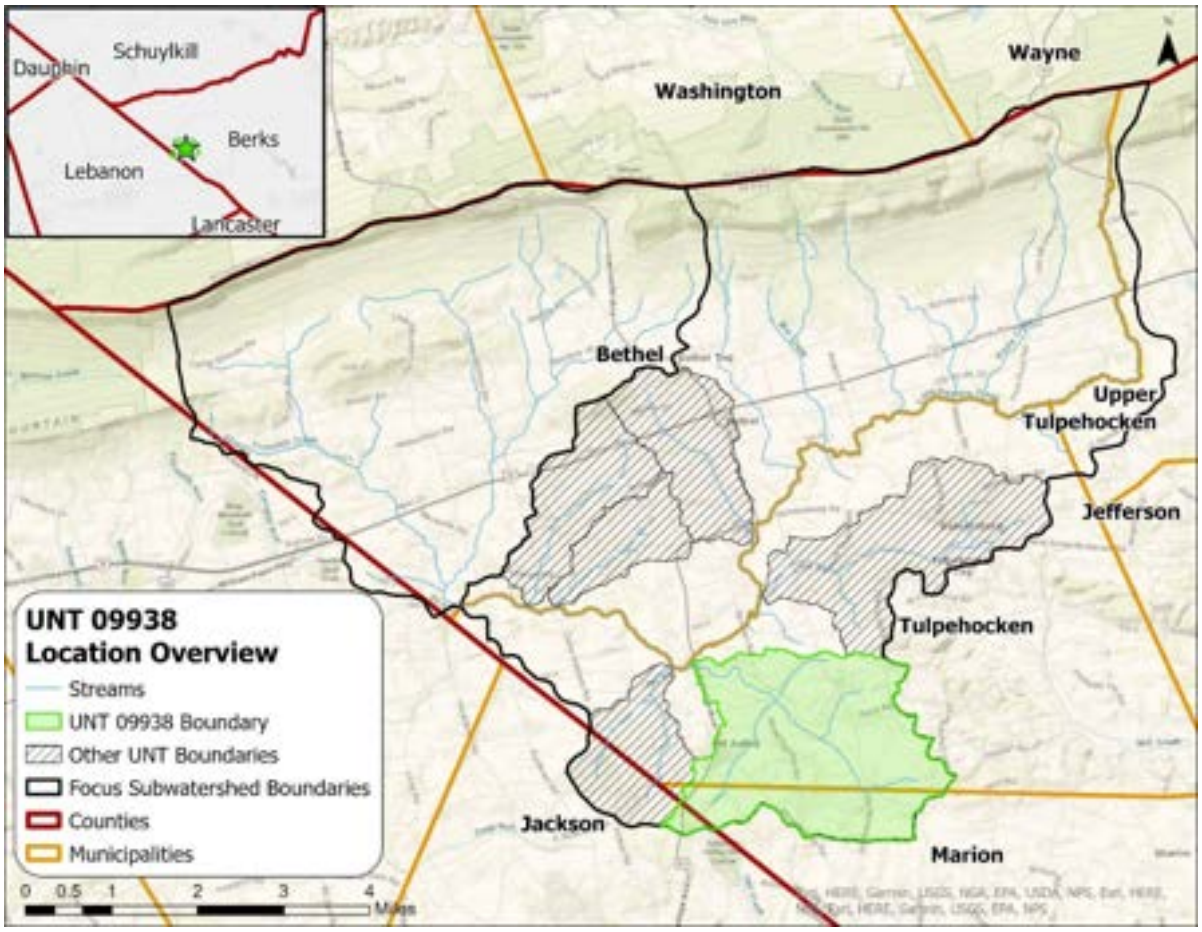

Figure 44. UNT 09938 location overview

The subwatershed land use/land cover is dominated by pasture hay (7.9%), cropland (65.8%) and turf cover (6.2%). The creek flows in a northerly direction through a landscape dominated by cropland and pasture/hay

before it meets the mainstem (Figure 45). The greatest concentration of imperviousness is located in the western portion (Mt. Aetna). There are no NPDES permits or biosolid operations, but there is one Captive Hazardous Waste Operation and three Concentrated Animal Feeding Operations (CAFOs). Permanent easements are held on 44.3% of the subwatershed land and ensure the land is used for agricultural production or commercial equine activity and not developed.

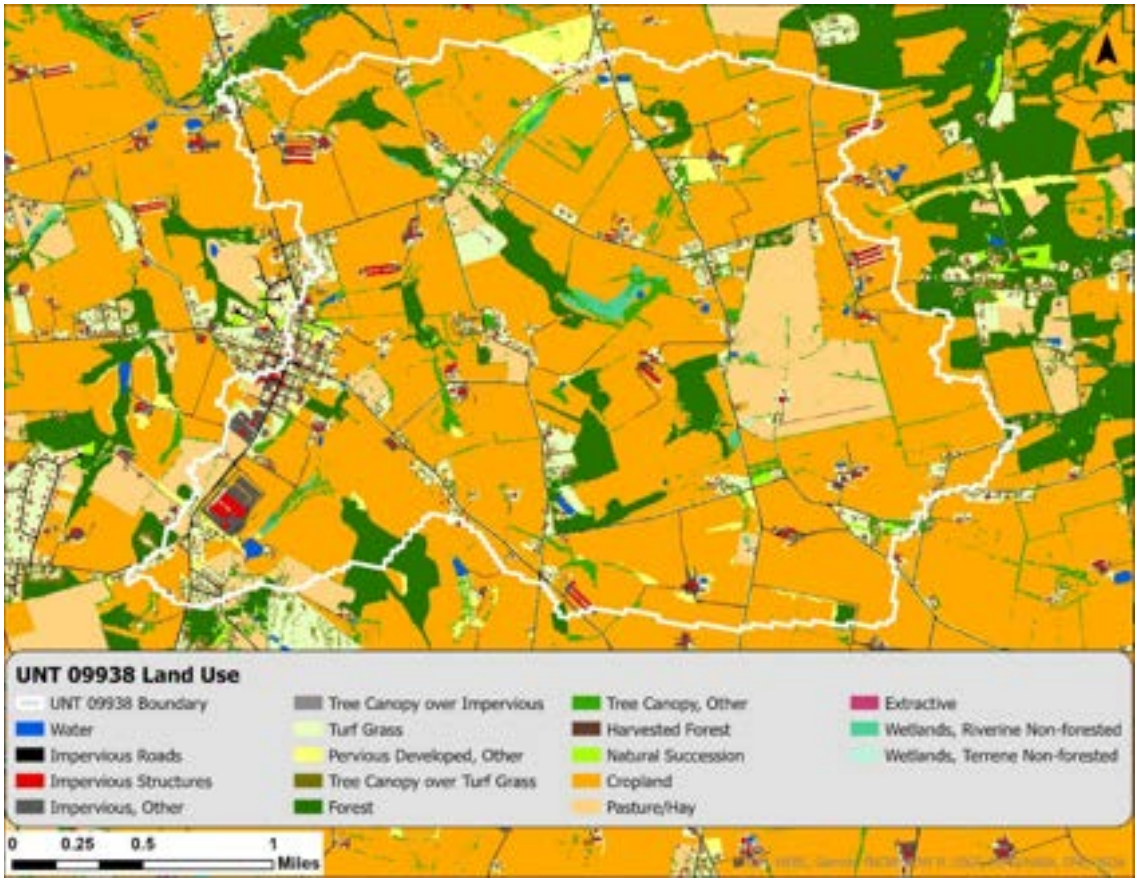

Figure 45. UNT 09938 land use land cover (LULC)

In 2011, a TMDL was developed to address phosphorus and sediment impairments identified in the 2008 303(d) list for seven tributary watersheds to the Little Swatara Creek (PA DEP, 2011). The Little Swatara Creek tributaries in the TMDL includes UNT 09938 and five other tributary subwatersheds located inside the total study watershed as shown in Figure 44. The TMDL also includes a tributary subwatershed located outside the total study watershed in Lebanon County. Identified sources of impairments are from agricultural and residential land use practices.

Biological sampling within the subwatershed was conducted by BCCD in 2021; however, there are no PA DEP sampling sites. The sampling site is located near the confluence with the mainstem Little Swatara and has an IBI value of 44.4 (Figure 46). The entire unnamed tributary is impaired for both Aquatic Life Use and Recreational. Interestingly, the Little Swatara mainstem is not impaired where the tributary meets the mainstem.

