Baken Creek Alternative Restoration Plan

Perry County, Pennsylvania

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DEPARTMENT OF ENVIRONMENTAL PROTECTION

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Executive Summary

An Alternative Restoration Plan (ARP) for sediment pollution was developed for the Baken Creek Watershed (Figure 1) to address the siltation impairments noted in the 2020 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report (Integrated Report), including the Clean Water Act Section 303(d) List. Because Pennsylvania does not have numeric water quality criteria for sediment, the loading rate from a similar unimpaired watershed was used to calculate allowable loading.

Existing sediment loading in the Baken Creek Watershed was estimated to be 1,187,527 pounds per year. To meet water quality objectives, sediment loading should be reduced by 50% to 594,788 pounds per year. Allocation of sediment loading among the ARP variables is summarized in Table 1. To achieve this reduction while maintaining a 10% margin of safety, loading from croplands should be reduced by 62% whereas loading from hay/pasture lands and streambanks should each be reduced by 40%.

Table 1. Summary of ARP Variables for the Baken Creek Watershed. All values are annual averages in lbs/yr.

Pollutant	AL	UF	SL	LNR	ASL
Sediment	594,788	59,479	535,309	3,802	531,507

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

An analysis of BMP opportunities suggests that, if fully implemented as prescribed, sediment loading in the subwatershed could be reduced by about 65%, or 770,749 pounds per year. The most effective BMP opportunities were determined to be the use of agricultural erosion and sedimentation plans, conservation tillage, riparian buffers and precision grass filter strips along concentrated overland flowpaths.

This plan proposes a joint effort between the Perry County Conservation District and the Pennsylvania Department of Environmental Protection (PA DEP), in cooperation with landowners and other organizations, to implement a suite of BMPs over a nine-year period that are estimated to achieve the prescribed reductions. A proposed monitoring plan is also included to evaluate the benefits to aquatic communities. The ultimate goal is the reversal of aquatic life impairments for the benefit of not only Baken Creek, but the larger Shermans Creek Watershed.

Introduction

Baken Creek is a tributary of Shermans Creek, with the confluence approximately 1.3 miles southeast of the Borough of Landisburg in Perry County. This alternative restoration plan has been prepared to address siltation impairments listed for the entire watershed (Figure 1, Table 2), per the 2020 Final Integrated Report (see Appendix A for a description of assessment methodology). The Baken Creek Watershed was approximately 4.3 square miles and occurred entirely within Perry County. It contained approximately 10.7 stream miles, most of which were designated for Cold-Water Fishes (CWF). All stream segments were also designated for migratory fishes.

Baken Creek is of particular interest for stream restoration because of the broader goal of protecting water quality within Shermans Creek. Shermans Creek is a large stream, approximately 50 miles long and 5th order at its mouth, that is noted for fishing, boating and exceptional scenery, while being within 10 miles of both greater Harrisburg and Carlisle urbanized areas. In fact, a 2008 survey for the PA Fish and Boat Commission indicated that Shermans Creek was the 15th most popular trout stream in the state (Responsive Management 2008). Much of the headwaters of Shermans Creek originate within the Tuscarora State Forest lands of western Perry County, leading to a series of cold, clear mountain streams entering throughout the upper and middle parts of the watershed (Figure 2). Many of these streams have wild trout populations and are designated for High-Quality Cold-Water Fishes.

The lower reaches of Shermans Creek are popular for smallmouth bass fishing, kayaking and tubing. A popular boating shop, “Blue Mountain Outfitters” considers Shermans Creek to be “by far the most rural” of the “big 4 of Harrisburg area creeks” (which also includes the Conodoguinet, the Yellow Breeches, and the Swatara Creek) (Reilly 2010). According to Blue Mountain Outfitters, Shermans Creek has “some of the most scenic cruising miles in the Harrisburg Area” and the final 7.5 miles, which includes a high gradient reach that runs along Cove Mountain, is a “Harrisburg boaters’ classic” (Reilly 2010).

Sherman’s Creek has recently become even more popular since Duncannon Borough sold a conservation easement that protects 1,620 acres of their watershed property along Sherman’s Creek near its mouth with the Susquehanna River (Ryan, 2017, We Conserve PA 2018). This area is popular for hiking and hunting to the extent that it can be difficult to find a parking space on pleasant weekends.

Another reason for concern over the water quality within Shermans Creek is a reported crash in a eastern hellbender (*Cryptobranchus alleganiensis alleganiensis)* population. This salamander species is noted for its exceptionally large (up to 2+ foot) size, and as of 2019, status as Pennsylvania’s “Official State Amphibian”. From 1967 through 1995, surveys conducted over a 100m reach of Shermans Creek’s mainstem, in an area downstream of the confluence with Baken Run, would generally result in the observation of multiple individuals within about a half an hour of searching (Wingert 2018). However, starting in 1995 no more hellbenders were observed, and this loss coincided with the author’s observations of “an abrupt siltation of the creek” as well as “signs of eutrophication, most notably extensive growth of filamentous algae” (Wingert 2018). The author of this study, Eugene Wingert, has been unable to find hellbenders again in Shermans Creek as of April 2021 (personal communication), though he has received unconfirmed reports of their presence in the watershed (Wingert 2018). While the cause(s) of the hellbender population crash in Shermans Creek is unknown, excessive sedimentation is often hypothesized as a cause of hellbender extirpations, as nonembedded large rocky substrate is recognized as a necessary component of hellbender habitat (Quinn et al. 2013). It is hoped that by improving water quality in Sherman’s Creek, this project may help protect what may remain, or perhaps even improve, the watershed’s hellbender population. This is especially important since hellbender populations have exhibited concerning declines and extirpations in many areas of their range (USFWS 2018).

While currently designated for “Warmwater Fishes”, the middle reaches of the Shermans Creek mainstem, which includes the confluence with Baken Creek, was included on PA DEP’s “Existing Use Classification” table (Revised 1/10/2022) with a statement of “Exceptional Value” in the existing use column. Similarly, the lower mainstem was listed on the same table with a statement of “High-Quality Warm Water Fishes” in the existing use column. These considerations for special protection classification were based on DEP’s benthic macroinvertebrate scoring test, which suggest that areas of Shermans Creek might qualify for special protection. However, it is important to note that, as of the drafting of this document, an official rulemaking in accordance with 25 PA Code Chapter 93, section 93.4d. has not been finalized to redesignate these segments.

While Baken Creek itself is not being considered for special protection redesignation, stream restoration within this watershed will further the goal of protecting Shermans Creek. If restoration efforts in the Baken Creek Watershed are successful, restoration plans for other impaired tributaries may be developed as well (see Figure 2).

According to the 2020 Integrated Report, "removal of riparian vegetation" was identified as the cause of the impairments in the Baken Creek Watershed (Table 2). However, based on site observations and GIS analysis, these impairments can be more broadly attributed to agriculture in general. According to USDA's 2020 Cropland Data Layer, agricultural lands comprised nearly half (46%) of the land use in the watershed. The remaining lands were primarily forest/naturally vegetated lands (47%), while developed lands were a small amount of the total land area (6%) (see Appendix B, Table B1). There were no NPDES permitted point source discharges in the watershed with limits relevant to sedimentation (Table 3).

The removal of natural vegetation and soil disturbance associated with agriculture increases soil 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 Chapter 93.6 (a)); and,*
>
> *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, Chapter 93.6 (b))*.

While agriculture appears to be the primary cause of the impairments noted in this watershed, the loading target prescribed in this document is applicable to all significant sources of fine sediment that may settle to form deposits, regardless of source.

Table 2. Aquatic-Life Impaired Stream Segments in the Baken Creek Watershed per the 2020 Final Pennsylvania Integrated Report

HUC: 02050305 – Lower Susquehanna-Swatara				
Source	EPA 305(b) Cause Code	Miles	Designated Use	Use Designation
Removal of Riparian Vegetation	Siltation	10.7	CWF, MF	Aquatic Life

HUC= Hydrologic Unit Code; CWF= Cold Water Fishes; MF= Migratory Fishes
The use designations for the stream segments in this TMDL can be found in PA Title 25 Chapter 93.
See Appendix A for more information on the listings and listing process, and Appendix C for a listing of each stream segment.

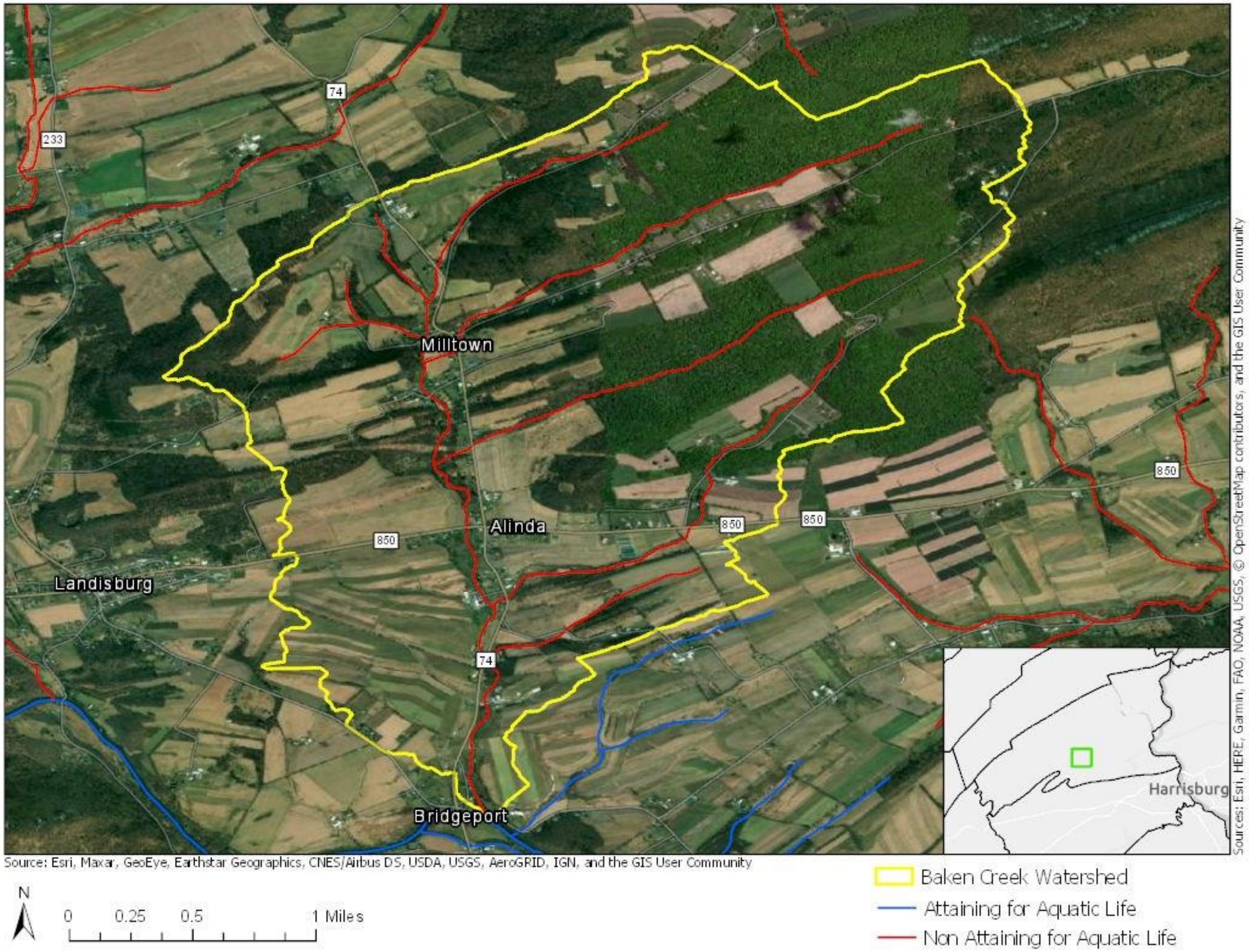


Figure 1. Baken Creek Watershed. All stream segments within the watershed were listed as impaired for aquatic life per the 2020 Final Pennsylvania Integrated Report. The reported cause of the impairment was siltation due to removal of riparian vegetation.

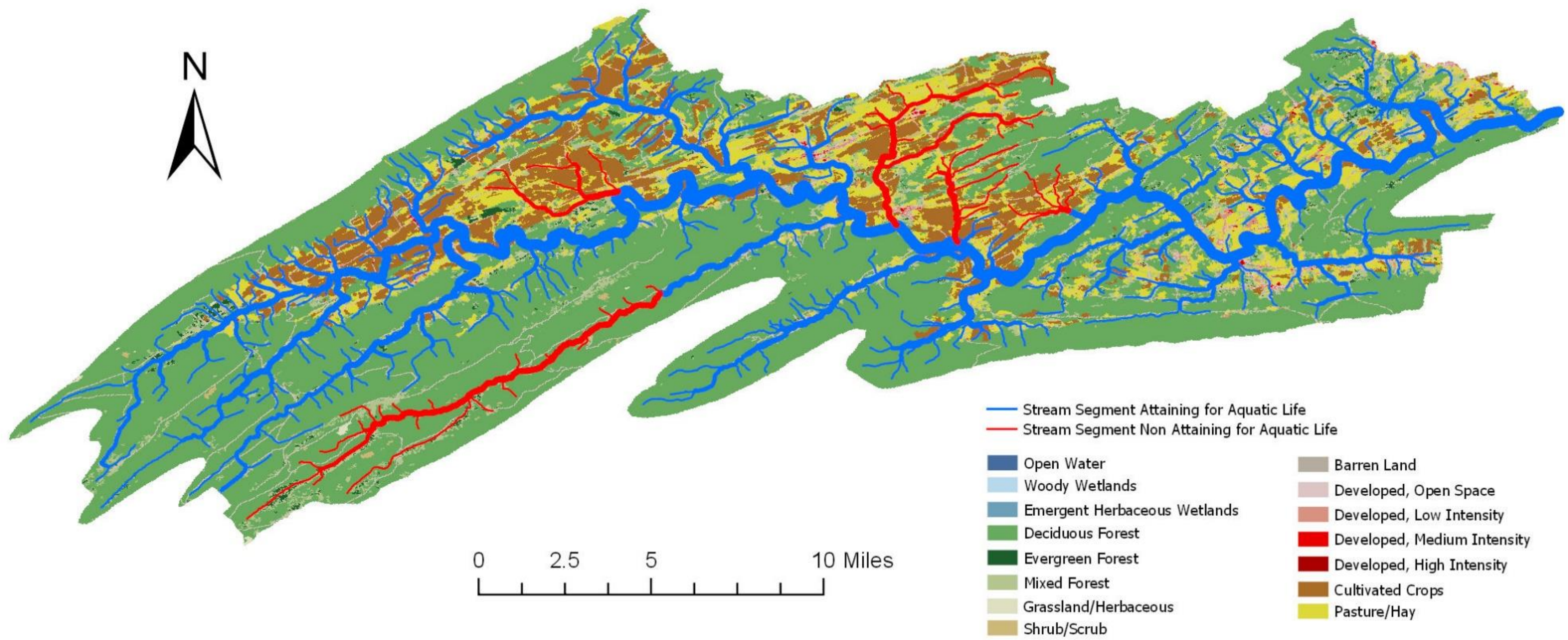


Figure 2. Shermans Creek Watershed. All stream segments are shown as either impaired or attaining for aquatic life use per the 2020 Final Pennsylvania Integrated Report. Land use classifications are per NLCD 2016. The watershed can be loosely summarized into three broad regions based on dominant land uses. The “mountainous area” in the far west and southern margin of the watershed; the “intensive agricultural area” north of the mainstem in the central region of the watershed; and the “mixed forest/low intensity agricultural area” in the eastern end of the watershed. Aquatic life impairments occurred in four major tributary systems of the “intensive agricultural area”: Cisna Run, Montour Creek, Baken Creek, and UNT Shermans Creek (west to east). Note that the impairments shown for the tributary system in the forested southwest area of the watershed (Laurel Run), were attributed to metals due to atmospheric deposition. This figure was made in ArgGISPro by Esri.

Table 3. Existing NPDES-Permitted Discharges in the Baken Creek Watershed.		
Permit No.	Facility Name	Load, lbs/yr
NA	NA	NA

Permits within the watershed were based on DEP's eMapPA available at http://www.depgis.state.pa.us/emappa/ and EPA's Watershed Resources Registry available at https://watershedresourcesregistry.org/map/?config=stateConfigs/pennsylvania.json

Note that given their transient nature, any stormwater construction permits were not included above.

ARP Approach

Per the Federal Clean Water Act, waters with pollutant impairments typically require the establishment of "Total Maximum Daily Loads" (TMDLs) that set allowable pollutant loading limits. The TMDL is then allocated among point source dischargers, nonpoint sources, natural and anthropogenic background sources not considered responsible for the impairments as well as a margin of safety factor. TMDLs can then be used to set appropriate loading limits for NPDES permitted dischargers. However, where the pollution problem is due primarily to unpermitted nonpoint sources there may be no effective mechanism to force pollution reduction. Thus, historically there have been many nonpoint source TMDLs developed that have led to little actual stream improvements.

In recognition of this, EPA has allowed an alternative approach, which is essentially a short-term restoration plan that is to be implemented to address the pollution impairments. If it can be shown that the plan can be implemented and could result in the reversal of the impairments, the development of a TMDL may be postponed. If, however, the ARP fails to reverse impairments then a TMDL would be required.

The same basic TMDL process is also relevant to ARPs. These steps include:

1. Collection and summarization of pre-existing data (watershed characterization, inventory contaminant sources, determination of pollutant loads, etc.);
2. Calculation of a TMDL, or in the case of the ARP, an allowable loading value that appropriately accounts for critical conditions and seasonal variations;
3. Allocation of pollutant loads to various sources;
4. Submission of draft reports for public review and comments; and
5. EPA approval of the TMDL, or recognition of the ARP.

Because Pennsylvania does not have numeric water quality criteria for sediment, the "Reference Watershed Approach" was used. This method estimates sediment loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired for sediment. 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 impaired stream segments attaining their designated uses.

Selection of the Reference Watershed

In addition to anthropogenic influences, there are many other natural factors affecting sediment loading rates and accumulation. 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 allowable loading calculations that suggest that sediment loading in the impaired watershed should be increased.

To find a reference, the Department's Integrated Report GIS-based website (available at https://gis.dep.pa.gov/IRViewer2020/), or GIS data layers consistent with the Integrated Report, were used to search for nearby watersheds that were of similar size as the size as the Baken Creek Watershed, but lacked stream segments impaired for sediment. 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 use 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 a reasonable pollution reduction.

Considering that: it was partially within the same section of the same Physiographic Province (the Susquehanna Lowland Section of the Ridge and Valley Physiographic Province), it had similar topographic characteristics, and there was good evidence that it was attaining its aquatic life use, a subwatershed of Black Run (Figure 3) in Union County was considered for use as a reference. Key watershed characteristics are summarized in Table 4.

