Pennsylvania Department of Environmental Protection

BUREAU OF CLEAN WATER
BAKEN CREEK WATERSHED SEDIMENT TMDL
PERRY COUNTY
DRAFT FOR PUBLIC COMMENT, August 10, 2026

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EXECUTIVE SUMMARY

"Total Maximum Daily Loads" (TMDLs) for sediment were developed for Baken Creek watershed to address the siltation impairments noted in the 2022 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report (Integrated Report), including the Clean Water Act Section 303(d) List. "Removal of Riparian Vegetation" was identified as the source of these impairments. Because Pennsylvania does not have numeric water quality criteria for sediment, the loading rates from a similar unimpaired watershed were used to calculate the TMDLs.

"TMDLs" were calculated using both a long-term annual average value ($TMDL_{Avg}$) which would be protective under most conditions, as well as a 99th percentile daily value ($TMDL_{Max}$) which would be relevant to extreme flow events. Current annual average sediment loading in the Baken Creek watershed was estimated to be 971,357 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 48% to 505,190 pounds per year. Allocation of annual average sediment loading among the TMDL variables is summarized in Table 1. To achieve this reduction while maintaining a 10% margin of safety and minor allowance for point sources, annual average loading from croplands should be reduced by 59%, while the loading from hay/pasture lands and streambanks should each be reduced by 46%.

Table 1. Summary of annual average TMDL ($TMDL_{Avg}$) variables for the Baken Creek watershed. All values are in lbs/yr.

Pollutant	$TMDL_{Avg}$	MOS_{Avg}	WLA_{Avg}	LA_{Avg}	LNR_{Avg}	ALA_{Avg}
Sediment	505,190	50,519	5,052	449,619	4,938	444,681

TMDL=Total Maximum Daily Load; MOS = Margin of Safety; WLA=Wasteload Allocation (point sources); LA = Load Allocation (nonpoint sources). The LA is further divided into LNR = Loads Not Reduced and ALA=Adjusted Load Allocation. Subscript "Avg" indicates that these values are expressed as annual averages.

Current 99th percentile daily loading in the Baken Creek watershed was estimated to be 33,488 pounds per day. To meet water quality objectives, 99th percentile daily sediment loading should be reduced by 39% to 20,324 pounds per day. Allocation of 99th percentile daily sediment loading among the TMDL variables is summarized in Table 2.

Table 2. Summary of 99th percentile daily loading TMDL ($TMDL_{Max}$) variables for the Baken Creek watershed. All values are in lbs/d.

Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}	LNR_{Max}	ALA_{Max}
Sediment	20,324	2,032	203	18,088	199	17,890

TMDL=Total Maximum Daily Load; MOS = Margin of Safety; WLA=Wasteload Allocation (point sources); LA = Load Allocation (nonpoint sources). The LA is further divided into LNR = Loads Not Reduced and ALA=Adjusted Load Allocation. Subscript "Max" indicates that these values are expressed as 99th percentile for daily loading.

INTRODUCTION

The study watershed, Baken Creek (Figure 1), is located in Perry County. Its mouth with Shermans Creek is less than one and a half miles southeast of the Borough to Landisburg. The Baken Creek watershed was approximately 4.3 square miles and it contained approximately 10.7 miles of United States Geological Survey (USGS) high-resolution National Hydrography Dataset (NHD) flowlines, all of which are currently designated Cold Water Fishes, Migratory Fishes at 25 PA. Code § 93. This Total Maximum Daily Load (TMDL) document has been prepared to address siltation impairments listed within this watershed, per the Integrated Report (Figure 1, Table 3). The source of these impairments was attributed to “removal of riparian vegetation” (Table 3).

Prior to the development of this TMDL, a watershed restoration plan had been developed for Baken Creek (DEP 2022a). Baken Creek was of particular interest for restoration because it is a tributary of Shermans Creek, a large stream in southcentral Pennsylvania that is noted for its fishing, boating and exceptional scenery, while being within 10 miles of both greater Harrisburg and Carlisle urbanized areas. Furthermore, Shermans Creek once had a large population of eastern hellbenders (*Cryptobranchus alleganiensis alleganiensis)* that has since crashed, and it was hypothesized that pollution may have been a contributing factor (Wingert 2018). Hellbenders are of special conservation concern, as populations have exhibited concerning declines and extirpations in many areas of their range (USFWS 2018). Unfortunately, outreach efforts by the Perry County Conservation district failed to gain sufficient landowner support for the Baken Creek watershed restoration plan, and thus it is being replaced with the present TMDL.

According to the 2022 Integrated Report, “removal of riparian vegetation” was identified as the cause of the impairments in the Baken Creek watershed (Table 3). However, based on site observations and GIS analysis, these impairments can be more broadly attributed to agriculture in general. Agricultural lands were estimated to comprise nearly half (45%) of the land area in the watershed (Appendix A, Table A1), and the lower watershed area was almost exclusively agriculture. The remaining lands in the watershed were primarily forest/naturally vegetated lands (46%), while developed lands accounted for a small amount of the overall land area (8%) (see Appendix A, Table A1). There were no NPDES permitted point source discharges in the watershed with limits relevant to sedimentation (Table 4).

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

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

While the present TMDL is focuses on agricultural practices, it is applicable to all significant sources of solids that may settle to form deposits.

Table 3. Aquatic Life Use impaired stream segments in the Baken Creek watershed per the 2022 Final Pennsylvania Integrated report (DEP 2022b). See Shull (2023) and Shull and Whiteash (2023) for more information on the listing process

Source	USEPA 305(b) Cause Code	Miles
Removal of Riparian Vegetation	Siltation	10.7

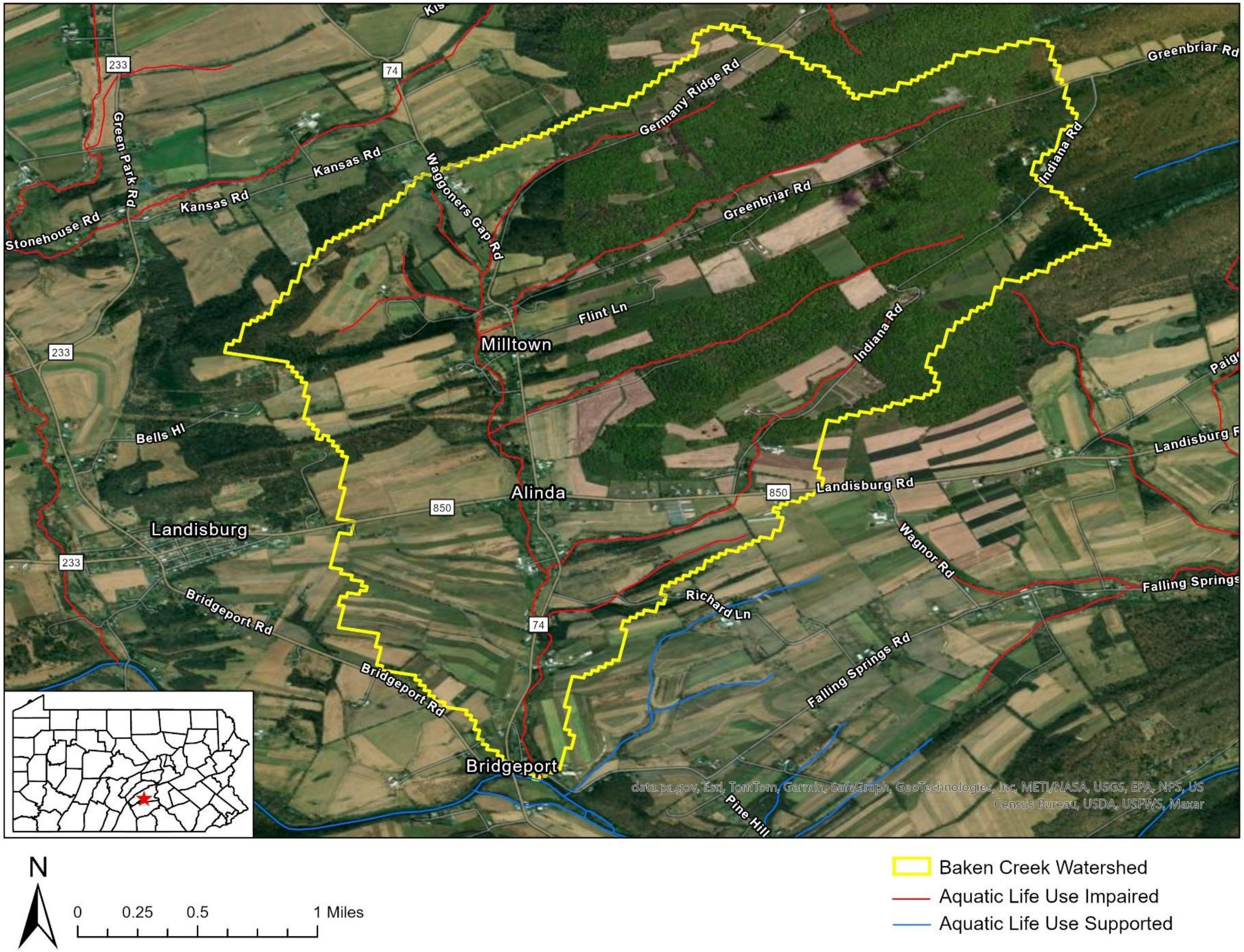

Figure 1. Baken Creek watershed. Per the 2022 Integrated Report viewer, the Aquatic Life Use impairments within the watershed were due to siltation from the removal of riparian vegetation (DEP 2022b).

Table 4. Existing NPDES-permitted discharges in the Baken Creek watershed and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

		Permit Based Limits		DMR Based Loading	
Permit No.	**Facility Name**	**Load, mean** (lbs/yr)	**Load, max** (lbs/d)	**Load, mean** (lbs/yr)	**Load, max** (lbs/d)
None	None	NA	NA	NA	NA

Permits within the delineated watershed were based on eMapPA (DEP 2024) and Watershed Resources Registry (USEPA 2023).

TMDL APPROACH

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

1. Collection and summarization of pre-existing data (watershed characterization, inventory contaminant sources, determination of pollutant loads, etc.);
2. Calculation of a TMDL 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. United States Environmental Protection Agency (USEPA) approval of the TMDL.

