SPRING CREEK AREA OF INTEREST WATERSHED IMPLEMENTATION PLAN

December 2025

Prepared for The Doc Fritchey Chapter of Trout Unlimited

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Michael Morris
Pennsylvania Department of Environmental Protection

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ACRONYMS & ABBREVIATIONS

Acronym/Abbreviation	Definition
AL	Allowable Load
AOI	Area of Interest
ARP	Alternative Restoration Plan
ASL	Adjusted Source Load
BANCS	Bank Assessment for Non-point source Consequences of Sediment
BMP(s)	Best Management Practice(s)
BOD	Biological Oxygen Demand
CAFO	Concentrated Animal Feeding Operation
CAP	Countywide Action Plan
CAST	Chesapeake Assessment Scenario Tool
CBP	Chesapeake Bay Program
CWP	Center for Watershed Protection, Inc.
DCCD	Dauphin County Conservation District
DTMA	Derry Township Municipal Authority
EMPR	Equal Marginal Percent Reduction
EPR	Ecosystem Planning and Restoration
GIS	Geographic Information System(s)
HSG	Hydrologic Soil Group
IBI	Index of Biotic Integrity
LA	Load Allocation
LCCD	Lebanon County Conservation District
LNR	Loads Not Reduced
MHS	Milton Hershey School
MMW	Model My Watershed
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
NFWF	National Fish and Wildlife Foundation
NHD	National Hydrography Dataset
NPDES	National Pollutant Discharge Elimination System
PA DCED	Pennsylvania Department of Community and Economic Development
PA DCNR	Pennsylvania Department of Conservation and Natural Resources
PA DEP	Pennsylvania Department of Environmental Protection
PDA	Pennsylvania Department of Agriculture
PENNVEST	Pennsylvania Infrastructure Investment Authority
PFBC	Pennsylvania Fish and Boat Commission
PSU	Penn State University (Penn State Agriculture and Environment Center)
SL	Source Load
SCEWA	Spring Creek East Watershed Alliance
SSURGO	Soil Survey Geographic Database
SWA	Swatara Watershed Association
TMDL	Total Maximum Daily Load
TU	Trout Unlimited Doc Fritchey Chapter
UF	Uncertainty Factor
USDA FSA	U.S. Department of Agriculture Farm Service Agency
USDA NRCS	U.S. Department of Agriculture Natural Resources Conservation Service
US FWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
US EPA	U.S. Environmental Protection Agency
UVM SAL	University of Vermont Spatial Analysis Lab
WIP	Watershed Implementation Plan
WLA	Wasteload Allocation

EXECUTIVE SUMMARY

A Watershed Implementation Plan (WIP) for a portion of the Spring Creek East watershed was created through a cooperative effort of the Doc Fritchey Chapter of Trout Unlimited, the Center for Watershed Protection (CWP), Ecosystem Planning and Restoration (EPR), Penn State University (PSU), the Dauphin County Conservation District (DCCD), Lebanon County Conservation District (LCCD), and other stakeholders to provide an action plan to reduce sediment loads and accompanying nutrient loads. 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) estimated reduction needs for sediment. A PA DEP Nonpoint Source 319 grant funded this project, and it is hoped that having an approved WIP can provide additional 319 funding for project implementation in the future.

This WIP is developed specifically for the headwaters of the Spring Creek East watershed, referred to in this plan as the "Area of Interest" watershed (AOI). The AOI designation was made to differentiate between those portions of the watershed that were eligible for 319 grant funding (this WIP was created using 319 funding), and those that are designated as being covered through municipal pollution reduction plans. The AOI watershed drains approximately 10.6 square miles (sq. mi.) of the larger Spring Creek watershed. The larger Spring Creek East watershed includes portions of Derry Township, but portions are also in North Londonderry Township, Palmyra Borough, South Londonderry Township, and Conewago Township. Figure 1 shows the location of the AOI watershed and its relationship to the larger Spring Creek East watershed.

Watershed Baseline Assessment

The baseline assessment (Sections 1-4) summarizes watershed characteristics for the AOI watershed including geology, land use, stream condition, and pollution sources. Land use is dominated by forest (10%), turf grass (~20%), and cropland (32%), with impervious cover around 18% and associated primarily with development in the lower watershed and roadways. Dominant crops include no-till corn grain, soybean, and small grain for silage, and livestock operations primarily include swine and chickens.

The streams in the AOI watershed are designated as protected for aquatic life use as cold-water fishery and recreational use (PA Chapter 93). Nearly all of the stream miles in the watershed are listed as impaired for aquatic life use and/or recreational use (Figure 11 and Figure 12). The primary causes of aquatic life use impairments are siltation (from agriculture, golf courses, urban runoff/storm sewers, and unknown sources), habitat alteration (from habitat modification and urban runoff/storm sewers), flow regime modification (from habitat modification and urban runoff/storm sewers) and organic enrichment (from agriculture).

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 Spring Creek East watershed does not currently have any prescribed TMDLs and the development of this WIP will hopefully reduce the chances that will happen in the future.

Field Assessments and Findings

Field assessments were conducted to identify restoration opportunities within the AOI watershed. Field assessments included identification of stormwater retrofit projects for pollutant reduction and restoration opportunities on commercial, institutional, and municipal properties, assessment of agricultural practices and potential opportunities for additional implementation projects, as well as stream restoration opportunity assessments conducted following a modified version of the FBRSA Data Sheet to evaluate restoration opportunities at identified reaches. A summary is found in Section 5.

The retrofit inventory identified 6 stormwater retrofit opportunities in the AOI watershed, with another 7 located in the larger Spring Creek East watershed outside the AOI. In total, the projects cumulatively treat about 40 acres of urban land, with about 25 acres of that drainage located in the AOI watershed. Stormwater retrofits identified include 11 bioretention practices, and two sites for modification of an existing pond to a dry extended detention pond. 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 one year, and the cost effectiveness for all retrofits identified.

An agricultural practice assessment was done for the Spring Creek East watershed including the AOI watershed that is the focus of this plan. A combination of a GIS-based desktop analysis of aerial photography as well as a windshield visual survey were used to identify areas that had implemented practices and candidate sites for future practices. Practices assessed fell into three overall categories: 1) potential agriculture best management practices, such as opportunities for grassed waterways, contour strop cropping, pasture management, etc., 2) potential best management practices for environmental restoration, like forest riparian buffers, floodplain restoration and wetland restoration areas, and 3) stormwater management practices like stormwater basin retrofits, conservation landscaping, and bioswale opportunities. These locations were recorded in a GIS database file and designated with the appropriate potential BMP code or conservation practice code (Table 17). More than 200 locations were identified for potential site visits by the field team, with more than 70 potential practices in the AOI watershed.

Stream assessments were conducted along select target reaches to provide an understanding of the degree of streambank erosion and potential for stream restoration projects. EPR conducted a comprehensive assessment of stream reaches in the AOI watershed utilizing both GIS-based desktop analysis and field verification, EPR classified stream segments into three condition categories—good, fair, and poor—based on criteria such as channel stability, riparian vegetation, and sediment load. These assessments guided the identification and prioritization of 30 restoration project reaches, categorized as high, medium, or low priority, to address ecological uplift and cost-efficiency. The project prioritization emphasizes cost-efficiency, environmental stewardship, and collaboration with landowners and local stakeholders, ensuring that selected sites provide significant ecological benefits while remaining financially viable.

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 AOI 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, 2022). 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 and information provided by partners.

The model results were compared to sediment load reduction estimates calculated by the PA DEP to determine if implementation of the BMPs identified would address stream impairments. A "Reference Watershed Approach" method is used because Pennsylvania does not have numeric water quality criteria for sediment, so an estimate of pollutant loading rates in both an impaired watershed as well as a similar watershed that is not listed as impaired is used to calculate necessary load reductions based on scaling the loading rate in the unimpaired watershed to the similar area of the impaired watershed.

Recommended Watershed Management Actions and Implementation Plan

Ten primary recommendations are provided to achieve the goals of the WIP and reduce sediment loads. These include implementation of agricultural and urban BMPs, stakeholder engagement, agricultural land preservation, water quality monitoring, and increase staff capacity to support BMP implementation. Section 7 provides a summary of the cost for implementation of all identified priority BMPs at a total of approximately $6 to $9 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. An implementation table that lists the plan's recommendations, along with a suggested timeframe for implementation, partners, and milestones is found in Section 9. Recommendations include:

1. Finalize development of the Watershed Association.
2. Document practice implementation.
3. Implement prioritized Agricultural BMPs for water quality improvement.
4. Engage landowners through outreach to the entire watershed.
5. Promote preservation of agricultural lands
6. Work with the Hershey Corporation and others to implement restoration practices.
7. Implement priority stormwater management BMP retrofits for water quality improvement.
8. Implement priority streambank restoration projects for water quality improvement.
9. Conduct chemical and biological stream monitoring.
10. Revisit conservation plans and add staff as needed.

Sections 1 through 4 of this WIP present a snapshot of the characteristics of the watershed, and sections 5 through 11 are focused exclusively on the grant funded assessment of the AOI watershed. This was done in agreement with the PA DEP since 319 program funds are restricted to non-point source planning done in non-MS4 areas. Projects in the MS4 portions of the Spring Creek East watershed are considered part of PA DEP required municipal pollution reduction planning efforts and 319 funds cannot be used for those efforts. The hope is that future WIP plans may be developed for other portions of the Spring Creek East watershed and the characterization here may prove useful for those efforts.

SECTION 1. INTRODUCTION

This plan serves to both document the existing conditions and develop a basic Watershed Implementation Plan (WIP) for a portion of the Spring Creek East watershed. The Spring Creek East watershed is located in Dauphin and Lebanon counties, Pennsylvania and is a tributary of Swatara Creek, which drains to the Susquehanna River and ultimately the Chesapeake Bay. The watershed referred to as Spring Creek East as another stream with the name Spring Creek is located nearby in Dauphin County closer to Harrisburg, PA. The watershed drains just over 24 square miles (sq. mi.) and is located in eastern Dauphin County, with a small portion located in Lebanon County (Figure 1). The Spring Creek watershed is encompassed primarily by Derry Township, but portions are also in North Londonderry Township, Palmyra Borough, South Londonderry Township, and Conewago Township.

Within the Spring Creek East watershed, 91% of the stream miles are listed as impaired for aquatic life use (PA DEP, 2024). The primary cause of aquatic life use impairment is siltation, with habitat alteration, flow regime modification, and organic enrichment as additional identified causes. The WIP document focuses specifically on resolving impairments associated with sediment loading, since it is hoped that addressing siltation impairments may also help resolve other problems such as excess nutrients. The sources of these impairments are primarily agriculture, golf courses, urban runoff/storm sewers, stream habitat modification and unknown. This WIP will primarily focus on addressing sedimentation impairment in the target watershed from agricultural and urban sources and steam habitat modification. The document identifies the nonpoint source pollution loads currently in the watershed study area and necessary load reductions to improve impaired waters.

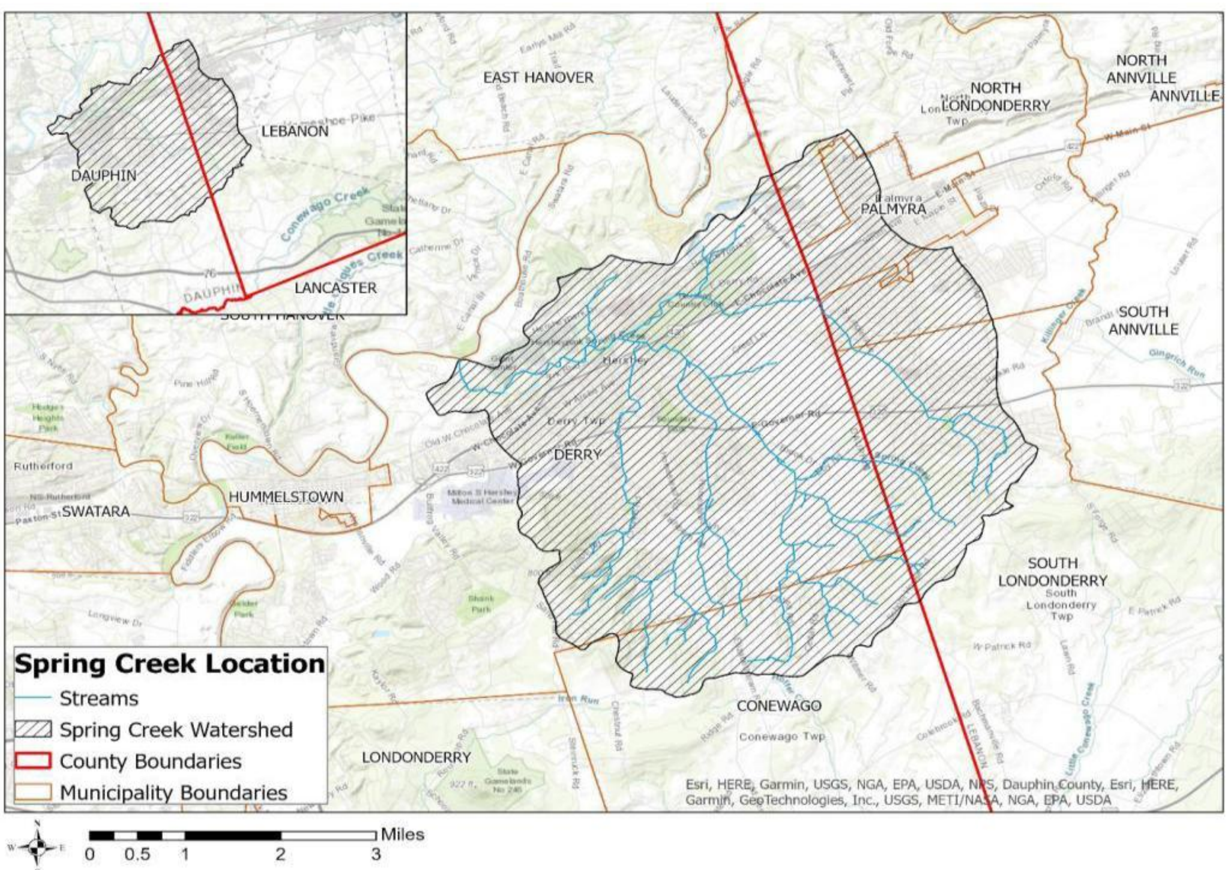

Figure 1. Location overview of the Spring Creek East watershed

This plan focuses on a specific portion of the Spring Creek East watershed (Figure 2), which consists of the headwaters of Spring Creek in the Hershey area. This watershed will be referred to in the document as the Area of Interest (AOI) watershed. The AOI designation was made to differentiate between those portions of the watershed that were eligible for 319 grant funding (this WIP was created using 319 funding), and those that are designated as being covered through municipal pollution reduction plans. The AOI watershed that this plan focuses on drains approximately 10.6 square miles and has a little over 24 miles of stream length split between 1st, 2nd, and 3rd order streams. The AOI watershed is located primarily in the non-MS4 area, where land use is dominated by agriculture (Figure 2). Cultivated crops and pasture and hay comprise close to 52% of the land use in addition to some livestock agriculture, consisting primarily of broiler chickens. Additionally, approximately 13% of land use is turfgrass.

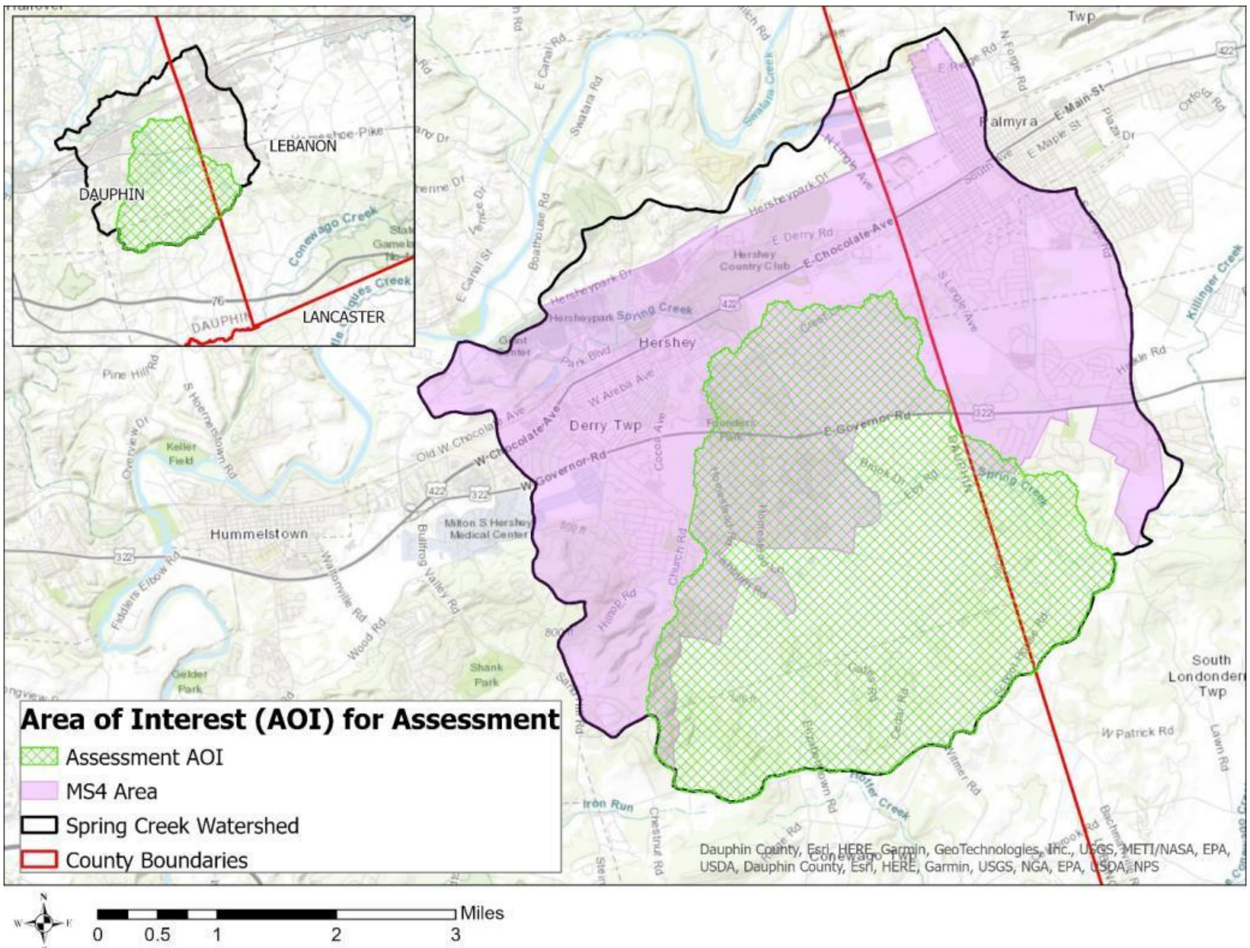

Figure 2. AOI watershed and MS4 area

Agriculture dominates in the upper and middle reaches of the Spring Creek East watershed where the AOI is located, and many of the agricultural parcels are owned by the Hershey Trust Company or Milton Hershey School. Some of these agricultural lands are either farmed by their employee farmers or by tenant farmers. There are land use changes to a more suburban nature in the Borough of Palmyra and Derry Township. Much of the AOI watershed consists of Milton Hershey School property, an educational institution that has more than 7,000 acres of land in the Hershey area. A complete description of the AOI watershed land use is provided in Section 4.

The Spring Creek East watershed contains both municipal seperate storm sewer system (MS4) areas and non-MS4 areas (Figure 2). As growth has continued in the watershed, the split between the two categories has changed. Recent data (PASDA, 2022) designates that just over 63% of the watershed land as MS4 areas and just under 37% as non-MS4 areas. MS4 areas include DerryTownship, North Londonderry Township, South Londonderry Township, and the Borough of Palmyra.

Sections 2 through 4 of the WIP present a snapshot of the characteristics of the AOI watershed, while sections 5 through 11 are focused exclusively on the grant funded AOI watershed assessment. This was done in agreement with the PA DEP since 319 program funds are restricted in use to non-point source planning done in non-MS4 areas. Projects in the MS4 portions of the Spring Creek East watershed are considered part of PA DEP required municipal pollution reduction planning efforts and 319 funds cannot be used for those efforts. The hope is that future WIP plans may be developed for other portions of the Spring Creek East watershed and the characterization here may prove useful for those efforts.

Section 2. Watershed Description

Geology

The geological map of the Spring Creek East watershed is found in Figure 3. There are 13 different geologic formations within the Spring Creek East watershed, with the dominant geology in the watershed being Epler Formation in the north portion and Gettysburg Formation in the south. Limestone formations are present in the Spring Creek East watershed; and the impact of this limestone geology is described in Section 3. Surface Water Conditions.

Table 1 provides the geologic formations in the Spring Creek East watershed with their total area and percentage. Table 2 provides a definition for each of the geologic formations with a description of the color and texture of the formation type.

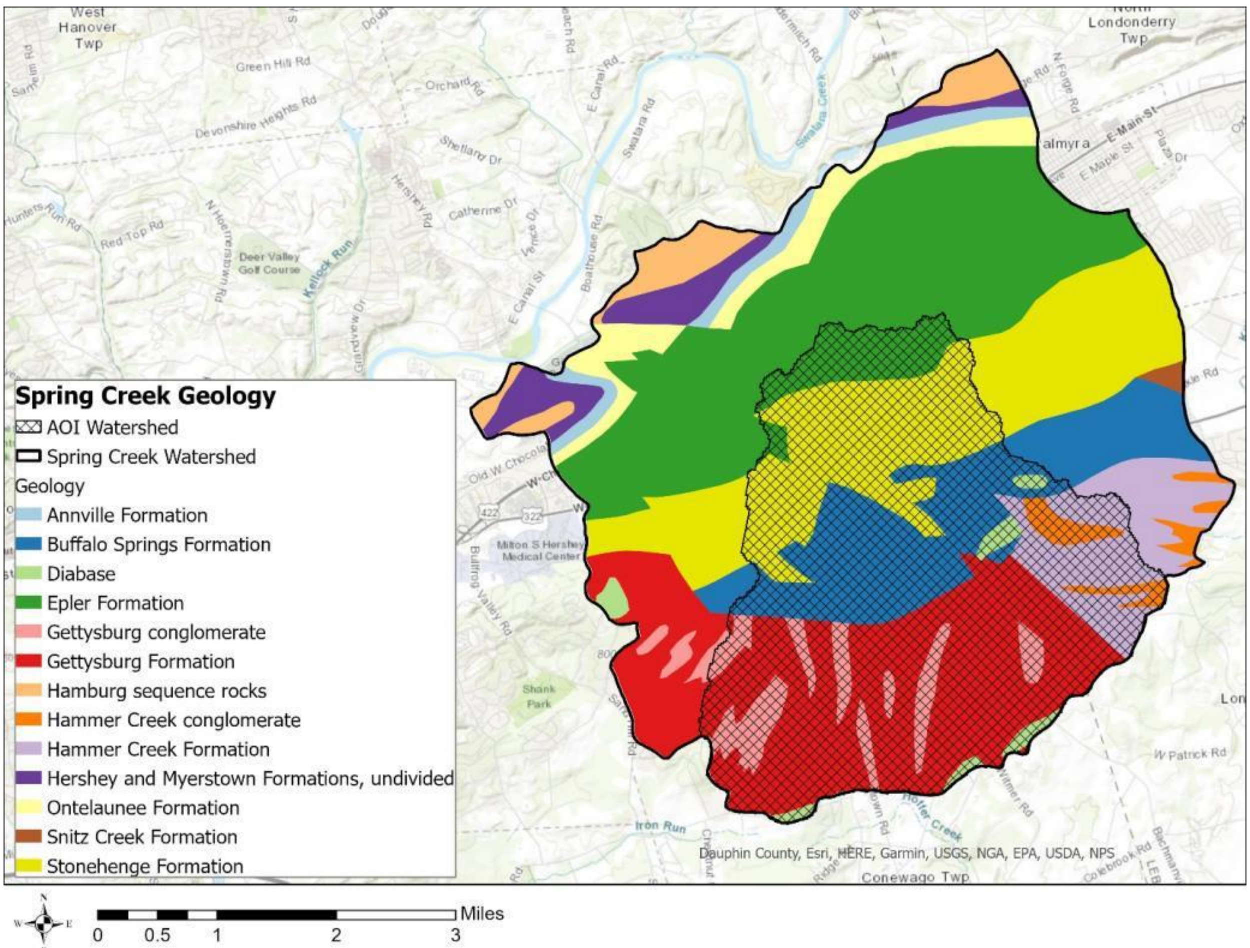

Figure 3. Geologic formations underlying the AOI watershed.

Table 1. Geologic formations underlying the AOI Watershed		
Geologic Formation Name	**Area (ac)**	**Percentage of Watershed**
Buffalo Springs Formation	1232.24	18.2%
Diabase	134.88	2.0%
Epler Formation	425.34	6.3%
Gettysburg conglomerate	505.03	7.5%

Table 1. Geologic formations underlying the AOI Watershed		
Geologic Formation Name	**Area (ac)**	**Percentage of Watershed**
Gettysburg Formation	2447.21	36.2%
Hammer Creek conglomerate	155.48	2.3%
Hammer Creek Formation	554.06	8.2%
Stonehenge Formation	1303.90	19.3%

Table 2. Definitions of types of underlying geology (Berg et al., 1980)	
Underlying Geology	**Definition**
Annville Formation	Light-gray, massive, calcium limestone; mottled at base.
Buffalo Springs Formation	Light gray to pinkish gray, finely to coarsely crystalline limestone and interbedded dolomite; numerous siliceous and clayey laminae; stromatolitic limestone beds near top; some thin sandy beds.
Diabase	Medium- to coarse-grained, quartz-normative tholeiite; composed of labradorite and various pyroxenes; occurs as dikes, sheets, and a few small flows. Includes the dark-gray York Haven Diabase (high titanium oxide) and the slightly younger Rossville Diabase (low titanium oxide). In chilled margins, the Rossville is distinguished from the York Haven by its lighter gray color and distinctive, sparse, centimeter-sized calcic-plagioclase phenocrysts.
Epler Formation	Very finely crystalline, light-gray limestone interbedded with gray dolomite; coarsely crystalline limestone lenses present.
Gettysburg conglomerate	Gray quartz conglomerate, sandstone, red siltstone, and mudstone.
Gettysburg Formation	Reddish-brown to maroon, silty mudstone and shale containing thin red sandstone interbeds; several thin beds of impure limestone.
Hamburg sequence rocks	Predominantly greenish gray, gray, purple, and maroon shale, siltstone, and graywacke; includes some wildflysch having Martinsburg matrix.
Hammer Creek conglomerate	Cobble and pebble quartz conglomerate interbedded with red sandstone.
Hammer Creek Formation	Gray and pale red, fine- to coarse-grained quartzose sandstone, siltstone, and mudstone.
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.
Ontelaunee Formation	Light- to dark gray, very finely to medium-crystalline dolomite containing interbeds of light-gray limestone; interbedded nodular, dark-gray chert at base.
Snitz Creek Formation	Thick-bedded, medium- to coarsely crystalline dolomite, in part oolitic, containing laminated limestone and sandstone interbeds.
Stonehenge Formation	Gray, finely crystalline limestone containing dark-gray silty laminations; numerous edgewise conglomerate beds.

Karst Features

The Spring Creek East watershed is located in an area with karst topography characterized by sinkholes, caves, and underground drainage of water. This is due to the interaction of the carbonate bedrock (limestone and dolomite) with water resulting in a weak, natural acid that more easily dissolves the underlying rock creating karst features. This has implications not just for human safety and land use due to sinkhole formation but can also affect water quality since contaminants may move more quickly into streams and groundwater and compromise drinking water sources as well as aquatic habitat. The presence of karst topography influences the types of insects and fish found in a stream, and limestone streams often have a low number of sensitive taxa and only a few of these taxa are generally found in large numbers (PA DEP, 2021). There are 830 surface depressions and 11 sinkholes within the AOI watershed (Figure 4).

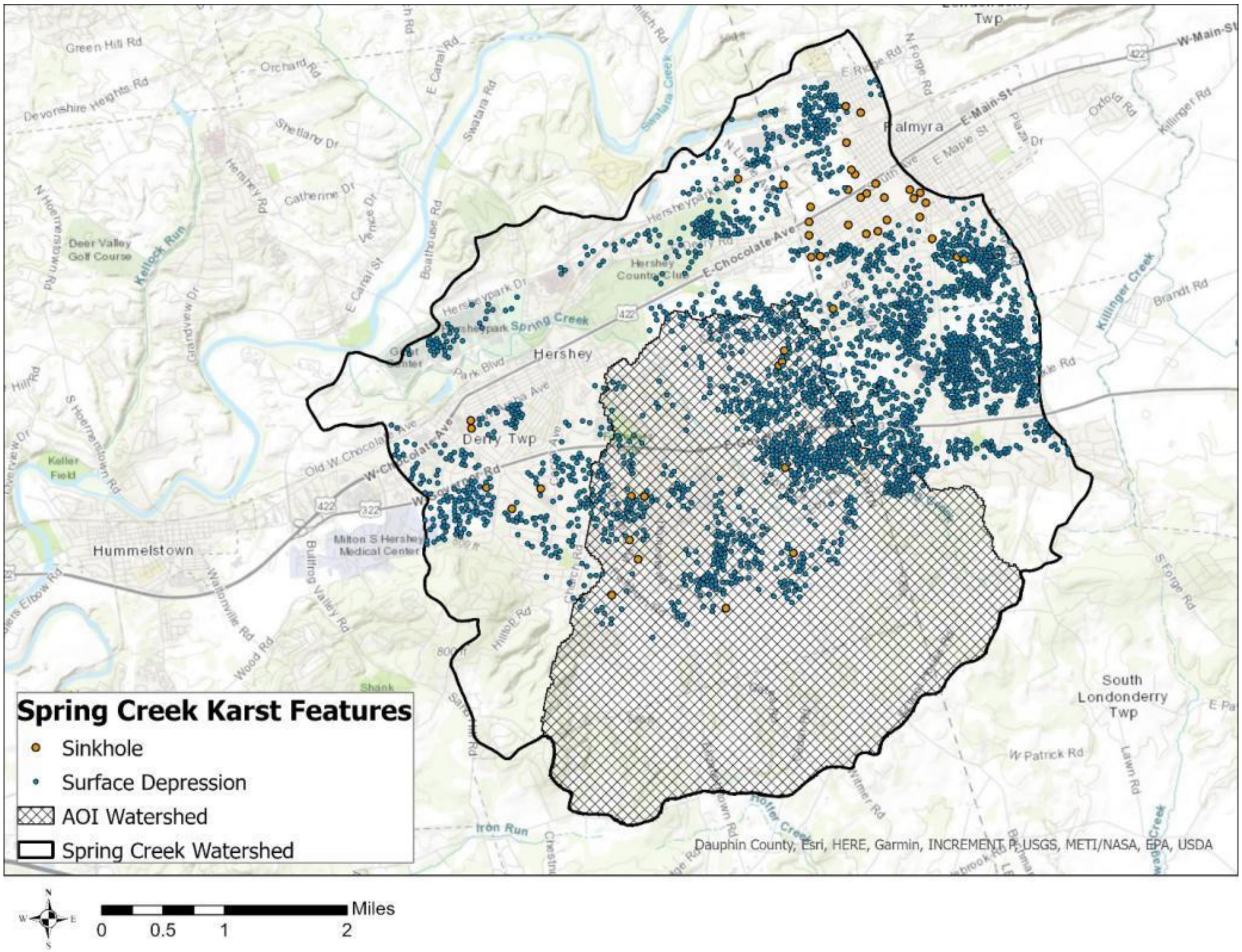

Figure 4. Karst features within the AOI and Spring Creek East watershed

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 into a 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 Soil Survey Geographic Database (SSURGO), which is developed and maintained by the U.S. Department of Agriculture's Natural Resource Conservation Service (USDA NRCS).

Figure 5 shows the HSG distribution for the AOI and Spring Creek East watershed. Table 4 provides more detail on the different HSG types by area and percentage. Within the AOI watershed, HSG-B soils—which are well-drained and moderately coarse—are dominant at 64.0%. The second most dominant soils are HSG-A, which comprise 22.3% of the Spring Creek East watershed and are typically highly infiltrative. There are some areas, primarily in the northern portions of the Spring Creek East watershed, where there is no HSG assignment; however, these areas underlay Palmyra and Hershey Park, which are more developed relative to the rest of the watershed, and are likely to have more compacted, urban soils.

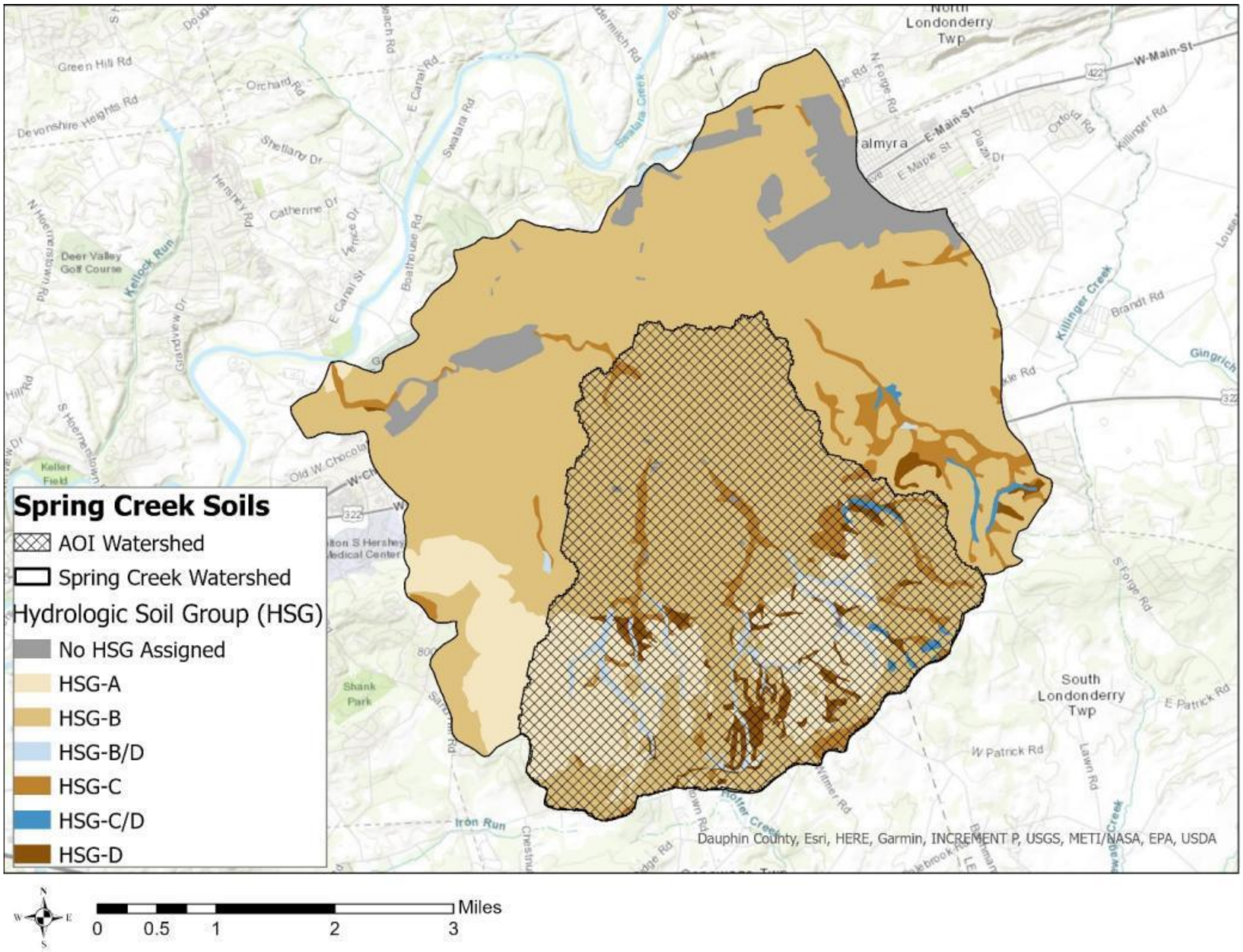

Figure 5. Hydrologic Soil Groups (HSGs) within the AOI watershed

Table 3. Overview of Hydrologic Soil Groups (HSGs)[1] found in the AOI watershed

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-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 SSURGO.

[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.

Table 4. Hydrologic soil groups (HSG) in the AOI watershed		
Hydrologic Soil Group (HSG)	**Area (ac)**	**Percentage of Watershed**
HSG-A	1,506.3	22.3%
HSG-B	4,347.6	64.0%
HSG-B/D	184.5	2.7%
HSG-C	394.7	5.8%
HSG-C/D	42.0	0.6%
HSG-D	291.3	4.3%
No HSG Assigned	17.6	0.3%

Annual Precipitation

The townships and boroughs in the Spring Creek East watershed average approximately 42 inches of rain and an annual average temperature of 52 degrees Fahrenheit (Stroud Water Research Center, Model My Watershed, 2022).

Flood Zones

Flood zones in the AOI watershed are characterized by the impact associated with the 100-year and 500-year flood events (Table 5). Nearly all of the mapped flood zone is in the "X" zone, which is associated with minimal to moderate flood hazard, except for some of the areas outside the AOI watershed in the surrounding Spring Creek and its tributaries (Figure 6; Table 6). No data is available for the 10-, 25-, or 50-year flood events.

Table 5. Definitions of flood zones in the Spring Creek East watershed	
Flood Zone	**Definition***
A	Areas subject to inundation by the 1-percent-annual-chance (100-year) flood event where no hydraulic analyses have been performed.
AE	Areas subject to inundation by the 1-percent-annual-chance (100-year) flood event where hydraulic analyses have been performed.
AO	Areas subject to inundation by the 1-percent-annual-chance (100-year) shallow flooding where average depths are between one and three feet.
VE	Areas subject to inundation by the 1-percent-annual-chance (100-year) flood event with additional hazards due to storm-induced velocity wave action.
X	An area of minimal to moderate flood hazard that is outside of the Special Flood Hazard Area and either 1) between the limits of the base flood and the 0.2-percent-annual-chance (500-year) flood, or 2) above the elevation of the 0.2-percent-annual-chance (500-year) flood.
* Definitions adapted from https://floodpartners.com/flood-zones/	

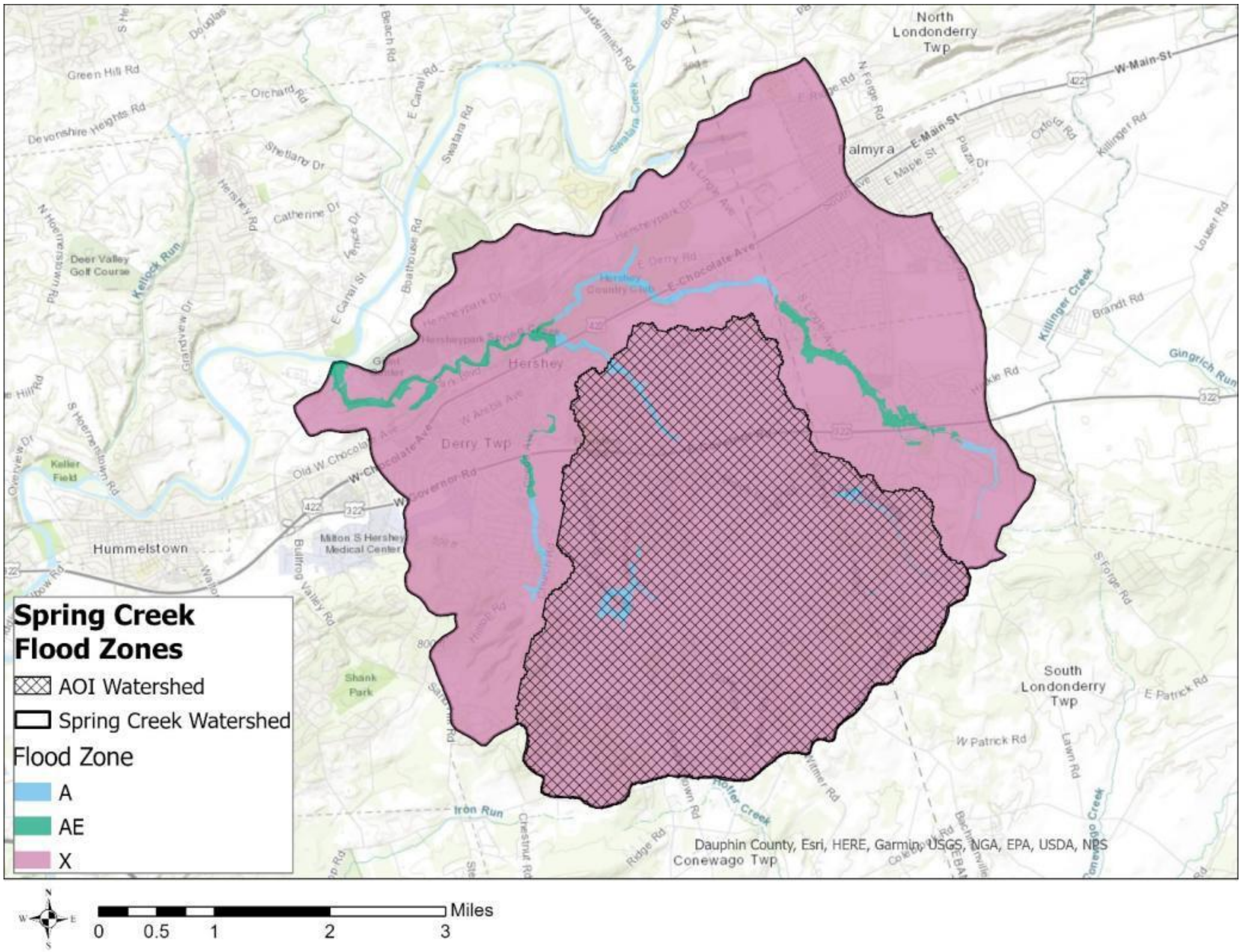

Figure 6. Flood zones in the AOI and Spring Creek East watershed.

Table 6. Flood zones in the Spring Creek East watershed		
Flood Zone	**Area (ac)**	**Percentage of Total Watershed**
A	240.4	1.6%
AE	244.8	1.6%
X	14,911.1	96.8%
Total	15,396.3	100.0%

SURFACE WATER FEATURES

Surface water features (streams, freshwater ponds, lakes, and wetlands) are illustrated in Figure 7 and Figure 8 using Chapter 93 Designated Use streams from the PA DEP and wetland/waterbody data from the U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI). There are 24.4 miles of stream in the AOI watershed, the majority of which (55.7%) are first-order streams. First-order streams are typically dominated by overland flow and are typically most susceptible to the impacts of non-point source pollution. Stream orders within the Spring Creek East watershed are included in Table 7.

There are 34.6 acres of freshwater ponds and freshwater emergent wetlands in the AOI watershed. These areas correspond to the "Freshwater Pond" and "Lacustrine" wetland types in the NWI dataset. Areas of each of the types of wetlands are illustrated in Figure 8 and summarized in Table 8. The majority of wetlands in the AOI watershed are classified as riverine and are located along the streams.

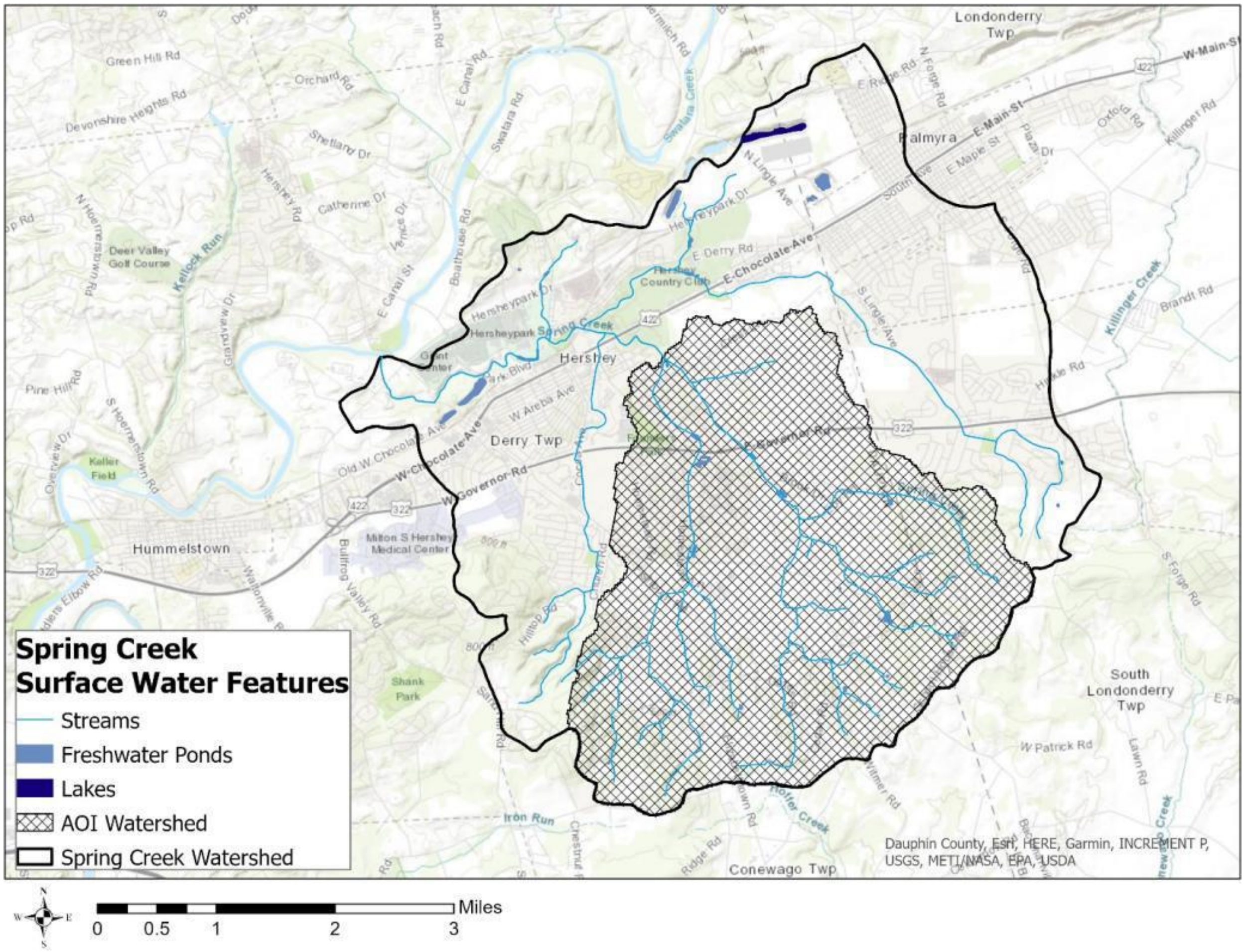

Figure 7. Surface water features within the AOI and Spring Creek East watershed

Table 7. Summary of stream orders in the AOI watershed		
Stream Order	**Total Length (miles)**	**Percentage of Total Length**
1st	13.6	55.7%
2nd	5.4	22.2%
3rd	5.4	22.0%
4th	.01	0.1%
Total	24.4	100.0%

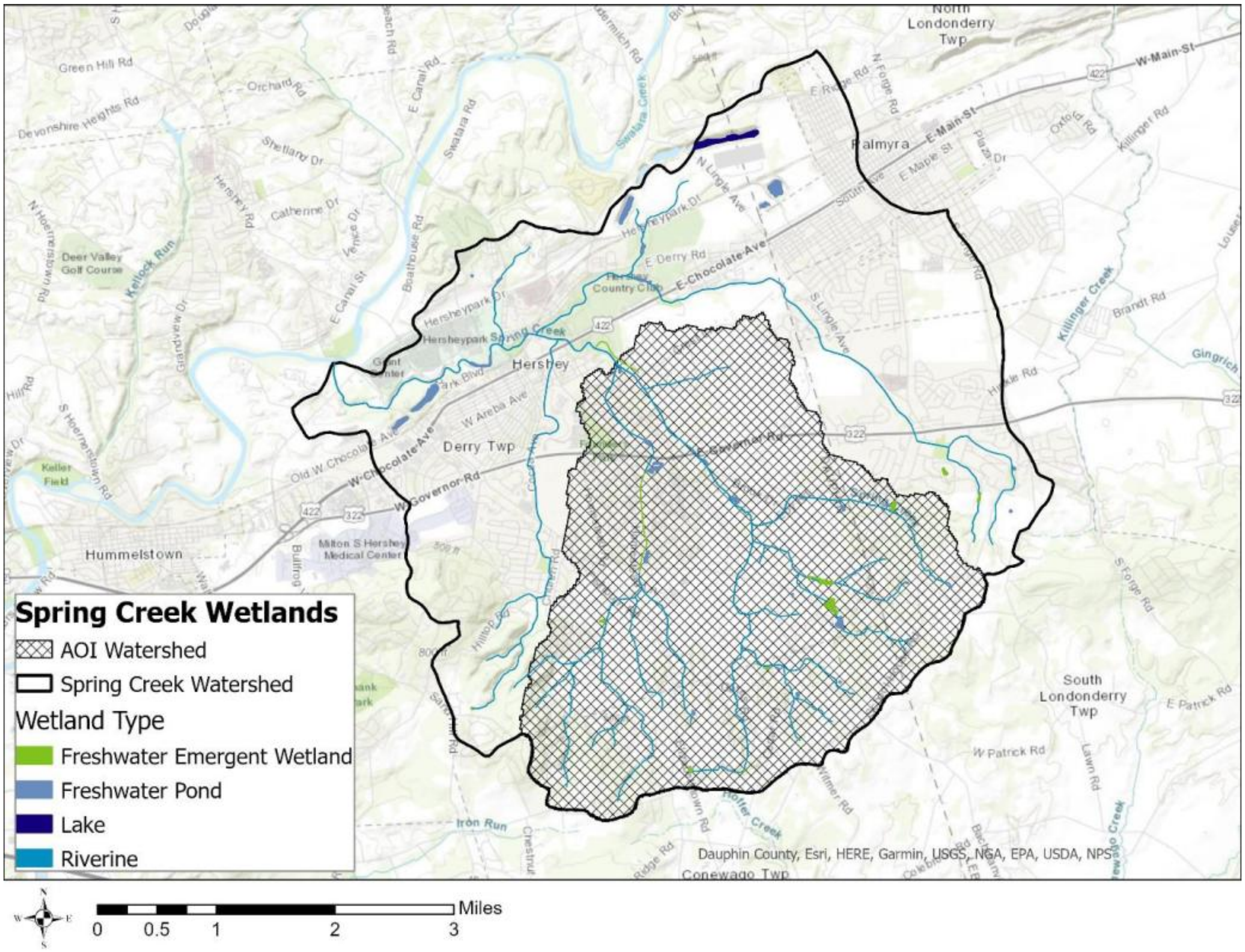

Figure 8. Wetlands within the AOI and Spring Creek East watershed

Table 8. Wetland areas within the Spring Creek East watershed		
Wetland Type	**Area (ac)**	**Percentage of Total Wetland Area**
Freshwater Emergent Wetland	15.7	16.5%
Freshwater Pond	18.2	19.1%
Riverine	61.4	64.4%
Total	95.3	100.0%

Surface Water Conditions

Within the AOI watershed, nearly all of the stream miles are listed as impaired for aquatic life use, and all streams have a designated use for warm-water fisheries and recreational use (PA DEP, 2024). One of the major tributaries is also listed as impaired for recreational use.

The primary causes of aquatic life use impairments are siltation (from agriculture, golf courses, urban runoff/storm sewers, and unknown sources), habitat alteration (from habitat modification and urban runoff/storm sewers), flow regime modification (from habitat modification and urban runoff/storm sewers) and organic enrichment (from agriculture). The recreational use impairments are caused by pathogens from unknown sources.

Additionally, the Spring Creek East watershed is known to harbor wild trout, likely as a result of the watershed's limestone geology that can create cold-water springs. According to the Pennsylvania Fish and Boat Commission's 2022 database of stream sections that support wild trout populations, 13.3 miles of streams in the Spring Creek East watershed (31.7% of streams) support natural trout reproduction (Figure 9) including one of the streams in the AOI watershed.

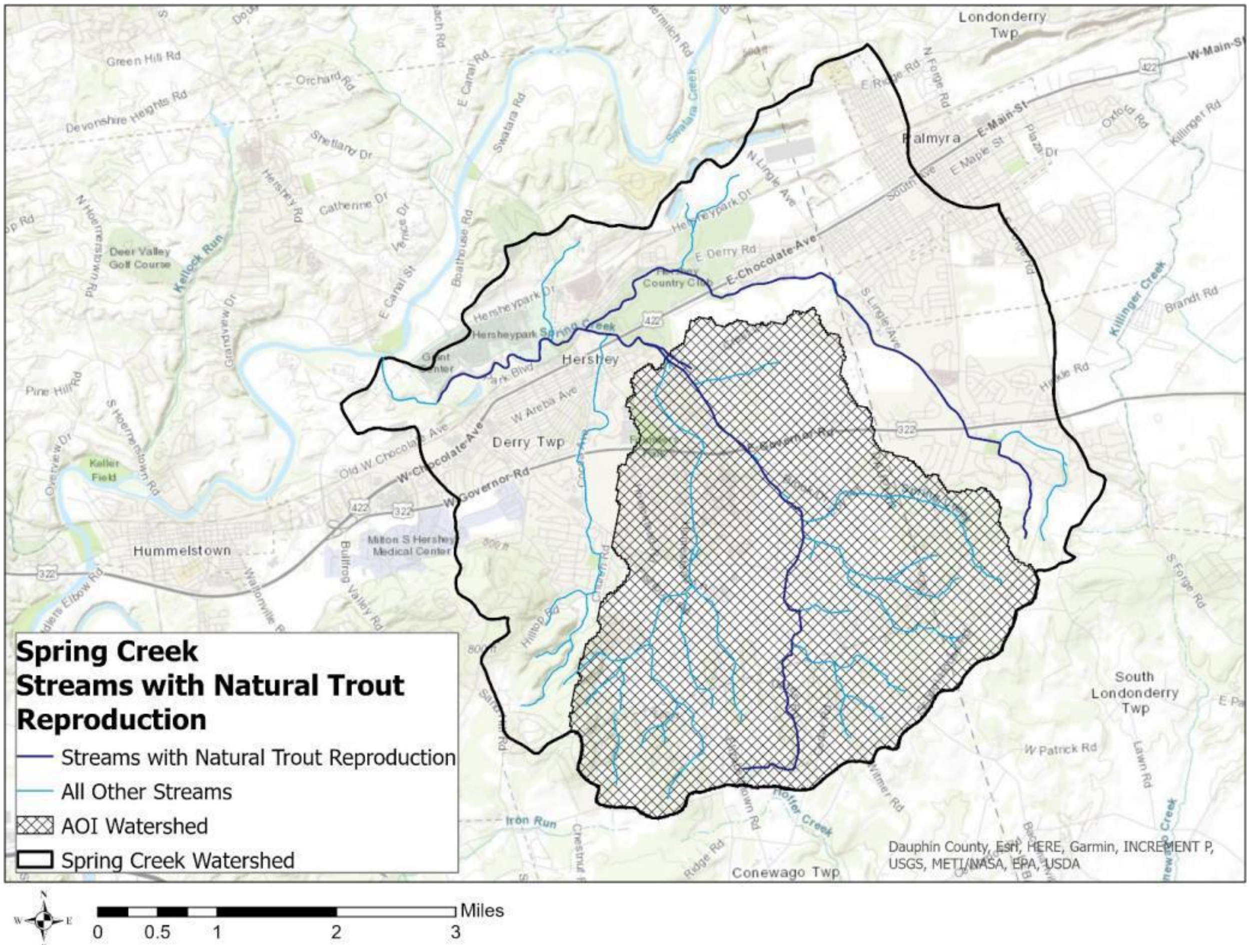

Figure 9. Streams with natural trout reproduction in the AOI and Spring Creek East watershed

Figure 10 shows the streams in the AOI watershed that are impaired for both uses, and Figure 11 and Figure 12 show the streams that are supporting/impaired for aquatic life use and recreational use, respectively. Table 9 summarizes the lengths of streams that are supporting/impaired for each use.