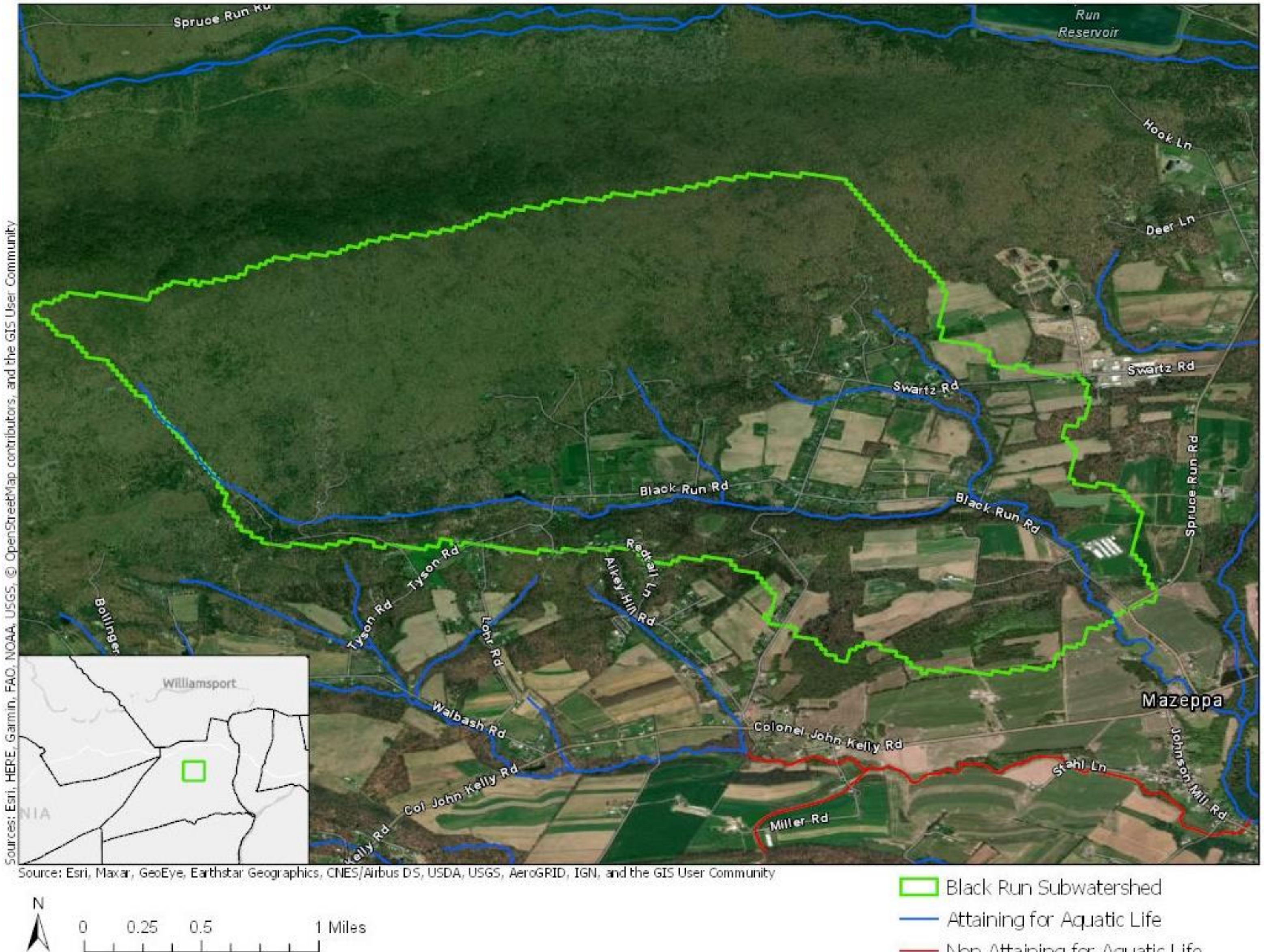


Figure 3. Black Run Subwatershed. All stream segments within the watershed were listed as attaining for aquatic life per the 2020 Final Pennsylvania Integrated Report.

Table 4. Comparison of the Impaired (Baken Creek) and Reference (Black Run) Watersheds.

	Baken Creek	Black Run
Phys. Province[1]	100% Susquehanna Lowland Section of Ridge and Valley	51% Appalachian Mountain Section of Ridge and Valley 49% Susquehanna Lowland Section of Ridge and Valley
Land Area[2], ac	2,779	2,857
Land Use[2]	46% Agriculture 47% Forest/Natural Vegetation 6% Developed	20% Agriculture 75% Forest/Natural Vegetation 5% Developed
Soil Infiltration[3]	52% Group A 21% Group B 2% Group B/D 3% Group C 7% Group C/D 15% Group D	26% Group A 43% Group B 2% Group B/D 6% Group C 16% Group C/D 8% Group D
Dominant Bedrock[4]	40% Calcareous Shale 33% Shale 28% Limestone	65% Shale 31% Quartzite 3% Calcareous Shale 1% Sandstone
Average Precipitation[5], in/yr	41.5	41.5
Average Surface Runoff[5], in/yr	1.5	1.9
Average Elevation[5] (ft)	745	937
Average Slope[5]	11%	13%
Average Stream Channel Slope[5]	1st Order:3.0% 2nd Order: 1.1	1st Order: 2.0 2nd Order: 0.8

[1]Per PA_Physio_Sections GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources
[2]MMW output/input based on USDA's Cropland Data Layer as reported by Cropscape see https://nassgeodata.gmu.edu/CropScape/
[3]As reported by Model My Watershed's analysis of USDA gSSURGO 2016
[4]Per Bedrock_V GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources
[5]As reported by Model My Watershed

Both watersheds were similar in that the upstream areas were forested uplands, while the lower watersheds were agricultural valleys (Figures 1 and 3). The upland area however was steeper and more mountainous in the Black Run Subwatershed whereas it was more comparable to large hills in the Baken Creek Watershed. Even so, the average slope was only slightly greater in the Black Run Subwatershed (13% vs 11%) while reported stream slopes were actually greater on average in the Baken Creek Watershed (Table 4).

While Baken Creek was entirely within the Susquehanna Lowland Section of the Ridge and Valley Physiographic Province, Black Run was halfway within the Appalachian Mountain Section of the Ridge and Valley Physiographic Province as well (Table 4). There was far more agricultural land area in the Baken Creek Watershed (46%) versus the Black Run Subwatershed (20%) (Table 4). As would be expected then, the amount of forested/naturally vegetated lands was far higher in the Black Run Subwatershed (75% vs. 47%). The amount of developed lands in both watersheds was approximately the same (6 and 5%).

Both watersheds were dominated by high and moderate infiltration (A and B) soils and surface runoff rates were similar (Table 4). Shale was the predominant bedrock type in both waterhseds. However, there was also a significant amount of limestone in the Baken Creek Watershed while the Black Run Subwatershed lacked limestone (Table 4). However, Baken Creek's limestone was of the Keyser and Tonoloway Formation, which tends to not form strongly karst features, and no sinkholes or surface depressions were mapped in this watershed per a GIS layer provided by PA DCNR's Bureau of Topographic and Geological Survey (PAGS).

While Baken Creek was designated for "cold-water fishes", Black Run was actually designated for "high-quality cold-water fishes". While this might suggest that use of the Black Run Subwatershed as a reference could create unnecessarily stringent pollution reduction standards, this concern was dismissed because the most recent assessment information from Black Run suggests that its assessment scores were not high enough to attain a special protection use based on macroinvertebrate assessment data alone. Its score was sufficient however to attain a basic "cold-water fishes" use.

Like the Baken Creek Watershed, there were no significant NPDES-permitted point source discharges with numeric load limits relevant to sediment in the Black Run Subwatershed (Table 5).

Table 5. Existing NPDES-Permitted Discharges in the Black Run Subwatershed and their Potential Contribution to Sediment Loading.

Permit No.	Facility Name	Load, lbs/yr

PA0229105	Amos Newswanger Garreau Farm CAFO[1]	NA
PAS224804	Kuhns Brothers Lumber Co, Inc[2]	NA

Permits within the watershed were based on DEP's eMapPA available at http://www.depgis.state.pa.us/emappa/ and EPA's Watershed Resources Registry available at https://watershedresourcesregistry.org/map/?config=stateConfigs/pennsylvania.json

Note that given their transient nature, any stormwater construction permits were not included above.

[1]In Pennsylvania, routine, dry-weather discharges from concentrated animal feeding operations (CAFOs) are not allowed. Wet weather discharges are controlled through best management practices, resulting in infrequent discharges from production areas and reduced sediment loadings associated with lands under the control of CAFOs owner or operators, such as croplands where manure is applied. Although not quantified in this table, sediment loading from CAFOs is accounted for since the modelling program estimates loadings from croplands and hay/pasturelands.

[2]Permit for industrial stormwater.

After selecting the potential reference, the two subwatersheds were visited during spring 2021 to confirm the suitability of the reference as well as to explore whether there were any obvious land use differences that may help explain why one watershed was impaired for sediment while the other was attaining. Substantial fine sediment deposition was obvious in many stream segments of the agricultural valley area of Baken Creek's lower watershed (Figure 4). However, conditions were typically not as severe as is often observed in highly polluted watersheds, and tributaries originating from the forested uplands tended to be primarily rocky (Figure 5). Together, these observations suggest that the pollution problem was moderate in this watershed.

Agricultural land uses were typically intensive within the lower valley area of the Baken Creek Watershed (Figures 6 and 7), and the need for BMPs was obvious. Many stream segments lacked expansive forested riparian buffers, and in some cases crop and hay/pasture lands were in close proximity to streams. Sites were also observed where livestock had direct access to the stream resulting in bank erosion. Conditions that may be protective against agricultural pollution were observed as well (Figure 8), including streams in forested areas or with forested buffers.

Overall, stream substrate conditions appeared to be much healthier in the Black Run Subwatershed (Figure 9), likely due to a lesser intensity of agricultural land uses. While substantial agriculture occurred in the valley area of the lower watershed (Figure 10), the agricultural area of the Black Run Subwatershed was smaller relative to the Baken Creek Watershed (compare Figures 1 and 3). Furthermore, stream segments in the Black Run Subwatershed commonly flowed through forested areas or at least had expansive forested buffers (Figure 11), though with some exceptions (Figure 12).

Figure 4. Example substrate conditions in the lower valley area of the Baken Creek Watershed. The lower mainstem (A and B) exhibited obvious fine sediment deposition and embeddedness. Some tributaries (C and D) also exhibited substantial sediment deposition.

Figure 5. Examples of substrate conditions within small tributaries of the Baken Creek Watershed. Many small tributary reaches exhibited rocky conditions, especially those originating in primarily forested higher gradient areas of the upper watershed.

Figure 6. Landscapes within the Baken Creek Watershed. The headwaters of the upper watershed originated in a hilly/mountainous area that was primarily forested whereas the lower watershed was a broad agricultural valley.

Figure 7. Factors that may contribute to high levels of sediment loading in the Baken Creek Watershed. In many cases, streams passed through agricultural landscapes without expansive riparian buffers (A through D). While it is difficult to see in this photo, the streambanks shown in D exhibited substantial erosion.

Figure 8. Factors that may be protective against sediment loading in the Baken Creek Watershed. Large forested patches were common along headwater tributaries (A) and occasionally along larger mainstem reaches (B). C shows narrower forested buffers and D shows an area with new riparian buffer plantings.

Figure 9. Stream substrate conditions in the Black Run Subwatershed. Stream segments were primarily rocky throughout the watershed, though what appears to be sand deposition can be observed in photograph B.

Figure 10. Landscapes within the Black Run Subwatershed. The upper watershed was largely forested whereas the lower watershed was a broad agricultural valley.

Figure 11. Factors that may be protective of water quality in the Black Run Subwatershed. Large forested patches (A through C) or riparian buffers (D) were common along many stream segments.

Figure 12. Factors that may exacerbate sediment loading in the Black Run Subwatershed. In some cases expansive riparian buffers were lacking along streams and drainageways within agricultural landscapes.

Hydrologic / Water Quality Modeling

Estimates of sediment loading for the impaired and reference watersheds were calculated using the "Model My Watershed" application (MMW), which is part of the WikiWatershed web toolkit developed through an initiative of the Stroud Water Research Center. 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, the watershed area for the Black Run Subwatershed was defined using MMW's Watershed Delineation tool (see https://wikiwatershed.org/documentation/mmw-tech/#delineate-watershed). The watershed area for Baken Creek was determined primarily using TauDEM and ArcGISPro tools (see the later "Precision Grass Filter Strips Section"). 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 Model My Watershed'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 EPA 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 was 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 (2021).

Model My Watershed 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 modelling run, except that landcovers were adjusted to reflect the latest data from USDA's Cropland Data Layer (year 2020), as reported by Cropscape (see https://nassgeodata.gmu.edu/CropScape/). To do this, the watershed shapefiles were imported into Cropscape, which provided summaries of landcover that were exported to Microsoft Excel. Cropland Data Layer output classes were converted into MMW input classes as described in Table 6.

Table 6. Conversion of 2020 Cropland Data Layer (CDL) categories into Model My Watershed (MMW) input categories.

MMW Category	**CDL Category**
Hay/Pasture	Alfalfa, Other Hay/Non Alfalfa, Grass/Pasture
Cropland	Corn, Sorghum, Soybeans, Barley, Winter Wheat, Dbl Crop WinWht/Soybeans, Rye, Oats, Dry Beans, Potatoes, Peaches, Apples, Christmas Trees, Triticale, Broccoli, Dbl Crop WinWht/Corn, Dbl Crop Triticale/Corn, Pumpkins, Blueberries, Dbl Crop WinWht/Sorghum, Dbl Crop Barley/Corn, Dbl Crop Barley/Soybeans
Wooded Areas	Deciduous Forest, Evergreen Forest, Mixed Forest, Shrubland
Wetlands	Woody Wetlands, Herbaceous Wetlands
Open Land	Fallow/Idle Cropland
Barren Areas	Barren

Low-Density Mixed	Developed/Low Intensity
Medium-Density Mixed	Developed/Medium Intensity
High-Density Mixed	Developed/High Intensity
Low-Density Open Space	Developed/Open Space

A correction for the presence of existing riparian buffers was made in the BMP Spreadsheet Tool provided by Model My Watershed following the model run. The following paragraphs describe the riparian buffer correction methodology.

Riparian buffer coverage was estimated via a GIS analysis in ArcGISPro. Briefly, landcover per a high resolution landcover dataset (University of Vermont Spatial Analysis Laboratory 2016) was examined within 100 feet of NHD flowlines. To determine riparian buffering within the “agricultural area,” a polygon tool was used to clip riparian areas that, based on cursory visible inspection, appeared to be in an agricultural-dominated valley or have significant, obvious agricultural land on at least one side (Figures 13 and 14). 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 53% in the agricultural area of the impaired subwatershed versus 79% in the reference subwatershed.

An additional reduction credit was given to the reference subwatershed to account for the fact it had more riparian buffers than the impaired subwatershed. Applying a reduction credit solely to the reference watershed to account for its extra buffering was chosen as more appropriate than taking a reduction 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 a reference site.

When accounting for the buffering of croplands using the BMP Spreadsheet Tool, the user enters the length of buffer on both sides of the stream. To estimate the extra length of buffers in the agricultural area of the reference subwatershed over the amount found in the impaired subwatershed, the approximate length of NHD flowlines within the reference subwatershed was multiplied by the proportion of riparian pixels that were within the agricultural area selection polygon (see Figure 14) and then by the difference in the proportion of buffering between the agricultural area of the reference subwatershed versus that of the impaired subwatershed, 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.

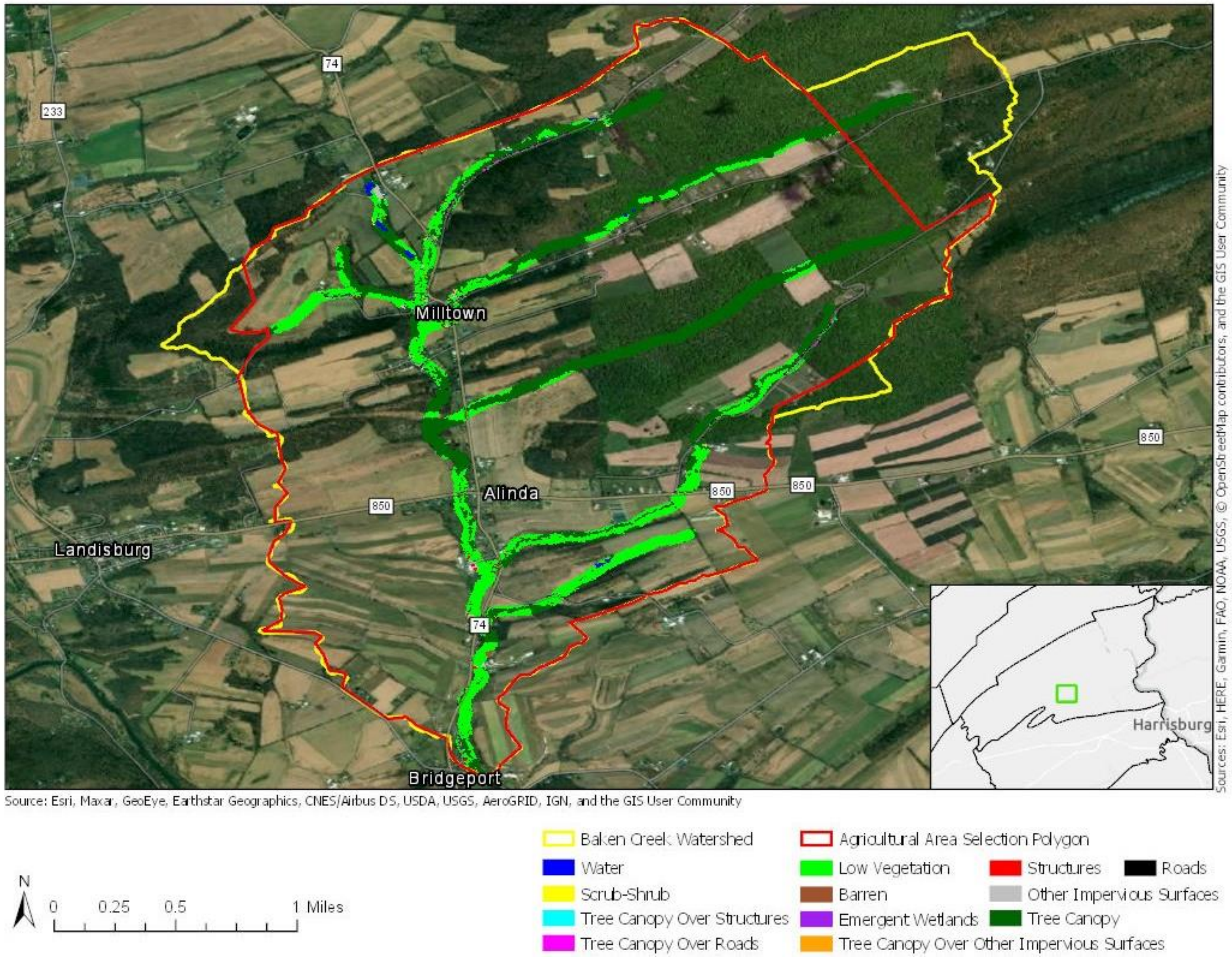


Figure 13. Riparian buffer analysis in the Baken Creek Watershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of NHD flowlines. The agricultural area selection polygon is shown in red. It was estimated that approximately 53% of land within 100 feet of NHD flowlines of the agricultural area was comprised of tree canopy, shrub/scrub or emergent wetlands.