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

SELECTION OF THE REFERENCE WATERSHED

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

GIS Analysis

To find a reference, GIS data layers largely consistent with the 2022 Integrated Report (DEP 2022b) were used to search for nearby watersheds that were of similar size as the Baken Creek watershed but lacked stream segments listed as impaired for sediment. In order to increase the likelihood of matching key watershed characteristics, special emphasis was given to finding a reference that, like the Baken Creek watershed, occurred within the Susquehanna Lowland section of the Ridge and Valley Physiographic Province. 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 covers etc. Preliminary modelling was conducted to make sure that use of a particular reference would result in a reasonable pollution reduction. Over twenty potential references were identified. Once the list was narrowed down to a few best candidates, benthic macroinvertebrate and physical habitat assessment scores were reviewed to confirm that a reference was acceptable.

Considering that: it was nearby (about five miles to the southeast), within the same section of the same physiographic province, had similar topography, and there was good evidence that it was supporting its Aquatic Life Use, an Unnamed Tributary (UNT) of Shermans Creek watershed, also in Perry County, was considered for use as a reference (Figures 2 and 3, Table 5).

Table 5. Comparison of the Baken Creek and UNT Shermans Creek watersheds.

	Baken Creek	**UNT Shermans Creek**
Physiographic Province[1]	Susquehanna Lowland Section of the Ridge and Valley Physiographic Province	Susquehanna Lowland Section of the Ridge and Valley Physiographic Province
Land Area[2], km^2	11.33	10.12
Land Cover[2]	45% Agriculture 46% Forest/Natural Vegetation 8% Developed	29% Agriculture 60% Forest/Natural Vegetation 11% Developed
Soil Infiltration[3]	54% Group A 20% Group B 2% Group B/D 3% Group C 7% Group C/D 15% Group D	22% Group A 35% Group B 0% Group B/D 5% Group C 3% Group C/D 35% Group D
Dominant Bedrock[4]	39% Calcareous Shale 34% Shale 26% Limestone	57% Siltstone 41% Shale 2% Mudstone

Average Precipitation[5], in/yr	41.5	41.5
Average Surface Runoff[5], in/yr	1.9	1.9
Average Elevation[5], ft	752	650
Average Slope[5]	11%	13%
Average Stream Channel Slope (High Resolution NHD)[5]	1st order: 3.01% 2nd order: 1.92% 3rd order: 1.09%	1st order: 5.15% 2nd order: 2.01% 3rd order: 1.12%

[1]Per DCNR_Physiographic_Sections_of_Pennsylvania202306 GIS layer provided by Department of Conservation and Natural Resources
[2]MMW output based on NLCD 2019
[3]As reported by Model My Watershed's analysis of USDA gSSURGO 2016. A = high infiltration soils; B=moderate infiltration soils, C= slow infiltration soils and D= very slow infiltration soils. See technical documentation for more details.
[4]Per bedrock geology (V) GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Department of Conservation and Natural Resources
[5]As reported by Model My Watershed

The two watersheds were topographically similar in that many of their headwater tributaries originated within forested hills, while their lower watershed areas harbored a greater intensity of agricultural lands (Figures 1 and 3). However, whereas the lower Baken Creek watershed flowed into one major valley with a nearly entirely agricultural land cover (Figure 1), the central and lower portions of the UNT Shermans Creek watershed also had significant forested hills (Figure 3). Consequently, there were lesser agricultural and greater forested lands in the UNT Shermans Creek watershed (Table 5). Developed lands were a minor contributor to the overall land cover in both watersheds (8 and 11%, Table 5).

As for geology, a notable difference between the two watersheds was that the Baken Creek watershed had substantial limestone, while the UNT Shermans Creek watershed did not (Table 5). This may be concerning since karst features associated with limestone geology may greatly influence hydrology and pollutant transport. However, this limestone was of the Keyser and Tonoloway formation (Per bedrock geology (V) GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Department of Conservation and Natural Resources), which has a low tendency to form karst features. In fact, no sinkholes or surface depressions were mapped in this watershed per eMapPA (DEP 2024). Otherwise, the bedrock of the Baken creek watershed was dominated by shale, which was also a major component of the bedrock of the UNT Shermans Creek watershed, along with siltstone and mudstone (Table 5).

Both watersheds had a wide range of soil drainage classes that were weighted toward high and moderate infiltration soils, and average estimated surface runoff rates were approximately the same (Table 5). Terrain slopes were similarly steep on average in both watersheds (11 and 13%, Table 5). Likewise, both watersheds exhibited a similar distribution of stream slopes that tended to be fairly high gradient (Table 5).

Whereas stream segments within the Baken Creek watershed were designated Cold Water Fishes, Migratory Fishes, stream segments within the UNT Shermans Creek watershed were designated Warm Water Fishes, Migratory Fishes at 25 Pa. Code § 93. Neither had stream segments that were designated special protection (HighQuality Waters or Exceptional Value Waters).

Also, like the Baken Creek watershed, NPDES permitted point source discharges were not a significant source of fine sediment in the UNT Shermans Creek watershed (Tables 4 and 6). For the Carroll Township Elementary School Wastewater Treatment Plant (PA0084034) the mean annual total suspended solids (TSS) discharge was calculated as follows. Electronic discharge monitoring report (eDMR) data were reviewed from 2018 through 2023. Average monthly TSS concentrations, in mg/l, as well as average monthly flows, in MGD, were reported. These values were used to calculate the average monthly loads in lbs/d, which were then multiplied by the number of days in the month, and then all months within a year were summed to calculate lbs/yr. The value reported in Table 6 is the average of those six years. The daily maximum value was based on the maximum of monthly-reported daily maximum flows since January 2018. It was assumed that they continuously discharged at this rate and their Instantaneous maximum TSS concentration limit of 60 mg/l per their NPDES permit. Note that this likely overestimates their true daily maximum TSS load, but in any case, this facility is a minor contributor to the watershed's overall sediment load. No point source loads were reported in Table 6 for the Keith Musser concentrated animal feeding operation (CAFO) (PAG123845) for the following reason. In Pennsylvania, routine, dry-weather discharges from CAFOs are not allowed. Wet weather discharges are controlled through best management practices, which result in infrequent discharges from production areas and reduced sediment loadings from lands under the control of CAFOs owner or operators, such as croplands where manure is applied. Although not quantified in this table, pollutant loading from CAFOs is accounted for in the modeling of land uses within the watershed, with the assumption of no additional CAFO-related BMPs.

Table 6. Existing NPDES-permitted discharges in the UNT Shermans Creek and their potential contribution to sediment loading. Given their transient nature, stormwater construction permits were not included.

		DMR Based Loading	
Permit No.	**Facility Name**	**Load, mean** (lbs/yr)	**Load, max** (lbs/d)
PA0084034	Carroll Twp Elem WWTP	19.6	7.5
PAG123845	Keith Musser CAFO	NA	NA

Permits within the delineated watershed were based on eMapPA (DEP 2024) and Watershed Resources Registry (USEPA 2023).

Site Observations

The Baken Creek watershed was visited during spring of 2021 and summer of 2023 as part of the prior restoration plan development efforts. Photographs and observations from both of those visits are included herein. The reference watershed, UNT Shermans Creek, was visited during March 2024 to confirm its suitability as a reference.

Baken Creek was obviously degraded by agriculture; of particular note was the lower mainstem's turbidity even during summer low flows (Figure 4). However, while some slower flowing areas exhibited significant fine sediment deposition, Baken Creek typically maintained a primarily rocky substrate, likely due to its fairly high gradient (Figures 4 and 5). Swiftly flowing streams are more resilient against the heavy fines deposition that is often observed in more sluggish streams. On the other hand, this means that high sediment loads exported by Baken Creek are a pollution source for Shermans Creek. Smaller tributary reaches within the Baken Creek watershed exhibited variable conditions, with some appearing apparently healthy while others appearing degraded (Figure 6).

The need for best management practices was obvious in many areas of the Baken Creek watershed, particularly in the main agricultural valley (Figures 7 and 8). Many stream reaches lacked expansive forested riparian buffers, and some agricultural fields were proximate to streams. In some cases livestock had direct access to the stream, resulting in habitat degradation, bank erosion, and direct pollution from animal wastes. One pasture area of the lower watershed was especially problematic, as heavy animal use of a streamside hillslope resulted in soil exposure that must runoff to the stream (Figure 8). The presence of steep eroding banks within one area of the lower watershed also suggested the possibility of “legacy sediment” deposits from a historic milldam. Conditions that may be protective against agricultural pollution were observed as well (Figure 9), including streams in forested areas or with forested buffers.

Figures 10, 11 and 12 illustrate conditions within the lower and middle mainstem of the UNT Shermans Creek watershed. Like Baken Creek, UNT Shermans Creek was fairly high gradient and exhibited obvious turbidity during the site visit. However, this turbidity was likely due to high flow conditions associated with recent storms, which is far less concerning than the baseflow turbidity observed within Baken Creek. High gradient areas within the UNT Shermans Creek watershed were typically rocky. And, even slower moving pools were primarily rocky, though with some light to moderate fines deposition. Travelling further upstream, UNT Shermans Creek splits into two major tributaries, one flowing east from the Mecks Corner area, and the other flowing west from the Crums Corner area (Figure 3). The eastern tributary originated in an area of intensive croplands and exhibited concerning siltation (Figure 13). However, conditions improved as the stream progressed through a large forested area and picked up volume from additional tributaries. Thus, the degraded area might not be of sufficient length (at least one half mile per Shull and Pulket 2021) to be officially listed as impaired. In contrast, the western main tributary appeared far healthier (Figure 14). Conditions within smaller tributaries were variable (Figure 15).

Figure 16 illustrates example landscapes within the UNT Shermans Creek watershed. While the watershed harbored some intensive agriculture, the overall amount was substantially less than what occurred in the Baken Creek watershed, and there was greater forested land cover. In addition, there was also very high rates of riparian buffering in the UNT Shermans Creek watershed (Figure 17). With that said, there were also areas where conditions could be improved, for instance by: increasing the use for forested riparian buffers, improving drainageway protection, increasing the use of conservation tillage, and protecting streambanks from erosion (Figure 18). In conclusion, the UNT Shermans Creek watershed appeared to be a suitable reference based on its similarities to the Baken Creek watershed and lack of obvious impairment.