Table 9. Summary of stream impairments in the AOI watershed[1]

Designated Use	Supporting Length (mi)	Impaired Length (mi)	Percentage of Total Length of Streams that are Impaired
Aquatic Life	1.4	23	94.3%
Recreational	9.9	14.4	59.0%

[1] The sum of the supporting and impaired stream lengths is greater than the total length of streams in the watershed because there is known overlap between the stream segments and between/within uses in the Integrated List GIS datasets.

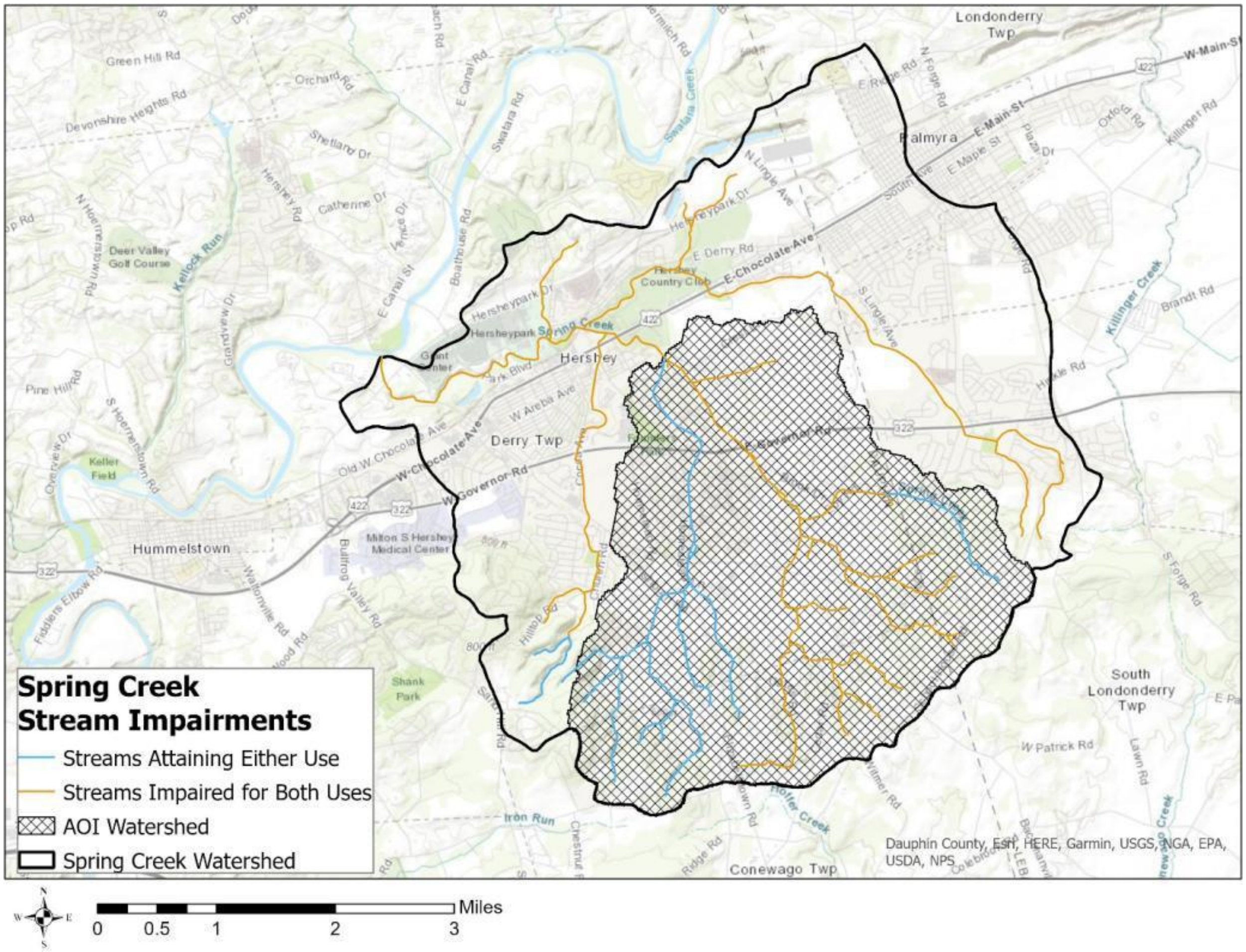

Figure 10. Overall stream impairments in the AOI and Spring Creek East watershed

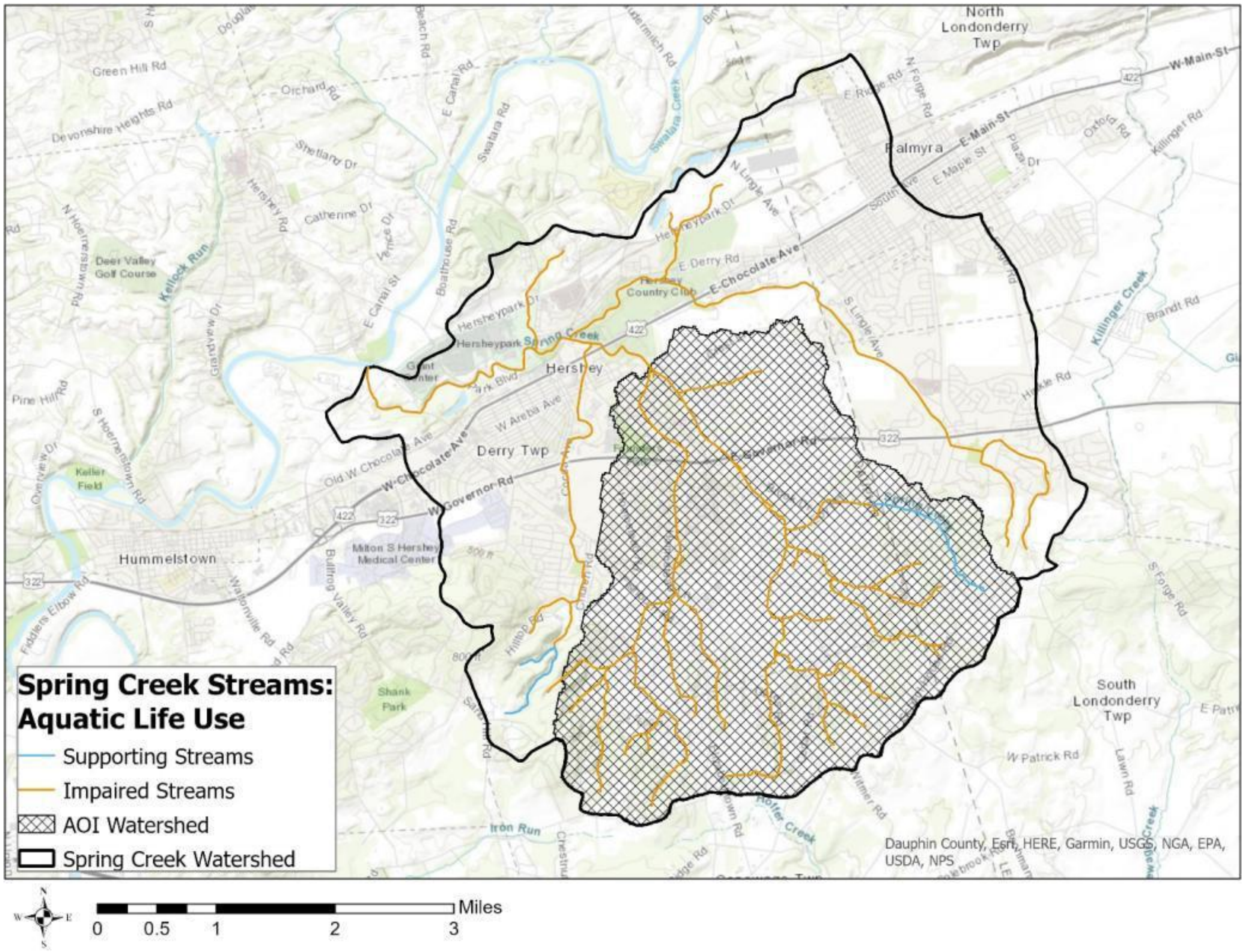

Figure 11. Streams supporting and impaired for aquatic life use in the AOI and Spring Creek East watershed

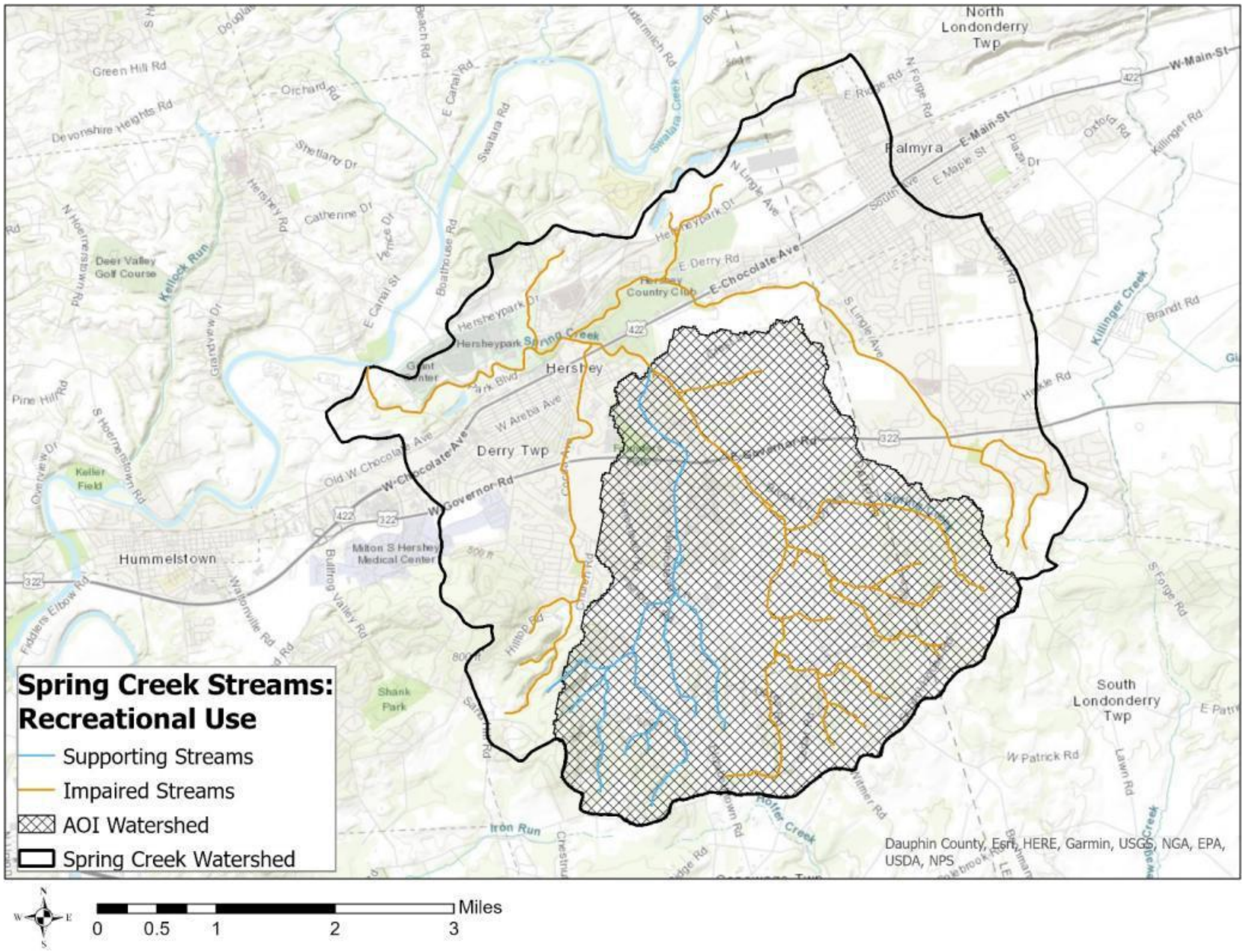

Figure 12. Streams supporting and impaired for recreational use in the AOI and Spring Creek East watershed

LAND COVER AND LAND USE

Land cover and land use were summarized using 2017/2018 data from the Chesapeake Bay Program Office's "One-Meter Resolution Land Use/Land Cover Dataset for the Chesapeake Bay Watershed"[1]. These datasets were developed in collaboration between Chesapeake Conservancy, the U.S. Geological Survey (USGS), and the University of Vermont Spatial Analysis Lab (UVM SAL) with funding from the Chesapeake Bay Program (CBP).

While both the land cover and land use datasets are one-meter resolution, the land use dataset has the most detailed classification with 37 more unique classes than the land cover dataset. Land cover within the AOI watershed is illustrated in Figure 13 and summarized in Table 10, and land use within the watershed is in Figure 14 and Table 11.

Land cover within the AOI watershed is primarily herbaceous cover (69.2%), followed by tree canopy (23.0%). Most of this herbaceous cover corresponds to cropland (47.9%), pasture/hay (6.8%), and turf grass (13.0%) land uses.

[1] https://www.chesapeakeconservancy.org/conservation-innovation-center/high-resolution-data/lulc-data-project-2022/

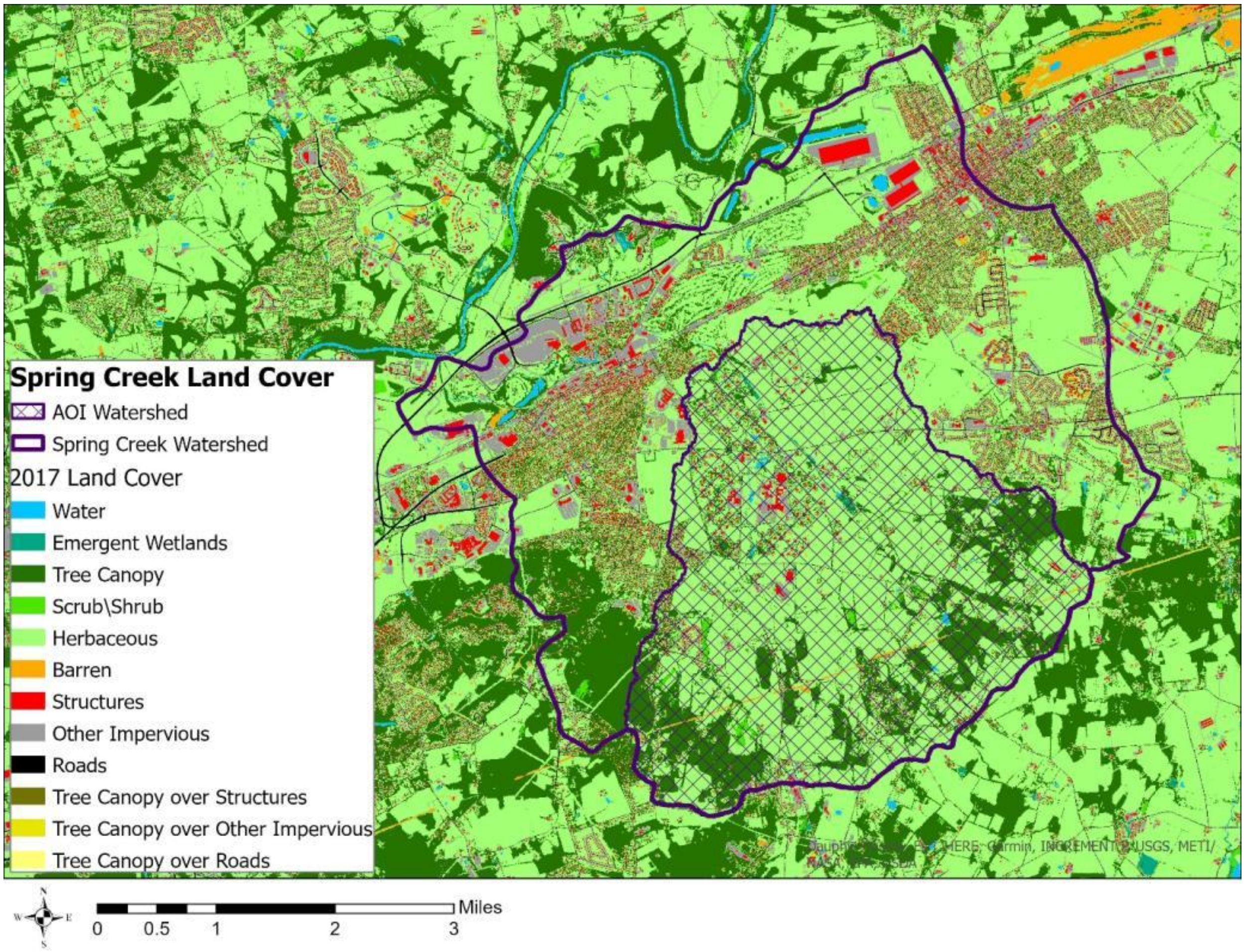

Figure 13. Land cover within the AOI and Spring Creek East watershed

Table 10. Summary of land cover within the AOI watershed

Land Cover Category	Area (ac)	Percentage of Watershed
Water	16.3	0.2%
Emergent Wetlands	10.0	0.1%
Tree Canopy	1553.6	23.0%
Scrub\Shrub	46.4	0.7%
Herbaceous	4674.0	69.2%
Barren	24.3	0.4%
Structures	129.7	1.9%
Other Impervious	198.0	2.9
Roads	76.3	1.1%
Tree Canopy over Structures	3.7	0.1%
Tree Canopy over Other Impervious	19.0	0.3%
Tree Canopy over Roads	6.0	0.1%

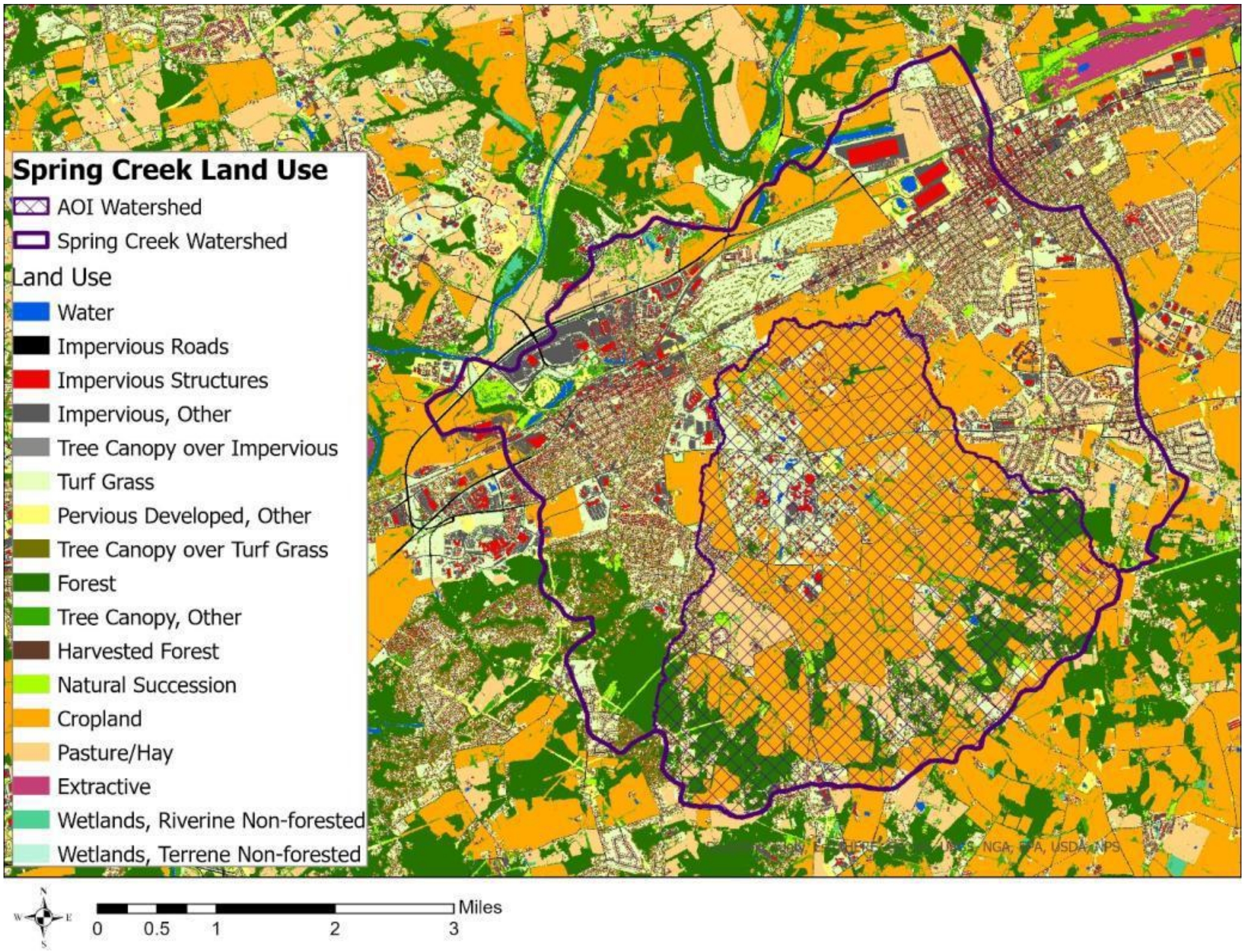

Figure 14. Land use within the AOI and Spring Creek East watershed

Table 11. Summary of land uses within the AOI watershed

Land Use Category	Area (ac)	Percentage of Watershed
Cropland	3237.6	47.9%
Forest	992.3	14.7%
Impervious Roads	76.7	1.1%
Impervious Structures	129.8	1.9%
Impervious, Other	206.7	3.1%
Natural Succession	70.1	1.0%
Pasture/Hay	456.6	6.8%
Pervious Developed, Other	88.6	1.3%
Tree Canopy over Impervious	28.4	0.4%
Tree Canopy over Turf Grass	329.4	4.9%
Tree Canopy, Other	229.6	3.4%
Turf Grass	881.2	13.0%
Water	16.3	0.2%
Wetlands, Riverine Non-forested	14.6	0.2%
Wetlands, Terrene Non-forested	0.1	0.0%

IMPERVIOUS COVER

Approximately 2,758 acres (17.9%) of the Spring Creek East watershed is categorized as impervious cover, and there are approximately 177 miles of roads (Figure 15[2]). Based on the Impervious Cover Model, the Spring Creek East watershed is in the "impacted" category defined as impervious cover between 10% and 25%. Within this range, the streams within the watershed contain evidence of declining stream health, although reaches with extensive riparian buffers may score higher within the model (Schueler et al., 2009). Impervious cover was calculated as the sum of the following classes from the land cover dataset (Table 10): structures, roads, other impervious, tree canopy over structures, tree canopy over roads, and tree canopy over other impervious.

The AOI watershed has a much lower impervious cover percentage (6.4%) which reflects its agricultural nature. Approximately 433 acres fall within the land cover categories used to define impervious cover (Table 10): structures, roads, other impervious, tree canopy over structures, tree canopy over roads, and tree canopy over other impervious. Based on the Impervious Cover Model, the AOI watershed is in the "sensitive" category defined as impervious cover between 0% and 10%. Within this range, the streams within the watershed are influenced more by other watershed metrics such as forest cover, road density, riparian continuity, and cropping practices than by the amount of impervious cover (Schueler et al., 2009).

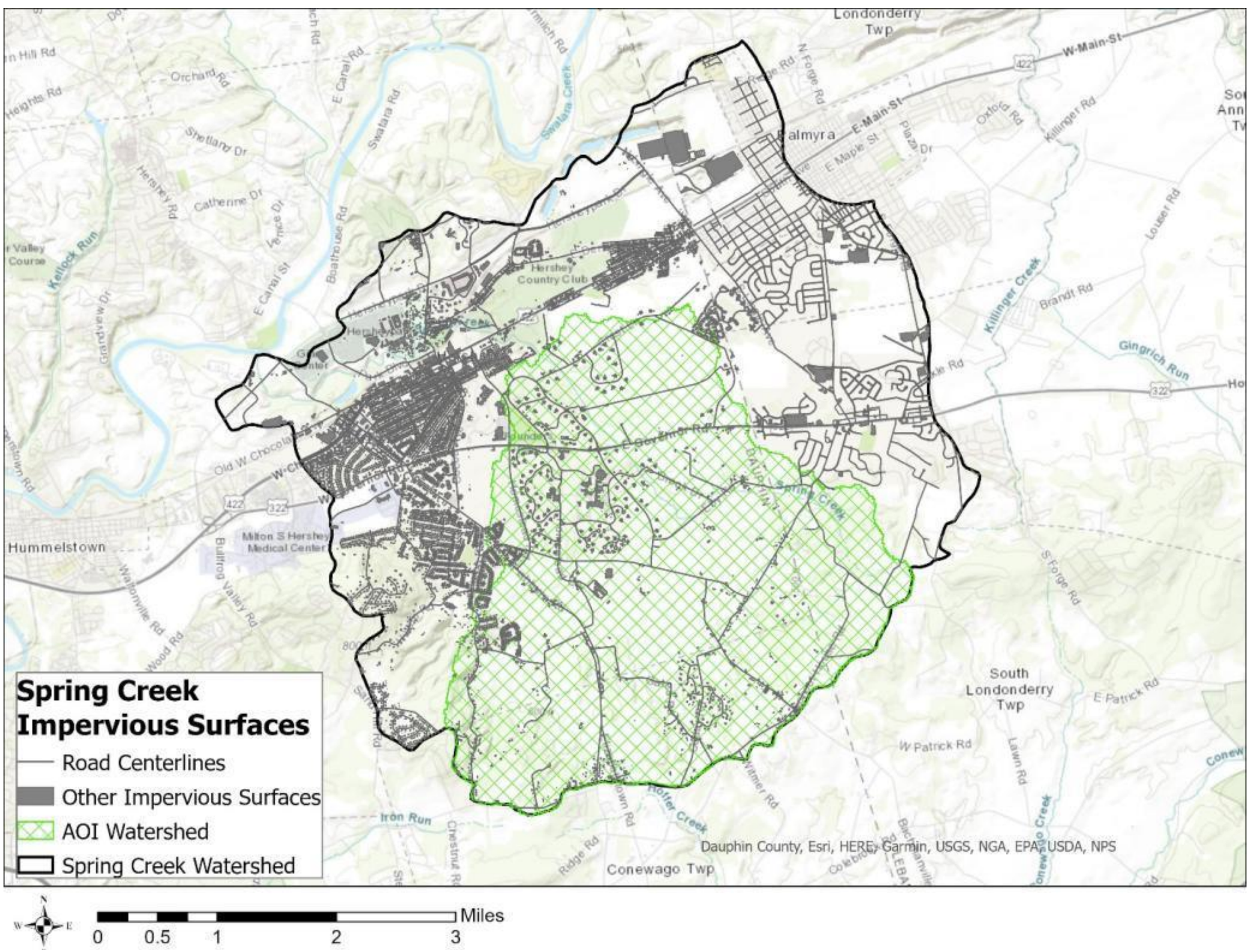

Figure 15. Impervious surfaces in the AOI and Spring Creek East watershed

[2] Note that "Other Impervious Surfaces" in Figure 15 are not comprehensive. Buildings, parking lots, and other impervious surfaces may not be displayed due to unavailable data.

EASEMENTS

The Pennsylvania Bureau of Farmland Preservation administers Preserved Farmland Easements through the Pennsylvania Agricultural Conservation Easement Purchase Program. Since its approval in 1988, this program has purchased easements for over 5,300 farms covering a total of over 550,000 acres throughout the state of Pennsylvania. In the Spring Creek East watershed, the Conservation Districts for Dauphin and Lebanon Counties administer this program.

Land protected by an agricultural conservation easement can only be used for agricultural production or other specified activities and cannot be developed. 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 Dauphin and Lebanon Counties. Protecting groups or clusters of farms helps maintain the local agricultural industry. Agricultural conservation easements are purchased or donated voluntarily by a landowner to protect farms for agriculture in perpetuity.

Landowners apply to participate in the program, and their properties are required to meet minimum criteria for eligibility, including: a minimum farm size, enrollment in an Agricultural Security Area, possession of a conservation plan, and other specifications related to land use and underlying soils. Applications with eligible farms are ranked using a state-approved scoring system. Upon easement finalization, the landowner is compensated based on appraisal values and maximum compensation per acre (DCCD, n.d.). In Lebanon County, the easement application requirements and process are similar (LCCD, n.d.). In addition to the Lebanon County Conservation District (LCCD), the Lebanon Valley Conservancy, a non-profit organization that serves a role as a land trust, also preserves agricultural land in the county through agricultural conservation easements with the goal of protecting the historical, cultural, and environmental values of the land (WeConservePA, 2020).

In the AOI watershed, there are three unique easement acquisitions covering a total of 210 acres, which is 3.1% of the watershed's area (Figure 16).

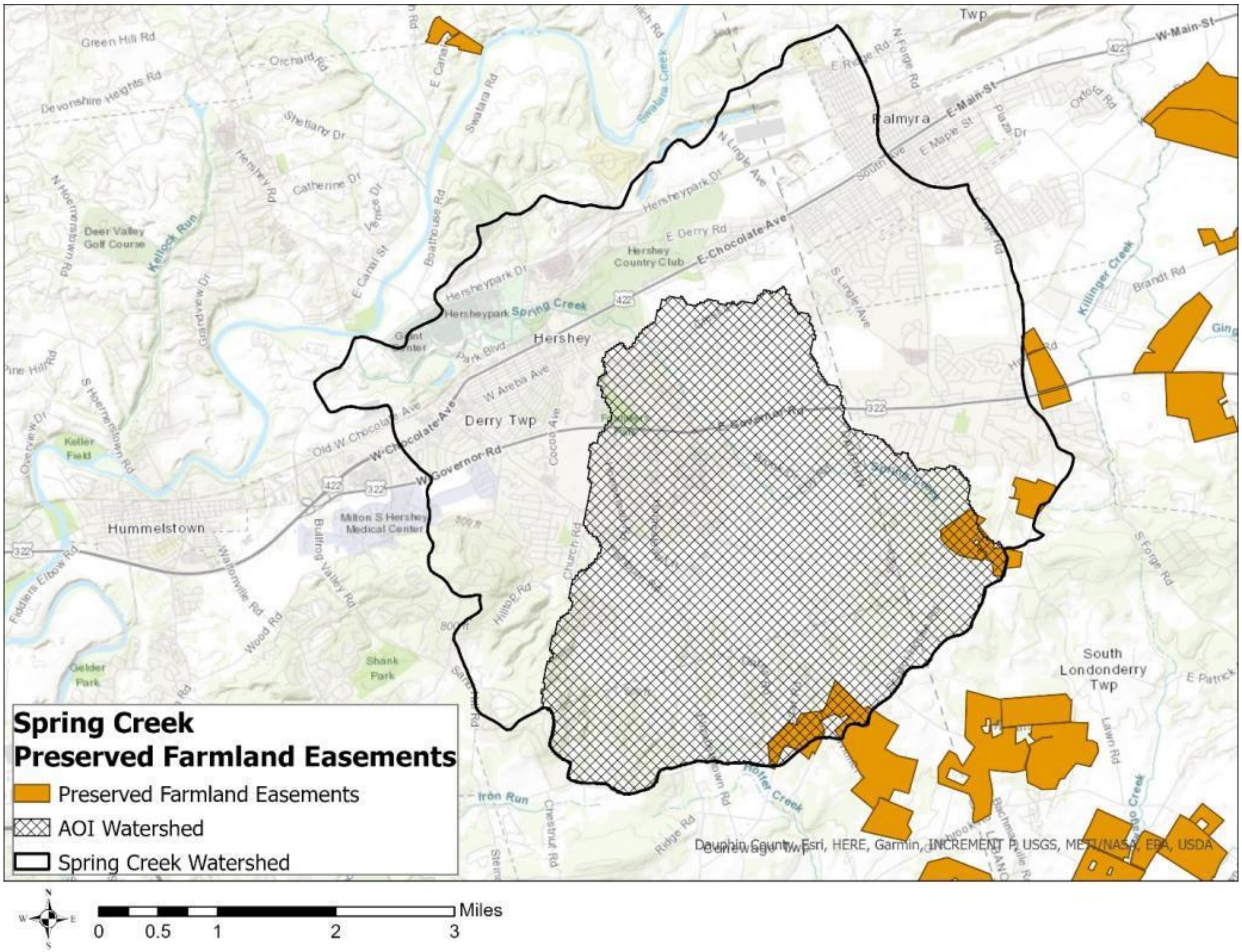

Figure 16. Preserved Farmland Easements in the AOI and Spring Creek East watershed

SECTION 3. WATER QUALITY

TOTAL MAXIMUM DAILY LOADS (TMDLS)

Under the Clean Water Act, each state is required to designate uses for each waterbody and to establish water quality criteria that must be met to support those uses. States regularly assess whether water quality criteria are being met through the collection and analysis of surface water monitoring data. There are 10 Instream Comprehensive Evaluation (ICE) water sampling stations within the AOI watershed (Figure 17). These stations mark where PA DEP has sampled surface waters to determine whether surface waters are supporting their designated use(s). The ICE evaluation includes water properties such as pH, temperature, alkalinity, conductivity, and dissolved oxygen. It also includes macroinvertebrate collection. All sampling is done following PA DEP data collection protocols as highlighted in Water Quality Monitoring Protocols for Streams and Rivers (PA DEP, 2021).

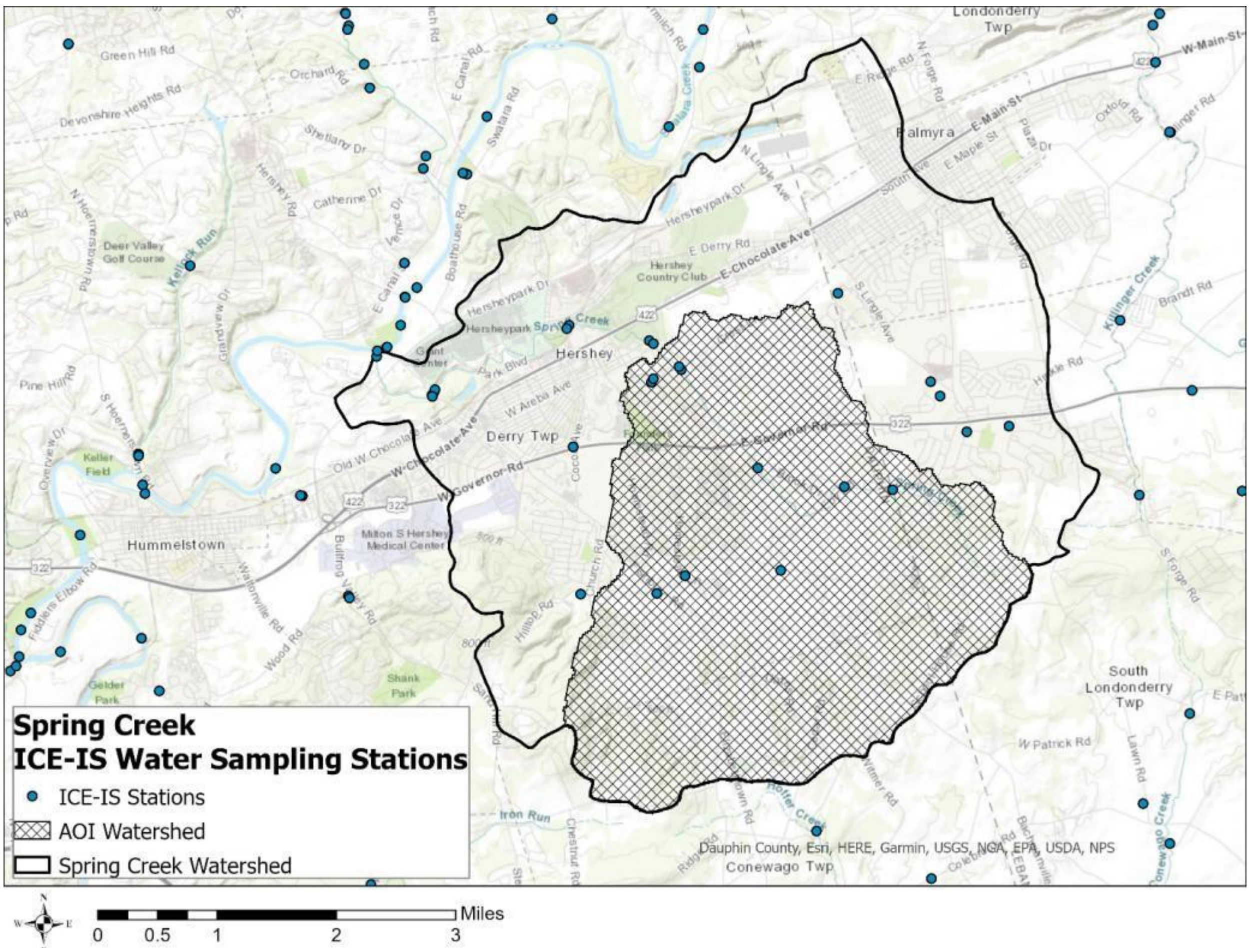

Figure 17. ICE water sampling stations in the AOI and Spring Creek East watershed

Where water bodies are too polluted to meet the designated uses, they are added to an "impaired waters list." In Pennsylvania, the PA DEP develops a Total Maximum Daily Load (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. At the time of the creation of this WIP, there are no TMDLs for the AOI or Spring Creek East watershed.

HABITAT & WATER QUALITY MONITORING

Additional surface water quality monitoring has been conducted in the Spring Creek East watershed by the DCCD. Habitat data is available from watershed metrics analyses completed in 2006, 2011, and 2015. Water quality monitoring data is available from April 2015 through August 2020. This monitoring data has not been provided with spatial information, so the habitat data and most recent years of water quality data are summarized in Table 12 and Table 13, respectively.

Table 12 contains the Index of Biotic Integrity (IBI) scores for monitoring stations in the Spring Creek East watershed in 2006, 2011, and 2015. The IBI score is a measure of a stream's biological health, and these values are typically determined using a combination of desktop and field assessments (Watershed Science Institute, n.d.). The first three stations (SPRE 03.03, SPRN 00.06, and UNTS 00.24) show a decrease in IBI scores from 2006 to 2015, while the remaining four stations (UNTS 01.67, UNTS 02.71, UNTS 02.90, UNTS 03.27) show increasing IBI scores, indicating improved biological health. However, all the sites are still considered Poor (score of 0-49) which is classified as a degraded site dominated by tolerant organisms and the site is not supporting aquatic life use (DCCD, 2019). All sampling was done using approved PA DEP monitoring protocols (DCCD, 2019).

Table 12. Habitat monitoring data (Index of Biotic Integrity, IBI, scores) from 2006, 2011, and 2015 at monitoring stations (source: DCCD)

Site Name	IBI (2006)	IBI (2011)	IBI (2015)
SPRE 03.03	33.80	26.00	32.32
SPRN 00.06	21.24	18.72	17.18
UNTS 00.24	26.66	22.27	20.10
UNTS 01.67	21.41	27.95	30.11
UNTS 02.71	29.33	27.46	39.17
UNTS 02.90	33.26	34.18	46.43
UNTS 03.27	28.79	35.09	30.71

Table 13 contains summarized water quality data (April 2015 – August 2020) from a single monitoring station in the Spring Creek watershed (SPRN 00.06). This station is part of the DCCD Long Term Nutrient Monitoring (LTNM) program. Physico-chemical properties (dissolved oxygen, pH, specific conductance, and temperature) are measured in the field using calibrated water quality meters and/or prescribed water quality kits. While this station was also monitored for total nitrogen (TN), total phosphorus (TP), and orthophosphate, the dataset contains very few points with data for these parameters, so they are not included in Table 13.

Table 13. Water quality monitoring data (2015 – 2020) for station SPRN 00.06 (source: DCCD)

Date (MM/DD/YYYY)	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Nitrate (mg/L)
04/02/2015	13.2	15.39	565.0	8.26	5.0
07/16/2015	16.0	11.61	581.0	7.84	5.0
10/14/2015	14.3	15.74	625.0	7.90	5.7
12/11/2015	10.6	14.21	570.0	7.96	5.6
02/29/2016	10.0	12.53	494.5	7.58	5.1
04/14/2016	14.3	13.62	603.0	7.79	5.2
06/07/2016	17.9	12.04	653.0	7.73	5.6

Table 13. Water quality monitoring data (2015 – 2020) for station SPRN 00.06 (source: DCCD)					
Date (MM/DD/YYYY)	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**Conductivity (µS/cm)**	**pH**	**Nitrate (mg/L)**
08/24/2016	17.6	11.97	meter error	7.69	5.3
10/24/2016	12.9	13.13	624.0	7.99	5.2
12/19/2016	7.4	13.59	573.0	7.95	4.9
02/21/2017	10.3	12.14	622.0	8.20	5.5
04/28/2017	17.1	17.46	615.0	8.05	5.3
06/19/2017	19.3	13.08	655.0	7.44	5.2
08/08/2017	17.0	16.11	642.0	8.20	4.9
10/18/2017	14.2	14.93	632.0	7.91	5.0
02/28/2018	11.1	12.61	564.0	7.79	4.9
05/29/2018	17.2	10.87	598.0	7.91	5.0
06/26/2018	17.7	11.23	663.0	8.07	5.3
09/27/2018	15.2	11.37	585.0	6.90	4.7
11/20/2018	10.6	12.54	475.8	7.25	5.1
01/28/2019	7.6	10.64	488.7	6.44	5.1
04/08/2019	15.3	13.03	595.5	8.17	5.6
05/28/2019	18.0	10.30	634.0	7.92	5.1
07/26/2019	19.3	11.67	609.1	8.17	5.4
09/18/2019	16.1	11.98	627.5	8.06	5.3
11/21/2019	10.7	13.74	543.6	8.12	5.4
02/12/2020	9.8	12.67	492.5	8.03	5.3
05/27/2020	17.0	13.28	596.9	8.03	4.7
08/06/2020	18.4	11.39	562.1	7.80	3.7

Section 4. Potential Pollutant Sources

Pollutant sources are summarized using data on biosolid sites, Commercial 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.

NPDES Permits

At the time that this WIP was submitted to EPA, the Enforcement and Compliance History Online database accessed in 2025 indicated there were 13 NPDES permits in the AOI watershed with active permits. These permit locations are illustrated in Figure 18 and listed in Table 14.

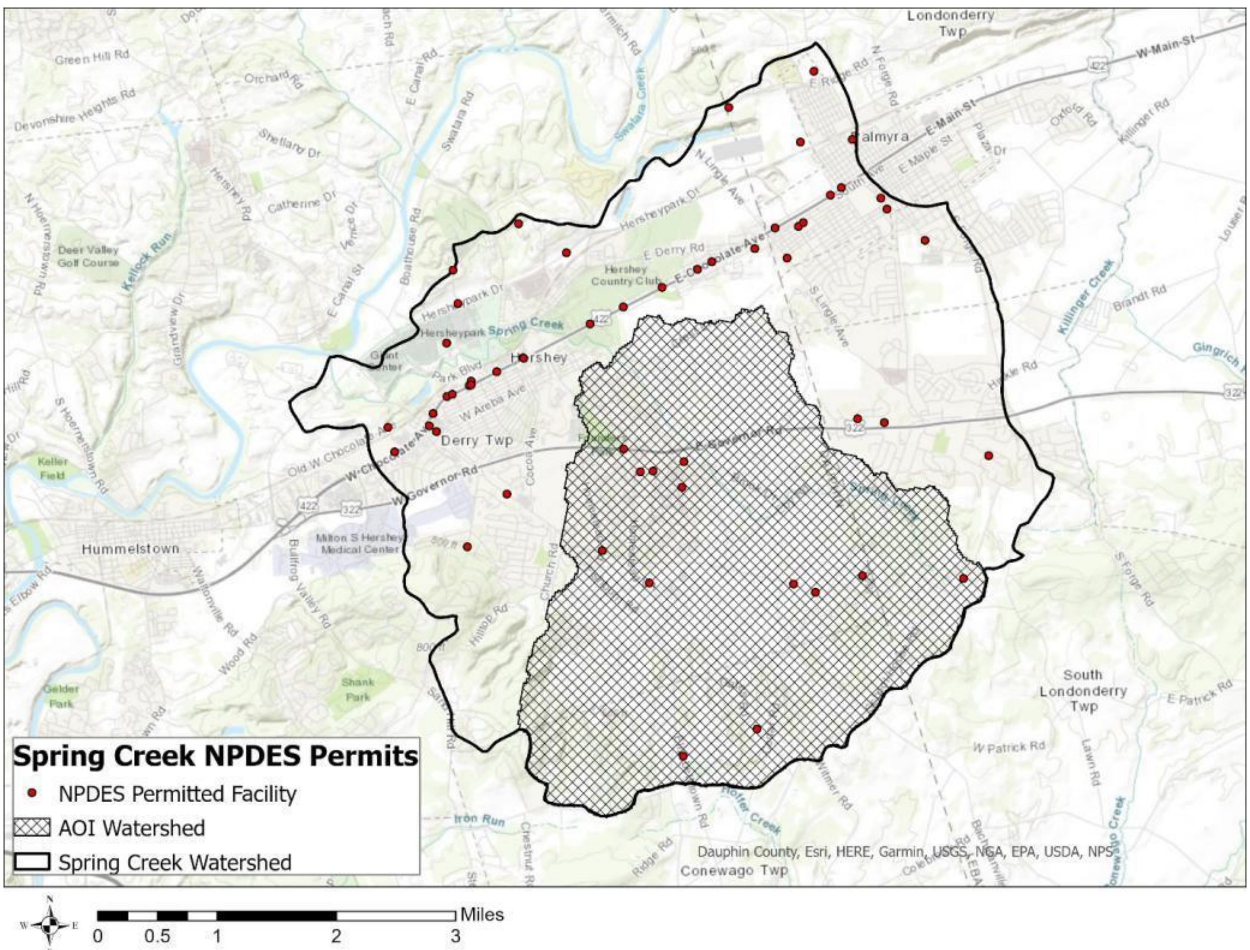

Figure 18. NPDES permits in the AOI and Spring Creek East watershed

Table 14. NPDES permits in the Spring Creek East watershed			
Facility Name (Facility ID, if available)	**Link to Facility Report**	**City**	**County**
Agate Elevator (PAD980715163)	https://echo.epa.gov/detailed-facility-report?fid=110007773711	Hershey	Dauphin
Chicken House #3 (PAC380164)	https://echo.epa.gov/detailed-facility-report?fid=110070696151	Palmyra	Lebanon
Dans Auto Body (PA0000039420)	https://echo.epa.gov/detailed-facility-report?fid=110006116158	Hershey	Dauphin
Elizabethtown Road Subdivision	https://echo.epa.gov/detailed-facility-report?fid=110007773711	Conewago Township	Dauphin
Family Center (PAC220431)	https://echo.epa.gov/detailed-facility-report?fid=110071885361	Derry Township	Dauphin
George Cvijic (PAC220375)	https://echo.epa.gov/detailed-facility-report?fid=110071407975	Derry Township	Dauphin
Hershey Hills Preserve & Estates (PAC220398)	https://echo.epa.gov/detailed-facility-report?fid=110071656469	Palmyra	Lebanon
Milton Hershey Sch (PA0009288)	https://echo.epa.gov/detailed-facility-report?fid=110010149623	Hershey	Dauphin
Milton Hershey Sch (PAC220106)	https://echo.epa.gov/detailed-facility-report?fid=110070251080	Derry Township	Dauphin
Milton Hershey Sch/CTL Boiler PLT	https://echo.epa.gov/detailed-facility-report?fid=110043702124	Hershey	Dauphin
Milton Hershey School (PAD069795110)	https://echo.epa.gov/detailed-facility-report?fid=110001117504	Hershey	Dauphin
Roundabout At Bachmanville Road (PAC220344)	https://echo.epa.gov/detailed-facility-report?fid=110071358192	Derry Township	Dauphin
Sunoco Svc Sta (PAD987341401)	https://echo.epa.gov/detailed-facility-report?fid=110001047830	Hershey	Dauphin

BIOSOLIDS

Biosolids refer 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 or areas for forestry, gardening and landscaping, and agriculture. The PA DEP regulates biosolids under the Pennsylvania permit PAG-08. There are four biosolid sites in the Spring Creek East watershed that apply fertilizer on agricultural lands, only one of which is active and is located in the AOI watershed (Figure 19).

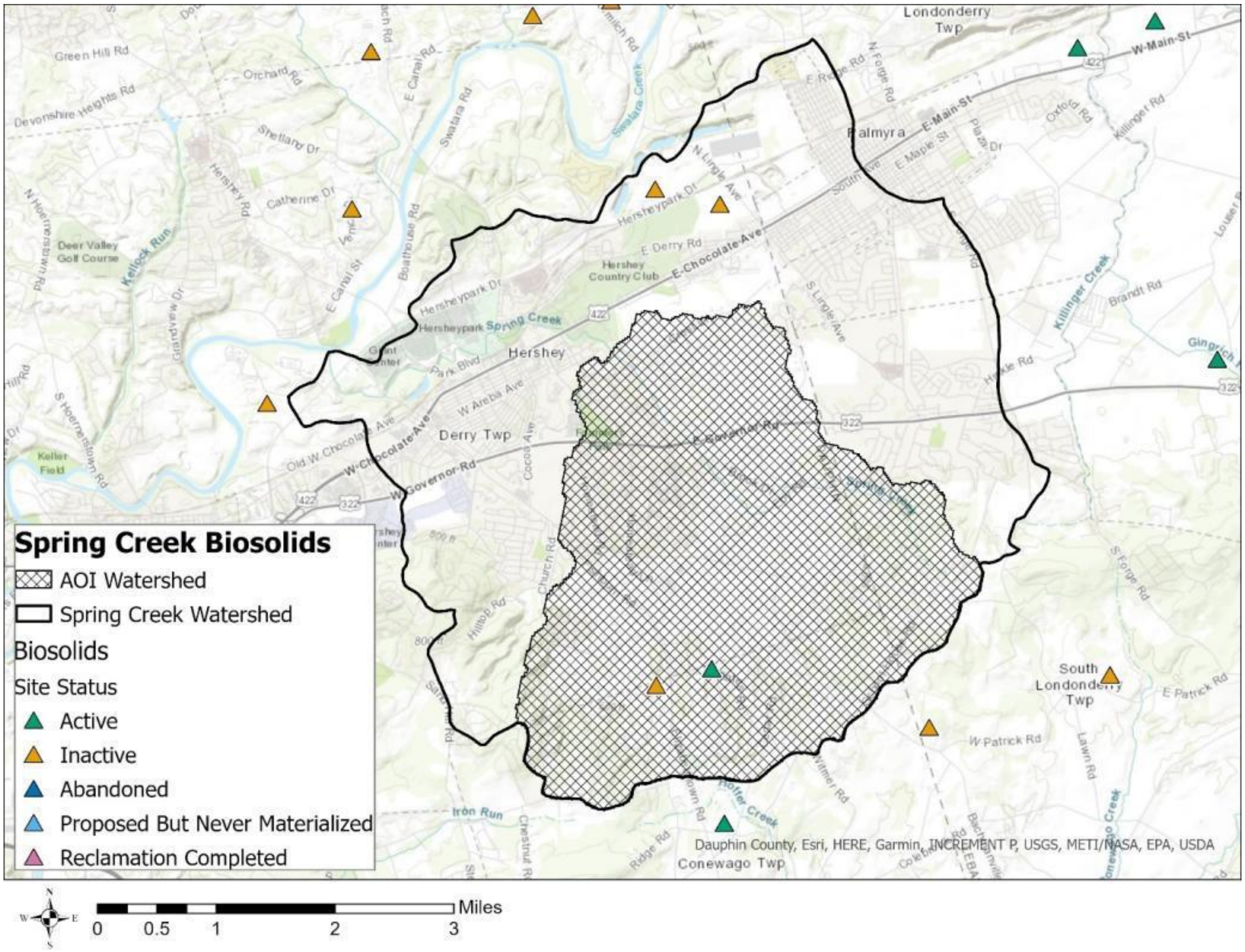

Figure 19. Biosolids sites by status in the AOI and Spring Creek watershed

Livestock Agriculture

Agriculture is a prominent land use in the AOI watershed. Livestock agriculture operations can be point sources of pollution since waste is typically collected at a point like a manure lagoon or tank. There are nearly 45,000 animals used for agriculture in the AOI watershed, and almost 130.000 in the larger Spring Creek East watershed. Counts by livestock type in the AOI watershed and the Spring Creek East watershed were obtained from Model My Watershed and are summarized in Table 15.

Table 15. Counts of livestock in the Spring Creek East watershed

Livestock Type	Count of Animals	
	AOI	**Spring Creek East**
Chickens, Broilers	43,806	124,804
Cows, Beef	31	77
Cows, Dairy	246	748
Horses	47	112
Pigs/Hogs/Swine	751	2,571
Sheep	71	163
Total	44,987	128,475

Water Resource Facilities

A Water Resource Facility is a primary facility type of PA DEP related to the Water Use Planning Program. These facilities are categorized by use (e.g., agricultural, commercial, industrial, sewage treatment) and by subtype (e.g., discharge, interconnection, surface water withdrawal, groundwater withdrawal). There are 2 Water Resource facilities in the AOI watershed (Figure 20) both for groundwater withdrawal agricultural use.

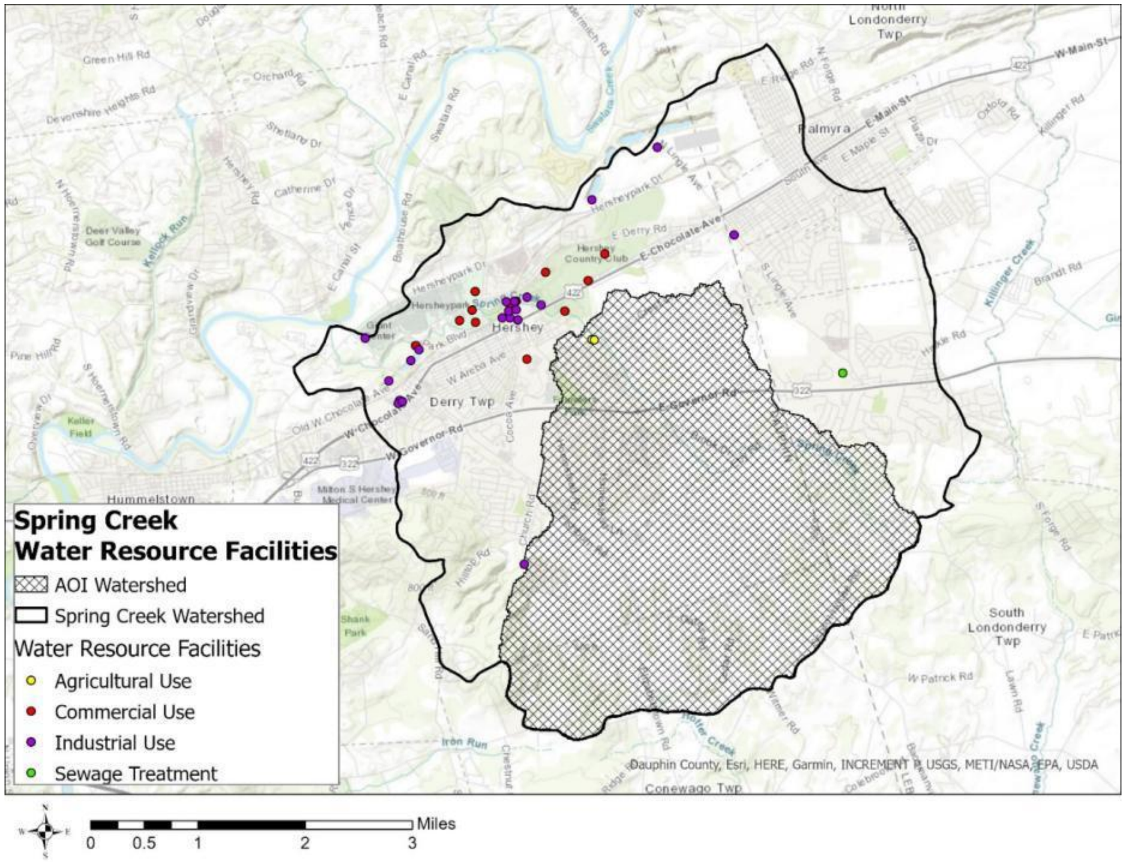

Figure 20. Water Resource Facilities by use in the AOI and Spring Creek watershed

ENCROACHMENT LOCATIONS

Encroachment locations are a primary facility type of PA DEP related to the Water Resources Management Obstructions Program. There are 38 encroachment locations within the AOI watershed, all of which are active and compliant (Figure 21). There are many sub-facility types of encroachment locations; counts by sub-facility type in the AOI watershed are included in Table 16.