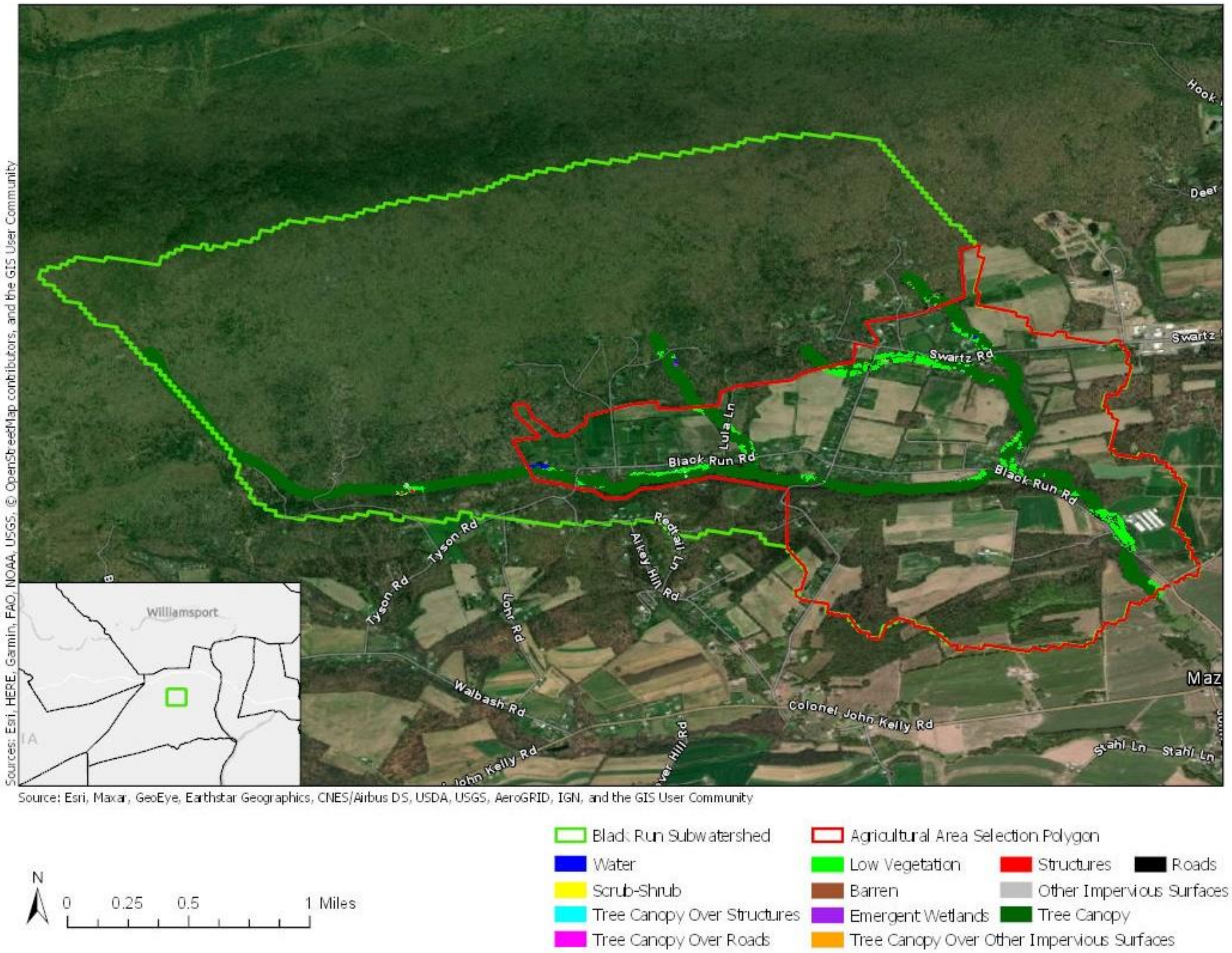


Figure 14. Riparian buffer analysis in the Black Run Subwatershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of NHD flowlines. The agricultural area selection polygon is shown in red. It was estimated that approximately 79% of land within 100 feet of NHD flowlines of the agricultural area was comprised of tree canopy, shrub/scrub or emergent wetlands.

Calculation of the Allowable Loading Rate

The mean watershed-wide sediment loading rate for the unimpaired reference subwatershed (Black Run Subwatershed) was estimated to be 214 pounds per acre per year (Table 7). This was substantially lower than the estimated loading rate in the impaired Baken Creek Watershed (427 pounds per acre per year, Table 8). Thus, to achieve the loading rate of the unimpaired subwatershed, sediment loading in the Baken Creek Watershed should be reduced to 594,788 pounds per year (Table 9).

Table 7. Existing Annual Average Loading Values for the Black Run Subwatershed, reference

Source	Area, ac	Sediment, lbs/yr	Unit Area Load, lb/ac/yr
Hay/Pasture	190	17,212	91
Cropland	383	549,528	1,435
Forest and Shrub/Scrub	2,147	6,933	3
Wetland	2	0	0
Low Intensity Mixed Development	133	1,349	10
Medium Intensity Mixed Development	0	34	84
Streambank[1]		77,360	
Point Sources		0	
Riparian Buffer Discount[2]		-41,033	
total	2,857	611,382	214

[1]"Streambank" sediment loads were calculated using Model My Watershed's streambank routine which uses length rather than area.

[2]Accounts for the extra amount of riparian buffering of the reference subwatershed versus the impaired subwatershed

Note that 0 lbs per year of sediment from wetlands appears to be an error resulting from how the model handled a new landcover input that wasn't previously recognized. A later model run with a newer version of Model My Watershed that uses newer landcover data suggests that sediment loading from wetlands in the watershed was about 2.2 lbs/yr. Since this is only about 0.0004% of the total load, this error was determined too inconsequential to go back and correct.

Table 8. Existing Annual Average Loading Values for the Baken Creek Watershed, impaired			
Source	Area ac	Sediment, lbs/yr	Unit Area Load, lbs/ac/yr
Hay/Pasture	538	203,948	379
Cropland	751	831,622	1,107
Forest and Shrub/Scrub	1,316	1,750	1
Wetland	1	0	0
Herbaceous/Grassland	2	36	23
Bare Rock	2	0	0
Low Intensity Mixed Development	167	1,813	11
Medium Intensity Mixed Development	2	184	77
High Intensity Mixed Development	0	18	92
Streambank		148,154	
Point Sources		0	
total	2,779	1,187,527	427

"Streambank" sediment loads were calculated using Model My Watershed's streambank routine which uses length rather than area.

Note that 0 lbs per year of sediment from wetlands appears to be an error resulting from how the model handled a new landcover input that wasn't previously recognized. A later model run with a new version of Model My Watershed that uses newer landcover data suggests that sediment loading from wetlands in the watershed was about 12 lbs/yr. Since this is only about 0.001% of the total load, this error was determined too inconsequential to go back and correct.

Table 9. Annual Average Allowable Loading for the Baken Creek Watershed			
Pollutant	Loading Rate in Reference, lbs/ac/yr	Total Land Area in Impaired Watershed, ac	Target AL Value, lbs/yr
Sediment	214	2,779	594,788

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

594,788 lbs/yr AL * 0.1 = 59,479 lbs/yr UF

Then, the SL is calculated as:

594,788 lbs/yr AL – 59,479 lbs/yr UF = 535,309 lbs/yr SL

Calculation of the Adjusted Source Load

In the ARP equation the Source Load 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 loads not reduced must also be defined.

Since the impairment addressed by this ARP is for sedimentation due to agriculture, sediment contributions from forests, non-agricultural herbaceous/grasslands, bare rock and developed lands within the Baken Creek Watershed were considered loads not reduced (LNR). LNR was calculated to be 3,802 lbs/yr (Table 10).

Then, the ASL is calculated as:

535,309 lbs/yr SL – 3,802 lbs/yr LNR = 531,507 lbs/yr ASL

Table 10. Source Load, Loads Not Reduced and Adjusted Source Load as Annual Averages

	Sediment, lbs/yr
Source Load (SL)	**535,309**

Loads Not Reduced (LNR):	**3,802**
Forest	1,750
Non-Agricultural Herbaceous/Grasslands	36
Bare Rock	0
Low Intensity Mixed Development	1,813
Medium Intensity Mixed Development	184
High Density Mixed Development	18
Adjusted Source Load (ASL)	**531,507**

Calculation of Sediment Load Reductions by Source Sector

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

In this evaluation, croplands exceeded the adjusted source load by itself. Thus, croplands received a greater percent reduction (62%) than hay/pasture lands and streambanks (40% each) (Table 11). Note however, the prescribed reductions by source sectors 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 adjusted source load is achieved.

Table 11. Sediment Load Allocations for Source Sectors in the Baken Creek Watershed, Annual Average Values

		Load Allocation	Current Load	Reduction Goal
Land Use	Acres	lbs/yr	lbs/yr	
CROPLAND	751	319,711	831,622	62%
HAY/PASTURE	538	122,679	203,948	40%
STREAMBANK		89,117	148,154	40%
AGGREGATE		531,507	1,183,725	55%

Consideration of Critical Conditions and Seasonal Variations

According to Model My Watershed's technical documentation (see Stroud Water Research Center 2021), Model My Watershed uses 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." The source of the weather data (precipitation and temperature) was a dataset compiled by USEPA ranging from 1961-1990. Therefore, variable flow conditions and seasonal changes are inherently accounted for in the loading calculations.

An Analysis of Possible BMPs

The following proposes a hypothetical set of Best Management Practices (BMPs) that are calculated to exceed the prescribed sediment loading reductions and address the specific problems observed in the Baken Creek Watershed. Table 12 presents the proposed BMPs and their calculated sediment reductions. Key locations for the proposed physical BMPs are shown in Figure 15.

Where relevant, BMP implementation should follow USDA-NRCS standards from the Field Office Technical Guide for Pennsylvania, unless there is a good reason to deviate from these standards. In cases where there are deviations from these standards, a review should be made of the BMP to determine whether the changes would likely result in substantially diminished sediment pollution prevention. If so, a decision could be made to not credit the BMP. It should be noted that there are likely be other BMP opportunities beyond what is envisioned here, and what is ultimately implemented will largely be dependent on the landowner's preferences. In any case, it will be important to keep careful track what is implemented so that progress may be documented.

Table 12. BMP opportunities and their calculated sediment loading reductions.

Proposed BMPs	**Sediment reduction** *lbs/yr*
7,182 feet streambank stabilization	88,267
95% ag. erosion and sedimentation plan implementation	212,944
10% more cropland with cover crops (75 acres)	8,314
30% more conservation tillage (225 acres)	102,257
15 acres grazing land management	1,706
96 acres forested riparian buffers	99,896
31 acres croplands retired for establishing the riparian buffers	34,286
65 acres hay/pasture lands retired for establishing the riparian buffers	24,570
13 acres precision grass filter strips[1]	264,680
Corrected Subtotal[2]	*770,749*
	lbs/yr
current loading for targeted sectors[3]	1,183,725
current loading for targeted sectors - all reductions	412,976
adjusted source load	531,507

[1] *Need to be installed along main drainagelines shown in Figure 15 to receive these sediment reductions. Deviation from proposed design (location, length, width) will require new modelling of reductions.*

[2] *Total corrected for precision grass filter strips/agricultural erosion and sedimentation plan double counting issue, as described in the "An Analysis of Possible BMP's section".*

[3] *Targeted sectors include croplands, hay/pasture lands, and streambanks*

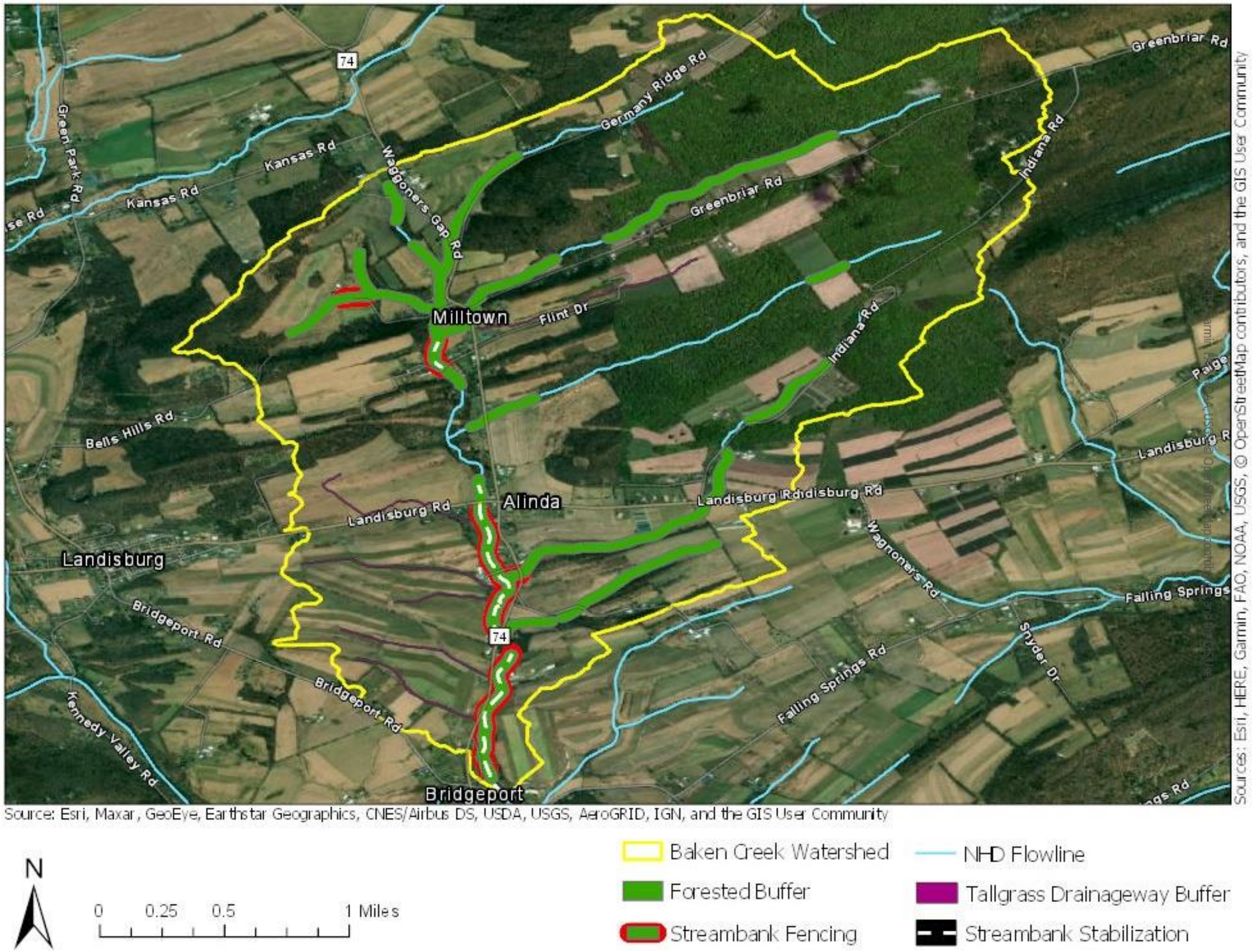


Figure 15. Proposed physical BMPs in the Baken Creek Watershed.

Table 13. Cost analysis of BMP opportunities. All costs are reported as dollars.

BMP	Unit	Lifespan in years	Capital Cost per unit	Annual O&M Cost per unit	One Time Opportunity Cost per unit (land cost)	Total Annualized Cost per unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost per pound of sediment per year
Streambank Stabilization[1]	ft	20	74.75	0.00	0.00	6.00	7,182	536,830	536,830	43,075	0.488
Erosion and Sedimentation Plans[2]	ac	10	15.00	0.00	0.00	1.94	1,225	18,368	18,368	2,376	0.011
Cover Crops[3]	ac	1	0.00	75.5	0.00	75.50	75	0	0	5,663	0.681
Conservation Tillage[3]	ac	1	0.00	0.00	0.00	0.00	225	0	0	0	0.000
Grazing Land Management[3]	ac	1	0.00	81.27	0.00	81.27	15	0	0	1,219	0.715
Forested Riparian Buffer w/o Fence[3]	ac	40	4,062.42	81.25	1,770.23	406.51	69	281,119	403,619	28,130	0.237
Forested Buffer w/Fence[3]	ac	30	7,216.47	238.95	971.31	756.96	26	186,185	211,245	19,530	0.485
Grass Filter Strips[3]	ac	10	899.15	35.97	1,770.23	240.93	13	12,018	35,677	3,220	0.012
							sum	***1,034,520***	***1,205,740***	***103,212***	

Where necessary, costs were annualized using CAST methodology. See https://cast.chesapeakebay.net/Documentation/CostProfiles

[1] Current CAST methodology reports a much higher cost for "Non Urban Stream Restoration Protocol". However, per personal communication with Shaun McAdams of Trout Unlimited, smaller projects using general permit type structures and restoration designs provided by government agencies tend to be much cheaper, approximately $50 per foot. To be conservative, $63.56 per foot was used in accordance to the second most recent CAST methodology for Pennsylvania. This value however was multiplied by 1.176 to adjust for inflation from April 2010 to April 2020 per the CPI inflation calculator provided at https://data.bls.gov/cgi-bin/cpicalc.pl.

[2]Based in internal discussions at DEP, the most current CAST estimate of $24.91 per year for "Soil Conservation and Water Quality Plans" does not seem to reflect typical costs and longevity for agricultural erosion and sedimentation plans in Pennsylvania. Thus the prior CAST cost estimate was used.