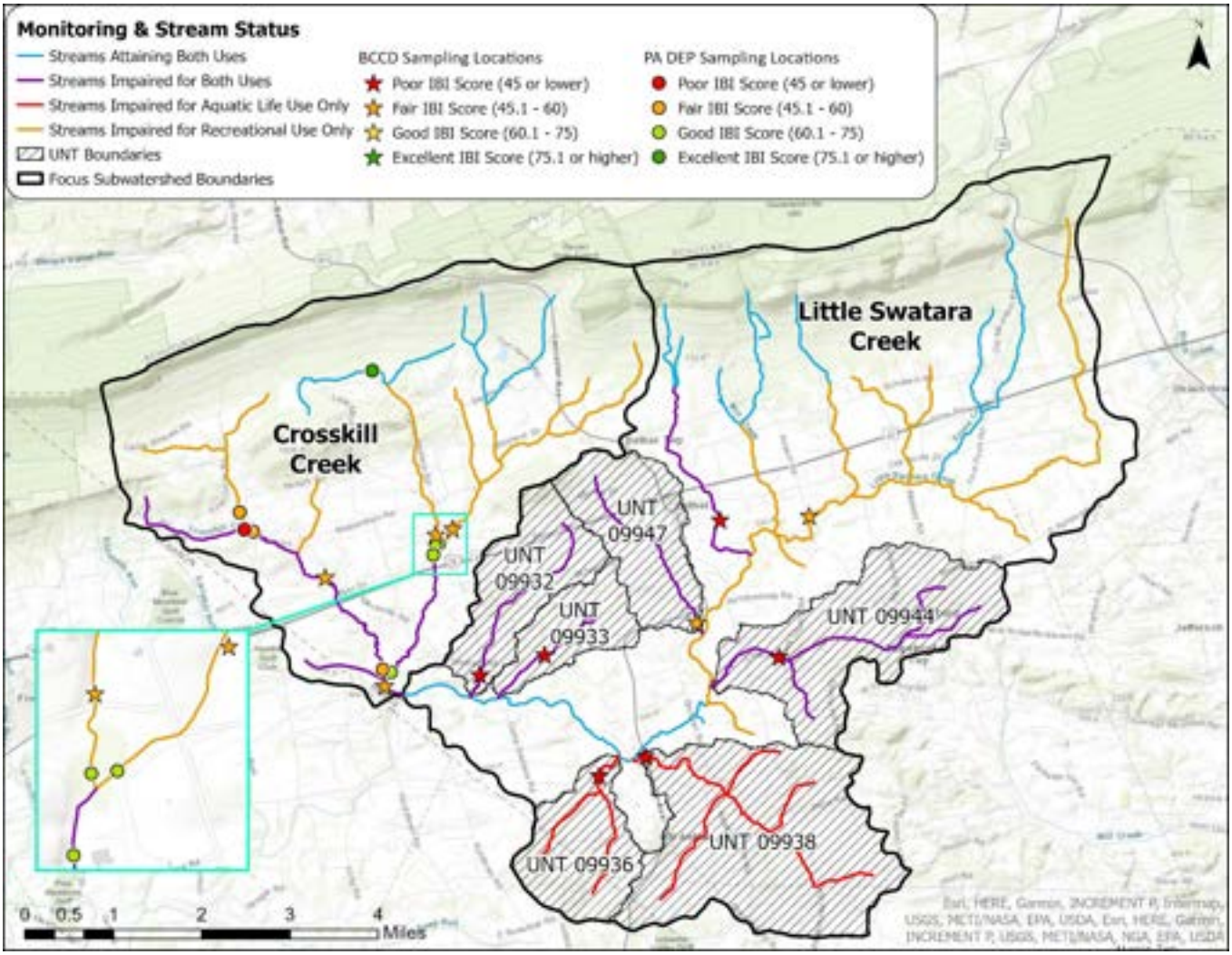

Figure 46. UNT 09938 monitoring and stream status

NUTRIENT MODELING RESULTS

MMW was used to estimate the reduction in sediment and phosphorus achieved through proposed urban and agricultural BMPs in each subwatershed. Table 52 provides a summary of sediment and phosphorus reductions starting from the initial baseline load of 1,660,972pounds/year and 3,241 pounds/year respectively. UNT 09938 has a phosphorus and sediment TMDL target reduction of 67% or 1,112,851 pounds/year and 80% or 2,593 pounds/year respectively. The total phosphorus load reduction achieved through current and future proposed BMP implementation results in an 82% reduction for phosphorus which exceeds the TMDL target reductions by 15%. The total sediment load reduction achieved through current and future proposed BMP implementation results in a 30% reduction for sediment which does not meet the TMDL target reduction. Proposed BMPs are provided in Table 53 and Section 8.2 Implementation Cost Estimates and Funding Sourcesprovides information on cost of BMP implementation.

Table 52. UNT 09938 targets and loading

TMDL Target	Loading (lbs/yr)	
	Sediment	Phosphorus
Baseline Load	1,660,972	3,241
TMDL Reduction Target	67%	80%
Target Load Reduction	1,112,851	2,593
2021 Progress Load Reduction	85,729	185

Table 52. UNT 09938 targets and loading		
TMDL Target	**Loading (lbs/yr)**	
	Sediment	**Phosphorus**
Load Reduction Achieved by Proposed Practices	1,270,994	797
Total Load Reduction	1,356,723 (82%)	982 (30%)
Modeled load reduction meets TMDL target reduction	Yes, exceeds by 15%	No, 50% less than goal

Table 53. UNT 09938 Proposed BMPs		
Proposed BMP	**Unit**	**Amount**
Bioretention	Acres of DA	2.9
Wet Ponds and Wetlands	Acres of DA	11.5
Cover Crops	Acres	1,831
Nutrient Management (Core P)	Acres	792
Tillage Management (high residue)	Acres	1,836
Streambank Restoration	Linear Feet	1,897

Unnamed Tributary 09944 Subwatershed

The Unnamed Tributary 09944 begins just to the east of Rehrersburg and flows in a westerly direction to the Little Swatara Creek mainstem. The tributary receives drainage from the Town of Rehrersburg in Upper Tulpehocken Township as well as agricultural areas (Figure 47). The subwatershed is located along the eastern portion of the Little Swatara Creek watershed. The 3.5 square mile subwatershed contains a total of 5.4 miles of streams (Table 54). The entire subwatershed is currently designated as protected for aquatic life use as cold-water fishery and recreational use (PA Chapter 93). In the subwatershed, all stream miles are impaired for recreational use and aquatic life use designation. The dominant underlying geology is shale, sandstone, and limestone. The dominant hydrologic soil groups are well drained soils (HSG B, 69.2%) and slow to drain soils (HSG D, 26.4%) are scattered throughout the subwatershed.

Table 54. Overview facts about the UNT 09944 subwatershed

Drainage Area	3.5 mi^2
Existing Impervious Cover	5.3%
TMDL	2011 Sediment and Phosphorus
Stream Miles	5.4 mi
Recreational Use	
Impaired	100.0%
Supporting	0.0%
Aquatic Life Use	
Impaired	100.0%
Supporting	0.0%

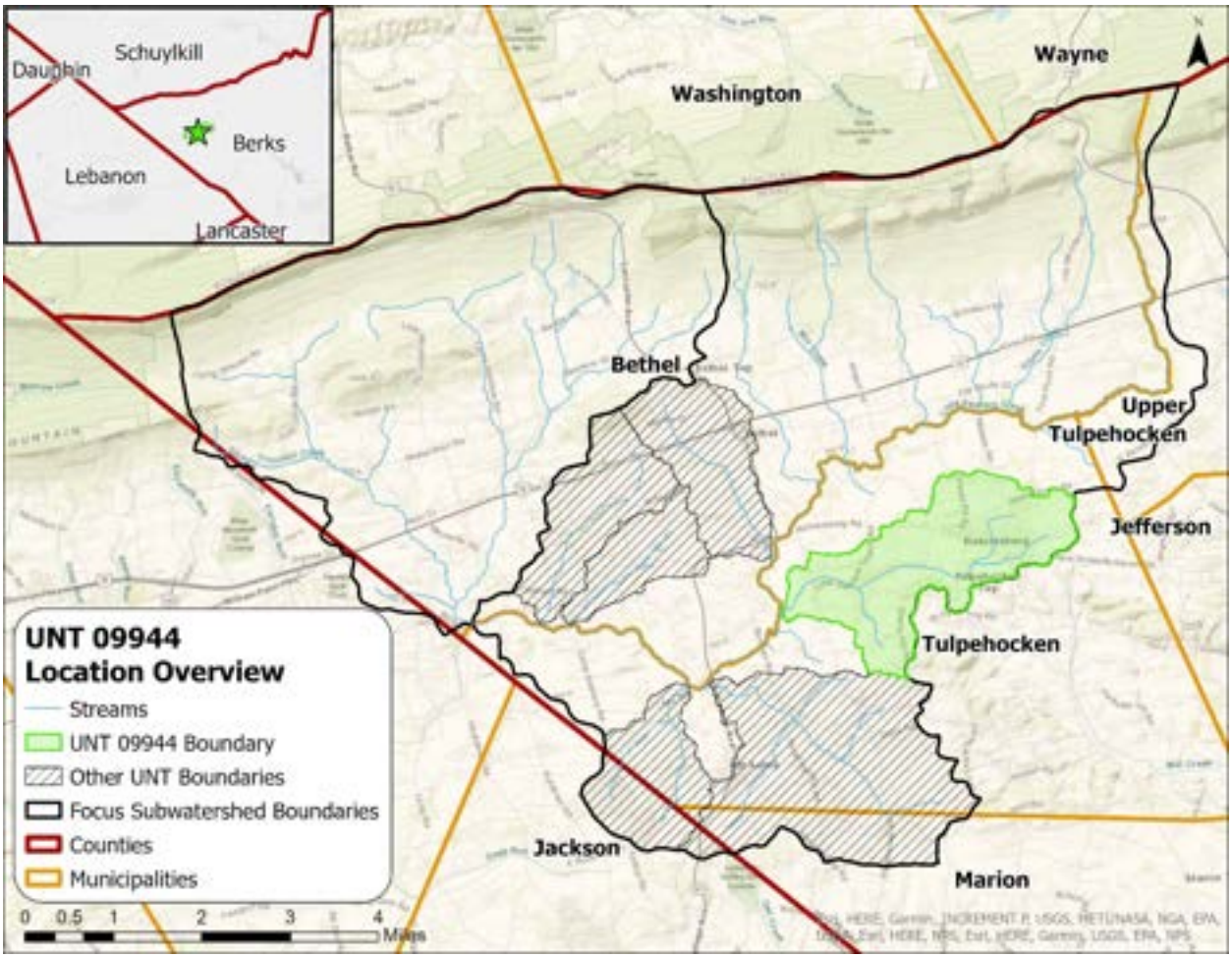

Figure 47. UNT 09944 location overview

The subwatershed land use/land cover is dominated by pasture hay (16.3%), cropland (55.4%) and forest cover (5.0%). The creek flows in a westerly direction through a landscape dominated by cropland and pasture/hay before it meets the mainstem (Figure 48). The area of Rehrersburg represents the greatest concentration of impervious cover in the subwatershed. There are no NPDES permits, biosolid operations or Captive Hazardous Waste Operation. Permanent easements are held on 31.8% of the subwatershed land and ensure the land is used for agricultural production or commercial equine activity and not developed.