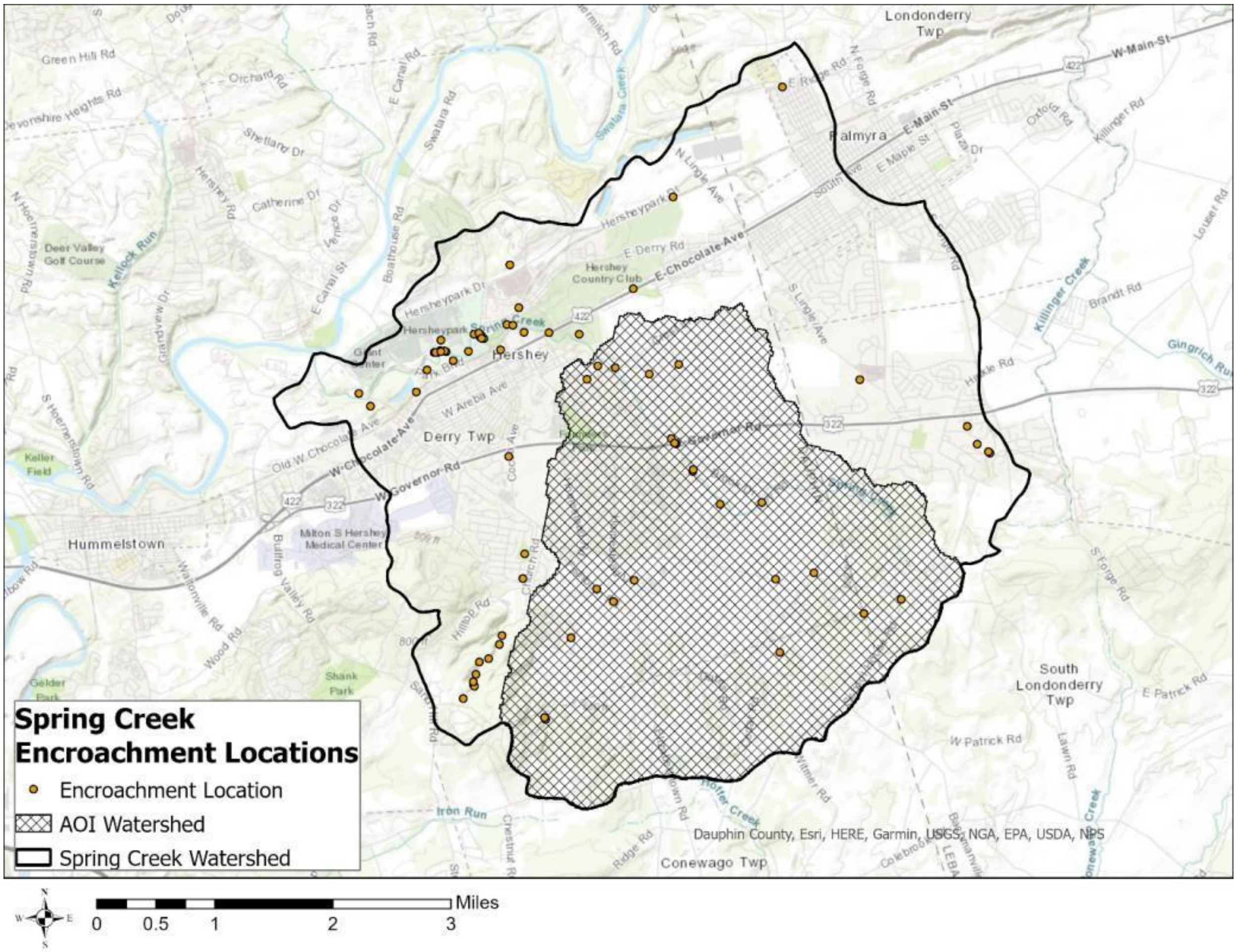

Figure 21. Encroachment locations within the AOI and Spring Creek watershed

Table 16. Encroachment facilities, by sub-facility type,	
Encroachment Location Type	**Count within Watershed**
Pipeline or Conduit	7
Other Activities	4
Bridge	4
Culvert	8
Stream Bank Protection	4
Stream Direct Impact	2
Floodway Direct Impact	2
Wetland Impact	2
Temporary Floodway Impact	2
Dock	1
Temporary Stream Impact	1
Temporary Wetland Impact	1

SECTION 5. FIELD ASSESSMENTS AND FINDINGS

Field assessments for the WIP were conducted by PSU, EPR, and CWP at various times throughout the project. PSU conducted an agriculture windshield survey assessment in the summer of 2022, as well as a Tillage survey in 2024. EPR completed their stream restoration assessments in Summer of 2024. (CWP) conducted field assessments to identify stormwater retrofit opportunities on September 12th – 14th, 2023.

This section provides an overview of the field methods for each assessment, field results, and recommendations.

Agricultural BMP Assessment

PSU assessed the entire Spring Creek East watershed including the AOI watershed that is the focus of this WIP. Since the AOI watershed is located in the non-MS4 area of the Spring Creek East watershed, an evaluation of agricultural practices and potential locations for BMPs was an important step in creating the WIP. The assessment consisted of two portions, a desktop assessment using GIS and aerial imagery, and a field verification of agricultural practices and potential restoration sites.

DESKTOP ASSESSMENT

To begin the watershed windshield survey workflow, a variety of desktop tools were employed to complete a preliminary watershed review. Mapped datasets used in this process included high resolution aerial imagery, municipal parcel boundaries, watershed boundaries and National Hydrography Dataset waterways. The desktop review involved the manual process of recording potential restoration and BMP locations visible in google earth and on aerial imagery. Watershed assessments focus on identifying areas that would benefit from BMPs and are divided into agriculture BMPs, restoration BMPs, and stormwater BMP recommendations. These locations were recorded in a GIS database file and designated with the appropriate potential BMP code or conservation practice code (Table 17). More than 200 locations were identified for potential site visits by the field team.

FIELD ASSESSMENT

The next step was to conduct field surveys to verify the desktop review. Field surveys were split into tillage surveys and watershed assessment outings. Tillage surveys were conducted to determine land use practices on agricultural land within the watershed. Existing agriculture land use practices were recorded based on information gathered from driving by the farm. Specific information documented for each farm field included information on tillage practices, cover crop use, and the presence or absence of crop residue, etc. Other potential project types were identified and recorded in the landscape, including potential agriculture best management practices such as opportunities for grassed waterways, contour strip cropping, pasture management etc., potential BMPs for environmental restoration, including forest riparian buffers, floodplain restoration, and wetland restoration areas, and stormwater management practices including stormwater basin retrofits, conservation landscaping, and bioswale opportunities. Project notes were recorded on data forms and paper maps, along with a pre-designed and pre-populated GIS field application. All field data was post-processed, data review and quality control were completed, and final spatial data files were combined into a project-specific GIS map. The results of the survey were used to identify the location of future agricultural practices for implementation. More than 70 sites were identified in the AOI watershed for possible BMP implementation and Table 17. BMP or conservation practice codes for field assessment project types. Figure 22 identifies the field locations that were evaluated for restoration potential.

Table 17. BMP or conservation practice codes for field assessment

Project Code	Project Type	Number of potential projects in AOI
Agriculture BMPs		
BRC	Barnyard Runoff Controls	1
PM	Pasture Management	1
ACA	Improved Animal Concentration Area (aka Loafing Lot Mgt)	3
CSC	Contour Strip Cropping	1
NT	Conversion to No Till	9
CC	Cover Crops	26
Restoration Practice BMPs		
RB	Forest Riparian Buffers	26
Stormwater Practice BMPs		
SWR	Stormwater Basin Retrofit	7
BI	Other Bioinfiltration BMP	6
CL	Conservation Landscaping	4

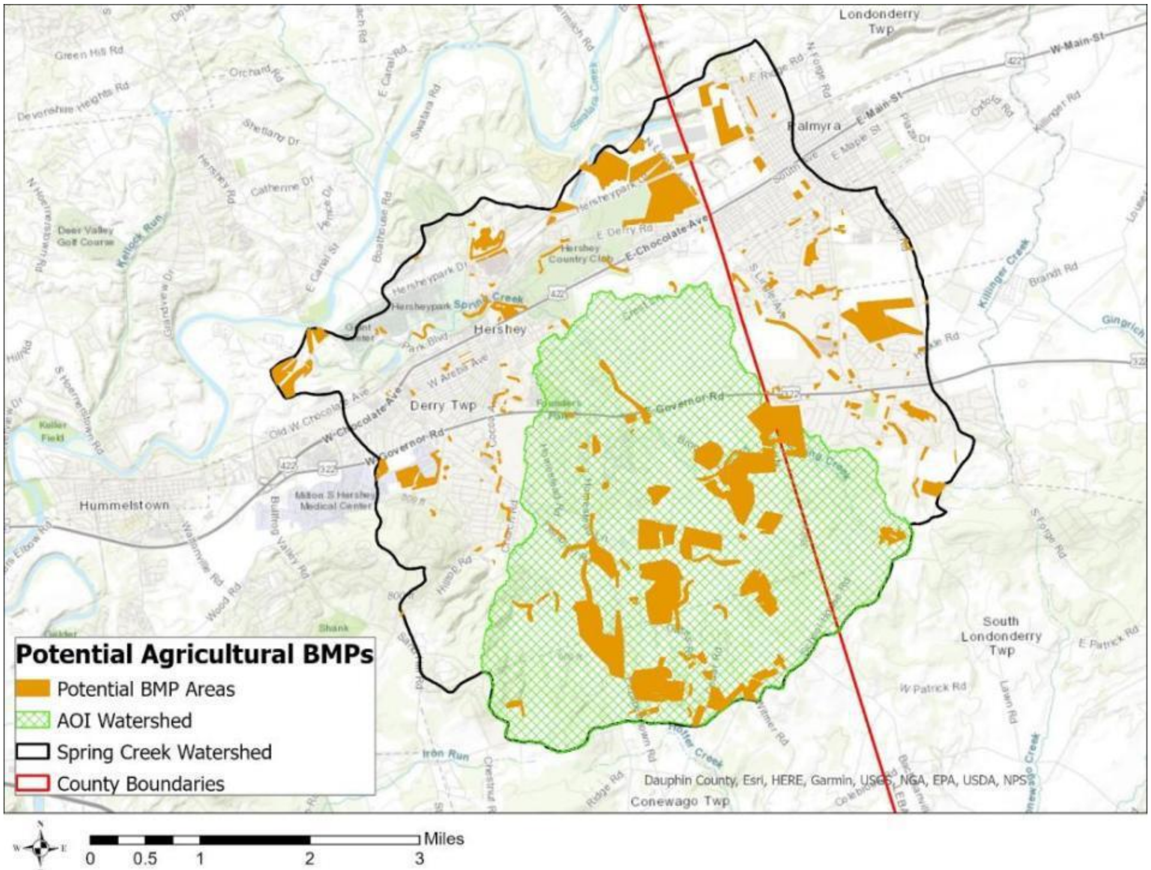

Figure 22. Potential agricultural best management practices in the AOI watershed

Stormwater Retrofit Reconnaissance Inventory (RRI)

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, the streams. 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 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. Appendix A includes an example RRI field form that was completed during field work. The RRI forms were incorporated into an ArcGIS Field Maps App for mobile data collection. Field teams used a tablet to complete the retrofit site form and took pictures of the conceptual sketches, so they were associated with the data collection point in the mobile application. 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 generally were located on municipal or institutional sites and could serve as a demonstration project.

Desktop Assessment

In preparation for the field assessment, CWP first conducted a desktop analysis using a combination of data provided by PASDA and aerial imagery from Esri and Google Earth. The goal was to identify potential locations to visit in the AOI watershed since data for existing stormwater BMP locations was not available. The aerial imagery and the watershed boundary delineated by PA DEP were used to identify municipal and institutional areas in the AOI watershed in both Dauphin and Lebanon County. This data was combined with the stormwater retrofit data from the PSU windshield survey and input from the meeting with residents held as part of the project to select the final sites to visit. Table 18 shows the sites visited for potential retrofit opportunities.

Table 18. Sites visited for potential stormwater retrofit opportunities

Site ID	Site	Notes	Retrofit?
1	Hershey Christian Academy	Possible retrofit of existing practice	Yes
2	Private residence pond	Possible retrofit of existing practice	No
3	Private residence	New retrofit	No
4	Private residence	New retrofit	No
5	Milton Hershey School	Possible retrofit of existing practice	No
6	Milton Hershey School	Possible retrofit of existing practice	No
7	Milton Hershey School	Possible retrofit of existing practice	No
8	Milton Hershey School	Possible retrofit of existing practice	Yes
9	Milton Hershey School	Possible retrofit of existing practice	Yes
10	Milton Hershey School	Possible retrofit of existing practice	No
11	Milton Hershey School	Possible retrofit of existing practice	Yes
12, 18	Evangelical Free Church of Hershey property	Undeveloped	No
13	Milton Hershey School	Possible retrofit of existing practice	Yes
14	Milton Hershey School	Possible retrofit of existing practice	No
15	Milton Hershey School	Possible retrofit of existing practice	No
16	Milton Hershey School	Possible retrofit of existing practice	No
19	Fishburn United Methodist Church	New retrofit	No
20	Living Legacy Church	New retrofit	No

Table 18. Sites visited for potential stormwater retrofit opportunities			
Site ID	**Site**	**Notes**	**Retrofit?**
21	Hershey Church Of the Nazarene	New retrofit	No
23-26	Evangelical Free Church of Hershey buildings and parking lot	Possible retrofit of existing practices	Yes (4)
27	Conewago Church Of Brethren	New retrofit	Yes
30	Encounter Church	Possible raingardens?	Yes (2)
31	Derry Township Community Center	Existing stream restoration and BMPs	No
32	Pollinator Garden Cocoa Avenue	Invasive Species Management	No
33	Milton Hershey School	Flooding on road	No
34	Existing Rain Garden	Northside Road	No
35	Palmyra Road	Flooding	No
36	Catherine Hershey School	Tree Planting	No
37	Hershey Trust	Tree Planting	No
38	Derry Township	Brookside Park	No
39	Campbelltown United Methodist Church	New retrofit	Yes
41	Township Of South Londonderry	Park	No
42	Township Of South Londonderry	Park	No
43	Campbelltown Volunteer Fire Co	New retrofit	No

Field Assessment

A total of 38 sites were identified through desktop analysis. After visiting all potential retrofit locations identified, only 13 of these locations were deemed suitable for retrofits. The remaining 25 sites were not suitable for a retrofit project due to topography, land use, space constraints, or other reasons that would make constructing a stormwater retrofit inherently difficult or expensive.

Many of the retrofit opportunities proposed are bioretention practices. Additional opportunities identified include modifications to existing detention practices that would provide additional pollutant removal. Approximately 0.27% (29.5 acres) of the AOI watershed would be treated if all retrofit opportunities were implemented and about 2% of the impervious cover would be treated. Figure 23 show the location of the proposed retrofits within the AOI watershed,

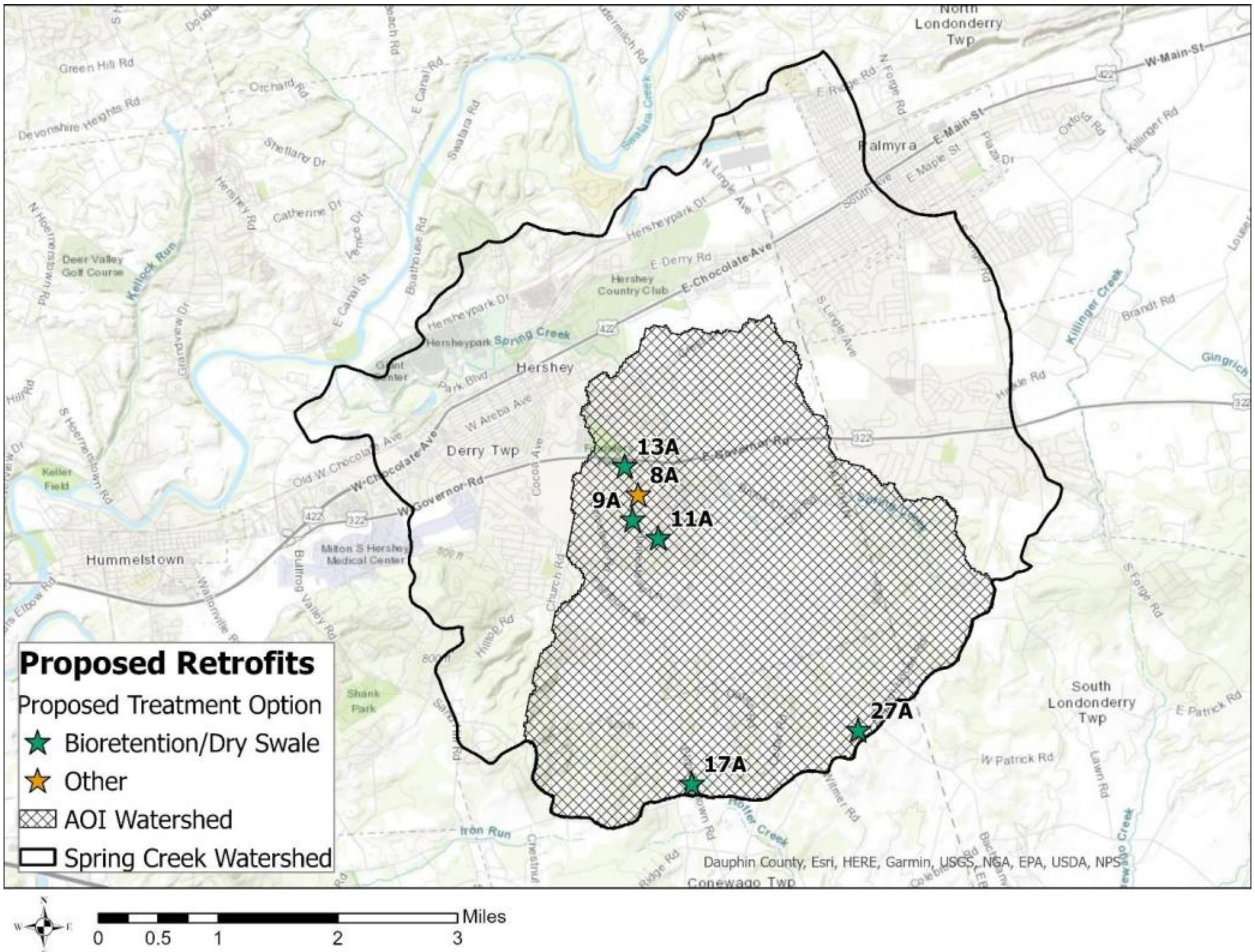

Figure 23. Location of Possible Retrofit Locations in AOI Watershed

Table 19includes the summary of projects located outside the AOI watershed but they are located in the larger Spring Creek East watershed. Several of the designs would be excellent demonstration projects assuming the churches would be willing partners. The information is presented here for potential future use by the local organizations in the watershed (SCEWA;TU) in identifying additional projects that could be implemented to help address water quality in upland areas of the watershed. The potential retrofits listed in Table 19 were not used to calculate estimated pollutant load reductions or compliance with the required pollutant loading reductions from DEP that were assigned to the AOI as discussed in Section 6.

Table 19. Stormwater retrofits identified in the Spring Creek East watershed outside the AOI area								
Location Name	**ID**	**BMP Type**	**Drainage Area Treated (acres)**	**Total TSS Removal (tons/yr)**	**Total Phosphorus Removal (lbs/yr)**	**Total Nitrogen Removal (lbs/yr)**	**Cost $ (Design, Construct) ***	**Maintenance Cost Per Year****
Hershey Free Church	0.71	Dry Extended Detention Pond	0.71	0.14	0.04	0.24	$9,967.64	$54.71
Hershey Free Church	2.87	Bioretention/ raingardens A/B soils, underdrain	2.87	0.73	0.54	3.34	$26,443.56	$972.05
Hershey Free Church	6.23	Bioretention/ raingardens A/B soils, underdrain	6.23	1.59	1.17	7.24	$182,031.54	$8,024.92
Hershey Free Church	2.17	Bioretention/ raingardens A/B soils, underdrain	2.17	0.55	0.41	2.52	$14,688.50	$439.18
Encounter Church of Palmyra	0.91	Bioretention/ raingardens A/B soils, underdrain	0.91	0.23	0.17	1.06	$33,405.08	$1,287.62
Encounter Church of Palmyra	0.92	Bioretention/ raingardens A/B soils, underdrain	0.92	0.24	0.17	1.07	$31,554.37	$1,203.72
Campbell-town United Methodist	1.65	Bioretention/ raingardens A/B soils, underdrain	1.65	0.42	0.31	1.92	$18,362.15	$605.71
		Totals	**15.46**	**3.9**	**2.81**	**17.39**	**$316,452.84**	**$12,587.91**

* 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 percentage of water quality volume per BMP.

Prioritized Ranking of Recommended Actions

Table lists each proposed practice and the ranking they received based on various criteria, such as pollutant removal, cost, cost effectiveness, maintenance cost, and land ownership. The factors in the rating are based on typical factors found in stormwater grants. This allows the strongest projects to be proposed for grant funding. The ranking also seeks to balance the primary focus of the plan (sediment load reduction) with other factors such as cost for implementation and maintenance burden to provide a suggested schedule for project implementation. The table is divided into those located within the AOI watershed and those outside that designated boundary.

Cost of the Practice

The cost for each practice was calculated based on estimates in the CAST Cost Profiles for the State of Pennsylvania (Appendix F). Projects that cost less than $25,000 received a 10, projects that cost between $25,000 to $60,000 received a 5, and projects that cost over $60,000 received a 1.

Total Suspended Solids (TSS) Removal

The TSS Removal was rated based on how much suspended sediment would be removed each year by this project. Projects above 0.75 tons/yr received a 10, projects between 0.75 to 0.1 tons/yr received a 5, and projects under 0.1 tons/yr received a 1.

Total Phosphorus (TP) Removal

The TP Removal was rated based on how much total phosphorus would be removed each year by this project. Projects above 0.50 lbs/yr received a 10, projects between 0.50 to 0.10 lbs/yr received a 5, and projects under 0.10 lbs/yr received a 1.

Cost Effectiveness for Total Suspended Solids (TSS) Removal

Rankings are based on the calculated removal efficiencies for sediment and the costs of each practice. Projects with a cost effectiveness of less than $30,000/tons/yr received a 10, projects with a cost effectiveness between $30,000/tons/yr to $80,000/tons/yr received a 5, and projects with a cost effectiveness over $80,000/tons/yr received a 1.

Cost Effectiveness for Total Phosphorus (TP) Removal

Rankings are based on the calculated nutrient removal efficiencies for phosphorus and the costs of each practice. Projects with a cost effectiveness of $40,000/lbs/yr received a 10, projects with a cost effectiveness between $40,000/lbs/yr to $140,000/lbs/yr received a 5, and projects with a cost effectiveness over $140,000/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. Practices on privately held land are given a score of 1; and 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 involve maintenance. The maintenance needs are based on the cost per year for each practice. Projects that cost less than $300 received a 10, projects that cost between $300 to $,1000 received a 5, and projects that cost over $1,000 received a 1.

Table 20. Priority ranking of 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**
Inside the AOI watershed											
Milton Hershey School Memorial Hall	8A	Dry Extended Detention Ponds	10	10	5	10	5	1	10	51	1
Conewago Church of The Brethren	27A	Bioretention/ raingardens, A/B soils, underdrain	10	10	10	1	1	1	10	43	2
Milton Hershey Elementary School	9A	Bioretention/ raingardens - A/B soils, underdrain	1	5	5	10	10	1	1	33	3
Milton Hershey School Pennland Lane and Brook Drive	11A	Bioretention/ raingardens - A/B soils, underdrain	1	1	1	10	10	1	1	25	4
Milton Hershey School Harvest Lane and Homestead Lane	13A	Bioretention/ raingardens - A/B soils, underdrain	1	1	1	10	10	1	1	25	5
Hershey Christian Academy	17A	Bioretention/ raingardens - A/B soils, underdrain	5	1	1	5	5	1	1	19	6
Outside of the AOI watershed											
Hershey Free Church	26B	Bioretention/ raingardens - A/B soils, underdrain	10	10	10	5	5	1	5	46	1
Campbelltown United Methodist	39A	Bioretention/ raingardens, A/B soils, underdrain	10	10	10	5	5	1	5	46	2
Hershey Free Church	23B	Bioretention/ raingardens - A/B soils, underdrain	5	10	10	5	10	1	5	46	3
Hershey Free Church	23A	Dry Extended Detention Ponds	10	10	5	5	1	1	10	42	4
Hershey Free Church	26A	Bioretention/ raingardens - A/B soils, underdrain	1	5	5	10	10	1	1	33	5
Encounter Church of Palmyra	30A	Bioretention/ raingardens - A/B soils, underdrain	5	5	5	5	5	1	1	27	6
Encounter Church of Palmyra	30B	Bioretention/ raingardens, A/B soils, underdrain	5	5	5	5	5	1	1	27	7

Stream Restoration Assessments

A standardized stream assessment process was used to evaluate existing stream conditions and restoration potential of a diverse selection of stream sites in the AOI watershed.

Desktop Assessment

Potential stream restoration opportunities were first assessed using a desktop process. The desktop assessment involved an evaluation of 32.72 miles of stream across 276 distinct reaches. EPR categorized the baseline health of the stream reaches in the AOI with a condition score based on GIS data and on-line aerials. Stream reaches/segments defined by GIS hydrology lines (shapefiles) were segmented for analysis based on 1,000 linear feet of stream length unless intersected by a confluence of a tributary. EPR gathered relevant data on stream lengths, soils, sinuosity, vegetative cover, slope, and various forms of land use/land cover on which existing conditions were ranked based on the effect on stream channel stability and then summed to yield the desktop stream condition scores. The following categories were taken into equally weighted consideration for the creation of the condition scores: sinuosity, slope, riparian vegetation, agriculture encroachment, development encroachment, road presence, and soil erodibility. Except for sinuosity (ratings of only 0 or 1), every category was scored with ratings of 1 – 3, with three (3) being the rating for instability, and one (1) being the most stable. A more detailed explanation of the scoring technique is in Appendix C.

Scores are then added up to yield the overall stream segment condition score. The worst overall score possible is a 19, but no reach scored worse than a rating of 15. Given this distribution, scores were then sorted into three equal sub-ranges for stream stability: 7 – 9 is good condition, 10 – 12 is fair condition, and 13 – 15 is poor condition.

Streams were assessed and assigned lengths and scores, categorizing them into three conditions: Good, Fair, and Poor. Specifically, 75 reaches were rated as Good with a combined length of 34,937 linear feet. 134 reaches were rated as Fair, covering another 83,963 linear feet, and 67 reaches fell into the Poor rating category, spanning 53,879 linear feet. Figure provides information on the reaches and their score. Breaking down the results further for the AOI, 27% of the stream reaches and 20% of the stream length (34,937 LF) were rated as Good. In contrast, 49% of the reaches and 49% of stream length (83,963 LF) were rated Fair, and 24% of the reaches equating to 31% of the stream length (53,873LF) were rated as Poor. Appendix C

Field Assessment

EPR conducted a modified version of a rapid stream function-based assessment of desktop-identified selected sites based on the Stream Functions Pyramid (Harman, Starr et al., 2012) and Rapid Function-based Stream Assessment Protocol (Starr et al, 2015). Critical functions on two levels of the stream functions pyramid were assessed so that the existing conditions for these levels and potential changes in defined stream functions could be evaluated for the selection of priority sites.

The following assessment parameters, by function pyramid level, were evaluated:
Level 2 - Hydraulics – floodplain connectivity, floodplain drainage, and vertical stability extent.
Level 3 - Geomorphology – lateral stability, riparian vegetation, and bedform diversity.

Ten sites, totaling approximately 2.5 miles of stream, were selected by EPR for field validation. Priority field sites were chosen for equal representation of stream segment condition (estimated), varied locations within the watershed and on the main stem and tributaries, and stream segment access. For these priority sites, the modified Rapid Stream Function-based Assessment (RSFBA) as described above was utilized to rate the existing stream segment condition. The RSFBA used the assessment ratings of Functioning, Functioning-at-

Risk, and Not-Functioning to parallel the overall rating conditions of good, fair, and poor from the desktop assessment. A representative reach of the identified field assessed stream segment was conducted; full stream segment lengths were not assessed. EPR field assessed approximately 11,207 linear feet of streams in the Spring Creek watershed. Of these field sites, three segments were rated as "good condition," 10 segments were "fair condition", and two segments were rated as "poor condition."

"Good" Sites
A "good" site is characterized by optimal performance in Level 2 (Hydraulics) and Level 3 (Geomorphology) of the Stream Functions Pyramid. Hydraulics at this level involves effective transport of water and sediment, assessed through floodplain connectivity, drainage complexity, and vertical stability. Key metrics include a low Bank Height Ratio (BHR), indicating frequent floodplain access, a high Entrenchment Ratio (ER), signifying extensive floodplain availability, and stable vertical conditions with minimal aggradation or degradation. In geomorphology, good sites exhibit diverse riparian vegetation over 100 feet wide, minimal bank erosion, and high-quality fish habitats with substantial stable substrate.

"Fair" Sites
"Fair" sites demonstrate moderate performance in both Hydraulics and Geomorphology. These sites have a BHR that allows occasional floodplain access and an ER that provides limited floodplain availability. Vertical stability shows potential for localized aggradation or degradation. Geomorphologically, fair sites have riparian vegetation between 25 – 100 feet wide, a moderate rate of bank erosion (less than 50%), and in-stream habitats with 20% – 70% stable substrate. These conditions indicate a moderate connection and dynamic equilibrium yet show signs of disturbance or limited diversity.

"Poor" Sites
"Poor" sites perform inadequately across the assessed criteria. Hydraulically, they exhibit high BHR, hindering floodplain access, and low ER, indicating minimal floodplain availability. Vertical stability in these sites shows high potential for widespread aggradation or degradation. In terms of geomorphology, poor sites have riparian vegetation less than 25 feet wide, often dominated by invasive species or significantly impacted by human activity. Over 50% of the banks in these sites are actively eroding, and fish habitats contain less than 20% stable substrate, leading to poor in-stream conditions and habitat quality. A map of the scored reaches is provided in Figure .

After conducting a comprehensive field assessment, the EPR team refined the GIS-based desktop analysis for each stream reach within the AOI. This calibration aimed to align the condition scores more closely with the empirical field data collected. Once a sufficient sample of field data had been gathered, EPR reviewed the calibration process to ensure the desktop analysis closely matched the observed field conditions. Discrepancies between the desktop analysis and field observations, particularly regarding stream sinuosity, resulted in a change in scoring methodology for the final condition score calculations. The change was attributed to an outdated GIS hydrology layer, which no longer accurately represented the current stream planform due to ongoing erosion and other changes. Consequently, sinuosity was removed as a parameter from the final condition score calculations. Appendix C has the final desktop and field assessment results in a tabular format.

Revised scores were then added to yield the overall condition score. The worst score possible is a 15, but no reach segment scored worse than a rating of 13. Given this distribution, scores were then sorted into three sub-ranges of stream condition: 6-8 is good condition, 9 – 11 is fair condition, and 12 – 13 is poor condition.

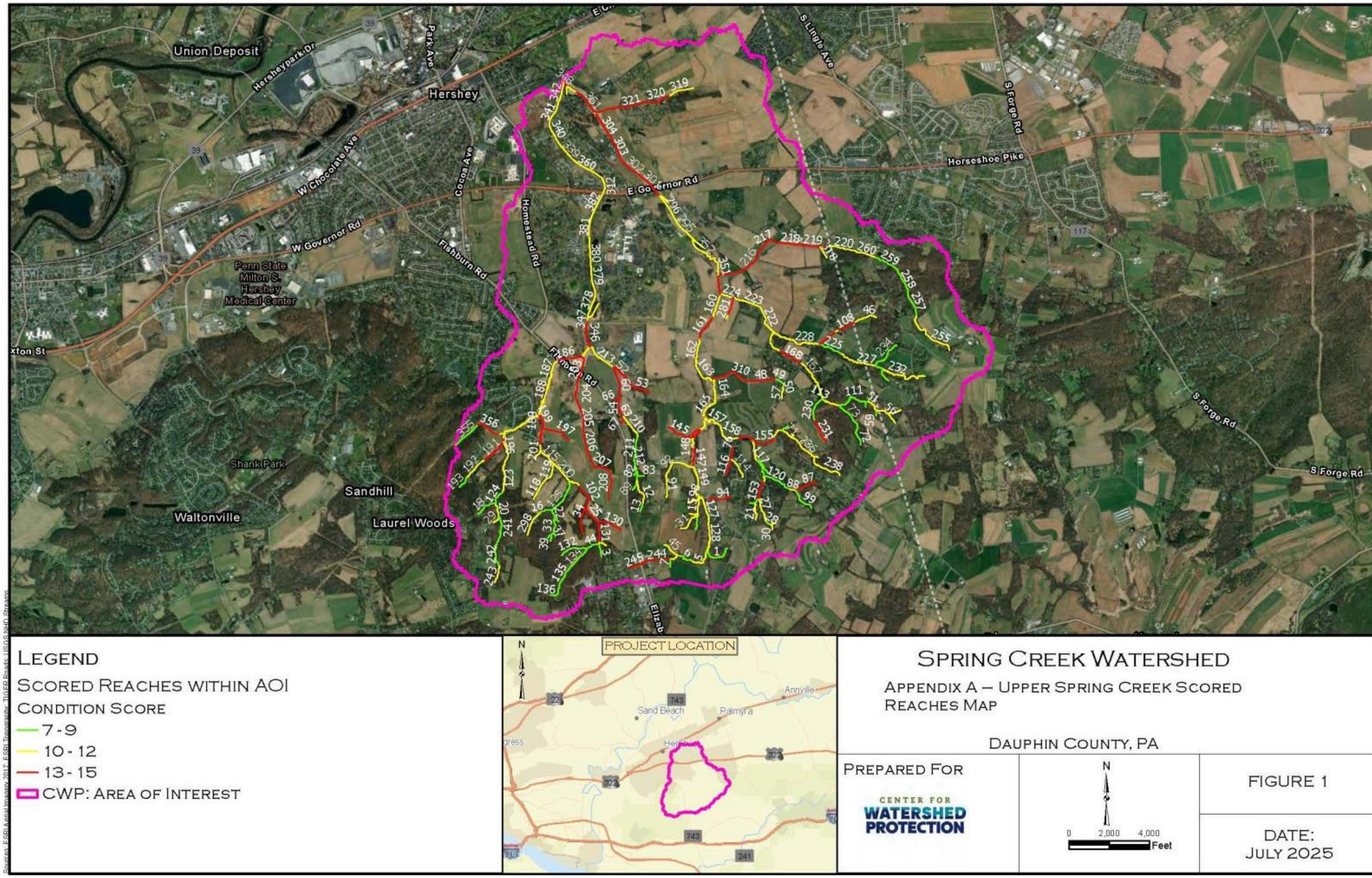

Figure 24. Map of existing stream condition ratings

Prioritized Ranking of Recommended Actions

The process of identifying potential stream restoration sites was driven by a comprehensive set of criteria designed to balance ecological objectives with logistical feasibility. A critical factor was property ownership, which is essential for accessing the streams and ensuring their long-term upkeep and success. Streams identified as high priority for restoration were between 1,000 to 4,000 feet in length—manageable sizes that still allow for significant ecological impact. These segments had previously received Poor to Fair ratings in desktop assessments, highlighting a substantial potential for ecological improvement.

When selecting priority stream restoration sites, the potential for functional lift and floodplain reconnection was decisive, particularly where floodplain reconnection and Legacy Sediment Removal was likely to be most cost-effective. Legacy Sediment Removal involves the excavation and management of accumulated sediments, typically deposited over centuries in floodplains and stream valleys, to restore natural water flow, improve water quality, and revitalize floodplain wetlands. High-priority sites were those where the restoration could be achieved with minimal impacts to large trees, preserving valuable riparian tree cover and maintaining existing habitat.

Additionally, sites with limited impact on active agricultural crop fields were preferred to avoid disrupting ongoing farming activities. The proximity of soil disposal locations was also a key factor, reducing transportation costs and further enhancing cost efficiency. Good access for construction equipment and sites with limited constraints were prioritized to minimize potential complications during the restoration process.

Financial considerations were equally important; cost-efficiency and the potential for significant pollutant load reductions influenced the prioritization process. Restoration efforts were targeted at streams where the costs per linear foot were likely to be competitive for funding.

Assessed stream reaches were combined into priority project areas to maximize potential pollutant load reduction credit and ecological uplift. A total of 30 reaches were categorized into High Priority- Milton Hershey Land, High Priority- Private Land, and Medium Priority. In total, there were:

- 16 High Priority Reaches- Milton Hershey Land sites (Table)
- 10 High Priority Reaches- Private Land sites (Table)
- 4 Medium Priority Reaches (Table)

Table 21. High priority stream restoration opportunities at Milton Hershey School or Trust property

Project Area	Reach ID	Length (LF)
Project Area 1	143	477
	144	473
	145	100
	146	66
	147	862
	148	544
	151	684
	157	800
	166	53
	165	824
	Total	**4883**
Project Area 2	161	1000
	160	1000
	221	225

	327	601
	215	1000
	224	737
	Total	**4563**

Table 22. High priority stream restoration opportunities on private property

Reach ID	Length (LF)	Number of Owners
155	806	1
159	614	1
48	1000	1
310	1000	1
311	537	1
218	1000	1
219	800	1
167	925	1
168	881	2
	439	
94	509	2
	478	
Total	**8989**	**12**

Several stream reaches rated as "Poor" nonetheless scored low in prioritization. This typically reflected other prioritization criteria, such as floodplain reconnection potential, legacy-sediment removal, protection of large trees, preservation of riparian vegetation, and maintenance of existing habitat, that take precedence over raw condition scores. Lower-ranked reaches not selected may also have characteristics such as close proximity to adjoining houses, roads, and other infrastructure, relatively short lengths, or encroachment on prime farmland, all attributes that lowered their condition scores and, as well as reduced their priority for restoration.

Medium priority sites are located adjacent to High Priority Milton Hershey Land sites and could be included in broader restoration efforts. However, these sites present significant additional constraints, such as proximity to roads, which are likely to impact restoration strategies and potential pollutant load reductions.

Table 23**.** Medium priority stream restoration opportunities

Reach ID	Length (LF)
92 and 93	1197
217	1000
216	1000
Total	**3197**

The identification of high-priority stream restoration projects is essential for targeting efforts where they can have the most significant impact on ecological health and watershed stability. Two specific stream restoration project locations on Milton Hershey property (Table) have been identified as top priorities based on their potential for substantial environmental improvement and long-term sustainability. These sites also offer the best opportunities for cost-effective outcomes of the restoration efforts. A map of the potential stream restoration locations is provided in Figure *25*. Map of potential stream restoration projects from Spring Creek

Alternative Restoration Plan Stream Assessment Report (Appendix C), which is extracted from Appendix C to EPR’s Spring Creek Alternative Restoration Plan Stream Assessment Report. The full report is provided as Appendix C to this plan.

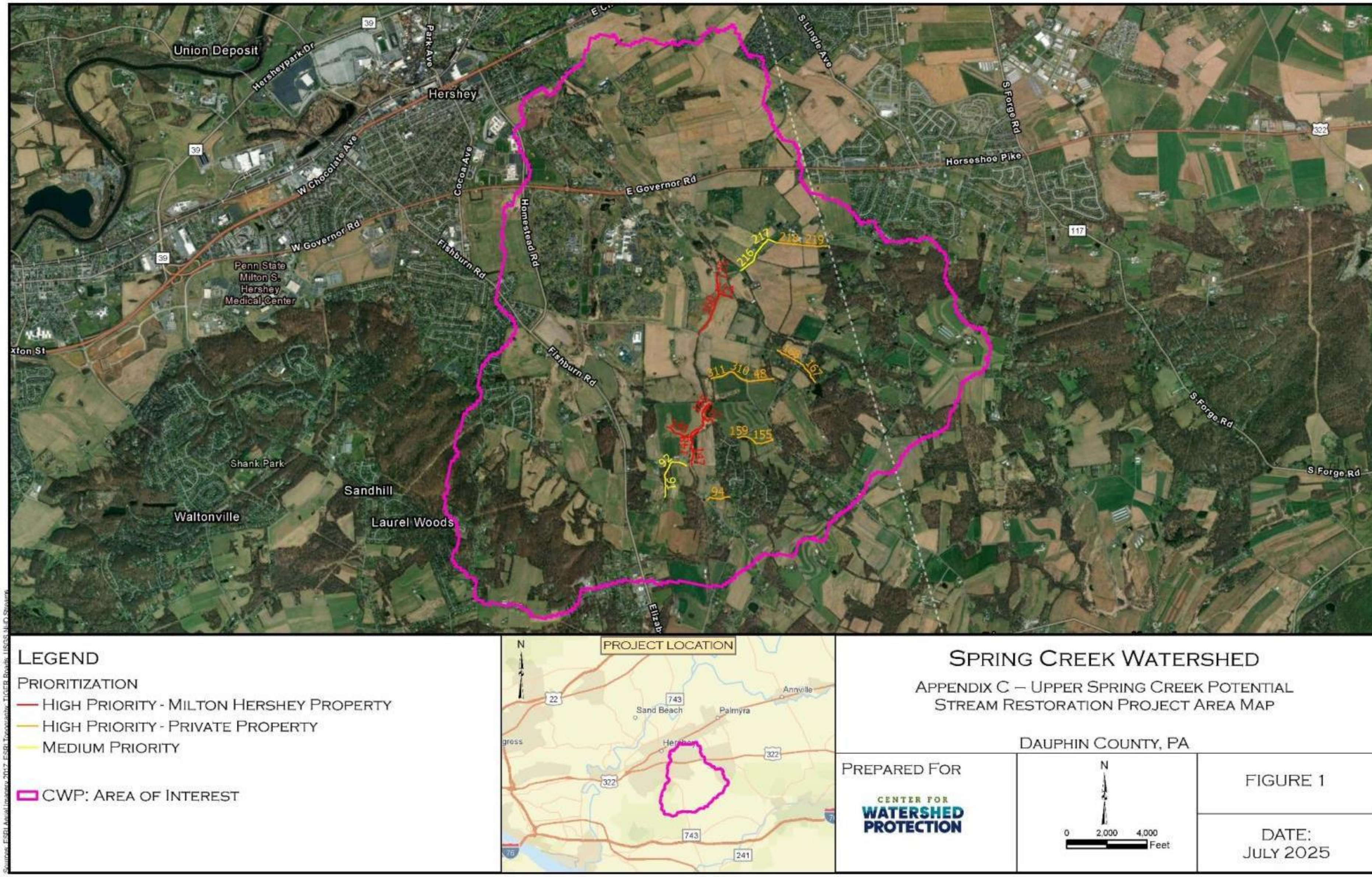

Figure 25. Map of potential stream restoration projects from Spring Creek Alternative Restoration Plan Stream Assessment Report (Appendix C)

SECTION 6. POLLUTANT LOADING

Reference Watershed

The PA DEP TMDL section graciously assisted in development of this plan and calculated an estimate of the sediment reductions needed to achieve water quality standards and address stream impairments. The full document created by the DEP can be accessed in Appendix E. Prescribed reductions were made for the subwatershed using a Reference Watershed Approach. Because Pennsylvania does not have numeric water quality criteria for sediment, the "Reference Watershed Approach" method is used to estimate pollutant loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired for the same use. The loading rate in the unimpaired watershed is then scaled to the area of the impaired watershed to calculate necessary load reductions. The assumption is that reducing loading rates in the impaired watershed to the levels found in the reference watershed will result in progress toward eliminating siltation impairments.

To find a reference, DEP used GIS data layers largely consistent with the stream impairments noted in Pennsylvania's Integrated Report (DEP 2022b) to search for nearby watersheds that were similar to the AOI but lacked stream segments listed as impaired for Aquatic Life Use. Factors such as landscape position, topography, hydrology, soil drainage types, and land cover were used to screen for comparable watersheds. Benthic macroinvertebrate and physical habitat assessment scores were also reviewed to confirm that a reference was acceptable, and preliminary modelling was conducted to make sure that use of a particular reference would result in reasonable pollution reductions. Special emphasis was given to searching the Great Valley section of the Ridge and Valley Province as well as the Gettysburg-Newark Lowland section of the Piedmont Province since Spring Creek partially occurred in both.

Ontelaunee Creek occurring about 50 miles to the northeast of Spring Creek East (Figure), was selected as the reference watershed as it is primarily within the Great Valley Section of the Ridge and Valley Province and it was listed as supporting its Aquatic Life Use, despite having a high amount of agricultural land cover (Table). Various subwatersheds of Ontelaunee Creek have also been used as references in prior studies. The Ontelaunee Creek watershed was delineated at two different points to approximate the size of both the Spring Creek East watershed and AOI watershed. The larger Ontelaunee Creek delineation was also designed to avoid Leeser Lake as this feature may confound sediment and hydrologic modelling. Table contains a comparison of key watershed characteristics for the entire Spring Creek East and Ontelaunee watersheds, as well as the smaller AOI watershed in Spring Creek and its corresponding Ontelaunee Creek reference area.

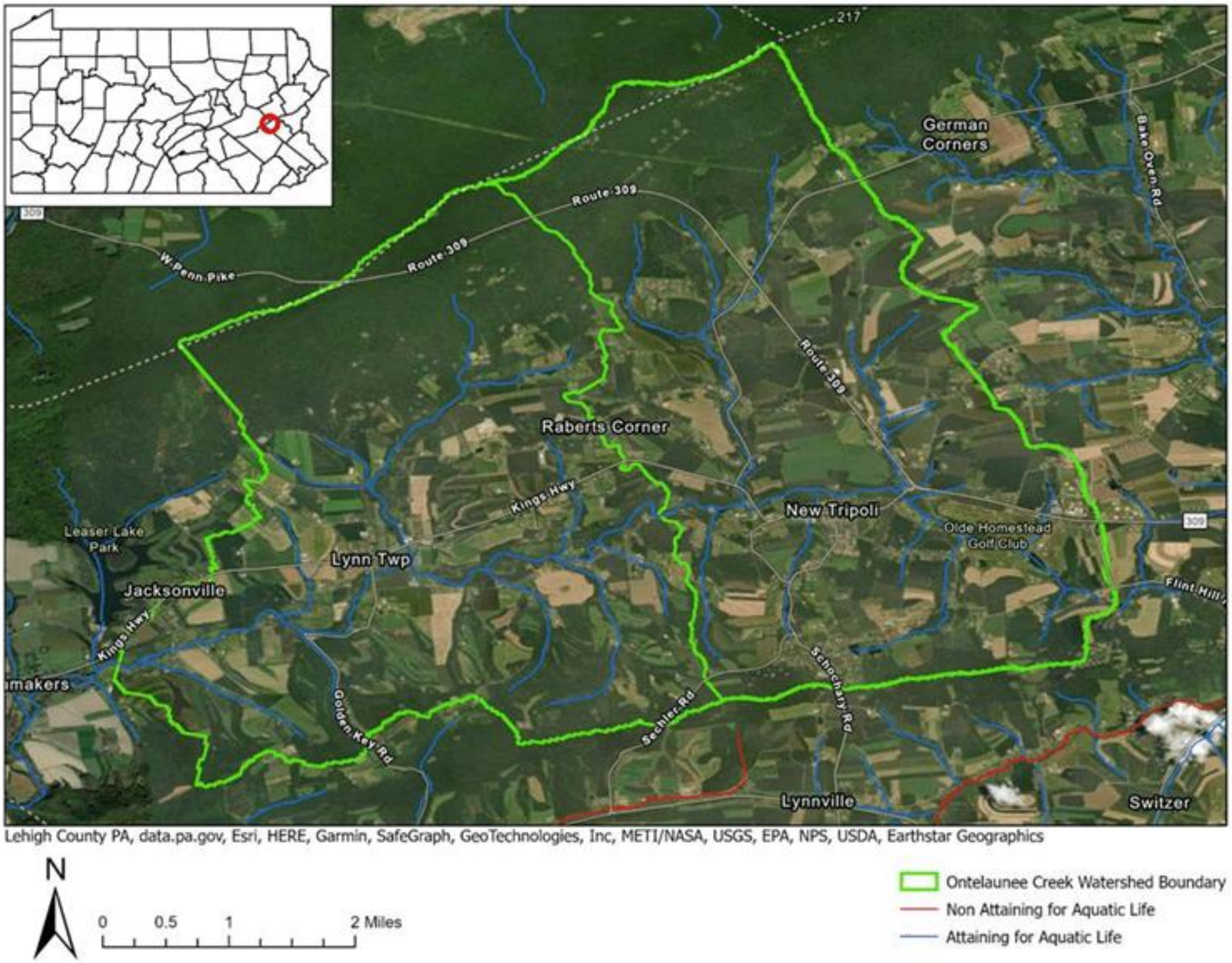

Figure 26. Ontelaunee Creek watershed. All stream segments within the delineated watersheds were listed as supporting their Aquatic Life Use per the 2022 Integrated Report viewer (DEP 2022)

The Spring Creek East and Ontelaunee Creek watersheds had substantial agricultural land cover, though the percentage was somewhat lesser in the Spring Creek East watershed (36% vs 49%). This can be attributed to the loss of agricultural lands to developed lands, which comprised approximately 50% of the Spring Creek East watershed area. In contrast, the Ontelaunee Creek watershed only had about 12% developed lands. For the AOI watershed and Ontelaunee Creek reference subwatershed the percentage of land in agriculture was close (52% vs 51%), while the developed land showed a greater difference (27% vs 14%). The AOI watershed had 21% of its land cover in natural vegetation, and the Ontelaunee Creek reference watershed had 35% of the land in natural lands.

While there was little room remaining for natural vegetation in the Spring Creek East watershed (13% of total land cover), substantial natural lands occurred in the Ontelaunee Creek watershed (40% of total land cover).

Table 24. Comparison of the Spring Creek East and Ontelaunee Creek watersheds

Watershed	Spring Cr. East	Ontelaunee Creek	AOI	Ontelaunee Reference
Physiographic Province[1]				
Gettysburg-Newark Lowland of Piedmont	33	-	56	-
Great Valley of Ridge and Valley	67	83	44	86
Blue Mountain of Ridge and Valley		17		14
Land Area (ac)	15,314	13,326	6,758	6,723
Landuse[2] **(%)**				
Agriculture	36	49	52	51
Forest/Natural Vegetation	13	40	21	35
Developed	50	12	27	14
Soil Infiltration[3] **(%)**				
A	14	12	22	15
B	72	65	64	62
B/D	1	5	3	4
C	10	7	6	8
C/D	1	0	1	0
D	2	11	4	10
Dominant Bedrock[4] **(%)**				
Argillaceous Limestone	3	-	-	-
Diabase	1	-	2	-
Dolomite	4	-	-	-
Graywacke	-	28	-	39
High-Calcium Limestone	2	-	-	-
Limestone	55	-	44	-
Quartz Conglomerate	5	-	10	-
Sandstone	6	3	8	2
Shale	3	69	-	59
Silty Mudstone	20	-	36	-
Average Precipitation[5] **(in/yr)**	41.5	39.9	41.5	39.9
Average Surface Runoff[5] **(in/yr)**	4.4	2.1	2.8	2.3
Average Elevation[5] **(ft)**	471	696	484	727
Average Slope[5] **(%)**	4	9	4	8
Average Stream Channel Slope[6] **(%)**				
1st order	2.2	2.5	2.2	2.4
2nd order	0.7	1.2	1.0	1.1
3rd order	0.4	0.5	0.4	0.6
4th order	0.3	0.2	0.0	-

[1]Per pags_physsections2008 GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources
[2]Based on MMW output utilizing NLCD 2019
[3]Based on MMW output utilizing USDA gSSURGO 2016. A = high infiltration soils; B=moderate infiltration soils, C= slow infiltration soils and D= very slow infiltration soils.
[4]Per Bedrock_V GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources.
[5]Hydrologic and terrain variables were generated by MMW.
[6]MMW output based on USGS high-resolution NHD flowlines

Soil drainage classes for both watersheds were dominated by moderate infiltration soils, but the Spring Creek East watershed had a much higher surface runoff rate (4.4 versus 2.1 inches per year) that is likely driven by its greater amount of developed lands.

Differences in bedrock geology also exist between the watersheds, especially in that the Spring Creek East watershed has higher amounts of limestone than the Ontelaunee Creek watershed. PA DEP noted that because karst geology has such a strong influence on a watershed's hydrogeologic characteristics, use of a karst reference would be ideal. However, finding such a large, similarly low-gradient karst reference in Pennsylvania is problematic because Aquatic Life Use impairments in such areas is typical, as karst geology produces some of the state's best agricultural soils.

As noted in Section 2, stream segments within the Spring Creek East watershed are designated Warm Water Fishes, Migratory Fishes. Stream segments within the Ontelaunee Creek watershed are designated Cold Water Fishes, Migratory Fishes at 25 Pa. Code § 93. However, given the considerable amounts of karst geology in the Spring Creek East watershed and the presence of wild trout, the Warm Water Fishes designation may largely reflect anthropogenic impacts, and restoration may help restore a cold-water community. Neither watershed had stream segments that are designated for special protection.

DEP field observations suggest that restoration of the AOI watershed may be the most feasible way to improve the mainstem of Spring Creek East from the Hershey area downstream. For one, the siltation impairments within the AOI watershed appeared to be far worse than what was observed in other parts of the watershed. Secondly, removing dams and legacy sediments and improving agricultural practices are all technically feasible and with little downside apart from their expense. Finally, the fact that both of the major tributaries outside of the AOI watershed appear to infiltrate completely before flowing into the mainstem makes their role as sediment sources to the downstream areas unclear. If much of the sediment load that is carried by these tributaries is lost upon infiltration, or if soils within these subwatersheds tend not to runoff into streams because they are underground, then restoration may have little effect on downstream areas, even if beneficial locally. Thus, in consideration of severity, feasibility, and hydrology, it is suggested that highest priority should be given to restoring the AOI watershed.

PA DEP Prescribed Overall Sediment Reductions Needed

The existing annual average sediment loading in the subwatershed modeled using a no existing BMPs scenario and was estimated to be 5,850,363 pounds per year (2,925 tons per year). To meet water quality objectives, it was determined that annual average sediment allowable loading (AL) should be reduced by 42% to 3,400,477 pounds per year (1700.2 tons per year). To achieve these reductions while maintaining a 10% margin of safety, it was estimated that the annual average loading from croplands should be reduced by 53%, while loading from streambanks, hay/pasture lands and developed lands should each be reduced by 36%. Allocation of annual average sediment allowable loading among the restoration plan variables is summarized in Table . All values are annual averages in lbs/yr.