[3]Based on most recent CAST methodology, except that cover crops and grazing land management were considered annual O&M costs rather than captial costs due to their 1yr lifespans

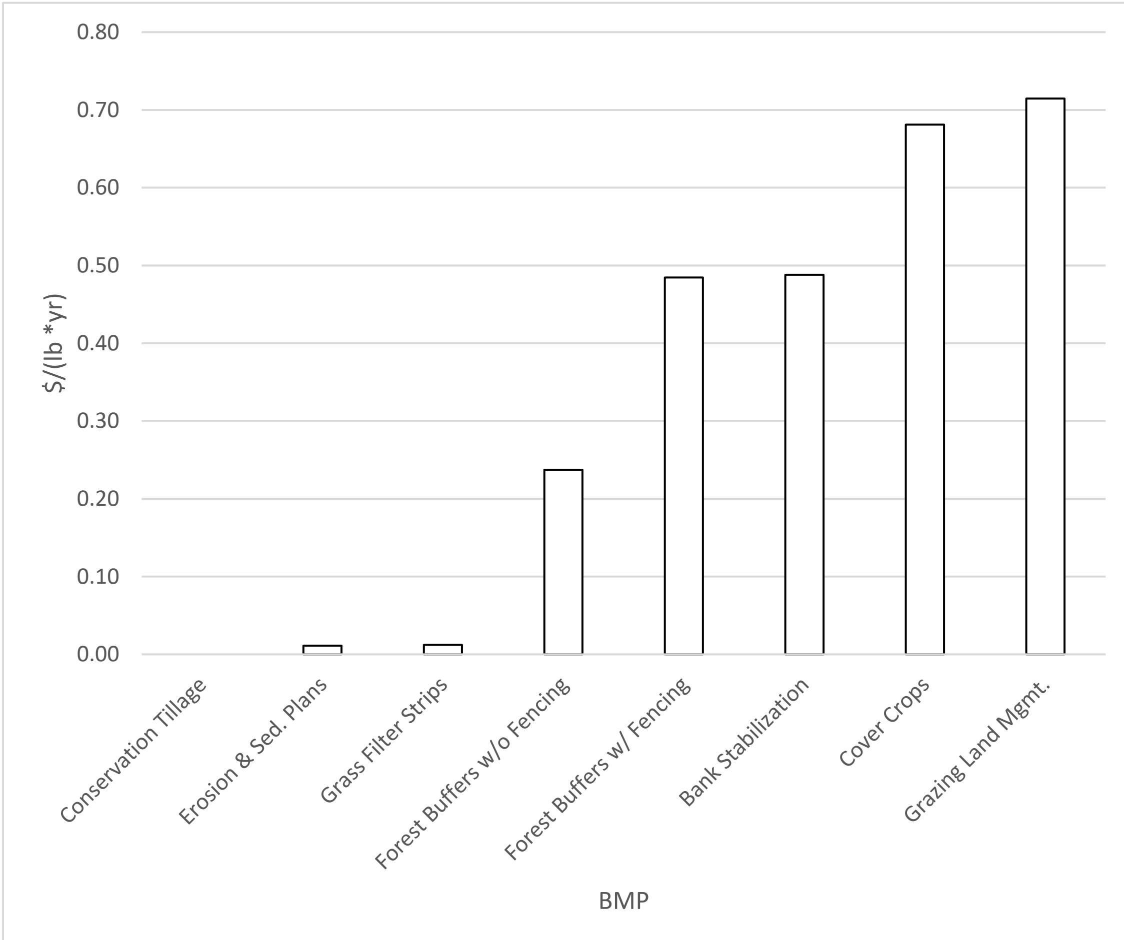


Figure 16. Estimated total annualized cost per pound of sediment removed per year for BMPs. See footnotes in Table 13 for a description of how costs were derived.

Agricultural Erosion and Sedimentation Control Plans

PA DEP and County Conservation Districts are currently working towards ensuring that agricultural operations are implementing required erosion and sedimentation control plans, and a 95% implementation rate was assumed. Note that this is not to be interpreted as an acceptable 5% rate of noncompliance. Rather such a conservative assumption may help account for factors such as temporary noncompliance, implementation lag time during transitions, potential error in land use classifications, acreage comprised of by BMPs, etc. This would result in an estimated 714 acres of cropland and 511 acres of hay/pasture lands covered by plans. Based primarily on the Chesapeake Bay Program (2018) methodology, it was assumed that these plans would reduce sediment loading on croplands by 25% and loading on hay/pasture lands by 8% (See Appendix F). Therefore, an annual sediment reduction of 212,944 lbs/yr is predicted (Table 12).

Based on internal discussions at DEP and prior CAST methodology, these plans were estimated to have a capital cost of about $15 per acre, so, if applied to 95% of the acreage of croplands and hay/pasture lands in the watershed, the total capital cost of these plans would be about $18,368 (Table 13). The total annualized cost per pound of sediment removed per year was only $0.011 (Table 13), which suggests that this BMP is very cost effective (Figure 16).

For tracking purposes, load reductions associated with agricultural erosion and sedimentation plan implementation may be calculated as:

lb/yr reduction = acres of agricultural lands with implemented plan * agricultural land loading rate * reduction coefficient

where: cropland loading rate = 1,107 lbs/(ac*yr)

hay/pasture land loading rate = 379 lbs/(ac*yr)

reduction coefficient for croplands = 0.25

reduction coefficient for hay/pasture lands = 0.08

Note that the loading rates for croplands and hay/pasture lands given above should not be confused with erosion rates reported in agricultural erosion and sediment plans, as the above values reflect loading rates transported to the watershed outlet.

Conservation Tillage

The current rate of conservation tillage use is unknown, but it was assumed that it could be increased by 30% of the current cropland acreage, or about 225 acres. Based primarily on Chesapeake Bay Program (2018) methodology, a sediment reduction efficiency of 41% was assumed (See Appendix F). Therefore, implementation of this BMP as proposed is estimated to reduce the sediment load by about 102,257 lbs/yr (Table 12).

Note however, that Chesapeake Bay Program (2018) methodology actually has different reduction percentages based on crop residue levels immediately after planting: “low residue tillage” (15-29% residue cover) gets an 18% sediment reduction; “conservation tillage” (30-59% residue cover) gets a 41% sediment reduction; and "high residue" (≥ 60% residue cover) gets a 79% sediment reduction. For simplicity given that the current residue levels as well as farmers future plans were unknown, the reductions proposed herein were based simply on going from conventional tillage to conservation tillage. However, these other categories could be used for crediting is well if more detailed information becomes available.

According to CAST documentation, use of conservation tillage is considered to be cost neutral; thus with a cost estimate of $0 per pound of sediment removed per year this is the most cost effective BMP (Table 13, Figure 16).

For tracking purposes, load reductions associated with conservation tillage implementation may be calculated as:

> lb/yr reduction = acres croplands with new/recent conservation tillage * cropland loading rate * reduction coefficient
>
> where: cropland loading rate = 1,107 lbs/(ac*yr)
>
> reduction coefficient = 0.41
>
> In addition, reduction coefficients for low residue (0.18) and high residue (0.79) could be considered as well.

If an additional 225 acres are not available for implementation of this BMP relative to current conditions, increased use of this BMP since 2013 could be credited, if implementation since then can be clearly demonstrated. An argument can be made for using 2013 as the baseline year because it was the last time that physical habitat assessment scores, which included a sedimentation component, were taken for the Baken creek Watershed. Much progress may have already been made in implementing this BMP, because on a statewide level, no-till use went from a little over 20% in 2004 to close to 70% by 2014 (USDA-NRCS 2019).

Cover Crops

According to Chesapeake Bay Program (2018) methodology, no additional credit is given for the use of cover crops on croplands that are already managed with low tillage. And, on lands with higher tillage, use of cover crops would provide much less sediment reductions versus converting to conservation tillage. Thus, only a small amount of cover crops, 75 acres or 10% of the cropland land area, were presently proposed, to account for areas where landowners are unwilling to implement conservation tillage.

Based primarily on Chesapeake Bay Program (2018) methodology, this BMP was given a 10% sediment reduction efficiency (See Appendix F). It should be noted however that crediting is only applicable when this BMP is used on high tillage lands and when the cover crop is not a commodity crop. It is estimated that this would reduce sediment loading by a meager 8,314 lbs/yr.

Use of cover crops is estimated to have an annual operation and maintenance cost of $75.50 per acre (Table 13). Thus, if applied to 10% of the acreage of cropland in the subwatershed, the total annual cost of the proposed cover crops would be about $5,663 (Table 13). The total annualized cost per pound of sediment removed per year is $0.681, which indicates that this BMP is expensive (Figure 16).

For tracking purposes, load reductions associated with cover crop implementation may be calculated as:

lb/yr reduction = acres croplands on high tillage lands with new/recent cover crop use * cropland loading rate * reduction coefficient

where: cropland loading rate = 1,107 lbs/(ac*yr)

reduction coefficient = 0.1

If an additional 75 acres are not available for implementation of this BMP relative to current conditions, increased use of this BMP since 2013 could be credited, if implementation since then can be clearly demonstrated. An argument can be made for using 2013 as the baseline year because it was the last time that physical habitat assessment scores, which included a sedimentation component, were taken for the Baken Creek Watershed. Much progress may have already been made in implementing this BMP; for instance, in Berks, Lancaster, Lebanon and York Counties, use of cover crops after growing corn went from about 40% in 2009 to about 65% in 2012 (USDA-NRCS 2019).

Conventional Riparian Buffers

It is widely recognized that riparian buffers are highly beneficial to stream communities for many reasons. Not only do they filter out pollutants such as sediment and nutrients, but they also provide habitat and nutrition for aquatic, semi-aquatic and terrestrial organisms; protect streambanks; and moderate stream temperature. Thus, riparian buffers should be encouraged *wherever* possible. Therefore, Figure 15 essentially shows proposed 100-foot wide forested buffers for all streamside areas where they are substantially lacking. The acreages of buffer opportunities reported in Table 12 were reduced relative to the full area shown in Figure 15 to reflect only the area with croplands or hay/pasture coverage per the 2020 USDA cropland data layer, as some areas may already have some natural vegetative cover and it is unlikely that significant buffers would be established on many developed lands.

While many experimental studies suggest riparian buffers can be very effective at removing upland pollutant loads, recent research suggests that buffer filtration performance may be limited by real-world environmental conditions, especially due to the existence of concentrated flowpaths (Dosskey et al. 2002, Sweeney and Newbold 2014). Furthermore, for any given buffer there may not be much uplands contributing pollutants to it. Or, if there are too much uplands communicating to a unit area of buffer it is thought that its filtration capacity may become less effective. For such reasons, the CAST expert panel report chose to very conservatively assume that the sediment load from only two acres of uplands are filtered by about half (though variable by region) per acre of buffer created. Credit is also given for the land conversion associated with the creation of the buffer. For more information, see Belt et al. (2014) and Appendix F. Similarly, to Belt et al. (2014) and Chesapeake Bay Program (2018), reductions associated with conventional buffers may be calculated as:

lb/yr reduction = (acres of new streamside buffers created * 2 * cropland loading rate * filtration reduction coefficient) + [acres of new streamside buffers created * (current land use loading rate – forest land use loading rate]

where: cropland loading rate = 1,107 lbs/(ac*yr)

filtration reduction coefficient = 0.47

current land use loading rate for hay/pasture lands (if needed) = 379 lbs/(ac*yr)

forest land use loading rate = 1 lbs/(ac*yr)

One advantage to crediting buffers by the acre rather than by length of stream buffered is that buffer width and configuration will likely vary depending on the landowner's degree of commitment to this BMP. While ≥ 100 foot buffers are preferable, the above formula allows for crediting buffers of varying widths.

Using the above methodology, it is estimated that the proposed buffers shown in Figure 15 would remove 158,752 pounds of sediment per year (Table 12).

Note that while forested buffers are preferable for wildlife habitat, grass buffers are thought to provide a similar sediment filtration benefit (see Belt et al. 2014). Reductions associated with streamside grass buffers could be modelled using the above formula, in which case the loading for hay/pasture could be used for the loading rate of the grass buffers when calculating the reductions associated with the change of land use.

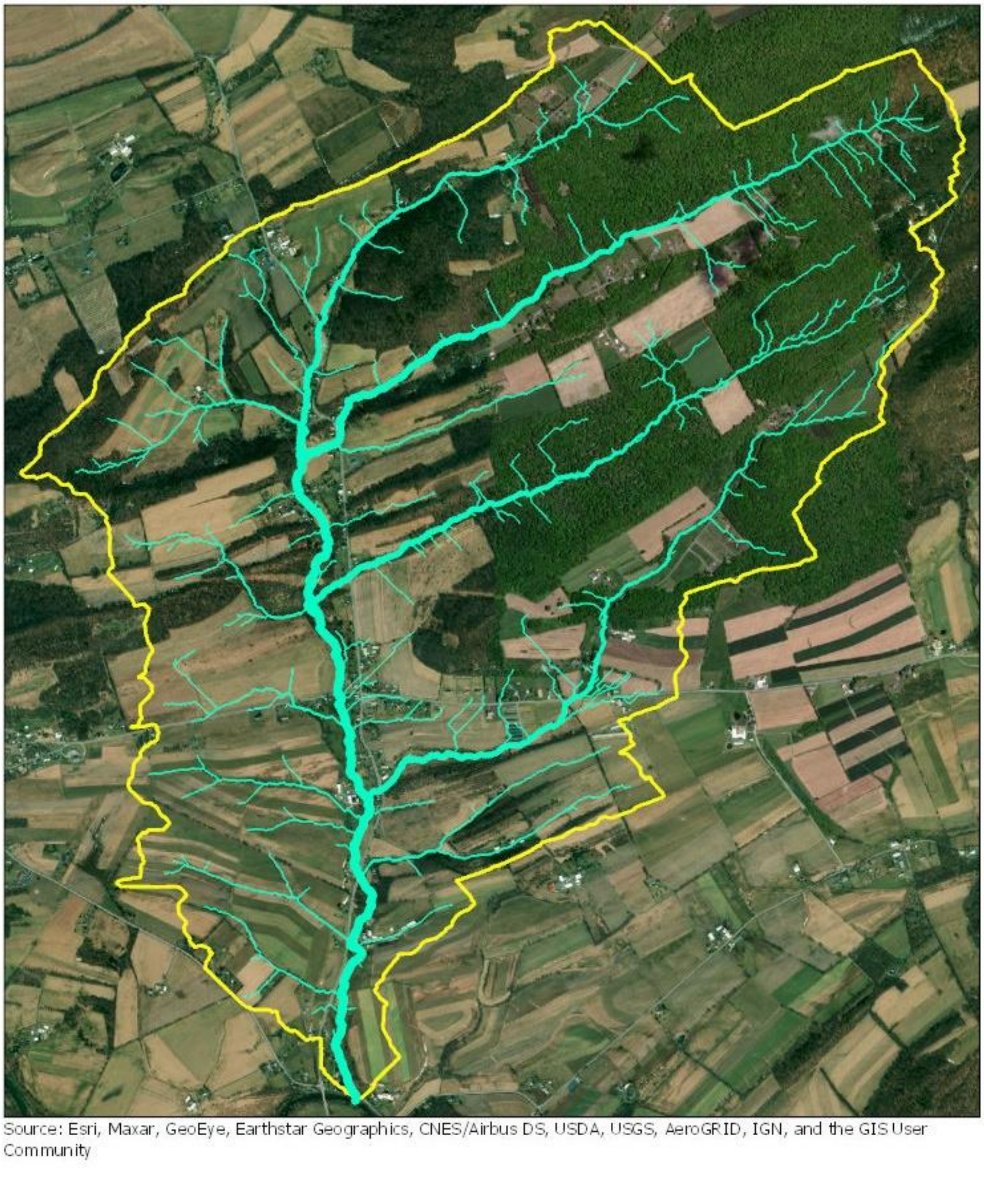
According to CAST's cost estimates for Pennsylvania, the cost of forested riparian buffer is substantially higher if livestock exclusion fencing is necessary. If implemented as proposed in Figure 15, exclusion fencing would be necessary about a quarter of the time. Without fencing, riparian buffers are expected to have a capital cost of $4,062.42 per acre, so, for the 69 acres of forested buffers proposed, the capital cost is expected to be $281,119 (Table 13). For forested buffers with exclusion fencing, the capital cost is expected to be $7,216.47 per acre, so for the 26 acres proposed the total capital cost is expected to be $186,185.

If the cost of the land is included, the total estimated capital + land cost for all the proposed buffers is $614,864. With a total annualized cost of $0.24 per pound of sediment removed per year, conventional forested buffers without fencing appear to be moderately cost effective (Table 13, Figure 16), even with very conservative assumptions of sediment removal. In contrast, buffers where fencing is needed are moderately expensive, at around $0.49 per pound of sediment removed per year (Table 13, Figure 16).

Precision Grass Filter Strips

As mentioned previously, CAST derived methodology for calculating the effectiveness of riparian buffers was purposely very conservative to account for: lack of knowledge of how much sediment communicates to any given buffer and the possibilities of concentrated flowpaths and saturation of filtration effectiveness. Rather than using very conservative crediting to account for these uncertainties, it was sought to directly address these concerns by strategically placing buffers where they would intercept the most agricultural runoff and design them so they would be effective at sediment removal (see Dosskey et al. 2005, Allenby and Burke 2012, Holden et al. 2013).

To determine the locations where buffers may intercept the most storm runoff/sediment loads, USGS Digital Elevation Models (USGS 2020) were analyzed using the TauDEM Version 5 toolkit in ArcGISPro. Briefly, the combined DEMs were clipped to the general area of the Baken Creek Watershed, and then the "Pit Remove", "D8 Flow Direction", "D8 Contributing Area", "Grid Network" and "Stream Definition by Threshold" tools were used to create a drainage network based on an accumulated stream source grid cell threshold value of 10,000. Different thresholds were explored in a similar prior analysis, but this value was chosen as sufficient for displaying the major drainageways without overwhelming their visualization with too much detail. The “D8 Contributing Area” tool was used to delineate the Baken Creek Watershed at a delineation point placed near the mouth with Shermans Creek. Then the “Stream Definition by Threshold” tool, again with a threshold value of 10,000, was used to define drainageways within the delineated watershed. Then the “Stream Reach and Watershed” tool was used to create a shapefile of the watershed’s drainage networks. See Figure 17. The “Watershed Grid to Shapefile” tool was used to help create a shapefile of the DEM delineated watershed. The outline of the watershed was converted to a simple polygon shapefile using ArcGISPro (Figure 17).



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

Figure 17. Drainage networks within the Baken Creek Watershed. Drainage networks were mapped using a USGS Digital Elevation Model and the TauDEM toolkit in ArcGISPro. The drainage networks are shown in light blue.

As is obvious when comparing the drainageways to the assessed stream segments (Figure 18), these results confirm the presence of concentrated overland flowpaths. Therefore, riparian buffers in certain areas would intercept larger amounts of overland flow, whereas buffers established in other areas would filter virtually no upland runoff. To choose the areas that would be most important for buffering, it was sought to define the key overland drainagesheds that drained the greatest amount of agricultural lands. Key drainagesheds were then delineated using the aforementioned TauDEM tools at outlet points near where main drainagelines entered the stream (Figure 18). Additional shapefile editing was done in ArcGISPro to create simple outline polygons.

To determine the sediment load associated with these drainagesheds, the proportion of land uses within each drainageshed were estimated using CDL 2020. These proportions were then grouped into Model My Watershed input classes per Table 6, and then multiplied by the total area of the drainageshed reported by Model My Watershed to produce land area estimates. These areas were then multiplied by the landcover loading rates in the BMP spreadsheet tool provided by Model My Watershed. Estimated sediment loads for each key drainageshed labeled in Figures 18 and 19 are reported in Table 14. Approximately one quarter of the Baken Creek Watershed's total sediment load appears to derive from these key drainagesheds, and thus pass through the six outlets (delineation points) shown in Figure 19.

