Cisna Run Sediment and Phosphorus TMDLs

Perry County, Pennsylvania

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Executive Summary

“Total Maximum Daily Loads” (TMDLs) for sediment and phosphorus were developed for the Cisna Run Watershed (Figure 1) to address the siltation and nutrient impairments noted in the 2016 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report (Integrated Report), including the Clean Water Act Section 303(d) List. Grazing related agriculture has been identified as the cause of these impairments. Because Pennsylvania does not have numeric water quality criteria for sediment or phosphorus, 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. Existing annual average sediment loading in the Cisna Run Watershed is estimated to be 2,824,140 pounds per year. Phosphorus loading was estimated to be 5,043 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 49% to 1,432,843 pounds per year, and phosphorus loading should be reduced by 38% to 3,109 pounds per year. Allocation among the annual average TMDL variables is summarized in Table 1. To achieve these reductions while maintaining 10% margins of safety and minor allowances for point sources, annual average sediment loading from croplands should be reduced by 60% whereas loading from hay/pasture lands and streambanks should be reduced by 48%. Annual average phosphorus loadings from croplands, hay/pasture lands, streambanks, and farm animals should be reduced by 51% each.

Table 1. Summary of Annual Average $TMDL_{Avg}$ Variables for the Cisna Run Watershed

	lbs/yr:					
Pollutant	$TMDL_{Avg}$	MOS_{Avg}	WLA_{Avg}	LA_{Avg}	LNR_{Avg}	ALA_{Avg}
Sediment	1,432,843	143,284	14,328	1,275,231	5,112	1,270,119
Phosphorus	3,109	311	31	2,767	606	2,161

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 99thpercentile daily loading in the Cisna Run Watershed was estimated to be 105,659 pounds per day of sediment and 213 pounds per day of phosphorus. To meet water quality objectives, 99th percentile daily sediment loading should be reduced by 50% to 52,366 pounds per day. 99th percentile daily phosphorus loading should be reduced by 40% to 128 pounds per day. Allocation of 99th percentile daily sediment and phosphorus loading among the TMDL variables is summarized in Table 2.

Table 2. Summary of 99th Percentile Daily Loading TMDL ($TMDL_{Max}$) Variables for the Cisna Run Watershed						
lbs/d:						
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}	LNR_{Max}	ALA_{Max}
Sediment	52,366	5,237	524	46,606	187	46,419
Phosphorus	128	12.8	1.3	114	25	89

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

Cisna Run is a tributary of Sherman Creek, with the confluence near the Village of Cisna Run in Perry County, PA. This Total Maximum Daily Load (TMDL) document has been prepared to address the siltation and nutrient impairments noted in the Cisna Run Watershed per the 2016 Final Integrated Report (see Appendix A for a description of assessment methodology). The study watershed (Figure 1) contains approximately 9.6 stream miles, all of which were designated for high-quality cold-water fishes (Table 3). Cisna Run is of special interest because it is a pollutant source to Sherman Creek which is listed as attaining an exceptional value use both upstream and downstream of Cisna Run. Considering that an exceptional value listing is quite rare for such a large stream in southcentral Pennsylvania, it is hoped that this TMDL will not only benefit the Cisna Run Watershed, but will also have a positive effect on downstream reaches of Sherman Creek (Figure 2).

Grazing related agriculture was identified as the source of the impairments, and indeed recent site visits revealed problematic grazing practices. The removal of natural vegetation and disturbance of soils 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. Soil erosion, along with animal waste and fertilizer use, may lead to excessive phosphorus loading in streams and in turn eutrophication, which may lower dissolved oxygen concentrations, increase pH, change community composition, and degrade aesthetic value.

While Pennsylvania does not have numeric water quality criteria for sediment or phosphorus, 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 grazing-related agriculture has been identified as the source of the impairments, this TMDL document is applicable to all significant sources of phosphorus that may contribute to eutrophication, as well as all significant sources of sediment and solids that may settle to form deposits. In addition to grazing lands, croplands are of particular interest because they comprise a large proportion of the land area in the watershed (approximately 29%, see Appendix B, Table B1) and they often have high nutrient and sediment runnoff rates.

According to the "Model My Watershed" application, land use in this watershed is estimated to be 22% forest/naturally vegetated lands, 72% agriculture, and 6% mixed development. It is apparent in Figure 1 that forested lands are mostly restricted to the uplands on the margins of the watershed, whereas the lowlands have been nearly completely deforested. The agricultural lands were dominated by pasture/hay lands (43% or total land cover, see Appendix B, Table B1). There were no NPDES permitted point source discharges in the watershed with numeric limits relevant to sedimentation or phosphorus (Table 4).

Table 3. Aquatic-Life Impaired Stream Segments in the Cisna Run Watershed per the 2016 Final Pennsylvania Integrated Report

HUC: 02050305 – Lower Susquehanna-Swatara				
Source	EPA 305(b) Cause Code	Miles	Designated Use	Use Designation
Grazing Related Ag.	Siltation	9.6	HQ-CWF, MF	Aquatic Life
Grazing Related Ag.	Nutrients	9.6	HQ-CWF, MF	Aquatic Life

HUC= Hydrologic Unit Code; HQ-CWF=High Quality-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 C for a listing of each stream segment and Appendix A for more information on the listings and listing process