In 2011, a TMDL was developed to address phosphorus and sediment impairments identified in the 2008 303(d) list for seven tributary watersheds to the Little Swatara Creek (PA DEP, 2011). The Little Swatara Creek tributaries in the TMDL includes UNT 09944 and five other tributary subwatersheds located inside the total study watershed as shown in Figure 47. The TMDL also includes a tributary subwatershed located outside the total study watershed in Lebanon County. Identified sources of impairments are from agricultural and residential land use practices.

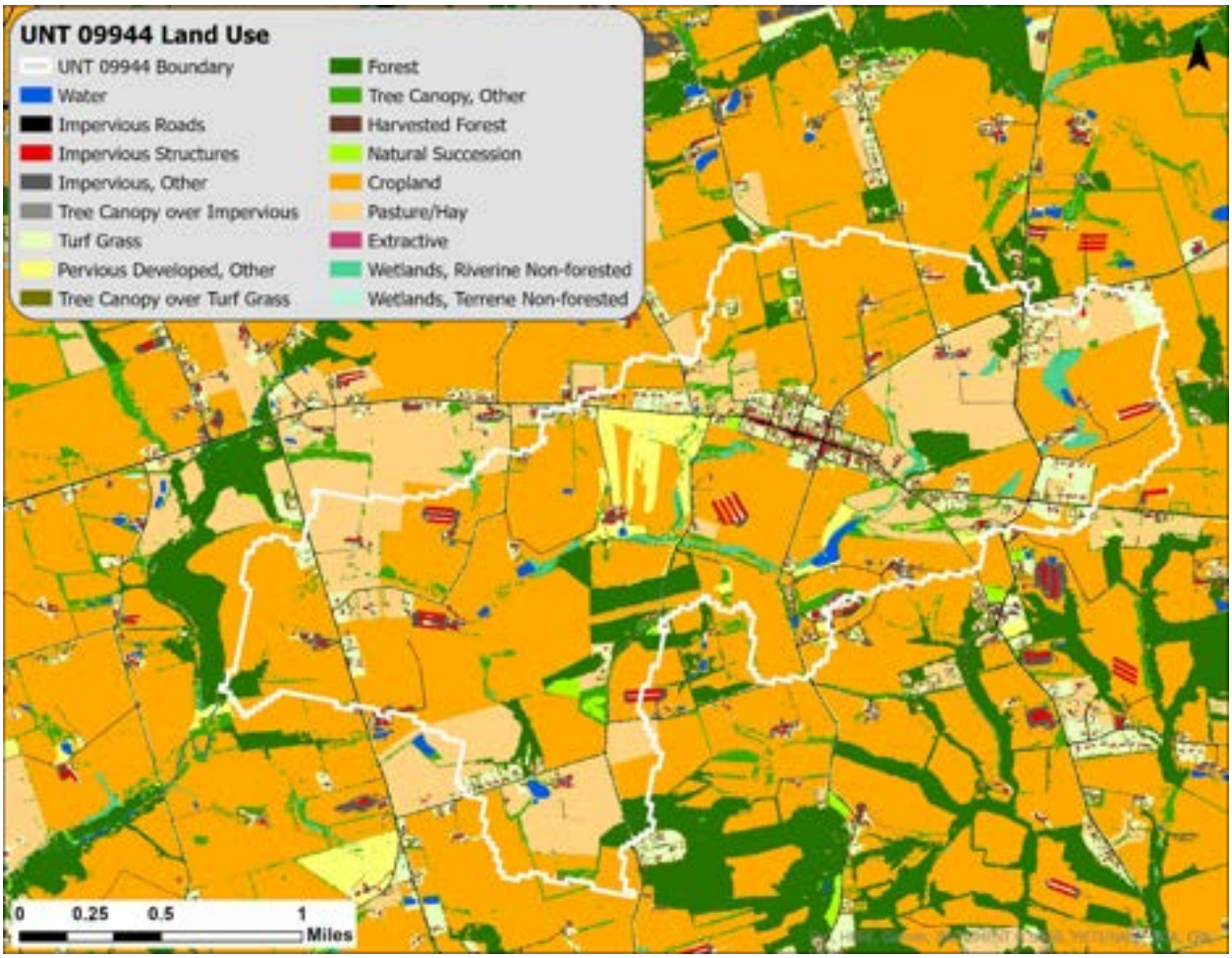

Figure 48. UNT 09944 land use land cover (LULC)

Biological sampling within the subwatershed was conducted by BCCD in 2021; however, there are no PA DEP sampling sites. The sampling site is located in the lower portion of the subwatershed where a tributary enters the subwatershed mainstem (Figure 49). This site was sampled by BCCD and has an IBI value of 41.0. The entire unnamed tributary is impaired for both Aquatic Life Use and Recreational Use.

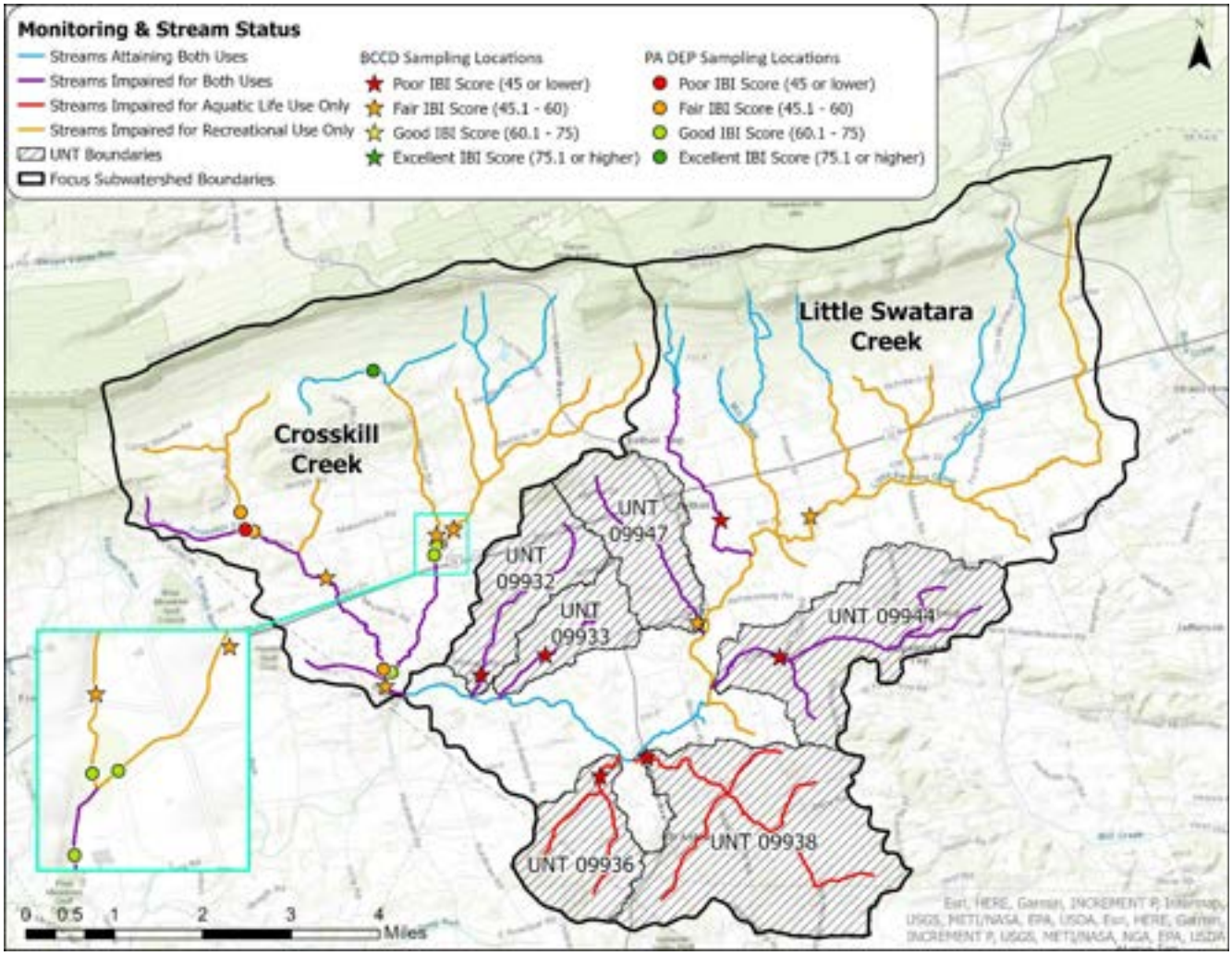

Figure 49. UNT 09944 monitoring and stream status

NUTRIENT MODELING RESULTS

MMW was used to estimate the reduction in sediment and phosphorus achieved through proposed urban and agricultural BMPs in each subwatershed. Table 55 provides a summary of sediment and phosphorus reductions starting from the initial baseline load of 1,127,006 pounds/year and 2,196 pounds/year respectively. UNT 09944 has a phosphorus and sediment TMDL target reduction of 21% or 236,671 pounds/year and 64% or 1,405 pounds/year respectively. The total phosphorus load reduction achieved through current and future proposed BMP implementation results in a 29% reduction for phosphorus which does not meet the TMDL target reduction. The total sediment load reduction achieved through current and future proposed BMP implementation results in a 60% reduction for sediment which exceeds the TMDL target reductions by 39%. Proposed BMPs are provided in Table 56 and Section 8.2 Implementation Cost Estimates and Funding Sourcesprovides information on cost of BMP implementation.