Simply establishing riparian buffers along the flowing stream at the outlet of the drainagesheds may be ineffective because large amounts of sediment and flow could overwhelm very small areas of buffers (Dosskey et al. 2002 and personal observations). Thus, to provide adequate area to buffer these drainagesheds, it was proposed to extend buffers up the main flowline of each key drainageway (Figures 18 and 19).

Because these drainage lines pass through agricultural fields, establishing forested buffers, though preferable for wildlife habitat, would likely be unacceptable to farmers. Thus, it was proposed to use tall grass buffers instead. Such grass lined waterways are a commonly used BMP, and the CAST Expert Panel Report (See Belt et al. 2014) indicates that grass buffers may be as effective as forested buffers for sediment removal.

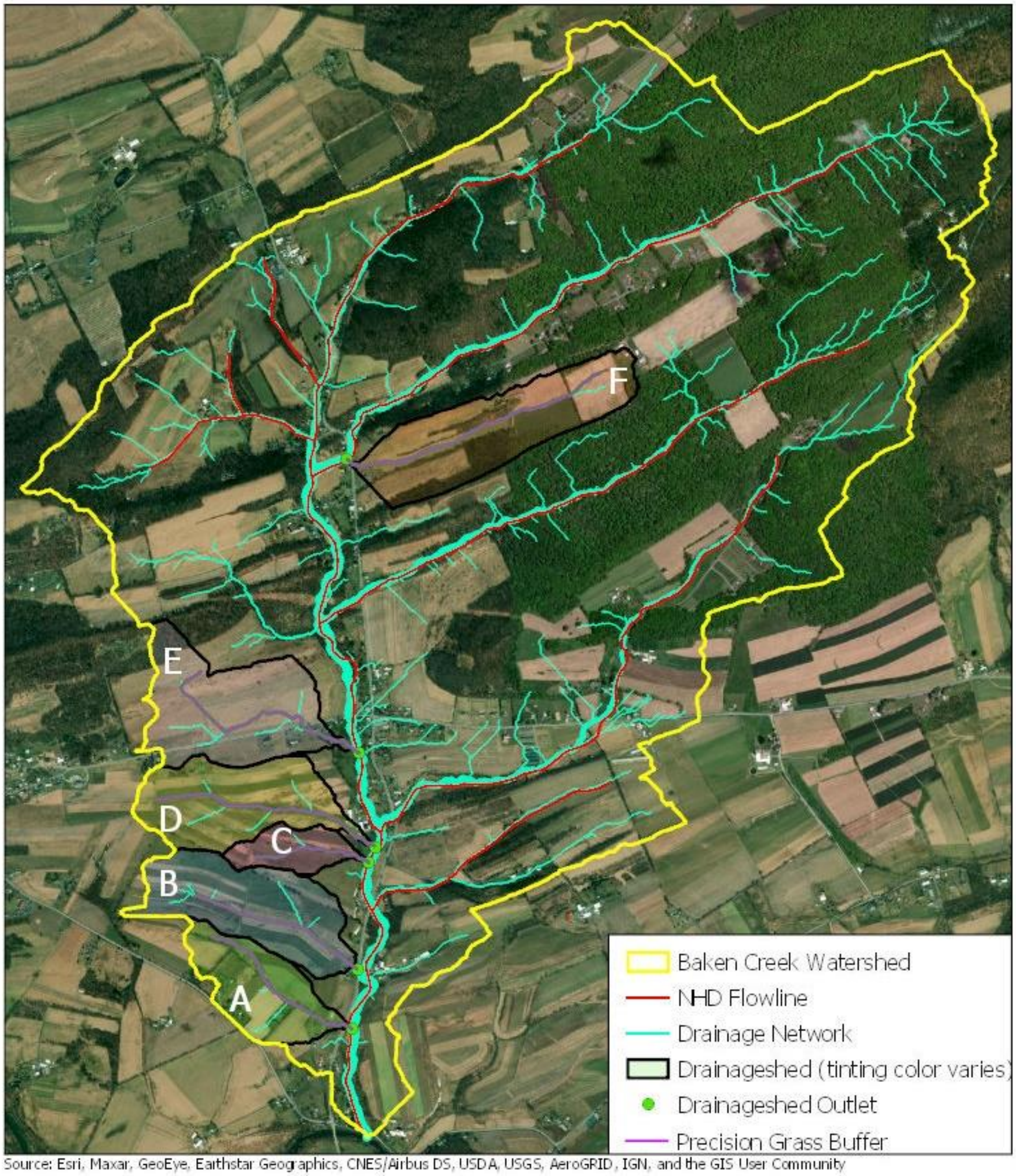
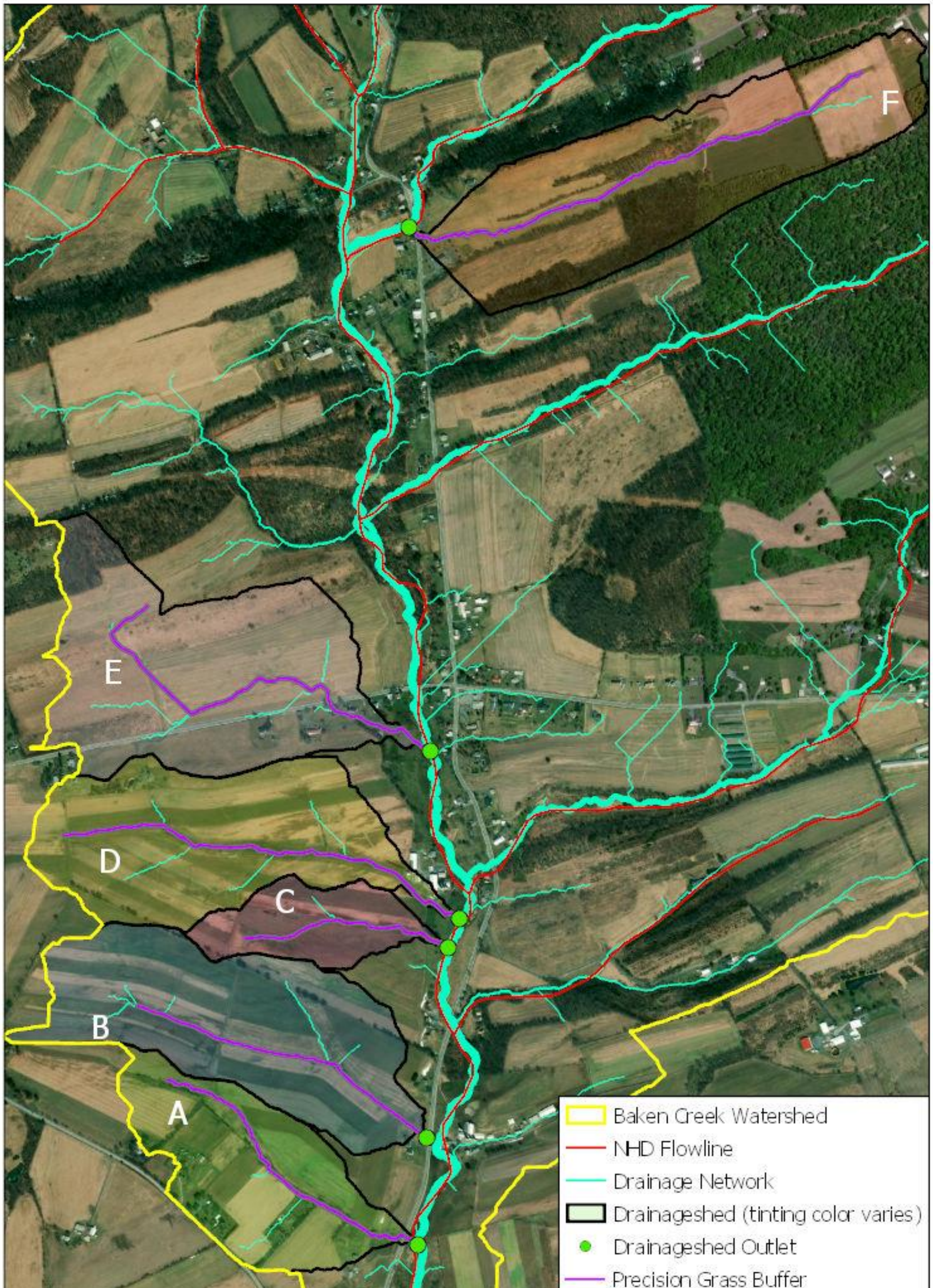


Figure 18. Key drainagesheds with proposed precision grass buffers. The green dots show the outlet of the drainageshed near where it empties into a regularly flowing channel. Because key drainagesheds were chosen to be areas that drained a large amount of agricultural lands, it is estimated that approximately one-quarter of the subwatershed's sediment load gets into the stream through these six outlets. Each precision buffer would be comprised of a dense, tall grass mixture within five meters (16.4 ft) of either side of the main drainage flowline. The letter labels correspond to the labels in Table 14.



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

Figure 19. Key drainagesheds with proposed precision grass buffers (closeup of Figure 18).

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Table 14. Contribution of sediment from each drainageshed to the watershed total and predicted % sediment removal by the 5-m wide precision buffers for the 5-yr storm. Note: drainageshed labels correspond to labels in Figures 18 and 19.

Drainageshed	acres	Contribution to watershed total mean, lbs/yr	Reductions for the 5yr storm %	lbs/yr
A	52.1	46,147	90%	41,440
B	76.8	70,130	77%	53,860
C	22.5	24,242	96%	23,321
D	72.9	59,872	86%	51,490
E	89.2	72,705	83%	59,982
F	93.7	38,644	90%	34,587
	Total:	**311,741**	**Total:**	**264,680**

Note: % reduction corresponds to % sediment reduction due to retention in the buffer during the 5-yr storm. The lbs/yr reductions were calculated by simply multiplying the % reduction for 5yr storm by the average annual sediment contribution of each drainageshed to the subwatershed total per Model My Watershed and its BMP spreadsheet tool.

In order to design and credit these buffers for sediment removal, a rigorous, scientifically-justifiable approach was sought. Ultimately the VFSMOD program was chosen because it was a freely-available mechanistic model designed to estimate sediment and other pollutant removal from grass buffers based on site specific conditions. Further, this model has been the subject of numerous peer-reviewed scientific publications and it has been validated under experimental conditions.

Using user defined parameters, VFSMOD simulates storm events, generates landscape runoff and sediment loads, and estimates sediment retention versus export in grass filter strips. Since the model cannot accommodate complex site geometry, the total non-buffer land area of the drainageshed was assumed to be a uniform rectangle that drained to a rectangular 5m (or 16.4 ft) wide grass buffer that was twice as long (to account for two sides) as the purple strips shown in Figures 18 and 19. To be conservative, simulations were conducted using the five-year storms for this region of Pennsylvania: 91.6 mm in 24 hours (PENNDOT 2010). The buffer was assumed to have uniform slope and be comprised of a dense grass mixture. See Appendix G for VFSMOD parameter inputs and further details on how site geometry was simplified.

According to the VFSMOD output, the proposed vegetated filter strips were predicted to remove most of the sediment during the 5-year storm in all cases. While they would perform even better during the 1-yr storm, it was decided to be very conservative and base claimed reductions on the 5-yr storm. Thus, % reductions during the 5-year storm were multiplied by the drainageshed's contribution to the overall annual average sediment load (Table 14). Another reason to believe these results are conservative is that the estimated amount of sediment getting through these buffers is really just sediment reaching the center-line of the drainageway. To actually get to the stream this sediment would have to flow down through the buffer and reach the drainageshed outlet. Filtration in this flow direction was not even accounted for. This likely compensates for one reason the buffers might not perform as well as expected: the fact that additional concentrated flowpaths feed into the main drainageline and perhaps overwhelm the buffers at certain points. Note that if this is the case, the buffer would be underwhelmed at other points.

Note that preliminary modelling was also conducted using 10m wide buffers. However, since the narrower buffers were determined to be so effective, they are being prescribed herein to increase the likelihood of adoption by farmers.

Using strategically placed buffers and crediting them with realistic methodology suggests they may be the most effective BMP opportunity for sediment removed (Table 13, Figure 16). If implemented as proposed, these filter strips would only occupy only 13 acres, or about 1% of current agricultural lands. Yet these buffers would be conservatively estimated to remove more than a quarter million pounds of sediment per year (Table 12), which is more than a fifth of watershed's annual sediment load.

According to CAST's cost estimates for Pennsylvania, grass buffers/filter strips are expected to have a capital cost of $899.15 per acre, so, for the 13 acres proposed, the total capital cost is expected to be $12,018 (Table 13). If the cost of the land is also included, the total cost would be about $35,677. There was also an annual operation and maintenance cost of $35.97 per acre. Given the high amount of predicted sediment removal, these filter strips are predicted to be the most cost effective physical (as opposed to practice) BMP, with a total annualized cost of about 1 cent per pound of sediment removed per year (Table 13, Figure 16).

For tracking purposes, the following credit can be claimed for fully implementing the 5m wide (each side) precision grass filter strips as shown in Figures 18 and 19:

Sediment reduction credit for installing 5m wide tall grass buffers on each side of the drainagelines as shown in Figures 18 and 19.

Drainageshed	Length (ft)	lbs/yr rduction no E&S Plan	lbs/yr with E&S Plan
A	760	41,440	31,080
B	823	53,860	40,395
C	512	23,321	17,491
D	1043	51,490	38,617
E	1050	59,982	44,986
F	1221	34,587	25,940

Note that deviations from the configurations proposed herein will require additional modelling to calculate appropriate reductions.

Note that two crediting options are provided to solve a logical problem, the fact that implementation of agricultural erosion and sedimentation plans would already be estimated to reduce cropland loading by 25%, so when combined with the high percent reductions from filter strips reported in Table 14, calculated reductions for a drainageshed could exceed 100%. A simple solution to this “double counting” problem was to reduce each drainageshed’s sediment load contribution to the watershed total (see Table 14) by 25% before applying the filtration reduction in Table 14. Note that this is conservative because an erosion and sedimentation plans’ reduction of inputs to the buffer would likely result in a higher filtration efficiency by the buffer, and this was not even accounted for. Both crediting options are provided different purposes. The uncorrected numbers are partially used in Table 12, relating to BMP opportunities; as well as Tables 13 and 15 and Figure 16 which relate to costs, since these tables and figure are important to comparing the relative effectiveness and costs of BMPs. However, only the corrected figures are used in the forthcoming “Schedule and Milestones” section, since it is proposed to implement agricultural erosion and sedimentation plans first.

Streambank Stabilization/Stream Restoration

Substantial streambank erosion was observed within some areas of the Baken Creek Watershed (Figure 4). Based on site observations and examination of satellite imagery, the length of the NHD flowlines with obvious bank erosion problems was estimated to be 7,182 feet (Figure 15). It was conservatively assumed that streambanks in these areas loaded sediment at ten-times the rate as other areas.

This being the case, the normal erosion rate (X) was calculated as follows:

> (ft of flowlines with normal banks)(X) + (ft of flowlines with degraded banks)(10)(X) = total streambank erosion

Therefore, for the Baken Creek Watershed:

> (48,772 ft)(X) + (7,182 ft)(10X) = 148,154 lbs/yr

Thus, the normal streambank sediment loading rate was calculated to be 1.23 lbs/(ft*yr), in which case the credit given for stabilizing the eroding reaches was calculated to be 10X or 12.3 lbs/(ft*yr). In reality, site to site differences in streambank erosion rates are highly variable and actual site measurements could be used to justify higher or lower credit claims.

Using this new methodology, stabilization of the proposed 7,182 feet of streams with suspected degrading banks would reduce sediment loading by 88,267 lbs/yr (Table 12). Most of the proposed stabilization sites were observed from a distance during site visits, so further detailed inspection should be done to choose the most important sites for streambank stabilization.

For the purposes of calculating the costs associated with streambank stabilization, it was assumed that simpler stabilization structures would be used rather than more complex comprehensive stream restoration methods that are often used when there is a trout population of concern. Such simple restoration utilizing general permit approved structures and only light equipment (S. McAdams, Trout Unlimited personal communication) is estimated to cost approximately $75 per foot (Table 13). Thus, at about $0.49 per pound of sediment removed per year (Table 13), basic stabilization projects appear to be moderately expensive, but may be used anyways, at least in the most severe cases, for the benefit of aquatic habitat and because of its popularity with landowners.

For tracking purposes, reductions associated with streambank stabilization/stream restoration may be calculated as:

Feet of streambank stabilized * estimated annual erosion rate per foot

Where estimated annual erosion rate per foot is either:

the modeled value of 12.3 lbs/ft*yr

or, an empirically derived value based on site specific measurements

Grazing Land Management

A target of 15 acres was set for grazing land management programs. According to Chesapeake Bay Program (2018), such programs are predicted to reduce sediment loading by 30% per acre in cattle pastures (See Appendix F). If implemented as proposed, grazing land management would then reduce sediment loading by a very modest 1,706 lbs/yr (Table 12). With a total annualized cost of $0.72 per pound of sediment removed per year (Table 13, Figure 16), this BMP is very expensive. Thus, it may be sensical to choose more cost effective BMPs, except perhaps where this BMP is necessary to address severely degraded pasturelands or a localized water quality problem.

For tracking purposes, reductions associated with grazing land management may be calculated as:

lb/yr reduction = acres with implemented grazing land management plan * hay/pasture land loading rate * reduction coefficient

where: hay/pasture land loading rate = 379 lbs/(ac*yr)

reduction coefficient = 0.3

Considerations of Cost Effectiveness in Implementation and Funding Sources

Note that the aforementioned analysis sought to identify BMP *opportunities*, and the total reduction associated with them (770,749 lbs/yr) substantially exceeded the estimated reduction needed to achieve water quality standards (652,217 lbs/yr). Showing more BMP opportunities than necessary is important, however, because implementation of most requires the voluntary cooperation of landowners. Plus, it allows for the selection of the most cost effective BMPs. While the total capital cost of all BMP opportunities was about one million dollars (Table 13), Table 15 shows how the reduction goal could be met for about a $566,000 capital cost.

Table 15. Reduced estimates of project costs that take into account selective implementation based on cost effectiveness and assumptions of landowner willingness. All costs are reported as dollars.