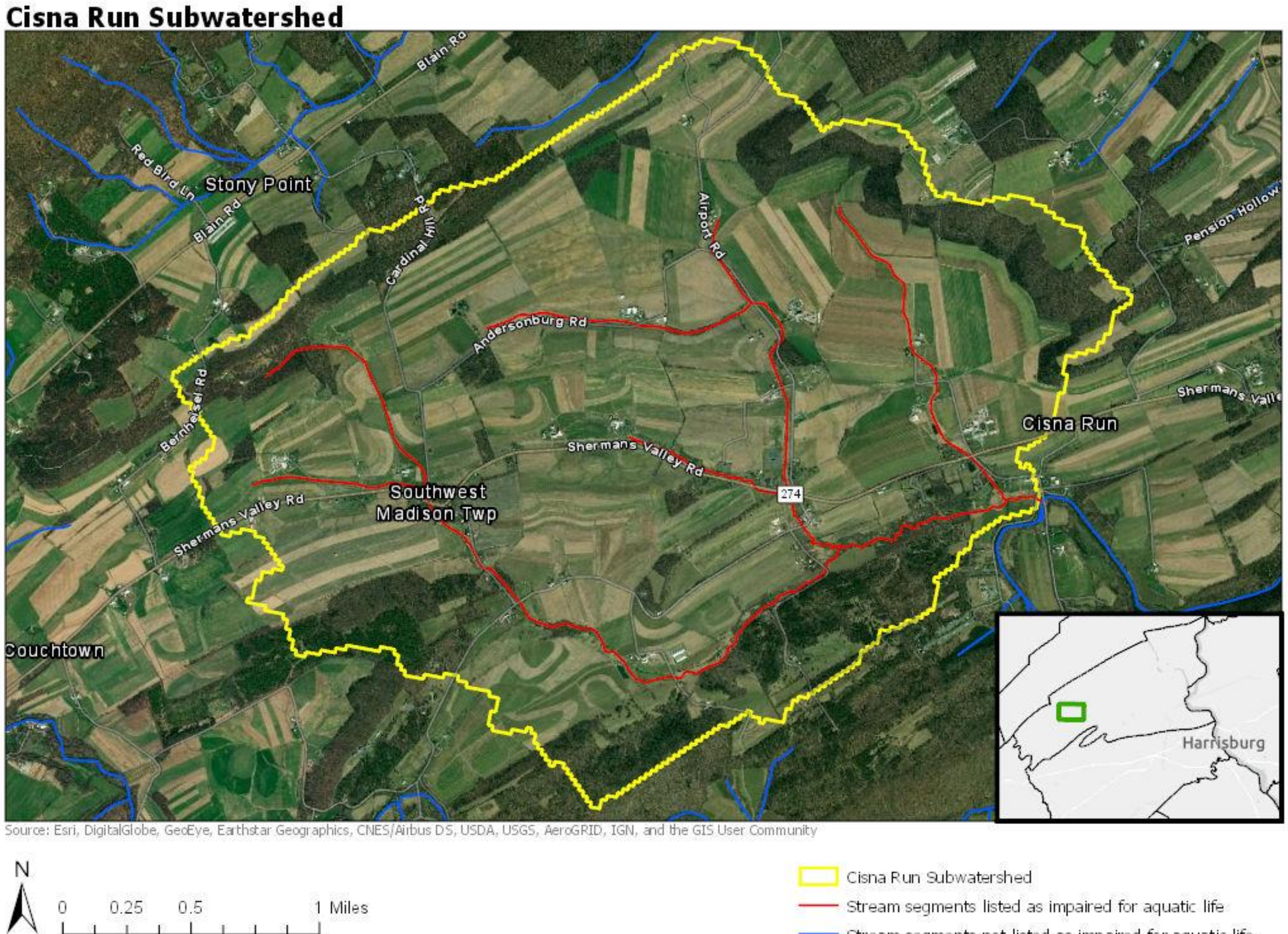


Figure 1. Cisna Run Watershed. All stream segments within the watershed were listed as impaired for siltation and nutrients per the 2016 final Integrated Report (see PA DEP's 2016 Integrated Report Viewer available at: http://www.depgis.state.pa.us/integrated_report/index.html.)

Table 4. Existing NPDES Permitted Discharges in the Cisna Run Watershed and their Potential Contribution to Sediment and Phosphorus Loading.					
		Sediment Load		Phosphorus Load	
Permit No.	Facility Name	mean lb/yr	max lb/d	mean lb/yr	max lb/d
PA0262081	Texas Eastern Trans LP[1]	NA	NA	NA	NA
PA0246735	Texas Eastern Trans LP[2]	NA	NA	NA	NA
PA0265934	David S. Morrow Farm CAFO[3]	NA	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

NA – Not applicable. NPDES permit did not include numeric effluent limits relevant to sediment or phosphorus loading.

[1]Inactive permit for discharge associated with hydrostatic testing of pipeline.

[2]Terminated permit for discharge associated with hydrostatic testing of pipeline.

[3]Permit for a concentrated animal feeding operation (CAFO). 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/nutrient 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, loadings from CAFOs are accounted for in the modeling of land uses, with the assumption of no additional CAFO-related BMPs.

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

Figure 2. Mouth of Cisna Run at Sherman Creek. After a few days of rain, water from Cisna Run was very turbid whereas Sherman Creek was otherwise clear.

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 any 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.

Because Pennsylvania does not have numeric water quality criteria for sediment or phosphorus, the "Reference Watershed Approach" was used. This method estimates loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired. Then, the loading rates in the unimpaired watersheds are 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 unimpaired 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 and nutrient loading rates. 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 reduction goals that are unattainable, or nonsensical TMDL calculations that suggest that loadings in the impaired watershed should be increased.

To determine the suitability of the reference site, the Department's Integrated Report GIS-based website (available at http://www.depgis.state.pa.us/integrated_report/index.html) was used to search for nearby watersheds that were of similar size as the Cisna Run Watershed, but lacked stream segments listed as impaired for sediment or nutrients.

Considering that it was nearby (only about 20 miles away), occupied a similar landscape position within the same ridge and valley system (Figure 3), and not listed as impaired for sediment or nutrients, the Wildcat Run Watershed, also in Perry County, was explored for use as a reference. Since it is required that the reference watershed be +/-30% of the impaired watershed's area, a delineation point was chosen upstream of the mouth of Wildcat Run to create a subwatershed that was approximately the same size as the impaired watershed (Figure 4, Table 5).

To confirm the suitability of the reference site, Model My Watershed, DEP's internal GIS databases, and various other GIS based applications were used to compare factors such as land cover/use, geology, soil drainage and slope (Table 5). Pre-existing macroinvertebrate and physical habitat assessment data were reviewed and both watersheds were visited to explore conditions. It was ultimately concluded that Wildcat Run was a suitable reference.

Table 5. Comparison of the Impaired (Cisna Run) and Reference (Wildcat Run) Watersheds.

	Cisna Run Watershed	Wildcat Run Subwatershed
Phys. Province[1]	100% Susquehanna Lowland Section of the Ridge and Valley Province	88% Susquehanna Lowland Section of the Ridge and Valley Province 12% Anthracite Upland Section of the Ridge and Valley Province
Land Area, ac[2]	4,123	4,457
Land Use [2]	72% Agriculture 22% Forest/Natural Vegetation 6% Other	40% Agriculture 53% Forest/Natural Vegetation 7% Other
Soil Infiltration[3]	9% Group A 76% Group B 1% Group B/D 4% Group C 3% Group C/D 8% Group D	12% Group A 57% Group B 0.9% Group B/D 10% Group C 4% Group C/D 16% Group D
Dominant Bedrock [4]	47% Limestone 40% Calcareous Shale 14% Shale	42% Siltstone 23% Sandstone 22% Mudstone 13% Shale
Average Precipitation[5], in/yr	41.5	41.5
Average Surface Runoff[5], in/yr	2.1	2.2
Average Elevation[5] (ft)	741	677

Average Slope[5]	8%	13%
Stream Channel Slope[5]	1st order:1.2% 2nd order: 0.4%	1st order: 1.7% 2nd order 0.7%

[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 based on NLCD 2011
[3]As reported by Model My Watershed's analysis of USDA gSSURGO 2016
[4]Per Bedrock Geology GIS layer provided by Pennsylvania Bureau of Topographic and Geological Survey, Dept. of Conservation and Natural Resources
[5]As reported by Model My Watershed

Based on the summaries of landcover reported by the "Model My Watershed" application, both watersheds had significant agricultural land coverage, though at 72% of land area, it was the dominant land use type in the Cisna Run Watershed. In contrast, forests/naturally vegetated lands comprised slightly more than half of the landcover in the Wildcat Run Subatershed (Table 5). Both watersheds had very little developed lands and were dominated by moderate infiltration, Class B soils. The calculated surface runoff rates were nearly identical in the two watersheds.

The two watersheds differed in that the Cisna Run Watershed had large amounts of limestone bedrock whereas Wildcat Run did not, and there was a concern that this could cause large differences in hydrology. However, this difference was deemed acceptable because Cisna Run's limestone was of the Keyser-Tonoloway formation, which is less often associated with the karst features, such as sinkholes, that produce high-volume springs in other regions of Pennsylvania. In fact, a GIS analysis revealed no mapped sinkholes in the Cisna Run Watershed or surrounding areas. And, in any case, the surface runnof rate in the two watersheds was nearly identical. It should also be noted that Wildcat Run's topography was moderately steeper (13% versus 8%), and its stream segments tended to be more incised, particularly in the lower reaches. However, the topographic differences between the two watersheds were not extreme, and no better nearby low-gradient references could be found.

Finally, it should also be considered that Cisna Run was designated for high-quality cold-water fishes whereas Wildcat Run was listed simply for cold-water fishes. However, this difference was also deemed acceptable for the following reasons. For one, Cisna Run's high-quality designation appears to be part of a larger high-quality designation associated with the Sherman Creek Watershed. Based on a review of historic aerial photographs, the Cisna Run Watershed was largely cleared for agriculture long before the Clean Water Act, making it unlikely that it ever supported a high-quality use in modern times. Secondly, no clearly attaining, high-quality, similarly low-gradient reference streams could be found nearby. Such references could be found in distant parts the state, but they often had so little agricultural cover that, if used as a reference, the prescribed sediment and nutrient reductions would be so high as to be practically unachievable without largescale agricultural land retirement. Thus, use of a non-high-quality reference was determined to be most appropriate in this situation.