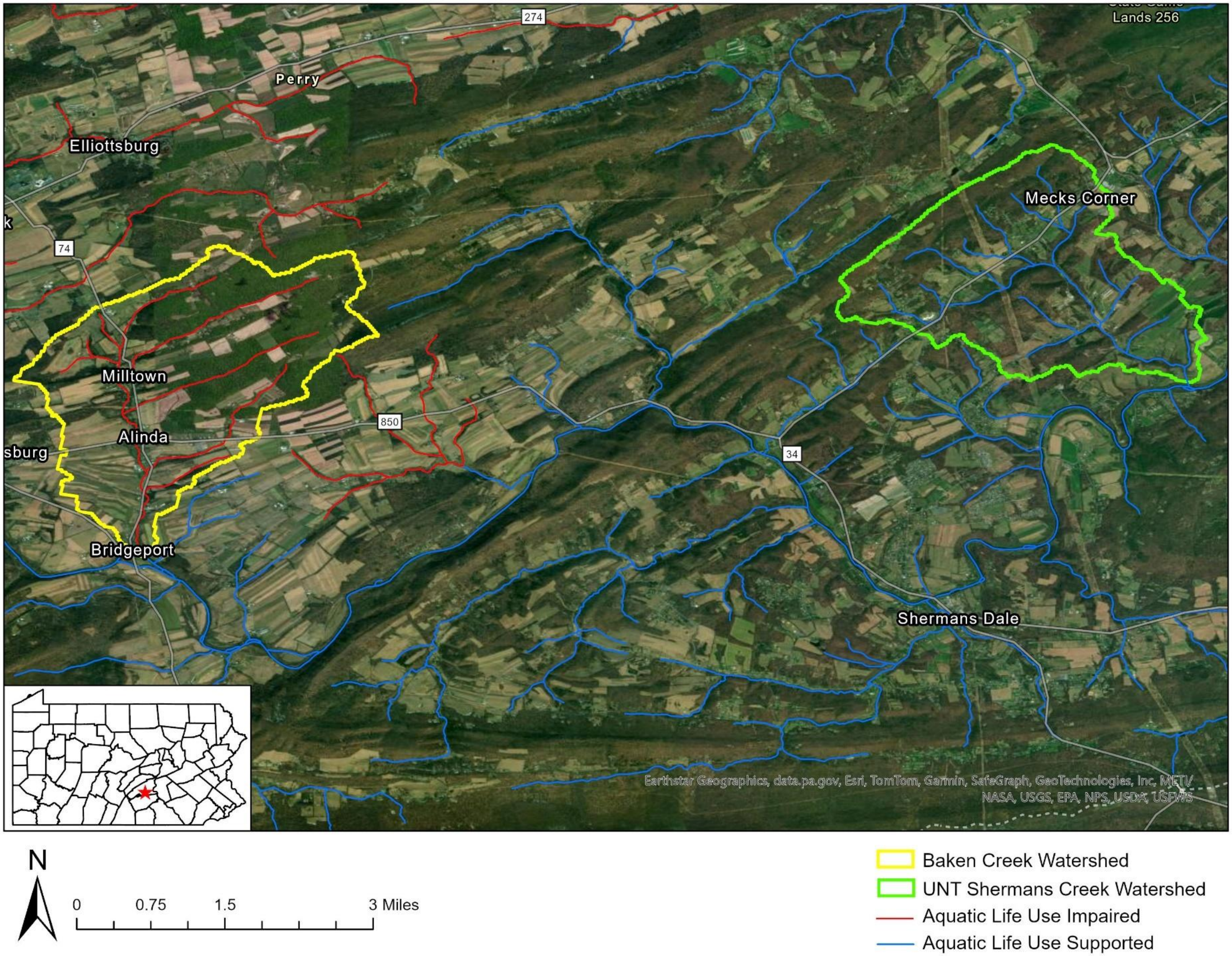

Figure 2. Baken Creek and UNT Shermans Creek watersheds.

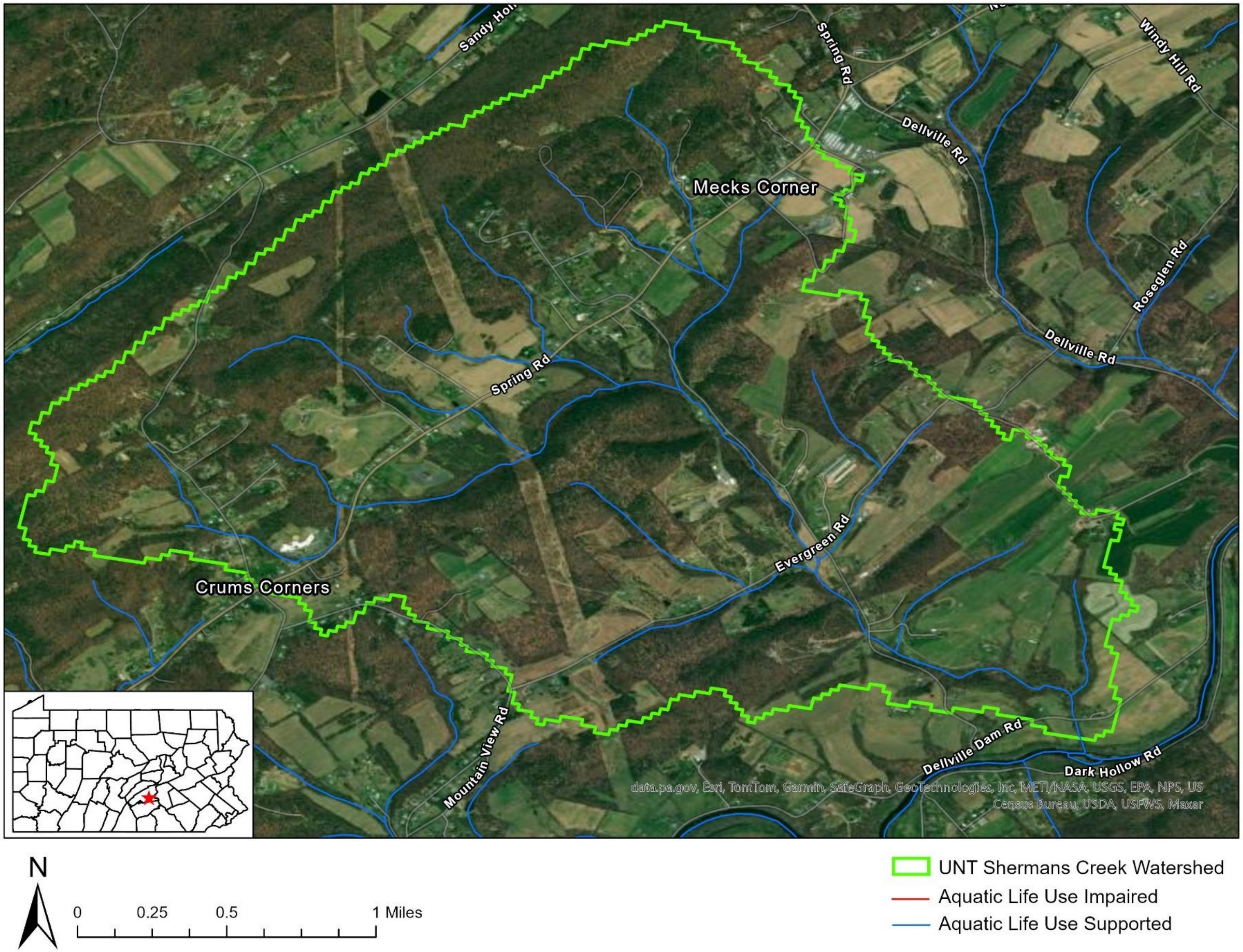

Figure 3. UNT Shermans Creek watershed. All stream segments within the watershed were listed as supporting their Aquatic Life Use per the Integrated Report viewer (DEP 2022b).

Figure 4. Example conditions within Baken Creek's lower mainstem. Much of the lower mainstem was fairly high gradient, and such areas tended to be rocky and free of heavy fine sediment deposition (A and B). However, some fine sediment deposition was apparent in pools (D). Note the obvious turbidity in A and B.

Figure 5. Example stream conditions in middle mainstem or larger tributaries of the Baken Creek watershed. Conditions were variable, with some swifter areas harboring largely rocky substrate (A), while other areas obviously impacted by fine sediment deposition (C and D).

Figure 6. Examples of variable conditions within smaller tributaries of the Baken Creek watershed.

Figure 7. Example landscapes within the Baken Creek watershed. The headwaters of the upper watershed originated in a hilly/mountainous area that was primarily forested, while the lower watershed was a broad agricultural valley.

Figure 8. Factors that may contribute to excessive fine sediment loading in the Baken Creek watershed. In many cases streams passed through agricultural landscapes without expansive riparian buffers (A through D). Note the substantial bank erosion in photograph A and the bare hillslope that drains to the stream in the pasture shown in D.

Figure 9. Factors that may be protective against excessive fine 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.