BMP	Unit	Lifespan in years	Capital Cost per unit	Annual O&M Cost per unit	One Time Opportunity Cost per unit (land cost)	Total Annualized Cost per unit	Units Proposed	Total Capital Cost	Total Capital + Land Cost	Total Annualized Cost	Total Annualized Cost per pound of sediment per year	Total Reductions lbs/yr	Relative to table Table 13...
Streambank Stabilization[1]	ft	20	74.75	0.00	0.00	6.00	3,000	224,240	224,240	17,993	0.488	36,900	assume 3,000 feet
Erosion and Sedimentation Plans[2]	ac	10	15.00	0.00	0.00	1.94	1,225	18,368	18,368	2,376	0.011	212,944	assume full 95%
~~Cover Crops[3]~~	~~ac~~	~~1~~	~~0.00~~	~~75.50~~	~~0.00~~	~~75.50~~	~~75~~	~~0~~	~~0~~	~~5,663~~	~~0.681~~	0	assume none
Conservation Tillage[3]	ac	1	0.00	0.00	0.00	0.00	225	0	0	0	0.000	102,257	assume full
~~Grazing Land Management[3]~~	~~ac~~	~~1~~	~~0.00~~	~~81.27~~	~~0.00~~	~~81.27~~	~~15~~	~~0~~	~~0~~	~~1,219~~	~~0.715~~	0	assume none
Forested Riparian Buffer w/o Fence[3]	ac	40	4,062.42	81.25	1,770.23	406.51	46	187,413	269,080	18,754	0.237	78,966	assume 2/3
Forested Buffer w/Fence[3]	ac	30	7,216.47	238.95	971.31	756.96	17	124,123	140,830	13,020	0.485	26,869	assume 2/3
Grass Filter Strips[3]	ac	10	899.15	35.97	1,770.23	240.93	13	12,018	35,677	3,220	0.012	198,510	assume full
							sum	***566,162***	***688,195***	***55,362***		**656,446**	> 652,217 lbs/yr target

Where necessary, costs were annualized using CAST methodology. See https://cast.chesapeakebay.net/Documentation/CostProfiles

[1] Current CAST methodology reports a much higher cost for "Non Urban Stream Restoration Protocol". However, per personal communication with Shaun McAdams of Trout Unlimited, smaller projects using general permit type structures and restoration designs provided by government agencies tend to be much cheaper, approximately $50 per foot. To be conservative, $63.56 per foot was used in accordance to the second most recent CAST methodology for Pennsylvania. This value however was multiplied by 1.176 to adjust for inflation from April 2010 to April 2020 per the CPI inflation calculator provided at https://data.bls.gov/cgi-bin/cpicalc.pl.

[2]Based in internal discussions at DEP, the most current CAST estimate of $24.91 per year for "Soil Conservation and Water Quality Plans" does not seem to reflect typical costs and longevity for agricultural erosion and sedimentation plans in Pennsylvania. Thus the prior CAST cost estimate was used.

[3]Based on most recent CAST methodology, except that cover crops and grazing land management were considered annual O&M costs rather than captial costs due to their 1yr lifespans

Grass filter strips reductions reported in the final numeric column were based on the assumption that agricultural erosion and sedimentation plans were already in place.

In this analysis, full implementation of agricultural erosion and sedimentation plans, conservation tillage, and grass filter strips relative to the opportunities identified in Table 12 was assumed due to cost effectiveness and suspected landowner willingness. Two-thirds implementation of riparian buffers was assumed to account for suspected limitations on landowner willingness. Only 3,000 feet of streambank stabilization was proposed due to the high costs associated with this BMP, while no implementation of cover crops or grazing land management was assumed due to the very high costs associated with these BMPs per pound of sediment removed per year.

To be clear, the primary purpose of this analysis was not to recommend against particular BMPs, but rather to show how reductions could be achieved cost effectively. In fact, there may be good reason to implement BMPs that are less cost effective. For instance, while not the most cost effective BMP for sediment removal, forested riparian buffers are very important to stream health for factors beyond just sediment removal, such as the providing habitat and nutrition for aquatic organisms, filtering out other pollutants, providing shade and moderating stream temperature, etc. Thus, they should be implemented wherever possible. Furthermore, while stream bank stabilization is expensive, its use would likely have positive habitat implications as well and this BMP tends to be popular with landowners. And, cover crops may at least provide some benefit in situations where a farmer is unwilling or unable to use conservation tillage.

Since it is recommended to overshoot the reduction goal as an additional margin of safety factor, the project can be expected to have a total capital cost somewhere between about a half a million (Table 15) to a million dollars (Table 13).

This project seeks funding under Section 319 of the Clean Water Act which is specifically allocated for addressing nonpoint source pollution. In addition to use of 319 funds, BMPs may also be paid for as described in the following.

Since agricultural erosion and sedimentation plans are the responsibility of the individual agricultural operator/landowner, they would be responsible for expenses associated with them. In some cases farmers may be able to write their own plans. Where a consultant is utilized, funding assistance may be available from USDA-NRCS, the Resource Enhancement and Protection (REAP) Tax Credit, and DEP's Agricultural Planning Reimbursement Program for Pennsylvania's Chesapeake Bay watershed.

There are many ways to fund the establishment of streamside buffers. In fact, there is an entire document describing funding opportunities. See "A Landowner's Guide to Conservation Buffer Incentive Programs in Pennsylvania" (Talbert 2009). In short, there are various programs that range from loan programs that provide funding assistance for designing and implementing buffers, all the way to programs that pay landowners more than the county's average agricultural land rental rate for the land use associated with the buffers. Specific sources of such funding include the USDA Conservation Reserve Program (CRP), USDA-NRCS's Wetlands Reserve Program, Pennsylvania's Conservation Reserve Enhancement Program (CREP), USDA Environmental Quality Incentives Program (EQIP), USDA's Wildlife Habitat Incentives Program (WHIP), PA DEP's Chesapeake Bay Financial Assistance Funding Program (FAFP), Chesapeake Bay Foundation/Ducks Unlimited Habitat Stewardship Program, PA DEP's Stream Bank Fencing Program, US Fish and Wildlife Service's Partners for Fish and Wildlife Program, the State Treasury's AgriLink loan program, Pennsylvania's Growing Greener program, USEPA's 319 program, and the State Conservation Commission's Nutrient Management Plan Implementation Grant Program (NMPIGP). PA DCNR also gives grants for the establishment of riparian buffers. Given the complexities of potential funding sources, the County Conservation District should discern on a case by case basis the most appropriate funding options.

With regard to agriculture specific BMPs such as, cover crops, conservation tillage, grazing land management, grass filter strips and streambank fencing there may be numerous ways to fund such projects, especially through various programs administered through USDA's Natural Resources Conservation service. See https://www.nrcs.usda.gov/wps/portal/nrcs/main/pa/programs/financial/. Pennsylvania's Growing Greener program may also fund agricultural BMPs and farmers and businesses who install BMPs may be eligible for REAP tax credits.

Stream restoration specific BMPs may be paid for through various funding sources, such as Pennsylvania's Growing Greener program and the National Fish and Wildlife Foundation. In the past, organizations such as the Pennsylvania Fish and Boat Commission and the US Fish and Wildlife service has supported stream restoration projects, for instance by providing restoration design work.

The above paragraphs only list some of the major funding opportunities for BMP implementation as part of this project. Consultation with groups such as USDA-NRCS, and DEP grant administrators should be done on a case by case basis for choosing the best way to fund specific BMPs.

Stakeholder Roles

Trienniel Update Report

It is proposed that DEP, in coordination with the Perry County Conservation District (Figure 20), prepare a brief triennial (every 3 year) report over the nine-year project period (Figure 21) that, among other things, reports progress towards prescribed pollutant reduction goals, improvements in water quality, and any other updates on key activities. Furthermore, a public meeting is planned after the first two triennial reports to review the report, update the public, and encourage additional participation (Figure 20). It is proposed that the triennial reports be shared with EPA's TMDL and 319 sections.

Education

With the exception of the Triennial Report, which would be a joint effort with DEP, the Perry County Conservation District would be responsible for education. At the onset of the project, mailings, phone calls, and door-to door visits with landowners should be used to notify landowners of the project and to encourage farmers to adopt the best management practices called for in this document. Depending on public interest, a public meeting could also be held around the time of project initiation. After this, it is planned at a minimum to have mailings to landowners, a public report, and a public meeting on a triennial basis to keep the public informed and involved in the project (Figure 21). Perry County would cover necessary expenses associated with the aforementioned activities with their own funding.

In addition to these activities, it is proposed to construct signs informing the public of significant restoration sites in the watershed as well as more general educational signs. These signs would be paid for with grant money, with an estimated cost perhaps of $5,000 total over the life of the project. While there are no frequented parks or public lands within the Baken Creek Watershed itself, the more general educational signs could be placed within the Shermans Creek Watershed at the parking area for Hawk Rock/Duncannon Watershed Lands, the nearby Mark Henry Memorial park in Landisburg, Fowlers Hollow State Park, or Tuscarora State Forest Lands.

Implementing BMPs

The Perry County Conservation District would ultimately be responsible for implementation of most of the BMPs called for in this plan (Figure 20). They would be responsible for day to day logistics, such as applying for funds, landowner outreach, acquiring site designs, hiring contractors, and assuring that work is done according to schedule. The Perry County Conservation district may partner with other organizations such as USDA's Natural Resources Conservation Service (NRCS), who can offer a great deal of expertise with agricultural BMPs, as well as the US Fish and Wildlife Service and the Pennsylvania Fish and Boat Commission who may assist with the development of stream restoration/banks stabilization designs. DEP would partner with the County Conservation District for confirming that agricultural operations were operating in accordance with legally-required erosion and sedimentation plans.

Prescription and Tracking of Pollutant Reductions

The present document, largely drafted by the DEP, establishes a quantitative sediment reduction goal and includes an analysis of hypothetical BMPs that are estimated to achieve the prescribed reduction. Furthermore, this document provides simple ways to calculate the credit received for implementing most BMPs. DEP's TMDL section plans on being involved over the life of the project to aid in additional modelling and the calculation of BMP reductions. It is proposed that the Department, in coordination with the county conservation district, prepare a brief triennial update report over the nine-year project period that, among other things, reports progress towards prescribed pollutant reduction goals (Figure 20). It will be important therefore for stakeholders and cooperating organizations to keep accurate records of all BMPs and report them to DEP when possible for tracking in the triennial report. It is understood however that careful consideration must be given to landowner confidentiality agreements.

Assessment

DEP is responsible for assessing and monitoring The Commonwealth's waterways. Thus, even before the inception of this project, DEP had already assessed the Baken Creek Watershed using benthic macroinvertebrates and physical habitat screening to determine the impairment status. And, The Department would continue to assess the watershed even if this project did not go forward. However, given the interest in this project, it is expected that Baken Creek will be the focus of additional assessment by The Department. These proposed measures will be detailed in the "Effectiveness Monitoring and Evaluation of Progress Section". While DEP would be responsible for most of the macroinvertebrate, fish and streambed sediment sampling, the Perry County Conservation District would be responsible for installing and maintaining the turbidity, temperature and conductivity monitoring stations (see "Effectiveness Monitoring and Evaluation of Progress" section below).

Disclaimer

It must be stated up front that the administrative and BMP implementation goals in this document cannot be firm commitments because among other things: 1) DEP and the Perry County Conservation District's ability to commit to the project may change with changing personnel, resources, funding and management goals and 2) most of the proposed BMPs require the voluntary consent of land owners. Since the bulk of the grant monies are allocated on a project by project basis, the funding organizations may choose to stop funding projects proposed in this document if satisfactory progress is not made. It should also be noted that even if implemented BMPs do not allow for the full amelioration of all impairments in the Baken Creek Watershed, water quality will almost assuredly improve both in this watershed and in downstream areas. If it becomes clear that the impairments will not be reversed as a result of this project, then a TMDL will be required.

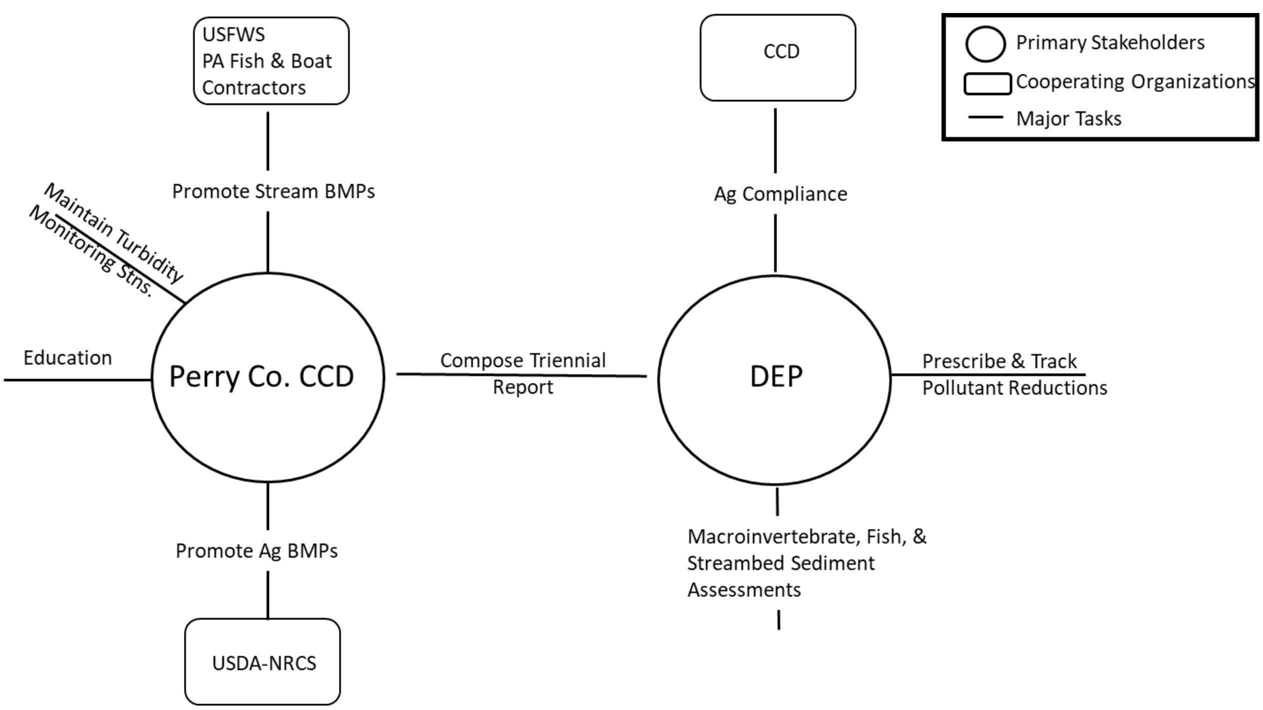


Figure 20. Proposed organizational structure for the Baken Creek Watershed Alternate Restoration Plan. DEP = Pennsylvania Department of Environmental Protection, CCD = Perry County Conservation District, USDA-NRCS = United States Department of Agriculture Natural Resources Conservation Service, SRBC = Susquehanna River Basin Commission, USFWS = United States Fish and Wildlife Service. The Perry County Conservation District and PA DEP would be the primary stakeholders but would require cooperation from landowners and assistance from cooperating organizations for completion of the major tasks shown above.

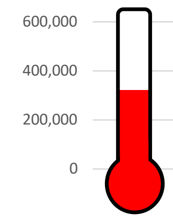
Schedule and Milestones

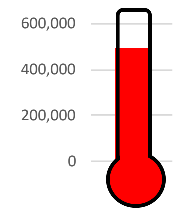
Figure 21 details a schedule of major goals and milestones for the restoration plan. The basic organizational unit of the schedule is a 3-year period after which there is proposed to be a “Triennial Report” that summarizes: progress made to date, updated assessment information, and makes needed adjustments to future goals. Depending on stakeholder interest, a public meeting may also be held at the onset of the project, as well as after preparation of the first two triennial reports. Such meetings would be used to solicit more stakeholder involvement and review the triennial reports. A public mailing would likely be used in advance of the meetings to solicit public involvement. The total active length of the project is anticipated to be nine years, plus additional assessment samplings around year twelve.

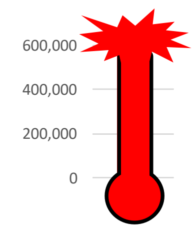
A subset of BMP opportunities that together are sufficient to satisfy the prescribed sediment reduction goal are approximately evenly divided among the three triennial periods (Figure 21). However, 95% implementation of agricultural erosion and sedimentation plans are projected for the first three years, as these are a current legal requirement and there is an effort underway to evaluate for compliance as part of the Chesapeake Bay Watershed Implementation Plan. It is expected that such compliance evaluation will involve site visits to farms and will be a joint effort between DEP and the Perry Conservation District. The need for more conservation tillage could then be considered during the second two triennial periods based on what is discovered in the agricultural erosion and sedimentation plans. Otherwise, the major BMPs of precision grass filter strips, streambank stabilization, and forested buffers were distributed approximately evenly across the three triennial periods. Note that while streambank stabilization was not considered a highly cost-effective BMP per Figure 16, it was included as a scheduled goal due to its popularity with landowners and its positive effects on stream habitat.

It must be clearly stated, however, that there will likely be substantial deviations from the schedule. Specific BMPs would be implemented as opportunity allows and there may be other BMPs that are not even on the schedule. These “goals” presented herein are not intended to limit other opportunities. Also, from prior experience, landowner involvement may ramp up over time as they see examples of successful projects on neighboring properties. But, in any case, the BMP implementation goals as well as the schedule presented herein cannot be firm commitments, as explained in the previous section.

Timeline	Administrative Goal	BMP Target Goal	Responsible Party	Sediment reductions (lbs/yr)
2022	*Approval of Restoration Plan*		PA DEP and US EPA	
	Meeting (if sufficient public interest)		PA DEP and Perry Co. CCD	
	Macroinvertebrate, Fish and Sediment Sampling. Install turbidity monitoritoring stns.		PA DEP & Perry Co. CCD	
		95% Implement Ag. Erosion & Sediment. Plans	PA DEP and Perry Co. CCD	212,944
		1,000 feet streambank stabilization	Perry Co. CCD	12,300
		4.5 acres precision grass filter strips[1]	Perry Co. CCD	66,170
		21.3 acres forested buffers	Perry Co. CCD	35,278
2025	*First Triennial Report and Meeting*		PA DEP and Perry Co. CCD	
	Macroinvertebrate, Fish and Sediment Sampling		PA DEP	
		1,000 feet streambank stabilization	Perry Co. CCD	12,300
		4.5 acres precision grass filter strips[1]	Perry Co. CCD	66,170
		21.3 acres forested buffers	Perry Co. CCD	35,278
		112.5 acres more conservation tillage	Perry Co. CCD	51,129
2028	*Second Triennial Report and Meeting*		PA DEP and Perry Co. CCD	
	Macroinvertebrate, Fish and Sediment Sampling		PA DEP	
		1,000 feet streambank stabilization	Perry Co. CCD	12,300
		4.5 acres precision grass filter strips[1]	Perry Co. CCD	66,170
		21.3 acres forested buffers	Perry Co. CCD	35,278
		112.5 acres more conservation tillage	Perry Co. CCD	51,129
2031	*Third Triennial Report*		PA DEP and Perry Co. CCD	
	Macroinvertebrate, Fish and Sediment Sampling		PA DEP	
2033	Macroinvertebrate, Fish and Sediment Sampling		PA DEP	







[1]Reductions for prescision grass filter strips used the corrected values that assumed prior agricultural erosion and sedimentation plan implementation.

Note-because most of these BMPs require the voluntary cooperation of the landowner; DEP priorities, personell and resources may change; and grant funds are allocated on a case by case basis, the above are "target goals" rather than firm commitments. Furthermore, other BMPs may be substituted in as opportunities arise. And, because potential reductions overshoot the target, failure to fully implement any of the BMPs listed above may still allow for the the pollutant reduction goal to be reached.