Table 25. Summary of variables for the AOI watershed

Subwatershed	AL (lbs/yr)	UF (lbs/yr)	SL (lbs/yr)	LNR	ASL
AOI	3,400,477	340,048	3,060,429	38,585	3,021,845

AL=Allowable Load

UF = Uncertainty Factor

SL = Source Load; the SL is further divided into LNR = Loads Not Reduced and ASL= Adjusted Source

DEP Calculation of Allowable Loading

The estimated mean annual sediment loading rates were 504 lbs/(ac*yr) in the Ontelaunee Creek reference watershed and was substantially lower than the estimated mean annual loading rates in the impaired Spring Creek AOI watershed at 866 lbs/(ac*yr) (Table). Thus, to achieve the loading rates of the unimpaired watershed, sediment loading in the AOI watershed should be reduced by 42% to 3,400,477 lbs/yr (Table 27).

Table 26. Existing annual average loading values for the AOI watershed and the Ontelaunee Creek reference watershed

Land Cover	AOI			Ontelaunee Creek		
	Acres	Sediment (lbs/yr)	Sediment lbs/(ac*yr)	Acres	Sediment (lbs/yr)	Sediment lbs/(ac*yr)
Hay/Pasture	1,274	426,107	334	765	245,426	321
Cropland	2,269	4,089,212	1,802	2,674	2,683,119	1,003
Forest	1,348	1,790	1	2,279	2,028	1
Wetland	27	57	2	44	103	2
Open Land	15	475	32	20	499	25
Bare Rock	2	1	1	-	1	-
Low Density Mix Dev	1,563	19,197	12	825	10,132	12
Med Density Mix Dev	205	13,736	67	81	5,752	71
High Density Mix Dev	49	3,319	67	17	1,202	70
Stream Bank		1,296,461			542,966	
Riparian Buffer Discount					-116,307	
Point Sources		8			1,933	
Total	**6,753**	**5,850,363**	**866**	**6,706**	**3,376,854**	**504**

Table 27. Annual average allowable loading in the AOI watershed

Subwatershed	Reference Loading Rate (lbs/(ac*yr))	Land Area (ac)	Target AL (lbs/yr)
AOI watershed	504	6,753	3,400,477

Calculation of the Uncertainty Factor and Source Load

In the ARP equation, the Allowable Load (AL) is comprised of the Source Load (SL), which accounts for all significant natural and anthropogenic sources of the pollutant, plus an Uncertainty Factor (UF). Thus:

AL = SL + UF

Reserving a portion of the load as a UF requires further load reductions from targeted sectors to achieve the AL. For this analysis, the UF was explicitly designated as ten percent of the AL based on professional judgment. Thus:

Spring Creek East: 6,288,428 lbs/yr AL * 0.1 = 628,843 lbs/yr UF
AOI watershed: 3,400,477 lbs/yr AL * 0.1 = 340,048 lbs/yr UF

Then, the SL is calculated as:

Spring Creek East: 6,288,428 lbs/yr AL – 628,843 lbs/yr UF = 5,659,585 lbs/yr SL
AOI watershed: 3,400,477 lbs/yr AL – 340,048 lbs/yr UF = 3,060,429 lbs/yr SL

Calculation of the Adjusted Source Load

In the ARP equation the SL is further divided into the Adjusted Source Load (ASL), which is comprised of the sources causing the impairment and targeted for reduction, as well as the loads not reduced (LNR), which is comprised of the natural and anthropogenic sources that are not considered responsible for the impairment nor targeted for reduction. Thus:

SL =ASL + LNR

Therefore, before calculating the allowable loading from the targeted sectors, the LNR must also be defined.

Since the impairments addressed by this WIP were for sedimentation due to agriculture and development, sediment contributions from forests, wetlands, non-agricultural herbaceous/grasslands, bare rock and point sources within the Spring Creek East watershed were considered loads not reduced (LNR). However, within the AOI watershed, the same categories plus developed lands were considered LNR, as the focus of this area is agriculture and streambanks rather than developed lands.

LNR was calculated to be 38,585 lbs/yr in the AOI watershed and 4,848 lbs/yr in the Spring Creek East watershed (Table 28. Source load, loads not reduced, and adjusted source loads). All values were expressed as annual average lbs/yr.

Table 28. Source load, loads not reduced, and adjusted source loads

Source Load (SL)	3,060,429
Loads Not Reduced (LNR)	
Forest	1,790
Wetland	57
Open Land	475
Bare Rock	1
Low Density Mixed Dev	19,197
Medium Density Mixed Dev	13,736
High Density Mixed Dev	3,319
Point Sources	8
Total LNR	38,585
Adjusted Source Load (ASL)	3,021,845

Then, the ASL is calculated as:

Spring Cr. East.: 6,288,428 lbs/yr SL – 4,848 lbs/yr LNR = 5,654,737 lbs/yr ASL
AOI watershed: 3,060,429 lbs/yr SL – 38,585 lbs/yr LNR = 3,021,845 lbs/yr ASL

Calculation Of Sediment Load Reductions by Source Sector

To calculate prescribed load reductions by source, the ASLs were further analyzed using the Equal Marginal Percent Reduction (EMPR) allocation method described in Appendix E. Although the AOI watershed WIP was developed to address impairments caused by agriculture and development, streambanks were also significant contributors to the sediment load, and such erosion rates are influenced by agriculture and development. Thus, streambanks were included in the ASLs and targeted for reduction (**Error! Reference source not found.**).

For the AOI watershed area, croplands exceeded the ASL by itself, thus it received a greater percent reduction (53%) than hay pasture lands or streambanks (36% each). Note however, the prescribed reductions by source sector are simply suggested targets and not rigid goals that must be met. During implementation, greater or lesser reductions can be made for each source sector, so long as the overall ASL is achieved.

Table 29. Annual average sediment load allocations for source sectors in the AOI watershed

Source	Load Allocation lbs/yr	Current Load lbs/yr	Reduction Goal %
Cropland	1,924,695	4,089,212	53%
Hay/Pasture Land	271,399	426,107	36%
Streambank	825,751	1,296,461	36%

Pollutant Modeling and Cost Estimates

Model My Watershed (MMW) was used to estimate the total phosphorus (TP), total nitrogen (TN), and total sediment loads for the AOI 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, 2022). MMW estimates loads for three different conditions, representing three different points in time:

* *Baseline* represents loads exported by MMW, without BMPs entered into the model. In this watershed plan, there are currently no TMDL loading baselines.
* *Existing* reflects loads with BMPs implemented prior to 2023.
* *Future* represents conditions with all of the BMPs implemented in the Existing condition, in addition to BMPs that were or identified as a part of this project.

Pollutant modeling was done using the Model My Watershed BMP spreadsheet tool.[3] The information required to characterize the watershed (land cover breakdown, count of animals, and stream length) and associated pollutant load estimates were generated using the online version of the model. That data was input into the spreadsheet tool to develop the pollutant removal estimates for stormwater retrofits and agricultural practices. The data tables can be found in Appendix D.

A limitation of MMW is that not all potential projects identified in the watershed have a corresponding category and assigned loading rate in the model. This was true primarily for the agricultural practices identified, as some of the project types listed in Table 17 do not have a comparable category in MMW or an assigned reduction coefficient and were not used in calculating sediment reduction loads. This means that there may be current practices providing additional sediment reductions that are not reflected in the model numbers.

[3] https://github.com/WikiWatershed/MMW-BMP-spreadsheet-tool

Cost estimates for stormwater retrofits and agricultural practices were developed using the construction estimates based on Chesapeake Bay Assessment Tool (CAST) Cost Profiles for Pennsylvania. CAST bases the implementation cost and maintenance cost using the drainage area treated by the BMP practice. Stormwater retrofit estimates capped the drainage area treated at the 1-inch storm for water quality to ensure the cost estimates were more accurate to the size of the BMP practice. The implementation cost also includes design cost which is based on an 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.

Model Input Data

Drainage Area Boundaries

The MMW model platform requires a drainage area boundary or point of interest from which to delineate a watershed. This boundary is then used to summarize both land cover (using data from the 2019 National Land Cover Classification Dataset, NLCD) and hydrologic soils group (HSG; from the SSURGO database) present in the watershed. For this plan, the AOI watershed delineation was provided by PA DEP using MMW (DEP, 2023 draft).

Stormwater Retrofit Data

Existing Conditions

Existing urban stormwater BMP data (Table 30. Existing Stormwater BMPs in the AOI watershed) was derived using data provided by the Milton Hershey School and field observations. The difficulty in securing data for existing practices resulted in the use of geospatial information to calculate both the size and drainage areas for existing BMPs. This means additional BMPs may be present, and a more thorough accounting of the watershed is recommended.

Table 30. Existing Stormwater BMPs in the AOI watershed

Project Name	BMP Type	Total TSS Removal (tons/yr)	Total Phosphorus Removal (lbs/yr)	Total Nitrogen Removal (lbs/yr)
CHSB-00001	Dry Detention Ponds and Hydrodynamic Structures	0.06	0.03	0.11
SWB-00025	Dry Detention Ponds and Hydrodynamic Structures	0.13	0.10	0.34
SWB-00026	Dry Detention Ponds and Hydrodynamic Structures	0.37	0.29	0.96
SWB-00027	Dry Detention Ponds and Hydrodynamic Structures	0.00	0.00	0.00
SWB-00032	Dry Detention Ponds and Hydrodynamic Structures	0.01	0.01	0.02
SWB-00033	Dry Detention Ponds and Hydrodynamic Structures	0.00	0.00	0.00
SWB-00034	Dry Detention Ponds and Hydrodynamic Structures	0.14	0.11	0.37
SWB-00037	Dry Detention Ponds and Hydrodynamic Structures	0.00	0.00	0.00

Table 30. Existing Stormwater BMPs in the AOI watershed				
Project Name	**BMP Type**	**Total TSS Removal (tons/yr)**	**Total Phosphorus Removal (lbs/yr)**	**Total Nitrogen Removal (lbs/yr)**
SWB-00043	Dry Detention Ponds and Hydrodynamic Structures	0.00	0.00	0.00
SWB-00044	Dry Detention Ponds and Hydrodynamic Structures	0.00	0.00	0.00
SWB-00047	Dry Detention Ponds and Hydrodynamic Structures	0.01	0.01	0.02
SWB-00049	Dry Detention Ponds and Hydrodynamic Structures	0.30	0.17	0.53
SWB-00050	Dry Detention Ponds and Hydrodynamic Structures	0.02	0.01	0.04
SWB-00051	Dry Detention Ponds and Hydrodynamic Structures	0.19	0.11	0.34
SWB-00052	Dry Detention Ponds and Hydrodynamic Structures	0.06	0.05	0.15
SWB-00065	Dry Detention Ponds and Hydrodynamic Structures	0.04	0.03	0.10
SWB-00066	Dry Detention Ponds and Hydrodynamic Structures	0.00	0.00	0.00
SWB-00067	Dry Detention Ponds and Hydrodynamic Structures	0.24	0.53	1.09
SWB-00069	Dry Detention Ponds and Hydrodynamic Structures	0.26	0.60	1.22
SWG-00001	Bioretention/raingardens - A/B soils, no underdrain	0.05	0.04	0.24
SWG-00002	Bioretention/raingardens - A/B soils, no underdrain	0.02	0.02	0.11
SWG-00004	Bioretention/raingardens - A/B soils, no underdrain	0.32	0.23	1.47
SWG-00060	Bioretention/raingardens - A/B soils, no underdrain	0.75	0.44	2.61
SWM-00002	Filter Strip - Runoff Reduction	1.43	0.79	1.84
SWRB-00001	Dry Detention Ponds and Hydrodynamic Structures	0.02	0.01	0.03
SWRB-00002	Dry Detention Ponds and Hydrodynamic Structures	0.27	0.21	0.70
SWRB-00003	Dry Detention Ponds and Hydrodynamic Structures	0.22	0.14	0.44
SWRB-00004	Dry Detention Ponds and Hydrodynamic Structures	0.01	0.01	0.02
SWRB-00005	Dry Detention Ponds and Hydrodynamic Structures	0.00	0.00	0.00
SWRB-00006	Dry Detention Ponds and Hydrodynamic Structures	0.03	0.02	0.06
SWRB-00007	Dry Detention Ponds and Hydrodynamic Structures	0.00	0.00	0.00
SWRB-00008	Dry Detention Ponds and Hydrodynamic Structures	0.11	0.07	0.21
SWRB-00009	Dry Detention Ponds and Hydrodynamic Structures	0.00	0.00	0.00

Table 30. Existing Stormwater BMPs in the AOI watershed				
Project Name	**BMP Type**	**Total TSS Removal (tons/yr)**	**Total Phosphorus Removal (lbs/yr)**	**Total Nitrogen Removal (lbs/yr)**
SWRB-00010	Filter Strip - Runoff Reduction	0.05	0.03	0.07
	Totals	**5.11**	**4.06**	**13.09**

The equation used to estimate the drainage area or volume treated was slightly different for each BMP, and the calculations used the MMW defaults of Low-Density Mixed (15% impervious cover) Medium-Density Mixed (52% impervious cover) or High-Density Mixed (87% impervious cover).

Since MMW is based on curves that assume by default a 1" treatment depth, the area treated for structural stormwater BMPs assumed this treatment depth to normalize the drainage area. The area treated is calculated in Equation 1.

Equation 1. Calculation for drainage area treated by stormwater BMPs

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

where:
DA_{SW-BMP} = Drainage Area (acres)
V=Treatment Volume (cf)
d =Assumed Treatment Depth (1 inch)
I=Assumed Impervious Cover Fraction (0.87)Z
3,630=Conversion factor from (ac-in) to cf

Future Conditions

Future urban BMP data for the AOI (Table 31) was provided from stormwater BMP opportunities identified during stormwater retrofit field work (see Stormwater Retrofit Reconnaissance Inventory (RRI)" section). 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 31. Stormwater retrofits identified in the Spring Creek East watershed inside the AOI area								
Location Name	**ID**	**BMP Type**	**Drainage Area Treated (acres)**	**Total TSS Removal (tons/yr)**	**Total Phosphorus Removal (lbs/yr)**	**Total Nitrogen Removal (lbs/yr)**	**Cost $ (Design, Construct) ***	**Maintenance Cost Per Year****
Milton Hershey School Memorial Hall	8A	Dry Extended Detention Pond	4.5	0.82	0.21	1.41	$20,499.68	$170.71
Milton Hershey Elementary School	9A	Bioretention/ raingardens A/B soils, underdrain	4.8	1.22	0.90	5.56	$77,700.89	$3,295.57
Milton Hershey School Pennland Lane and Brook Drive	11A	Bioretention/ raingardens A/B soils, underdrain	5.90	1.51	1.11	6.85	$376,552.07	$16,842.63
Milton Hershey School Harvest Lane and Homestead Lane	13A	Bioretention/ raingardens A/B soils, underdrain	7.53	1.92	1.41	8.74	$479,129.77	$21,492.53
Hershey Christian Academy	17A	Bioretention/ raingardens A/B soils, underdrain	0.81	0.21	0.15	0.94	$55,916.59	$2,308.07
Conewago Church of The Brethren	27A	Bioretention/ raingardens A/B soils, underdrain	0.27	0.07	0.05	0.32	$10,930.97	$268.85
		Totals	**23.81**	**5.75**	**3.83**	**23.82**	**$1,020,729.97**	**$44,378.36**

* 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 percentage of water quality volume per BMP.

Agricultural BMP Data

Generalized existing agricultural BMP information was provided by the USDA-NRCS Dauphin Field Office using information from the Practice Keeper database, and results from a 2024 Tillage survey by PSU. Specific locations were not included with the data for privacy reasons, and as a result Agricultural BMPs in the subwatershed are provided in more general acres of practice implemented. The amount of implementation for existing practices (Table 32. Existing agricultural BMPs with estimated pollutant reductions) is based on field observations and conservation plan estimates for Hershey Trust related lands in the subwatershed. The amount of implementation was quantified by relating the NRCS Name in Practice Keeper to the equivalent name in MMW. Not all practices identified in the field assessment (Table 18) have a comparable category in

MMW and are not included in the calculation of sediment reductions but may also be contributing to reduced loading.

Table 32. Existing agricultural BMPs with estimated pollutant reductions					
BMP	**Unit**	**Amount**	**Sediment Reduction (tons/yr)**	**Nitrogen Reduction (lbs/yr)**	**Phosphorus Reduction (lbs/yr)**
Cover Crops	Acres	690	62.6	988.5	42.6
Conservation Tillage, 30% - 59% residue	Acres	30	11.2	19.5	16.7
Conservation Tillage, >60 residue	Acres	1238	886.7	1,128.6	1,050.2
Total		1958	960.5	2,136.6	1,109.5
* Assuming acres currently in other levels of tillage residue are converted to 60%					

Future agricultural BMPs (Table *33*. 33) were credited using data provided by PSU from their agricultural field assessment. 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 potential overestimation of BMP implementation and correct for double counting restrictions, a conservative approach was used where the reduction efficiency of a practice in MMW determined the number of acres entered. Practices where double counting is not allowed (cover crops and conservation tillage) were adjusted so the maximum amount of the practice with a higher reduction coefficient was entered and a corresponding reduction in the other practices was made to keep the model from entering negative territory when error checking was done. Project implementation funding cannot be used for conservation tillage and cover crops projects through the 319 program, so another source of funding as outlined in Section 8 will be needed for these projects

Table 33. Proposed agricultural BMPs with estimated pollutant reductions and costs						
Proposed BMP	**Unit**	**Amount**	**Sediment Reduction (tons/yr)**	**Nitrogen Reduction (lbs/yr)**	**Phosphorus Reduction (lbs/yr)**	**Cost ($)**
Cover Crops	Acres	126	11.4	180.51	7.8	$9,513.0
Conservation Tillage, >60	Acres	182	130.4	141.3	131.5	$0.0
Riparian Grass Buffers	Acres	102	181.5	1,425.59	267.55	$91,713.3
Total		410	323.3	1,747.4	406.85	$101,226.30
* Assuming acres currently in other levels of tillage residue are converted to 60%						

Stream Restoration

Stream restoration projects identified by EPR during the field assessment were credited as an Agricultural BMPs. MMW defines stream restoration as 'streambank stabilization' and applies a pollutant reduction (lb/ft) based on the feet of stream stabilized.

There were no current stream restoration projects identified as completed in the target AOI as of the date of this WIP. For the modeling effort using MMW, only those streams rated as a high priority and located on Milton Hershey School or Trust Property were assessed to calculate future load reductions for sediment. Table 34. Proposed high priority stream restoration sites with estimated pollutant reductions and costsincludes information on the estimated load reductions and potential costs for those high priority sites and Appendix C Section 5 provides a more detailed description of the actual stream restoration projects. Additional information has been added to the table with the estimated reductions if all the high priority reaches on private land were also implemented. These additional reductions are not included in the results for sediment loading reductions but are only provided to illustrate additional opportunities to

Table 34. Proposed high priority stream restoration sites with estimated pollutant reductions and costs					
Proposed Project Area	**Length (linear feet)**	**Sediment Reduction (tons/yr)**	**Nitrogen Reduction (lbs/yr)**	**Phosphorus Reduction (lbs/yr)**	**Cost ($)**
1	4,883	280.8	849.6	937.5	$2,929,800 - $3,906,400
2	4,563	262.4	794.0	876.1	$2,737,800 - $3,650,400
Total	**9,446**	**543.2**	**1643.6**	**1813.6**	**$5,667,600 - $7,556,800**

Results

MMW was used to estimate both current and future load reductions based on implementation of agricultural and stormwater best management practices that can prevent sediment from entering the stream system. Table 35. Summary of Existing and Future Sediment Load Reductions provides a summary of the predicted sediment load reductions based on the project type.

Table 35. Summary of Existing and Future Sediment Load Reductions		
Project Type	**Sediment Load Reductions**	
	Existing BMPs	**Future BMPs**
Agriculture BMP	960.5	323.3
Stormwater Retrofits	5.1	3.9
Stream Restoration	0	543.1
	965.6	870.3

The sediment reduction targets for the AOI watershed were expressed as a percent reduction from the baseline load. Agricultural areas contributed the highest sediment loads (77%), followed by stream bank erosion (22%). Loads from other land uses accounted for about 1% of the sediment loading. Based on the MMW modeling runs, the pollutant load reduction targets for sediment are achievable. The MMW results provide achievable overall reductions of approximately 63% for sediment from the initial model load estimates if all the proposed BMPS are implemented (Table 36).

Table 36. Estimated Reductions in Sediment loading (tons/year)	
Current	
Calculated Baseline Load No BMPs	2,925
Load Reduction with Existing BMPs	966
MMW % reduction from baseline	33%
Remaining Baseline Load[1]	1,959
Future	
Load Reduction with Proposed BMPs	870
MMW % reduction from baseline	30%
Remaining Baseline Load[2]	1,089
Targets	
DEP Allowable Load	1,700
Required Load Reduction[3]	1,225
Reduction Target (%) from baseline	42%
Load Reduction with Existing and Future BMPs	1,836

Table 36. Estimated Reductions in Sediment loading (tons/year)	
Overall Load Reduction achieved	63%
[1] This is the adjusted load with existing BMPs [2] This is the adjusted load with future BMPs [3] From DEP document (Appendix E)	

The analysis shows that to completely meet the sediment load reduction assigned by PA DEP (42% or 1,125 tons/year) a significant portion of the proposed future BMPs need to be implemented. While the focus of this plan is primarily on sediment reduction, the same BMPs used to address siltation problems also help with nutrient load reductions. The baseline and expected reductions for nitrogen and phosphorus are in Table 37. Phosphorus and nitrogen loading from MMW

Table 37. Phosphorus and nitrogen loading from MMW

MMW Loading	TN (lbs/yr)	TP (lbs/yr)
Baseline	82,635	7,137
Loads Removed w/Existing BMPs	2,150	1,113
Loads Removed w/Proposed BMPs	3,603	2,076
Total Load Reduction	5,753	3,190
Percent reduction from baseline	7.0%	44.7%

Section 7. Costs and Funding Resources

Estimated Costs

Estimated costs for implementation of all the recommended BMPs in this WIP range from $5,970,068.72 to $7,859,268.72 (Table 38). The range includes only those stream restoration projects that were found on Milton Hershey school or Hershey Trust properties, and does not include high priority stream restoration potentially located on private property Implementation of the recommended agricultural, stormwater and stream restoration practices will achieve the necessary sediment load reductions calculated by PA DEP. The bulk of the costs were from the high priority stream restoration projects with a total cost of $5,667,600 - $7,556,800. The estimated costs for implementation of agriculture and stormwater BMPs totaled $302,468.72. If all the additional high priority stream restoration projects located on private lands are also pursued, the total estimated costs would jump to $11,363,468.72 to $15,050,468.72.

Estimated costs for agriculture and stormwater BMPS were determined using capital costs per unit provided in the CAST Cost Profiles for the State of Pennsylvania (Appendix F). For stream restoration, the identified priority projects in the AOI watershed are comparable to several initiatives in the nearby Hammer Creek Watershed, both utilizing the Legacy Sediment Removal design approach. These similar projects provide valuable benchmarks for estimating unit costs, which range from $572 to $768 per linear foot of restoration. Consequently, for planning purposes, an estimated cost of $600 to $800 per linear foot should be considered for stream restoration projects using this design process in the Spring Creek Watershed.

Table 38. Estimated costs for BMP implementation in the AOI watershed

Urban BMP Type	Number of Practices	Unit Cost (per acre treated)	Total Cost
Bioretention/raingardens – A/B soils, underdrain	5	$39,377.89	$196,889.45
Dry Extended Detention Pond	1	$4,351.97	$4,351.97
Total Urban BMP Costs			**$201,241.42**
Agricultural BMP Type	**Area treated (acres)**	**Unit Cost (per acre treated)**	**Total Cost**
Cover Crops	126	$75.50/acre	$9,513.0
Tillage Management (High Residue)	182	$0.00/acre	$0
Riparian Grass Buffers	102	$899.15/acre	$91,713.30
Total Agricultural BMP Costs			**$101,226.30**
Stream Restoration Type	**Area treated (linear feet)**	**Unit Cost (per linear foot)**	**Total Cost**
High priority located on Milton Hershey School or Trust Property	9,446	$600 – $800	$5,667,600 - $7,556,800
Total Costs All Modeled Projects*	**$5,970,068.72 to $7,859,268.72**		

* If high priority stream restoration projects located on private l are also implemented, costs then total cost would jump to $11,363,468.72 to $15,050,468.72

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 account for inflation, maintenance, etc. All costs are estimates and it is recommended that a detailed cost analysis is provided prior to requesting funding for a proposed BMP.

Funding

There are many financial assistance programs which may provide funding for project implementation activities within the AOI watershed. This includes both federal and state funding, as well as some nonprofits that may provide monetary assistance. Many of the programs involve cost sharing, and some may allow the local contribution of materials, land, and in-kind services (such as construction and staff assistance) to cover a portion or the entire local share of the project. These programs are presented in Table 39.

Table 39. Funding sources for BMP implementation

Grant Name (Linked)	Agency	Activities Funded	BMPS Funded
319 Nonpoint Source Management Program	US EPA through PA DEP	Watershed plan development; implementation of projects in approved watershed plans. The 319 program primarily funds BMP implementation in priority 1 sites first, however, priority 2 or lower projects could be funded if there is significant justification for a new/unforeseen opportunity or environmental benefit.	Ag BMPs, Stream Restoration
Agricultural Management Assistance	NRCS	A program that helps agricultural producers manage financial risk through diversification, marketing, or natural resource conservation practices.	Ag BMPs
Agriculture Conservation Assistance Program	PA DOA	The Agriculture Conservation Assistance Program (ACAP) provides financial and technical assistance for the implementation of best management practices (BMPs) on agricultural operations within the Commonwealth.	Ag BMPs
Chesapeake Small Watershed Grants	NFWF	Water quality and habitat restoration project implementation	Ag BMPs, Stormwater BMPS Stream Restoration
Clean Water State Revolving Fund (CWSRF)	PENNVEST	Provides low interest financing for projects related to wastewater collection, treatment or disposal facilities, stormwater management, and nonpoint source pollution controls. Installation of agricultural BMPs and watershed management qualify.	Ag BMPs, Stormwater BMPS
Clean Water Procurement Program	PENNVEST	The Clean Water Procurement Program provides for the purchase of verified nutrient or sediment reduction through a competitive bidding process to improve water quality from the installation of best management practices to help achieve the most current total maximum daily load limits.	Ag BMPs, Stormwater BMPS
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.	Ag BMPs,
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.	Ag BMPs,

Table 39. Funding sources for BMP implementation

Grant Name (Linked)	Agency	Activities Funded	BMPS Funded
Conservation Reserve Enhancement Program (CREP)	Farm Service Agency	Provides a yearly payment to farmers who remove erodible and flood-prone land from agricultural production and covers costs for reforesting and replanting to control erosion and provide wildlife habitat.	Ag BMPs,
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.	Ag BMPs,
Consumptive Use Mitigation Grant Program	Susquehanna River Basin Commission	This is a competitive grant program offering grant funds for projects that reduce water use or increase water availability during critical low flow periods to help prevent water quality impacts and support ecological flow needs throughout the Susquehanna Basin.	Ag BMPs, Stormwater BMPS
County Action Plan (CAP) Implementation Grant	PADEP	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.	Ag BMPs, Stormwater BMPS,
Environmental Quality Incentives Program (EQIP)	NRCS	Works one-on-one to develop a plan that outlines conservation practices and activities to help solve on-farm resource issues.	Ag BMPs
Growing Greener	PA DEP	Growing Greener provides funding for farmland-preservation projects; protecting open space; eliminating the maintenance backlog in watersheds; helping communities address land use; and provide for new and upgraded water and sewer systems.	Ag BMPs, Stormwater BMPS
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	Ag BMPs
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.	Ag BMPs
Resource Enhancement and Protection Program (REAP)	PDA	REAP enables farmers, businesses, and landowners to earn PA income tax credits to offset the cost of implementing conservation practices that reduce nitrogen, phosphorus, and sediment pollution.	Ag BMPs
Stream & Watershed Enhancement Grant Program	Susquehanna River Basin Commission	The Stream & Watershed Enhancement Grant program provides funding for community-based environmental and water resources projects or events that improve, restore, or protect Susquehanna River Basin local watersheds.	Stream Restoration
Watershed Restoration and Protection Program (WRPP)	PA DCED	PA Department of Community and Economic Development WRPP grants to restore and maintain stream reaches impaired by the uncontrolled discharge of nonpoint source polluted runoff and ultimately to remove these streams from the Department of Environmental Protection's Impaired Waters list.	Stream Restoration

Section 8. Education and Outreach

The AOI WIP is the first plan developed in the Spring Creek East watershed. Engagement with the residents in the watershed will be important in developing stakeholder buy-in for potential projects. Education and outreach activities are a vital component to building community support for projects to help reach WIP target reduction goals. Partners from state, regional, and local entities need to be involved in education and outreach efforts, and outreach activities need to focus on the impact of individual actions on watershed habitat. Everyone who lives in Spring Creek East watershed is a stakeholder, especially the landowners who have property directly impacted by flooding, and the people and businesses who benefit from recreational tourism.

Education efforts in the AOI watershed need to identify common themes and messages that can then be tailored to target audiences. The general public, area businesses and landowners, farmers, and municipal officials are all target audiences. Target audiences often have preferred methods for receiving and acting on information, so the use of multiple avenues of message distribution is recommended. Table 40 provides an overview of possible target audiences, their potential water quality related interests and concerns, and communication channels to best engage with each audience.

Table 40. Example targets for education efforts in the AOI watershed

<table>
<tr><th>Target Audience</th><th>Potential Audience Concerns</th><th>Communication Channels</th></tr>
<tr><td>General public</td><td>• Livability for current and future generations
• Quality of habitat
• Recreation opportunities
• Flooding</td><td rowspan="3">• Newspapers
• Websites
• Social media
• Community/civic groups and events
• Local media
• Local government
• Conservation Districts</td></tr>
<tr><td>Landowners</td><td>• Property values
• Flooding</td></tr>
<tr><td>Local businesses</td><td>• Property values
• Promoting tourism
• Flooding</td></tr>
<tr><td>Agricultural (livestock and crop) community</td><td>• Manure and nutrient management
• Fertilizer use and regulations
• Tillage practices
• Funding/cost share opportunities
• Flooding</td><td>• Crop Advisors
• 4-H groups
• Word of mouth
• Demonstration projects
• Newspapers
• DCCD and LCCD training events
• PSU Extension events</td></tr>
<tr><td>Elected officials and County staff</td><td>• Compliance with current regulations
• Potential additional programmatic and regulatory requirements
• Technical and financial support
• Property values and revenue</td><td>• State agencies
• Other local governments
• County Commissioners Association of Pennsylvania
• Pennsylvania State Association of Elected County Officials
• Conservation Districts</td></tr>
</table>

Existing Education and Outreach

Existing Organizations

The Spring Creek East watershed has a number of organizations that can assist with education and outreach associated with the plan. An active watershed association called the Spring Creek East Watershed Alliance (SCEWA) is currently being developed to help with protecting and restoring the Spring Creek East watershed. The SCEWA is a nonprofit volunteer organization founded in 2024 and committed to the mission of restoring, improving, and maintaining the Spring Creek watershed for a sustainable, ecologically diverse, and recreationally friendly environment. It is envisioned that this group will be the primary driver for public outreach and education in the Spring Creek East watershed with support from other organizations with a presence in the watershed.

Additional education and outreach partners include Penn State Extension, DCCD, LCCD, and the Doc Fritchey Chapter of Trout Unlimited. DCCD, LCCD, and Penn State Extension are already active in the watershed, both working directly with the agricultural community and applying for grants for implementation. The Conservation Districts work directly with farmers to educate and install conservation practices and also support education efforts to a range of audiences on subjects such as protecting water resources, stormwater management, and erosion and sediment control. Several programs through the Penn State Extension office are active in Dauphin and Lebanon County and in the watershed. One program is the Penn State Master Watershed Steward Program, designed to educate and empower volunteers to protect environmental resources. Training and volunteer services are coordinated by extension staff, partners, or trained volunteers. To become a certified Master Watershed Steward, volunteers must complete a minimum of 40 hours of training and fulfill 20 hours of volunteer service. For each subsequent year, volunteers can maintain their certification by giving at least 20 additional volunteers hours and attending at least 10 hours of continuing education annually. More information on the Master Water Steward Program is available: https://extension.psu.edu/programs/watershed-stewards. There is also a Future Master Watershed Stewards focused on youth groups providing education on water properties, water use and conservation, and water quality using existing project and curriculum materials provided by Penn State Extension and DCNR along with activities from other science-based resources. The Extension also has a collection of articles, webinars, workshops, and other resources focused on multiple topics including watershed protection and restoration,

Other organizations that can assist include the Swatara Watershed Association, which is also active in the area, as Spring Creek East does drain to Swatara Creek; Manada Conservancy which has volunteer opportunities, native plant sales, and can provide speakers on topics relating to land preservation, conservation, and gardening with native plants. The Derry Township Municipal Authority also provides information on stormwater management and their offices are located within the watershed so they may be willing partners in educational efforts. Milton Hershey School includes Agricultural and Environmental Education in their curriculum, and this could represent an avenue for spreading the word about watershed stewardship and protecting local streams. There may also be an opportunity to partner with the school for individual restoration projects such as tree planting as well as volunteer monitoring.

Stakeholder Meeting

As part of this project, two stakeholder meetings were held. The first meeting was in January 2023 prior to field assessments to help identify potential locations for project implementation. The meeting was held at the Hershey Historical Society, and presentations were provided by PSU, CWP, DCCD, and TU. The meeting was well attended, with a turnout of more than 35 residents of the watershed. The residents were able to participate by asking questions to each presenter, as well as participating in selecting field sites to visit by reviewing watershed maps and placing pins on maps to indicate locations pertaining to both areas of known impacts (i.e., flooding, bank erosion), special places in need of preservation, and potential locations for projects such as rain gardens. This feedback was incorporated into the final site selection for both the stormwater retrofit and stream restoration field assessments.

The second meeting was held in October 2024 to present the findings of the field work and calculations of potential reductions to the SCEWA and other interested stakeholders. The meeting was held at the Derry Municipal Township Authority (DTMA) conference room in Hershey, PA. Fifteen stakeholders attended the meeting and provided insight into problems they were facing with regards to flooding issues as well as exploring the continued formation of the new watershed association and possible project implementation.

Education and Outreach Metrics

This WIP provides recommended outreach and educational activities that can be conducted in the AOI to meet plan goals. Currently, multiple partner organizations maintain websites that provide valuable watershed and agriculture related information for the public including soil testing and links to sources of information on public participation events in the watershed. Adding information on the new SCEWA to all partner websites should be a high priority as a recommendation. Visibility for the group is important to ensure staying power and increase members and attendance at future planned events.

The measures of success for the outreach efforts are straightforward as this plan will help lay the groundwork for any additional future WIP plans and help to better understand the most effective engagement techniques. Table 41 provides example methods and metrics to document progress in educating the general public about the AOI watershed and improvements in stream health. Successful outreach will be measured using these three indicators:

- Strong attendance in project-related meetings and community events. Measures could include the number of meetings with landowners, and the number of interactions with the public.
- An increase in the number of landowners implementing recommended practices on their property.
- Positive increase in public awareness of the Spring Creek East watershed through surveys and coverage in public media outlets, like news articles, social media, website visits, and community presentations.

Table 41. Outreach methods and metrics for the AOI watershed

Outreach Approach	Partners	Outreach Methods	Number of Contacts/ Possible Venues
One-on-One Farmer Engagement Education and technical assistance to advance water quality BMPs on working Agriculture Lands	DCCD, LCCD, NRCS, Penn State Agricultural Extension	Demonstration Projects, In person meetings	Meet with 5 farmers annually, install 2-3 projects in the first 5 years after official WIP approval
One-on-One Municipal Engagement Onsite or offsite education to enhance knowledge of water quality BMPs on agriculture and urban land uses.	SCEWA, DCCD, Trout Unlimited, Penn State Agricultural Extension	Presentations at meetings In person meetings	Quarterly presentations on plan progress at Board of Supervisors Meetings
Specific or Broad Audience Engagement Targeted or stakeholder outreach on water quality concerns in the watershed	SCEWA, DCCD, LCCD	Websites Social media Community/civic groups and events	Fair (annual event), Presentations to school classrooms (2 per year), Development of SCEWA website
Regional Partnerships Development of cross watershed and cross county partnerships.	Swatara Watershed Association	Meeting participation	Participation in the regional CAP planning effort

Table 41. Outreach methods and metrics for the AOI watershed			
Outreach Approach	**Partners**	**Outreach Methods**	**Number of Contacts/ Possible Venues**
	Manada Conservancy, Regional CAP planning with Counties		
Adaptive Management Practices Stakeholders will be involved in evaluating the WIP to make changes and adapt the plan over time.	Interested Stakeholders from the watershed	Newspapers, Websites, Social media	One annual meeting

Section 9. Implementation Schedule and Milestones

A key part of all WIPs are interim milestones that provide evaluation points and demonstrate progress over time. Milestones may not only be documented by changes in water quality, but also measure program implementation steps that help direct resources in an effective way. A multi-year implementation schedule is assumed and divided into three phases: short term, medium term, and long term. For this plan, short-term is considered 1 – 2 years, medium-term is 3 – 5 years, and long-term is 5-8 years. Each phase will rely on an adaptive management approach and will build upon previous phases. The plan recommendations are summarized below, and Table 42. Implementation schedule and milestones lists the recommendations with a suggested timeframe for implementation, partners, and milestones.

Overall Plan Recommendations

1. **Finalize the formation of the SCEWA as the primary watershed association.**
   The creation of this new group will allow local residents to assume a more hands-on role in project implementation. The group's first role will be to raise awareness of the issues in the watershed and relay information to residents on actions they can take to help improve water quality. This can include public engagement events such as tree plantings and trash removal events while they prepare larger proposals for more complex restoration projects.

2. **Document practices in the watershed in a centralized database.**
   An updated and centralized accounting of practices will help with tracking implementation progress and evaluating sediment reduction values in the future. This should include any stormwater structural treatment practices and conservation practices on agricultural lands implemented to keep a permanent record moving forward. Project tracking is a potential role for SCEWA. The MMW spreadsheet tool could be used to track implementation of some stormwater projects and evaluate estimated sediment reductions. Another database (Practice Keeper) is used by the conservation districts and NRCS to track stormwater BMPs associated with Chapter 102 permits, and restoration and conservation practices on agricultural lands. Although this information is not publicly available, the local NRCS office or DCCD might be able to share more generalized information on the amount of acres of agricultural land where conservation practices are being implemented to estimate pollutant load reductions.

3. **Implement prioritized agricultural BMPs for water quality improvement.**
   The priority agricultural BMPs throughout the watershed include stream side buffers, tillage management (High Residue), and cover crops. The acres of implementation and estimated sediment reduction associated with these practices are provided in Section 6. Pollutant Loading. The increase in agricultural practice implementation will be a critical component to achieving the required sediment reductions since currently agricultural lands account for the highest sediment loads in the AOI watershed.

4. **Engage landowners through outreach to the entire watershed.**
   The DCCD and LCCD along with Penn State extension are the lead organizations working with agricultural operators on agricultural resource conservation. Since agriculture is currently the largest land use in the entire watershed, watershed restoration practices focused on implementation of agricultural BMPs are necessary as discussed in recommendation #3. Section 8. Education and

Outreach of this WIP provides additional information on outreach techniques that may prove successful for this group of stakeholders.

5. **Promote preservation of agricultural lands through easements.**
The Conservation districts for both counties can promote agricultural conservation easements while conducting outreach to landowners. These efforts will further promote the protection of agricultural lands from development.

6. **Implement priority stormwater management BMP retrofits for water quality improvement.**
While the developed lands in the watershed are a minimal source of sediment in comparison to agricultural areas, they provide an opportunity for public engagement in high visibility locations that can act as demonstration projects. The largest landowners in the watershed are the Hershey Corporation through its various entities. Representatives from the Hershey Corporation have been involved in meetings involving the development of this plan and maintaining communication will make project implementation on Hershey Corporation property more likely in the future. The stormwater retrofits located at the Milton Hershey School site provide this type of opportunity as well as the possibility of functioning as a learning lab site for the school science classes. Other project partners involved in the WIP process can help with project implementation, especially in the MS4 areas of the watershed that are outside the AOI such as the DTMA stormwater program.

7. **Implement priority streambank restoration projects for water quality improvement and conduct a rapid BANCS assessment of stream sites to better determine sediment reductions from stream restoration projects.**
Pollutant reduction credits are available based on the Chesapeake Bay Program Expert Panel reports (Schueler and Stack, 2014) and (Wood, 2020). At high priority streambank restoration sites (Table 34), sediment and nutrient load reductions should be estimated using the protocols highlighted by the Chesapeake Bay Program. A Legacy Sediment Removal (LSR) approach is recommended for both sites and is focused on grading down the existing floodplain to its historic level, exposing the gravel basal layer, and constructing a base flow channel. Unique conditions such as the presence of active agricultural fields in the floodplain and larger trees along the tributaries will require careful consideration during the design phase.

8. **Conduct pre- and post-implementation chemical and biological monitoring for stream restoration and stormwater retrofit sites.**
Stream monitoring information is important in demonstrating habitat and water quality improvements and progress toward WIP benchmarks. DCCD already conducts monitoring in the AOI watershed (see Section 11. Monitoring Plan) but additional monitoring of specific project sites can help to better quantify sediment load reductions and the impact of projects on water quality. As noted earlier in the WIP, the presence of karst topography influences the types of insects and fish found in a stream, and limestone streams often have a small number of sensitive taxa and only a few of these taxa are generally found in large numbers (PA DEP, 2021). Specific monitoring protocols for limestone influenced streams can be found in "Water Quality Monitoring Protocols for Streams and Rivers" (Pennsylvania Department of Environmental Protection, 2021).

9. **Update conservation plans as necessary and increase DCCD staff capacity for BMP implementation.**
Agricultural land management can change due to multiple factors including changes in ownership, topography, and climate. Conservation plans written in the past need to be reviewed to ensure that the recommendations are updated to reflect these changes and any changes in BMP implementation

calculations and procedures. To increase capacity and accelerate implementation of recommended BMPs, increased staffing for agencies responsible for the development and tracking of conservation plans is necessary. Along with this recommendation is to continue to identify new sources of funding to support staff and BMP implementation as highlighted in Section 7. Costs and Funding Resources.

Table 42 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 to 8 years.

Table 42. Implementation schedule and milestones for AOI Watershed

Recommendation	Timeframe for Implementation	Partners	Milestones
1. Finalize development of the Watershed Association.	Short-term	SCEWA, TU,	Develop charter and board and hold informational events
	Medium term		Write 2 proposals for project implementation
	Long Term		Write 5 new proposals for project implementation
2. Document practice implementation.	Short-term	DCCD, LCCD	Develop systematic method to record information for existing and new stormwater practices
	Medium term	DCCD, LCCD, SCEWA	Continue to add new records for implemented practices
	Long Term	SCEWA, TU, PSU	Conduct field assessment to confirm implemented practices are maintained
3. Implement prioritized Agricultural BMPs for water quality improvement.	Short-term	DCCD, LCCD PSU, NRCS	Implement at least 10% (38 acres) of proposed Ag BMPs as funding becomes available.
	Medium term		Implement at least 30% (105 acres) of proposed Ag BMPs as funding becomes available.
	Long Term		Implement at least 60% (144 acres) of proposed Ag BMPs as funding becomes available.
4. Engage landowners through outreach to the entire watershed.	Short-term	DCCD, LCCD PSU, NRCS	Outreach events that result in 4 or more farmers willing to implement proposed Ag BMPs
	Medium term	DCCD, LCCD PSU, NRCS	Install two or more retrofits on private property
	Long Term		40% increase in farmer participation in conservation.
5. Promote preservation of agricultural lands	Short-term	DCCD, LCCD PSU, NRCS	Conserve an additional 5% of agricultural land
	Medium term		Conserve an additional 10% of agricultural land
	Long Term		Conserve an additional 15% of agricultural land

Table 42. Implementation schedule and milestones for AOI Watershed

Recommendation	Timeframe for Implementation	Partners	Milestones
6. Implement priority stormwater management BMP retrofits for water quality improvement.	Short-term	SCEWA, HT, MHS	Develop and implement concepts for high priority stormwater BMP treating ~ 1 acre of drainage
	Medium term	SCEWA, HT, MHS	Develop and implement concepts for high priority stormwater BMPs treating ~ 5 acres
	Long Term		Develop and implement concepts for high priority stormwater BMPs treating ~ 15 acres
7. Implement priority streambank restoration projects for water quality improvement	Short-term	SCEWA, HT, MHS, DCCD, TU	Develop and implement a high priority restoration project of at least 2,000 LF
	Medium term		Develop and implement a high priority restoration project of at least 2,800 LF
	Long Term		Develop and implement a high priority restoration project of at least 4,500 LF
8. Conduct chemical and biological stream monitoring for stream restoration and retrofit projects to document impact	Short-term	DCCD, SCEWA	Secure PA DEP 319 Funding to perform chemical and biological stream monitoring
	Medium term		Confirm reductions in siltation through IBI scores and water quality monitoring
	Long Term		Develop citizen science monitoring group
9. Revisit agriculture soil conservation plans	Short-term	NRCS, DCCD	NRCS local office review of 10% of current conservation plans
	Medium term		NRCS local office review of 30% of current conservation plans
	Long Term		NRCS local office review of 60% of current conservation plans

Section 10. Evaluating Progress and Adaptive Management

Adaptive management is a strategy to address natural resource management efforts that use the state of a managed system to determine the best action at each decision point. The iterative nature of adaptive management offers flexibility for responsible parties to monitor implementation actions, determine success, and base future management decisions upon the results of completed implementation actions. The processes involved in watershed assessment, planning, and management build on previous work and some actions might not result in complete success during the first or second cycle of plan implementation. The implementation milestones and benchmarks from Section 9. Implementation Schedule and Milestones will guide the adaptive management process, helping to determine the type of monitoring and project implementation that will be necessary to gauge progress over time. Sediment reductions from recommended management measures calculated using Model My Watershed are expected to exceed the PA DEP reductions to meet water quality standards, so adaptive management can help determine if and when those standards are met and adjust management efforts as needed to achieve cost effective restoration.

The WIP is intended to be an adaptive and integrated management strategy that is evaluated and updated over time. It will be measured by benchmarks to track and evaluate advancement towards attaining implementation goals. Project implementation can be tracked in cooperation through the MMW spreadsheet tool by SCEWA. Table 43 identifies progress benchmarks that include water quality indicators, outreach efforts, and BMP implementation. It is recommended that SCEWA take an active role in evaluating project impacts by annually gathering available water quality data from project partners, in addition to using public engagement metrics (Table 41) to monitor progress in reaching milestones.

Table 43. Progress benchmarks

Benchmark	Year 5	Year 10	Year 15
IBI scores	5% improvement	10% additional improvement	IBI scores consistent with those expected for limestone streams
General public engagement	•Development of SCEWA website page on WIP plan for watershed •Development of presentation materials for schools and community groups	•Participation in 4 annual fairs/events in local area •6-8 annual presentations to local community groups •1 to 2 community events such as tree planting or stream cleanups per year	•Survey of residents to demonstrate increased knowledge of watershed restoration •4 articles in local paper on WIP progress •3-4 restoration events per year
Stream Restoration Projects	2,000 linear feet of high priority stream restored	2,800 linear feet of high priority stream restored	4,500 linear feet of high priority stream restored
Agricultural BMPs	10% implementation of future agricultural practices	40% of additional implementation target	60% additional implementation target
Urban BMPs	Implementation of 1-2 practices on public land as demonstration projects	Implementation of all 5 practices on public land	Implementation of additional 2 practices on private lands
Load Reduction Achieved	10% reduction in sediment loads	30% reduction in sediment loads	60% reduction in total sediment loads
Watershed Association Development	Established Board Developed local partnerships	Sustainable membership Planned events twice a year	2-3 proposals per year Planned events 3-4 times a year

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 WIP should be evaluated annually by the SCEWA to track progress and achievement of milestones, especially at 3, 5 and 10 years (Table 42. Implementation schedule and milestones). If there is less progress being made than expected, the reasons should be explored, and strategies adjusted. This might include increased monitoring efforts to evaluate potential pollution sources, reprioritization of projects for implementation, and adjustments to the timeline or budget for implementation.

Adaptive management for this WIP may incorporate a set of threshold-based criteria to trigger reassessment and modification of strategies. Required adaptive changes to WIP implementation timelines can be determined in two ways: evidence-based adaptations or opportunity-based adaptations.

Examples of evidence-based adaptations to restoration strategies may be based on:

- Documented positive changes in IBI scores to show measurable improvement within projected timelines.
- Modeling of reduction targets for pollutants of concern to determine positive trends based on observed data.
- Reexamination of adoption of identified BMPs from the WIP within reasonable timeframes or demonstrated interest from landowners in adopting recommended BMPs

Water quality monitoring in the AOI watershed provides the basis for the evidence-based portion of the adaptive management strategy and is paramount to success. Section 11 discusses the current water quality, macroinvertebrate, and similar stream health data collected by the DCCD as part of their Countywide Stream Assessment Program (CSAP). The program will provide insights into the health of the ecosystem and the impact of specific interventions. This data driven approach will ensure that management decisions are based on documented evidence of what is working and what is not.

Opportunity-based adaptations examine resource allocations and changes in opportunities and funding to determine if WIP implementation will improve with a reconsideration of priorities. This may include an examination of budgeting to determine if lower implementation cost BMPs may be more effective or treat a greater area in a watershed than one high-cost BMP. As an example, streambank stabilization is recognized as an effective BMP for reducing sedimentation and improving aquatic habitat but may carry a high price tag or be limited by landowner willingness. A lower cost BMP such as retirement of farmland may actually be more effective in some cases since implementation costs are lower and financial incentives to landowners may increase their willingness to adopt the practice.

The majority of stream restoration projects identified in this WIP are focused on land owned by partners in the WIP development (Hershey and the MHS) to avoid taking agricultural lands out of production. As part of an adaptive management strategy, targeted efforts may be made in the future to increase the implementation of streambank stabilization on privately held lands based on landowner willingness.

SECTION 11. MONITORING PLAN

Water quality and habitat monitoring are important benchmarks to measure WIP implementation progress. Modeling can help estimate nutrient and sediment reductions, but streams and their aquatic life communities take time to respond to watershed implementation practices. Monitoring the physical, chemical, or biological conditions of a waterbody is a tool to track on-the-ground progress of the implementation actions in improving habitat and water quality and support future resource management decisions. PA DEP often uses macroinvertebrate IBI scores to determine if a water body is impaired or attaining its use.

The DCCD currently runs a countywide monitoring effort that includes the AOI watershed and larger Spring Creek East watershed. The monitoring follows the approved monitoring protocols outlined in state guidance (Pennsylvania Department of Environmental Protection, 2021). The monitoring protocols can be found on DEP's website.[4] The Countywide Stream Assessment Program (CSAP) collects data to determine the present condition of Dauphin County's streams. The CSAP documents and measures changes in stream conditions occurring over time to protect, maintain, and restore streams to meet designated uses. Data collected consists of macroinvertebrate sampling, water chemistry, flow measurements, and land use information for 101 sites throughout the county. The watersheds in the program are assessed on a five-year cycle. There is also Long-term Nutrient Monitoring (LTNM) which collects data on temperature, dissolved oxygen, pH, conductivity, and nitrates. Fourteen sites throughout the county are monitored for phosphates and nitrates bi-monthly in areas where BMPs are being implemented to assess changes over time.

The Spring Creek East watershed has eight sites that are monitored through CSAP, three on the mainstem and five on unnamed tributaries. The three sites on the mainstem are outside the AOI watershed, but the five on the unnamed tributaries fall within the drainage area of the AOI watershed and this WIP (**Error! Reference source not found.**). A 2019 report from the DCCD on stream health indicates that all the sites were assigned a poor rating that was attributed to limestone influence from underlying geology which can impact water chemistry and the types of macroinvertebrates present (DCCD, 2019). The streams in these limestone areas often have higher counts of pollution tolerant species due to changes in water chemistry that must be considered when developing realistic milestones for expected changes in IBI scores. The three sites on the mainstem reported either no Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (EPT) types present or rated poor for having a fair number of total taxa but low numbers of pollution sensitive types. The rest of the sites on unnamed tributaries in Spring Creek East ranked poor with no EPT types present and showed low numbers of pollution sensitive macroinvertebrate types.

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[4] https://files.dep.state.pa.us/water/Drinking Water and Facility Regulation/WaterQualityPortalFiles/Technical Documentation/MONITORING_BOOK.pdf

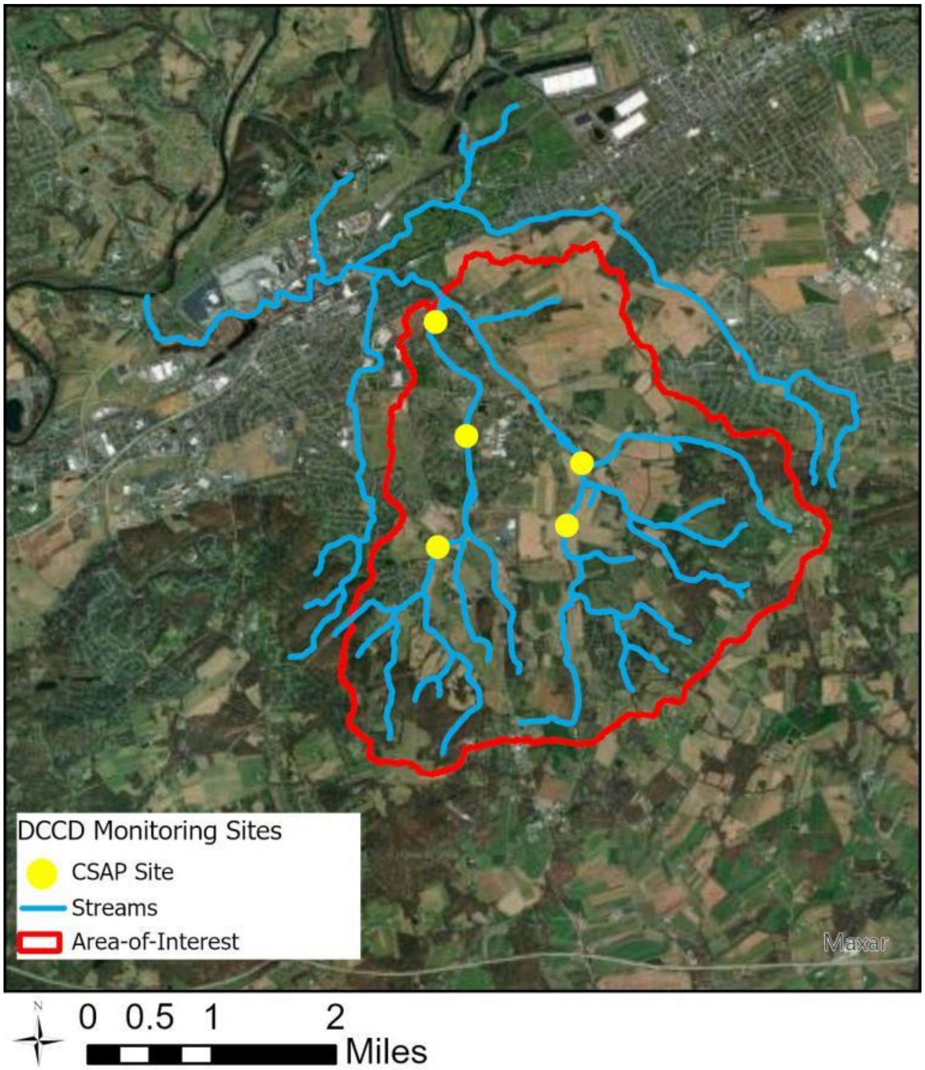

Figure 27. Current location map for CSAP monitoring stations in the AOI watershed

The monitoring plan for this WIP is to continue to have the DCCD coordinate the monitoring effort and provide expertise for data collection. This is partly due to a lack of staffing at the DCCD which prevents the agency from increasing current monitoring efforts. The LTNM station (SPRN 00.06) produces bimonthly water quality samples every year that can show changes in water chemistry based on its location at the confluence of Spring Creek East and Swatara Creek as well as a snapshot of the overall health of the watershed. In addition, water quality data collected will provide a baseline for future comparisons to determine incremental success of project implementation at reducing sediment loads.