As was the case for the Cisna Run Watershed, there were no NPDES permitted point source discharges in the Wildcat Run Subwatershed with numeric limits relevant to sedimentation or phosphorus (Table 6).

Table 6. Existing NPDES Permitted Discharges in the Wildcat Run Subwatershed and their Potential Contribution to Sediment and Phosphorus Loading.					
		Sediment Load		Phosphorus Load	
Permit No.	Facility Name	mean lb/yr	max lb/d	mean lb/yr	max lb/d
None	None	NA	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.

After selecting the potential reference, the two watersheds were visited during October 2019 to confirm the suitability of the reference as well as to explore whether there were any obvious land use differences that may help to explain why one watershed was impaired for sediment and nutrients while the other was attaining. Based on site observations and GIS analysis, it is hypothesized that the Cisna Run Watershed's impairments are attributable to three key factors: 1) the extreme amount of landcover devoted to agriculture, 2) the lack of expansive forested riparian buffers and 3) poor grazing land management. The nearly 72% agricultural coverage of the Cisna Run Watershed is comparable to watersheds of the most heavily farmed regions of the state, so impairment may be expected even if agricultural practices were good. Indeed, much effort appears to have been made to incorporate cropland BMPs such as conservation tillage, strip-cropping, contour farming. Of particular note was the use of herbaceous buffers/grassy strips along both waterways and drainage swales (Figures 5 and 7). What was largely missing however, was the expansive forested buffers that were common in the Wildcat Run Subwatershed. Finally, a few instances were observed where pasturelands were degraded to the point of leaving bare soils (Figure 6), and some of these sites were near streams.

In contrast, the attaining Wildcat Run reference subwatershed had large forested tracts on both its northern and southern margins and also along much of its stream segments (Figures 4 and 8). It was estimated that approximately 75% of the land cover within 100 ft of its stream segments (NHD flowlines) were comprised of forests versus only 28% in the Cisna Run Watershed. As was the case for the Cisna Run Watershed, cropland management typically incorporated BMPs such as conservation tillage, contour farming, and herbaceous buffers, though there were some obvious cases where practices could be improved (Figures 8 and 9).Unlike the Cisna Run Watershed, no highly problematic pasture lands were observed near stream segments within the Wildcat Run Subwatershed. In addition to anthropogenic land use factors, it should also be noted that better streambed conditions within the Wildcat Run Subwatershed may also be in part due to it having somewhat steeper stream channel slopes versus the Cisna Run Watershed (Table 5).

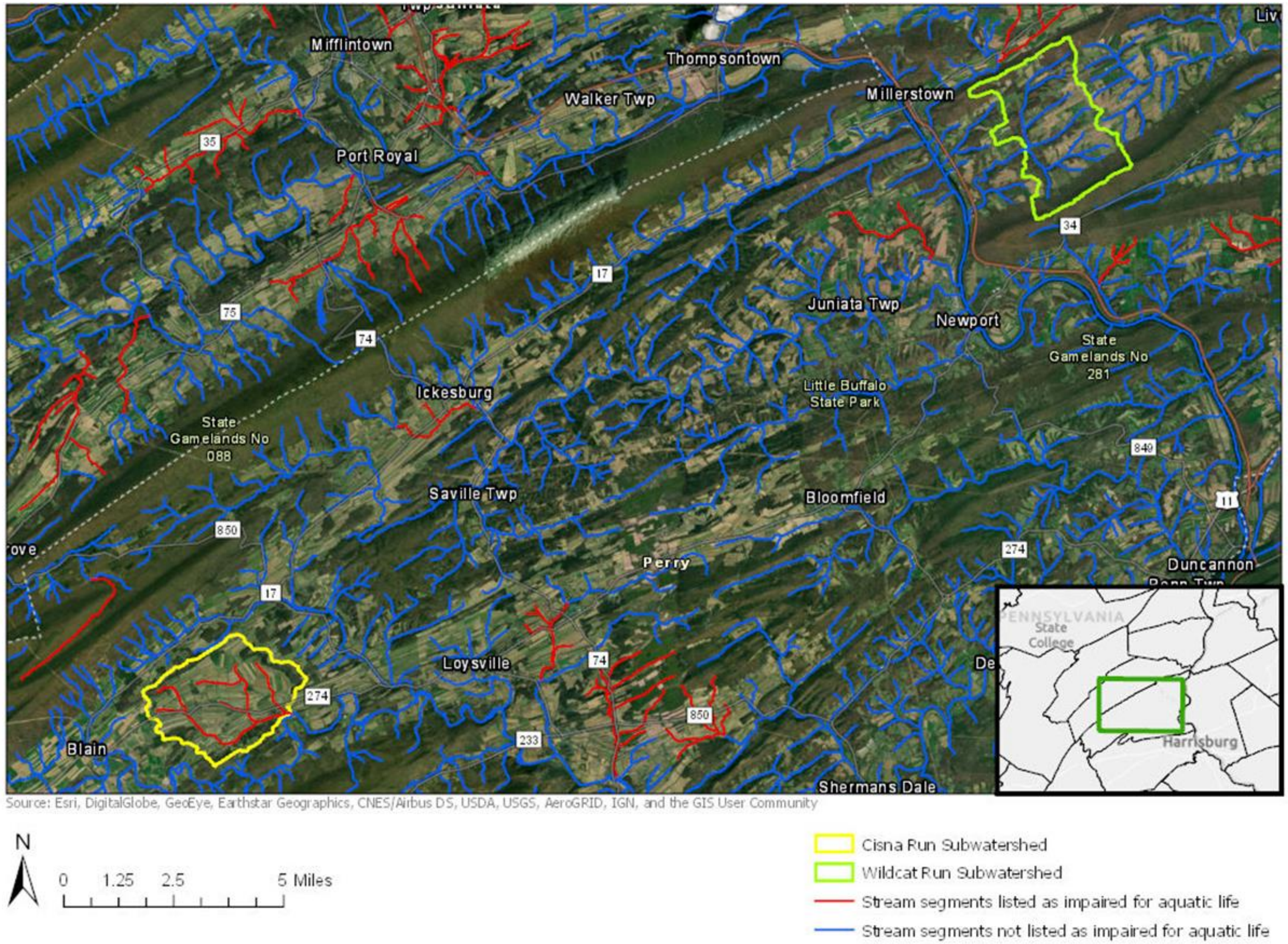


Figure 3. Cisna Run and Wildcat Run Watersheds.