Table 55. UNT 09944 targets and loading

TMDL Target	Loading (lbs/yr)	
	Sediment	Phosphorus
Baseline Load	1,127,006	2,196
TMDL Reduction Target	21%	64%
Target Load Reduction	236,671	1,405
2021 Progress Load Reduction	68,722	131

Table 55. UNT 09944 targets and loading		
TMDL Target	**Loading (lbs/yr)**	
	Sediment	**Phosphorus**
Load Reduction Achieved by Proposed Practices	609,249	516
Total Load Reduction	677,971 (60%)	647 (29%)
Modeled load reduction meets TMDL target reduction	Yes, exceeds by 39%	No, 35% less than goal

Table 56. UNT 09944 Proposed BMPs		
Proposed BMP	**Unit**	**Amount**
Bioretention	Acres of DA	0.85
Permeable Pavement	Acres	0.14
Cover Crops	Acres	1,162
Nutrient Management (Core P)	Acres	241
Tillage Management (high residue)	Acres	1,191

Unnamed Tributary 09947 Subwatershed

The Unnamed Tributary 09947 begins north of Interstate 78 and flows in a southeasterly direction to the Little Swatara Creek mainstem. The tributary receives drainage from several large distribution centers located north of I-78 in the northwestern portion of the subwatershed (Figure 50) as well as Bethel Township and agricultural areas. The 2.0 square mile watershed contains a total of 2.3 miles of streams (Table 57). The entire subwatershed is currently designated as protected for aquatic life use as cold-water fishery and recreational use (PA Chapter 93). In the subwatershed, 100% of stream miles are impaired for recreational use and aquatic life use designation. The dominant underlying geology is shale, sandstone, and limestone. The dominant hydrologic soil groups are well drained soils (HSG B, 56.7%) and slow to drain soils (HSG D, 26.7%) are scattered throughout the subwatershed.

Table 57. Overview facts about the UNT 09947 subwatershed

Drainage Area	2.0 mi^2
Existing Impervious Cover	14.1%
TMDL	2011 Sediment and Phosphorus
Stream Miles	2.3 mi
Recreational Use	
Impaired	100.0%
Supporting	0.0%
Aquatic Life Use	
Impaired	100.0%
Supporting	0.0%

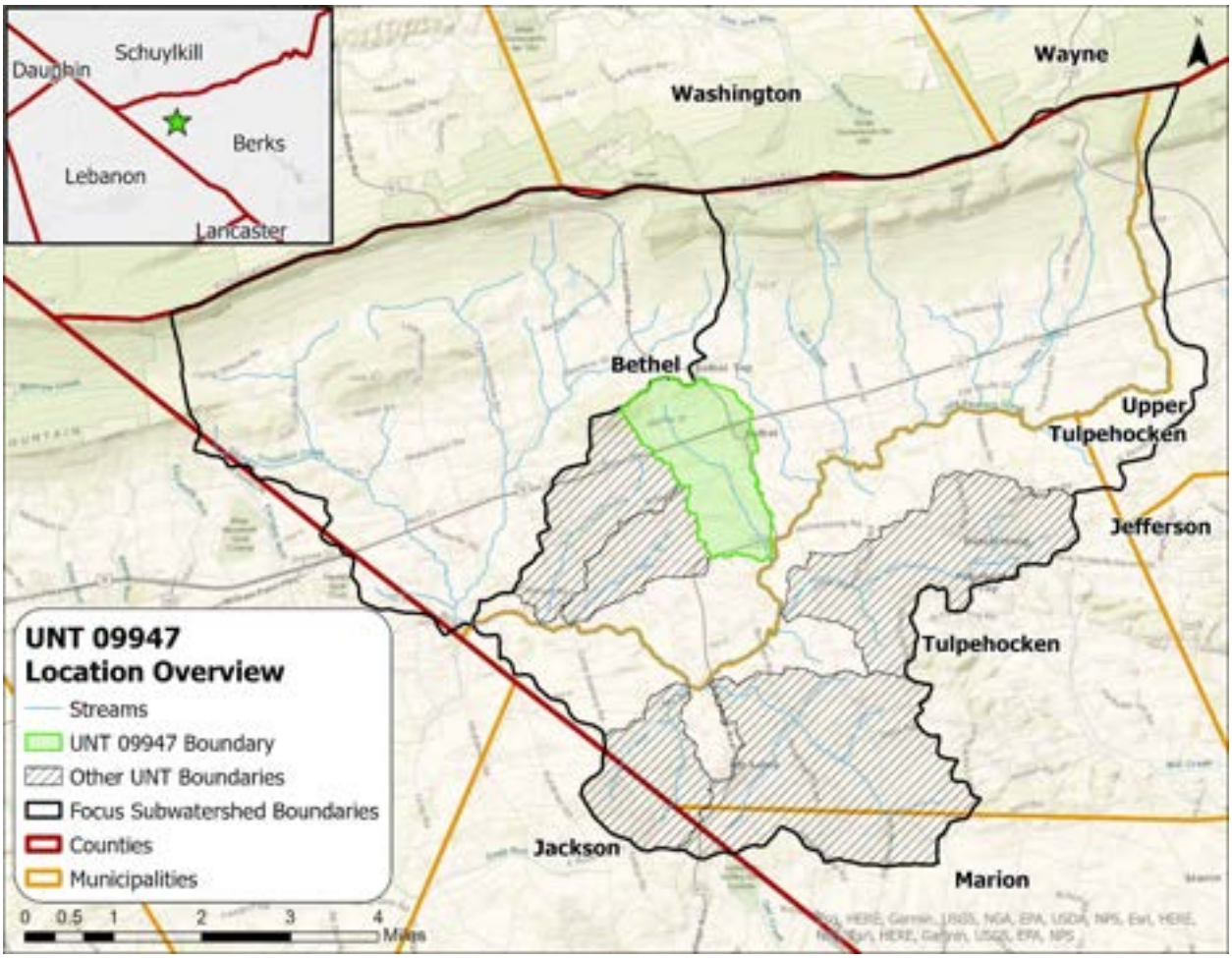

Figure 50. UNT 09947 location overview

The subwatershed land use/land cover is dominated by cropland (47.7%), pasture hay (11.9%) and forest cover (9.4%). The forest cover is located mainly in the northern portion of the subwatershed, just north of the distribution center. The creek flows in a southernly direction through a landscape dominated by cropland and pasture/hay just before it meets the mainstem (Figure 51). Bethel Township and the land uses just north of Interstate-78 contribute to the overall impervious cover levels in the subwatershed. There are 2 biosolid sites in the subwatershed that apply fertilizer on agricultural lands with 1 active and 1 inactive. In addition, there are three NPDES industrial stormwater permits for a lumber mill, auto salvage yard, and truck parts shop. Permanent easements are held on 13.2% of the subwatershed land and ensure the land is used for agricultural production or commercial equine activity and not developed.

In 2011, a TMDL was developed to address phosphorus and sediment impairments identified in the 2008 303(d) list for seven tributary watersheds to the Little Swatara Creek (PA DEP, 2011). The Little Swatara Creek tributaries in the TMDL includes UNT 09947 and five other tributary subwatersheds located inside the total study watershed as shown in Figure 50. The TMDL also includes a tributary subwatershed located outside the total study watershed in Lebanon County. Identified sources of impairments are from agricultural and residential land use practices.

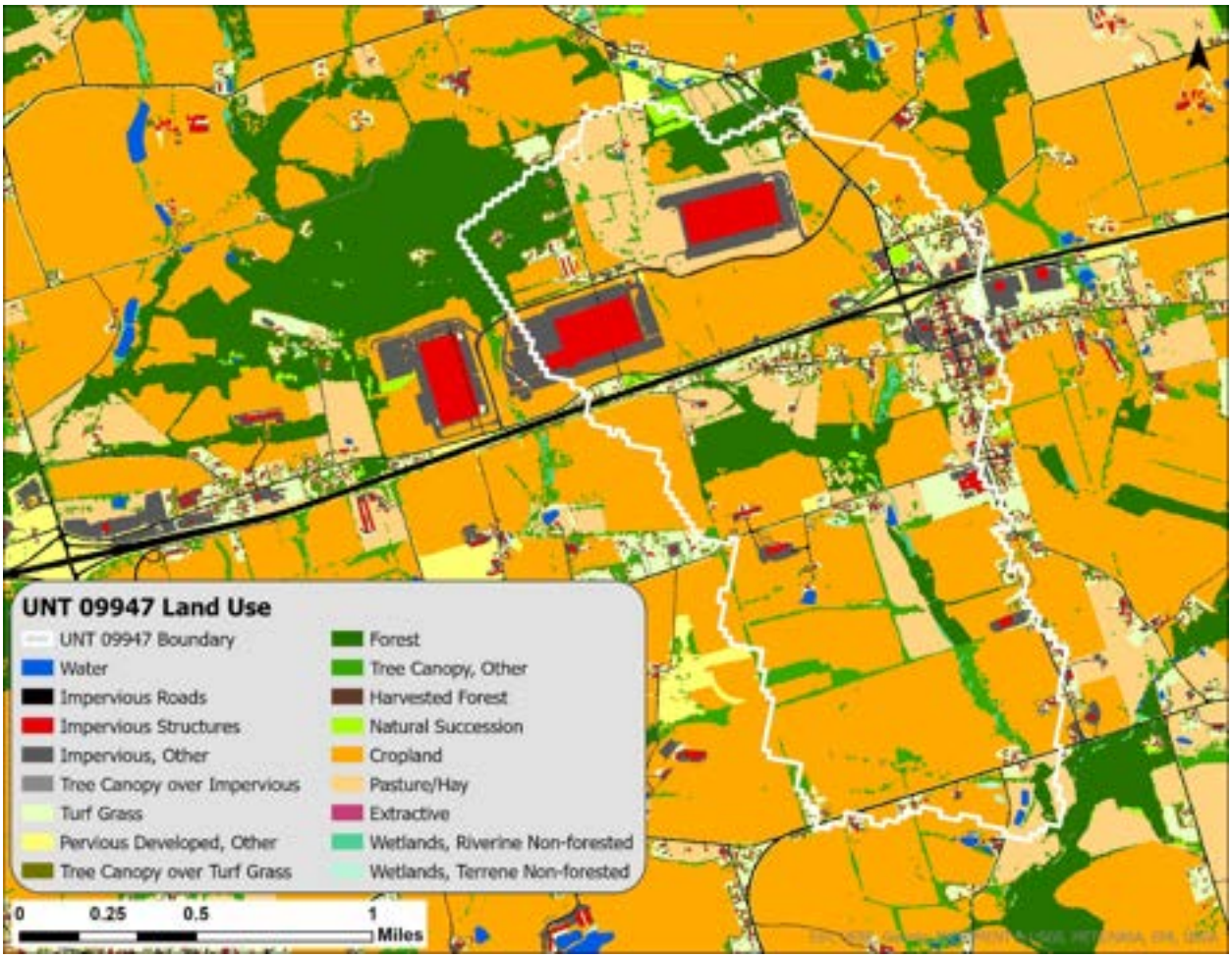

Figure 51. UNT 09947 land use land cover (LULC)

Biological sampling within the subwatershed was conducted by BCCD in 2021; however, there are no PA DEP sampling sites. The sampling site is located near the confluence with the mainstem Little Swatara and was sampled by PA DEP in 2019 with an IBI score of 45.8 (Figure 52). The entire unnamed tributary is impaired for both Aquatic Life Use and Recreational Use.