Macroinvertebrate sampling will also continue using the 5 unnamed tributary sampling locations in the CSAP. It is also recommended that pre-and-post monitoring of the sites be performed for the two stream restoration projects recommended in the WIP as another way to demonstrate improvements in habitat and water quality. The ultimate goal is to use this data to remove the stream segments impaired for aquatic life use from the PA DEP Integrated Water Quality Report. In addition, the new SCEWA may be able to develop a citizen science monitoring effort in cooperation with other local partners that can provide additional information on the health of the stream as part of their future planning.

Section 12. References

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APPENDICES

APPENDIX A. EXAMPLE RETROFIT RECONNAISSANCE INVESTIGATION (RRI) FORM

WATERSHED:	**SUBWATERSHED:**	**UNIQUE SITE ID:**	
DATE:	**ASSESSED BY:**	**CAMERA ID:**	**PICTURES:**
GPS ID:	**LMK ID:**	**LAT:**	**LONG:**

SITE DESCRIPTION

Name:____
Address:____

Ownership: ☐ Public ☐ Private ☐ Unknown
If Public, Government Jurisdiction: ☐ Local ☐ State ☐ DOT ☐ Other:_____________________

Corresponding USSR/USA Field Sheet? ☐ Yes ☐ No If yes, Unique Site ID:_______________

Proposed Retrofit Location:

Storage
☐ Existing Pond ☐ Above Roadway Culvert
☐ Below Outfall ☐ In Conveyance System
☐ In Road ROW ☐ Near Large Parking Lot
☐ Other:_____________________________

On-Site
☐ Hotspot Operation ☐ Individual Rooftop
☐ Small Parking Lot ☐ Small Impervious Area
☐ Individual Street ☐ Landscape / Hardscape
☐ Underground ☐ Other:_____________
____

DRAINAGE AREA TO PROPOSED RETROFIT

Drainage Area ≈ _______________
Imperviousness ≈ _______________%
Impervious Area ≈ _______________

Notes:

Drainage Area Land Use:
☐ Residential
☐ SFH (< 1 ac lots)
☐ SFH (> 1 ac lots)
☐ Townhouses
☐ Multi-Family
☐ Commercial
☐ Institutional
☐ Industrial
☐ Transport-Related
☐ Park
☐ Undeveloped
☐ Other:_____________

EXISTING STORMWATER MANAGEMENT

Existing Stormwater Practice: ☐ Yes ☐ No ☐ Possible
If Yes, Describe:

Describe Existing Site Conditions, Including Existing Site Drainage and Conveyance:
Existing Street Width:_________

Existing Head Available:

Note where points are measured from: (i.e. street elevation to catch basin invert, manhole rim to catch basin invert, other)

PROPOSED RETROFIT

Purpose of Retrofit:
☐ Water Quality ☐ Recharge ☐ Channel Protection ☐ Flood Control
☐ Demonstration / Education ☐ Repair ☐ Other:______________________________

Retrofit Volume Computations - Target Storage:	**Retrofit Volume Computations - Available Storage:**

Proposed Treatment Option:
☐ Extended Detention ☐ Wet Pond ☐ Created Wetland ☐ Bioretention
☐ Filtering Practice ☐ Infiltration ☐ Swale ☐ Other:______________________

Describe Elements of Proposed Retrofit, Including Surface Area, Maximum Depth of Treatment, and Conveyance:

Available Width:	________
Available Length:	________
Available Area:	________
Ponding Depth:	________
Soil Depth:	

SITE CONSTRAINTS

Adjacent Land Use:
☐ Residential ☐ Commercial ☐ Institutional
☐ Industrial ☐ Transport-Related ☐ Park
☐ Undeveloped ☐ Other:______________________
Possible Conflicts Due to Adjacent Land Use? ☐ Yes ☐ No
If Yes, Describe:

Access:
☐ No Constraints
Constrained due to
☐ Slope ☐ Space
☐ Utilities ☐ Tree Impacts
☐ Structures ☐ Property
Ownership
☐ Other:______________________

Conflicts with Existing Utilities:

	Yes	**Possible/ Modifiable**	**No**	**Unknown**
Sewer:	☐	☐	☐	☐
Water:	☐	☐	☐	☐
Gas:	☐	☐	☐	☐
Electric to Streetlights:	☐	☐	☐	☐
Other:	☐	☐	☐	☐

____
____

Potential Permitting Factors:

Dam Safety Permits Necessary	☐ Probable	☐ Not Probable
Impacts to Wetlands	☐ Probable	☐ Not Probable
Impacts to a Stream	☐ Probable	☐ Not Probable
Floodplain Fill	☐ Probable	☐ Not Probable
Impacts to Forests	☐ Probable	☐ Not Probable
Impacts to Specimen Trees	☐ Probable	☐ Not Probable

How many?_______________
Approx. DBH______________

Other factors:______________________________
____
____

Soils:

Soil auger test holes:	☐ Yes	☐ No
Evidence of poor infiltration (clays, fines):	☐ Yes	☐ No
Evidence of shallow bedrock:	☐ Yes	☐ No
Evidence of high water table (gleying, saturation):	☐ Yes	☐ No

SKETCH

Unique Site ID:______

DESIGN OR DELIVERY NOTES

FOLLOW-UP NEEDED TO COMPLETE FIELD CONCEPT

- ☐ Confirm property ownership
- ☐ Confirm drainage area
- ☐ Confirm drainage area impervious cover
- ☐ Confirm volume computations
- ☐ Complete concept sketch
- ☐ Obtain existing stormwater practice as-builts
- ☐ Obtain site as-builts
- ☐ Obtain detailed topography
- ☐ Obtain utility mapping
- ☐ Confirm storm drain invert elevations
- ☐ Confirm soil types
- ☐ Other:____

INITIAL FEASIBILITY AND CONSTRUCTION CONSIDERATIONS

SITE CANDIDATE FOR FURTHER INVESTIGATION: ☐ YES ☐ NO ☐ MAYBE

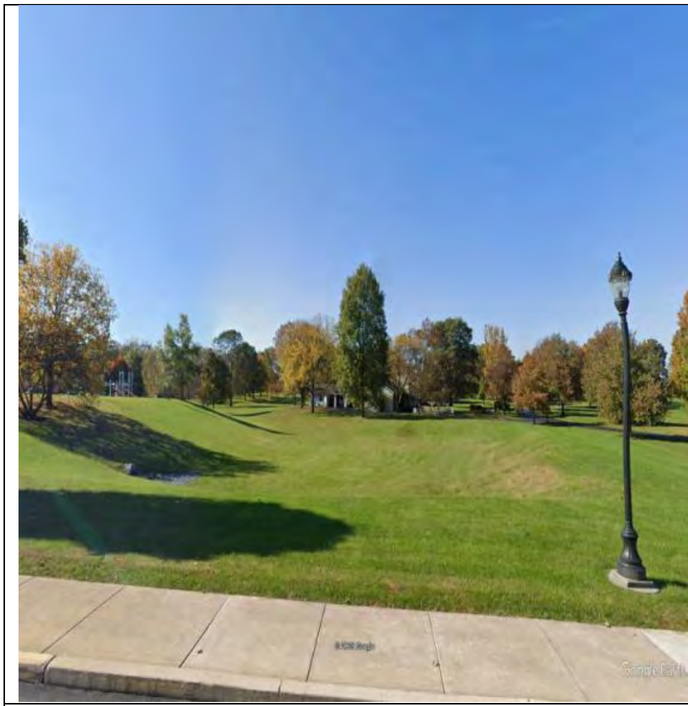
IS SITE CANDIDATE FOR EARLY ACTION PROJECT(S): ☐ YES ☐ NO ☐ MAYBE

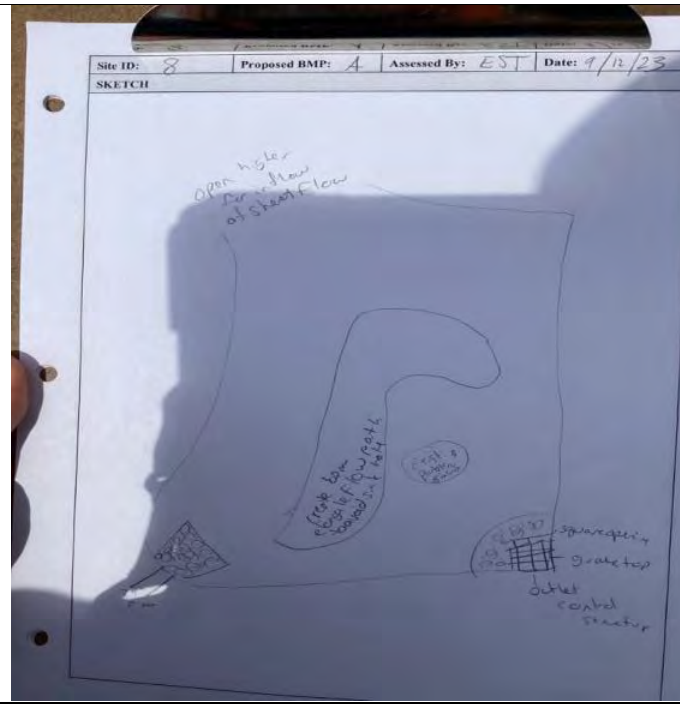
IF NO, SITE CANDIDATE FOR OTHER RESTORATION PROJECT(S): ☐ YES ☐ NO ☐ MAYBE

IF YES, TYPE(S):____

Unique Site ID:______

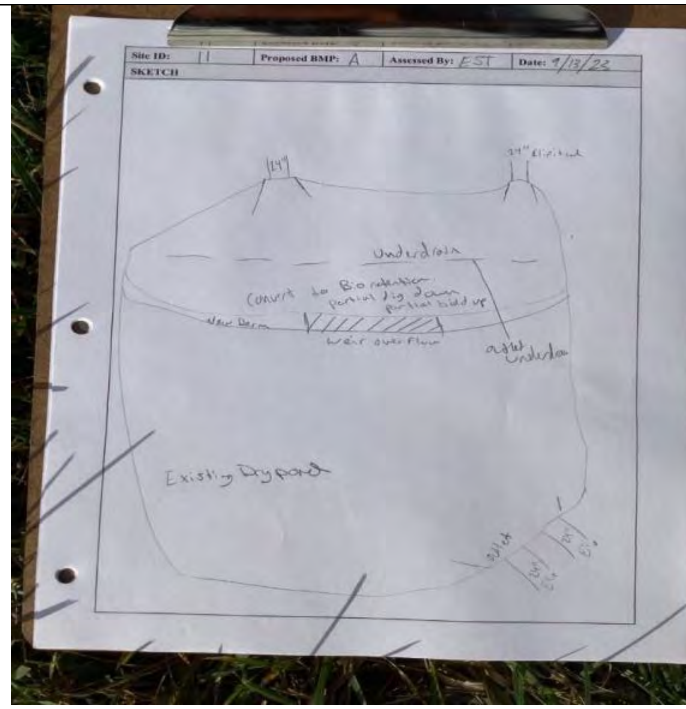
Appendix B. Photos of Retrofit Locations in AOI



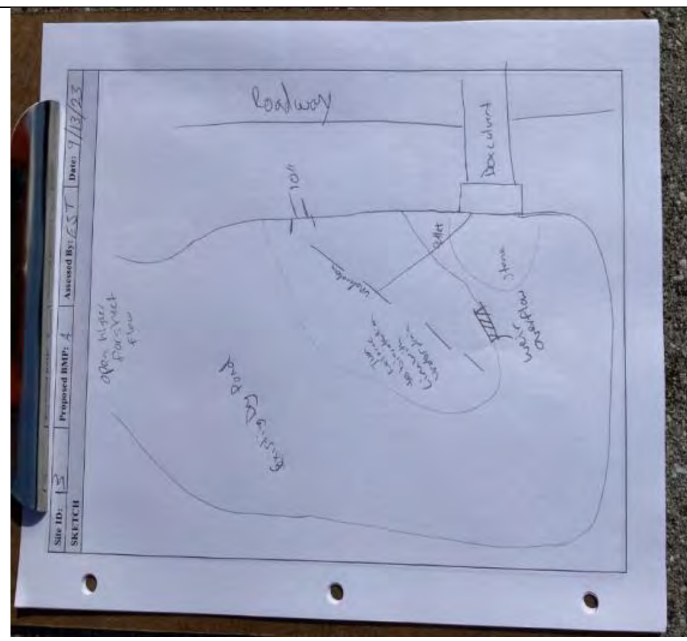


Site 8A. Milton Hershey School Memorial Hall

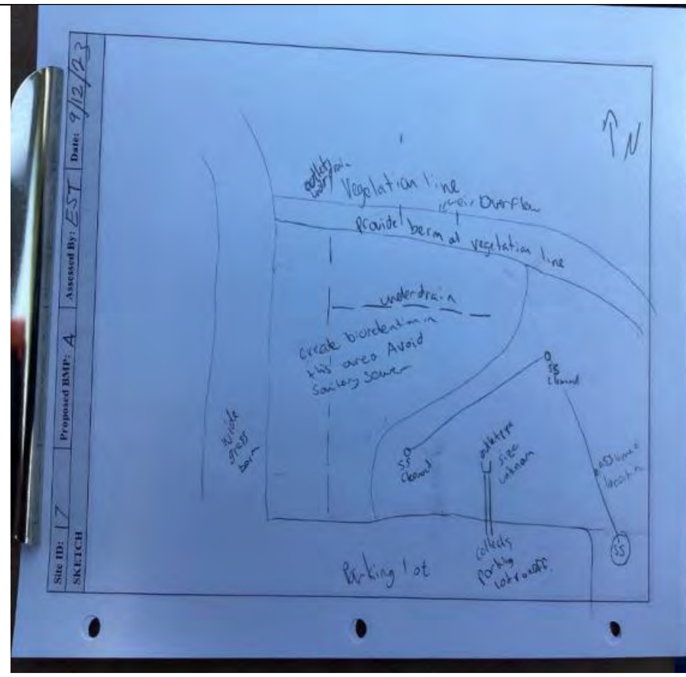
Site 9A. Milton Hershey Elementary School



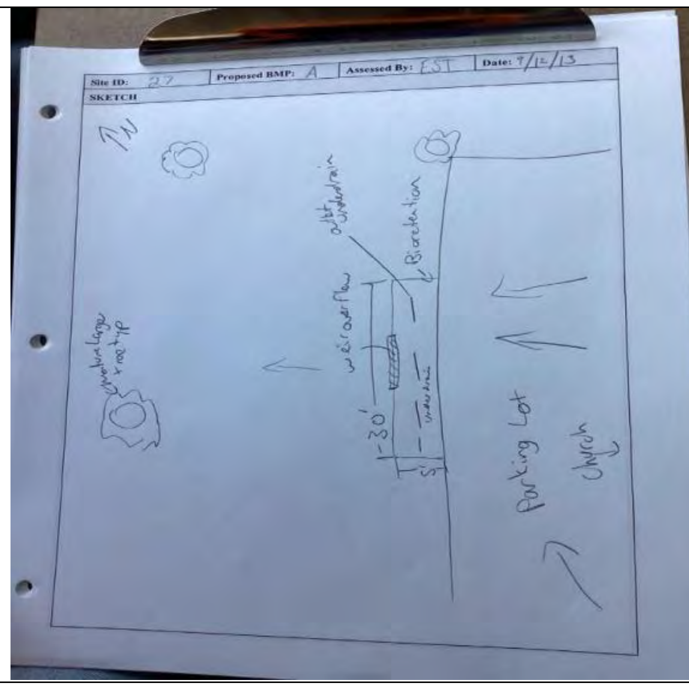
Site 11A. Milton Hershey School Pennland Lane and Brook Drive



Site 13A. Milton Hershey School Harvest Lane and Homestead Lane



Site 17A. Hershey Christian Academy



Site 27A. Conewago Church of The Brethren

Appendix C. Spring Creek Alternative Restoration Plan Stream Assessment Report Dauphin County, Pennsylvania

SPRING CREEK ALTERNATIVE RESTORATION PLAN
STREAM ASSESSMENT REPORT
DAUPHIN COUNTY, PENNSYLVANIA

Prepared for:

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Revised July 2025

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APPENDICES

Appendix A – Upper Spring Creek Watershed: Scored Reaches Map
Appendix B – Upper Spring Creek Stream Assessment Results Table
Appendix C – Upper Spring Creek Potential Stream Restoration Project Area Map

1 Purpose

Ecosystem Planning and Restoration, LLC (EPR) has prepared the Stream Assessment Report as the Task 4 "WIP/ARP Preparation" component of the Spring Creek Alternative Restoration Plan report. It specifically addresses the evaluation of stream restoration potential of a diverse selection of stream sites in the Spring Creek watershed and identifies specific locations for stream restoration sites as a part of Dauphin County Soil Conservation District's Best Management Practices (BMP's) that will become part of the Spring Creek watershed implementation plan. The Spring Creek watershed defined here is the Spring Creek watershed delineated upstream of the Swatara Creek confluence as described in the Spring Creek Watershed Characterization Report (Fox, Swann, & Morris, 2022).

The stream assessment study area encompasses Spring Creek upstream of the Swatara Creek watershed confluence and its associated upstream tributaries in Dauphin County, PA, all of which drain into the Susquehanna River and ultimately the Chesapeake Bay. This upper Spring Creek watershed study area covers approximately 10.6 square miles, characterized by a mix of land uses: 10% forest cover, 18% impervious surfaces, and significant agricultural activity, with 32% of the land dedicated to crops and 6% to pasture and hay.

This report documents the findings of EPR's initial GIS-based desktop stream segment analysis, the desktop-identified stream segments field verified by rapid function-based stream assessments, stream restoration sites identified as priority sites via the desktop and field-verified assessments, and preliminary costs of the priority stream restoration sites.

2 Assessment Methodology

This section documents the methodology of EPR's GIS-based desktop analysis, field validation, recalibration of desktop and field data, and identification of priority stream restoration sites. It is noted that the additional collection of detailed desktop and field data over an extended period would provide a greater understanding of existing conditions, the causes of stream functional impairments, and the ability to assess the stream conditions to determine need for restoration.

2.1 GIS-Based Desktop Analysis Methodology

EPR categorized the baseline health of the stream reaches in the upper Spring Creek watershed with a condition score based on GIS data and on-line aerials. Stream reaches/segments defined by GIS hydrology lines (shapefiles) were segmented for analysis based on 1,000 linear feet of stream length unless intersected by a confluence of a tributary. EPR gathered relevant data on stream lengths, soils, sinuosity, vegetative cover, slope, and various forms of land use/land cover on which existing conditions were ranked based on effect on stream channel stability and then summed to yield the desktop stream condition scores. The following categories were taken into equally weighted consideration for the creation of the condition scores: sinuosity, slope, riparian vegetation, agriculture encroachment, development encroachment, road presence, and soil erodibility. Except for sinuosity (ratings of only 0 or 1), every category was scored with ratings of 1-3, with three (3) being the rating for instability, and one (1) being the most stable. A further explanation of the scoring technique is below:

1. **Sinuosity**: The sinuosity of a stream's flow path is a crucial parameter in analyzing potential stream bank erosion. When a stream exhibits an overly low or high sinuous pattern, it often signifies heightened vulnerability to erosion. Similarly stream slope significantly influences stream energy, the higher the stream slope the higher the stream energy which can lead to stream erosion. To evaluate sinuosity, we compare the elevations of the start and end of a reach were compared over the length of the reach to yield a slope. Slopes between 0-3%, presumed to be alluvial, were given a 0 if in the designated stable sinuosity is between 1.2 to 1.4. If an alluvial stream was out of this range and thus considered unstable (using professional judgement), it received a rating score of 1. Slopes higher than 3% were not considered in the sinuosity categorization.
2. **Slope**: The slope of a landscape plays a crucial role in determining stream condition by influencing both the physical stability of the stream banks and the hydrological patterns within the watershed. Steeper slopes tend to increase the velocity of water flow, which can lead to heightened erosion and sediment transport, thereby destabilizing stream banks and altering the channel morphology. To evaluate slope each stream segment in an identified valley type received scores based on the ideal slope percentage range pertaining to that specific valley type. For alluvial streams, a 1 indicates a good slope of 0-1 percent, a 2 indicates a fair slope of 1-2 percent, and a 3 indicates a poor slope of 2-3 percent. For alluvial streams, a 1 indicates a good slope of 3-4 percent. Colluvial slopes were not considered outside this range. For steeper streams with a non-categorized valley type “N/A”, a 2 indicates a fair slope of 4-5 percent, and a 3 indicates a poor slope greater than 5 percent. There is no score for “most stable slope” for land features categorized as N/A because stable slopes do not exist in this category.
3. **Riparian Vegetation**: The presence absence and composition of riparian vegetation can significantly impact stream stability by impacting both mechanical stability through root systems that reinforce soil and prevent erosion, and hydrological dynamics by moderating soil moisture and reducing erosion risks. Furthermore, riparian vegetation is vital for maintaining ecological balance, moderating stream temperatures, influencing biodiversity and protecting water quality. To evaluate riparian vegetation the areas within 25 feet of the stream, if the stream segment is more than 75% forested, the stream segment receives a score of 1; if 50-75% forested, the segment receives a score of 2, and less than 50% forested the segment receives a rating of 3.
4. **Agriculture Encroachment**: Area Agricultural practices often cause soil compaction and erosion, increasing runoff and negatively impacting water quality and aquatic habitats by destabilizing streambanks. Chemical runoff from fertilizers and pesticides contributes to eutrophication in nearby streams, leading to oxygen depletion and harm to aquatic life. Additionally, water diversion for irrigation and stream channel alteration to optimize land use further disrupt natural water flows and stream health, increasing flood risks and affecting biodiversity. To evaluate agriculture encroachment the areas within 100 feet of the stream, if land use adjacent to the stream is estimated more than 50% agriculture, the stream segment receives a rating of 3; if the land use is 25- 50% agriculture, the segment receives a score of 2, and if less than 25% agriculture, the segment receives a rating of 1.

5. **Development Encroachment**: Development encroachment on stream corridors can lead to several adverse effects on stream stability. Increased impervious surfaces result in higher stormwater runoff, causing erosion, sedimentation, and altered stream flows, which degrade aquatic habitats and ecosystem health. Additionally, urban runoff introduces pollutants like oils and heavy metals into streams, disrupting ecological balance, while development-related channel modifications and the loss of riparian buffers exacerbates erosion and destabilizes natural stream dynamics. To evaluate development encroachment the areas within 100 feet of the stream, if the stream is estimated to be more than 50% developed (graded, built upon, cleared for non-agricultural use) the stream segment receives a rating score of 3; if the segment is estimated as 25- 50% developed, the segment receives a score of 2, and if less than 25% developed receives a score of 1.
6. **Road Presence**: Area Similar to development encroachment, the presence of roads in the riparian areas and their crossings over streams significantly impacts stream stability through various mechanisms. Roads alter natural water flow patterns and increase runoff, leading to exacerbated streambank erosion, channel incision, and sediment buildup that disrupt the stream's natural equilibrium and morphological health. Furthermore, crossings, if improperly designed or in a state of disrepair, can obstruct the movement of aquatic organisms and lead to the degradation or removal of crucial riparian vegetation, carrying pollutants like heavy metals and oils into streams, which harms water quality, aquatic habitats, and biodiversity. To evaluate the amount of impact from roads on stream stability areas within 25 feet of the stream, if the stream segment intersects with more than 5,000 feet of paved road the segment receives a rating score of 3; if intersecting between 0-5,000 feet, the segment receives a rating of 2, and if 0 feet of road presence receives a score of 1.
7. **Soil Erodibility**: The soil erodibility factor (K factor) is essential for predicting soil's response to erosive forces like rain and runoff, crucial for stream stability. To assess soil erodibility areas within 25 feet of the stream, if the K factor (erodibility factor provided in US NRCS' on-line soil survey) of the stream segment is more than a factor of 0.4, the stream segment receives a rating score of 3; if the K factor is between 0.2-0.4, the segment receives a score of 2, and if the factor is under 0.2, it receives a score of 1.

Scores are then added up to yield the overall stream segment condition score. The worst overall score possible is theoretically a 19, but no reach scored worse than a rating of 15. Given this distribution, scores were then sorted into three equal sub-ranges for stream stability: 7-9 is good condition, 10-12 is fair condition, and 13-15 is poor condition.

2.2 Field Validation Methodology

EPR conducted a modified version of a rapid stream function-based assessment of desktop-identified selected sites based on the Stream Functions Pyramid (Harman, Starr et al., 2012) and Rapid Function-based Stream Assessment Protocol (USFWS - Starr et al, 2015). Critical functions on two levels of the stream functions pyramid were assessed so that the existing conditions for these levels and potential changes in defined stream functions could be evaluated for the selection of priority sites.

The following assessment parameters, by function pyramid level, were evaluated:

Level 2 - Hydraulics – floodplain connectivity, floodplain drainage, and vertical stability extent.
Level 3 - Geomorphology – lateral stability, riparian vegetation, and bedform diversity.

Per the tasks outlined by the contract, 10 sites, totaling approximately 2.5 miles of stream, were then selected by EPR for field validation. Priority field sites were chosen for equal representation of stream segment condition (estimated), varied locations within the watershed and on the main stem and tributaries, and stream segment access. For these priority sites, the modified Rapid Stream Function-based Assessment (RSFBA) as described above was utilized to rate the existing stream segment condition. The RSFBA used the assessment ratings of Functioning, Functioning-at-Risk, and Not-Functioning to parallel the overall rating conditions of good, fair, and poor presented at the end of Section 2.1. A representative reach of the identified field assessed stream segment was conducted; full stream segment lengths were not assessed.

2.3 Desktop-Field Recalibration Methodology

After conducting a comprehensive field assessment, the EPR team refined the GIS-based desktop analysis for each stream reach within the upper Spring Creek Watershed. This calibration aimed to align the condition scores more closely with the empirical field data collected. Once a sufficient sample of field data had been gathered, EPR reviewed the calibration process to ensure the desktop analysis closely matched the observed field conditions.

During this process, EPR noted discrepancies between the desktop analysis and field observations, particularly regarding stream sinuosity. Much of the sinuosity observed in the field did not correspond with the GIS basemap imagery. This misalignment was expected, given that the FEMA hydrology layer used in the GIS analysis was over a decade old. The hydrology layer, which included the Spring Creek main stem and tributary stream segments, no longer accurately represented the current stream planform due to ongoing erosion and other changes.

As a result, EPR determined that the outdated GIS data was not reliable for evaluating sinuosity in the desktop analysis. Consequently, sinuosity was removed as a parameter from the final condition score calculations. The revised scoring metrics, reflecting this adjustment, are detailed in *Section 3.1 GIS Based Desktop Results.*

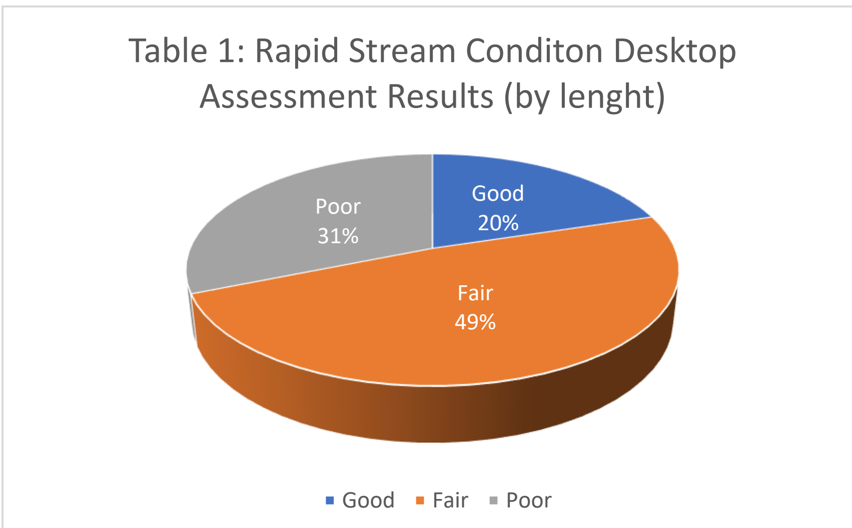
Revised scores were then added up to yield the overall condition score. The worst score possible is theoretically a 15, but no reach segment scored worse than a rating of 13. Given this distribution, scores were then sorted into three sub-ranges of stream condition: 6-8 is good condition, 9-11 is fair condition, and 12-13 is poor condition.

3 Assessment Results

3.1 Desktop Assessment Results

The desktop assessment involved evaluating 32.72 miles of stream across 276 distinct reaches, as illustrated in Appendix A – Upper Spring Creek Watershed: Scored Reaches. These reaches were focused on the upper portion of the Spring Creek watershed.

The analysis was structured around the methodology outlined in section *2.1 GIS-Based Desktop Analysis Methodology*. Streams were assessed and assigned lengths and scores, categorizing them into three conditions: Good, Fair, and Poor. Specifically, 75 reaches were rated as Good with a combined length of 34,937 linear feet. 134 reaches were rated as Fair, covering another 83,963 linear feet, and 67 reaches fell into the Poor rating category, spanning 53,879 linear feet.



Breaking down the results further (Table 1) for the Upper Spring Creek watershed, 27% of the stream reaches and 20% of the stream length (34,937 LF) were rated as Good. In contrast, 49% of the reaches and 49% of stream length (83,963 LF) were rated Fair, and 24% of the reaches equating to 31% of the stream length (53,873LF) were rated as Poor (Table 1).

3.2 Field Assessment Results

EPR field assessed approximately 11,207 linear feet of streams in the Spring Creek Watershed. Of these field sites, 3 segments were rated as “good condition”, 10 segments were rated as “fair condition”, and 2 segments were rated as “poor condition”.

The characterization of a “good” site is rated by the performance of the following stream function-based criteria listed below.

1. Level 2 – Hydraulics, as described by the Stream Functions Pyramid, is the transport of water and sediment both in the channel and on the floodplain. This level of the pyramid was assessed using floodplain connectivity, floodplain drainage/complexity, and vertical stability extent.
    a. Bank Height Ratio: BHR provides a measurement of how quickly stream flows can overtop banks and inundate the floodplain. A good BHR signifies that flood flows can frequently access the floodplain relative to the bankfull elevation, and as such the floodplain is well-connected to the stream.
    b. Entrenchment Ratio: ER is calculated as floodprone area width divided by bankfull width. A good ER is a high ER, as this indicates much of the floodplain is available for flood flows once stream flows have overtopped the banks.
    c. Vertical Stability: vertical stability extent describes the potential for aggradation or degradation in the channel bed, which can lead to changes in channel dimensions and flow dynamics. It measures the magnitude of streambed adjustments and is best described as either local or system wide. A good vertical stability rating does not currently have high potential to aggrade or degrade.
2. Level 3 – Geomorphology, as described by the Stream Functions Pyramid, is the transport of wood and sediment to create diverse bedforms and a dynamic equilibrium. This pyramid level was assessed using riparian vegetation, lateral stability, and bedform diversity.
    a. Riparian vegetation: RV primarily measures the width of riparian vegetation and how far along the stream corridor it extends, as well as its quality, density, diversity and composition. A good riparian corridor extends over 100 feet wide, with diversity and density in its vegetation community, no adverse human impacts, and none/sparse invasive species presence.
    b. Dominant Bank Erosion Rate Potential: erosion rate assesses how quickly banks are eroding and the total extent to which banks along the stream are eroding to determine lateral stability. A good Dominant Bank Erosion Rate Potential occurs when very few of the banks are actively eroding.
    c. Bedform Diversity – Shelter for Fish: shelter for fish assesses the quality of in-stream aquatic habitat. Good shelter for fish contains greater than 70% of substrate favorable for colonization and fish cover, in which a mix of snags, submerged logs, undercut banks, rubble, gravel, cobble, large rocks, and other stable habitat aspects allow for full colonization potential.

The characterization of a “fair” site is rated by the performance of the following stream function-based criteria listed below.

1. Level 2 – Hydraulics, as described by the Stream Functions Pyramid, is the transport of water and sediment both in the channel and on the floodplain. This level of the pyramid was assessed using floodplain connectivity, floodplain drainage/complexity, and vertical stability extent.
    a. Bank Height Ratio: BHR provides a measurement of how quickly stream flows can overtop banks and inundate the floodplain. A fair BHR signifies that flood flows

can sometimes access the floodplain relative to the bankfull elevation, and as such the floodplain is moderately connected to the stream.

b. Entrenchment Ratio: ER is calculated as flood prone area width divided by bankfull width. A fair ER indicates some, but not much, floodplain is available for flood flows once stream flows have overtopped the banks.
c. Vertical Stability: vertical stability extent describes the potential for aggradation or degradation in the channel bed, which can lead to changes in channel dimensions and flow dynamics. It measures the magnitude of streambed adjustments and is best described as either local or system wide. A fair Vertical Stability has potential to aggrade or degrade and has a magnitude of streambed adjustments contained only to instances of local instability.

2. Level 3 – Geomorphology, as described by the Stream Functions Pyramid, is the transport of wood and sediment to create diverse bedforms and a dynamic equilibrium. This pyramid level was assessed using riparian vegetation, lateral stability, and bedform diversity.
   a. Riparian vegetation: RV primarily measures the width of riparian vegetation and how far along the stream corridor it extends, as well as its quality, density, diversity and composition. A fair riparian corridor extends to a width of 25-100 feet, where composition is dominated by two or three species, human activities have caused great negative impact, and invasive species have altered the vegetation community.
   b. Dominant Bank Erosion Rate Potential: erosion rate assesses how quickly banks are eroding and the total extent to which banks along the stream are eroding to determine lateral stability. A fair Dominant Bank Erosion Rate Potential occurs when a moderate amount—yet less than 50%—of the banks are actively eroding.
   c. Bedform Diversity – Shelter for Fish: shelter for fish assesses the quality of in-stream aquatic habitat. Fair shelter for fish contains a mix of 20-70% stable habitat with a potential for full colonization, but not yet prepared for colonization. Habitat aspects may be suited for maintenance of fish population, but are in the form of new fall, and are not well-integrated into the in-stream ecosystem.

The characterization of a "poor" site is rated by the performance of the following stream function-based criteria listed below.

1. Level 2 – Hydraulics, as described by the Stream Functions Pyramid, is the transport of water and sediment both in the channel and on the floodplain. This level of the pyramid was assessed using floodplain connectivity, floodplain drainage/complexity, and vertical stability extent.
   a. Bank Height Ratio: BHR provides a measurement of how quickly stream flows can overtop banks and inundate the floodplain. A poor BHR signifies that flood flows can barely access the floodplain relative to the bankfull elevation, and as such the floodplain is not well connected to the stream.

   b. Entrenchment Ratio: ER is calculated as flood prone area width divided by bankfull width. A fair ER indicates very little floodplain is available for flood flows once stream flows have overtopped the banks.
   c. Vertical Stability: vertical stability extent describes the potential for aggradation or degradation in the channel bed, which can lead to changes in channel dimensions and flow dynamics. It measures the magnitude of streambed adjustments and is best described as either local or system wide. A poor Vertical Stability has high potential to aggrade or degrade and has a high magnitude of streambed adjustments to yield widespread instability.
2. Level 3 – Geomorphology, as described by the Stream Functions Pyramid, is the transport of wood and sediment to create diverse bedforms and a dynamic equilibrium. This pyramid level was assessed using riparian vegetation, lateral stability, and bedform diversity.
   a. Riparian vegetation: RV primarily measures the width of riparian vegetation and how far along the stream corridor it extends, as well as its quality, density, diversity and composition. A poor riparian corridor extends to a width less than 25 feet, with little to no vegetation due to human impact, and/or a majority of the vegetation is invasive.
   b. Dominant Bank Erosion Rate Potential: erosion rate assesses how quickly banks are eroding and the total extent to which banks along the stream are eroding to determine lateral stability. A poor Dominant Bank Erosion Rate Potential occurs when over 50% of the banks are actively eroding.
   c. Bedform Diversity – Shelter for Fish: shelter for fish assesses the quality of in-stream aquatic habitat. Poor shelter for fish contains less than 20% of stable habitat in the mix, in which lack of available habitat visually and obviously undesirable, and substate is unstable or lacking.

Detailed desktop and field assessment results are presented in *Appendix B- Upper Spring Creek Stream Assessment Results.*

4 Stream Restoration Priority Sites

The process of identifying potential stream restoration sites was driven by a comprehensive set of criteria designed to balance ecological objectives with logistical feasibility. A critical factor was property ownership, which is essential for accessing the streams and ensuring their long-term upkeep and success. Streams identified as high priority for restoration were between 1,000 to 4,000 feet in length—manageable sizes that still allow for significant ecological impact. These segments had previously received Poor to Fair ratings in desktop assessments, highlighting a substantial potential for ecological improvement. *Reference Appendix C – Upper Spring Creek Potential Stream Restoration Project Area Map* for locations of recommended restoration reaches.

When selecting priority stream restoration sites, the potential for functional lift and floodplain reconnection was fundamental, particularly where floodplain reconnection and Legacy Sediment Removal was likely to be most cost-effective. Legacy Sediment Removal involves the excavation and management of accumulated sediments, typically deposited over centuries in floodplains and stream valleys, to restore natural water flow, improve water quality, and revitalize floodplain wetlands. High-priority sites were those where the restoration could be achieved with minimal impacts to large trees, preserving valuable riparian tree cover and maintaining existing habitat.

Additionally, sites with limited impact to active agricultural crop fields were preferred to avoid disrupting ongoing farming activities. The proximity of soil disposal locations was also a key factor, reducing transportation costs and further enhancing cost efficiency. Good access for construction equipment and sites with limited constraints were prioritized to minimize potential complications during the restoration process. Financial considerations were equally important; cost-efficiency and the potential for significant pollutant load reductions influenced the prioritization process. Restoration efforts were targeted to streams where the costs per linear foot were likely to be competitive for funding.

Assessed stream reaches were combined into priority project areas to maximize potential pollutant load reduction credit and ecological uplift. These 30 reaches were categorized into High Priority- Milton Hershey Land, High Priority- Private Land, Medium Priority, and Low Priority sites. In total, there were:

- 16 High Priority Reaches- Milton Hershey Land sites
- 10 High Priority Reaches- Private Land sites
- 4 Medium Priority Reaches

Several stream reaches rated as "Poor" nonetheless scored low in prioritization. This typically reflected other prioritization criteria, such as floodplain reconnection potential, legacy-sediment removal, protection of large trees, preservation of riparian vegetation, and maintenance of existing habitat, that take precedence over raw condition scores. For instance, lower-ranked

Figure 1. Example Non-Priority Reach with Poor Condition Scoring

reaches such as Reach 153 (Figure 1) adjoin houses, roads, and other infrastructure, are relatively short, or encroach on prime farmland, attributes that lowered their condition scores and, as well as reduced their priority for restoration.

4.1 High Priority Milton Hershey Land Sites (Table 2) are potential project locations situated on properties owned by the Milton Hershey School or the Milton Hershey Trust. These sites have been field assessed to evaluate their condition and feasibility for restoration.

Table 2: High Priority Stream Restoration Opportunities on Milton Hershey School or Trust Property

Project Area	Reach ID	Length (LF)
Project Area 1	143	477
	144	473
	145	100
	146	66
	147	862
	148	544
	151	684
	157	800
	166	53
	165	824
	Total	**4883**
Project Area 2	161	1000
	160	1000
	221	225
	327	601
	215	1000
	224	737
	Total	**4563**

4.3 High Priority Private Land Sites (Table 3) are potential project locations on privately owned land, where the project extent is controlled by one or two landowners who own both sides of the stream. These sites have been assessed through desktop evaluations, but no field assessments have been conducted to date.

Table 3: High Priority Opportunities on Private Property

Reach ID	Length (LF)	Number of Owners
155	806	1
159	614	1
48	1000	1
310	1000	1
311	537	1
218	1000	1
219	800	1
167	925	1
168	881	2
	439	
94	509	2
	478	

4.4 Medium Priority Sites (Table 4) are located adjacent to High Priority Milton Hershey Land sites and could be included in broader restoration efforts. However, these sites present significant additional constraints, such as proximity to roads, which are likely to impact restoration strategies and potential pollutant load reductions.

Table 4: Medium Priority Stream Restoration Opportunities on to Milton Hershey School or Trust Property

Reach ID	Length (LF)
92 and 93	1197
217	1000
216	1000
Total	**3197**

5 Stream Restoration Priority Sites

The identification of high-priority stream restoration projects is essential for targeting efforts where they can have the most significant impact on ecological health and watershed stability. In the section that follows, two specific stream restoration project locations have been identified as top priorities based on their potential for substantial environmental improvement and long-term sustainability. These sites also offer the best opportunities for cost-effective outcomes of the restoration efforts.

5.1 Stream Restoration Priority Site 1

This restoration area includes stream assessment reaches 143, 144, 145, 146, 151, 157, 165, and 166, totaling approximately 4,883 linear feet. The restoration extends from Gates Road northward towards Bachmanville Road. There is the potential to extend the project southward of Gates Road to include reaches 92 and 93 for an additional 1,197 feet but there are additional constraints given the proximity to Gates Road.

5.1.1 Current Conditions

5.1.1.1 Floodplain Connectivity

The floodplain within the project site has legacy sediments as a result of historic mill dams. Though there are no historic mill dams directly downstream of the project that could result in any ongoing backfill of sediment, there are mapped historic mill dam in other parts of the watershed that indicates historic mill dams were once a popular practice in Hershey. Legacy sediment deposits in this area range from 2-4 feet; as a result the stream at this location is characterized as being incised and having infrequent connection to the active floodplain

5.1.1.2 Riparian Vegetation

At this site, the riparian vegetation is characterized by the absence or minimal presence of a healthy tree stratum, with few or no trees having a diameter at breast height (dbh) greater than 3 inches and less than 60% tree canopy cover. The vegetation layer lacks optimal diversity and is dominated by reed canary grass (*Phalaris arundinacea*). The area is largely devoid of wetlands, or lacustrine resources greater than or equal to 10 acres, further reducing the quality of the riparian habitat.

5.1.1.3 Bank Erosion

This site has 2-3 feet high banks upstream in the reach and 3-4 feet high banks in the downstream reaches. Erosion of these incised stream banks contributes significant amounts of sediment, phosphorus and nitrogen to the aquatic system and downstream waterbodies. Excessive amounts of sediment and nutrient inputs can significantly impair stream ecosystems by reducing water quality, degrading habitat for aquatic organisms, and promoting eutrophication, which can lead to hypoxic conditions and loss of biodiversity. The upstream reaches had a conditional rating of "fair", and the downstream reaches rated as "poor" indicating that it is incised to a further degree, with additional vertically and laterally eroding banks.

5.1.1.4 In-stream Habitat

At this site, the instream habitat is characterized by the absence or minimal presence of varied substrate sizes, water velocity, and depths, woody and leafy debris, stable substrate, low embeddedness, shade, undercut banks, root mats, SAV, macrophytes, emergent vegetation, riffle-pool complexes, and stable features. The site's instream habitat is suboptimal, with physical elements that hinder its ability to support aquatic organisms, present in less than 50% of the reach. Furthermore, the substrate at this site is unfavorable for colonization by a diverse and abundant epifaunal community, with few to no suitable areas for epifaunal colonization or fish cover.

5.1.2 Restoration Approach

A Legacy Sediment Removal (LSR) design approach (Figure 1. Legacy Sediment Removal Restoration) involves grading down the existing floodplain to the historic floodplain level and gravel basal layer and building a base flow channel. The approach focuses on designing a valley topography to produce a high frequency, high duration and large extent of surface water and groundwater exchange between the channel and floodplain and to promote retention of organic matter, sediment, nutrients and water within the channel and floodplain. In this approach, the channels, which are highly varied in dimensions and planform, and the floodplain surface, are designed to evolve with vegetative succession. The channels and floodplains typically develop into stream-and-wetland complexes. This approach would likely result in the greatest potential of ecological benefits as well as nutrient and sediment load reductions, in comparison to the other design approach alternatives such as Natural Channel Design (NCD), Beaver Dam Analogs (BDA), and Bank Stabilization because of the benefits that may be achieved through connecting to the entire historic floodplain and gravel basal layer. It also best meets the design goals and objectives. However, potential impacts to existing natural resources may be greater and construction costs may be higher than the other design approach alternatives because it may result in the largest project area and require larger volumes of floodplain excavation.

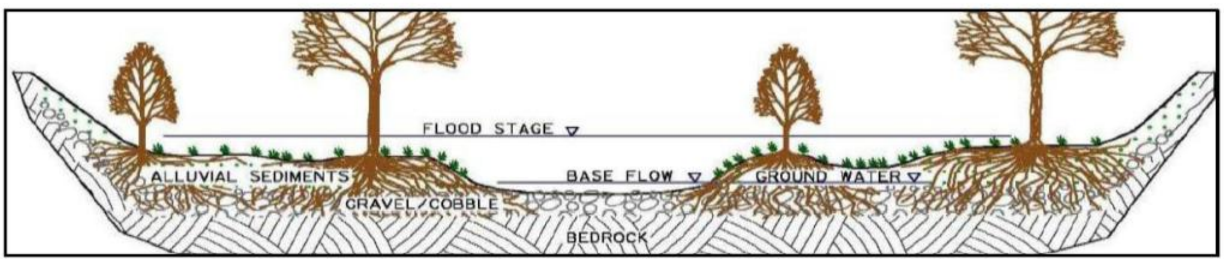


Figure 2. Legacy Sediment Removal restoration example cross section.

5.1.3 Access and Constraints

A noteworthy constraint of this project area is a gas line that crosses perpendicular to the stream in reach 147. This infrastructure element introduces a restriction, potentially limiting the extent of floodplain excavation in its vicinity. Aside from this utility crossing the majority of the project area appears to be devoid of other major utilities or structures. Access to the site is highly favorable from Gates Road.

5.1.4 Ecological Uplift

Restoration of this portion of Spring Creek would result in significant ecological benefits and increase resiliency to climate change. Ecological uplift and resiliency will result from the proposed floodplain reconnection that will increase floodplain access frequency, increase storm flow storage and attenuation, increase groundwater recharge, and ultimately evolve into a stream/wetland complex system. Restoration of the floodplain and stream will result in the extension of the hyporheic zone into the floodplain; raising of groundwater levels; greater interaction between the groundwater and riparian vegetative root zone; increased denitrification; increased floodplain habitat (e.g., food, cover, nesting) complexity for amphibians, reptiles, mammals, and birds; reduced bank erosion sediment inputs; increase sediment trapping; restored and enhanced riparian buffers and terrestrial habitats; reductions in invasive plant species; increased presence of large wood and detritus for organic processing; and improved bedform diversity and aquatic habitats for macroinvertebrate and fish. Water quality improvement will result from bank stabilization and connection of the groundwater to the riparian vegetative root zone that will decrease nutrient and sediment loads entering the stream. Water temperature is likely to improve through the reconnection of the hyporheic zone into the floodplain and enhanced riparian buffer. Biological benefits, in terms of increases in wildlife species diversity and density, will occur through the proposed improved stream and floodplain habitats.

5.2 Stream Restoration Priority Site 2

This restoration site extends 4,563 linear feet from Bachmanville Road northwards past Eby Road and consists of stream assessment reaches 160, 161, 221, 215, 224, 327. This site is located 4500 feet upstream of Priority Site 1. There is potential to extend the project by an additional 1,600 feet through the restoration of reaches 216 and 217; however, these reaches present additional constraints that will need to be addressed.

5.2.1 Current Conditions

5.2.1.1 Floodplain Connectivity

At the second site, the floodplain is also affected by legacy sediments resulting from historic mill dams, with deposits ranging from 2-3 feet deep. Due to these legacy sediment deposits, the stream at this location is characterized by significant incision and infrequent connection to the active floodplain, which affects the site's hydrology and the overall ecological health of the area.

5.2.1.2 Riparian Vegetation

At this site, the riparian vegetation is characterized by a limited presence of a healthy tree stratum, with only a few scattered trees having a diameter at breast height (dbh) greater than 3 inches and less than 60% tree canopy cover. While the main riparian area lacks optimal vegetation and is dominated by herbaceous vegetation, there are some larger trees scattered along the tributaries leading to the mainstem and a few newly planted buffer areas. Additionally, active agricultural fields occupy portions of the floodplain, further reducing the natural vegetation and contributing to the overall degradation of the riparian habitat. The area is devoid of wetlands or lacustrine resources greater than or equal to 10 acres, further impacting the quality of the habitat.

5.2.1.3 Bank Erosion

At this site, the stream has 2-3-foot-tall banks. Both the upstream reaches and the tributaries feature high, incised banks that contribute significant amounts of sediment, phosphorus and nitrogen pollution to the stream system and downstream water bodies. In the tributary reaches, where riparian conditions are somewhat better and provide additional bank protection, the area has a conditional rating of “fair” However, the mainstem reaches, with their limited larger trees and corresponding root structures, has a conditional rating of “poor”, indicating more significant incision and reduced stability.

5.2.1.4 In-stream Habitat

At this site, the stream has 2-3-foot tall banks. Both the upstream reaches and the tributaries have high, incised banks with infrequent connections to the active floodplain. In the tributary reaches, where riparian conditions are somewhat better and provide additional bank protection, had a conditional assessment of "fair". However, the mainstem reaches, with limited larger trees and corresponding root structures, had a conditional assessment of "poor", indicating more significant incision and reduced stability.

5.2.2 Restoration Approach

In alignment with the restoration strategy outlined for Site 1 in section 5.1.2, Site 2 is also prime for significant ecological uplift through a Legacy Sediment Removal (LSR) approach. At Site 2, the restoration efforts should be similarly focused on grading down the existing floodplain to its historic level, exposing the gravel basal layer, and constructing a base flow channel. However, the unique conditions at Site 2, such as the presence of active agricultural fields in the floodplain and the scattered larger trees along the tributaries, will require careful consideration during the design phase. Like the approach at Site 1, the restoration at Site 2 is expected to result in significant ecological uplift, with the potential to support diverse habitats and improve resilience to climate change.

5.2.3 Access and Constraints

A sanitary sewer line runs parallel to the stream, approximately 100 feet from the top of the bank, yet there remains adequate space for meaningful floodplain reconnection. Some impact on active agricultural land is anticipated, necessitating additional planning to evaluate restoration efforts with agricultural use. Access is good off both Eby Road and Bachmanville Road.

5.2.4 Ecological Uplift

For Site 2, ecological uplift is anticipated to yield significant benefits, analogous to those described in Section 5.1.4 for Site 1. Restoration efforts at this site will focus on reconnecting the stream to its floodplain, which will enhance floodplain access frequency, increase storm flow storage and attenuation, and improve groundwater recharge. These actions are expected to create a more resilient ecosystem as described in Section 5.1.4.

6 Stream Restoration Costs

Stream restoration in Pennsylvania is a complex endeavor, particularly in the context of improving water quality and addressing environmental challenges like sediment and nutrient pollution. The costs associated with these projects can vary significantly, driven by several critical factors.

6.1 Key Cost Drivers

The costs of stream restoration projects are primarily influenced by the scope of work, including the engineering and permitting processes, construction activities, and the ongoing monitoring and maintenance required to ensure the project's long-term success.

- **Restoration Strategy**: The specific restoration strategy chosen is a significant cost driver. For instance, natural channel design, floodplain reconnection, and the use of in-stream structures like logs or boulders all come with different cost implications. Some strategies, like floodplain reconnection, might require more extensive earthmoving and alteration of the landscape, leading to higher costs but multiple benefits. On the other hand, projects focusing on stabilizing banks with vegetation might have lower upfront costs but require more maintenance over time to ensure the vegetation establishes properly.

- **Engineering and Permitting**: These are often the initial and substantial costs, involving detailed design work and securing necessary regulatory approvals. These steps ensure that the restoration is not only effective but also compliant with environmental regulations.
- **Construction**: This phase includes earthmoving, regrading of stream banks, installation of stabilization structures, and planting of vegetation. The extent of work required depends on the existing condition of the stream and the goals of the restoration.
- **Monitoring and Maintenance**: After the initial restoration, ongoing efforts are needed to monitor the stream's health and maintain the structures and vegetation, ensuring the project's objectives are met over time.

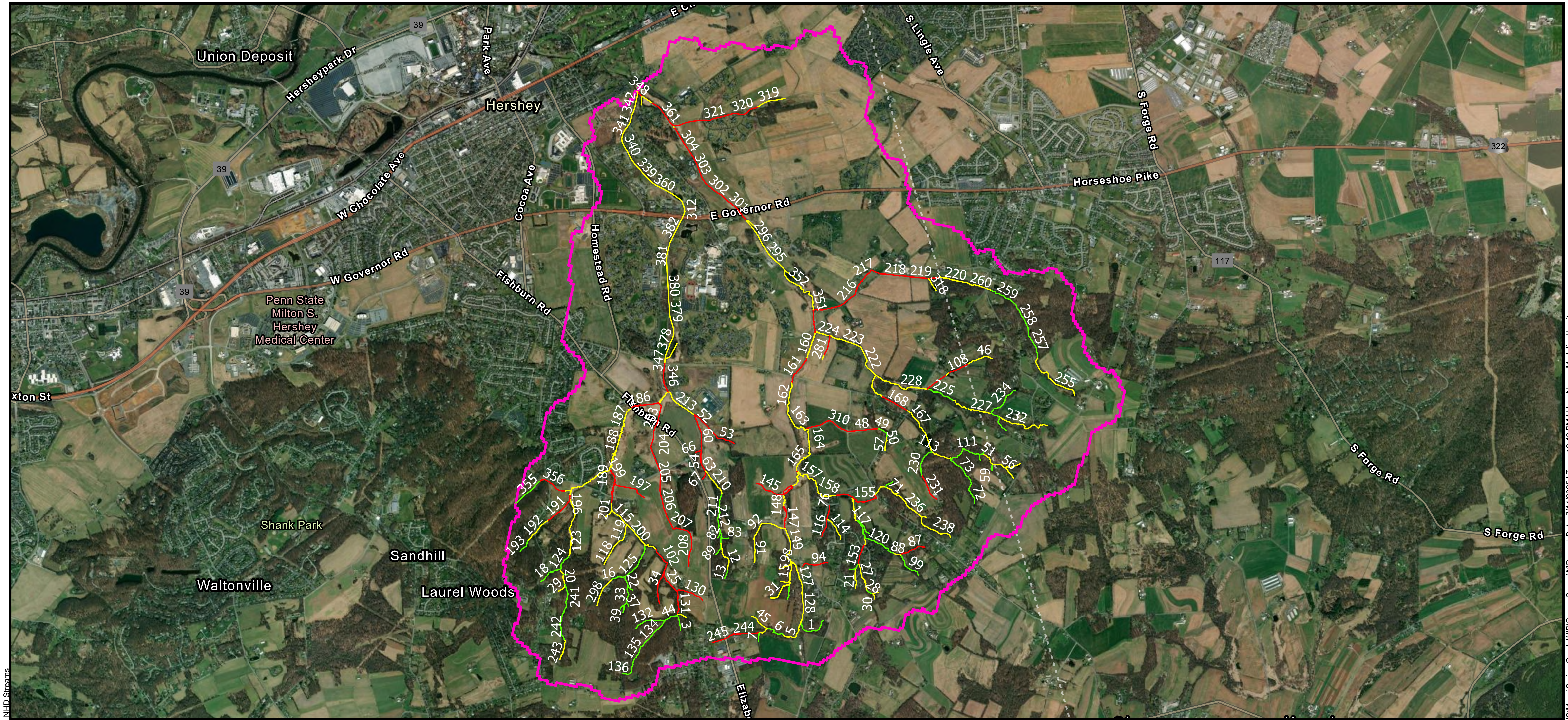
6.2 Estimated Stream Restoration Costs

The identified priority projects in the Spring Creek Watershed are comparable to several initiatives in the nearby Hammer Creek Watershed, both utilizing the Legacy Sediment Removal design approach. These similar projects provide valuable benchmarks for estimating unit costs, which range from $572 to $768 per linear foot of restoration. Consequently, for planning purposes, an estimated cost of $600 to $800 per linear foot should be considered for stream restoration projects using this design process in the Spring Creek Watershed.