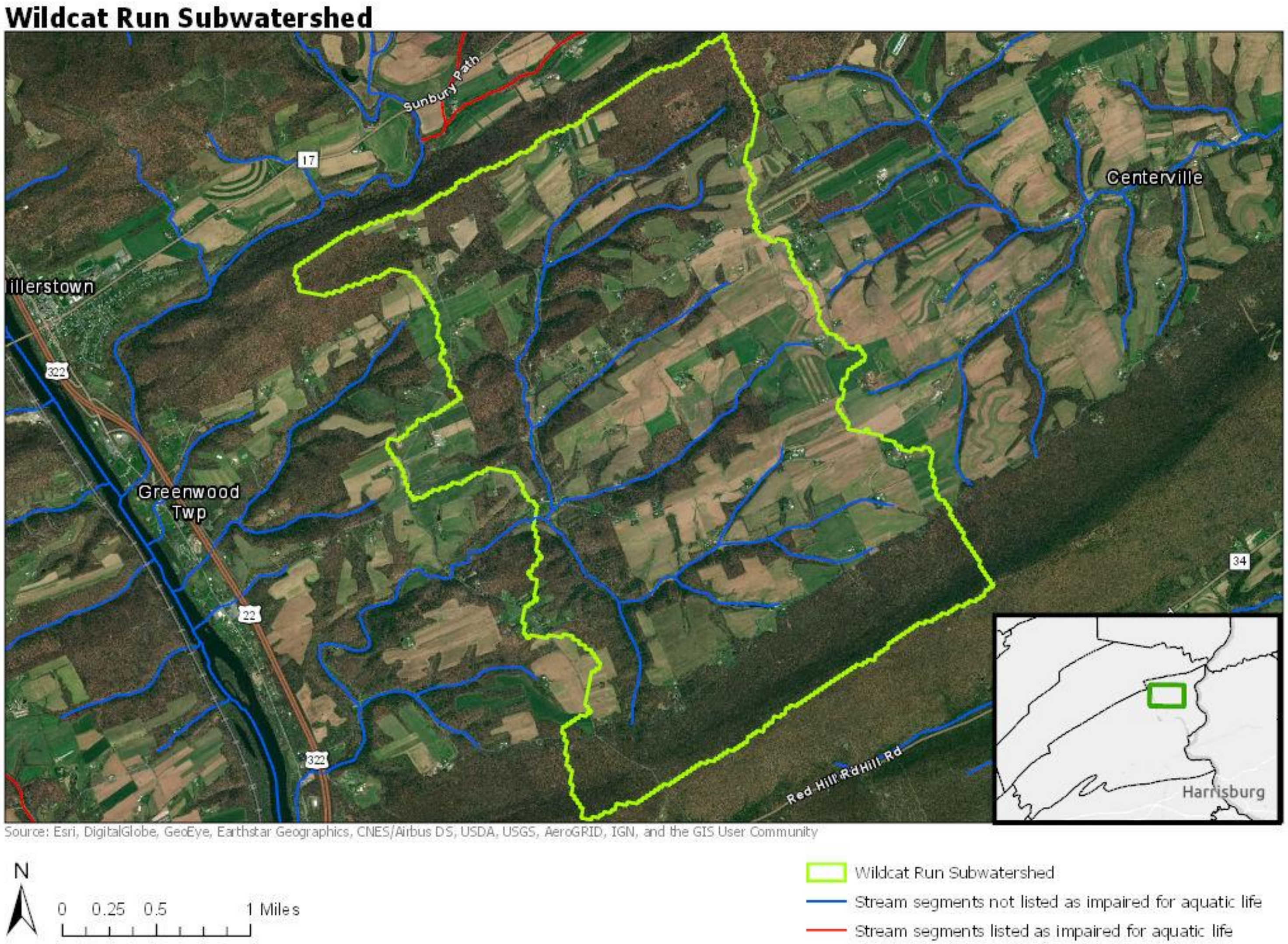


Figure 4. Wildcat Run reference subwatershed. All stream segments were listed as attaining for aquatic life per the 2016 Final Pennsylvania Integrated Report.

Figure 5. Typical landscape within the Cisna Run Watershed. This photo was enhanced to improve brightness and color.

Figure 6. Examples of degraded pasture lands in the Cisna Run Watershed. Note the lower photo was enhanced to improve brightness and color.

Figure 7. Stream segments among croplands in the Cisna Run Watershed. While expansive forested buffers were lacking in most cases, narrow herbaceous buffers commonly separated stream segments from crop fields (photographs A and B). Even drainageways without well-defined banks were often protected by herbaceous buffers (photographs C and D).

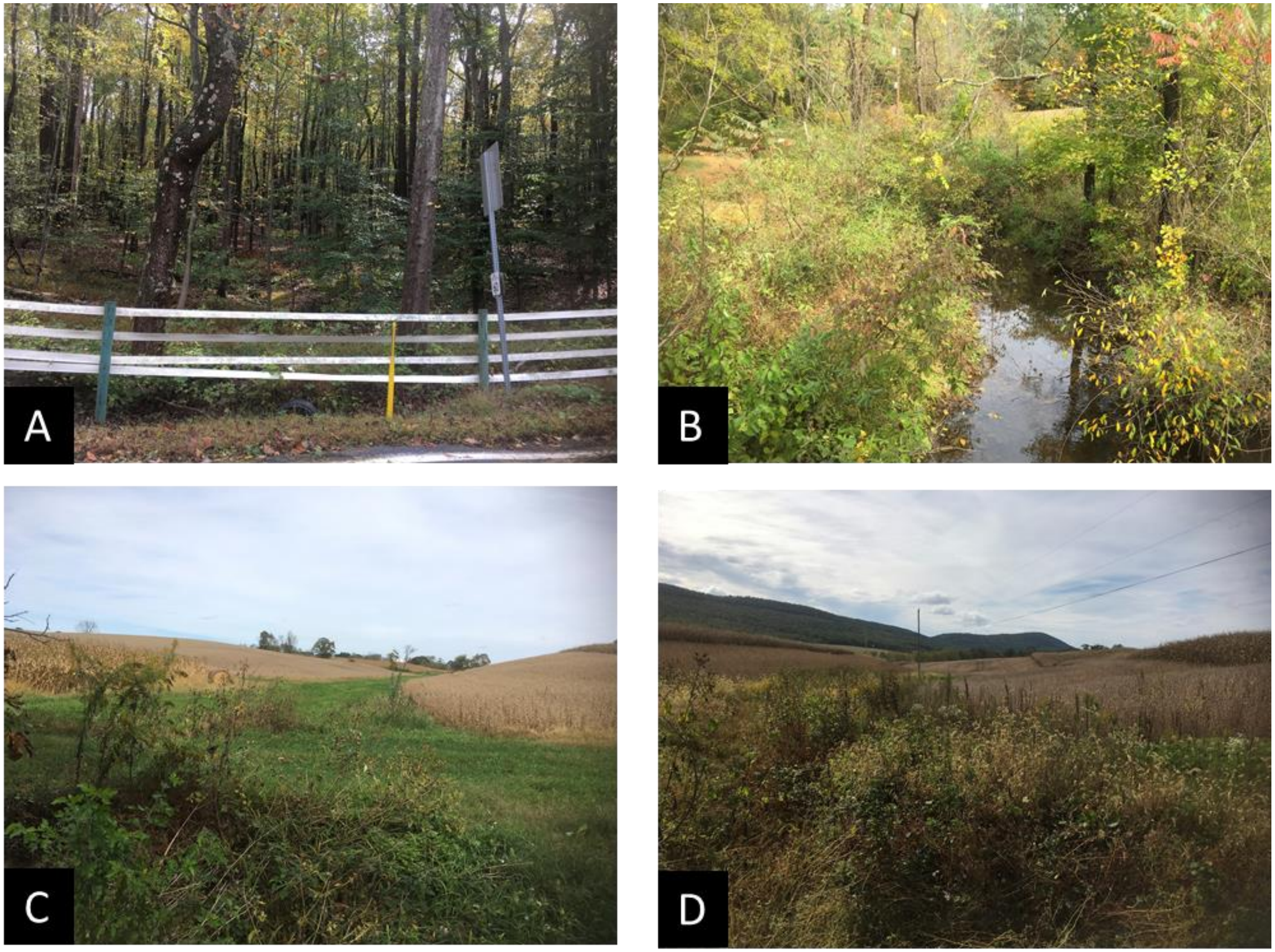


Figure 8. Examples stream segments in the Wildcat Run Subwatershed. Large forested tracts (photograph A) and expansive forested buffers (photograph B) were much more common in the Wildcat Run Subwatershed than in the Cisna Run Watershed. Herbaceous buffers were commonly used along small drainageways through croplands when forested buffers were lacking (photographs C and D).