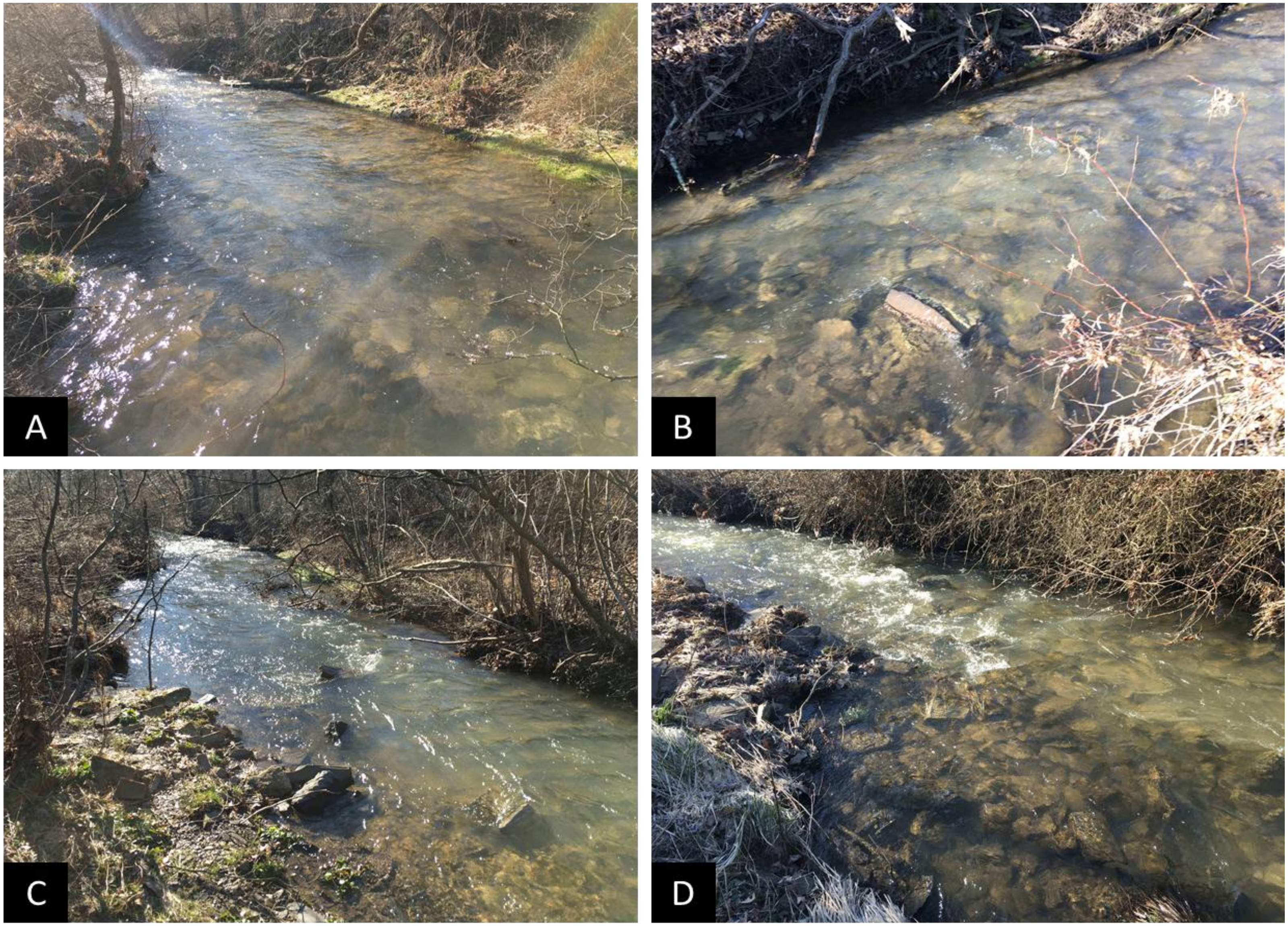

Figure 10. Example conditions within swifter reaches of the lower mainstem of the UNT Shermans Creek watershed. Such areas tended to be rocky. The obvious turbidity shown in these photos may be attributed to recent wet weather.

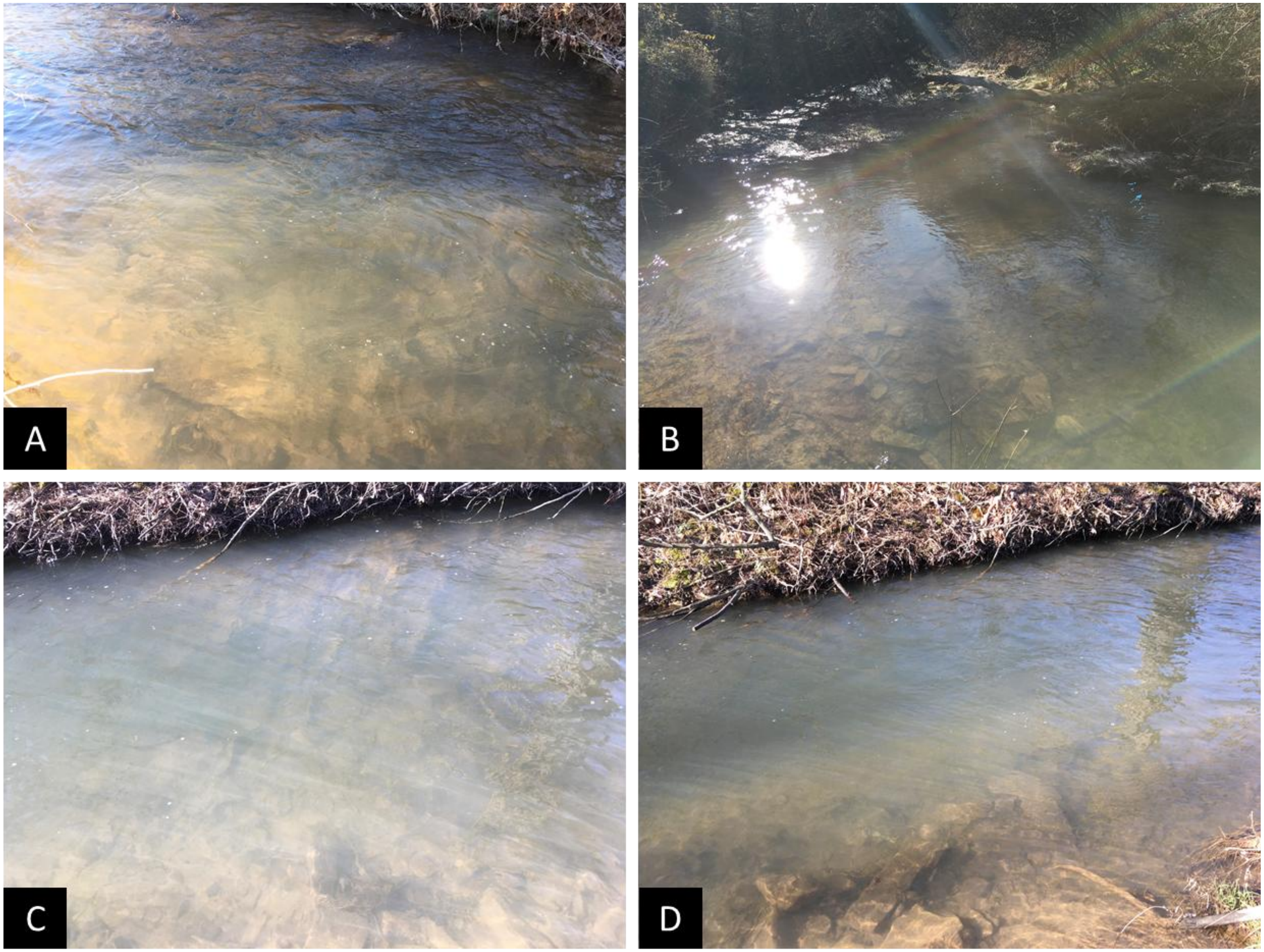

Figure 11. Example conditions within pools of the lower mainstem of the UNT Shermans Creek watershed. Even slower moving areas tended to have largely rocky substrate, though with some fine sediment deposition. Again, the obvious turbidity was likely due to recent wet weather.

Figure 12. Middle mainstem of the UNT Shermans Creek watershed. While some fine sediment deposition was obvious, the stream in this area appeared to be largely rocky and apparently healthy.

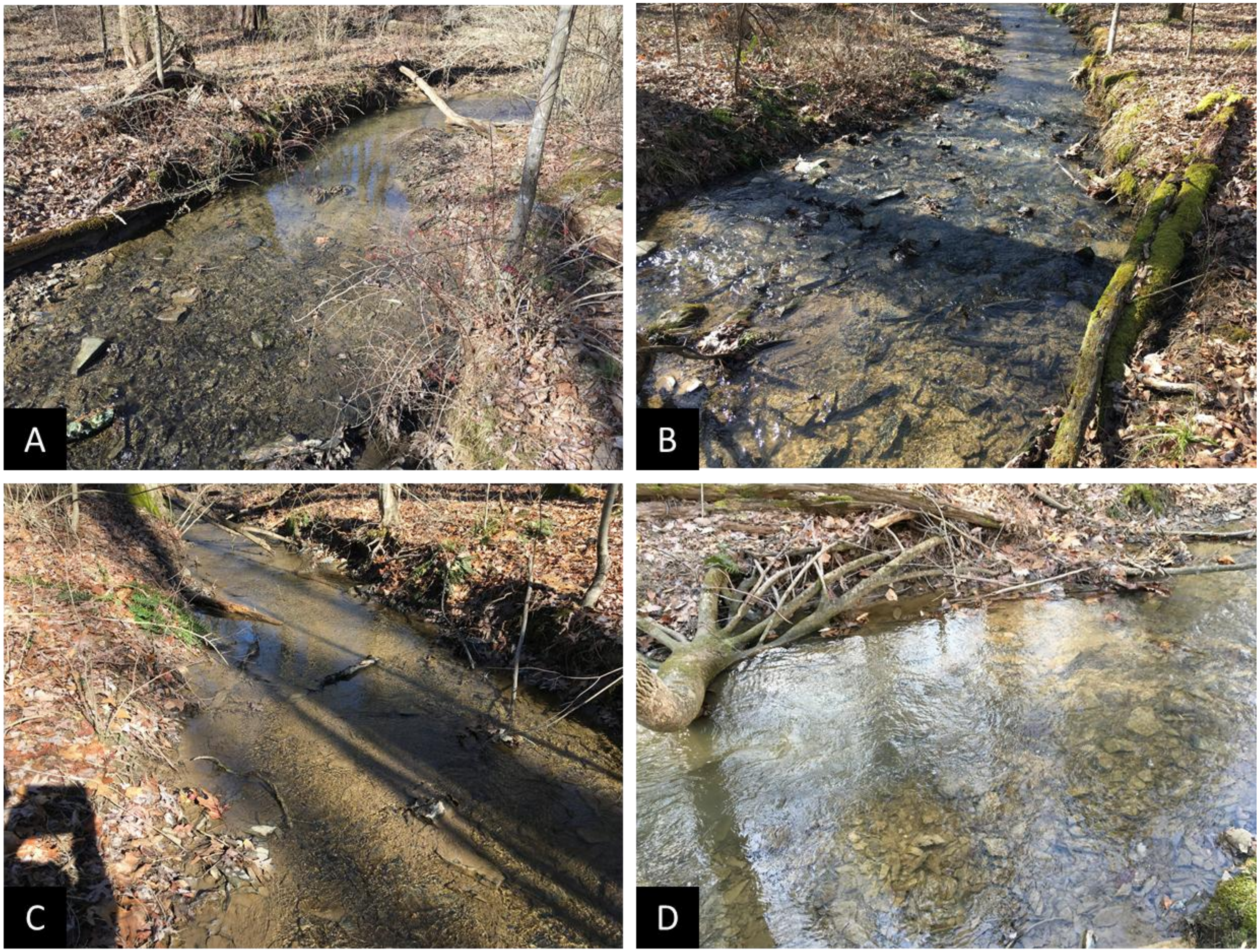

Figure 13. Eastern main tributary in the UNT Shermans Creek watershed. This tributary, which originates in an agricultural area, exhibited problematic sediment deposition for much of its initial length. However, it then passed through a large forested area where it gained additional flow volume and appeared healthier. Thus, the length of stream that was substantially degraded may not be long enough to be considered impaired.