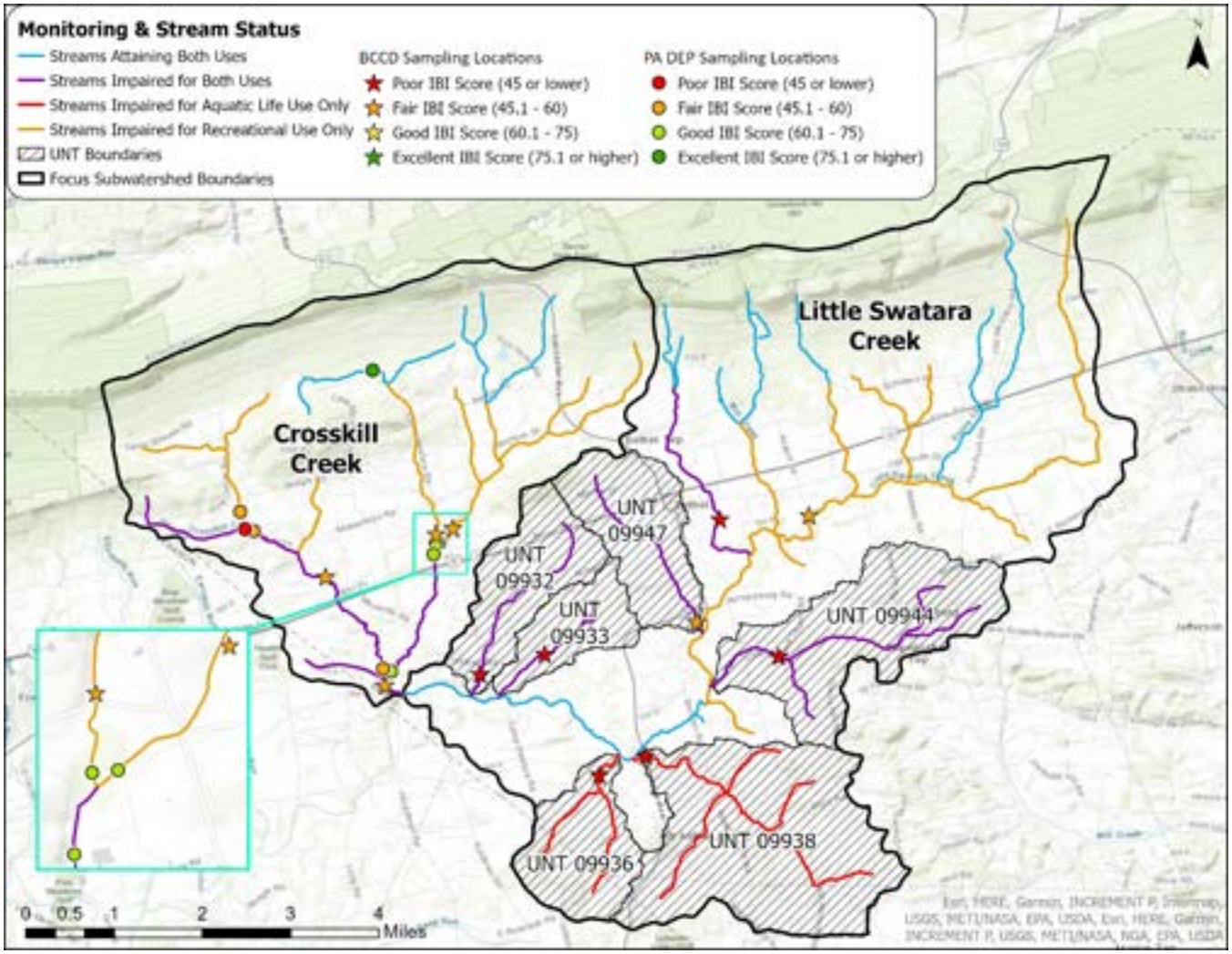

Figure 52. UNT 09947 monitoring and stream status

NUTRIENT MODELING RESULTS

MMW was used to estimate the reduction in sediment and phosphorus achieved through proposed urban and agricultural BMPs in each subwatershed. Table 58 provides a summary of sediment and phosphorus reductions starting from the initial baseline load of 690,519 pounds/year and 1,211 pounds/year respectively. UNT 09947 has a sediment TMDL and phosphorus target reduction of 60% or 414,311 pounds/year and 73% or 884 pounds/year respectively. The total sediment load reduction achieved through current and future proposed BMP implementation results in a 60% reduction for sediment which meets the TMDL target reductions. The total phosphorus load reduction achieved through current and future proposed BMP implementation results in a 31% reduction for phosphorus which does not meet the TMDL target reduction. Proposed BMPs are provided in Table 59 and Section 8.2 Implementation Cost Estimates and Funding Sourcesprovides information on cost of BMP implementation.

Table 58. UNT 09947 targets and loading

TMDL Target	Loading (lbs/yr)	
	Sediment	Phosphorus
Baseline Load	690,519	1,211
TMDL Reduction Target	60%	73%
Target Load Reduction	414,311	884
2021 Progress Load Reduction	15,253	58

Table 58. UNT 09947 targets and loading		
TMDL Target	**Loading (lbs/yr)**	
	Sediment	**Phosphorus**
Load Reduction Achieved by Proposed Practices	397,132	317
Total Load Reduction	412,385 (60%)	375 (31%)
Modeled load reduction meets TMDL target reduction	Meets goal	No, 42% less than goal

Table 59. UNT 09947 Proposed BMPs		
Proposed BMP	**Unit**	**Amount**
Cover Crops	Acres	509
Nutrient Management (Core P)	Acres	217
Tillage Management (high residue)	Acres	500

SECTION 8. RECOMMENDED WATERSHED MANAGEMENT ACTIONS AND IMPLEMENTATION PLAN

8.1 Overall Watershed Recommendations

1. **Implement prioritized Agricultural BMPs for water quality improvement.**
   The priority agricultural BMPs throughout the watershed include Nutrient Management (Core P), Tillage Management (High Residue), and cover crops. The acres of implementation and estimated sediment and phosphorus reduction associated with these practices are provided in Section 5.4.

2. **Continue to engage landowners through outreach to the entire watershed.**
   BCCD along with the NRCS are the lead organizations working with agricultural operators on agricultural resource conservation. Since agriculture is the largest land use in the entire watershed, watershed restoration practices are focused on implementation of agricultural BMPs as discussed in recommendation #1. The BCCD education and outreach plan provides details on efforts to engage and educate agricultural operators (Section 8.3).

3. **Implement priority stormwater management BMP retrofits for water quality improvement.**
   Twenty-one potential stormwater retrofits were identified throughout the watershed, consisting of smaller on-site retrofits. A complete list of identified stormwater retrofits is listed in Table 20. The construction of priority stormwater retrofits is critical because there are many developed areas in the watershed with little or no existing stormwater management. Numerous retrofit opportunities were identified at churches, schools, parks, and fire stations. Most of the proposed projects are bioretention practices. Additional opportunities identified include five permeable pavement practices, one bioswale, one sand filter, one site for additional plantings in an existing pond, and one site for conversion of a dry pond to a wet pond. These sites provide good opportunities for community education and outreach, and efforts should be made to involve the public in the design and construction of these retrofits.

4. **Implement priority streambank restoration projects for water quality improvement.**
   A rapid Bank and Nonpoint Source Consequences of Sediment (BANCS) assessment (Rosgen, 2009) was conducted along reaches at three stream assessment sites in the watershed to provide an understanding of the degree of streambank erosion. The results of this field work are summarized in Section 5.3 and identifies the stream reach along Weaver Farm as producing the largest sediment loss from erosion. As such, this site is prioritized for implementation as restoration will reduce the greatest amount of sediment from entering the stream.

5. **Provide outreach to businesses identified as hotspots.**
   Pollution producing behaviors were identified at Sites 115, Best Used Trucks of PA and 118, Trainer's Midway Diner. Follow-up actions are provided in the description column in Table 19 and photographs of the follow-up actions identified at Sites 115 and 118 are shown in Figure 17.

6. **Review municipal planning model ordinance to address warehouse development.**
   Warehouse development is occurring rapidly along PA Interstate 78 within the entire watershed. As heard at the stakeholder meeting, these projects are often fought by the local municipalities even though local zoning allows for such development. The Penn Future developed a model zoning

ordinance to address logistics use. This model ordinance should be shared with municipalities to provide the tools and performance standards they need to assess and mitigate the impacts. https://www.pennfuture.org/Files/Publications/PennFuture_Ordinance_Manual_7.pdf

7. **Continue to promote preservation of agricultural lands**
   BCCD can continue to promote the ACE while conducting outreach to landowners. These efforts will further promote the protection of agricultural lands from development.