Figure 9. Example stream segments in the Wildcat Run Subwatershed with potential agricultural impacts. The forested buffer in the above photograph may be too narrow to effectively protect the stream segment running along the bottom of the photograph, especially considering the steepness of the cropland. However, conservation tillage and an herbaceous buffer also appear to be used. A forested buffer is entirely lacking along most of the stream length shown in the lower photograph, though hay/pasture lands and narrow grass buffers may help protect the stream from croplands occurring further upslope.

Hydrologic / Water Quality Modeling

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

Estimates of sediment and phosphorus 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, watershed areas were defined using MMW's Watershed Delineation tool (see https://wikiwatershed.org/documentation/mmw-tech/#delineate-watershed). Then, the mathematical model used in MMW, GWLF-E, was used to simulate 30-years of daily water, nitrogen, phosphorus and sediment fluxes. To provide a general understanding of how the model functions, the following excerpts are quoted from 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 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 (2019).

Model My Watershed Version 1.25.0 allows the user to adjust model parameters, such as the area of land coverage types, the use of and efficiency of conservation practices, the watershed's sediment delivery ratio, etc. Default values were used for the modelling runs. However, after the modelling run, corrections were made for the presence of existing riparian buffers. These corrections were made using the BMP Spreadsheet Tool provided by Model My Watershed. The following paragraphs describe this methodology.

Riparian buffer coverage was estimated via a GIS analysis. Briefly, landcover per a high resolution landcover dataset (University of Vermont Spatial Analysis Laboratory 2016) was examined within 100 feet of NHD flowlines. Then the sum of raster pixels that were classified as either "Emergent Wetlands", "Tree Canopy" or "Shrub/Scrub" was divided by the total number of non-water pixels to determine percent riparian buffer. Using this methodology, percent riparian buffer was determined to be 28% in the Cisna Run Watershed versus 75% in the reference watershed.

Additional reduction credits were given to the reference watershed to account for the fact it had more riparian buffers than 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 (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 reference watershed over the amount found in the impaired watershed, the length of NHD flowlines within the reference watershed was multiplied by the difference in percent buffering between the reference watershed versus the impaired watershed, and then by two since both sides of the stream are considered. The BMP spreadsheet tool then calculates sediment and phosphorus reductions 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 and phosphorus 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 or phosphorus loading rate calculated for croplands, and then by a reduction coefficient of 0.54 for sediment and 0.40 for phosphorus. 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 equations was deleted for the present study since historic rather than proposed buffers were being accounted for.

Calculation of the TMDL

The mean annual loading rates for the unimpaired reference subwatershed (Wildcat Run) were estimated to be 347 pounds per acre per year of sediment and 0.75 pounds per acre per year of phosphorus (Table 7). These were substantially lower than the estimated mean annual loading rates in the impaired Cisna Run Watershed (685 pounds per acre per year of sediment and 1.22 pounds per acre per year of phosphorus, Table 8). To achieve the loading rates of the unimpaired watershed, loadings in the Cisna Run Watershed should be reduced to 1,432,843 pounds per year of sediment and 3,109 pounds per year of phosphorus, or less (Table 9).

Table 7. Existing Annual Average Loading Values for Wildcat Run, Reference

Source	Area, ac	Sediment, lbs/yr	Sediment, lb/ac/yr	P lbs/yr	P lbs/ac/yr
Hay/Pasture	751	341,784	455	408	0.54
Cropland	1,047	1,117,163	1,067	1,314	1.25
Forest and Shrub/Scrub	2,368	8,236	3	19	0.008
Low Intensity Mixed Development	291	2,918	10	7	0.023
Streambank[1]		231,948		55	
Farm Animals				1,310	
Groundwater				381	
Extra Buffer Discount[2]		-153,377		-133	
total	4,457	1,548,672	347	3,360	0.75

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

[2]Accounts for the amount of extra riparian buffering in the agricultural area of reference watershed versus the impaired watershed. For details on this calculation, see the "Hydrologic / Water Quality Modelling" section.

Table 8. Existing Annual Average Loading Values for Cisna Run, impaired					
Source	Area, ac	Sediment, lbs/yr	Sediment, lb/ac/yr	P lbs/yr	P lbs/ac/yr
Hay/Pasture	1,765	965,521	547	1,188	0.67
Cropland	1,202	1,658,377	1,379	1,992	1.66
Forest and Shrub/Scrub	909	2,278	3	6	0.007
Wetland	2	4	1	0	0
Low Intensity Mixed Development	242	2,747	11	7	0.03
Medium Intensity Mixed Development	2	83	34	0.2	0.09
Streambank		195,129		51	
Farm Animals				1,207	
Groundwater				593	
total	4,123	2,824,140	685	5,043	1.22

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

Table 9. Calculation of Annual Average TMDL Values for the Cisna Run Watershed			
Pollutant	Mean Loading Rate in Reference, lbs/ac/yr	Total Land Area in Impaired Watershed, ac	Target $TMDL_{Avg}$ Value, lbs/yr
Sediment	347	4,123	1,432,843
Phosphorus	0.75	4,123	3,109

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 total maximum daily load (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 load allocation is calculated as follows:

LA = TMDL - MOS - WLA

Thus, before calculating the load allocations, the margins of safety and wasteload allocations must be defined.

Margin of Safety

The margin of safety (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} for each TMDL was explicitly designated as ten-percent of the $TMDL_{Avg}$ based on professional judgment. Thus:

Sediment: 1,432,843 lbs/yr $TMDL_{Avg}$ * 0.1 = 143,284 lbs/yr MOS_{Avg}

Phosphorus: 3,109 lbs/yr $TMDL_{Avg}$ * 0.1= 311 lbs/yr MOS_{Avg}

Wasteload Allocation

The wasteload allocation (WLA) is the pollutant loading assigned to existing permitted point sources as well as future point sources. There were no National Pollutant Discharge Elimination System (NPDES) point source discharges in the impaired subwatershed with numeric limits for sediment or phosphorus (Table 4). Bulk reserves were included as part of the wasteload allocations to allow for insignificant dischargers and minor increases from point sources as a result of future growth of existing or new sources.

Since there were no permits with numeric effluent limits for sediment or phosphorus, the WLAs were simply comprised of the bulk reserves, which we defined as one percent of the targeted TMDLs. Therefore:

Sediment: 1,432,843 lbs/yr $TMDL_{Avg}$ * 0.01 = 14,328 lbs/yr bulk $reserve_{Avg}$ + 0 lb/yr permitted loads = 14,328 lbs/yr WLA_{Avg}

Phosphorus: 3,109 lbs/yr $TMDL_{Avg}$*0.01 = 31 lbs/yr bulk $reserve_{Avg}$ + 0 lbs/yr permitted loads = 31 lbs/yr WLA_{Avg}

It should be noted that the concentrated animal feeding operation (CAFO) listed in Table 4 was not provided individual wasteload allocations. Runoff from land application areas of CAFOs is typically considered nonpoint source pollution when permittees are operating in compliance with their permits. Furthermore, Pennsylvania does not allow routine point source discharges from CAFO production areas. If, however, effluent limits are necessary in the future, capacity would be available in the bulk reserves.