Figure 21. Proposed timeline of major goals. The thermometer graphs indicate progress towards the overall sediment reduction goal (lbs/yr) during the three main triennial periods. Note that only a subset of BMP opportunities were chosen as goals.

Effectiveness Monitoring and Evaluation of Progress

Evaluation of "progress" will include indicators of: whether the primary stakeholders (PA DEP and Perry County Conservation District) are making progress on required tasks, landowner commitment, BMP implementation, and assessments of: water quality, physical habitat and biotic communities. It is proposed to summarize such progress for each triennial report.

Indicators of task completion per the timeframe proposed in Figure 21 will include things such as whether Perry County Conservation District/DEP has confirmed agricultural erosion and sediment plan development, whether landowners have been contacted about implementation of voluntary BMPs, and whether sampling is being done. If it is clear by the second triennial report that these tasks are not being completed, a plan should be made to get the project back on track. If however there are substantial irreparable deviations from these tasks, the restoration plan approach should be abandoned in favor of TMDL development.

Sediment loading reductions associated with BMP implementation can be estimated using the methodology described in the "An Analysis of Possible BMPs" section. If at the time if the second triennial report it becomes clear that there are major irreparable problems such as: lack of progress towards the sediment reduction goals or failure in stakeholder involvement to the point that it is clear that there will be insufficient BMP implementation, the restoration plan approach should be abandoned in favor of TMDL development.

It is proposed to evaluate in-stream sediment pollution via both measurements of streambed sediment deposits as well as turbidity. Streambed sediment is proposed to be evaluated in accordance with the methodology discussed in the 2021 Hammer Creek Alternate Restoration Plan (see https://www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/tmdl/HammerCreekARP.pdf) Depending on access, it is hoped to collect such data within the reaches shown in Figure 22 at the onset of the project as well as approximately every three years over the expected duration of the project, and then again three years after the projected has ended. Furthermore, to explore for localized effects, this methodology may be used before and after BMP implementation at other yet to be determined restoration sites within the watershed. It is proposed to measure turbidity (in addition to conductivity and temperature) using the "EnviroDIY Mayfly Monitoring Station" methodology developed by the Stroud Water Research Center (see https://www.envirodiy.org/mayfly-sensor-station-manual/). These monitoring stations would estimate these parameters continuously at specified time intervals, and thus over varying weather and hydrograph conditions, thereby creating a rigorous dataset that may be used to determine whether BMPs are resulting in sediment reductions. It is proposed to install a monitoring station within the two proposed sampling regions shown in Figure 22. With an estimated cost of approximately $2,500 each, the total cost would be approximately $5,000 to be paid for with 319 Funding. An additional $5,000 is proposed to cover various expenses associated with installing, calibrating, repairing and keeping these units operational. These stations would be owned, operated and maintained by the Perry County Conservation District. Considering that there may be a lag time for benthic macroinvertebrate recolonization following restoration, or that other factors could continue to inhibit benthic communities once fine sediment loading has been reduced to an appropriate level, directly measuring fine sediment reductions will be important in demonstrating restoration progress.

The present aquatic life use impairments listed for the Baken Creek Watershed were based on macroinvertebrate sampling and descriptive physical habitat screening. Thus, the Baken Creek Watershed should continue to be evaluated for these attributes in accordance with DEP's most current protocols. Depending on resources, it is also proposed to add fish population sampling as well. The most current versions of these protocols, along with criteria for making assessments and delistings, are described in PA DEP's "Assessment Methodology for Rivers and Streams" (2018). It is suggested that macroinvertebrate sampling, physical habitat screening and fish population surveys be conducted somewhere within the study reaches shown in Figure 22. In addition to these major sites, such sampling may also occur at localized restoration sites. Since the most recent assessment samples were from 2013, it is suggested that new sampling should be conducted at the major sites around the time of project initiation in 2022. These major sites should continue to be sampled approximately every three years during the expected duration of the project, and then again three years after the project has ended to evaluate for impairment delistings (Figure 21).

A required element of the 319 plan is the setting of water quality improvement goals over the course of the project. This is difficult in the present study because the best method for demonstrating improvement would be via the collection of continuously monitored turbidity data. However, this requires expensive equipment that is proposed to be paid for with 319 funds. Thus, baseline data is currently lacking. Also, since measurements of sediment deposition in pools and riffles are time-consuming and require access to private property, those measurements are proposed to be made following formation of relationships with landowners. Nevertheless, we can speculate how these attributes might improve over the course of the project. The current watershed load is estimated to be 1,187,527 lbs/yr (Table 8) and it is proposed to reduce this load by 55%, or 656,446 lbs/yr (Table 15). Most of this reduction (about 28 of the 55% total) is proposed to be achieved via BMPs implemented in recent history or during the first three years. The second and third triennial periods each propose additional 14% reductions. Thus, it might be hypothesized that turbidity readings and streambed fines measurements would reduce by 28% then 14% and then 14% again over the course of the three triennial periods.

While these can serve as targeted expectations, we caution that there may be many reasons why measurements can show different rates of change. In addition to uncertainty in our modelling and BMP crediting, factors such as lack of good baseline data, environmental variability and lag times would likely confound these results. Consider that some BMPs, such as the implementation of erosion and sedimentation plans and use of conservation tillage are likely being adopted by farmers prior to the collection of baseline data, so the initial reductions may be lower than expected. Also, since the characteristics of individual storm events is a major driver of sediment loading, variability in sediment measurements is expected to be high and thus larger trends may only be elucidated with longer-term datasets. Also consider that it may take years for some BMPs to realize their maximum effectiveness. This especially true of new forested riparian buffer plantings. Also, where BMP implementation involves significant land disturbance, as in the case of stream restoration, a temporary increase in sediment loading may be expected.

Thus while "28%, 14% 14%" may serve as a hypothetical goal, the project would not necessarily be considered failing if these targets are not being achieved. Thus, each triennial report should consider such monitoring results in light of these expectations as well as estimated reductions associated with BMP implementation. For instance, if the BMP implementation targets are meeting expectations but sediment measurements seem far too low, it may be concluded that confounding factors such as lag times or environmental variability may explain the diminished response. If however, the lack of water quality improvement is consistent with major failures in achieving BMP implementation targets, then it should be considered whether the restoration plan should be abandoned in favor of a TMDL, or whether the plan should be amended to include actions to get the project back on track. The decision to continue with the restoration plan should take into consideration the likelihood that the problem may be corrected. For instance, if landowners have been reached out to multiple times that it is clear that they have little interest in voluntary cooperation, the plan should be abandoned in favor of a TMDL. However, if there appears to be a high degree of landowner interest, but a correctable factor such as the ability of the implementation organization to commit to the project is limiting progress, then other remedies, such as soliciting the participation of additional implementation partners could be considered. In the unlikely scenario that sampling indicates that the aquatic life use criteria improved to the point that the entire subwatershed is no longer impaired prior to the estimated completion date in 2031, a decision can be made to either: 1) end the project or 2) continue the project to overshoot prescribed reductions as a layer of protection and for the benefit of downstream aquatic resources.

It is expected that the earliest improvements will be noticed in physical habitat screening, sediment sampling and fish populations at the local sites of restoration projects and then further downstream as progress is made throughout the watershed. Based on prior experience, it is expected that benthic macroinvertebrate communities will take the longest time to improve. Since the sampling design includes both a site near the headwaters, as well as a site on the lower mainstem (Figure 22), it is possible that the upper watershed could be delisted as impaired should this occur before the entire watershed is delisted.

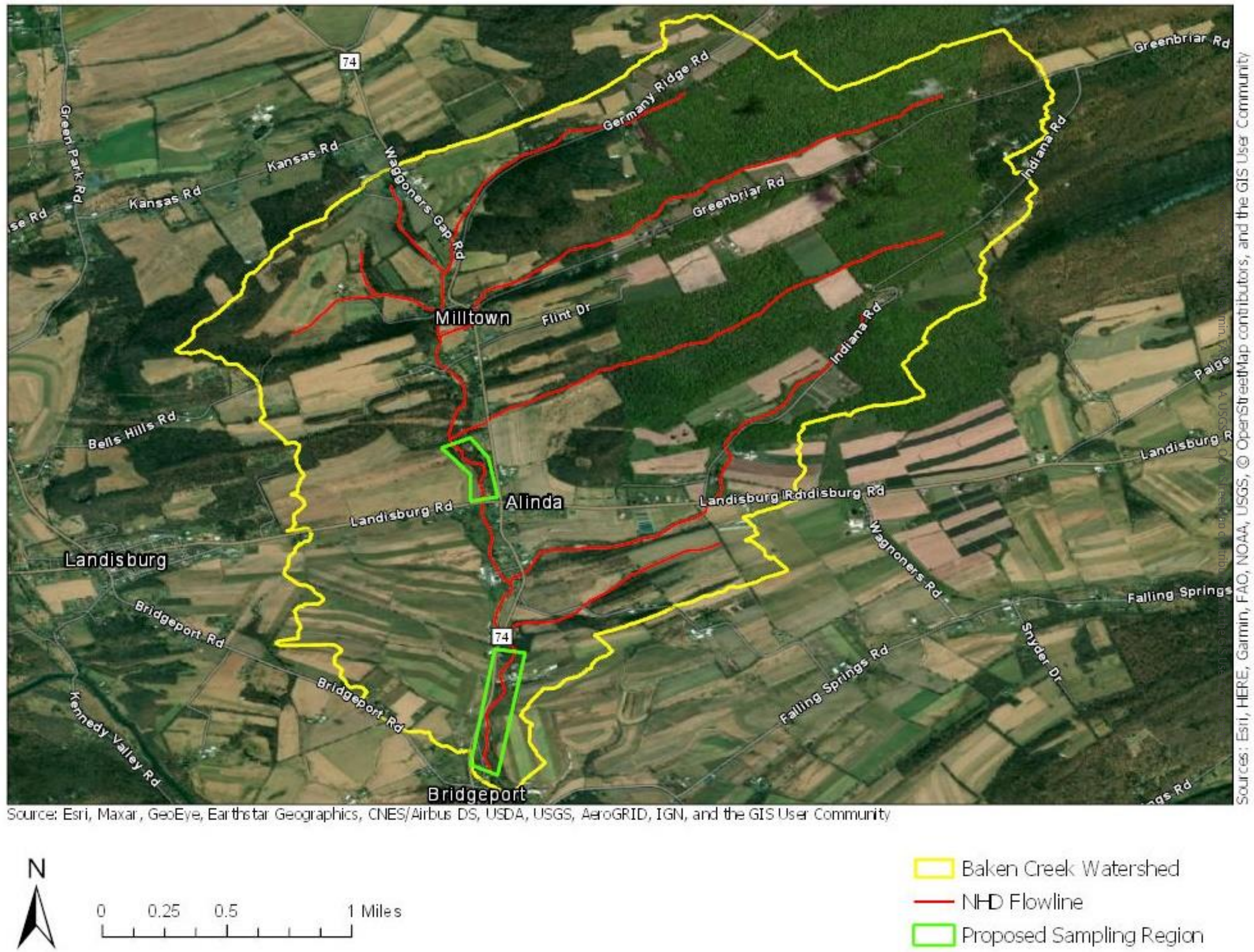


Figure 22. Proposed sampling reaches in the Baken Creek Watershed. The proposed regions are longer than necessary; ultimate site selection will depend on willingness of landowners to grant access. Depending on resources, it is proposed sample turbidity, sediment, benthic macroinvertebrates and fish within each of these two study reaches. Limited additional sampling focusing on streambed sediment may also take place at major BMP installation locations.

Summary

This document proposes a 50% reduction in sediment loading for the Baken Creek Watershed. To achieve this goal while maintaining a margin of safety and minor allowance for point sources, sediment loading from croplands should be reduced by 62% while loading from hay/pasture lands and streambanks should be reduced by 40% each. The present document proposes a nine-year restoration project to be administered jointly between the Perry County Conservation District and PA DEP, along with cooperation from landowners, and agencies such as the USDA's Natural Resources Conservation Service, the Pennsylvania Fish and Boat Commission, the Susquehanna River Basin Commission and the US Fish and Wildlife Service. Critical BMPs proposed herein include agricultural erosion and sedimentation plan implementation, use of conservation tillage, forested riparian buffers, and precision grass filter strips.

Public Participation

Public notice of the Alternative Restoration Plant will be published in the October 2, 2021 issue of the Pennsylvania Bulletin to foster public comment. A 30-day period will be provided for the submittal of comments. No public comments were received.

Citations

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Appendix A: Background on Stream Assessment Methodology

Integrated Water Quality Monitoring and Assessment Report, List 5, 303(d), Listing Process

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 2018 Assessment Methodology for Rivers and Stream, available at https://files.dep.state.pa.us/Water/Drinking%20Water%20and%20Facility%20Regulation/WaterQualityPortalFiles/Methodology/2015%20Methodology/Assessment_Book.pdf

Documentation of other historic methodologies are available upon request.

Assessment Methods:

Prior to developing TMDLs for specific waterbodies, there must be sufficient data available to assess which streams are impaired and should be listed 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 and found on List 5. Table A1. summarizes the changes to listing documents and assessment methods over time.

With guidance from EPA, the states have developed methods for assessing the waters within their respective jurisdictions. From 1996-2006, the primary method adopted by the Pennsylvania Department of Environmental Protection for evaluating waters found on the 303(d) lists (1998-2002) or in the Integrated Water Quality Monitoring and Assessment Report (2004-2006) was the Statewide Surface Waters Assessment Protocol (SSWAP). SSWAP was a modification of the EPA 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 land uses, 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 identified to the family level in the field.

The listings found in the Integrated Water Quality Monitoring and Assessment Reports from 2008 to present 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 land uses, 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 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 EPA Rapid Bioassessment Protocol III (RPB-III) and provides a more rigorous and consistent approach to assessing Pennsylvania's streams than the SSWAP.

After these surveys (SSWAP, 1998-2006 lists or ICE, 2008-present lists) were completed, the biologist determined the status of the stream segments. The decision was based on the performance of the segment using a series of biological metrics. If the stream segment was classified as impaired, it was then listed on the state's 303(d) List or presently the Integrated Water Quality Monitoring and Assessment Report 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 receives a separate and specific TMDL within that stream segment. Adjoining stream segments with the same source and cause listings are 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-Present	Integrated List	ICE

Integrated List= Integrated Water Quality Monitoring and Assessment Report
SSWAP= Statewide Surface Waters Assessment Protocol
ICE= Instream Comprehensive Evaluation Protocol

Justification of Mapping Changes to 303(d) Lists 1998 to Present

The following are excerpts from the Pennsylvania DEP Section 303(d) narratives that justify changes in listings between the 1996-2002 303(d) Lists and the 2004 to present Integrated Water Quality

Monitoring and Assessment Reports. The Section 303(d) listing process has undergone an evolution in Pennsylvania since the development of the 1996 list.

In the 1996 Section 303(d) narrative, strategies were outlined for changes to the listing process. Suggestions included, but were not limited to, a migration to a Global Information System (GIS), improved monitoring and assessment, and greater public input.

The migration to a GIS was implemented prior to the development of the 1998 Section 303(d) list. Because of additional sampling and the migration to the GIS, some of the information appearing on the 1996 list differed from the 1998 list. Most common changes included:

1. mileage differences due to recalculation of segment length by the GIS;
2. slight changes in source(s)/cause(s) due to new EPA codes;
3. changes to source(s)/cause(s), and/or miles due to revised assessments;
4. corrections of misnamed streams or streams placed in inappropriate SWP subbasins; and
5. unnamed tributaries no longer identified as such and placed under the named watershed listing.

Prior to 1998, segment lengths were computed using a map wheel and calculator. The segment lengths listed on the 1998 Section 303(d) list were calculated automatically by the GIS (ArcInfo) using a constant projection and map units (meters) for each watershed. Segment lengths originally calculated by using a map wheel and those calculated by the GIS did not always match closely. This was the case even when physical identifiers (e.g., tributary confluence and road crossings) matching the original segment descriptions were used to define segments on digital quad maps. This occurred to some extent with all segments, but was most noticeable in segments with the greatest potential for human errors using a map wheel for calculating the original segment lengths (e.g., long stream segments or entire basins).

<u>Migration to National Hydrography Data (NHD)</u>

New to the 2006 report is use of the 1/24,000 National Hydrography Data (NHD) streams GIS layer. Up until 2006 the Department relied upon its own internally developed stream layer. Subsequently, the United States Geologic Survey (USGS) developed 1/24,000 NHD streams layer for the Commonwealth based upon national geodatabase standards. In 2005, DEP contracted with USGS to add missing streams and correct any errors in the NHD. A GIS contractor transferred the old DEP stream assessment information to the improved NHD and the old DEP streams layer was archived. Overall, this marked an improvement in the quality of the streams layer and made the stream assessment data compatible with national standards but it necessitated a change in the Integrated Listing format. The NHD is not attributed with the old DEP five-digit stream codes so segments can no longer be listed by stream code but rather only by stream name or a fixed combination of NHD fields known as reachcode and ComID. The NHD is aggregated by Hydrologic Unit Code (HUC) watersheds so HUCs rather than the old State Water Plan (SWP) watersheds are now used to group streams together. A more basic change was the shift in data management philosophy from one of “dynamic segmentation” to “fixed segments”. The dynamic segmentation records were proving too difficult to manage from an historical tracking perspective. The fixed segment methods will remedy that problem. The stream assessment data management has gone through many changes over the years as system requirements and software changed. It is hoped that with the shift to the NHD and OIT’s (Office of Information Technology) fulltime staff to manage and maintain SLIMS the systems and formats will now remain stable over many Integrated Listing cycles.