8. **Continue to conduct chemical and biological stream monitoring in the entire watershed**
   Monitoring has been conducted throughout the entire watershed by both PA DEP and BCCD for both chemical and biological data. Recently, the draft PA 2024 Integrated Water Quality Report delisted a segment of the Crosskill Creek based on PA DEP 2022 monitoring data on IBI. As BCCD implements additional agricultural BMPs, it is anticipated that annual stream monitoring will continue to show improvements. The Watershed Implementation Plan is intended to be an adaptive and integrated management strategy that is evaluated and updated over time. It will be measured by progress benchmarks to track and evaluate progress towards attaining implementation goals. Section 8.4 identifies watershed benchmarks that include water quality indicators, outreach efforts, and BMP implementation.

9. **Hire additional engineers and trained technicians to increase capacity for BMP implementation.**
   To increase capacity and accelerate implementation of recommended BMPs, increased staffing of engineers and trained technicians at BCCD and NRCS is recommended. Along with this recommendation is to continue to identify new sources of funding to support staff and BMP implementation.

8.2 Implementation Cost Estimates and Funding Sources

Estimated costs for implementation of all recommended BMPs in the entire study watershed are $5.3 million (Table 60; Figure 53). Estimated costs were determined using capital costs per unit provided in the Chesapeake Assessment Scenario Tool (CAST) Cost Profiles for the State of Pennsylvania (Appendix B). It should be noted that based on professional experience, CAST costs values are found to be low, and a 30% cost increase should be added to these costs to account for inflation, maintenance, etc. These costs are estimates and it is recommended that a detailed cost analysis is provided prior to requesting funding for a proposed BMP. BMP quantities are summarized in the table as well.

Table 60. Estimated costs for implementation of recommended BMPs

BMP Type	Unit Cost (per acre treated)	UNT 09932	UNT 09933	UNT 09936	UNT 09938	UNT 09944	UNT 09947	Swatara (Berks)[1]	Crosskill Creek
Urban BMPs									
Bioswale	$17,420.79	N/A	N/A	N/A	N/A	N/A	N/A	7.6 acres $132,398.00	N/A
Bioretention/raingardens - A/B soils, underdrain	$39,377.89	1.35 acres $53,160.20	1.46 acres $57,491.70	N/A	2.9 acres $114,195.88	0.85 acres $33,471.21	N/A	5.1 acres $200,827.24	N/A
Bioretention/rain gardens - C/D soils, underdrain	$49,630.78	N/A	1.31 acres $65,016.32	N/A	N/A	N/A	N/A	0.62 acres $30,771.08	10.5 acres $521,123.19
Filtering Practices	$25,767.52	0.85 acres $21,902.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Permeable Pavement w/o Sand, Veg. - A/B soils, underdrain	$165,378.70	N/A	N/A	N/A	N/A	0.14 acres $23,153.02	N/A	2.54 acres $420,061.90	N/A
Permeable Pavement w/o Sand, Veg. - A/B soils, no underdrain	$125,057.41	N/A	0.58 acres $72,533.30	N/A	N/A	N/A	N/A	N/A	N/A
Permeable Pavement w/o Sand, Veg. - C/D soils, underdrain	$165,378.70	N/A	0.6 acres $99,227.22	N/A	N/A	N/A	N/A	N/A	N/A
Wet Ponds and Wetlands	$11,504.51	N/A	N/A	N/A	11.5 acres $132,301.87	N/A	N/A	N/A	N/A
Urban BMP Costs/Subwatershed		$75,062.59	$294,268.54	$0.00	$246,497.75	$56,624.23	$0.00	$784,058.22	$521,123.19
Total Urban BMP Costs/Watershed		$1,305,181.41							
Agricultural BMPs									
Cover Crops	$75.50/acre	485 acres $36,617.50	422 acres $31,861.00	493 acres $37,221.50	1,831 acres $138,240.50	1,162 acres $87,731.00	509 acres $38,429.50	7,629 acres $575,989.50	2,805 acres $211,777.50
Nutrient Management (Core P)	$8.86/acre	194 acres $1,718.84	188 acres $1,665.68	221 acres $1,958.06	792 acres $7,017.12	241 acres $2,135.26	217 acres $1,922.62	1,853 acres $16,417.58	797 acres $7,061.42
Streambank Restoration	$315.24/foot	N/A	N/A	N/A	1,897 ft $598,010.28	N/A	N/A	5,072 ft $1,598,897.28	5,120 ft $1,614,028.80
Tillage Management (High Residue)	$0.00/acre	493 acres	422 acres	493 acres	1,836 acres	1,191 acres	500 acres	5,496 acres	2,064 acres
Tillage Management (Low Residue)	$0.00/acre	N/A	N/A	N/A	N/A	N/A	N/A		N/A
Agricultural BMP Costs/Subwatershed		$38,336.34	$33,526.68	$39,179.56	$743,267.90	$89,866.26	$40,352.12	$2,191,304.36	$1,832,867.72
Total Agricultural BMP Costs/Watershed		$4,024,172.08							
Combined Urban and Agricultural BMP Costs for Each Subwatershed		$113,398.93	$327,795.22	$39,179.56	$989,765.65	$146,490.49	$40,352.12	$2,975,362.58	$2,353,990.91
Total Urban and Agricultural BMP Costs for the Watershed		$5,329,353.49							

[1] Implementation and costs in the Upper Little Swatara are inclusive of costs within the UNT Subwatersheds.

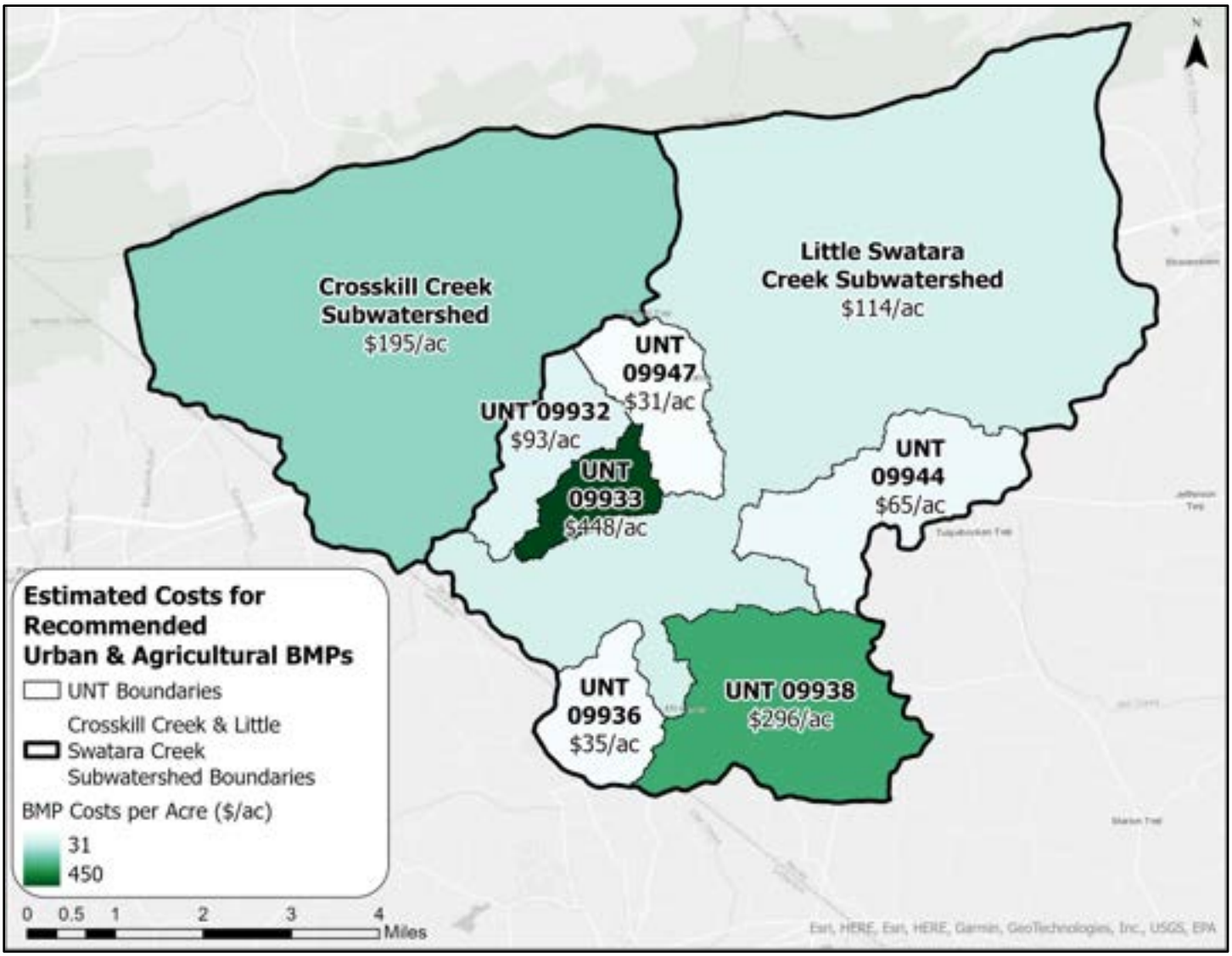

Figure 53. Estimated costs per acre for recommended urban and agricultural BMPs[6]

POTENTIAL FUNDING SOURCES

Given the projected cost to meet the TMDL goals, reliable funding sources for BMP implementation are needed. The Berks County Conservation District (BCCD) currently has been able to secure funding for agricultural projects. BCCD received a $1.7 million award from the USDA-NRCS Regional Conservation Partnership Program (RCPP) in 2021, $850,000 from NFWF Most Effective Basin (MEB) grant in 2022, CAP Implementation Grant of $381,594 in 2020, and $5.4 million through the Agricultural Conservation Assistance Program (ACAP) that ends in 2025.