Load Allocation

Now that the margins of safety and wasteload allocations have been defined, the load allocations (LA) are calculated as:

Sediment: 1,432,843 lbs/yr $TMDL_{Avg}$ – (143,284 lbs/yr MOS_{Avg} + 14,328 lbs/yr WLA_{Avg}) = 1,275,231 lbs/yr LA_{Avg}

Phosphorus: 3,109 lbs/yr $TMDL_{Avg}$ – (311 lbs/yr MOS_{Avg} + 31 lbs/yr WLA_{Avg}) = 2,767 lbs/yr LA_{Avg}

Loads Not Reduced and Adjusted Load Allocation

Since the impairments addressed by this TMDL are due to agriculture, sediment and phosphorus contributions from forests, wetlands, developed lands, and groundwater (for phosphorus) within the Cisna Run Watershed were considered loads not reduced (LNR). LNR_{Avg} were calculated to be 5,112 lbs/yr for sediment and 606 lbs/yr for phosphorus (Table 10).

The LNRs were subtracted from the LAs to determine the ALAs:

Sediment: 1,275,231 lbs/yr LA_{Avg} – 5,112 lbs/yr LNR_{Avg} = 1,270,119 lbs/yr ALA_{Avg}

Phosphorus: 2,767 lbs/yr LA_{Avg} – 606 lbs/yr LNR_{Avg} = 2,161 lbs/yr ALA_{Avg}

Table 10. Average Annual Load Allocation, Loads Not Reduced and Adjusted Load Allocation

	Sediment lbs/yr	Phosphorus lbs/yr
Load Allocation (LA_{Avg})	**1,275,231**	**2,767**
Loads Not Reduced (LNR_{Avg}):	**5,112**	**606**
Forest	2,278	6
Wetlands	4	0.0
Low Intensity Mixed Development	2,747	7.1
Med. Intensity Mixed Dev.	83	0.2
Groundwater	0	593

Adjusted Load Allocation (ALA_{Avg})	**1,270,119**	**2,161**

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

Calculation of Load Reductions

To calculate load reductions by source, the ALAs were further analyzed using the Equal Marginal Percent Reduction (EMPR) allocation method described in Appendix D. Although the Cisna Run TMDLs were developed to address impairments caused by agricultural activities, streambanks were also significant contributors to the sediment and phosphorus loadings in the watershed, and streambank erosion rates are influenced by agricultural activities. Thus, streambanks were included in the ALA and targeted for reduction.

In this analysis, croplands exceeded the entire allocable load of sediment by itself, so it received a greater annual average reduction goal (60%) than hay/pasture lands or streambanks (48% each) (Table 11). For phosphorus, all sectors (croplands, hay/pasture lands, streambanks and farm animals) received the same prescribed annual average reduction of 51% (Table 12).

Table 11. Annual Average Sediment Load Allocations for Source Sectors in the Cisna Run Watershed

		Allowable Loading	Load Allocation	Current Loading	Current Load	Reduction Goal
Land Use	Acres	lbs/ac/yr	lbs/yr	lbs/ac/yr	lbs/yr	
CROPLAND	1,202	552	663,659	1,379	1,658,377	60%
HAY/PASTURE	1,765	286	504,501	547	965,521	48%
STREAMBANK			101,958		195,129	48%
AGGREGATE			1,270,119		2,819,028	55%

Table 12. Annual Average Phosphorus Load Allocations for Source Sectors in the Cisna Run Watershed

		Allowable Loading	Load Allocation	Current Loading	Current Load	Reduction Goal
Land Use	Acres	lbs/ac/yr	lbs/yr	lbs/ac/yr	lbs/yr	

CROPLAND	1,202	0.8	970	1.7	1,992	51%
HAY/PASTURE	1,765	0.3	579	0.7	1,188	51%
STREAMBANK			25		51	51%
FARM ANIMALS			588		1,207	51%
AGGREGATE			2,161		4,437	51%

Calculation of Daily Maximum "$TMDL_{Max}$" Values

When choosing the best timescale for expressing pollutant loading limits for siltation and phosphorus, several factors must be considered:

1) Sediment and nonpoint-source phosphorus 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.
3) Nonpoint-source phosphorus pollution typically harms aquatic communities through eutrophication degradation as a result of chronically excessive loading.

Considering then that siltation and nonpoint-source phosphorus 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, true "Total Maximum Daily Loads" ($TMDL_{Max}$) are also calculated in the following.

Model My Watershed currently does not report daily loading rates, but its predecessor program, "MapShed" does. Thus, for the calculation of $TMDL_{Max}$ values, modelling was initially conducted in Model My Watershed, and the "Export GMS" feature was used to provide input data files that were run in MapShed. The daily output was opened in Microsoft Excel (Version 1902), and current maximum daily loads were calculated as the 99th percentiles (using the percentile.exc function) of estimated daily sediment and phosphorus loads in both the Cisna Run (impaired) and Wildcat Run (reference) Watersheds. The first years of data were excluded to account for the time it takes for the model calculations to become reliable. 99th percentiles were chosen because 1) sediment and phosphorus loading increases with the size of storm events, so, as long as there could be an even larger flood, true upper limits to loading cannot be defined and 2) 99% of the time attainment of water quality criteria is prescribed for other types of pollutants per PA regulations (see PA Code Title 25, Chapter 96, Section 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 percentage that was calculated previously for the average loading rate.

Then, similarly to the $TMDL_{Avg}$ values reported in Table 9, $TMDL_{Max}$ values were calculated as the 99th percentile daily loads of the reference watershed, divided by the acres of the reference watershed, and then multiplied by the acres of the impaired watershed. The $TMDL_{Max}$ loading rate for sediment was calculated as 52,366 pounds per day (Table 13), which would be a 50% reduction from Cisna Run's current 99th percentile daily loading rate of 105,659 pounds per day. For phosphorus, the $TMDL_{Max}$ loading rate was calculated as 128 pounds per day (Table 13), which would be a 40% reduction from Cisna Run's current 99th percentile daily loading rate of 213 pounds per day.

Table 13. Calculation of $TMDL_{Max}$ Values for the Cisna Run Watershed

Pollutant	99th Percentile Loading Rate in Reference, lbs/ac/d	Total Land Area in Impaired Watershed, ac	Target $TMDL_{Max}$ Value, lbs/d
Sediment	12.7	4,123	52,366
Phosphorus	0.031	4,123	128

Also, in accordance with the previous "Calculation of Load Allocations" section, the WLA_{Max} would consist solely of a bulk reserve defined as 1% of the $TMDL_{Max}$ and the MOS_{Max} would be 10% of the $TMDL_{Max}$. The LA_{Max} would then be calculated as the amount remaining after subtracting the WLA_{Max} and the MOS_{Max} from the $TMDL_{Max}$. See Table 14 for a summary of these $TMDL_{Max}$ variables.

Table 14. 99th Percentile of Daily Loading TMDL ($TMDL_{Max}$) Variables for the Cisna Run Watershed

lbs/d:				
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}
Sediment	52,366	5,237	524	46,606
Phosphorus	128	13	1	114

The modelling program however did not break down daily loads by land use 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 8% of LA_{Avg} it was assumed that it was also 8% 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 (see Sloto et al. 2012). See Tables 15 and 16 for a summary of these LA_{Max} variables.

Table 15. Allocation of the 99th Percentile Daily Sediment Load Allocation (LA_{Max}) for the Cisna Run Watershed			
	Annual Average (lbs/yr)	Proportion of Load Allocation	Max Daily (lbs/d)
Load Allocation	1,275,231		46,606
Loads Not Reduced	5,112	0.004	187
Adjusted Loads Allocation	1,270,119	0.996	46,419
Croplands	663,659	0.52	24,255
Hay/Pasturelands	504,501	0.40	18,438
Streambanks	101,958	0.08	3,726

Because the modelling program did not break down daily loadings by land use 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 8% of LA_{Avg} it was assumed that it was also 8% of LA_{Max}.