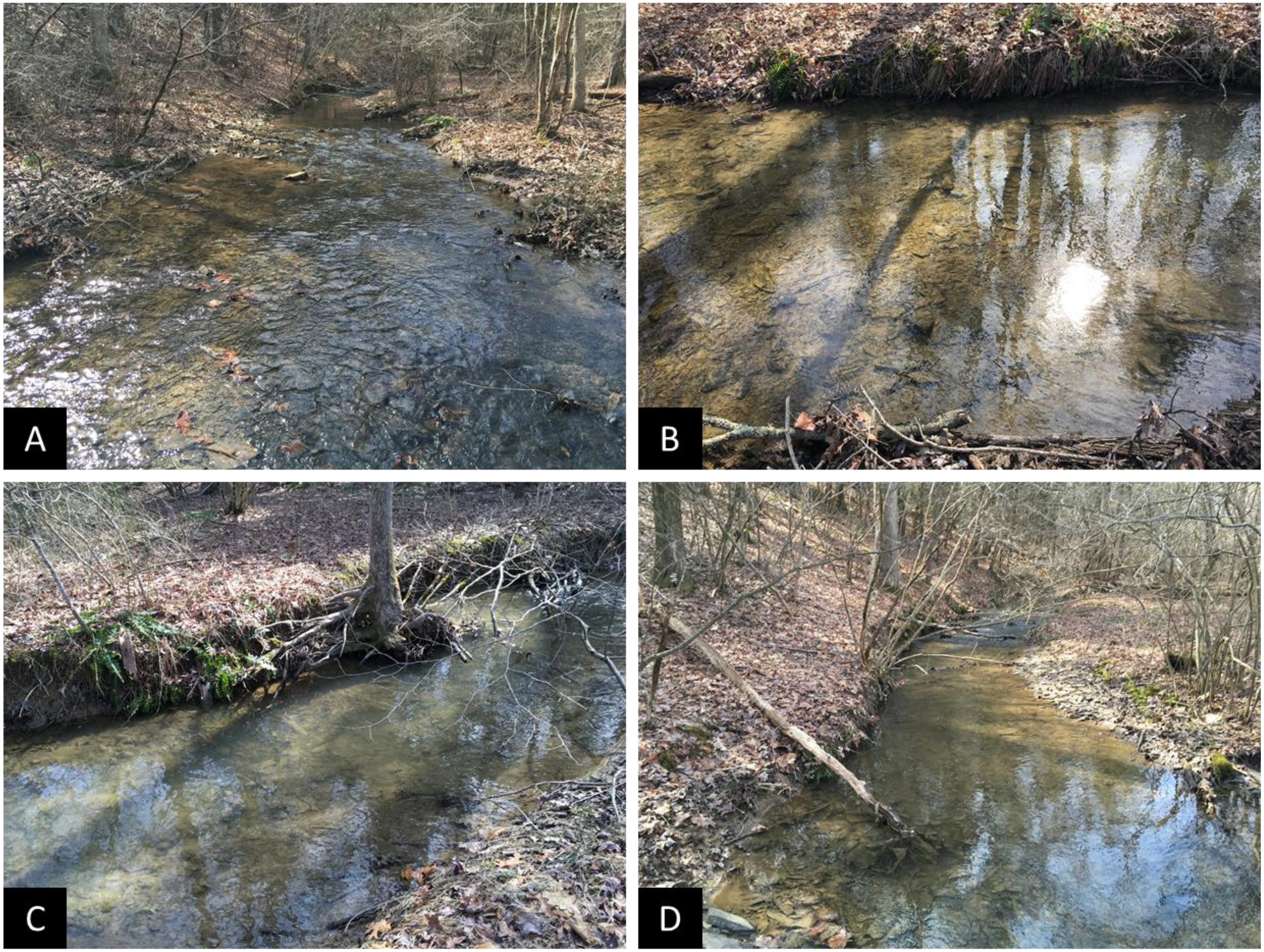

Figure 14. Western main tributary in the UNT Shermans Creek watershed. While some fine sediment deposition was apparent, this tributary appeared to be largely healthy.

Figure 15. Smaller tributaries in the UNT Shermans Creek watershed. Conditions within such tributaries were variable, with some appearing more healthy while others exhibiting obvious degradation.

Figure 16. Example landscapes within the UNT Shermans Creek watershed. This watershed tended to have large forested tracts intermixed with substantial agriculture lands.

Figure 17. Examples of conditions within the UNT Shermans Creek watershed that may be protective against fine sediment deposition. Much of the watershed was forested (A), including within riparian areas (B and C). Photograph D shows good overwinter crop residue coverage that may protect soils from erosion.

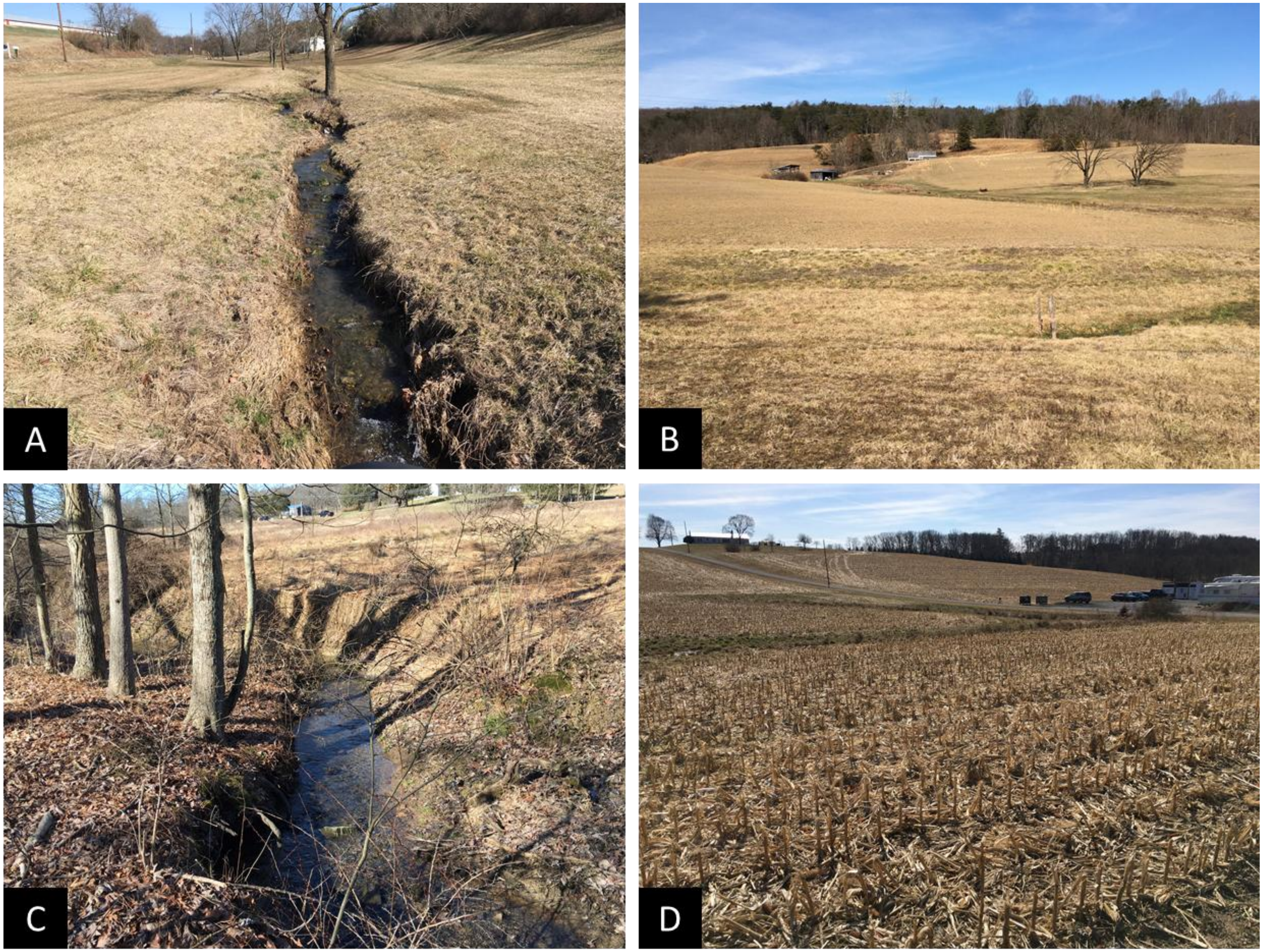

Figure 18. Examples of conditions within the UNT Shermans Creek watershed that may contribute to fine sediment pollution. In some cases streams lacked forested riparian buffers (A and C). Photographs B and D show large expanses of agricultural lands, which sometimes occurred on steep slopes.

HYDROLOGIC / WATER QUALITY MODELING

This section deals primarily with the $TMDL_{Avg}$ calculation, as use of annual average values was determined to be the most relevant way to express the "TMDL" variables. For information about the $TMDL_{Max}$ calculations, see the later "Calculation of a Daily Maximum '$TMDL_{Max}$'" section.

Estimates of sediment loading for the impaired and reference watersheds were calculated using the "Model My Watershed" application (MMW-Version 1.35.0), which is part of the WikiWatershed web toolkit developed through an initiative of the Stroud Water Research Center (Stroud Water Research Center 2024). MMW is a replacement for the MapShed desktop modelling application. Both programs calculate sediment and nutrient fluxes using the "Generalized Watershed Loading Function Enhanced" (GWLF-E) model. However, MapShed was built using a MapWindow GIS package that is no longer supported, whereas MMW operates with GeoTrellis, an open-source geographic data processing engine and framework. The MMW application is freely available for use at https://wikiwatershed.org/model/. In addition to the changes to the GIS framework, the MMW application continues to be updated and improved relative to its predecessor.

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

> *The GWLF model provides the ability to simulate runoff, sediment, and nutrient (nitrogen and phosphorus) loads from a watershed given variable-size source areas (e.g., agricultural, forested, and developed land). It also has algorithms for calculating septic system loads, and allows for the inclusion of point source discharge data. It is a continuous simulation model that uses daily time steps for weather data and water balance calculations. Monthly calculations are made for sediment and nutrient loads based on the daily water balance accumulated to monthly values.*
>
> *GWLF is considered to be a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple landuse/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 landuse/cover type. Finally, a water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values.

Streambank erosion is calculated as a function of factors such as the length of streams, the monthly stream flow, the percent developed land in the watershed, animal density in the watershed, the watersheds curve number and soil k factor, and mean topographic slope. For a detailed discussion of this modelling program, including a description of the data input sources, see Evans and Corradini (2016) and Stroud Research Center (2024).