Based on this rate, Priority Project 1, encompassing 4,883 linear feet (LF), has a projected cost estimate ranging from $2.92 million to $3.90 million. Similarly, Priority Project 2, spanning 5,563 linear feet, is estimated to cost between $2.73 million and $3.65 million. These planning-level cost estimates provide a financial framework for budgeting and resource allocation for the proposed restoration efforts.

7 References

1. Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. *A Function-Based Framework for Stream Assessment and Restoration Projects*. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, D.C. EPA 843-K-12-006.
2. Starr, R., Harman, W. and Davis, S., 2015. *Final Draft Function-Based Rapid Stream Assessment Methodology*. U.S. Fish and Wildlife Service. Annapolis, MD. CBFO-S15-06.
3. Fox, J., Swann, C., & Morris, M. (2022). *Spring Creek Watershed Characterization*. Center for Watershed Protection, Inc. Prepared for The Doc Fritchey Chapter of Trout Unlimited. Funded by the Pennsylvania Department of Environmental Protection and U.S. Environmental Protection Agency.

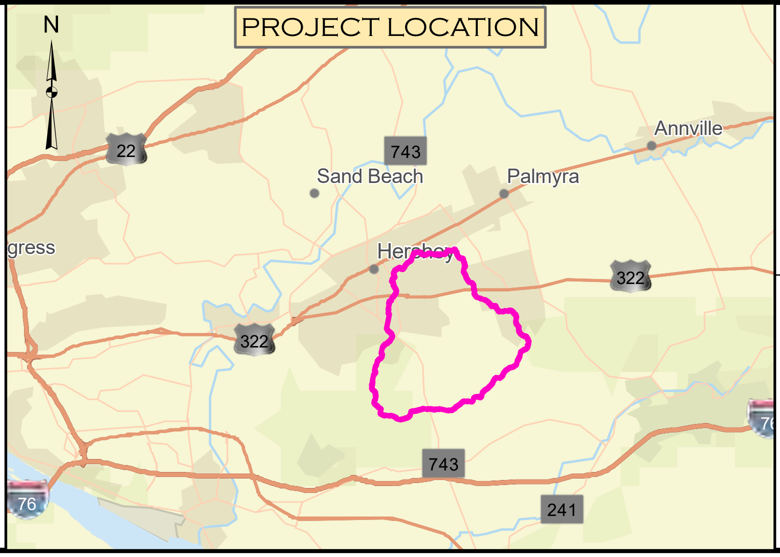


Legend

Scored Reaches within AOI

Condition Score

- 7 - 9
- 10 - 12
- 13 - 15
- CWP: Area of Interest



Spring Creek Watershed

Appendix A – Upper Spring Creek Scored Reaches Map

Dauphin County, PA

Prepared For

Center for Watershed Protection

N

0 2,000 4,000 Feet

FIGURE 1

DATE:
July 2025

Sources: ESRI Aerial Imagery 2017, ESRI Topography, TIGER Roads, USGS NHD Streams

Path: L:\Projects\000_Projects_Old\Baltimore\BAL0038_Spring Creek ARP\GIS\Maps\Spring Creek WIP\Spring Creek WIP.aprx | Date: 7/14/2025 | Time: 12:48 PM | User Name: MadelineHovitz

Appendix B: Upper Spring Creek Stream Assessment Results Table					
Index ID	Length (LF)	Existing Conditions Score	Existing Conditions Rating	Ownership (Milton Hershey or Private)	Priorty Project Area
1	1000	8	Poor	Private	
2	141	8	Poor	Private	
3	506	9	Poor	Private	
4	296	10	Fair	Private	
5	1000	10	Fair	Private	
6	712	9	Poor	Private	
7	330	9	Poor	Private	
12	1000	10	Fair	Milton Hershey	
13	339	9	Poor	Milton Hershey	
15	649	11	Fair	Milton Hershey and Private	
16	456	9	Poor	Private	
17	331	10	Fair	Private	
18	855	9	Poor	Private	
19	139	10	Fair	Private	
20	347	10	Fair	Private	
21	704	12	Fair	Private	
22	378	7	Poor	Private	
24	198	9	Poor	Milton Hershey and Private	
25	764	14	Good	Milton Hershey	
26	186	11	Fair	Private	
27	1000	11	Fair	Private	
28	247	7	Poor	Private	
29	343	11	Fair	Private	
30	206	10	Fair	Private	
31	877	10	Fair	Private	
32	509	8	Poor	Private	
33	582	9	Poor	Milton Hershey and Private	
34	1000	13	Good	Milton Hershey	
35	88	13	Good	Milton Hershey	
36	108	9	Poor	Milton Hershey	
37	146	9	Poor	Milton Hershey	
38	186	9	Poor	Milton Hershey and Private	
39	254	9	Poor	Milton Hershey and Private	
40	44	10	Fair	Milton Hershey and Private	
41	302	10	Fair	Milton Hershey and Private	
44	450	7	Poor	Private	
45	686	11	Fair	Private	
46	937	11	Fair	Private	
47	571	9	Poor	Private	
48	1000	14	Good	Private	

Appendix B: Upper Spring Creek Stream Assessment Results Table					
Index ID	Length (LF)	Existing Conditions Score	Existing Conditions Rating	Ownership (Milton Hershey or Private)	Priorty Project Area
49	524	9	Poor	Private	
50	55	12	Fair	Private	
51	525	10	Fair	Private	
52	1000	13	Good	Milton Hershey	
53	722	13	Good	Milton Hershey and Private	
54	414	13	Good	Milton Hershey	
55	402	10	Fair	Private	
56	488	10	Fair	Private	
57	397	12	Fair	Private	
58	49	10	Fair	Private	
59	210	9	Poor	Private	
60	1000	13	Good	Milton Hershey	
61	235	14	Good	Milton Hershey	
62	165	7	Poor	Private	
63	318	13	Good	Milton Hershey	
64	350	10	Fair	Private	
65	100	8	Poor	Private	
66	205	13	Good	Milton Hershey	
67	318	14	Good	Milton Hershey	
68	188	9	Poor	Private	
69	309	8	Poor	Private	
70	147	10	Fair	Private	
71	412	11	Fair	Private	
72	1000	7	Poor	Private	
73	887	8	Poor	Private	
76	477	13	Good	Private	
77	374	12	Fair	Private	
78	80	14	Good	Private	
80	607	7	Poor	Private	
81	194	9	Poor	Milton Hershey	
82	208	8	Poor	Milton Hershey	
83	271	8	Poor	Milton Hershey	
84	197	8	Poor	Milton Hershey	
85	51	9	Poor	Private	
87	929	13	Good	Private	
88	246	11	Fair	Private	
89	415	8	Poor	Milton Hershey	
90	81	10	Fair	Private	
91	1000	11	Fair	Milton Hershey	
92	1000	12	Fair	Milton Hershey	

Appendix B: Upper Spring Creek Stream Assessment Results Table					
Index ID	Length (LF)	Existing Conditions Score	Existing Conditions Rating	Ownership (Milton Hershey or Private)	Priorty Project Area
93	218	12	Fair	Milton Hershey	
94	935	15	Good	Private	
96	167	8	Poor	Private	
97	237	9	Poor	Private	
98	517	10	Fair	Milton Hershey and Private	
99	1000	9	Poor	Private	
100	16	10	Fair	Private	
102	1000	13	Good	Milton Hershey and Private	
103	479	11	Fair	Milton Hershey and Private	
104	196	10	Fair	Private	
105	140	9	Poor	Private	
108	393	13	Good	Private	
109	746	15	Good	Private	
110	297	8	Poor	Private	
111	1000	9	Poor	Private	
112	274	9	Poor	Private	
113	748	10	Fair	Private	
114	884	11	Fair	Private	
115	757	10	Fair	Private	
116	517	13	Good	Private	
117	726	9	Poor	Private	
118	1000	10	Fair	Private	
119	614	11	Fair	Private	
120	1000	7	Poor	Private	
121	74	9	Poor	Private	
122	1000	11	Fair	Private	
123	1000	10	Fair	Private	
124	593	9	Poor	Private	
125	1000	7	Poor	Private	
126	305	7	Poor	Private	
127	1000	10	Fair	Private	
128	1000	12	Fair	Private	
129	165	12	Fair	Private	
130	1000	15	Good	Milton Hershey	
131	812	14	Good	Milton Hershey	
132	1000	9	Poor	Milton Hershey and Private	
133	111	9	Poor	Private	
134	1000	8	Poor	Private	
135	1000	7	Poor	Private	
136	496	9	Poor	Private	

Appendix B: Upper Spring Creek Stream Assessment Results Table					
Index ID	Length (LF)	Existing Conditions Score	Existing Conditions Rating	Ownership (Milton Hershey or Private)	Priorty Project Area
143	477	13	Good	Milton Hershey	x
144	473	13	Good	Milton Hershey	x
145	1000	15	Good	Milton Hershey	x
146	66	14	Good	Milton Hershey	x
147	1000	13	Good	Milton Hershey	x
148	543	12	Fair	Milton Hershey	x
149	1000	12	Fair	Milton Hershey and Private	
150	332	11	Fair	Milton Hershey and Private	
151	684	12	Fair	Milton Hershey	x
152	954	10	Fair	Private	
153	660	13	Good	Private	
154	98	10	Fair	Private	
155	1000	13	Good	Private	
156	550	11	Fair	Milton Hershey and Private	
157	1000	12	Fair	Milton Hershey and Private	
158	1000	11	Fair	Private	
159	614	13	Good	Private	
160	1000	12	Fair	Milton Hershey	x
161	1000	13	Good	Milton Hershey and Private	x
162	1000	12	Fair	Private	
163	1000	12	Fair	Private	
164	1000	12	Fair	Private	
165	1000	12	Fair	Milton Hershey and Private	x
166	53	14	Good	Milton Hershey	
167	1000	11	Fair	Private	
168	1000	14	Good	Private	
169	967	11	Fair	Milton Hershey and Private	
185	631	11	Fair	Milton Hershey	
186	1000	13	Good	Milton Hershey	
187	1000	12	Fair	Milton Hershey	
188	1000	11	Fair	Milton Hershey	
189	1000	12	Fair	Milton Hershey	
190	28	13	Good	Milton Hershey	
191	1000	14	Good	Private	
192	1000	12	Fair	Private	
193	454	9	Poor	Private	
194	1000	11	Fair	Milton Hershey and Private	
195	1000	12	Fair	Private	
196	199	13	Good	Private	
197	1000	14	Good	Milton Hershey	

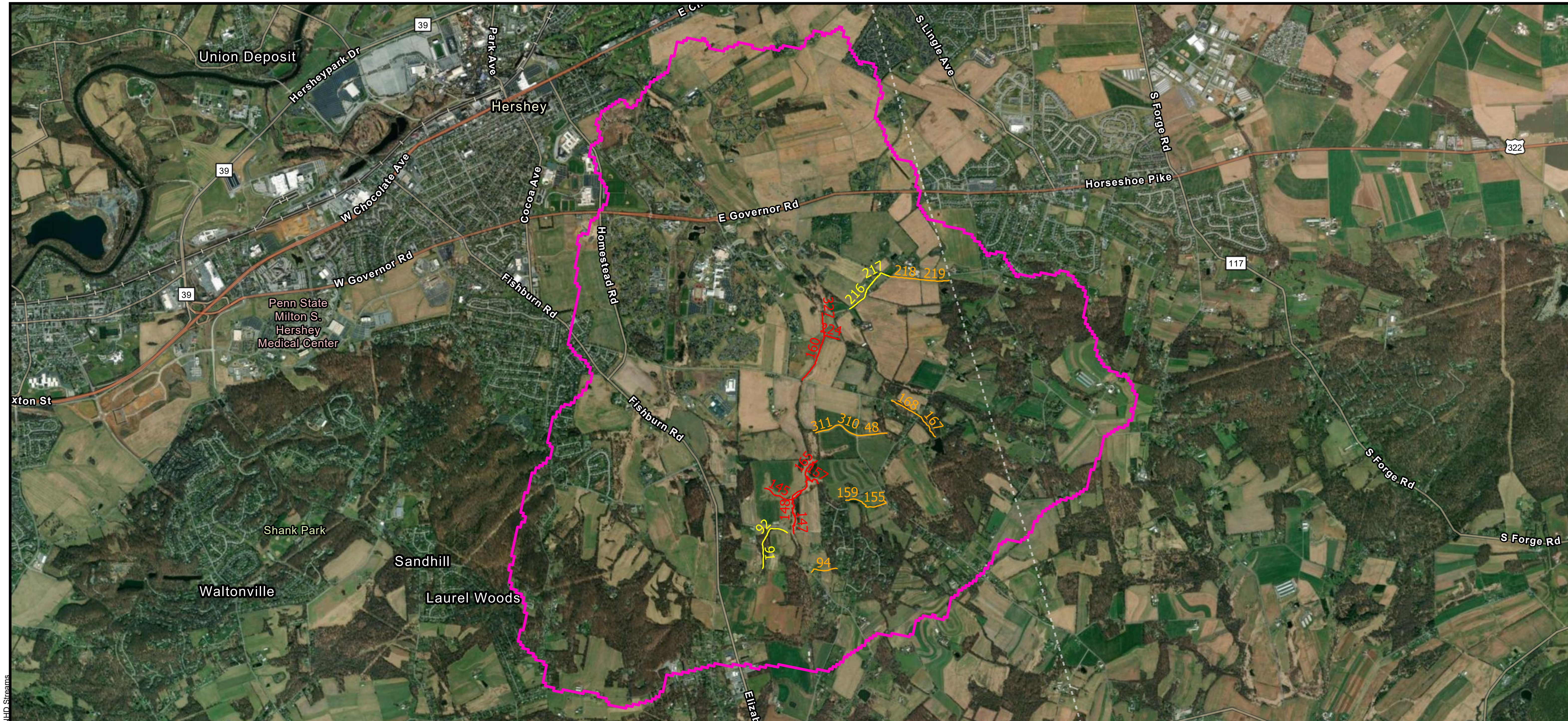
Appendix B: Upper Spring Creek Stream Assessment Results Table					
Index ID	Length (LF)	Existing Conditions Score	Existing Conditions Rating	Ownership (Milton Hershey or Private)	Priorty Project Area
198	177	14	Good	Milton Hershey	
199	779	13	Good	Milton Hershey	
200	935	11	Fair	Private	
201	1000	14	Good	Milton Hershey and Private	
202	191	10	Fair	Private	
203	1000	13	Good	Milton Hershey	
204	1000	13	Good	Milton Hershey	
205	1000	15	Good	Milton Hershey	
206	1000	14	Good	Milton Hershey	
207	1000	13	Good	Milton Hershey	
208	1000	13	Good	Milton Hershey	
209	215	14	Good	Milton Hershey	
210	1000	11	Fair	Milton Hershey	
211	1000	9	Poor	Milton Hershey	
212	362	9	Poor	Milton Hershey	
213	1000	12	Fair	Milton Hershey	
214	254	12	Fair	Milton Hershey	
215	1000	14	Good	Milton Hershey	x
216	1000	14	Good	Milton Hershey and Private	
217	1000	13	Good	Milton Hershey and Private	
218	1000	13	Good	Private	
219	1000	14	Good	Private	
220	982	10	Fair	Private	
221	223	14	Good	Milton Hershey	x
222	1000	12	Fair	Milton Hershey	
223	1000	12	Fair	Milton Hershey and Private	
224	876	12	Fair	Milton Hershey and Private	x
225	1000	9	Poor	Private	
226	611	11	Fair	Private	
227	799	10	Fair	Private	
228	1000	12	Fair	Private	
229	965	11	Fair	Milton Hershey and Private	
230	1000	7	Poor	Private	
231	949	14	Good	Private	
232	1000	11	Fair	Private	
233	998	10	Fair	Private	
234	1000	8	Poor	Private	
235	260	8	Poor	Private	
236	1000	12	Fair	Private	
237	212	11	Fair	Private	

Appendix B: Upper Spring Creek Stream Assessment Results Table

Index ID	Length (LF)	Existing Conditions Score	Existing Conditions Rating	Ownership (Milton Hershey or Private)	Priorty Project Area
238	1000	11	Fair	Private	
239	392	11	Fair	Private	
240	167	12	Fair	Private	
241	1000	9	Poor	Private	
242	1000	7	Poor	Private	
243	724	11	Fair	Private	
244	1000	13	Good	Private	
245	723	13	Good	Private	
253	81	12	Fair	Private	
255	1000	11	Fair	Private	
256	1000	12	Fair	Private	
257	1000	9	Poor	Private	
258	1000	9	Poor	Private	
259	1000	9	Poor	Private	
260	880	11	Fair	Private	
281	674	13	Good	Milton Hershey	
284	176	11	Fair	Milton Hershey	
285	422	10	Fair	Milton Hershey	
286	148	12	Fair	Private	
287	62	10	Fair	Milton Hershey	
294	346	10	Fair	Milton Hershey	
295	1000	12	Fair	Milton Hershey	
296	1000	10	Fair	Milton Hershey	
297	76	12	Fair	Milton Hershey	
298	1000	11	Fair	Private	
299	49	9	Poor	Private	
300	389	10	Fair	Milton Hershey	
301	1000	13	Good	Milton Hershey	
302	1000	13	Good	Milton Hershey	
303	1000	13	Good	Milton Hershey	
304	1000	13	Good	Milton Hershey	
305	120	12	Fair	Milton Hershey	
310	998	14	Good	Private	
311	537	14	Good	Private	
312	635	12	Fair	Milton Hershey	
314	80	10	Fair	Milton Hershey	
318	260	11	Fair	Private	
319	1000	12	Fair	Milton Hershey	
320	1000	13	Good	Milton Hershey	
321	1000	13	Good	Milton Hershey	

Appendix B: Upper Spring Creek Stream Assessment Results Table

Index ID	Length (LF)	Existing Conditions Score	Existing Conditions Rating	Ownership (Milton Hershey or Private)	Priorty Project Area
322	981	13	Good	Milton Hershey	
323	143	11	Fair	Private	
327	601	13	Good	Milton Hershey	x
331	181	11	Fair	Milton Hershey	
333	508	10	Fair	Milton Hershey	
339	1000	11	Fair	Milton Hershey	
340	1000	11	Fair	Milton Hershey	
341	1000	12	Fair	Milton Hershey	
342	603	12	Fair	Milton Hershey	
344	230	11	Fair	Milton Hershey	
346	1000	14	Good	Milton Hershey	
347	164	12	Fair	Milton Hershey	
348	184	13	Good	Milton Hershey	
349	222	12	Fair	Private	
351	1000	10	Fair	Milton Hershey	
352	1000	11	Fair	Milton Hershey	
353	16	13	Good	Milton Hershey	
354	99	9	Poor	Private	
355	1000	9	Poor	Private	
356	1000	13	Good	Private	
357	193	12	Fair	Private	
360	625	11	Fair	Milton Hershey	
361	1000	13	Good	Milton Hershey	
362	434	12	Fair	Milton Hershey	
368	86	12	Fair	Milton Hershey	
369	637	11	Fair	Private	
378	1000	11	Fair	Milton Hershey	
379	1000	11	Fair	Milton Hershey	
380	1000	10	Fair	Milton Hershey	
381	1000	11	Fair	Milton Hershey	
382	869	10	Fair	Milton Hershey	
389	65	12	Fair	Milton Hershey	
390	108	11	Fair	Private	
402	189	10	Fair	Private	
403	236	14	Good	Private	
404	58	13	Good	Private	
Total Length	**172774**				



Legend

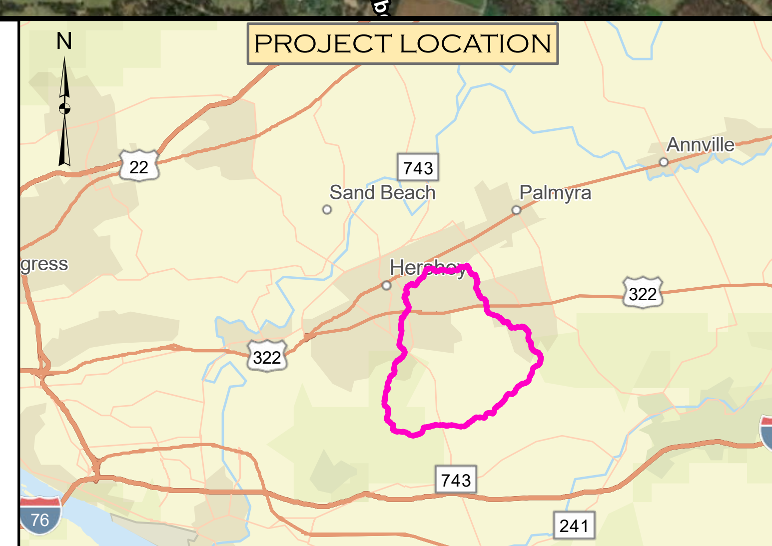
Prioritization

High Priority - Milton Hershey Property

High Priority - Private Property

Medium Priority

CWP: Area of Interest



Spring Creek Watershed

Appendix C – Upper Spring Creek Potential Stream Restoration Project Area Map

Dauphin County, PA

Prepared For

Center for Watershed Protection

N

0 2,000 4,000 Feet

FIGURE 1

DATE: July 2025

Sources: ESRI Aerial Imagery 2017; ESRI Topography; TIGER Roads; USGS NHD Streams

Path: L:\Projects\000_Projects_Old\Baltimore\BAL0038_Spring Creek ARP\GIS\Maps\Spring Creek WIP\Spring Creek WIP.aprx | Date: 7/23/2025 | Time: 2:13 PM | User Name: MadelineHorvitz

Appendix D. Model My Watershed (MMW) Data

Animal	Count
Chickens, Broilers	43,841
Chickens, Layers	0
Cows, Beef	31
Cows, Dairy	246
Horses	47
Pigs/Hogs/Swine	751
Sheep	71
Turkeys	0

Month	Mean Preci	Mean Temp. (°C)
January	7.7	-1.4
February	7	-0.7
March	8.7	4.5
April	8.6	10.6
May	9.9	16.3
June	10.1	21.1
July	10.5	23.6
August	9.5	22.6
September	9.7	18.8
October	8.6	12.5
November	7.8	6.4
December	8	0.6
Annual	106	11.2

Type	NLCD Code	Area (km^2)	Coverage (%)	Active River Area (km^2)
Open Water	11	0.02	0.06	0.02
Perennial Ice/Snow	12	0	0	0
Developed, Open Space	21	3.47	12.68	1.05
Developed, Low Intensity	22	2.86	10.46	0.88
Developed, Medium Intensity	23	0.83	3.05	0.27
Developed, High Intensity	24	0.2	0.73	0.04
Barren Land (Rock/Sand/Clay)	31	0.01	0.02	0
Deciduous Forest	41	3.86	14.09	1.35
Evergreen Forest	42	0	0	0
Mixed Forest	43	1.11	4.06	0.45
Shrub/Scrub	52	0.49	1.81	0.21
Grassland/Herbaceous	71	0.06	0.21	0.03
Pasture/Hay	81	5.16	18.85	1.76
Cultivated Crops	82	9.19	33.57	2
Woody Wetlands	90	0.1	0.35	0.09
Emergent Herbaceous Wetlands	95	0.01	0.05	0.01
Total		27.37	100	8.16

Type	Area (km^2)	Coverage (%)
A - High Infiltration	6.05	22.12
A/D - High/Very Slow Infiltration	0	0
B - Moderate Infiltration	17.55	64.14
B/D - Medium/Very Slow Infiltration	0.75	2.75
C - Slow Infiltration	1.66	6.06
C/D - Medium/Very Slow Infiltration	0.17	0.62
D - Very Slow Infiltration	1.18	4.31
Total	27.37	100

Stream Order	Total Length (km)	Mean Channel Slope (%)
1st	17.25	1.65%
2nd	7.6	0.27%
3rd	0.86	0.33%
4th	0	No Data
5th	0	No Data
6th	0	No Data
7th	0	No Data
8th	0	No Data
9th	0	No Data
10th	0	No Data
Other	0	No Data
Combined	25.71	1.20%

Length in agricultural areas = 9.94 km
Length in non-agricultural areas = 15.77 km

Sources	Sediment (kg)	Total Nitrogen (kg)	Total Phosphorus (kg)
Hay/Pasture	193,245.60	667.3	197.8
Cropland	1,854,835.40	6,701.30	1,587.20
Wooded Areas	811.9	22.8	1.7
Wetlands	25.8	3.9	0.2
Open Land	215.6	4.1	0.2
Barren Areas	0.6	0.2	0
Low-Density Mixed	3,937.20	103.5	11
Medium-Density Mixed	6,229.70	123.6	12.6
High-Density Mixed	1,505.30	29.9	3
Low-Density Open Space	4,769.00	125.3	13.4
Farm Animals	0	3,913.10	1,026.70
Stream Bank Erosion	576,406.00	367	107
Subsurface Flow	0	25,121.30	275.8
Point Sources	0	0	0
Septic Systems	0	293	0

Appendix E. PA DEP Load Calculations

pennsylvania
DEPARTMENT OF ENVIRONMENTAL
PROTECTION

BUREAU OF CLEAN WATER
PRESCRIBED SEDIMENT REDUCTIONS FOR SPRING CREEK
DAUPHIN AND LEBANON COUNTIES
DRAFT FOR STAKEHOLDERS, APRIL 14, 2023

Prepared by:
Michael Morris
PA Department of Environmental Protection
Office of Water Programs
Bureau of Clean Water
11th Floor: Rachel Carson State Office Building
Harrisburg, PA 17105

2023

Photo/Image Credit:
Aside from the imagery used in mapping, all photographs by Michael Morris, DEP

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EXECUTIVE SUMMARY

The Spring Creek watershed in Derry Township, Dauphin County was listed as Aquatic Life Use impaired per the Pennsylvania Department of Environmental Protection’s (DEP) 2022 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report (Integrated Report), including the Clean Water Act Section 303(d) List. These impairments were partially attributed to excessive siltation from sources such as agriculture and urban development. The purpose of this study is to prescribe sediment reduction goals as a basis for the development of a watershed restoration plan. Because Pennsylvania does not have numeric water quality criteria for sediment, the loading rates from a similar unimpaired watershed were used to calculate the reduction goals.

Reduction goals were reported for both the entire watershed, as well as for a smaller watershed that will be referred to as the “319 study area”. Existing annual average sediment loading in the whole Spring Creek watershed was estimated to be 12,986,361 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 52% to 6,288,428 pounds per year. Within the 319 study area, sediment loading should be reduced by 42%, from 5,850,363 pounds per year to 3,400,477 pounds per year.

To achieve these reductions while maintaining a 10% margin of safety within the whole watershed, annual average loading from streambanks should be reduced by 61%, while loading from croplands, hay/pasture lands and developed lands should each be reduced by 51%. Within the 319 study area, loading from cropland should be reduced by 53% while the loading from hay/pasture lands and streambanks should be reduced by 36% each. Allocation of annual average sediment loading among the restoration plan variables is summarized in Table 1.

Table 1. Summary of restoration plan variables for the Spring Creek watershed. All values are annual averages in lbs/yr.

Subwatershed	AL	UF	SL	LNR	ASL
Whole	6,288,428	628,843	5,659,585	4,848	5,654,737
319 Study Area	3,400,477	340,048	3,060,429	38,585	3,021,845

AL=Allowable Load; UF = Uncertainty Factor; SL = Source Load. The SL is further divided into LNR = Loads Not Reduced and ASL=Adjusted Source Load.

In addition to achieving these reductions, site observation suggest that dam and legacy sediment removal will be crucial to restoring this watershed.

INTRODUCTION

Spring Creek is a tributary of Swatara Creek, with its mouth occurring just west of the Town of Hershey in Derry Township, Dauphin County (Figure 1). While the Spring Creek watershed occurred primarily in Derry Township, portions of the watershed also occurred in Conewago Township, Dauphin County, as well as in South Londonderry Township, North Londonderry Township and Palmyra Borough in Lebanon County. The entire watershed, as delineated in Figure 1, is approximately 24 square miles, and all of its stream segments are currently designated Warm Water Fishes, Migratory Fishes at 25 Pa. Code § 93.

The Spring Creek watershed is notable for several reasons. According to the Pennsylvania Fish and Boat Commission (PFBC 2023b), portions of the watershed are known to harbor “Wild Trout” (Natural Reproduction), including the mainstem through the Hershey area and some tributary reaches. And, consideration is currently being given to upgrading this status to a “Class A” designation, which is reserved for the state’s most productive wild trout fisheries (PFBC 2023a). Wild trout streams are uncommon in Dauphin County, and their presence in this watershed is likely in large part due to the watershed’s limestone geology, which creates cold water springs. Secondly, the Spring Creek watershed occurs in a very commercially and culturally important region of Pennsylvania, as it is home to the Hershey Company, one of the world’s largest chocolate and candy manufacturers. The associated Hershey Entertainment and Resorts Company owns major tourist attractions such as Hersheypark, ZOOAMERICA, the Hotel Hershey, concert venues and a golf course. Finally, much of the Spring Creek watershed flows through the Milton Hershey School, a cost-free private boarding school for children of low-income families. According to their website, the school enrolls more than 2,000 students, and its 7,000 acre campus is one of the largest in the United States.

According to the 2022 Final Integrated Report (DEP 2022b), nearly all stream segments within the watershed are listed as Aquatic Life Use impaired due to excessive siltation (Figure 1). The listed sources of siltation varied throughout the watershed (Table 2), but agriculture and urban development were most common. Such impairments are consistent with expectations, since, according to an analysis of NLCD 2019 land cover data, as reported by Model My Watershed, the Spring Creek watershed was estimated to be 50% developed lands and 36% agricultural lands, with only 13% naturally vegetated lands remaining. Aquatic Life Use impairments are common in regions of Pennsylvania with such high amounts of anthropogenic land cover.

The removal of natural vegetation and soil disturbance associated with agriculture and land development increases erosion leading to sediment deposition in streams. Excessive fine sediment deposition may destroy the coarse-substrate habitats required by many stream organisms. While Pennsylvania does not have numeric water quality criteria for sediment, it does have applicable narrative criteria:

> *Water may not contain substances attributable to point or nonpoint source discharges in concentration or amounts sufficient to be inimical or harmful to the water uses to be protected or to human, animal, plant or aquatic life. (25 PA Code § 93.6 (a))*
>
> *In addition to other substances listed within or addressed by this chapter, specific substances to be controlled include, but are not limited to, floating materials, oil, grease, scum and substances which produce color, tastes, odors, turbidity or settle to form deposits. (25 PA Code, § 93.6 (b))*

The Doc Fritchey Chapter of Trout Unlimited, in cooperation with the Center for Watershed Protection, are seeking to develop a Watershed Implementation Plan that would make projects within the watershed eligible for funding under Section 319 of the Clean Water Act. However, since there are currently no Total Maximum Daily Loads (TMDLs) or other prescribed pollution reductions for this watershed, DEP's TMDL section has developed this document to estimate the sediment reductions needed to achieve water quality standards. Prescribed reductions were made for both the entire watershed as well as a smaller "319 study area" that was delineated to avoid regulated municipal separate storm sewer system (MS4) urbanized area (Figure 2), since Section 319 funding cannot be used for National Pollutant Discharge Elimination System (NPDES) permit compliance.

It should be noted that, in addition to siltation, various other causes of impairment have been identified in this watershed (Table 2). Figures 3 through 5 give further detail about the location of "organic enrichment" impairments as well as areas where impairments were attributed to agricultural and urban-related sources. While the causes and sources of impairment within the watershed are diverse, this document focuses specifically on resolving siltation impairments. Seeking to address one pollutant will simplify the watershed restoration plan, and it is believed that resolving the siltation impairments may also help resolve other problems. For instance, riparian buffers Best Management Practices (BMPs) may filter out both sediment and organic matter from runoff before it reaches the stream. Urban BMPs that promote stormwater infiltration may be effective against hydromodification impairments and reduce sediment loading from streambank erosion. Stream restoration BMPs, especially those that incorporate legacy sediment removal and floodplain wetland restoration, may also be effective at both reducing bank erosion and mitigating hydromodification and habitat alterations associated with urbanization. In addition to greatly simplifying the plan, the Department has more experience and better-established practices for addressing the siltation impairments, which further supports its use as the "common denominator" in this case.

Table 2. Aquatic Life Use impaired stream segments in the Spring Creek watershed per the 2022 final Pennsylvania Integrated Report (DEP 2022b). See Appendix A for more information on the listing process and Appendix C for a listing of each segment.

Source	United States Environmental Protection Agency 305(b) Cause Code	Miles
Habitat Modification- Other than Hydromodification	Flow Regime Modification	3.6
Urban Runoff/Storm Sewers	Flow Regime Modification	4.5
Habitat Modification- Other than Hydromodification	Habitat Alterations	3.6
Urban Runoff/Storm Sewers	Habitat Alterations	4.5
Agriculture	Organic Enrichment	22.0

Agriculture	Siltation	35.9
Golf Courses	Siltation	4.5
Source Unknown	Siltation	3.6
Urban Runoff/Storm Sewers	Siltation	13.0

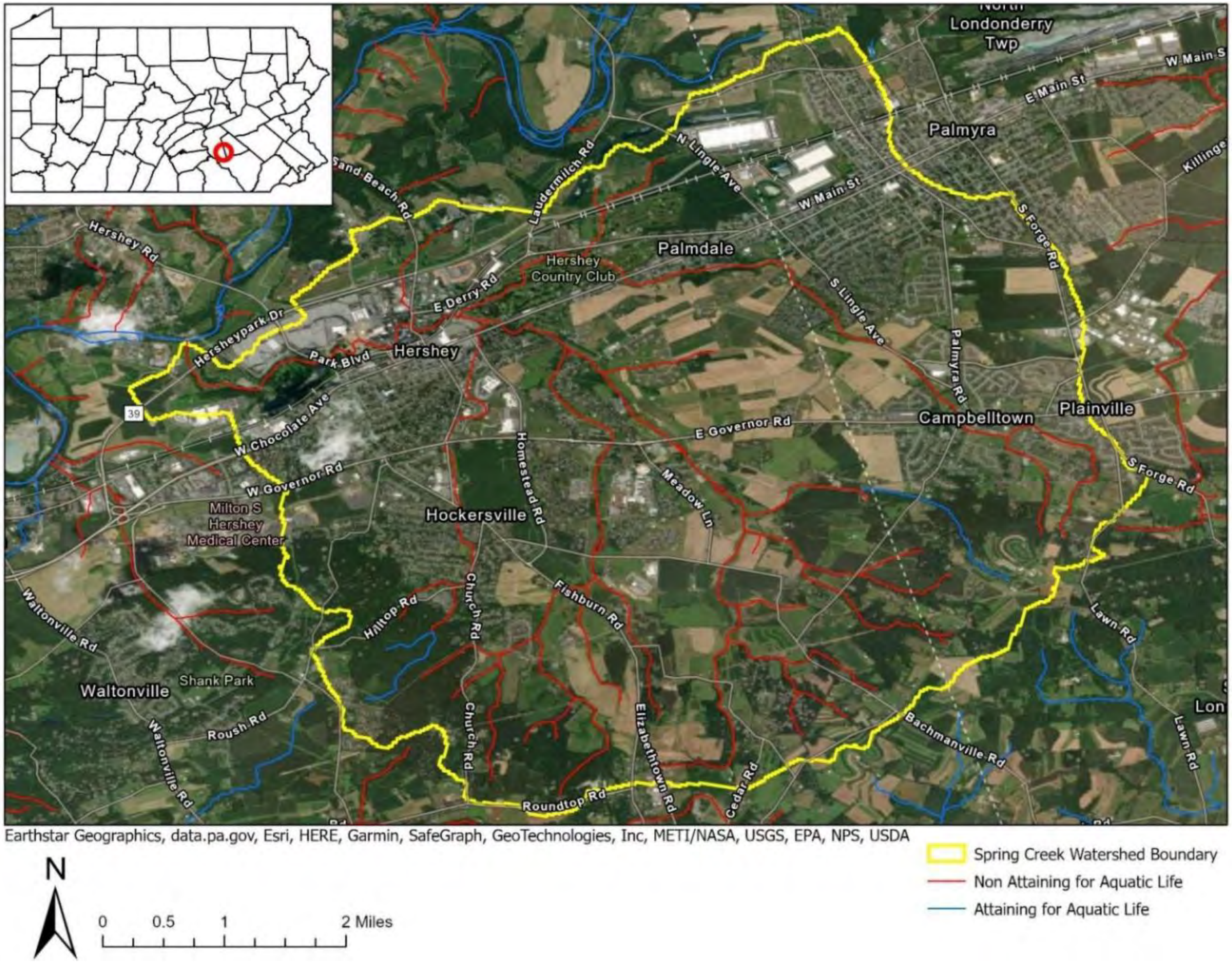

Figure 1. Spring Creek watershed. All stream segments shown as Aquatic Life Use impaired within the Spring Creek watershed were listed were listed as impaired for siltation per the 2022 Integrated Report (DEP 2022b).

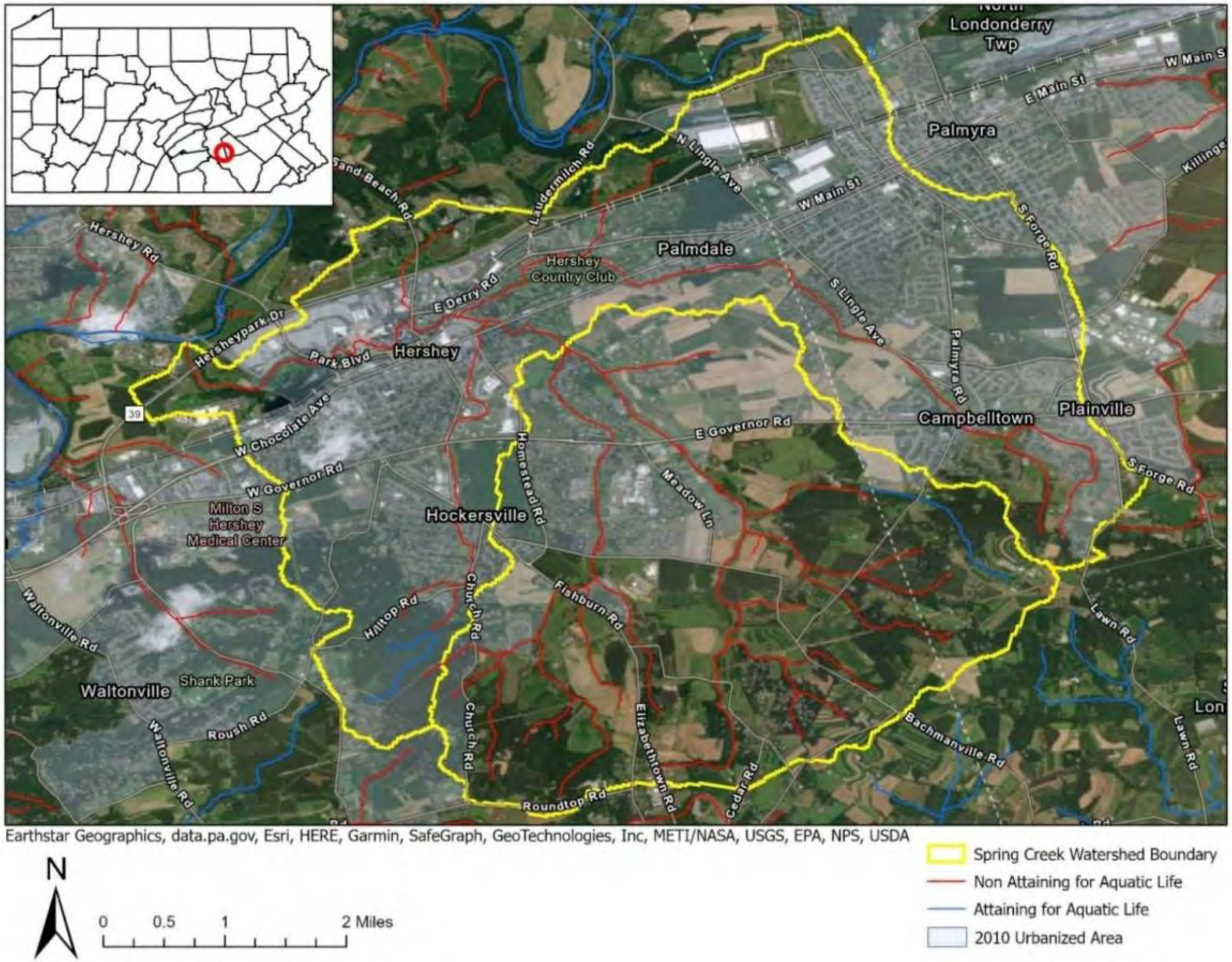

Figure 2. Spring Creek Watershed and the 319 study area. While the identified sources of the siltation varied, in general, agriculture alone was the primary source within most of the upper "319 study area". Urban runoff, often with agriculture, were identified as contributing sources outside of the 319 study area. See the 2022 Integrated Report for more details on the spatial patterns of identified sources (DEP 2022b). The Urbanized Area layer was from the U.S. Census Bureau.

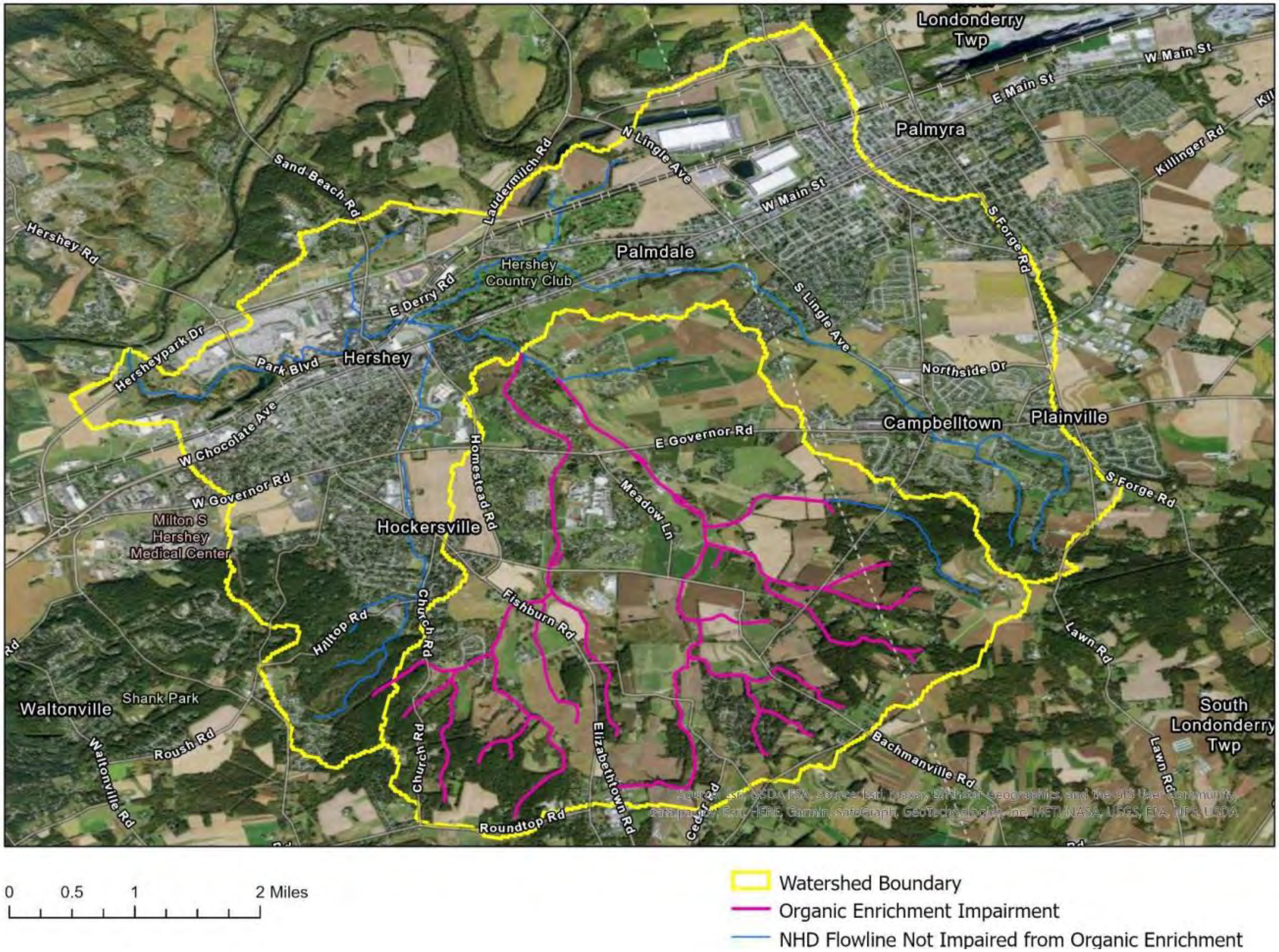

Figure 3. Stream segments within the Spring Creek watershed that were impaired from the cause of organic enrichment per the 2022 Integrated Report (DEP 2022b).

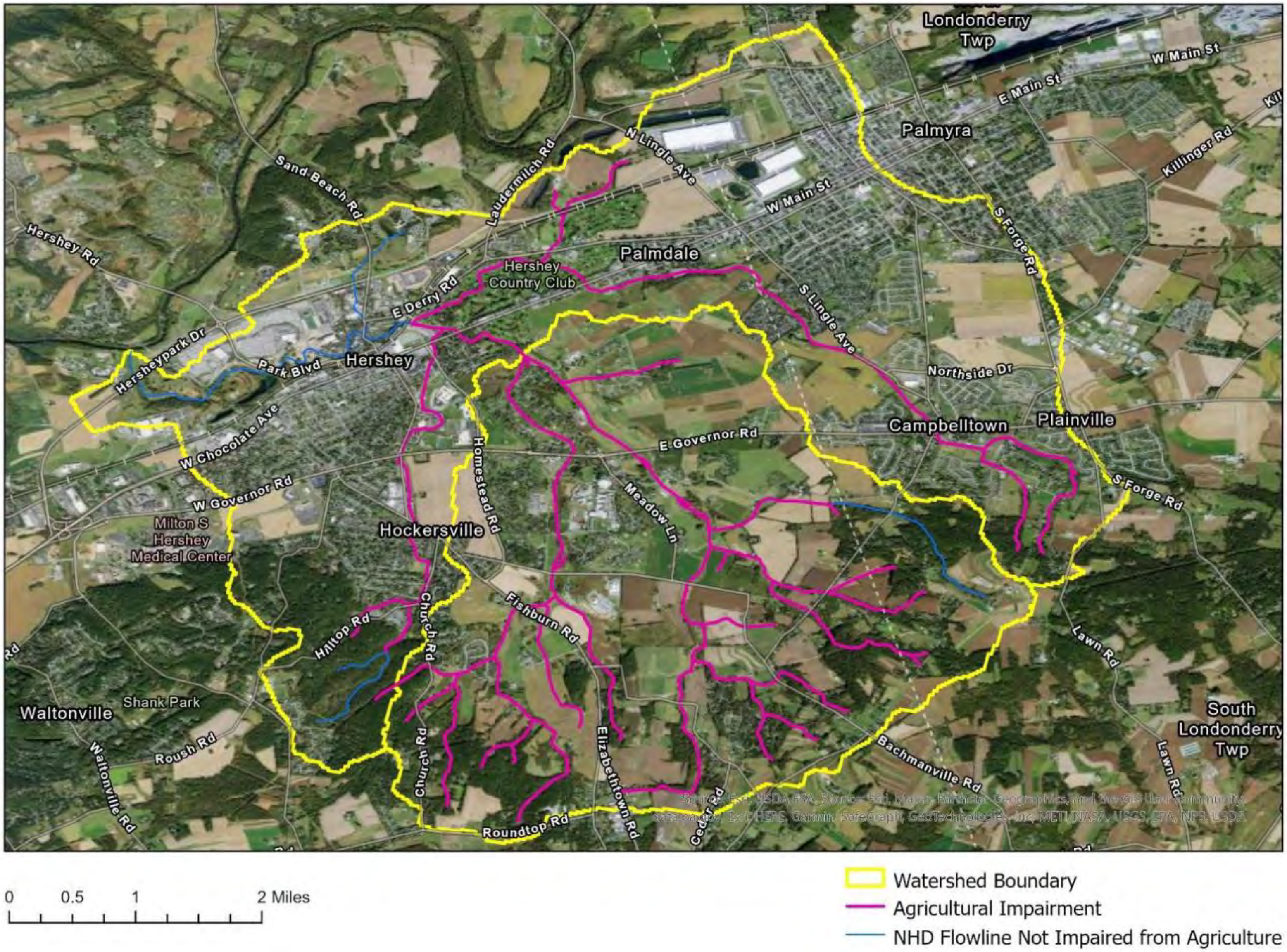

Figure 4. Stream segments within the Spring Creek watershed that were impaired from agricultural sources per the 2022 Integrated Report (DEP 2022b).

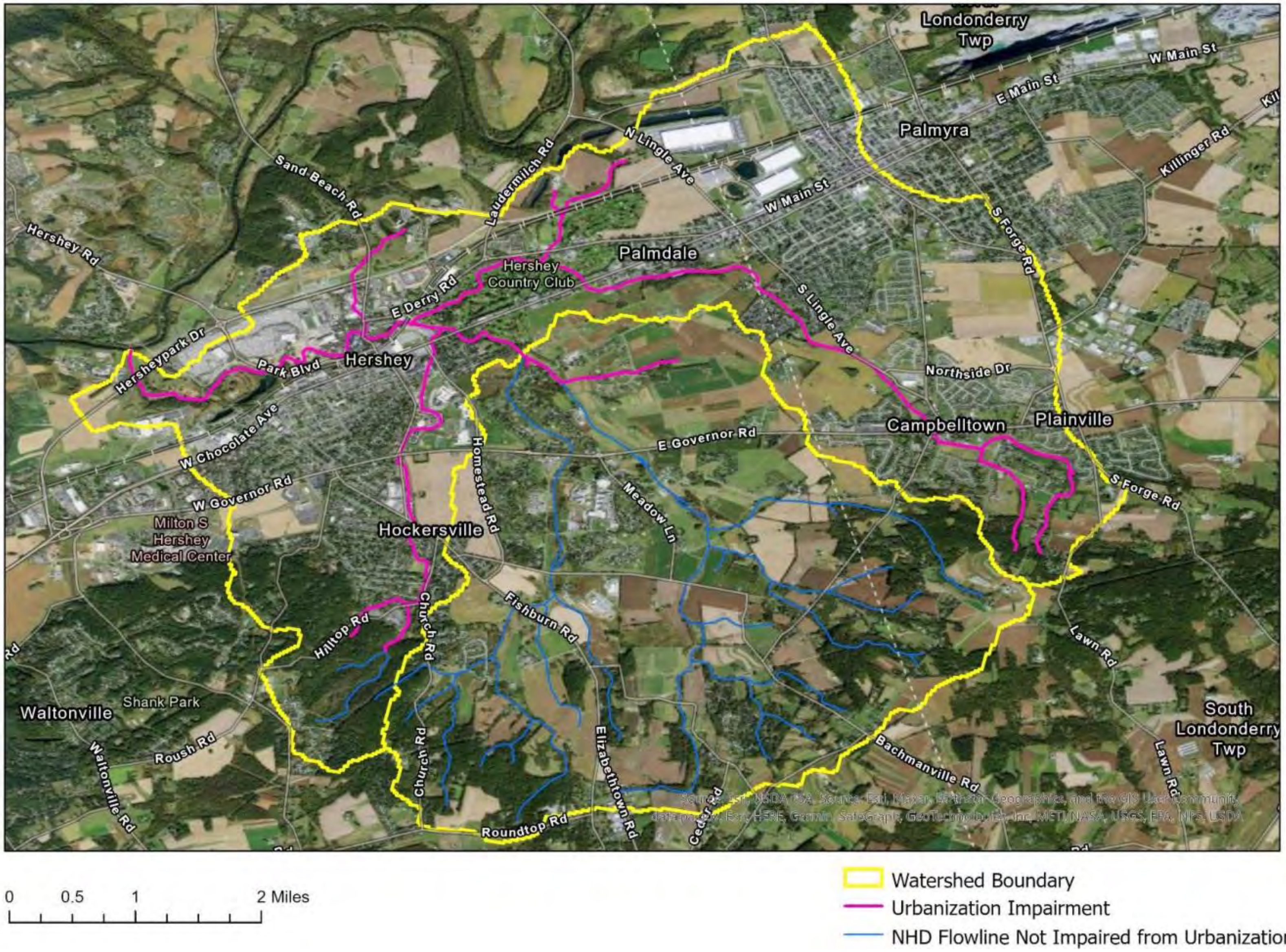

Figure 5. Stream segments within the Spring Creek watershed that were impaired from urbanization sources per the 2022 Integrated Report (DEP 2022b).

Table 3. Existing NPDES-permitted discharges in the Spring Creek watershed and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

Permit No.	Facility Name	Mean, lbs/yr
Within Upper Area		
PAG133637	Derry Twp MS4	N/A
PAG133621	Conewago Twp MS4	N/A
PAG133546	South Londonderry Twp MS4	N/A
PA0009288	Milton Hershey School IW	N/A
PAG043885	Michael Civils, SFS	8
Outside Upper Area		
PAG133563	North Londonderry Twp MS4	N/A
PAG133558	Palmyra Boro MS4	N/A
PA0008087	Hershey East Offices IW	N/A
PAR123505	Hershey Foods West Chocolate MFG PLT	N/A
PA0081302	South Londonderry Twp Muni Auth WWTP	2,159
PAR403507	Waste Management of Pennsylvania	N/A

Permits within the delineated watershed were based on DEP's eMapPA (DEP 2022a) and Watershed Resources Registry (USEPA 2022).

Milton Hershey School Industrial Waste (IW). Drainage from ice rink refrigeration equipment; flow was reported, but sediment was not measured.

Hershey East Offices IW. Noncontact cooling water and industrial stormwater; flow was reported, but sediment was not measured.

Hershey Foods West Chocolate MFG PLT. Industrial stormwater with no sediment of flow reporting.

Michael Civils, SFS. Permit for a small flow wastewater treatment facility. Mean annual sediment load was calculated assuming a flow rate of 262.5 gpd for a single-family residence and a total suspended solids concentration of 10 mg/l.

Waste Management of Pennsylvania. Industrial Stormwater with no sediment or flow reporting.