Table 16. Allocation of the 99th Percentile Daily Phosphorus Load Allocation (LA_{Max}) for the Cisna Run Watershed			
	Annual Average (lbs/yr)	Proportion of Load Allocation	Max Daily (lbs/d)
Load Allocation	2,767		114
Loads Not Reduced	606	0.22	25
Adjusted Loads Allocation	2,161	0.78	89
Croplands	970	0.35	40
Hay/Pasturelands	579	0.21	24
Streambanks	25	0.009	1
Farm Animals	588	0.21	24

Because the modelling program did not break down daily loadings by land use 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 0.9% of LA_{Avg} it was assumed that it was also 0.9% of LA_{Max}.

Because both sediment and phosphorus loading vary so greatly with discharge, the $TMDL_{Max}$ values 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 and nutrient loading (see-Sloto and Olson 2011, Sloto et al. 2012), it is cautioned that reliance solely on a $TMDL_{Max}$ values may not be protective because chronic excessive inputs occurring at lower discharge levels may be ignored. Take for instance an extreme scenario where the $TMDL_{Max}$ value for sediment was met every day but never exceeded. In this case, annual sediment loading in the Cisna Run Watershed would skyrocket to 19,113,545 lbs/yr, which is more than six-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 Cisna Run Watershed. Therefore, while adherence with the loading requirements of this TMDL include meeting both the $TMDL_{Avg}$ and the $TMDL_{Max}$, BMP implementation would ultimately be deemed adequate if the prescribed annual average reductions were satisfied.

Consideration of Critical Conditions and Seasonal Variations

Model My Watershed" uses a continuous simulation model with daily time steps for weather data and water balance (precipitation, stream flow, surface runoff, subsurface flow, and evapotranspiration) calculations. The source of the weather data (precipitation and temperature) was a dataset compiled by USEPA ranging from 1961-1990 (Stroud Water Research Center 2018). The evapotranspiration calculations also take into account the length of the growing season and changing day length. Monthly calculations are made for sediment loads, based on daily water balance accumulated in monthly values. Therefore, variable flow conditions and seasonal changes are inherently accounted for in the loading calculations. Furthermore, this document calculates both annual average and 99^{th} percentile daily "TMDL" values. See the discussion on the relevance of these values in the previous section. Seeking to attain both of these values will be protective under both long-term average and extreme flow event conditions.

Summary and Recommendations

This document proposes a 49% reduction in annual average sediment loading and 38% reduction in annual average phosphorus loading for the Cisna Run Watershed. To achieve these goals while maintaining margins of safety and minor allowances for point sources, it is proposed to reduce sediment loading from croplands by 60% and hay/pasture lands and streambanks by 48%. Annual average Phosphorus loading from croplands, hay/pasture lands, farm animals and streambanks should be reduced by 51% each. In addition, 99^{th} percentile daily sediment and phosphorus loading should be reduced by 50% and 40%, respectively.

Reductions in stream sediment and nutrient loading due to agricultural activities can be made through the implementation of required Erosion and Sediment Control and Nutrient Management Plans (Pennsylvania Clean Streams Law, Title 25 Environmental Protection, Chapter 102.4) and through the use of BMPs such as conservation tillage, cover crops, vegetated filter strips, rotational grazing, livestock exclusion fencing, riparian buffers, legacy sediment removal etc.

Use of forested riparian buffers is widely recognized as one of the best ways to promote stream health. Riparian buffers protect streams from sedimentation and nutrient impairments by filtering these pollutants from runoff and floodwaters and by protecting streambanks from erosion. However, 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.
Based on site observations, recent progress may have already been made towards achieving the prescribed reductions, as numerous cropland BMPs appeared to be in use. However, it appeared that

there was still great need for grazing land management, streambank fencing, and forested riparian buffer BMPs especially. Given the large magnitude of prescribed reductions, it may be difficult to achieve the sediment and phosphorus reduction goals with conventional BMPs alone. Thus, consideration should be given to agricultural land retirement as well.

Development of a more detailed watershed implementation plan is recommended. Further ground truthing should be performed to assess both the extent of existing BMPs and to determine the most cost effective and environmentally protective combination of new BMPs needed to achieve the prescribed sediment and phosphorus reductions. 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 of this TMDL was be published in the Pennsylvania Bulletin on February 15 to foster public comment. A 30-day period was provided for the submittal of comments. No public comments were received.

Citations

Note: maps for this document were made with ArcGIS Pro 2.2.0 by Esri.

Evans, B.M. and K.J. Corradini. 2016. Mapshed Version 1.5 Users Guide. Penn State Institutes of Energy and the Environment. The Pennsylvania State University. University Park, PA 16802

Mapshed Version 1.5.1. Penn State Institutes of Energy and the Environment. The Pennsylvania State University. University Park, PA 16802

Sloto, R. A. and L.E. Olson. 2011. Estimated Suspended -Sediment Loads and Yields in the French and Brandywine Creek Basins, Chester County, Pennsylvania, Water Years 2008-09. USGS Scientific Investigations Report 2011-5109. Available at https://pubs.usgs.gov/sir/2011/5109/support/sir2011-5109.pdf

Sloto, R.A., A.C. Gellis, and D.G. Galeone. 2012 Total Nitrogen and Suspended-Sediment Loads and Identification of Suspended-Sediment Sources in the Laurel Hill Creek Watershed, Somerset County, Pennsylvania, Water Years 2010-11. USGS Scientific Investigations Report 2012-5250. Available at https://pubs.usgs.gov/sir/2012/5250/support/sir2012-5250.pdf

Stroud Water Research Center. (2019). Model My Watershed [Software]. Version 1.25.0 Available from https://wikiwatershed.org/. Technical documentation available at: https://wikiwatershed.org/documentation/mmw-tech/

University of Vermont Spatial Analysis Laboratory. (2016). High-Resolution Land Cover, Commonwealth of Pennsylvania, Chesapeake Bay Watershed and Delaware River Basin, 2013. Available at: http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=3193

Appendix A: Background on Stream Assessment Methodology

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

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 sought to select 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 typically 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 subsampled for a target benthic macroinvertebrate sample of 200 ± 20% (N = 160-240). The benthic macroinvertebrates in this subsample were then 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 segment. 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).

Migration to National Hydrography Data (NHD)

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 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

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0	0
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	0.7	4.2
Developed, Low Intensity	22	0.28	1.7
Developed, Medium Intensity	23	0.01	0
Developed, High Intensity	24	0	0
Barren Land (Rock/Sand/Clay)	31	0	0
Deciduous Forest	41	3.01	18.1
Evergreen Forest	42	0.33	2
Mixed Forest	43	0.24	1.4
Shrub/Scrub	52	0.1	0.6
Grassland/Herbaceous	71	0	0
Pasture/Hay	81	7.15	42.8
Cultivated Crops	82	4.87	29.2
Woody Wetlands	90	0.01	0
Emergent Herbaceous Wetlands	95	0	0

Table B1. “Model My Watershed” Land Cover Outputs for the Cisna Run Watershed.