MMW allows the user to adjust model parameters, such as the area of land coverage types, the use and efficiencies of conservation practices, the watershed's sediment delivery ratio, etc. Default values were used for the modelling run. Following the model run, a correction for the presence of existing riparian buffers was made in a BMP Spreadsheet Tool (Evans et al. 2020) that had been provided by MMW. The following paragraphs describe the riparian buffer correction method.

Riparian buffer coverage was estimated via a GIS analysis in ArcGIS Pro (Figures 19 and 20). Briefly, land cover per a high-resolution land cover dataset (University of Vermont Spatial Analysis Laboratory 2016) was examined within 100 feet of USGS High-Resolution NHD flowlines (Pennsylvania Land Trust Association 2019). 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. Then the sum of raster pixels that were classified as either tree canopy, wetlands or scrub-shrub 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 73% in the agricultural area of the impaired watershed versus 50% in the reference watershed.

An additional reduction credit was given to the reference watershed to account for its greater riparian buffering versus the impaired watershed. 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 (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 (Version 2020-01-09, Evans et al. 2020) that was provided by MMW, 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 watershed over the amount found in the impaired watershed, the length of USGS high-resolution NHD flowlines within the reference watershed was multiplied by the difference in the proportion of buffering between the agricultural area of the reference watershed versus that of the impaired watershed, 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 is 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 credited.

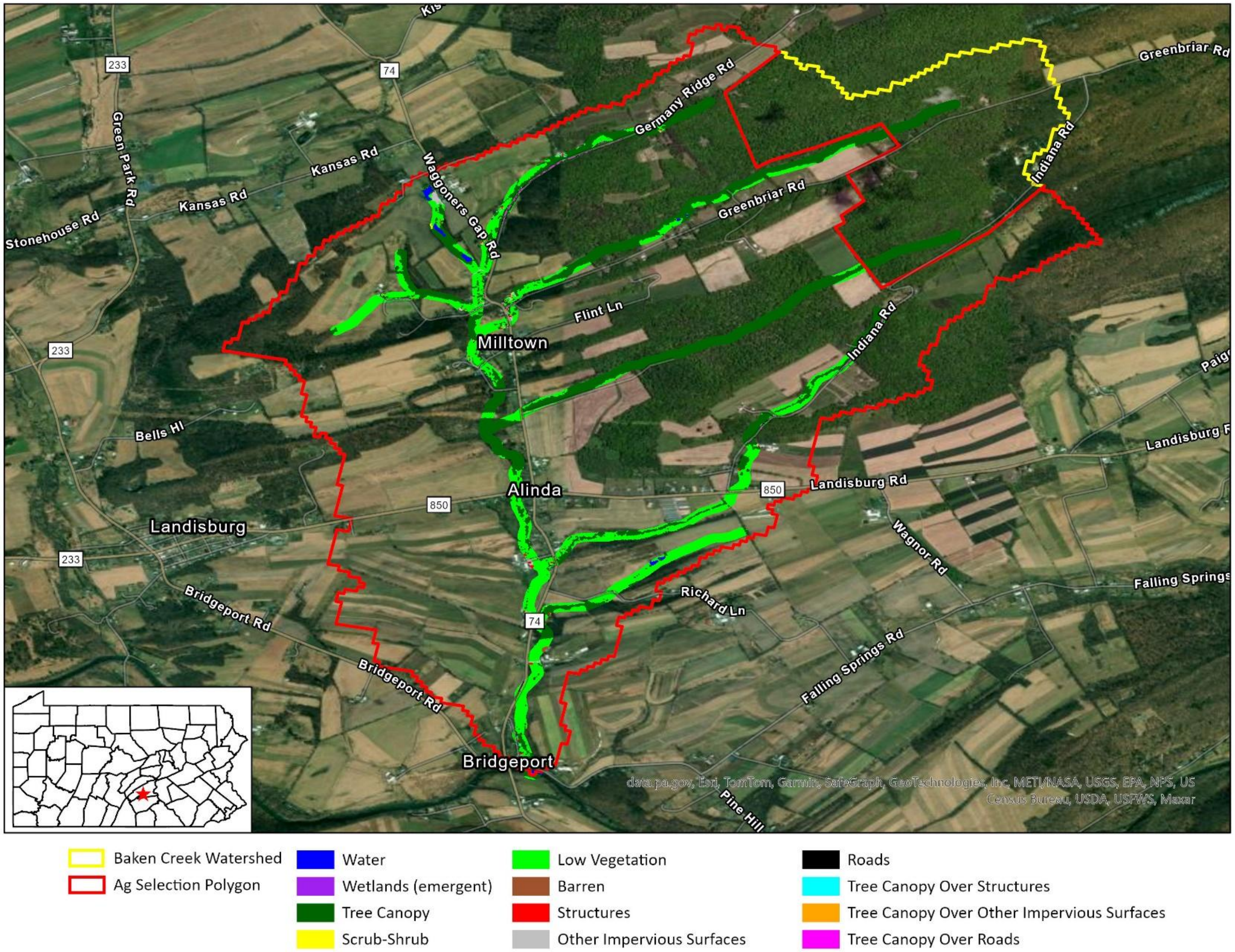

Figure 19. Riparian buffer analysis in the Baken Creek watershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. For this analysis, riparian buffers were considered to be comprised of tree canopy, shrub/scrub or wetlands. The rate of riparian buffering in the agricultural area was estimated to be about 50%.

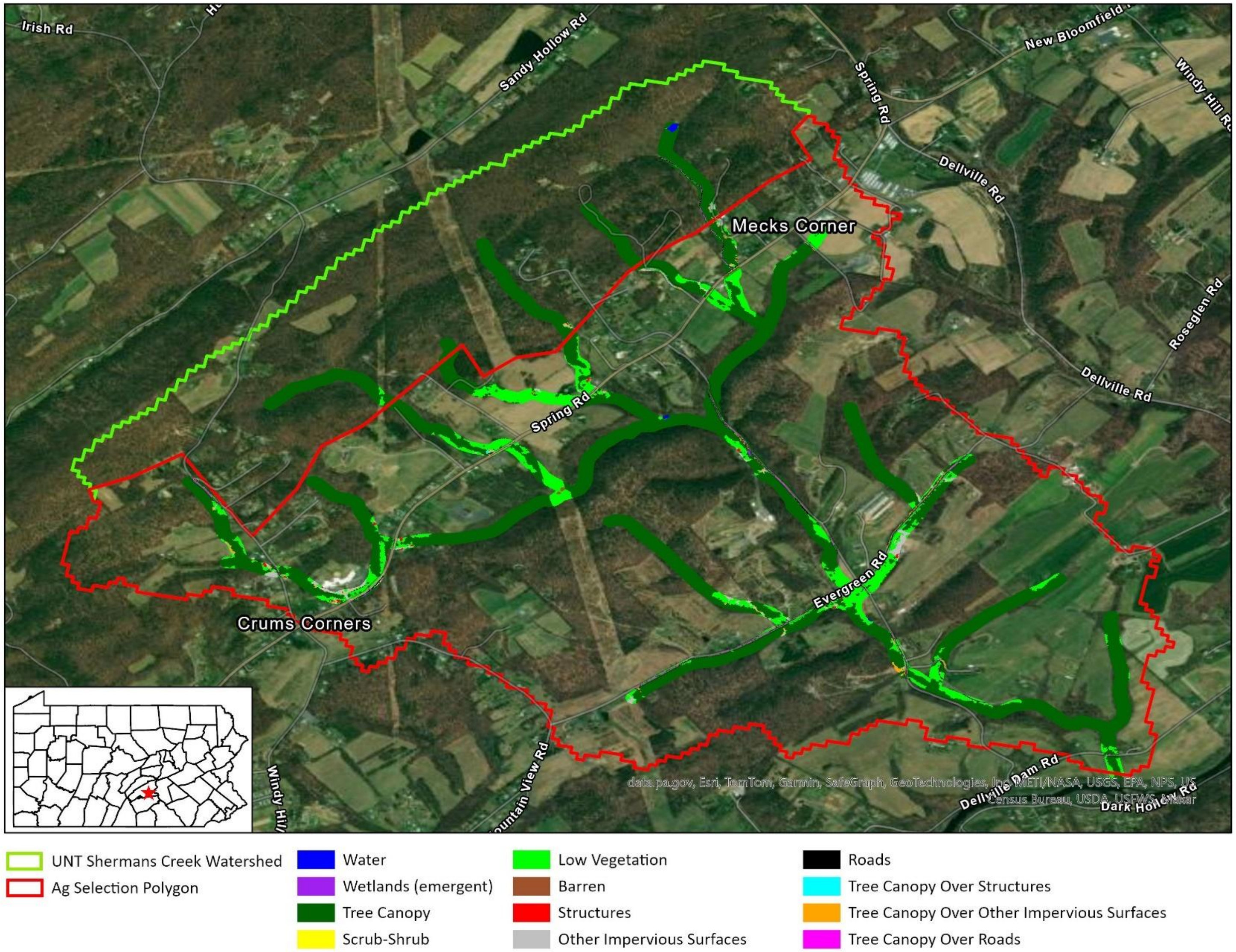

Figure 20. Riparian buffer analysis in the UNT Shermans Creek watershed. A raster dataset of high resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of USGS high-resolution NHD flowlines. For this analysis, riparian buffers were considered to be comprised of tree canopy, shrub/scrub or wetlands. The rate of riparian buffering in the agricultural area was estimated to be about 73%.

CALCULATION OF THE $TMDL_{AVG}$

The mean annual sediment loading rate for the unimpaired reference watershed (UNT Shermans Creek) was estimated to be 181 pounds per acre per year (Table 7). This was substantially lower than the estimated mean annual loading rate in the impaired Baken Creek watershed (347 pounds per acre per year, Table 8). Thus, to achieve the loading rate of the unimpaired watershed, sediment loading in the Baken Creek watershed should be reduced to 505,190 pounds per year or less (Table 9).

Table 7. Existing annual average loading values for the UNT Shermans Creek watershed, reference.

Source	Area (ac)	Sediment (lbs/yr)	Unit Area Load (lbs/ac*yr)
Hay/Pasture	635	249,347	393
Cropland	89	78,506	883
Forest and Shrub/Scrub	1,477	1,261	1
Wetland	10	28	3
Grassland/Herbaceous	7	525	71
Low Density Mixed Development	262	3,080	12
Medium Density Mixed Development	20	1,350	68
High Density Mixed	2	152	62
Streambank[1]		170,804	
Point Sources		20	
Riparian Buffer Discount[2]		-53,388	
total	2,501	451,683	181

[1]"Streambank" sediment loads were calculated using Model My Watershed's streambank routine which uses length rather than area.
[2]Riparian buffer discount provides a sediment reduction credit to account for the extra buffering in the reference watershed.