South Londonderry Township Muni Auth WWTP. Loading was estimated based on an analysis of electronic discharge monitoring report (eDMR) data. Total suspended solids loads were reported monthly for years 2009 through 2021. These values, in lbs/d, were multiplied by the number of days within each month and then all months were summed to derive yearly values. The value reported above is an average of those yearly loads.

MS4 Permits: Loading associated with MS4 NPDES permits will be treated via the modelling of land covers, as would be the case for other nonpoint sources.

SELECTION OF THE REFERENCE WATERSHED

Because Pennsylvania does not have numeric water quality criteria for sediment, the “Reference Watershed Approach” was used. This method estimates pollutant loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired for the same use. Then, the loading rate in the unimpaired watershed is scaled to the area of the impaired watershed so that necessary load reductions may be calculated. It is assumed that reducing loading rates in the impaired watershed to the levels found in the attaining watershed will result in the amelioration of the siltation impairments.

In addition to anthropogenic influences, there are many other natural factors affecting sediment loading and accumulation rates in a watershed. Thus, selection of a reference watershed with similar natural characteristics as the impaired watershed is crucial. Failure to use an appropriate reference watershed could result in problems such as the setting of sediment reduction goals that are unattainable, or nonsensical TMDL calculations that suggest that sediment loading in the impaired watershed should be increased.

To find a reference, GIS data layers largely consistent with the stream impairments noted in Pennsylvania’s Integrated Report were used to search for nearby watersheds that were similar to the Spring Creek watershed but lacked stream segments listed as Aquatic Life Use impaired. Once potential references were identified, they were screened to determine which ones were most like the impaired watershed with regard to factors such as landscape position, topography, hydrology, soil drainage types, land cover etc. Furthermore, benthic macroinvertebrate and physical habitat assessment scores were reviewed to confirm that a reference was acceptable. Preliminary modelling was conducted to make sure that use of a particular reference would result in reasonable pollution reductions.

To increase the likelihood of finding similar references, special emphasis was given to searching the Great Valley section of the Ridge and valley Province as well as the Gettysburg-Newark Lowland section of the Piedmont Province since Spring Creek partially occurred in both (Table 4). Numerous potential candidates from these areas were explored.

A subwatershed of Ontelaunee Creek (Figure 6), occurring about 50 miles to the northeast of Spring Creek, was of particular interest because, like Spring Creek, it was primarily within the Great Valley Section of the Ridge and Valley Province and it was listed as supporting its Aquatic Life Use, despite having a high amount of agricultural land cover (Table 4). Furthermore, various subwatersheds of Ontelaunee Creek had been used as references in prior studies.

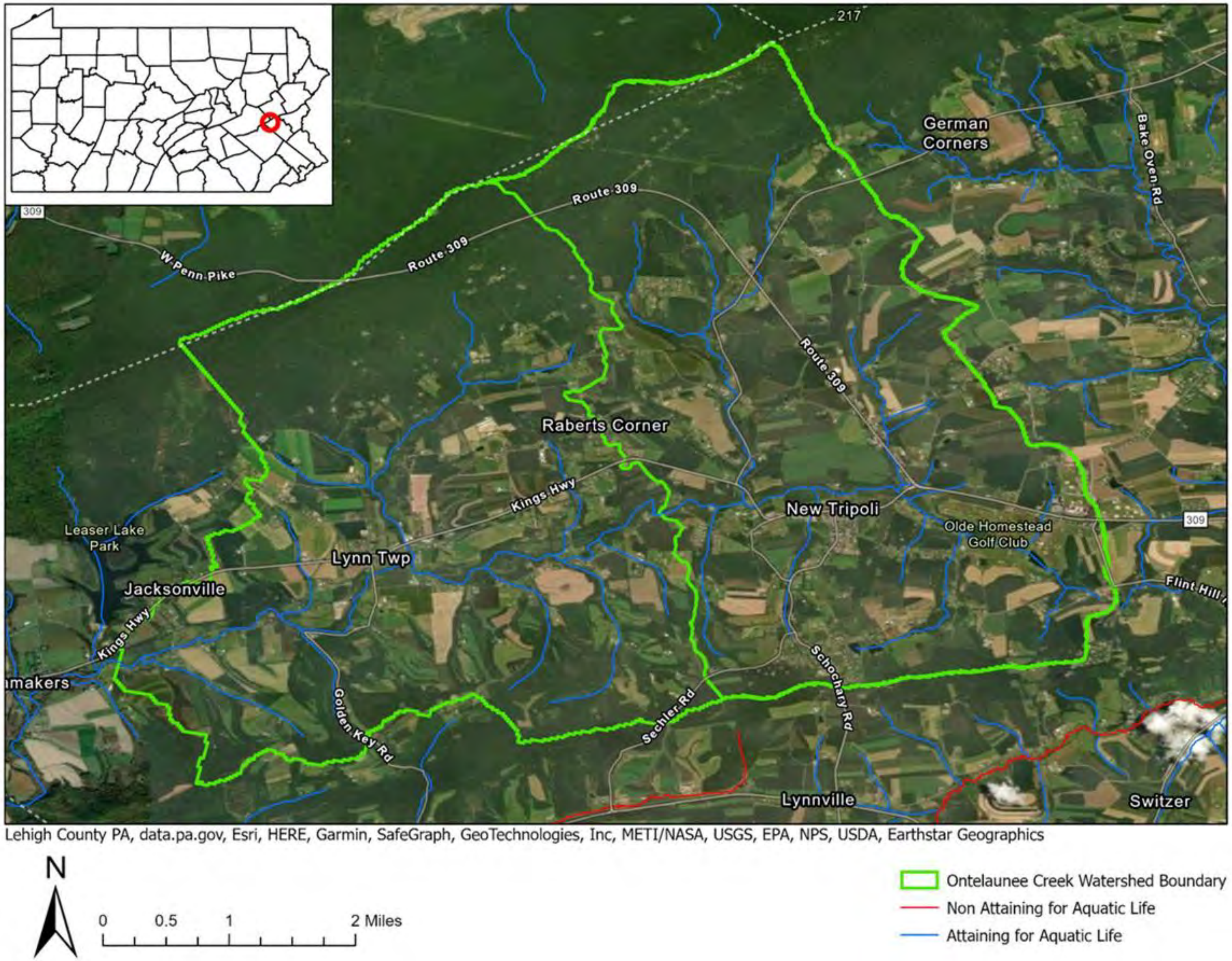

Figure 6. Ontelaunee Creek watershed. All stream segments within the delineated watersheds were listed as supporting their Aquatic Life Use per the 2022 Integrated Report viewer (DEP 2022).

The Ontelaunee Creek watershed was delineated at two different points to approximate the size of both the Spring Creek whole and 319 study area watersheds. The larger Ontelaunee Creek delineation was also designed to avoid Leeser Lake (Figure 6), as this feature may confound sediment and hydrologic modelling. To simplify the following discussion of watershed attributes, comparisons will focus on the whole Spring Creek watershed and the larger Ontelaunee Creek watershed. However, see Table 4 for further comparisons of key watershed characteristics within the smaller watershed areas.

Both the Spring Creek whole and Ontelaunee Creek larger watersheds had substantial agricultural land cover, though the percentage was somewhat lesser in the Spring Creek watershed (36 vs 49%). This can be attributed to the loss of agricultural lands to developed lands, which comprised approximately 50% of Spring Creek's watershed area. In contrast, the Ontelaunee Creek larger watershed only had about 12% developed lands. While there was little room remaining for natural vegetation in the Spring Creek watershed (13% of total land cover), substantial natural lands occurred in the Ontelaunee Creek watershed (40% of total land cover). As apparent in Figures 1 and 6, natural lands were most common in the uplands along the margins of both watersheds. Considering that both watersheds had similar distributions of soil drainage classes that were dominated by moderate infiltration soils, the much higher surface runoff rate estimated for the Spring Creek watershed (4.4 versus 2.1 inches per year) appears to be driven by its greater amount of developed lands.

The impaired and reference watersheds also differed in their bedrock geology, especially in that the Spring Creek watershed had high amounts of limestone whereas the Ontelaunee Creek watershed did not (Table 4). Because karst geology has such a strong influence on a watershed's hydrogeologic characteristics, use of a karst reference would be ideal. However, finding such a large, similarly low-gradient karst reference in Pennsylvania is problematic because Aquatic Life Use impairments in such areas is typical, as karst geology produces some of the state's best agricultural soils.

Another difference between the two watersheds was that Spring Creek had a moderately lower overall topographic slope (4 versus 9%). Even so, the average slope of the higher (3rd and 4th) order stream segments in both watersheds was approximately the same (Table 4).

Whereas stream segments within the Spring Creek watershed are designated Warm Water Fishes, Migratory Fishes, stream segments within the Ontelaunee Creek watershed are designated Cold Water Fishes, Migratory Fishes at 25 Pa. Code § 93. However, given the high amounts of karst geology in the Spring Creek watershed and the presence of wild trout, the Warm Water Fishes designation may largely reflect anthropogenic impacts, and restoration may help restore a cold water community. Neither watershed had stream segments that are designated for special protection. Also, while both watersheds contained non-MS4 NPDES permitted point sources, they were very minor contributors to sediment loading (Tables 3 and 5). Loading associated with MS4 NPDES permits will be treated via the modelling of land covers, as would be the case for other nonpoint sources.

Table 4. Comparison of the Spring and Ontelaunee Creek watersheds.

Watershed	Spring Cr. Whole	Ontelaunee Cr. Larger	Spring Cr. 319 Study	Ontelaunee Cr. Smaller
Physiographic Province[1]				
Gettysburg-Newark Lowland of Piedmont	33	-	56	-
Great Valley of Ridge and Valley	67	83	44	86
Blue Mountain of Ridge and Valley		17		14
Land Area (ac)	15,314	13,326	6,758	6,723
Landuse[2] **(%)**				
Agriculture	36	49	52	51
Forest/Natural Vegetation	13	40	21	35
Developed	50	12	27	14
Soil Infiltration[3] **(%)**				
A	14	12	22	15
B	72	65	64	62
B/D	1	5	3	4
C	10	7	6	8
C/D	1	0	1	0
D	2	11	4	10
Dominant Bedrock[4] **(%)**				
Argillaceous Limestone	3	-	-	-
Diabase	1	-	2	-
Dolomite	4	-	-	-
Graywacke	-	28	-	39
High-Calcium Limestone	2	-	-	-
Limestone	55	-	44	-
Quartz Conglomerate	5	-	10	-
Sandstone	6	3	8	2
Shale	3	69	-	59
Silty Mudstone	20	-	36	-
Average Precipitation[5] **(in/yr)**	41.5	39.9	41.5	39.9
Average Surface Runoff[5] **(in/yr)**	4.4	2.1	2.8	2.3
Average Elevation[5] **(ft)**	471	696	484	727
Average Slope[5] **(%)**	4	9	4	8
Average Stream Channel Slope[6] **(%)**				
1st order	2.2	2.5	2.2	2.4
2nd order	0.7	1.2	1.0	1.1
3rd order	0.4	0.5	0.4	0.6
4th order	0.3	0.2	0.0	-

[1]Per pags_physsections2008 GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources

[2]Based on MMW output utilizing NLCD 2019

[3]Based on MMW output utilizing USDA gSSURGO 2016. A = high infiltration soils; B=moderate infiltration soils, C= slow infiltration soils and D= very slow infiltration soils.

[4]Per Bedrock_V GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources.

[5]Hydrologic and terrain variables were generated by MMW.

[6]MMW output based on USGS high-resolution NHD flowlines

Table 5. Existing NPDES-permitted discharges in the Ontelaunee Creek reference watershed and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

Permit No.	Facility Name	Load, mean lbs/yr
PA0070254	Lynn Township WWTP	1,925
PA0062901	Derek Felts Residence SFTF	8

Permits within the delineated watershed were based on eMapPA (DEP 2022a) and Watershed Resources Registry (USEPA 2022).

Lynn Township WWTP. The load reported above was based on an analysis of electronic discharge monitoring report (eDMR) data. Total annual suspended solids loads were averaged from 2009 through 2021.

Derek Felts Residence SFTF. Permit for a small flow treatment facility. Mean annual load was calculated assuming a flow rate of 262.5 gpd for a single-family residence and a total suspended solids concentration of 10 mg/l.

EXPLORATION OF EXISTING CONDITIONS

Figure 7 and Table 6 present a review of assessment sampling within the Spring Creek watershed. These data are largely consistent with the conclusion that most of the watershed is impaired for siltation. Interestingly though, when assessed with Limestone stream-specific methodology, mainchannel reaches below the 319 study area watershed appeared to have a healthy benthic macroinvertebrate community in some cases, despite that sediment deposition plus embeddedness couplet scores indicated impairment for siltation. The presence of apparently healthy macroinvertebrate communities in some areas as well as a wild trout population gives hope that the watershed is restorable.

The 319 study area of the Spring Creek watershed was visited during the spring of 2022 to explore watershed conditions and observe the causes and severity of impairments. The non-319 study area was visited during summer of 2022. The Ontelaunee Creek watershed was visited for other studies during the past few years, but another visit was made during summer of 2022 to specifically look at conditions within the downstream areas of the larger Ontelaunee Creek watershed. Photographs from this and prior visits are included herein.

Observations of the Spring Creek 319 study area indicate severe siltation problems in both main branches, as evidenced by a thick blanketing of fines in many places (Figures 8 and 9). Lowland tributaries often exhibited similar problems (Figure 10), while upland tributaries appeared far healthier (Figure 11). High amounts of agriculture and minimal amounts of naturally vegetated lands (Figures 2 and 12) likely contributed to these impairments. There were also some obvious cases where agricultural practices could be improved, for instance by the establishment of additional riparian buffers (Figure 13).

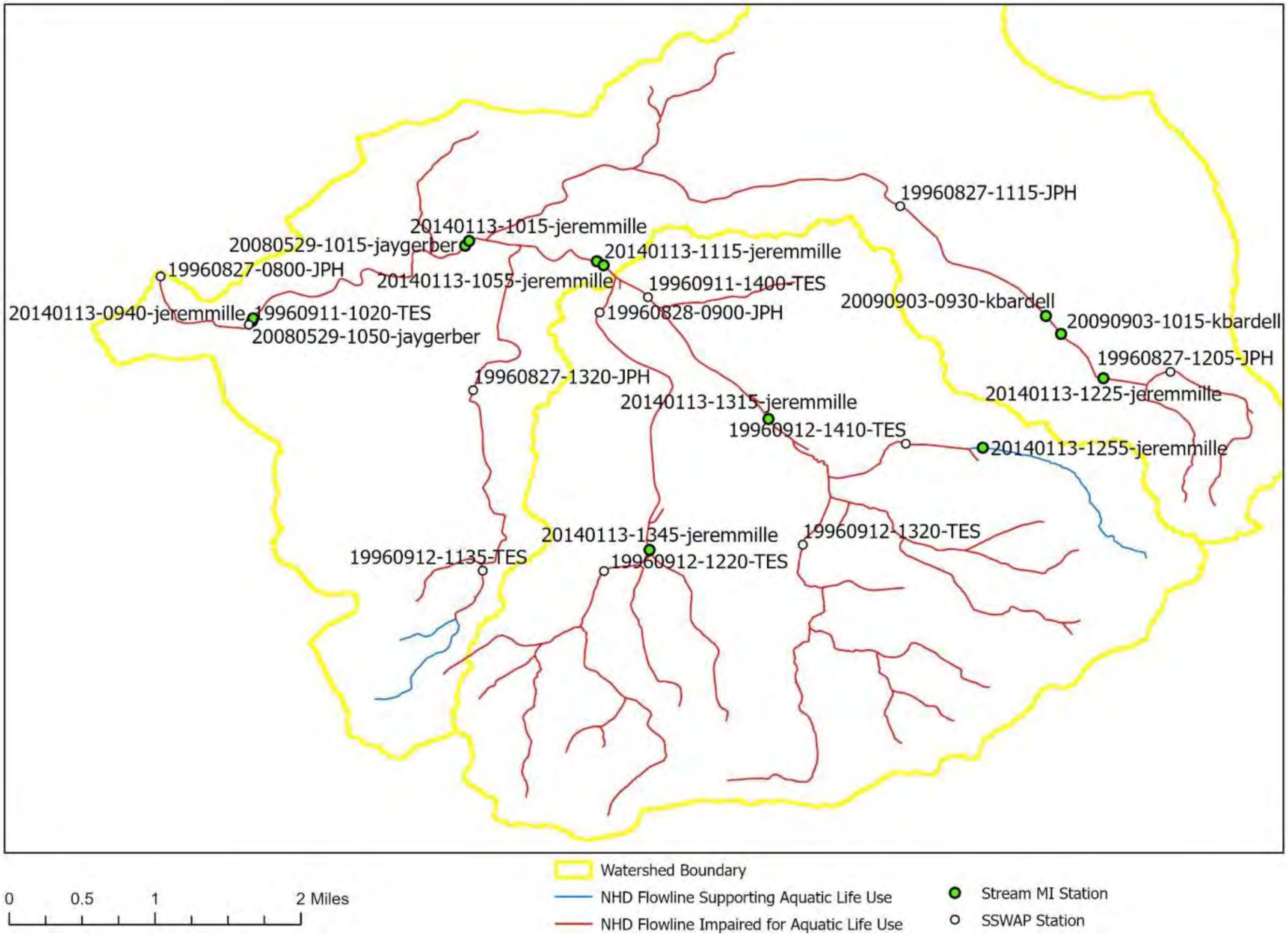

Figure 7. DEP sampling sites within the Spring Creek watershed. See Table 6 for a summary of the data.

Table 6. Summary of sampling data in the Spring Creek watershed. The following describes how to interpret this data. SSWAP samples were evaluated based on a series of questions from which the biologist drew conclusions about impairment status. More recent Stream MI samples utilize an Index of Biotic Integrity (IBI) score. For these 6d-200 samples, IBI scores <43 typically suggest impairment (Shull 2017). An exception however would be 20140113-1225-jeremille, where <50 would suggest impairment (Shull 2017). Also note that the 2009 samples used different impairment thresholds, but either way, these samples were clearly impaired. "Pass Q's" refers to supplemental questions that are considered along with IBI scores; "no" suggests impairment. For "limestone" samples, IBI scores <60 suggest impairment (Williams 2017). Sediment deposition + embeddedness couplet scores ≤24 suggest impairment for siltation (Walters 2017). See Figure 7 for the approximate locations for these samples. For more information on interpreting assessment data, see Lookenbill and Whiteash (2021) and Shull and Whiteash (2021).

Assessment ID	Station Type	IBI Score	Sample Type	Pass Q's?	SSWAP Bugs Impaired?	Sed Dep. + Embed.	Select Assessment Sheet Comments
20080529-1015-jaygerber	Stream MI	65.8	Limestone			16	-The stream banks consits of a large concrete wall…there area seires of weirs, causing pooling and an abundance of slow moving water…resulted in severe habitat degradation.
20080529-1050-jaygerber	Stream MI	72.8	Limestone			18	-Just upstream of this site is the Hershey Amusement Park which is primarily composed of concrete banks containing hardened and grit substrate. Additionally there are several weirs between Hershey Foods and the sample location which tends to lessen flow and create longs runs and pools...These unnatural stream modifications have had a detrimental impact on aquatic life in Spring Creek.
20090903-0930-kbardell	Stream MI	25.3	6d-200	No		11	-Downstream of Cambelltown West STP.
20090903-1015-kbardell	Stream MI	26.9	6d-200	No		14	-Upstream from Campbelltown West STP.
20140113-0940-jeremmille	Stream MI	55.4	Limestone			24	-just UPS from Derry Twp wastewater treatment plant
20140113-1015-jeremmille	Stream MI	68.2	Limestone			22	
20140113-1225-jeremmille	Stream MI	35.4	6d-200	No		14	
20140113-1055-jeremmille	Stream MI	46.4	Limestone			20	-Stream crossed by series of golf cart bridges, pipe crossings & weirs…no riffles found because water boards had been placed in the weirst causing water to dam/back up
20140113-1115-jeremmille	Stream MI	92.3	Limestone			16	
20140113-1315-jeremmille	Stream MI	37.2	6d-200	No		20	-agriculture, several weirs across stream affecting velocity/depth regimes and riffle frequency
20140113-1255-jeremmille	Stream MI	53.7	6d-200	Yes		26	
20140113-1345-jeremmille	Stream MI	48.8	6d-200	No		27	-Agriculture in and around sample reach. Weir present and remnants of old dam or bridge were within sample reach
19960827-0800-JPH	SSWAP				No	25	-Significant impervious urbanized conditions upstream in Hershey
19960827-1115-JPH	SSWAP				Yes	7	-Stream dries up, piped underground downstream of station. STP upstream; heavy erosion present at dairy farm located downstream of STP.
19960827-1205-JPH	SSWAP				Yes	28	-Impairment based on inverts and habitat score as a function of the small stream size more than "degraded" conditions. Water quality appears to be ok. Impairment appears to be due to naturally small stream size & headwater condition.
19960827-1320-JPH	SSWAP				Yes	21	-Impairment status…due to agriculture, housing development & stormwater runoff.
19960828-0900-JPH	SSWAP				Yes	27	-Impairment status…Agriculture, Resitential; NPDES STP(?) upstream
19960911-1020-TES	SSWAP				No	24	-Significant urbanized & impervious areas upstream in Hershey…(upstream) concrete banks containing hardended and grit substrate. Also, several weirs occur between Hershey Foods and the sampling location containing long runs and pools.
19960911-1400-TES	SSWAP				Yes	18	
19960912-1135-TES	SSWAP				Yes	8	-Predominantly forested headwaters. Due to natural conditions associated with headwaters, e.g. intermittent, low-flow
19960912-1220-TES	SSWAP				Yes	7	-Gradation from forested headwaters to flat old fields
19960912-1320-TES	SSWAP				Yes	7	-Poor habitat; smooth, shallow stream bottom; impairment due to heavy erosion caused by runoff from corn field
19960912-1410-TES	SSWAP				Yes	8	-Heavily degraded from unfenced pasture & cattle enrichment

Practices that may be protective against sediment pollution were observed in the Spring Creek watershed as well, including both historic and recently planted buffers in some areas, and the protection of drainageways. And, practices such as no-till or conservation tillage were common (Figures 12 and 14). The overall impression from these observations was, that aside from the very high amount of agricultural land cover, practices within the watershed did not appear to be especially problematic. For instance, obvious highly degraded conditions, such as widespread use of conventional tillage, bare pasture areas, large numbers of livestock in the stream, etc. were not typically observed during the site visit. Thus, current practices alone did not appear to be sufficient to fully explain the severity of the observed siltation.

Rather, severe siltation within the 319 study area may be in large part due to the historic accumulation of legacy sediments behind dams. Dams impede the downstream export of fine sediments, and the fine sediment deposits that accumulate in the pools behind dams may persist long after the dams are removed. Numerous existing small dams were observed within the Milton Hershey School campus (Figure 15). Other areas show evidence of historic dams as indicated by highly erosive banks comprised of thick, uniform sediment deposits, with the stream elevation at baseflow far below the floodplain level (Figure 16). Figure 17 shows an especially interesting site where the stream was actively eroding around a historic dam. The legacy sediments were so problematic in this watershed that it appears that there can be no reasonable hope of restoring this watershed without removing numerous existing dams and much of the existing legacy sediments. Otherwise, these streams may experience persistent 1) retardation of sediment transport resulting in benthic smothering and 2) severe bank erosion and thus high sediment loads long into the future. In fact, while numerous recent riparian buffer plantings such as those shown Figures 14 and 16 are commendable, it is suggested to such work be temporarily halted, as these trees may ultimately be lost during legacy sediment removal.

In contrast, the lower mainstem of Spring Creek appeared to have far less severe siltation problems relative to what was observed upstream in the 319 study area. Substrate was typically dominated by gravel, though conditions could be rockier or exhibit substantial fines deposition, dependent on local stream gradient (Figure 18). There were two other major tributaries outside of the 319 study area (Figure 2). The western tributary will be referred to as the Hockersville tributary while the eastern tributary will be referred to as the Campbelltown/Palmdale tributary. An interesting feature of both of these tributaries was that their lower reaches were completely dry during the summer visit, apparently due to infiltration into karst geology (Figures 19 and 20). While the presence of a channel suggests that the lower reaches of the Hockersville tributary may flow seasonally, much of the lower Campbelltown/Palmdale tributary appeared to lack any defined channel, suggesting a lack of sustained aboveground flow during any season. Where flow did exist in the middle and upper reaches, obvious siltation was often apparent, likely in part due to agriculture and urbanization (Figures 19 and 20). However, their low gradient nature and tendency to lose flow due to infiltration may also help explain the presence of semi-stagnant silty conditions in many places.

As can be seen in Figures 2 and 21, both of these tributaries and the lower mainstem of Spring Creek are heavily influenced by development, which was especially intensive in the Hershey and Palmyra areas. In addition to being a direct source of siltation, the impervious nature of such development may increase surface runoff rates and bank erosion. Some areas outside of the 319 study area also had significant agriculture, but again, agricultural practices were not observed to be especially problematic, though tillage practices could not be evaluated during the summer visit (Figure 22). BMPs such as historic and new riparian buffer plantings, as well as drainageway protection and urban runoff BMPs (Figure 23), were likely helping to improve water quality, though more work needs to be done (Figure 22).

Taken together, these observations suggest that restoration of the 319 study area may be the most feasible way to improve the mainstem of Spring Creek from the Hershey area downstream. For one, the siltation impairments within the 319 study area appeared to be far worse than what was observed in other parts of the watershed. Secondly, removing dams and legacy sediments and improving agricultural practices are all technically feasible and with little downside apart from their expense. Finally, the fact that both of the major tributaries outside of the 319 study area appear to infiltrate completely before flowing into the mainstem makes their role as sediment sources to the downstream areas unclear. If much of the sediment load that is carried by these tributaries is lost upon infiltration, or if soils within these subwatersheds tend not to runoff into streams because they are underground, then restoration may have little effect on downstream areas, even if beneficial locally. Thus, in consideration of severity, feasibility and hydrology, it is suggested that highest priority should be given to restoring the 319 study area.

In contrast, stream segments within the Ontelaunee Creek watershed appeared to be healthier (Figures 24 to 26). While some fines deposition was obvious especially in the slower reaches, this was often limited to a light blanketing of fines on top of otherwise rocky substrates. Swifter reaches were often very rocky and apparently healthy. Like the Spring Creek 319 study area, the Onteluanee Creek watershed did have expansive areas of agricultural fields (Figures 6 and 27). However, a remarkable feature of the Ontelaunee Creek watershed was its exceptionally high rate of riparian buffering (Figure 28). In fact, it was rare to see agricultural fields extending to stream banks (Figures 28 and 29). Still, there was some obvious areas where conditions could be improved, for instance, by expanding some buffers and protecting drainageways (Figure 29). Furthermore, while some bank erosion was observed, problems associated with bank erosion and legacy sediments in the Ontelaunee Creek watershed were far less severe versus what was observed in the Spring Creek 319 study area.

Figure 8. Stream conditions within the downstream mainstem of the eastern branch of the Spring Creek 319 study area watershed. Heavy siltation was obvious in many areas, although some rockier conditions could also occur.

Figure 9. Stream conditions within the downstream mainstem of the western branch of the Spring Creek 319 study area watershed. Heavy siltation was obvious in many areas, although rockier conditions could also occur.

Figure 10. Stream conditions within lowland tributary areas of the Spring Creek 319 study area watershed. Heavy siltation was obvious in many areas.

Figure 11. Stream conditions within the upland tributary areas of the Spring Creek 319 study area watershed. These stream segments often appeared far healthier than their lowland counterparts.

Figure 12. Landscapes within the Spring Creek 319 study area watershed. Upland areas (above photo) had large amounts of agriculture, though with patchy areas of forest especially along headwater streams. Downstream areas (below photo) often existed as broad areas of agriculture. The downstream area also had much development, though this is not visible in these photographs.

Figure 13. Factors promoting siltation within the Spring Creek 319 study area watershed. Photograph A shows an expanse of agricultural fields, while photograph B shows croplands draining to a stream segment. Also note the severe streambank erosion. Photograph C shows an area where it appears that livestock had direct access to the stream. Photograph D shows a stream running along a road amongst unbuffered croplands.

Figure 14. Factors that may protect against sediment pollution in the Spring Creek 319 study area watershed. Photographs A and B show large areas of new buffer plantings. Photograph C shows existing mature buffers. Photograph D shows a drainageway with a grass buffer. Note however, this could be improved by allowing for the growth of tall grass.

Figure 15. Examples of existing dams within the Spring Creek 319 study area watershed. These photographs show just a few of the numerous such dams that exist within this watershed.

Figure 16. Apparent legacy sediments and resultant bank erosion within the Spring Creek 319 study area watershed.

Figure 17. Erosive circumvention of an existing dam in the Spring Creek 319 study area watershed.

Figure 18. Lower mainstem reaches of Spring Creek downstream of the 319 study area. Photograph A shows the creek near its outlet to Swatara Creek. This area tended to be rocky, perhaps in part due to its higher gradient. While significant fines were apparent further upstream in the sluggish reach shown in B, much of the lower mainstem appeared to be dominated by gravel substrate (C and D).

Figure 19. Main tributary west of the 319 study area (near Hockersville). During the summer visit, the lower portion of this tributary (in the Hershey Area) had no surface flow. Areas further upstream could be rocky and clear, while other areas appeared sluggish and suffered significant fine sediment deposition.

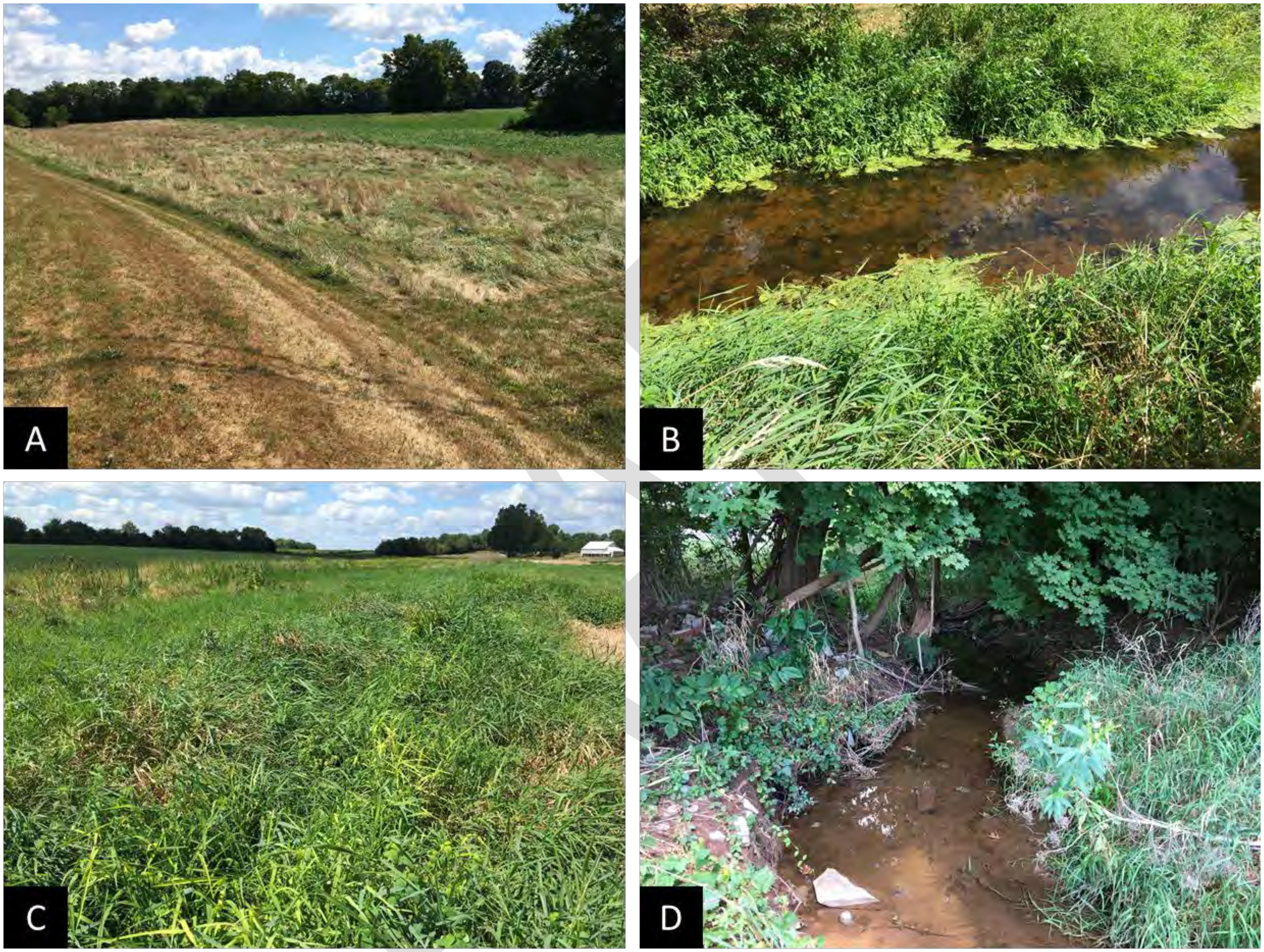

Figure 20. Main tributary east of the 319 study area (Campbelltown and Palmdale areas). As can be seen in photograph A, this tributary also lacked surface flow, at least from the Palmdale area to the Hershey Country Club Area (see Figure 2). Flow existed further upstream (photos B-D) and these areas tended to be sluggish and with silty substrate.

Figure 21. Developed lands outside of the 319 study area within the Spring Creek watershed. The Hershey area in particular had large amounts of high-density development and impervious area (A-C). Lower intensity development, as in D, occurred throughout the watershed.

Figure 22. Examples conditions outside the 319 study area that may result in excessive siltation. In addition to the development shown in Figure 21, there was also areas of substantial agriculture, as in A and B. Photograph C shows a reach within a golf course suffering from severe bank erosion. Photograph D shows an unbuffered drainageway through a developed area that outlets to a stream.

Figure 23. Examples of conditions that may be protective against sediment pollution outside of the 319 study area. Photograph A shows an area with existing mature riparian buffers while photograph B shows new riparian buffer plantings. Photograph C shows the use of tallgrass buffers along a drainageway while photograph D shows a stormwater basin serving a neighborhood.

Figure 24. Stream conditions within the middle and lower mainstem of the Ontelaunee Creek watershed. Stream conditions were often clear and rocky as in A and B. While some fines deposition was apparent in C and D, wading through such areas revealed that this was typically a light dusting of fines on otherwise rocky substrate. This may be in part due to very low flows during the midsummer site visit that may have promoted settling.

Figure 25. Conditions further upstream within the Lower School Creek tributary of the Ontelaunee Creek watershed. In many cases water was clear and stream segments were primarily rocky, though some significant fines deposition was apparent in some areas (D).

Figure 26. Stream conditions within smaller tributaries of the Ontelaunee Creek watershed. While such streams were typically rocky, significant fines deposition was present in some cases.

Figure 27. Typical landscapes within the Ontelaunee Creek watershed. Much of the watershed was dominated by agriculture, though some large forested tracts existed in uplands of the northern and southern margins of the watershed. While not shown above, streamside areas often had expansive forested buffers.

Figure 28. Factors that may be protective of water quality within the Ontelaunee Creek Watershed. Stream segments tended to be exceptionally well buffered.

Figure 29. Factors that may promote siltation pollution within the Ontelaunee Creek watershed. In addition to the overall high amount of agriculture, areas where buffering could be implemented or improved were also observed (A through C). Photograph D shows an area of substantial bank erosion.

HYDROLOGIC / WATER QUALITY MODELING

Estimates of sediment loading for the impaired and reference watersheds were calculated using the "Model My Watershed" application (MMW-Version 1.34.1, though watershed delineations may have been made using a prior version). MMW is a replacement for the MapShed desktop modelling application. Both programs calculate sediment and nutrient fluxes using the "Generalized Watershed Loading Function Enhanced" (GWLF-E) model. However, MapShed was built using a MapWindow GIS package that is no longer supported, whereas MMW operates with GeoTrellis, an open-source geographic data processing engine and framework. The MMW application is freely available for use at https://wikiwatershed.org/model/. In addition to the changes to the GIS framework, the MMW application continues to be updated and improved relative to its predecessor.

In the present study, watershed areas were defined using MMW's Watershed Delineation tool (see https://wikiwatershed.org/documentation/mmw-tech/#delineate-watershed). Then, the mathematical model used in MMW, GWLF-E, was used to simulate 30-years of daily water, nitrogen, phosphorus and sediment fluxes. To provide a general understanding of how the model functions, the following excerpts are quoted from MMW's technical documentation.

> *The GWLF model provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loads from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads based on the daily water balance accumulated to monthly values.*
>
> *GWLF is considered to be a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios, but each area is assumed to be homogenous in regard to various "landscape" attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but simply aggregates the loads from each source area into a watershed total; in other words there is no spatial routing. For subsurface loading, the model acts as a lumped parameter model using a water balance approach. No distinctly separate areas are considered for sub-surface flow contributions. Daily water balances are computed for an unsaturated zone as well as a saturated subsurface zone, where infiltration is simply computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.*
>
> *With respect to major processes, GWLF simulates surface runoff using the SCS-CN approach with daily weather (temperature and precipitation) inputs from the United States Environmental Protection Agency (USEPA) Center for Exposure Assessment Modeling (CEAM) meteorological data distribution. Erosion and sediment yield are estimated using monthly*

> *erosion calculations based on the USLE algorithm (with monthly rainfall-runoff coefficients) and a monthly KLSCP values for each source area (i.e., land cover/soil type combination). A sediment delivery ratio based on watershed size and transport capacity, which is based on average daily runoff, is then applied to the calculated erosion to determine sediment yield for each source sector. Surface nutrient losses are determined by applying dissolved N and P coefficients to surface runoff and a sediment coefficient to the yield portion for each agricultural source area.*
>
> *Evapotranspiration is determined using daily weather data and a cover factor dependent upon land use/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values.*

Streambank erosion is calculated as a function of factors such as the length of streams, the monthly stream flow, the percent developed land in the watershed, animal density in the watershed, the watersheds curve number and soil k factor, and mean topographic slope.

For a detailed discussion of this modelling program, including a description of the data input sources, see Evans and Corradini (2016) and Stroud Research Center (2022).

MMW allows the user to adjust model parameters, such as the area of land coverage types, the use of conservation practices and the efficiencies of those conservation practices, the watershed’s sediment delivery ratio, etc. Default values were used for the present study, except that estimated flows from NPDES permitted discharges (see Table 3) were added as inputs for the Spring Creek watershed. Based on an analysis of discharge monitoring report data, it was calculated that the Milton Hershey School IW facility discharged 556 m^3/d; the Hershey East Offices IW facility discharged 7,503 m^3/d; and the South Londonderry Municipal Authority WWTP discharged 417m^3/d. It was assumed that the Michael Civils facility discharged 1 m^3/d. Thus the total flow input for the whole Spring Creek watershed was estimated to be 8,477 m^3/d, while the flow input for the 319 study area was approximately 557 m^3/d. Adding these values as model inputs had the effect of causing modest increases in estimated streambank erosion. Additional flow inputs were not added to the Ontelaunee Creek watersheds because the model included default wastewater flow values.

Following the model run, a correction for the presence of existing riparian buffers was made in a BMP Spreadsheet Tool (Evans et al. 2020) that had been provided by MMW. The following paragraphs describe the riparian buffer correction method.

Riparian buffer coverage was estimated via a GIS analysis in ArcGISPro. Briefly, land cover per a high-resolution land cover dataset (University of Vermont Spatial Analysis Laboratory 2016) was examined within 100 feet of USGS high-resolution NHD flowlines. Then the sum of raster pixels that were classified as either “Emergent Wetlands”, “Tree Canopy” or “Shrub/Scrub” was divided by the total number of non-water pixels to determine percent riparian buffer. Using this methodology, percent riparian buffer was determined to be 41% in the impaired Spring Creek whole watershed versus 70% in the Ontelaunee Creek-larger reference watershed. The rate of riparian buffering was estimated to be 47% in the Spring Creek 319 study area watershed versus 72% on the Ontelaunee Creek-smaller watershed (Figures 30 and 31).

Additional reduction credit was given to the reference subwatersheds to account for their greater riparian buffering versus the impaired watersheds. Applying reduction credits solely to the reference watersheds to account for their extra buffering was chosen as more appropriate than taking reductions from both watersheds because the model has been calibrated at a number of actual sites (see https://wikiwatershed.org/help/model-help/mmw-tech/) with varying amounts of existing riparian buffers. If a reduction were taken from all sites to account for existing buffers, the datapoints would likely have a poorer fit to the calibration curve versus simply providing an additional credit to reference sites.

When accounting for the buffering of croplands using the BMP Spreadsheet Tool (Version 2020-01-09, Evans et al. 2020) provided by a prior version of MMW, the user enters the length of buffer on both sides of the stream. To estimate the extra length of buffers in the reference watersheds over the amounts found in the impaired watersheds, the approximate length of USGS high-resolution NHD flowlines within the reference watersheds was multiplied by the difference in the proportion buffering between the reference and the impaired watersheds (Figures 30 and 31), and then by two since both sides of the stream are considered. The BMP spreadsheet tool then calculates sediment reduction using a similar methodology as the Chesapeake Assessment Scenario Tool (CAST). The length of riparian buffers is converted to acres, assuming that the buffers are 100 feet wide. For sediment loading, the spreadsheet tool assumes that 2 acres of croplands are treated per acre of buffer. Thus, twice the acreage of buffer was multiplied by the sediment loading rate calculated for croplands and then by a reduction coefficient of 0.54. The BMP spreadsheet tool is designed to account for the area of lost cropland and gained forest when riparian buffers are created. However, this part of the reduction equation was deleted for the present study since historic rather than proposed buffers were being accounted for.

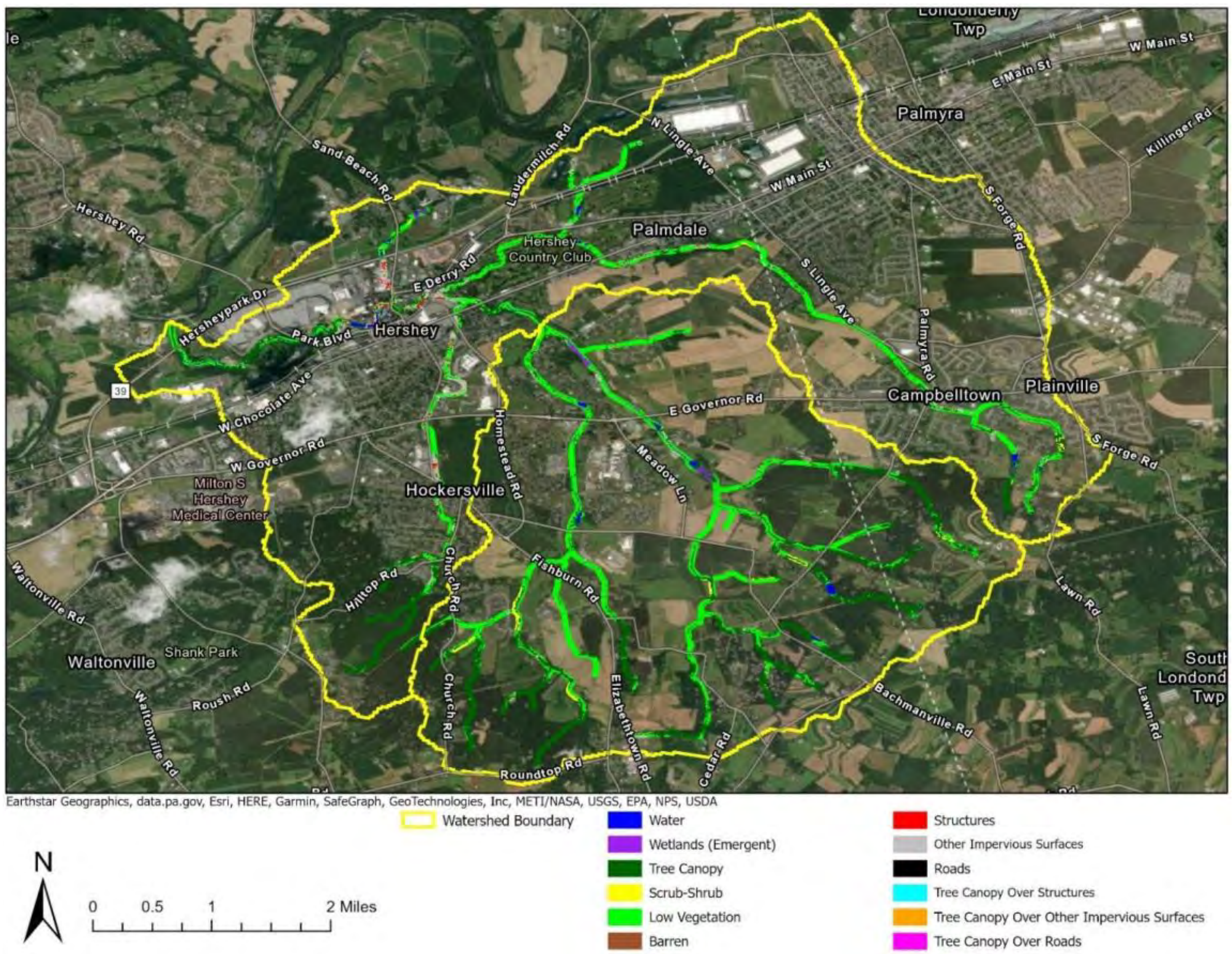

Figure 30. Riparian buffer analysis for the Spring Creek watershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. The rate of riparian buffering (comprised of tree canopy, scrub-shrub and wetlands) was estimated to be about 41% in the whole watershed and 47% in the 319 study area (upper watershed).

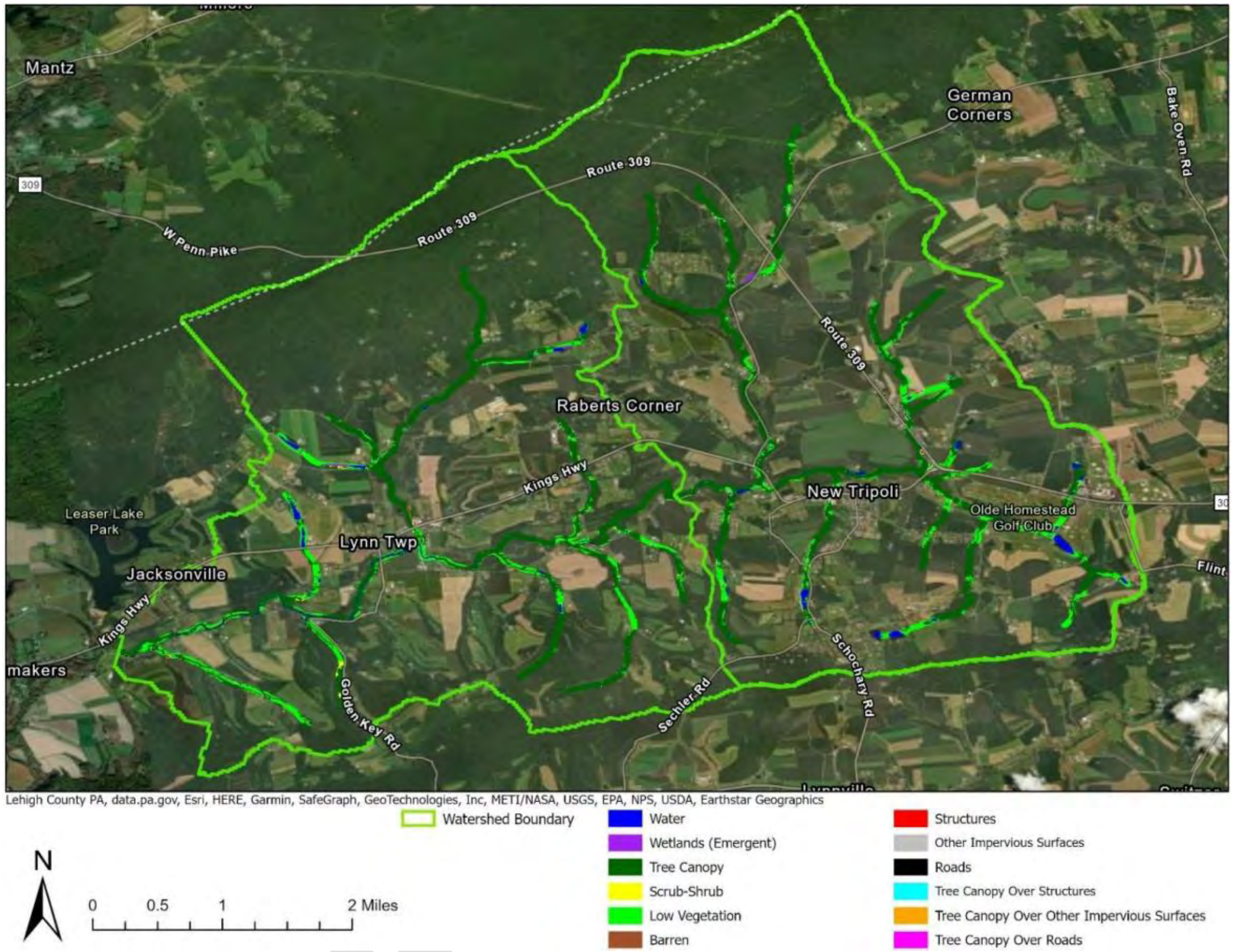

Figure 31. Riparian buffer analysis for the Ontelaunee Creek watershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. The rate of riparian buffering (comprised of tree canopy, scrub-shrub and wetlands) was estimated to be about 70% in the larger watershed and 72% in the smaller watershed.

CALCULATION OF ALLOWABLE LOADING

The estimated mean annual sediment loading rates were 411 lbs/(ac*yr) and 504 lbs/(ac*yr) in the larger and smaller Ontelaunee Creek reference watersheds, respectively (Tables 7 and 8). These were substantially lower than the estimated mean annual loading rates in the impaired Spring Creek watersheds (850 lbs/(ac*yr) in the whole watershed and 866 lbs/(ac*yr) in the 319 study area). Thus, to achieve the loading rates of the unimpaired watersheds, sediment loading in the Spring Creek whole watershed should be reduced by 52% to 6,288,428 lbs/yr while loading in the 319 study area should be reduced by 42% to 3,400,477 lbs/yr (Table 9).

Table 7. Existing annual average loading values for the Spring Creek whole (impaired) and the Ontelaunee Creek larger (reference) watersheds.

	Spring Creek Whole			**Ontelaunee Creek Larger**		
Land Cover	*acres*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*acres*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*
Hay/Pasture	2,007	487,467	243	1,928	484,731	251
Cropland	3,519	5,198,185	1,477	4,556	3,805,829	835
Forest	2,010	2,138	1	5,146	4,339	1
Wetland	30	50	2	101	199	2
Open Land	22	490	22	30	825	28
Bare Rock	2	3	1	2	1	-
Low Density Mix Dev	5,402	68,443	13	1,410	17,016	12
Med Density Mix Dev	1,632	105,065	64	109	7,622	70
High Density Mix Dev	662	42,542	64	20	1,430	72
Stream Bank		7,079,810			1,372,216	
Riparian Buffer Discount					-224,366	
Point Sources		2,167			1,933	
Total	**15,286**	**12,986,361**	**850**	**13,301**	**5,471,775**	**411**

Table 8. Existing annual average loading values for the Spring Creek 319 study area (impaired) and the Ontelaunee Creek smaller (reference) watersheds.

	Spring Creek 319 Study Area			Ontelaunee Creek Smaller		
Land Cover	*acres*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*	*acres*	*Sediment (lbs/yr)*	*Sediment lbs/(ac*yr)*
Hay/Pasture	1,274	426,107	334	765	245,426	321
Cropland	2,269	4,089,212	1,802	2,674	2,683,119	1,003
Forest	1,348	1,790	1	2,279	2,028	1
Wetland	27	57	2	44	103	2
Open Land	15	475	32	20	499	25
Bare Rock	2	1	1	-	1	-
Low Density Mix Dev	1,563	19,197	12	825	10,132	12
Med Density Mix Dev	205	13,736	67	81	5,752	71
High Density Mix Dev	49	3,319	67	17	1,202	70
Stream Bank		1,296,461			542,966	
Riparian Buffer Discount					-116,307	
Point Sources		8			1,933	
Total	**6,753**	**5,850,363**	**866**	**6,706**	**3,376,854**	**504**

Table 9. Annual average allowable loading in the Spring Creek whole and 319 study area watersheds.

Subwatershed	**Ref. Loading Rate** (lbs/(ac*yr))	**Land Area** (ac)	**Target AL** (lbs/yr)
Spring Creek Whole	411	15,286	6,288,428
Spring Creek 319 Study Area	504	6,753	3,400,477

CALCULATION OF THE SOURCE LOAD ALLOCATIONS

Calculation of the Uncertainty Factor and Source Load

In the ARP equation, the Allowable Load (AL) is comprised of the Source Load (SL), which accounts for all significant natural and anthropogenic sources of the pollutant, plus an Uncertainty Factor (UF). Thus:

AL = SL + UF

Reserving a portion of the load as a UF requires further load reductions from targeted sectors to achieve the AL. For this analysis, the UF was explicitly designated as ten-percent of the AL based on professional judgment. Thus:

Spring Creek whole: 6,288,428 lbs/yr AL * 0.1 = 628,843 lbs/yr UF
319 study area: 3,400,477 lbs/yr AL * 0.1 = 340,048 lbs/yr UF

Then, the SL is calculated as:

Spring Creek whole: 6,288,428 lbs/yr AL – 628,843 lbs/yr UF = 5,659,585 lbs/yr SL
319 study area: 3,400,477 lbs/yr AL – 340,048 lbs/yr UF = 3,060,429 lbs/yr SL

Calculation of the Adjusted Source Load

In the ARP equation the SL is further divided into the Adjusted Source Load (ASL), which is comprised of the sources causing the impairment and targeted for reduction, as well as the loads not reduced (LNR), which is comprised of the natural and anthropogenic sources that are not considered responsible for the impairment nor targeted for reduction. Thus:

SL =ASL + LNR

Therefore, before calculating the allowable loading from the targeted sectors, the LNR must also be defined.

Since the impairments addressed by this ARP were for sedimentation due to agriculture and development, sediment contributions from forests, wetlands, non-agricultural herbaceous/grasslands, bare rock and point sources within the Spring Creek whole watershed were considered loads not reduced (LNR). However, within the 319 study area, the same categories plus developed lands were considered LNR, as the focus of this area is agriculture and streambanks rather than developed lands.

LNR was calculated to be 38,585 lbs/yr in the 319 study area and 4,848 lbs/yr in the Spring Creek whole watersheds (Table 10).

Table 10. Source load, loads not reduced and adjusted source loads. All values were expressed as annual average lbs/yr.

	Spring Creek	
	Whole	**319 Study Area**
Source Load (SL)	5,659,585	3,060,429
Loads Not Reduced (LNR)		
Forest	2,138	1,790
Wetland	50	57
Open Land	490	475
Bare Rock	3	1
Low Density Mixed Dev	-	19,197
Medium Density Mixed Dev	-	13,736
High Density Mixed Dev	-	3,319
Point Sources	2167	8
Total LNR	4,848	38,585
Adjusted Source Load (ASL)	5,654,737	3,021,845

Then, the ASL is calculated as:

Spring Cr. whole.: 6,288,428 lbs/yr SL – 4,848 lbs/yr LNR = 5,654,737 lbs/yr ASL
319 study area: 3,060,429 lbs/yr SL – 38,585 lbs/yr LNR = 3,021,845 lbs/yr ASL

CALCULATION OF SEDIMENT LOAD REDUCTIONS BY SOURCE SECTOR

To calculate prescribed load reductions by source, the ASLs were further analyzed using the Equal Marginal Percent Reduction (EMPR) allocation method described in Appendix D. Although the Spring Creek watershed ARP was developed to address impairments caused by agriculture and development, streambanks were also significant contributors to the sediment load, and such erosion rates are influenced by agriculture and development. Thus, streambanks were included in the ASLs and targeted for reduction.