Table 61 lists the numerous grant, loan and cost-share programs that can be used for implementation of urban and agricultural BMPs.

[6] The Little Swatara Creek Subwatershed includes all of the UNT subwatersheds.

Table 61. Funding Sources for BMP Implementation

Grant Name (Linked)	Agency	Activities Funded
Agriculture Conservation Assistance Program	PA DOA	The Agriculture Conservation Assistance Program (ACAP) was created through the Clean Streams Fund established by the FY2022-2023 Pennsylvania State Budge. ACAP provides financial and technical assistance for the implementation of best management practices (BMPs) on agricultural operations within the Commonwealth.
Environmental Quality Incentives Program (EQIP)	NRCS	Works one-on-one with producers to develop a conservation plan that outlines conservation practices and activities to help solve on-farm resource issues.
Conservation Stewardship Program	NRCS	Works one-on-one with producers to develop a conservation plan that outlines and enhances existing efforts, using new conservation practices or activities, based on management objectives for your operation. Annual costs are offered for these practices.
Agricultural Management Assistance	NRCS	Program helps agricultural producers manage financial risk through diversification, marketing or natural resource conservation practices.
Conservation Innovation Grants	NRCS	Competitive program that supports the development of new tools, approaches, practices, and technologies to further natural resource conservation on private lands.
Regional Conservation Partnership Program (RCPP)	NRCS	RCPP provides funds for producers to install and maintain conservation activities. The program is not a grant program, but partners can leverage RCPP funding in their programs.
County Action Plan (CAP) Implementation Grant	PADEP Chesapeake Bay Program	The purpose of this program is to provide a mechanism to fund the implementation of CAPs developed at the county level to maximize specified nutrient and sediment reduction goals established as part of Pennsylvania's Phase 3 WIP.
PA Most Effective Basins	NFWF	Projects that accelerate implementation of cost-effective agricultural best management practices ("practices") in selected basins of the Chesapeake Bay watershed of Pennsylvania
319 Nonpoint Source Management Program	PA DEP	Watershed plan development; implementation of projects in approved watershed plans
Growing Greener	PA DEP	Growing Greener has helped to slash the backlog of farmland-preservation projects statewide; protect open space; eliminate the maintenance backlog in watersheds; provide funds for recreational trails and local parks; help communities address land use; and provide new and upgraded water and sewer systems.
Chesapeake Bay Stewardship Fund: Small Watershed Grants	NFWF	Water quality and habitat restoration project implementation
Climate Smart Commodities - Farmers for Soil Health Coalition	NFWF	This effort will expand markets for America's climate-smart commodities, leverage the greenhouse gas benefits of climate-smart commodity production, and provide direct, meaningful benefits to production agriculture, including for small and underserved producers.
Chesapeake Watershed Investments for Landscape Defense Grants (WILD) Program	NFWF	Implementation and planning and technical assistance grants with a focus on climate change, public access, clean water, and community partnerships.

8.3. Information, Education, and Public Participation

The purpose of this section is to describe an information and education component that enhances public understanding of the project and encourages public participation in selecting, designing, and implementing the NPS management measures that will be implemented. This section of the plan includes the stakeholder outreach strategy including planning for public meetings, listing of identified stakeholders, and education and outreach materials.

Public Meeting(s)

BCCD worked to get organizational stakeholders involved early in the planning stages of the watershed plan. A virtual project kick-off meeting was held on March 2, 2021 using Zoom. The meeting provided an overview of the project goals, project tasks and timeline. A total of sixteen people attended representing thirteen partnering organizations that include EPA, BCCD, CWP, Tulpehocken Township, Berks County Planning Commission, Bethel Township Environmental Advisory Council (EAC), AE Consultants, Farm Bureau, Berks Nature, Berks County Department of Agriculture, Stroud Water Research Center and Penn State Extension.

On August 26, 2021 the first stakeholder meeting was held for the development of this plan at Kauffman's Bar-B-Que Restaurant in Bethel Township, PA. Twenty eight people attended representing area farmers (7 or 8 different farms), Bethel Township EAC, Swatara Creek Watershed Association, Tulpehocken Township, Farm Bureau, Land Studies, County Planning Commission, and the Natural Resource Conservation Service (NRCS). The meeting provided an overview of the watershed Implementation Plan, findings from the watershed assessment and field work, funding opportunities and allowed time for stakeholders to comment and ask questions. The second stakeholder meeting was convened virtually using the Zoom platform. There were 26 attendees that represented the agricultural community and implementation partners. The meeting provided an overview of the project timeline, a presentation providing an overview of the Plan, followed by discussion and next steps. The Plan was posted on BCCD's website for stakeholders to provide comments.

Stakeholder Outreach

The BCCD will work with civic, environmental, university, county, and local government stakeholder groups to implement this watershed plan. A list of key stakeholder groups is provided in Table 62. BCCD will engage citizen volunteers in project implementation through the Bethel EAC, SCWA, local municipalities, and other organizations. Private landowners including farm owners and operators will be individually contacted by BCCD and/or NRCS regarding agricultural BMP implementation as determined appropriate. The final draft of the plan will be available on the county website and other websites or outreach media (such as newsletters) as appropriate.

Table 62. Key stakeholder groups

• Berks County Planning Commission (BCPC) • AE Consultants • PA Farm Bureau • Berks County Department of Agriculture (BC DOA) • Berks Nature • Stroud Water Research Center (Stroud) • Swatara Watershed Association (SWA) • Berks County Source Water Protection Program (BCSWP)	• Bethel Environmental Advisory Council (EAC) • PennState Extension • NRCS, District Conservationist • U.S. EPA Region 3 • Technical Service Providers (TSPs) • Tulpehocken Township • Chesapeake Bay Foundation (CBF)

The planning and implementation of the Plan will be communicated with the public and allow for public feedback using several outreach approaches shown in Table 63.

Table 63. Stakeholder Outreach Plan		
Outreach Approach	**Leads**	**Other Partners**
Coordination with BBAP – Quarterly meetings to report progress updates on projects identified in the BBAP.	Landstudies, Inc.	BCCD, BCPC
One-on-One Farmer Engagement – Onsite education and technical assistance to advance water quality BMPs on working Agriculture Lands.	BCCD, BC DOA	NRCS, Technical Service Providers (TSPs), Berks Nature, and Stroud
One-on-one municipal engagement – Onsite or offsite education to enhance knowledge of water quality BMPs on agriculture and urban land uses.	BCPC, BCCD, CWP	Local EAC, engineers/consultants, Landstudies, Inc.
Specific or Broad Audience Engagement – Targeted or stakeholder workshops and fields days within targeted watersheds.	BCCD	NRCS, Stroud, Berks Nature, County, Stroud, CWP, Municipalities and School Districts
Regional Partnerships – Development of cross watershed and cross county partnerships.	BCCD and BCPC	CBF, SWA, BCSP, Landstudies, Inc.
Adaptive Management Practices – Stakeholders will be involved in evaluating the WIP to make changes and adapt the plan over time.	BCCD	Stakeholders identified in Table Table 62. Key stakeholder groups

Communications, Education and Outreach Materials

In addition to the outreach approaches described in Table 63, BCCD communicates to the public through a monthly newsletter and publications and brochures. A monthly electronic newsletter is distributed to provide project updates and upcoming events. In addition, BCCD provides a series of informational brochures on their website under the various programs. For example, under the Agriculture & Soil program is a list of agricultural related documents.

8.4. Implementation Schedule and Milestones

Table 64 lists the plan's recommendations, along with a suggested timeframe for implementation, partners, and milestones. For this plan, short-term is considered 1-2 years, medium-term is 3-5 years, and long-term is > 5 years. Implementation is focused on the UNT and Crosskill Creek subwatersheds to achieve TMDL goals.

Table 64. Implementation schedule and milestones			
Recommendation	**Timeframe for Implementation**	**Partners**	**Milestones**
1. Implement prioritized Agricultural BMPs for water quality improvement.	Short-term	BCCD/Farmers	Implement Ag field practice BMPs on 10% of the proposed additional acres.
	Medium to Long-Term	BCCD/Farmers	Implement remaining proposed Ag BMPs.

Table 64. Implementation schedule and milestones

Recommendation	Timeframe for Implementation	Partners	Milestones
2. Continue to engage landowners through outreach to the entire watershed.	Short-term	Municipalities, Private Property Owners	Outreach events that result in 5-8 farmers willing to implement proposed Ag BMPs Achieve at least one retrofit on private property.
	Medium to Long-Term	Municipalities, Private Property Owners	Achieve an average of one retrofit per year across all three drainage areas Farmer participation is sufficient to meet implementation goals.
3. Implement priority stormwater management BMP retrofits for water quality improvement.	Short-term to Medium-term	Municipalities, County	Concepts developed and implemented for 1 high priority urban BMP
	Medium to Long-Term	Municipalities, County	Concepts developed and implemented for 5-8 high priority urban BMP
4. Implement priority streambank restoration projects for water quality improvement	Short to Medium-Term	BCCD, Municipalities, County	Restore stream in Crosskill Creek and UNT 09938 where feasible
5. Provide outreach to businesses identified as hotspots.	Short-Term	Municipalities	Educate and fix pollutant producing behaviors identified during the HSI
6. Review municipal planning model ordinance to address warehouse development	Short to Medium-Term	Municipalities	Municipalities to review model ordinance and existing zoning code to assess and mitigate the impacts.
7. Continue to promote preservation of agricultural lands	Medium to Long-Term	BCCD, County Agriculture Land Preservation Office	Conserve an additional 10% of agricultural land
8. Continue to conduct chemical and biological stream monitoring in the entire watershed	Short-Term	BCCD	Secure PA DEP 319 Funding to continue chemical and biological stream monitoring

Table 64. Implementation schedule and milestones			
Recommendation	**Timeframe for Implementation**	**Partners**	**Milestones**
	Medium to Long-Term	BCCD	Delist UNTs and Crosskill creek tributaries that are included in the TMDL plans
9. Hire additional engineers and trained technicians to increase capacity for BMP implementation	Short-Term	BCCD, NRCS	Hire 1-2 new staff
	Medium- to Long-Term	BCCD, NRCS	Continue to additional staff as needed

8.5. Evaluate Progress and Adaptive Management

The Watershed Implementation Plan is intended to be an adaptive and integrated management strategy that is evaluated and updated over time. It will be measured by progress benchmarks to track and evaluate progress towards attaining implementation goals. Project implementation is currently tracked by BCCD through Practice Keeper and other tools. Table 65 identifies watershed benchmarks that include water quality indicators, outreach efforts, and BMP implementation. It is recommended that BCCD continue project tracking as well as water quality data and public engagement to monitor progress in reaching milestones (Table 64) and progress benchmarks (Table 65).