Table 8. Existing annual average loading values for the Baken Creek watershed, impaired.

Source	Area ac	Sediment lbs/yr	Unit Area Load lb/(ac*yr)
Hay/Pasture	637	244,514	384
Cropland	625	592,607	949
Forest and Shrub/Scrub	1,289	1,800	1
Wetland	10	27	3
Grassland/Herbaceous	-	9	-
Low Intensity Mixed Development	225	2,483	11
Medium Intensity Mixed Development	10	532	54
High Intensity Mixed Development	2	86	35
Streambank[1]		129,299	
Point Sources		0	

total		2,798	971,357	347

Table 9. Calculation of an annual average TMDL value for the Baken Creek watershed.

Pollutant	**Reference Mean Loading Rate** lbs/(ac*yr)	**Impaired Watershed Area** ac	**Target $TMDL_{Avg}$** lbs/yr
Sediment	181	2,798	505,190

CALCULATION OF LOAD ALLOCATIONS

In the TMDL equation, the load allocation (LA) is the load derived from nonpoint sources. The LA is further divided into the adjusted loads allocation (ALA), which is comprised of the nonpoint 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:

LA = ALA + LNR

Considering that the TMDL is the sum of the margin of safety (MOS), the wasteload allocation (WLA), and the load allocation (LA):

TMDL = MOS + WLA + LA,

then the LA is calculated as follows:

LA = TMDL - MOS - WLA

Thus, before calculating the LA, the MOS and WLA must be defined.

Margin of Safety

The MOS is a portion of pollutant loading that is reserved to account for uncertainties. Reserving a portion of the load as a safety factor requires further load reductions from the ALA to achieve the TMDL. For this analysis, the MOS_{Avg} was explicitly designated as ten-percent of the $TMDL_{Avg}$ based on professional judgment. Thus:

505,190 lbs/yr $TMDL_{Avg}$ * 0.1 = 50,519 lbs/yr MOS_{Avg}

Wasteload Allocation

There were no existing NPDES permittees in the watershed in need of an individual WLA (Table 4). Thus, the WLA will consist solely of a bulk reserve, which is a minor allowance for: existing dischargers not assigned individual WLAs, as well as minor increases from point sources as a result of future growth of existing or new sources. The bulk reserve was assigned a value of 1% of the TMDL load.

Thus, the total WLA was calculated as:

505,190 lbs/yr $TMDL_{Avg}$ * 0.01 = 5,052 lbs/yr bulk $reserve_{Avg}$ + 0 lb/yr permitted loads = 5,052 lbs/yr WLA_{Avg}

Load Allocation
Now that the MOS and WLA have been defined, the LA is calculated as:

505,190 lbs/yr $TMDL_{Avg}$ – (50,519 lbs/yr MOS_{Avg} + 5,052 lbs/yr WLA_{Avg}) = 449,619 lbs/yr LA_{Avg}

Loads Not Reduced and Adjusted Load Allocation
Since the impairments addressed by this TMDL were for sedimentation due to agriculture, sediment contributions from forests, wetlands, open lands and developed lands within the Baken Creek watershed were considered loads not reduced (LNR). LNR_{Avg} was calculated to be 4,938 lbs/yr (Table 10).

The LNR is then subtracted from the LA to determine the ALA:

449,619 lbs/yr LA_{Avg} – 4,938 lbs/yr LNR_{Avg} = 444,681 lbs/yr ALA_{Avg}

Table 10. Average annual load allocation, loads not reduced and adjusted load allocation

	Sediment, lbs/yr
Load Allocation (LA_{Avg})	**449,619**
Loads Not Reduced (LNR_{Avg}):	4,938
Forest	1,800
Wetland	27
Open Land (Grassland/Herbaceous)	9
Low Intensity Mixed Development	2,483
Medium Intensity Mixed Development	532
High Intensity Mixed Development	86
Adjusted Load Allocation (ALA_{Avg})	**444,681**

Note, the ALA is comprised of the anthropogenic sediment sources targeted for reduction: croplands, hay/pasture lands and streambanks (assuming an elevated erosion rate). The LNR is comprised of both natural and anthropogenic sediment sources. While anthropogenic, developed lands were considered minor sediment source in this watershed and thus not targeted for reduction. Forests, wetlands, and open lands were considered natural sediment sources.

CALCULATION OF SEDIMENT LOAD REDUCTIONS

To calculate load reductions by source, the ALA was further analyzed using the Equal Marginal Percent Reduction (EMPR) allocation method described in Appendix C. In this evaluation, croplands received a 59% prescribed reduction while hay/pasture lands and streambanks received reductions of 46% (Table 11).

Table 11. Average annual sediment load allocations for source sectors in the Baken Creek watershed.

Source Sector	Acres	Load Allocation lbs/yr	Current Load lbs/yr	Reduction Goal
CROPLAND	625	241,592	592,607	59%
HAY/PASTURE	637	132,842	244,514	46%
STREAMBANK		70,247	129,299	46%
AGGREGATE		444,681	966,419	54%

CALCULATION OF A DAILY MAXIMUM "$TMDL_{MAX}$" VALUE

When choosing the best timescale for expressing pollutant loading limits for siltation, two major factors must be considered:

1) Sediment loading is driven by storm events, and loads vary greatly even under natural conditions.
2) Siltation pollution typically harms aquatic communities through habitat degradation as a result of chronically excessive loading.

Considering then that siltation pollution has more to do with chronic degradation rather than acutely toxic loads/concentrations, pollution reduction goals based on average annual conditions are much more relevant than daily maximum values. Nevertheless, a truer "Total Maximum Daily Load" ($TMDL_{Max}$) is also calculated in the following.

MMW currently does not report daily loading rates, but its predecessor program, "MapShed" does. Note, that the original versions of the modelling program reported loads as monthly, yearly, or mean annual, and the ability to report daily output was added in 2013. Rather than reconstruct the modelling routines, it was decided to back-calculate these values using monthly loads and daily hydrology results. For sediment, monthly upland loads were reallocated to days proportionally based on the amount of monthly runoff that each day accounted for. Streambanks were handled similarly, except that stream flow rather than runoff was used. In cases where point sources are considered by the model, the monthly loads are simply divided by the number of days in the month. Additional methods relevant to nutrient loading were also developed, but they are beyond the context of the present study. (Dr. Barry Evans, MMW Developer, personal communication).

Thus, for the calculation of a $TMDL_{Max}$ value, modelling was initially conducted in MMW as described above, and the "Export GMS" feature was used to provide an input data file that was run in the Generalized Watershed Loading Functions-Enhanced Version 1.51 Model Simulation application provided with MapShed. The daily output was opened in Microsoft Excel, and current "maximum" daily loads were calculated as the 99^{th} percentiles (using the percentile.exc function) of estimated daily sediment loads in both the Baken Creek (impaired) and UNT Shermans Creek (reference) watersheds. The first year of data was excluded to account for the time it takes for the model calculations to become reliable. The 99th percentile was chosen because 1) sediment loading increases with the size of storm events, so, as long as there could be an even larger flood, a true upper limit to sediment loading cannot be defined and 2) 99% of the time achievement of water quality criteria is prescribed for other types of pollutants at 25 Pa. Code § 96.3(e).

As with the average loading values reported previously (see the Hydrologic / Water Quality Modelling section), a correction was made for the additional amount of existing riparian buffers in the reference watershed versus the impaired watershed. This was calculated simply by reducing the 99th percentile loading rate for the reference watershed by the same reduction proportion calculated previously for the average loading rate. After this, any relevant daily maximum point source loads, based eDMR data if available, were added to the watershed totals (see Tables 4 and 6).

Then, similarly to the $TMDL_{Avg}$ value reported in Table 9, $TMDL_{Max}$ was calculated as the 99th percentile daily load of the reference watershed divided by the acres of the reference watershed and then multiplied by the acres of the impaired watershed. Thus, the $TMDL_{Max}$ loading rate was calculated as 20,324 pounds per day (Table 12), which would be a 39% reduction from Baken Creek watershed's current 99th percentile daily loading rate of 33,488 pounds per day.

Table 12. Calculation of $TMDL_{Max}$ for the Baken Creek watershed.

Pollutant	**Reference 99th Percentile Loading Rate** lbs/(ac*d)	**Impaired Watershed Total Land Area** ac	**Target $TMDL_{Max}$** lbs/d
Sediment	7.3	2,798	20,324

Also, in accordance with the previous "Calculation of Load Allocations" section, the WLA_{Max} will consist solely of a bulk reserve, which was defined as 1% of the $TMDL_{Max}$. The MOS_{Max} was defined as 10% of the $TMDL_{Max}$. The LA_{Max} was then calculated as the amount remaining after subtracting the WLA_{Max} and the MOS_{Max} from the $TMDL_{Max}$. See Table 13 for a summary of these $TMDL_{Max}$ variables.

Table 13. 99th percentile of daily loading TMDL ($TMDL_{Max}$) variables for the Baken Creek watershed. All values are lbs/d.

Pollutant	**$TMDL_{Max}$**	**MOS_{Max}**	**WLA_{Max}**	**LA_{Max}**
Sediment	20,324	2,032	203	18,088

Mapshed did not break down daily loads by land cover type. Thus, the daily maximum load allocation variables were calculated assuming the same distribution as occurred for the annual average load allocation variables. For instance, if the streambanks allocation was 16% of LA_{Avg} it was assumed that it was also 16% of LA_{Max}. While the distribution of sources likely changes with varying flow levels, this might be an acceptable assumption considering that the largest flow events may control the bulk of annual sediment loading (Sloto et al. 2012). See Table 14 for a summary of the LA_{Max} variables.

Table 14. Allocation of the 99th percentile daily load allocation (LA_{Max}) for the Baken Creek watershed.

	Annual Average (lbs/yr)	Proportion of Load Allocation[1]	Max Daily (lbs/d)
Load Allocation	449,619	-	18,088
Loads Not Reduced	4,938	0.01	199
Adjusted Loads Allocation	444,681	0.99	17,890
Croplands	241,592	0.54	9,719
Hay/Pasturelands	132,842	0.30	5,344
Streambanks	70,247	0.16	2,826

[1]Because the modelling program did not break down daily loadings by land cover types, the load allocations for $TMDL_{Max}$ were calculated by assuming the same distribution as occurred for the LA_{Avg} variables. For instance, if the streambanks allocation was 16% of LA_{Avg} it was assumed that it was also 16% of LA_{Max}.