Appendix B: Model My Watershed Generated Data Tables or Inputs

Land Cover Type	Area (Ha)	%
Hay/Pasture	217.7	19.3
Cropland	304.4	27.0
Wooded Areas	532.9	47.3
Wetlands	0.4	0.0
Open Land	0.6	0.1
Barren Areas	0.7	0.1
Low Density Mixed Development	12.4	1.1
Medium Density Mixed Development	1.0	0.1
High Density Mixed Development	0.1	0.0
Low Density Open Space	55.3	4.9

Table B1. "Model My Watershed" Land Cover Inputs for the Baken Creek Watershed based on the 2020 Cropland Data Layer

Land Cover Type	Area (Ha)	%
Hay/Pasture	77.0	6.7
Cropland	155.1	13.4
Wooded Areas	869.6	75.2
Wetlands	0.9	0.1
Open Land	0.0	0.0
Barren Areas	0.2	0.0
Low Density Mixed Development	4.3	0.4
Medium Density Mixed Development	0.2	0.0
High Density Mixed Development	0.0	0.0
Low Density Open Space	49.6	4.3

Table B2. "Model My Watershed" Land Cover Inputs for the Black Run reference subwatershed based on the 2020 Cropland Data Layer

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.38	0.48	4.9	0	0.31	7.15
Feb	6.13	0.61	5.52	0	0.48	7.31
Mar	7.34	0.28	7.05	0	1.69	8.36
Apr	6.44	0.08	6.36	0	4.37	8.41
May	4.66	0.06	4.6	0	8.56	10.51
Jun	3.62	0.66	2.96	0	12.1	10.58
Jul	1.62	0.09	1.52	0	11.82	9.86
Aug	0.6	0.06	0.54	0	9.37	8.64
Sep	0.73	0.5	0.24	0	6.21	9.04
Oct	1.06	0.33	0.73	0	3.5	8.06
Nov	2.08	0.22	1.86	0	1.7	9.38
Dec	4.66	0.35	4.31	0	0.66	8.11
Total	44.32	3.72	40.59	0	60.77	105.41

Table B3. “Model My Watershed” Hydrology Outputs for the Baken Creek Watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.89	0.65	5.24	0	0.3	7.15
Feb	6.43	0.81	5.61	0	0.46	7.31
Mar	7.49	0.36	7.14	0	1.67	8.36
Apr	6.38	0.09	6.29	0	4.26	8.41
May	4.49	0.07	4.42	0	8.32	10.51
Jun	3.54	0.8	2.74	0	11.52	10.58
Jul	1.38	0.12	1.26	0	11.17	9.86
Aug	0.46	0.08	0.39	0	9.06	8.64
Sep	0.86	0.64	0.22	0	5.95	9.04
Oct	1.48	0.44	1.04	0	3.41	8.06
Nov	2.78	0.28	2.5	0	1.63	9.38
Dec	5.59	0.45	5.13	0	0.64	8.11
Total	46.77	4.79	41.98	0	58.39	105.41

Table B4. “Model My Watershed” Hydrology Outputs for the Black Run reference subwatershed

Sources	Sediment (kg)
Hay/Pasture	92,493.60
Cropland	377,153.00
Wooded Areas	793.7
Wetlands	0
Open Land	16.5
Barren Areas	0
Low-Density Mixed	150.6
Medium-Density Mixed	83.3
High-Density Mixed	8.3
Low-Density Open Space	671.8
Farm Animals	0
Stream Bank Erosion	67,190.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B5. Model My Watershed outputs for Sediment in the Baken Creek Watershed.

Sources	Sediment (kg)
Hay/Pasture	7,805.70
Cropland	249,218.90
Wooded Areas	3,144.10
Wetlands	0
Open Land	0
Barren Areas	0
Low-Density Mixed	48.8
Medium-Density Mixed	15.2
High-Density Mixed	0
Low-Density Open Space	563.2
Farm Animals	0
Stream Bank Erosion	35,084.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B6. Model My Watershed outputs for Sediment in the Black Run reference subwatershed.

Appendix C: Stream Segments in the Baken Creek Watershed with Siltation Impairments per the 2020 Integrated Report

Stream Name:	Length (miles):	ATTAINS ID:	Impairment Source:	Impairment Cause:
Unnamed Tributary to Baken Creek	0.0	PA-SCR-56401525	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	0.1	PA-SCR-56401581	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	0.0	PA-SCR-56401587	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Baken Creek	1.1	PA-SCR-56401667	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	0.2	PA-SCR-56401669	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	1.7	PA-SCR-56401765	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	0.2	PA-SCR-56401773	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	0.0	PA-SCR-56401777	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Baken Creek	0.2	PA-SCR-56401783	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	0.2	PA-SCR-56401785	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	0.2	PA-SCR-56401831	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Baken Creek	0.1	PA-SCR-56401833	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	0.3	PA-SCR-56401855	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	1.7	PA-SCR-56402021	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Baken Creek	0.5	PA-SCR-56402023	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	1.7	PA-SCR-56402319	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Baken Creek	0.7	PA-SCR-56402321	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Unnamed Tributary to Baken Creek	0.8	PA-SCR-56402445	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Baken Creek	0.2	PA-SCR-56402447	REMOVAL OF RIPARIAN VEGETATION	SILTATION
Baken Creek	0.7	PA-SCR-56402763	REMOVAL OF RIPARIAN VEGETATION	SILTATION

Table C1. Stream segments with aquatic life use impairments per the 2020 Integrated Report.

Appendix D: Equal Marginal Percent Reduction Method

Equal Marginal Percent Reduction (EMPR) (An Allocation Strategy)

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute the Adjusted Load Allocation (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 Adjusted Load Allocation based on TMDL, MOS, WLA and existing loads not reduced.

Step 3: Actual EMPR Process:

a. Each land use/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

	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	831,622	yes	531,507		0.60	211,796	319,711	0.62
Hay/Pasture	203,948	no	203,948	352,102	0.23	81,270	122,679	0.40
Streambank	148,154	no	148,154		0.17	59,037	89,117	0.40
sum	**1,183,725**		**883,610**		**1.00**	**352,102**	**531,507**	**0.55**

Table D1. Equal Marginal Percent Reduction calculations for the Baken Creek Watershed.

Appendix E: Legal Basis for the TMDL and Water Quality Regulations for Agricultural Operations

Clean Water Act Requirements

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

Additionally, the federal Clean Water Act and the United States Environmental Protection Agency's (EPA) implementing regulations (40 CFR 130) require:

- States to develop lists of impaired waters for which current pollution controls are not stringent enough to meet water quality standards (the list is used to determine which streams need TMDLs);
- States to establish priority rankings for waters on the lists based on severity of pollution and the designated use of the waterbody; states must also identify those waters for which TMDLs will be developed and a schedule for development;
- States to submit the list of waters to EPA every two years (April 1 of the even numbered years);
- States to develop TMDLs, specifying a pollutant budget that meets state water quality standards and allocate pollutant loads among pollution sources in a watershed, e.g., point and nonpoint sources; and
- EPA to approve or disapprove state lists and TMDLs within 30 days of final submission.

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

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

Pennsylvania Clean Streams Law Requirements, Agricultural Operations

Pennsylvania farmers are required by law to operate within regulatory compliance by implementing the applicable requirements outlined in the Pennsylvania Clean Streams Law, Title 25 Environmental Protection, Part I Department of Environmental Protection, Subpart C Protection of Natural Resources, Article II Water Resources, Chapters: § 91.36 Pollution control and prevention at agricultural operations, § 92a.29 CAFO and § 102.4 Erosion and sediment control requirements. Water quality regulations can be found at following website: http://www.pacode.com/secure/data/025/025toc.html

Agricultural regulations are designed to reduce the amount of sediment and nutrients reaching the streams and ground water in a watershed.

Appendix F: Information on Use of the Chesapeake Bay Program's BMP Crediting

For many of the Best Management Practices (BMPs) proposed in this study, the calculated sediment reductions were based on the logic used by the Chesapeake Bay Program's Chesapeake Assessment Scenario Tool (CAST). See:

Chesapeake Bay Program. 2018. Chesapeake Bay Program Quick Reference Guide for Best Management Practices (BMPs): Nonpoint Source BMPs to Reduce Nitrogen, Phosphorus and Sediment Loads to the Chesapeake Bay and its Local Waters. CBP DOC ID. Downloaded at: https://www.chesapeakebay.net/documents/BMP-Guide_Full.pdf

The following explains how this study used some of the Chesapeake Bay Program's information. Please note that some BMP crediting in this study did not follow the Chesapeake Bay Program's methods, as described in the "An Analysis of Possible BMPs" section.

Agricultural Erosion and Sedimentation Plans

Chesapeake Bay Program:

"Soil Conservation and Water Quality Plans" (A-24): considers many types of agricultural lands. All croplands received a sediment reduction efficiency of 25%. Pasture lands received an 14% reduction efficiency and hay lands typically received an 8% efficiency.

This Study:

The 25% sediment reduction efficiency was used for croplands. Because land use classifications didn't distinguish between hay and pasture lands, the 8% efficiency was used to be conservative.

Cover Crops

Chesapeake Bay Program:

CAST "Cover Crops-Traditional" A-4*:* has numerous different cover crop types and breaks them into low and high till land uses. When used in combination with low till, there is no additional sediment reduction. Sediment reductions range from 0-20% on high till lands.

CAST "Cover Crops-Commodity" A-5: when grown as a commodity, there are no sediment reductions.

This Study:

For simplicity, this study settled on a 10% reduction in all cases to account for the fact that sometimes it will be 0 and sometimes it will be 20%, depending on the cover crop type. It was also specified that the reductions are only to be applied to non-commodity cover crops used on high till lands.

Conservation Tillage

Chesapeake Bay Program:

"Conservation Tillage" A-3: % reductions vary based on "low residue" (15-29% crop residue immediately after planting) "conservation tillage" (30-59% crop residue) or "high residue" (at least 60% crop residue) categories. For sediment, low residue tillage gets an 18% reduction, conservation tillage gets a 41% reduction and high residue tillage gets a 79% reduction.

This Study

For simplicity, the middle "conservation tillage" reduction value of 41% was assumed in all cases. However, if more detailed information becomes available about pre and post residue cover conditions, different crediting options could be used in accordance with Chesapeake Bay Program methodology.

Riparian buffers

Chesapeake Bay Program:

"Forest Buffers and Grass Buffers" A12: Forest Buffers and Grass Buffers with Stream Exclusion Fencing A13: Riparian buffers are credited two ways: the land conversion effect and the upland filtration effect. For the upland sediment filtration effect, it is assumed that the loading from two acres of upland is reduced by an efficiency value of 40-60% depending on hydrogeomorphic region. Note that for buffers less than 35 feet wide average width, only the land conversion, and not the upslope filtration effect is credited. Buffers less than 10 feet wide get no credit.

This Study:

For simplicity, rather than using a different upland efficiency by region, the average efficiency value for the geomorphic regions that occur in Pennsylvania, 47%, was used for proposed buffers. Also, it was assumed that loading from two acres of *cropland* are filtered per acre of buffer created. Note that CAST assumes two acres of *uplands*, not necessarily croplands, are filtered per acre of buffer created. However, there was an abundance of croplands in the Baken Creek Watershed, and logic would suggest that if there is something else upslope that loads at a lower rate, the buffer may be capable of filtering more of it. The land conversion factor from croplands and hay/pasture lands to forests was also taken into account. The present study doesn't specify a minimum buffer width. If buffers are very narrow then they will be of low acreage and thus will not get much filtration credit.

Grazing Land Management

Chesapeake Bay Program:

“Pasture and Grazing Management Practices” A8: for sediment there is a 30% reduction efficiency, except in the case of horse pasture management where there is a 40% efficiency.

This Study:

Given that horse pastures are far less common and the difference is not that great, the 30% efficiency was assumed for all cases.

Appendix G: Information on VFSMOD inputs

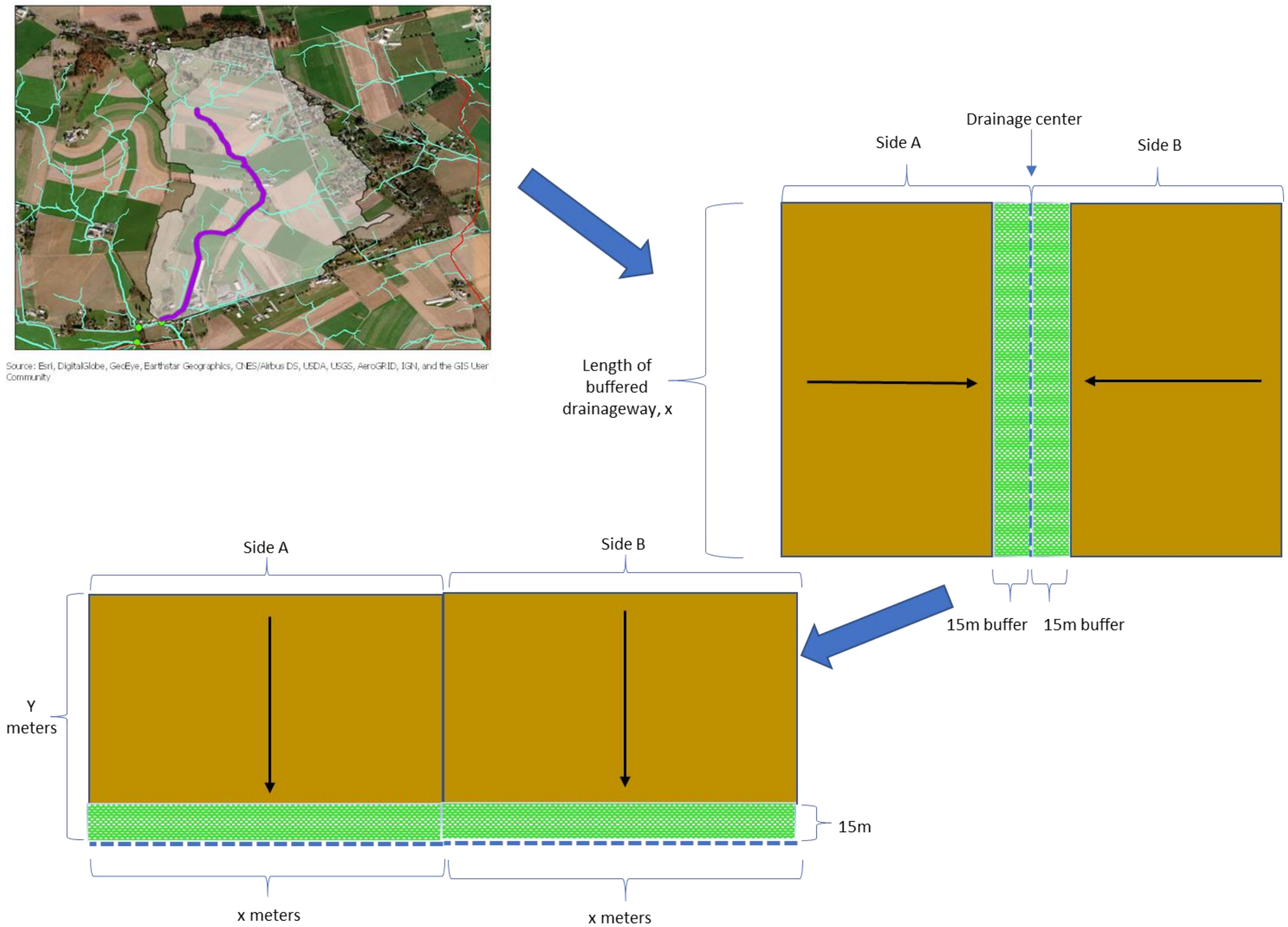

Figure G1. Conceptualization showing how site geometry was simplified for input into VFSMOD. Complex buffersheds were first assumed to be a uniform rectangle with a central buffered drainageway. The length of the rectangle (X) was assumed to be the length of the buffered drainageway. However, since VFSMOD only accepts inputs in one direction, from the source area to the buffer, the rectangle was split down the middle along the central drainageline and the two sides of the rectangle were laid end to end. Thus Y was solved by assuming that 2X * Y = total watershed area. The source area length along the slope was calculated as Y-5m. The upland area was calculated as the total watershed area minus the area of the buffer. Note the image in the upper left corner is from the approved Hammer Creek 2021 ARP.

	Drainageshed A	Drainageshed B	Drainageshed C	Drainageshed D	Drainageshed E	Drainageshed F
Source Area Inputs						
rainfall (mm) for the five year storm[1]	91.6	91.6	91.6	91.6	91.6	91.6
storm duration (hrs)	24	24	24	24	24	24
curve no[2]	80.1	80.1	81.7	79.3	76.9	57.2
storm type[3]	II	II	II	II	II	II
length along slope (m)[4]	134.1	184.0	83.8	136.8	167.0	150.3
watershed slope fraction[2]	0.041	0.051	0.041	0.063	0.074	0.101
upland area (ha)[4]	20.4	30.3	8.6	28.5	35.1	36.7
soil erodibility (metric ton*hectare*hour)/(hectare*megajoule*millimeter)[5]	0.0399	0.0327	0.0326	0.0295	0.0254	0.0167
soil type[6]	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam	Silt Loam
percent OM[6]	1.9	1.7	1.9	1.9	4.5	14.5
dp particle class diam[3]	default	default	default	default	default	default
crop factor[2]	0.08	0.08	0.08	0.08	0.08	0.08
practice factor[2]	0.69	0.69	0.69	0.69	0.69	0.69
rainfall factor[3]	Williams	Williams	Williams	Williams	Williams	Williams
Overland Flow Inputs						
buffer length from input to output (m)	5	5	5	5	5	5
Manning's n roughness for dense grass[3]	0.24	0.24	0.24	0.24	0.24	0.24
buffer slope, proportion[7]	0.112	0.164	0.073	0.081	0.053	0.100
double filter strip width in longest direction (m)[8]	1520	1646	1024	2086	2100	2442
kinematic wave parameters	default	default	default	default	default	default
Filter Strip Infiltration Inputs						
shallow water table[9]	No	No	No	No	No	No
number soil layers[9]	1	1	1	1	1	1
saturated conductivity, surface layer (m/s)[6]	1.0409E-05	9.1700E-06	1.0531E-05	9.3987E-06	1.2124E-05	2.0849E-05
bottom depth (cm)	default 15	default 15	default 15	default 15	default 15	default 15
average suction at the wetting front, Sav, (m)[3]	0.1668	0.1668	0.1668	0.1668	0.1668	0.1668
surf. layer initial water content (assume field capacity, or proportion at 1/3 Barr)[6]	0.2620	0.2630	0.2583	0.2612	0.2299	0.2344
saturated water content, proportion[3]	0.48	0.48	0.48	0.48	0.48	0.48
surface storage[9]	0	0	0	0	0	0
fraction ponding checked[9]	0	0	0	0	0	0
Buffer Vegetation Properties						
spacing for grass stems (cm)[3]	2.15	2.15	2.15	2.15	2.15	2.15
roughness, Manning's n[3]	0.012	0.012	0.012	0.012	0.012	0.012
height of grass(cm)[3]	18	18	18	18	18	18
roughness, bare surface Manning's n (default)[3]	0.04	0.04	0.04	0.04	0.04	0.04
feedback[3]	0	0	0	0	0	0
Outputs						
five year storm sediment delivery ratio	0.102	0.232	0.038	0.14	0.175	0.105

[1]PENNDOT 2010

[2]estimated from Model My Watershed or Mapshed

[3]per suggestions in VFSMOD help or Manual

[4]calculated assuming the subwatershed was a rectangle draining unidirectionally and uniformly to a rectangular buffer strip

[5]USDA WSS english units value multiplied by 0.1317 to convert to the metric value per VFSMOD manual and Foster et al. 1981. Note that one soil type (Hazelton Channery Sandy Loam) making up 4.2% of the area of drainageshed E and 18.8% of the area of drainageshed F had missing values, so those soils were disregarded.

[6]USDA WSS. Note that for the surface layer initial water content of drainageshed E, Calvin Shaly Loam, which comprised 12.2% of the area, had missing information. Thus it was disregareded for this case.

[7]estimated from USGS DEM and TAUDEM tools in ArcGISPro

[8]longest direction length of the filter strip estimated using measuring tool (geodesic) in ArcGISPro; multiplied by two because two sides to the centerline of the buffer

[9]assumed for simplicity and/or likely to have minor effections on modelling results and/or be conservative

Table G1. VFSMOD inputs.

Appendix H: Comment and Response

No public comments were received.