Table 65. Progress benchmarks			
Benchmark	**Year 5**	**Year 10**	**Year 15**
IBI scores	10% improvement	20% additional improvement	Attaining aquatic life use
General public engagement	Expanded education and outreach efforts	Implementation of 2-3 urban BMPs	Greater knowledge of watershed restoration and urban BMP implementation
Agricultural producer engagement	Continued 1 on 1 communication on benefits of BMPs	Expanded 1 on 1 communication on benefits of agricultural BMPs	Increased buy-in for agricultural BMPs
Agricultural BMPs	10% implementation	50% of additional implementation target	100% additional implementation target

Ultimately, the most important benchmark is improvement in the IBI score as it directly reflects water quality improvement in the streams. The IBI score should improve as the other benchmarks of outreach and BMP implementation progress. The plan should be evaluated annually for progress made and if milestones are being met, especially at 2, 5 and 10 years. If there is less progress being made than expected, the reasons should be explored, and strategies adjusted.

8.6 Monitoring Plan

The BCCD intends to submit a funding application in 2024 to the Pennsylvania Section 319 Nonpoint Source Management Program for a 5-year (2025 – 2030) water quality monitoring plan (the monitoring plan) in the Upper Little Swatara Watershed. The goal of the monitoring plan is to collect quarterly chemical water quality data and annual biological sampling (i.e. macroinvertebrates) to monitor stream improvement trends and ultimately support the delisting of aquatic life use impaired streams in the watershed. The BCCD is targeting BMP implementation in this watershed as the County has pollutant load reduction goals as part of the

Chesapeake Bay Total Maximum Daily Load (TMDL). This document provides a summary of the components for the proposed monitoring plan.

The plan will build upon the existing water quality monitoring conducted by BCCD in the spring of 2021 funded by a 2021 PA 319 grant. The monitoring is summarized in Section 2. Hydrology of the Watershed Implementation Plan. BCCD will conduct chemical, biological, and physical habitat assessments at the existing twelve stream sites sampled in 2021 (Figure 11). These sites were selected to focus on small subwatersheds (<5 mi^2) where past and future conservation activities and BMPs have been or will be implemented. The water quality data collected will be compared to the 2021 baseline data and provide a comparison for determining incremental success of future implementation and a long-term monitoring program.

PA DEP's Water Quality Monitoring Protocols for Streams and Rivers 2001 will be used for data collection and evaluation. It is anticipated that the Suburban Testing Labs, Inc. (STL) will be used for data analysis and the water quality parameters sampled in 2021 will be modified to meet PA DEP's protocols. This information will be updated as needed prior to conducting new monitoring. The monitoring plan will use the existing Quality Assurance Performance Plan (QAPP) (effective date of 5/20/2021) that is valid for 5 years and expires on 5/20/2026.

REFERENCES

Barry Evans, Drexel University & Penn State University. 2020. Model My Watershed BMP Spreadsheet Tool User Manual. https://raw.githubusercontent.com/WikiWatershed/MMW-BMP-spreadsheet-tool/master/docs/MMW_BMP_Spreadsheet_Tool_UserManual.pdf

Berg, T. M., Geyer, A. R., Edmunds, W. E., ... & Eds. (1980). Geologic map of Pennsylvania. Pennsylvania Geological Survey. 4th ser., Map 1.

Berks County Department of Agriculture. (n.d.). ACE Program Overview. Retrieved from: https://www.co.berks.pa.us/Dept/DeptofAg/Pages/ACEProgramOverview.aspx

Berks Nature. (n.d.). Protect Your Land. Retrieved from: https://berksnature.org/protect-your-land/

Center for Watershed Protection. (2021). Quality Assurance Project Plan. Upper Little Swatara Creek Watershed Implementation Plan Development. Effective date May, 2021.

Chesapeake Bay Program (CBP). 2017. Nutrient Management Practices For Use in Phase 6.0 of the Chesapeake Bay Program Watershed Model. Prepared by Tetra Tech. Document # CBP/TRS-307-16. CBP/TRS-307-16. Retrieved from: https://d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/Phase_6_NM_Panel_Report_11-28-2016_New_Template_FINAL.pdf

Chesapeake Conservancy Conservation Innovation Center. (2014). Land Cover Data Project 2013/2014. Retrieved from: https://www.chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/land-cover-data-project/

Chesapeake Conservancy Conservation Innovation Center. (n.d.). High-Resolution Land Cover Dataset 101. Retrieved from: https://chesapeakeconservancy.org/wp-content/uploads/2020/06/Chesapeake_Conservancy_LandCover101Guide_June2020.pdf

National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS). (n.d.). Swatara Creek Story Map. Retrieved from: https://www.arcgis.com/apps/MapJournal/index.html?appid=4201e9f85d6d424c9075d62caffe1620

25 Pa. Code § 93. (n.d.). Water Quality Standards. Retrieved from: http://www.pacode.com/secure/data/025/chapter93/chap93toc.html

Pennsylvania Department of Environmental Protection. 2021. Office of Water Programs. Bureau of Clean Water. Water Quality Monitoring Protocols for Streams and Rivers. Harrisburg, PA. Retrieved from: https://files.dep.state.pa.us/water/Drinking%20Water%20and%20Facility%20Regulation/WaterQualityPortalFiles/Technical%20Documentation/MONITORING_BOOK.pdf

Pennsylvania Department of Environmental Protection (PA DEP). (2020). Berks County Clean Water Technical Toolbox: Developing a County-Based Action Plan for Clean Water. Retrieved from: https://files.dep.state.pa.us/Water/ChesapeakeBayOffice/WIPIII/2021/Berks_County_Technical_Toolbox.pdf

Pennsylvania Department of Environmental Protection (PA DEP). (2018). Water Quality Monitoring Protocols for Streams and Rivers.

Pennsylvania Department of Environmental Protection (PA DEP). (2011). Little Swatara Creek Tributaries TMDL Lebanon and Berks and Counties. Retrieved from: https://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/tmdl/Little_Swatara_Creek_TMDL.pdf

Pennsylvania Department of Environmental Protection (PA DEP). (2004). Sediment Total Maximum Daily Load (TMDL) Crosskill Creek (stream code 09919) Berks and Lebanon Counties. Retrieved from: https://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/tmdl/CrosskillCreek_TMDL.pdf

Pennsylvania Department of Environmental Protection (PA DEP) Captive Hazardous Waste Operation (CAHWO) - Treatment Facility. Retrieved from: https://newdata-padep-1.opendata.arcgis.com/datasets/a2104442bf01480ab962bce4be846643_147?geometry=-76.436%2C40.305%2C-75.509%2C40.488&selectedAttribute=CLIENT_ID

Pennsylvania Fish and Boat Commission. Trout Stream Interactive Map. Retrieved from: https://pfbc.maps.arcgis.com/apps/webappviewer/index.html?id=65a89f6592234019bdc5f095eaf5c6ac

Quality Assurance Project Plan (QAPP): Upper Little Swatara Creek Watershed Implementation Plan Development. February 2021.

Rosgen, D.L., 2009. A Watershed Assessment for River Stability and Sediment Supply (WARSSS). Wildland Hydrology Books, Fort Collins, CO. http://www.epa.gov/warsss

Schueler, T.R., Fraley-McNeal, L., and Cappiella, K. 2009. Is Impervious Cover Still Important? Review of Recent Research. Journal of Hydrologic Engineering. American Society of Civil Engineers. P. 309-315. http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/02/Is-Imp-Cover-Still-Important.pdf

Schueler, T., and B. Stack. 2014. Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects.

Stroud Water Research Center. (2017). Model My Watershed [Software]. Available from https://wikiwatershed.org/

US Climate Data. Reading, PA. (n.d.). Retrieved from: https://www.usclimatedata.com/climate/reading/pennsylvania/united-states/uspa1348

US Environmental Protection Agency (US EPA). (2021). National Pollutant Discharge Elimination System (NPDES) Animal Feeding Operations (AFOs). Retrieved from: https://www.epa.gov/npdes/animal-feeding-operations-afos

US Environmental Protection Agency (US EPA). (no date). Nitrogen and Phosphorus in Agricultural Streams.

U.S. Geological Survey (USGS). 2016. The StreamStats program, online at http://streamstats.usgs.gov, accessed on November 7, 2021.

Wood, D. 2020. Consensus Recommendations for Improving the Application of the Prevented Sediment Protocol for Urban Stream Restoration Projects Built for Pollutant Removal Credit.

APPENDIX A. MMW BMP SPREADSHEETS FOR EACH SUBWATERSHED

The Model My Watershed (MMW) BMP spreadsheets completed for each subwatershed are provided as a separate Appendix, which can be accessed here: Appendix A_MMW BMP Spreadsheets for Each Subwatershed

Appendix B. Chesapeake Assessment Scenario Tool (CAST) Cost Profiles for the State of Pennsylvania

The Chesapeake Assessment Scenario Tool (CAST) cost profiles for the State of Pennsylvania are provided as a separate Appendix, which can be accessed here: Appendix B_CAST Cost Profiles for PA.xlsx