For the Spring Creek-whole watershed, streambanks exceeded the ASL by itself. Thus, streambanks received a greater percent reduction (61%) than hay/pasture lands, croplands or developed lands (51% each) (Table 11). For the 319 study area, croplands exceeded the ASL by itself, thus it received a greater percent reduction (53%) than hay pasture lands or streambanks (36% each). Note however, the prescribed reductions by source sector are simply suggested targets and not rigid goals that must be met. During implementation, greater or lesser reductions can be made for each source sector, so long as the overall ASL is achieved.

Table 11. Annual average sediment load allocations for source sectors in the Spring Creek watershed.

Subwatershed	Source	Load Allocation lbs/yr	Current Load lbs/yr	Reduction Goal %
Whole	Cropland	2,543,549	5,198,185	51%
	Hay/Pasture Land	238,525	487,467	51%
	Streambank	2,766,946	7,079,810	61%
	Developed Lands	105,717	216,050	51%
	Sum	*5,654,737*	*12,981,512*	*56%*
319 Study Area	Cropland	1,924,695	4,089,212	53%
	Hay/Pasture Land	271,399	426,107	36%
	Streambank	825,751	1,296,461	36%
	Sum	*3,021,845*	*5,811,779*	*48%*

RECOMMENDATIONS

As the foundation for the development of a Watershed Implementation Plan for Spring Creek, DEP has prepared this document to prescribe sediment reductions needed to meet water quality standards. It was estimated that a 52% sediment reduction is needed for the whole watershed while a 42% reduction is needed for the 319 study area.

In consideration of problem severity, feasibility and hydrologic characteristics, it is suggested that the greatest near-term benefits would be achieved by focusing on the 319 study area. And, for restoration to be successful, it is believed that dam and legacy sediment removal within this area will be crucial. Additionally, sediment loading from agricultural activities can be achieved via the implementation of required Erosion and Sediment Control Plans (Pennsylvania Clean Streams Law, Title 25 Environmental Protection, § 102.4, see also Appendix E) and through the use of BMPs such as conservation tillage, cover crops, vegetated filter strips, livestock exclusion fencing, and riparian buffers.

Use of forested riparian buffers is widely recognized as one of the best ways to promote stream health. Riparian buffers protect streams from sedimentation and nutrient impairments by filtering these pollutants from runoff and floodwaters and by protecting streambanks from erosion. Furthermore, riparian buffers are also beneficial for many other reasons beyond just protecting from sedimentation and nutrients. For instance, riparian buffers may: filter out other pollutants such as pesticides; provide habitat and nutrition for aquatic, semi-aquatic and terrestrial organisms; and moderate stream temperature. Thus, use of forested riparian buffers should be encouraged wherever possible. Much recent progress has been made in establishing riparian plantings. However, it is cautioned that some sites may require legacy sediment removal before riparian buffers are established.

Development of a more detailed watershed implementation plan is recommended. Further ground truthing should be performed to assess both the extent of existing BMPs and to determine the most cost effective and environmentally protective combination of BMPs required for meeting the prescribed sediment reductions.

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APPENDIX A: BACKGROUND ON STREAM ASSESSMENT METHODOLOGY

Note that the following contains generalizations about DEP's most commonly used aquatic life assessment methods, but doesn't seek to describe all of the current and historic variations of such methodology. For more information, see DEP's *Assessment Methodology for Streams and Rivers* (Shull and Whiteash 2021).
Documentation of other historic methodologies is available upon request.

Prior to developing TMDLs for specific waterbodies, there must be sufficient data available to assess which streams are impaired and should be listed as such in the Integrated Water Quality Monitoring and Assessment Report. Prior to 2004, the impaired waters were found on the 303(d) List; from 2004 to present, the 303(d) List was incorporated into the Integrated Water Quality Monitoring and Assessment Report (IR) and found on List 5. Table A1. summarizes the changes to listing documents and assessment methods over time.

With guidance from USEPA, the states have developed methods for assessing the waters within their respective jurisdictions. From 1996-2006, the primary method adopted by DEP for evaluating waters found on the 303(d) lists (1998-2002) or in the IR (2004-2006) was the Statewide Surface Waters Assessment Protocol (SSWAP). SSWAP was a modification of the USEPA Rapid Bioassessment Protocol II (RPB-II) and provided a more consistent approach to assessing Pennsylvania's streams.

The assessment method called for selecting representative stream segments based on factors such as surrounding landuses, stream characteristics, surface geology, and point source discharge locations. The biologist was to select as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment could vary between sites. The biological surveys were to include kick-screen sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Benthic macroinvertebrates were typically identified to the family level in the field.

The listings found in the Integrated Water Quality Monitoring and Assessment Reports from 2008 to 2018 were derived based on the Instream Comprehensive Evaluation protocol (ICE). Like the superseded SSWAP protocol, the ICE protocol called for selecting representative segments based on factors such as surrounding landuses, stream characteristics, surface geology, and point source discharge locations. The biologist was to select as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment could vary between sites. The biological surveys were to include D-frame kicknet sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Collected samples were returned to the laboratory where the samples were typically to be subsampled for a target benthic macroinvertebrate sample of 200 ± 20% (N = 160-240). The benthic macroinvertebrates in this subsample were typically identified to the generic level. The ICE protocol is a modification of the USEPA Rapid Bioassessment Protocol III (RPB-III) and provides a more rigorous and consistent approach to assessing Pennsylvania's streams than the SSWAP. More recent listings from 2020 to present were based on updated data collection protocols and Aquatic Life Use (ALU) assessment methods that are specific to the use(s) being assessed.

After these surveys (SSWAP, 1998-2006 lists; or ICE, 2008-2018 lists; ALU 2020-present lists) are completed, biologists are to determine the status of the stream segment. Decisions are to be based on the performance of the segment using a series of biological metrics. If the stream segment is classified as impaired, it is to be listed on the state's 303(d) List, or presently, the IR with the source and cause documented.

Once a stream segment is listed as impaired, a TMDL typically must be developed for it. A TMDL addresses only one pollutant. If a stream segment is impaired by multiple pollutants, each pollutant generally receives a separate and specific TMDL within that stream segment. Adjoining stream segments with the same source and cause listings may be addressed collectively on a watershed basis.

Table A1. Impairment Documentation and Assessment Chronology

Listing Date:	**Listing Document:**	**Assessment Method:**
1998	303(d) List	SSWAP
2002	303(d) List	SSWAP
2004	Integrated List	SSWAP
2006	Integrated List	SSWAP
2008-2018	Integrated List	ICE
2020-present	Integrated List	ALU

APPENDIX B: MODEL MY WATERSHED DATA TABLES

Table B1. “Model My Watershed” land cover outputs for the Spring Creek whole watershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.11	0.17
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	10.42	16.8
Developed, Low Intensity	22	11.46	18.48
Developed, Medium Intensity	23	6.61	10.66
Developed, High Intensity	24	2.68	4.32
Barren Land (Rock/Sand/Clay)	31	0.01	0.02
Deciduous Forest	41	6.19	9.98
Evergreen Forest	42	0	0
Mixed Forest	43	1.42	2.29
Shrub/Scrub	52	0.53	0.86
Grassland/Herbaceous	71	0.09	0.14
Pasture/Hay	81	8.13	13.1
Cultivated Crops	82	14.25	22.97
Woody Wetlands	90	0.1	0.16
Emergent Herbaceous Wetlands	95	0.02	0.03
Total		62.02	100

Table B2. “Model My Watershed” land cover outputs for the Spring Creek 319 study area watershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.02	0.06
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	3.47	12.68
Developed, Low Intensity	22	2.86	10.46
Developed, Medium Intensity	23	0.83	3.05
Developed, High Intensity	24	0.2	0.73
Barren Land (Rock/Sand/Clay)	31	0.01	0.02
Deciduous Forest	41	3.86	14.09
Evergreen Forest	42	0	0
Mixed Forest	43	1.11	4.06
Shrub/Scrub	52	0.49	1.81
Grassland/Herbaceous	71	0.06	0.21
Pasture/Hay	81	5.16	18.85
Cultivated Crops	82	9.19	33.57
Woody Wetlands	90	0.1	0.35
Emergent Herbaceous Wetlands	95	0.01	0.05
Total		27.37	100

Table B3. "Model My Watershed" land cover outputs for the Ontelaunee Creek larger watershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.1	0.19
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	4.16	7.7
Developed, Low Intensity	22	1.55	2.87
Developed, Medium Intensity	23	0.44	0.81
Developed, High Intensity	24	0.08	0.15
Barren Land (Rock/Sand/Clay)	31	0.01	0.01
Deciduous Forest	41	19.4	35.96
Evergreen Forest	42	0.03	0.05
Mixed Forest	43	1.23	2.27
Shrub/Scrub	52	0.18	0.33
Grassland/Herbaceous	71	0.12	0.22
Pasture/Hay	81	7.81	14.48
Cultivated Crops	82	18.45	34.19
Woody Wetlands	90	0.34	0.64
Emergent Herbaceous Wetlands	95	0.07	0.12
Total		53.96	100

Table B4. "Model My Watershed" land cover outputs for the Ontelaunee Creek smaller watershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.07	0.24
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	2.32	8.53
Developed, Low Intensity	22	1.02	3.74
Developed, Medium Intensity	23	0.33	1.23
Developed, High Intensity	24	0.07	0.26
Barren Land (Rock/Sand/Clay)	31	0	0.01
Deciduous Forest	41	8.53	31.35
Evergreen Forest	42	0.01	0.03
Mixed Forest	43	0.52	1.9
Shrub/Scrub	52	0.17	0.61
Grassland/Herbaceous	71	0.08	0.29
Pasture/Hay	81	3.1	11.38
Cultivated Crops	82	10.83	39.79
Woody Wetlands	90	0.16	0.58
Emergent Herbaceous Wetlands	95	0.02	0.07
Total		27.21	100

Table B5. "Model My Watershed" hydrology outputs for the Spring Creek whole watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.05	1.58	3.05	0.42	0.36	7.15
Feb	6.27	1.96	3.93	0.38	0.56	7.31
Mar	7.18	1.19	5.57	0.42	1.98	8.36
Apr	6.12	0.32	5.39	0.41	4.66	8.41
May	4.79	0.29	4.08	0.42	8.64	10.51
Jun	4.11	1.09	2.61	0.41	12.34	10.58
Jul	2.09	0.33	1.35	0.42	13.16	9.86
Aug	1.18	0.25	0.51	0.42	10.12	8.64
Sep	1.59	0.99	0.19	0.41	6.5	9.04
Oct	1.63	0.96	0.25	0.42	3.69	8.06
Nov	1.99	0.92	0.66	0.41	1.85	9.38
Dec	3.95	1.23	2.29	0.42	0.74	8.11
Total	45.95	11.11	29.88	4.96	64.6	105.41

Table B6. "Model My Watershed" hydrology outputs for the Spring Creek 319 study area watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	4.71	1	3.65	0.06	0.34	7.15
Feb	5.91	1.25	4.61	0.06	0.52	7.31
Mar	7.01	0.67	6.28	0.06	1.84	8.36
Apr	6.12	0.18	5.88	0.06	4.58	8.41
May	4.57	0.16	4.35	0.06	8.72	10.51
Jun	3.74	0.9	2.77	0.06	12.64	10.58
Jul	1.68	0.2	1.42	0.06	13.01	9.86
Aug	0.74	0.14	0.53	0.06	10.03	8.64
Sep	1.04	0.78	0.2	0.06	6.48	9.04
Oct	0.99	0.63	0.3	0.06	3.65	8.06
Nov	1.43	0.52	0.86	0.06	1.8	9.38
Dec	3.63	0.75	2.82	0.06	0.7	8.11
Total	41.57	7.18	33.67	0.72	64.31	105.41

Table B7. "Model My Watershed" hydrology outputs for the Ontelaunee Creek larger watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.33	0.81	4.51	0.01	0.27	6.69
Feb	5.93	1.06	4.86	0.01	0.41	6.47
Mar	6.67	0.46	6.2	0.01	1.52	7.4
Apr	6.31	0.44	5.86	0.01	3.28	8.25
May	4.94	0.18	4.74	0.01	7.39	9.96
Jun	3.39	0.29	3.09	0.01	10.72	9.81
Jul	1.74	0.26	1.47	0.01	11.04	10.08
Aug	0.84	0.19	0.64	0.01	9.26	9.66
Sep	1.04	0.51	0.52	0.01	5.98	9.19
Oct	1.48	0.26	1.2	0.01	3.4	7.27
Nov	2.95	0.42	2.52	0.01	1.58	8.82
Dec	5.14	0.58	4.54	0.01	0.57	7.62
Total	45.76	5.46	40.15	0.12	55.42	101.22

Table B8. "Model My Watershed" hydrology outputs for the Ontelaunee Creek smaller watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.37	0.87	4.47	0.03	0.26	6.69
Feb	5.95	1.14	4.79	0.02	0.39	6.47
Mar	6.66	0.51	6.13	0.03	1.47	7.4
Apr	6.35	0.48	5.85	0.02	3.18	8.25
May	5.04	0.2	4.82	0.03	7.26	9.96
Jun	3.52	0.31	3.18	0.02	10.62	9.81
Jul	1.87	0.28	1.56	0.03	11.01	10.08
Aug	0.93	0.21	0.69	0.03	9.24	9.66
Sep	1.11	0.54	0.55	0.02	5.95	9.19
Oct	1.52	0.28	1.21	0.03	3.35	7.27
Nov	3.01	0.46	2.53	0.02	1.54	8.82
Dec	5.16	0.63	4.51	0.03	0.56	7.62
Total	46.49	5.91	40.29	0.31	54.83	101.22

Table B9. "Model My Watershed" outputs for sediment in the Spring Creek whole watershed.

Sources	Sediment (kg)
Hay/Pasture	221,073.50
Cropland	2,357,453.70
Wooded Areas	969.8
Wetlands	22.9
Open Land	222
Barren Areas	1.3
Low-Density Mixed	16,257.50
Medium-Density Mixed	47,648.40
High-Density Mixed	19,293.60
Low-Density Open Space	14,782.50
Farm Animals	0
Stream Bank Erosion	3,210,798.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B10. "Model My Watershed" outputs for sediment in the Spring Creek 319 study area watershed.

Sources	Sediment (kg)
Hay/Pasture	193,245.60
Cropland	1,854,517.70
Wooded Areas	811.9
Wetlands	25.8
Open Land	215.6
Barren Areas	0.6
Low-Density Mixed	3,937.20
Medium-Density Mixed	6,229.70
High-Density Mixed	1,505.30
Low-Density Open Space	4,769.00
Farm Animals	0
Stream Bank Erosion	587,964.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B11. "Model My Watershed" outputs for sediment in the Ontelaunee Creek larger watershed.

Sources	Sediment (kg)
Hay/Pasture	219,832.50
Cropland	1,725,999.60
Wooded Areas	1,967.60
Wetlands	90.1
Open Land	374.3
Barren Areas	0.5
Low-Density Mixed	2,094.10
Medium-Density Mixed	3,456.90
High-Density Mixed	648.7
Low-Density Open Space	5,623.00
Farm Animals	0
Stream Bank Erosion	622,320.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B12. "Model My Watershed" outputs for sediment in the Ontelaunee Creek smaller watershed.

Sources	Sediment (kg)
Hay/Pasture	111,304.30
Cropland	1,216,833.90
Wooded Areas	919.8
Wetlands	46.8
Open Land	226.3
Barren Areas	0.3
Low-Density Mixed	1,399.60
Medium-Density Mixed	2,608.80
High-Density Mixed	545.1
Low-Density Open Space	3,195.30
Farm Animals	0
Stream Bank Erosion	246,243.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

APPENDIX C: STREAM SEGMENTS IN THE SPRING CREEK WATERSHED AQUATIC LIFE USE IMPAIRMENTS DUE TO SILTATION

319 study area:

ATTAINS ID:	Stream Name:	Length (miles):	Impairment Source:	Impairment Cause:	Impairment Cause Context:
PA-SCR-56400749	Unnamed Tributary to Spring Creek	0.044	AGRICULTURE, GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400803	Unnamed Tributary to Spring Creek	0.749	AGRICULTURE, GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400805	Spring Creek	0.272	AGRICULTURE, GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56401041	Unnamed Tributary to Spring Creek	0.685	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401113	Unnamed Tributary to Spring Creek	0.015	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401115	Spring Creek	0.782	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401123	Unnamed Tributary to Spring Creek	0.065	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401187	Unnamed Tributary to Spring Creek	0.042	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401207	Unnamed Tributary to Spring Creek	0.050	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401227	Spring Creek	0.394	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401233	Unnamed Tributary to Spring Creek	0.016	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401249	Unnamed Tributary to Spring Creek	0.080	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401329	Spring Creek	0.367	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401331	Spring Creek	0.862	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401381	Unnamed Tributary to Spring Creek	0.144	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401393	Unnamed Tributary to Spring Creek	0.103	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401433	Unnamed Tributary to Spring Creek	0.286	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401439	Unnamed Tributary to Spring Creek	0.034	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401441	Unnamed Tributary to Spring Creek	0.027	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401459	Unnamed Tributary to Spring Creek	0.130	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401485	Unnamed Tributary to Spring Creek	0.034	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401507	Unnamed Tributary to Spring Creek	0.426	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401517	Unnamed Tributary to Spring Creek	0.149	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401519	Unnamed Tributary to Spring Creek	0.342	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401535	Unnamed Tributary to Spring Creek	0.665	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401563	Unnamed Tributary to Spring Creek	0.097	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401573	Unnamed Tributary to Spring Creek	0.034	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401643	Unnamed Tributary to Spring Creek	0.552	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401705	Unnamed Tributary to Spring Creek	0.027	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401711	Unnamed Tributary to Spring Creek	0.070	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401713	Unnamed Tributary to Spring Creek	0.119	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401725	Unnamed Tributary to Spring Creek	0.451	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401731	Unnamed Tributary to Spring Creek	0.538	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401733	Unnamed Tributary to Spring Creek	0.762	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401755	Unnamed Tributary to Spring Creek	0.074	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401757	Unnamed Tributary to Spring Creek	0.097	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401771	Unnamed Tributary to Spring Creek	0.022	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401879	Unnamed Tributary to Spring Creek	0.324	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401919	Unnamed Tributary to Spring Creek	0.450	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401977	Unnamed Tributary to Spring Creek	0.753	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401981	Unnamed Tributary to Spring Creek	0.789	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56401989	Unnamed Tributary to Spring Creek	0.603	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402053	Unnamed Tributary to Spring Creek	0.291	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402067	Unnamed Tributary to Spring Creek	0.244	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402099	Unnamed Tributary to Spring Creek	0.405	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402101	Unnamed Tributary to Spring Creek	0.094	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402189	Unnamed Tributary to Spring Creek	1.107	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402193	Unnamed Tributary to Spring Creek	0.598	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402211	Unnamed Tributary to Spring Creek	0.398	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402231	Unnamed Tributary to Spring Creek	0.642	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402251	Unnamed Tributary to Spring Creek	0.560	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402261	Unnamed Tributary to Spring Creek	0.849	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402317	Unnamed Tributary to Spring Creek	0.426	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402343	Unnamed Tributary to Spring Creek	0.243	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402345	Unnamed Tributary to Spring Creek	0.454	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402423	Unnamed Tributary to Spring Creek	0.149	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402469	Unnamed Tributary to Spring Creek	0.283	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402487	Unnamed Tributary to Spring Creek	0.762	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402637	Unnamed Tributary to Spring Creek	0.585	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-56402661	Unnamed Tributary to Spring Creek	1.038	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-133783998	Unnamed Tributary to Spring Creek	0.930	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-133784001	Unnamed Tributary to Spring Creek	0.217	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-133784004	Unnamed Tributary to Spring Creek	0.118	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-133784007	Unnamed Tributary to Spring Creek	0.073	AGRICULTURE	SILTATION	SEDIMENT
PA-SCR-133784010	Unnamed Tributary to Spring Creek	0.121	AGRICULTURE	SILTATION	SEDIMENT

Outside of the 319 study area:

ATTAINS ID:	Stream Name:	Length (miles):	Impairment Source:	Impairment Cause:	Impairment Cause Context:
PA-SCR-133783855	Spring Creek	0.041	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-133783857	Spring Creek	0.355	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-133783859	Unnamed Tributary to Spring Creek	0.171	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-133783987	Unnamed Tributary to Spring Creek	0.511	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-133783989	Unnamed Tributary to Spring Creek	1.308	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-133783992	Unnamed Tributary to Spring Creek	0.133	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-133783995	Unnamed Tributary to Spring Creek	0.442	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-133784013	Unnamed Tributary to Spring Creek	0.189	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-133784016	Unnamed Tributary to Spring Creek	0.961	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-133784019	Unnamed Tributary to Spring Creek	0.272	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-133784022	Unnamed Tributary to Spring Creek	0.139	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-56400145	Unnamed Tributary to Spring Creek	0.019	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400213	Unnamed Tributary to Spring Creek	0.658	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400215	Unnamed Tributary to Spring Creek	0.221	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400241	Unnamed Tributary to Spring Creek	0.091	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400295	Unnamed Tributary to Spring Creek	0.089	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400383	Unnamed Tributary to Spring Creek	0.229	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400385	Unnamed Tributary to Spring Creek	0.092	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400387	Unnamed Tributary to Spring Creek	0.080	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400463	Unnamed Tributary to Spring Creek	0.366	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56400487	Unnamed Tributary to Spring Creek	0.056	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56400529	Unnamed Tributary to Spring Creek	0.078	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56400563	Unnamed Tributary to Spring Creek	0.052	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56400673	Unnamed Tributary to Spring Creek	0.290	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56400675	Unnamed Tributary to Spring Creek	1.046	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400681	Spring Creek	0.185	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400709	Spring Creek	0.651	AGRICULTURE; GOLF COURSES	SILTATION	SEDIMENT
PA-SCR-56400739	Unnamed Tributary to Spring Creek	2.971	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-56400777	Unnamed Tributary to Spring Creek	0.242	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-56400851	Unnamed Tributary to Spring Creek	0.493	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-56400853	Spring Creek	0.405	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56400859	Unnamed Tributary to Spring Creek	0.014	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-56400865	Unnamed Tributary to Spring Creek	0.022	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-56400987	Spring Creek	0.010	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56401037	Spring Creek	0.094	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56401119	Spring Creek	0.173	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56401153	Spring Creek	1.343	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56401155	Spring Creek	0.142	URBAN RUNOFF/STORM SEWERS; SOURCE UNKNOWN	SILTATION	SEDIMENT
PA-SCR-56401223	Unnamed Tributary to Spring Creek	0.775	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-56401991	Unnamed Tributary to Spring Creek	0.516	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT
PA-SCR-56402037	Unnamed Tributary to Spring Creek	0.436	AGRICULTURE; URBAN RUNOFF/STORM SEWERS	SILTATION	SEDIMENT

APPENDIX D: EQUAL MARGINAL PERCENT REDUCTION METHOD

Note that the following is based on a calculator that was developed using terminology that is used for Pennsylvania's TMDL documents. Since the present document does not constitute a TMDL, different terminology was used. However, the terms used in this study are essentially analogous to TMDL terms, as follows:

Allowable Load (AL) ≈ Total Maximum Daily Load (TMDL)
Uncertainty Factor (UF) ≈ Margin of Safety (MOS)
Source Load (SL) ≈ Load Allocation (LA)
Adjusted Source Load (ASL) ≈ Adjusted Load Allocation (ALA)

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute the ALA between the appropriate contributing nonpoint sources. The load allocation and EMPR procedures were performed using a MS Excel spreadsheet. The 5 major steps identified in the spreadsheet are summarized below:

Step 1: Calculation of the TMDL based on impaired watershed size and unit area loading rate of reference watershed.

Step 2: Calculation of ALA based on TMDL, MOS, WLA and existing LNR.

Step 3: Actual EMPR Process:

a. Each landuse/source load is compared with the total ALA to determine if any contributor would exceed the ALA by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load of the receiving waterbody. If the contributor exceeds the ALA, that contributor would be reduced to the ALA. If a contributor is less than the ALA, it is set at the existing load. This is the baseline portion of EMPR.

b. After any necessary reductions have been made in the baseline, the multiple analyses are run. The multiple analyses will sum all the baseline loads and compare them to the ALA. If the ALA is exceeded, an equal percent reduction will be made to all contributors' baseline values. After any necessary reductions in the multiple analyses, the final reduction percentage for each contributor can be computed.

Step 4: Calculation of total loading rate of all sources receiving reductions.

Step 5: Summary of existing loads, final load allocations, and percent reduction for each pollutant source

Table D1. Equal Marginal Percent Reduction calculations for the Spring Creek whole watershed.

	Current Load, lbs/yr	Any > ALA?	If > ALA, reduce to ALA	How much does sum exceed ALA?	Proportions of total after initial adjust	Assign reductions still needed per proportions after intial adjust	ALA: subtract reductions still needed from initial adjust	proportion Reduction
Cropland	5,198,185	no	5,198,185		0.45	2,654,636	2,543,549	0.51
Hay/Pasture	487,467	no	487,467	5,901,703	0.04	248,942	238,525	0.51
Streambank	7,079,810	yes	5,654,737		0.49	2,887,790	2,766,946	0.61
Developed Lands	216,050	no	216,050		0.02	110,334	105,717	0.51
sum	**12,981,512**		**11,556,439**		**1.00**	**5,901,703**	**5,654,737**	**0.56**

Table D2. Equal Marginal Percent Reduction calculations for the Spring Creek 319 study area watershed.

	Current Load, lbs/yr	Any > ALA?	If > ALA, reduce to ALA	How much does sum exceed ALA?	Proportions of total after initial adjust	Assign reductions still needed per proportions after intial adjust	ALA: subtract reductions still needed from initial adjust	proportion Reduction
Cropland	4,089,212	yes	3,021,845		0.64	1,097,150	1,924,695	0.53
Hay/Pasture	426,107	no	426,107	1,722,567	0.09	154,708	271,399	0.36
Streambank	1,296,461	no	1,296,461		0.27	470,710	825,751	0.36
sum	**5,811,779**		**4,744,412**		**1.00**	**1,722,567**	**3,021,845**	**0.48**

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

Land BMP Costs

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Monitored P removal system for animal production area	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Soil Conservation and Water Quality Plans	1	24.91	$/acre	0	$/acre/year	0	$/acre	26.16
Agriculture	Grass Buffer-Narrow with Exclusion Fencing	19	10366.19	$/acre	509.32	$/acre/year	971.31	$/acre	1415.64
Agriculture	Forest Buffer-Narrow with Exclusion Fencing	25	13529.46	$/acre	554.6	$/acre/year	971.31	$/acre	1563.11
Agriculture	Forest Buffer	40	4062.42	$/acre	81.25	$/acre/year	1770.23	$/acre	406.51
Agriculture	Agricultural Stormwater Management	10	7187.4	$/acre	287.5	$/acre/year	0	$/acre	1218.3
Agriculture	Tree Planting	40	1433.84	$/acre	21.51	$/acre/year	1770.23	$/acre	193.58
Agriculture	Land Retirement to Ag Open Space	10	601.86	$/acre	18.06	$/acre/year	1770.23	$/acre	184.52
Agriculture	Grass Buffer	10	899.15	$/acre	35.97	$/acre/year	1770.23	$/acre	240.93
Agriculture	Land Retirement to Pasture	10	173.85	$/acre	5.22	$/acre/year	798.92	$/acre	67.68
Agriculture	Drainage Water Management	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Alternative Crops	10	344.49	$/acre	10.33	$/acre/year	1085.03	$/acre	109.19
Agriculture	Forest Buffer-Streamside with Exclusion Fencing	30	7216.47	$/acre	238.95	$/acre/year	971.31	$/acre	756.96
Agriculture	Off Stream Watering Without Fencing	20	5.29	$/acre	0.08	$/acre/year	0	$/acre	0.5
Agriculture	Precision Intensive Rotational/Prescribed Grazing	1	81.27	$/acre	0	$/acre/year	0	$/acre	85.33
Agriculture	Horse Pasture Management	5	359.82	$/acre	3.6	$/acre/year	0	$/acre	86.71
Agriculture	Water Control Structures	10	1265.55	$/acre	37.97	$/acre/year	0	$/acre	201.86

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Monitored denitrifying bioreactor for spring or seep	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Cover Crop Traditional Rye Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Brassica Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Rye Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Wheat Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Wheat Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Wheat Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Grass Buffer - Narrow	10	899.15	$/acre	35.97	$/acre/year	1770.23	$/acre	240.93
Agriculture	Forest Buffer - Narrow	40	4062.42	$/acre	81.25	$/acre/year	1770.23	$/acre	406.51
Agriculture	Barnyard Runoff Control	15	6013.28	$/acre	0.6	$/acre/year	0	$/acre	579.93
Agriculture	Loafing Lot Management	10	154966.64	$/acre	25	$/acre/year	0	$/acre	20093.89
Agriculture	Denitrifying Ditch Bioreactors	20	388.91	$/acre	0.93	$/acre/year	0	$/acre	32.14
Agriculture	Cover Crop Traditional Wheat Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Wheat Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Manure Injection	1	0	$/acre	85.28	$/acre/year	0	$/acre	85.28
Agriculture	Cover Crop Traditional Wheat Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Manure Incorporation Low Disturbance Early	1	0	$/acre	20.23	$/acre/year	0	$/acre	20.23
Agriculture	Manure Incorporation High Disturbance Early	1	0	$/acre	20.23	$/acre/year	0	$/acre	20.23
Agriculture	Cover Crop Traditional Wheat Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Manure Incorporation Low Disturbance Late	1	0	$/acre	20.23	$/acre/year	0	$/acre	20.23
Agriculture	Manure Incorporation High Disturbance Late	1	0	$/acre	20.23	$/acre/year	0	$/acre	20.23
Agriculture	Cover Crop Traditional Barley Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Barley Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Barley Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Barley Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Barley Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Forage Radish Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Irrigation Water Capture Reuse	15	530.25	$/acre	15.91	$/acre/year	0	$/acre	67
Agriculture	Cover Crop Commodity Early	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Commodity Normal	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Commodity Late	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Annual Ryegrass Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Oats, Winter Hardy Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Plus Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Plus Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Forage Radish Plus Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	P removal systems	7	13.89	$/acre treated	9.32	$/acre treated/year	0	$/acre treated	11.72
Agriculture	Saturated Buffer	20	5439.76	$/acre	91.11	$/acre/year	1565.01	$/acre	605.86
Agriculture	Cover Crop Traditional Forage Radish Plus Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Forage Radish Plus Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Tillage Management-Low Residue	1	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Tillage Management-Conservation	1	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Cover Crop Traditional with Fall Nutrients Brassica Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Legume Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Nutrient Management Core N	5	8.86	$/acre	4.1	$/acre/year	0	$/acre	6.15
Agriculture	Nutrient Management Core P	5	8.86	$/acre	4.71	$/acre/year	0	$/acre	6.76
Agriculture	Cropland Irrigation Management	1	38.42	$/acre	0	$/acre/year	0	$/acre	40.34
Agriculture	Nutrient Management N Rate	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Nutrient Management P Rate	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Nutrient Management N Placement	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Grass Buffer-Streamside with Exclusion Fencing	18	4053.2	$/acre	193.67	$/acre/year	971.31	$/acre	588.97
Agriculture	Nutrient Management P Placement	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Nutrient Management N Timing	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Nutrient Management P Timing	1	8.8	$/acre	0	$/acre/year	0	$/acre	9.24
Agriculture	Blind inlets with P-sorbing materials	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Legume Plus Grass 25-50% Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Triticale Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Annual Ryegrass Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Hardy Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Oats, Winter Hardy Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Hardy Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Tillage Management-Continuous High Residue	1	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Blind inlets	0	0	$/acre	0	$/acre/year	0	$/acre	0
Agriculture	Cover Crop Traditional Oats, Winter Hardy Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Hardy Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Killed Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Killed Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Oats, Winter Killed Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Brassica Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Brassica Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Brassica Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Early Aerial	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional Legume Plus Grass 50% Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Rye Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Wheat Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Barley Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Barley Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Barley Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Barley Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Forage Radish Plus Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Forage Radish Plus Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
	Forage Radish Plus Normal Drilled								
Agriculture	Cover Crop Traditional with Fall Nutrients Forage Radish Plus Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Normal Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Late Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Triticale Late Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Annual Ryegrass Early Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Annual Ryegrass Early Other	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Cover Crop Traditional with Fall Nutrients Annual Ryegrass Normal Drilled	1	75.5	$/acre	0	$/acre/year	0	$/acre	79.27
Agriculture	Wetland Restoration - Floodplain	15	544.56	$/acre	52.11	$/acre/year	1770.23	$/acre	193.09

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Agriculture	Wetland Restoration - Headwater	15	3246.67	$/acre	52.11	$/acre/year	1770.23	$/acre	453.41
Agriculture	Wetland Creation - Floodplain	15	3240.84	$/acre	52.11	$/acre/year	1565.01	$/acre	442.59
Agriculture	Wetland Creation - Headwater	15	3393.93	$/acre	52.11	$/acre/year	1770.23	$/acre	467.6
Developed	Advanced Grey Infrastructure Nutrient Discovery Program (IDDE)	5	5.37	$/acre treated	9.91	$/acre treated/year	0	$/acre treated	11.15
Developed	Forest Conservation	1	0	$/acre	0	$/acre/year	0	$/acre	0
Developed	Impervious Surface Reduction	21	711456.42	$/acre	1968.74	$/acre/year	0	$/acre	57459.57
Developed	Conservation Landscaping Practices	10	206.9	$/acre	-329.69	$/acre/year	0	$/acre	-302.9
Developed	Forest Buffer	40	4062.42	$/acre	0	$/acre/year	0	$/acre	236.75
Developed	Grass Buffers	10	899.15	$/acre	35.97	$/acre/year	0	$/acre	152.41
Developed	Dirt & Gravel Road Erosion & Sediment Control - Driving Surface Aggregate + Raising the Roadbed	25	14.98	$/foot	0.3	$/foot/year	0	$/foot	1.36
Developed	Wet Ponds and Wetlands	32	11504.51	$/acre treated	361.51	$/acre treated/year	780.79	$/acre treated	1128.56
Developed	Dry Detention Ponds and Hydrodynamic Structures	30	10008.07	$/acre treated	155.54	$/acre treated/year	380.78	$/acre treated	825.62
Developed	Dry Extended Detention Ponds	23	4351.97	$/acre treated	76.69	$/acre treated/year	761.56	$/acre treated	437.41
Developed	Infiltration Practices w/o Sand, Veg. - A/B soils, no underdrain	35	21810.28	$/acre treated	1032.04	$/acre treated/year	1951.97	$/acre treated	2461.63
Developed	Infiltration Practices w/ Sand, Veg. - A/B soils, no underdrain	35	23481.02	$/acre treated	1070.44	$/acre treated/year	1951.97	$/acre treated	2602.06

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Developed	Filtering Practices	22	25767.52	$/acre treated	763.45	$/acre treated/year	487.99	$/acre treated	2745.42
Developed	Stormwater Performance Standard-Runoff Reduction	25	33195.59	$/acre	1709.24	$/acre/year	1951.97	$/acre	4162.15
Developed	Stormwater Performance Standard-Stormwater Treatment	21	16243.99	$/acre	462.48	$/acre/year	1724.24	$/acre	1815.66
Developed	Impervious Disconnection to amended soils	5	0	$/impervious acre	0	$/impervious acre/year	217046.1	$/impervious acre	10852.31
Developed	Filter Strip Runoff Reduction	10	11459.95	$/acre	262.46	$/acre/year	7807.87	$/acre	2136.97
Developed	Filter Strip Stormwater Treatment	10	11459.95	$/acre	262.46	$/acre/year	3903.93	$/acre	1941.77
Developed	Forest Planting	28	470.95	$/acre	7.06	$/acre/year	0	$/acre	38.67
Developed	Tree Planting - Canopy	40	1433.84	$/acre	21.51	$/acre/year	0	$/acre	105.07
Developed	Dirt & Gravel Road Erosion & Sediment Control - Driving Surface Aggregate with Outlets	25	15.87	$/foot	0.44	$/foot/year	0	$/foot	1.57
Developed	Dirt & Gravel Road Erosion & Sediment Control - Outlets only	10	0.89	$/foot	0.14	$/foot/year	0	$/foot	0.26
Developed	Bioretention/raingardens - A/B soils, underdrain	22	39377.89	$/acre treated	2856.03	$/acre treated/year	1171.18	$/acre treated	5906.15
Developed	Bioswale	35	17420.79	$/acre treated	1219.76	$/acre treated/year	780.79	$/acre treated	2322.72
Developed	Permeable Pavement w/ Sand, Veg. - A/B soils, underdrain	22	165378.7	$/acre treated	11745.32	$/acre treated/year	19519.67	$/acre treated	25285.21
Developed	Permeable Pavement w/o Sand, Veg. - A/B soils, underdrain	22	165378.7	$/acre treated	11745.32	$/acre treated/year	19519.67	$/acre treated	25285.21

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Developed	Vegetated Open Channels - A/B soils, no underdrain	20	44589.14	$/acre treated	2271.82	$/acre treated/year	780.79	$/acre treated	5888.81
Developed	Floating Treatment Wetland 10% Coverage of Pond	3	3819.5	$/acre	190.97	$/acre/year	0	$/acre	1593.52
Developed	Floating Treatment Wetland 20% Coverage of Pond	3	7638.99	$/acre	381.95	$/acre/year	0	$/acre	3187.05
Developed	Floating Treatment Wetland 30% Coverage of Pond	3	11458.49	$/acre	572.92	$/acre/year	0	$/acre	4780.58
Developed	Floating Treatment Wetland 40% Coverage of Pond	3	15277.98	$/acre	763.9	$/acre/year	0	$/acre	6374.11
Developed	Floating Treatment Wetland 50% Coverage of Pond	3	19097.48	$/acre	954.87	$/acre/year	0	$/acre	7967.63
Developed	Nutrient Management Plan	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Nutrient Management Plan High Risk Lawn	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Nutrient Management Plan Low Risk Lawn	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Nutrient Management Maryland Commercial Applicators	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Nutrient Management Maryland Do It Yourself	1	1.9	$/acre	0	$/acre/year	0	$/acre	1.99
Developed	Vegetated Open Channels - C/D soils, no underdrain	20	73270.44	$/acre treated	3614.74	$/acre treated/year	780.79	$/acre treated	9533.19
Developed	Permeable Pavement w/o Sand, Veg. - A/B soils, no underdrain	22	125057.41	$/acre treated	8881.67	$/acre treated/year	19519.67	$/acre treated	19358.33

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Developed	Permeable Pavement w/o Sand, Veg. - C/D soils, underdrain	22	165378.7	$/acre treated	11745.32	$/acre treated/year	19519.67	$/acre treated	25285.21
Developed	Permeable Pavement w/ Sand, Veg. - A/B soils, no underdrain	22	125057.41	$/acre treated	8881.67	$/acre treated/year	19519.67	$/acre treated	19358.33
Developed	Permeable Pavement w/ Sand, Veg. - C/D soils, underdrain	22	165378.7	$/acre treated	11745.32	$/acre treated/year	19519.67	$/acre treated	25285.21
Developed	Bioretention/raingardens - A/B soils, no underdrain	22	17720.05	$/acre treated	1285.21	$/acre treated/year	1171.18	$/acre treated	2689.97
Developed	Bioretention/raingardens - C/D soils, underdrain	23	49630.78	$/acre treated	1770.61	$/acre treated/year	1171.18	$/acre treated	5508.64
Developed	Advanced Sweeping Technology - 2 pass/week	8	3788.19	$/acre	3091.16	$/acre/year	0	$/acre	3677.28
Developed	Advanced Sweeping Technology - 1 pass/week	8	1894.1	$/acre	1545.58	$/acre/year	0	$/acre	1838.64
Developed	Advanced Sweeping Technology - 1 pass/2 weeks	8	947.05	$/acre	772.79	$/acre/year	0	$/acre	919.32
Developed	Advanced Sweeping Technology - 1 pass/4 weeks	8	473.52	$/acre	386.4	$/acre/year	0	$/acre	459.66
Developed	Advanced Sweeping Technology - 1 pass/8 weeks	8	236.76	$/acre	193.2	$/acre/year	0	$/acre	229.83
Developed	Advanced Sweeping Technology - 1 pass/12 weeks	8	156.63	$/acre	127.81	$/acre/year	0	$/acre	152.04
Developed	Advanced Sweeping Technology - spring 1 pass/1-2 weeks else monthly	8	655.65	$/acre	535.01	$/acre/year	0	$/acre	636.45

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Developed	Advanced Sweeping Technology - fall 1 pass/1-2 weeks else monthly	8	874.2	$/acre	713.35	$/acre/year	0	$/acre	848.61
Developed	Mechanical Broom Technology - 2 pass/week	5	1894.1	$/acre	6182.33	$/acre/year	0	$/acre	6619.82
Developed	Mechanical Broom Technology - 1 pass/week	5	947.05	$/acre	3091.16	$/acre/year	0	$/acre	3309.9
Developed	Mechanical Broom Technology - 1 pass/4 weeks	5	236.76	$/acre	772.79	$/acre/year	0	$/acre	827.48
Developed	Storm Drain Cleaning	1	0.77	$/lb of TSS	0	$/lb of TSS/year	0	$/lb of TSS	0.81
Developed	Erosion and Sediment Control Level 1	1	1439.26	$/acre	0	$/acre/year	0	$/acre	1511.22
Developed	Erosion and Sediment Control Level 2	1	6040.36	$/acre	0	$/acre/year	0	$/acre	6342.38
Developed	Erosion and Sediment Control Level 3	1	7550.45	$/acre	0	$/acre/year	0	$/acre	7927.97
Natural	Abandoned Mine Reclamation	20	18986.21	$/acre	113.67	$/acre/year	0	$/acre	1637.17
Natural	Urban Stream Restoration Protocol	20	513.24	$/foot	64.16	$/foot/year	0	$/foot	105.34
Natural	Non Urban Stream Restoration Protocol	20	513.24	$/foot	64.16	$/foot/year	0	$/foot	105.34
Natural	Urban Stream Restoration	20	513.24	$/foot	64.16	$/foot/year	0	$/foot	105.34
Natural	Non Urban Stream Restoration	20	513.24	$/foot	64.16	$/foot/year	0	$/foot	105.34
Natural	Urban Shoreline Management	20	590.18	$/foot	29.51	$/foot/year	0	$/foot	76.87
Natural	Oyster reef restoration – nutrient assimilation	50	18036.15	$/acre	179.31	$/acre/year	0	$/acre	1167.27

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Natural	Oyster reef restoration – enhanced denitrification	50	18036.15	$/acre	179.31	$/acre/year	0	$/acre	1167.27
Natural	Non Urban Shoreline Management	20	100.72	$/foot	5.04	$/foot/year	0	$/foot	13.12
Natural	Forest Harvesting Practices	1	56.45	$/acre	0	$/acre/year	0	$/acre	59.27
Natural	Non Urban Shoreline Erosion Control Non-Vegetated	20	163	$/foot	8.15	$/foot/year	0	$/foot	21.23
Natural	Non Urban Shoreline Erosion Control Vegetated	20	45.19	$/foot	2.26	$/foot/year	0	$/foot	5.89
Natural	Urban Shoreline Erosion Control Non-Vegetated	20	1076.21	$/foot	53.81	$/foot/year	0	$/foot	140.17
Natural	Urban Shoreline Erosion Control Vegetated	20	104.15	$/foot	5.21	$/foot/year	0	$/foot	13.57
Natural	Algal Flow-way Tidal	50	701953.68	$/acre	29043.49	$/acre/year	0	$/acre	67494.22
Natural	Algal Flow-way Tidal Monitored	50	0	$/acre	39.13	$/acre/year	0	$/acre	39.13
Natural	Algal Flow-way Non-Tidal	50	701953.68	$/acre	29043.49	$/acre/year	0	$/acre	67494.22
Natural	Algal Flow-way Non-Tidal Monitored	50	0	$/acre	39.13	$/acre/year	0	$/acre	39.13
Natural	Wetland Enhancement	15	1336.9	$/acre	52.11	$/acre/year	1770.23	$/acre	269.42
Natural	Wetland Rehabilitation	15	3246.67	$/acre	52.11	$/acre/year	1770.23	$/acre	453.41
Natural	Diploid Oyster Aquaculture 2.25 Inches	2	-0.01	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Diploid Oyster Aquaculture 3.0 Inches	3	-0.01	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.12
Natural	Diploid Oyster Aquaculture 4.0 Inches	4	-0.02	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Diploid Oyster Aquaculture 5.0 Inches	5	-0.02	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.12
Natural	Diploid Oyster Aquaculture Greater 6.0 Inches	6	-0.02	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.12

Sector	BMP	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Natural	Triploid Oyster Aquaculture 2.25 Inches	2	-0.01	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Triploid Oyster Aquaculture 3.0 Inches	2	-0.02	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Triploid Oyster Aquaculture 4.0 Inches	3	-0.03	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Triploid Oyster Aquaculture 5.0 Inches	4	-0.04	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Triploid Oyster Aquaculture Greater than 6.0 Inches	5	-0.05	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.11
Natural	Site-Specific Monitored Oyster Aquaculture	4	-0.01	$/oyster harvested	0.12	$/oyster harvested/year	0	$/oyster harvested	0.12
Septic	Septic Effluent - Advanced	30	23296.95	$/system	1457.49	$/system/year	0	$/system	2972.99
Septic	Septic Secondary Treatment - Advanced	30	34067.99	$/system	1753.65	$/system/year	0	$/system	3969.82
Septic	Septic Denitrification - Advanced	30	46249.61	$/system	2972.37	$/system/year	0	$/system	5980.97
Septic	Septic Denitrification - Enhanced	30	57396.87	$/system	2612.92	$/system/year	0	$/system	6346.67
Septic	Septic Secondary Treatment - Enhanced	30	30296.02	$/system	1164.67	$/system/year	0	$/system	3135.47
Septic	Septic Denitrification - Conventional	30	37871.89	$/system	1744.4	$/system/year	0	$/system	4208.02
Septic	Septic Effluent - Enhanced	30	19524.98	$/system	868.52	$/system/year	0	$/system	2138.65
Septic	Septic Secondary Treatment - Conventional	30	10771.04	$/system	1753.65	$/system/year	0	$/system	2454.32
Septic	Septic Connection	25	14457.83	$/system	234.4	$/system/year	0	$/system	1260.22
Septic	Septic Pumping	1	0	$/system	114	$/system/year	0	$/system	114

Animal BMP Costs

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Transport	pullets	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	turkeys	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	hogs and pigs for breeding	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	beef	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	broilers	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	dairy	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	hogs for slaughter	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	horses	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	layers	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	other cattle	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	sheep and lambs	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Manure Transport	goats	1	19.53	$/ton	0	$/ton/year	0	$/ton	20.51
Mortality Composters	pullets	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	turkeys	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	hogs and pigs for breeding	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	beef	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	broilers	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	dairy	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	hogs for slaughter	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	horses	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	layers	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	other cattle	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	sheep and lambs	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Mortality Composters	goats	15	352.1	$/animal unit	29.93	$/animal unit/year	0	$/animal unit	63.85
Poultry Nutrient Reduction	pullets	1	0	$/animal unit	0	$/animal unit/year	0	$/animal unit	0
Poultry Nutrient Reduction	turkeys	1	0	$/animal unit	0	$/animal unit/year	0	$/animal unit	0

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Poultry Nutrient Reduction	broilers	1	0	$/animal unit	0	$/animal unit/year	0	$/animal unit	0
Poultry Nutrient Reduction	layers	1	0	$/animal unit	0	$/animal unit/year	0	$/animal unit	0
Dairy Precision Feeding and/or Forage Management	dairy	1	0	$/animal unit	-43.99	$/animal unit/year	0	$/animal unit	-43.99
Poultry Litter Amendments (alum, for example)	pullets	1	92.57	$/animal unit	0	$/animal unit/year	0	$/animal unit	97.2
Poultry Litter Amendments (alum, for example)	turkeys	1	92.57	$/animal unit	0	$/animal unit/year	0	$/animal unit	97.2
Poultry Litter Amendments (alum, for example)	broilers	1	92.57	$/animal unit	0	$/animal unit/year	0	$/animal unit	97.2
Poultry Litter Amendments (alum, for example)	layers	1	92.57	$/animal unit	0	$/animal unit/year	0	$/animal unit	97.2
Biofilters	pullets	20	333.23	$/animal unit	12.5	$/animal unit/year	0	$/animal unit	39.24
Biofilters	turkeys	20	333.23	$/animal unit	12.5	$/animal unit/year	0	$/animal unit	39.24
Biofilters	broilers	20	333.23	$/animal unit	12.5	$/animal unit/year	0	$/animal unit	39.24
Biofilters	layers	20	333.23	$/animal unit	12.5	$/animal unit/year	0	$/animal unit	39.24
Lagoon Covers	hogs and pigs for breeding	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Lagoon Covers	beef	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Lagoon Covers	dairy	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Lagoon Covers	hogs for slaughter	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Lagoon Covers	other cattle	10	1872.03	$/animal unit	56.16	$/animal unit/year	0	$/animal unit	298.6
Animal Waste Management System	pullets	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	turkeys	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Animal Waste Management System	hogs and pigs for breeding	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	beef	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	broilers	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	dairy	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	hogs for slaughter	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	horses	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	layers	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	other cattle	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	sheep and lambs	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Animal Waste Management System	goats	15	898.7	$/animal unit	26.96	$/animal unit/year	0	$/animal unit	113.54
Manure Treatment Slow Pyrolysis	pullets	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	turkeys	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	hogs and pigs for breeding	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	beef	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	broilers	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	dairy	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	hogs for slaughter	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Slow Pyrolysis	horses	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	layers	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	other cattle	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	sheep and lambs	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Slow Pyrolysis	goats	20	377.17	$/ton	64.09	$/ton/year	0	$/ton	94.36
Manure Treatment Fast Pyrolysis	pullets	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	turkeys	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	hogs and pigs for breeding	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	beef	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	broilers	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	dairy	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	hogs for slaughter	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	horses	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	layers	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	other cattle	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	sheep and lambs	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3
Manure Treatment Fast Pyrolysis	goats	20	408.03	$/ton	16.56	$/ton/year	0	$/ton	49.3

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Low Heat Gasification	pullets	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	turkeys	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	hogs and pigs for breeding	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	beef	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	broilers	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	dairy	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	hogs for slaughter	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	horses	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	layers	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	other cattle	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	sheep and lambs	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Low Heat Gasification	goats	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	pullets	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	turkeys	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	hogs and pigs for breeding	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	beef	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	broilers	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment High Heat Gasification	dairy	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	hogs for slaughter	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	horses	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	layers	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	other cattle	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	sheep and lambs	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment High Heat Gasification	goats	10	388.4	$/ton	88.06	$/ton/year	0	$/ton	138.36
Manure Treatment Combustion	pullets	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	turkeys	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	hogs and pigs for breeding	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	beef	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	broilers	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	dairy	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	hogs for slaughter	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	horses	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	layers	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	other cattle	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Combustion	sheep and lambs	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Combustion	goats	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	pullets	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	turkeys	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	hogs and pigs for breeding	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	beef	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	broilers	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	dairy	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	hogs for slaughter	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	horses	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	layers	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	other cattle	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	sheep and lambs	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment High Heat Combustion	goats	10	381.11	$/ton	100.7	$/ton/year	0	$/ton	150.06
Manure Treatment Rotating Bin	pullets	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	turkeys	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	hogs and pigs for breeding	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Rotating Bin	beef	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	broilers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	dairy	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	hogs for slaughter	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	horses	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	layers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	other cattle	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	sheep and lambs	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin	goats	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	pullets	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	turkeys	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	hogs and pigs for breeding	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	beef	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	broilers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	dairy	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	hogs for slaughter	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	horses	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Rotating Bin High CN	layers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	other cattle	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	sheep and lambs	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin High CN	goats	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	pullets	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	turkeys	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	hogs and pigs for breeding	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	beef	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	broilers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	dairy	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	hogs for slaughter	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	horses	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	layers	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	other cattle	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	sheep and lambs	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Rotating Bin Low CN	goats	15	186.89	$/ton	115.69	$/ton/year	0	$/ton	133.7
Manure Treatment Forced Aeration	pullets	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Forced Aeration	turkeys	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	hogs and pigs for breeding	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	beef	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	broilers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	dairy	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	hogs for slaughter	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	horses	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	layers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	other cattle	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	sheep and lambs	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Treatment Forced Aeration	goats	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	pullets	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	turkeys	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	hogs and pigs for breeding	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	beef	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Forced Aeration High CN	broilers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	dairy	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	hogs for slaughter	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	horses	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	layers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	other cattle	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	sheep and lambs	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration High CN	goats	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	pullets	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	turkeys	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	hogs and pigs for breeding	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Forced Aeration Low CN	beef	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	broilers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	dairy	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	hogs for slaughter	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	horses	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	layers	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	other cattle	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	sheep and lambs	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Forced Aeration Low CN	goats	15	214.47	$/ton	-9.19	$/ton/year	0	$/ton	11.47
Manure Compost Turned Pile Windrow	pullets	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	turkeys	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	hogs and pigs for breeding	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	beef	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Turned Pile Windrow	broilers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	dairy	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	hogs for slaughter	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	horses	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	layers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	other cattle	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	sheep and lambs	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow	goats	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	pullets	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	turkeys	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	hogs and pigs for breeding	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	beef	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	broilers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	dairy	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Turned Pile Windrow High CN	hogs for slaughter	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	horses	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	layers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	other cattle	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	sheep and lambs	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow High CN	goats	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	pullets	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	turkeys	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	hogs and pigs for breeding	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	beef	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	broilers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Turned Pile Windrow Low CN	dairy	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	hogs for slaughter	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	horses	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	layers	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	other cattle	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	sheep and lambs	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Turned Pile Windrow Low CN	goats	15	101.91	$/ton	-20.6	$/ton/year	0	$/ton	-10.78
Manure Compost Static Pile Windrow	pullets	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	turkeys	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	hogs and pigs for breeding	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	beef	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	broilers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	dairy	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	hogs for slaughter	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Static Pile Windrow	horses	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	layers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	other cattle	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	sheep and lambs	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow	goats	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	pullets	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	turkeys	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	hogs and pigs for breeding	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	beef	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	broilers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	dairy	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	hogs for slaughter	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	horses	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Static Pile Windrow High CN	layers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	other cattle	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	sheep and lambs	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow High CN	goats	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	pullets	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	turkeys	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	hogs and pigs for breeding	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	beef	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	broilers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	dairy	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	hogs for slaughter	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Compost Static Pile Windrow Low CN	horses	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	layers	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	other cattle	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	sheep and lambs	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Compost Static Pile Windrow Low CN	goats	15	95.49	$/ton	-20.6	$/ton/year	0	$/ton	-11.4
Manure Treatment Direct Monitor	pullets	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	turkeys	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	hogs and pigs for breeding	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	beef	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	broilers	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	dairy	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	hogs for slaughter	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	horses	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	layers	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	other cattle	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54

BMP	Animal	Lifespan Years	Capital	Capital Unit	O and M	O and M Unit	Opportunity	Opportunity Unit	Total Annualized Cost Per Unit
Manure Treatment Direct Monitor	sheep and lambs	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Manure Treatment Direct Monitor	goats	15	292.53	$/ton	25.82	$/ton/year	0	$/ton	54
Broiler Mortality Freezers	broilers	15	7836.06	$/ton of carcasses	1751.84	$/ton of carcasses/year	0	$/ton of carcasses	2506.78