Because sediment loading varies so greatly with discharge, the $TMDL_{Max}$ value would probably only be relevant on a handful of days each year with the highest flow conditions. And, while these times are especially important to overall annual sediment loading (Sloto and Olson 2011, Sloto et al. 2012), it is cautioned that reliance solely on a $TMDL_{Max}$ value may not be protective of the Baken Creek watershed since chronic excessive sediment inputs occurring at lower discharge levels may be ignored. Take for instance an extreme scenario where the $TMDL_{Max}$ was met every day but never exceeded. In this case, the annual sediment loading in the Baken Creek watershed would skyrocket to 7,418,189 lbs/yr, which is more than seven-times the current annual average. The $TMDL_{Avg}$ value on the other hand is sensitive to typical conditions, extreme events, and long-term effects, and thus is the most relevant of the two TMDL targets for achieving restoration in the Baken Creek watershed. Therefore, BMP implementation would ultimately be deemed adequate if the prescribed annual average reduction was satisfied.

CONSIDERATION OF CRITICAL CONDITIONS AND SEASONAL VARIATIONS

According to MMW's technical documentation (Stroud Water Research Center 2024), MMW 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. Furthermore, this document calculates both annual average and 99th percentile daily TMDL values. See the discussion of the relevance of these values in the previous section. Seeking to support both of these values would be protective under both long-term average and extreme flow event conditions.

RECOMMENDATIONS

This document proposes a 48% reduction in annual average sediment loading for the Baken Creek watershed. To achieve this goal while maintaining a margin of safety and minor allowance for point sources, annual average sediment loading from croplands should be reduced by 59%, while loading from hay/pasture lands and streambanks should be reduced by 46% each. The 99th percentile daily sediment loading should be reduced by 39%. Reductions in stream sediment loading due to agricultural activities can be made through the implementation of required Erosion and Sediment Control Plans (Pennsylvania Clean Streams Law, Title 25 Environmental Protection, § 102.4, see also Appendix D) and through the use of BMPs such as conservation tillage, cover crops, vegetated filter strips, rotational grazing, livestock exclusion fencing, riparian buffers, etc.

Should sufficient landowner interest develop in the future, restoration of this watershed is recommended, especially since Baken Creek is a pollution source to Shermans Creek, which is of special conservation and recreational significance. The prior restoration plan for this watershed (see DEP 2022a) may provide much of the foundation for a new plan, though at least some updating would likely be needed in the future. According to site observations and prior analysis, increased use of livestock exclusion fencing, riparian buffers, drainageway protection, stream restoration/legacy sediment removal, agricultural erosion and sedimentation plan implementation and conservation tillage may be especially beneficial.

Use of riparian buffers is widely recognized as one of the best ways to promote stream health. Riparian buffers protect streams from sedimentation and nutrient impairments by filtering these pollutants from runoff and floodwaters and by protecting streambanks from erosion. Furthermore, riparian buffers are also beneficial for many other reasons beyond just protecting from sedimentation and nutrients. For instance, riparian buffers may: filter out other pollutants such as pesticides; provide habitat and nutrition for aquatic, semi-aquatic and terrestrial organisms; and moderate stream temperature. Thus, use of forested riparian buffers should be encouraged wherever possible.

Key personnel from the regional DEP office, the County Conservation District and other state and local agencies and/or watershed groups should be involved in developing a restoration strategy. There are a number of possible funding sources for agricultural BMPs and stream restoration projects, including: The Federal Nonpoint Source Management Program (§ 319 of the Clean Water Act), PA DEP's Growing Greener Grant Program, United States Department of Agriculture's Natural Resource Conservation Service funding, and National Fish and Wildlife Foundation Grants.

PUBLIC PARTICIPATION

Public notice of a draft sediment TMDL for the Baken Creek watershed was published in the August 22, 2026 issue of the *Pennsylvania Bulletin* to foster public comment. A 30-day period was provided for the submittal of comments. Public comments and their responses will be placed in Appendix E.

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APPENDIX A: MODEL MY WATERSHED GENERATED DATA TABLES

Table A1. Model My Watershed land cover outputs for the Baken Creek watershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0	0.03
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	0.72	6.38
Developed, Low Intensity	22	0.19	1.69
Developed, Medium Intensity	23	0.04	0.32
Developed, High Intensity	24	0.01	0.06
Barren Land (Rock/Sand/Clay)	31	0	0
Deciduous Forest	41	4.54	40.07
Evergreen Forest	42	0.01	0.12
Mixed Forest	43	0.67	5.95
Shrub/Scrub	52	0	0
Grassland/Herbaceous	71	0	0.02
Pasture/Hay	81	2.58	22.75
Cultivated Crops	82	2.53	22.34
Woody Wetlands	90	0.03	0.22
Emergent Herbaceous Wetlands	95	0.01	0.06
Total		11.33	100

Table A2. Model My Watershed land cover outputs for the UNT Shermans Creek watershed based on NLCD 2019.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0	0
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	0.67	6.59
Developed, Low Intensity	22	0.39	3.86
Developed, Medium Intensity	23	0.08	0.79
Developed, High Intensity	24	0.01	0.09
Barren Land (Rock/Sand/Clay)	31	0	0
Deciduous Forest	41	4.89	48.29
Evergreen Forest	42	0.05	0.52
Mixed Forest	43	1.03	10.21
Shrub/Scrub	52	0.01	0.08
Grassland/Herbaceous	71	0.03	0.29
Pasture/Hay	81	2.57	25.37
Cultivated Crops	82	0.36	3.55
Woody Wetlands	90	0.03	0.27
Emergent Herbaceous Wetlands	95	0.01	0.1
Total		10.12	100

Table A3. 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	5.44	0.63	4.81	0	0.33	7.15
Feb	6.15	0.8	5.35	0	0.51	7.31
Mar	7.24	0.36	6.88	0	1.79	8.36
Apr	6.3	0.1	6.2	0	4.53	8.41
May	4.51	0.07	4.44	0	8.81	10.51
Jun	3.57	0.78	2.79	0	12.21	10.58
Jul	1.51	0.12	1.39	0	11.59	9.86
Aug	0.57	0.08	0.49	0	9.26	8.64
Sep	0.83	0.62	0.21	0	6.02	9.04
Oct	1.11	0.43	0.68	0	3.6	8.06
Nov	2.07	0.28	1.79	0	1.77	9.38
Dec	4.68	0.45	4.24	0	0.69	8.11
Total	43.98	4.72	39.27	0	61.11	105.41

Table A4. Model My Watershed hydrology outputs for the UNT Shermans Creek watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.85	0.64	5.21	0	0.36	7.15
Feb	6.29	0.81	5.48	0	0.56	7.31
Mar	7.25	0.39	6.86	0	1.97	8.36
Apr	6.17	0.11	6.06	0	4.75	8.41
May	4.31	0.09	4.23	0	8.97	10.51
Jun	3.37	0.76	2.61	0	11.22	10.58
Jul	1.42	0.12	1.29	0	10.38	9.86
Aug	0.61	0.09	0.52	0	8.49	8.64
Sep	1.03	0.6	0.43	0	5.85	9.04
Oct	1.69	0.43	1.26	0	3.72	8.06
Nov	2.83	0.3	2.53	0	1.84	9.38
Dec	5.56	0.46	5.09	0	0.74	8.11
Total	46.38	4.8	41.57	0	58.85	105.41

Table A5. Model My Watershed outputs for sediment in the Baken Creek watershed.

Sources	Sediment (kg)
Hay/Pasture	110,890.50
Cropland	268,755.90
Wooded Areas	816.4
Wetlands	12.4
Open Land	4.2
Barren Areas	0
Low-Density Mixed	235.8
Medium-Density Mixed	241.1
High-Density Mixed	39.1
Low-Density Open Space	890.3
Farm Animals	0
Stream Bank Erosion	58,639.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table A6. Model My Watershed outputs for sediment in the UNT Shermans Creek watershed.

Sources	Sediment (kg)
Hay/Pasture	113,082.60
Cropland	35,603.50
Wooded Areas	571.9
Wetlands	12.5
Open Land	237.9
Barren Areas	0
Low-Density Mixed	515.3
Medium-Density Mixed	612.3
High-Density Mixed	68.9
Low-Density Open Space	881.7
Farm Animals	0
Stream Bank Erosion	77,462.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

APPENDIX B: STREAM SEGMENTS IN THE BAKEN CREEK WATERSHED WITH AQUATIC LIFE USE IMPAIRMENTS

ATTAINS ID:	Length (miles):	Impairment Source:	Impairment Cause:
PA-SCR-56401525	0.04	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401581	0.14	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401587	0.03	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401667	1.14	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401669	0.19	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401765	1.72	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401773	0.18	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401777	0.01	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401783	0.16	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401785	0.22	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401831	0.16	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401833	0.11	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56401855	0.31	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56402021	1.74	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56402023	0.45	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56402319	1.71	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56402321	0.67	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56402445	0.78	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56402447	0.24	REMOVAL OF RIPARIAN VEGETATION	SILTATION
PA-SCR-56402763	0.70	REMOVAL OF RIPARIAN VEGETATION	SILTATION

APPENDIX C: EQUAL MARGINAL PERCENT REDUCTION METHOD

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

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

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

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

Table C1. Equal marginal percent reduction calculations for the Baken Creek watershed.

	Current Load, lbs/yr	Any > ALA?	If > ALA, reduce to ALA	How much does sum exceed ALA?	Proportions of total after initial adjust	Assign reductions still needed per proportions after intial adjust	ALA: subtract reductions still needed from initial adjust	proportion Reduction
Cropland	592,607	yes	444,681		0.54	203,089	241,592	0.59
Hay/Pasture	244,514	no	244,514	373,813	0.30	111,671	132,842	0.46
Streambank	129,299	no	129,299		0.16	59,052	70,247	0.46
sum	**966,419**		**818,494**		**1.00**	**373,813**	**444,681**	**0.54**

APPENDIX D: 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 USEPA’s implementing regulations (40 CFR 130) require:

- States to develop lists of impaired waters for which current pollution controls are not stringent enough to meet water quality standards (the list is used to determine which streams need TMDLs);
- States to establish priority rankings for waters on the lists based on severity of pollution and the designated use of the waterbody; states must also identify those waters for which TMDLs will be developed and a schedule for development;
- States to submit the list of waters to USEPA every 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
- USEPA to approve or disapprove state lists and TMDLs within 30 days of final submission.

Pennsylvania Clean Streams Law Requirements, Agricultural Operations

Pennsylvania farms 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 DEP, 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 groundwater in a watershed.

APPENDIX E: COMMENT AND RESPONSE