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.01	0
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	1.09	6
Developed, Low Intensity	22	0.09	0.5
Developed, Medium Intensity	23	0	0
Developed, High Intensity	24	0	0
Barren Land (Rock/Sand/Clay)	31	0	0
Deciduous Forest	41	8.78	48.7
Evergreen Forest	42	0.45	2.5
Mixed Forest	43	0.36	2
Shrub/Scrub	52	0	0
Grassland/Herbaceous	71	0	0
Pasture/Hay	81	3.04	16.8
Cultivated Crops	82	4.24	23.5
Woody Wetlands	90	0	0
Emergent Herbaceous Wetlands	95	0	0

Table B2. “Model My Watershed” Land Cover Outputs for the Wildcat Run Subwatershed

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.99	0.72	5.27	0	0.35	7.15
Feb	6.36	0.9	5.46	0	0.54	7.31
Mar	7.29	0.41	6.88	0	1.91	8.36
Apr	6.16	0.11	6.05	0	4.8	8.41
May	4.2	0.08	4.12	0	9.15	10.51
Jun	3.27	0.83	2.44	0	10.89	10.58
Jul	1.27	0.13	1.14	0	10.01	9.86
Aug	0.56	0.09	0.47	0	8.42	8.64
Sep	1.16	0.67	0.49	0	5.88	9.04
Oct	1.84	0.48	1.36	0	3.77	8.06
Nov	3.02	0.32	2.71	0	1.88	9.38
Dec	5.8	0.51	5.3	0	0.73	8.11
Total	46.92	5.25	41.69	0	58.33	105.41

Table B3. “Model My Watershed” Hydrology Outputs for the Cisna Run Watershed

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	5.61	0.77	4.84	0	0.31	7.15
Feb	6.36	0.96	5.39	0	0.48	7.31
Mar	7.41	0.44	6.96	0	1.71	8.36
Apr	6.28	0.12	6.16	0	4.39	8.41
May	4.36	0.09	4.26	0	8.59	10.51
Jun	3.44	0.86	2.59	0	12.13	10.58
Jul	1.3	0.14	1.16	0	11.82	9.86
Aug	0.42	0.1	0.32	0	9.36	8.64
Sep	0.83	0.71	0.12	0	6.2	9.04
Oct	1.12	0.51	0.61	0	3.52	8.06
Nov	2.19	0.35	1.84	0	1.68	9.38
Dec	4.95	0.55	4.4	0	0.66	8.11
Total	44.27	5.6	38.65	0	60.85	105.41

Table B4. “Model My Watershed” Hydrology Outputs for the Wildcat Run Subwatershed

Sources	Sediment (kg)	Phosphorus (kg)
Hay/Pasture	437,878.10	538.8
Cropland	752,098.60	903.2
Wooded Areas	1,033.00	2.7
Wetlands	1.6	0
Open Land	0	0
Barren Areas	0	0
Low-Density Mixed	356.5	0.9
Medium-Density Mixed	37.7	0.1
High-Density Mixed	0	0
Low-Density Open Space	889.5	2.3
Farm Animals	0	547.3
Stream Bank Erosion	88,494.00	23
Subsurface Flow	0	268.8
Point Sources	0	0
Septic Systems	0	0

Table B5. Model My Watershed outputs for sediment and phosphorus in the Cisna Run Watershed.

Sources	Sediment (kg)	Phosphorus (kg)
Hay/Pasture	155,004.30	185.1
Cropland	506,649.70	595.8
Wooded Areas	3,735.10	8.4
Wetlands	0	0
Open Land	0	0
Barren Areas	0	0
Low-Density Mixed	95.8	0.2
Medium-Density Mixed	0	0
High-Density Mixed	0	0
Low-Density Open Space	1,227.50	2.9
Farm Animals	0	594
Stream Bank Erosion	105,192.00	25
Subsurface Flow	0	172.8
Point Sources	0	0
Septic Systems	0	0

Table B6. Model My Watershed outputs for sediment and phosphorus in the Wildcat Run Subwatershed.

Appendix C: Stream Segments in the Cisna Run Watershed with Aquatic Life Impairments

Assessed Use:	Status:	Impairment Source:	Impairment Cause:	Date Listed:	COMID:	Length (mi):
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56403041	1.01
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56403095	0.67
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56403357	2.25
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56402985	0.35
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56402471	0.38
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56403041	1.01
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56403357	2.25
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56402871	0.87
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56402761	1.43
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56402759	0.15
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56402975	0.75
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56402975	0.75
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56402761	1.43
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56402759	0.15
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56403095	0.67
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56402873	0.69
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56402873	0.69
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56402985	0.35
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56402603	1.08
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56402603	1.08
Aquatic Life	Impaired	Grazing Related Agric	Nutrients	2002	56402871	0.87
Aquatic Life	Impaired	Grazing Related Agric	Siltation	2002	56402471	0.38

Table C1. Listing of stream segments with aquatic life impairments in the Cisna Run Watershed.

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:

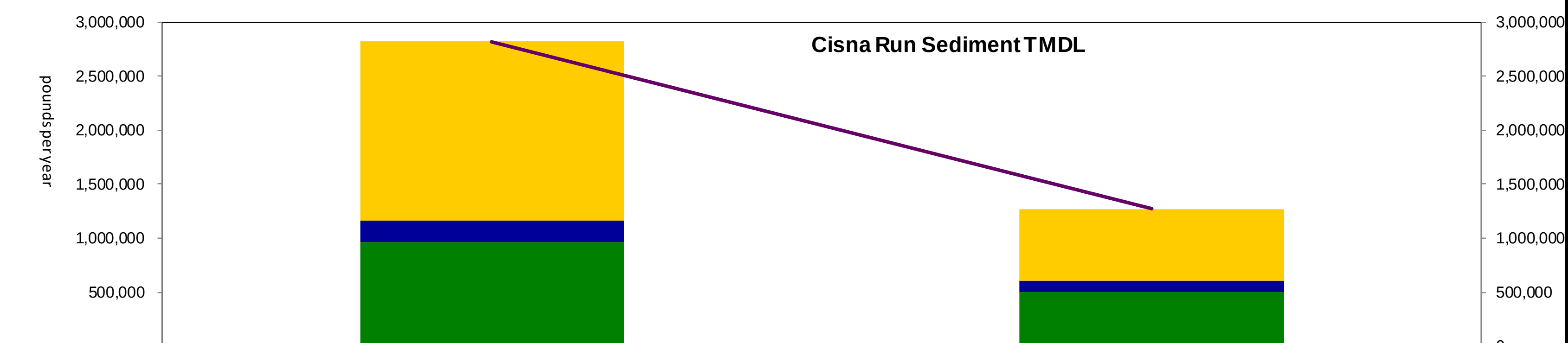
a. Each land use/source load is compared with the total ALA to determine if any contributor would exceed the ALA by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load of the receiving waterbody. If the contributor exceeds the ALA, that contributor would 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

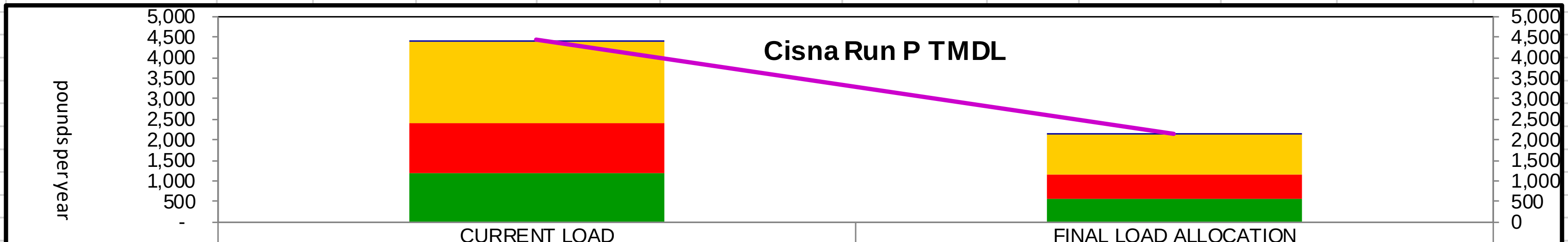
	TMDL				2	ALA = TMDL total load - (MOS + WLA + loads not reduced)						
	TMDL = Sediment loading rate in ref. * Impaired Acres					1270118.8	1270118.8					
	1432843.5											
		Annual				Recheck	% reduction	Load			Allowable	%
3		Avg. Load	Load Sum	Check	Initial Adjust	Adjust	allocation	Reduction	Initial LA	Acres	Loading Rate	Reduction
	CROPLAND	1658377.4	2819027.9	bad	1270118.8		0.5	606459.9	663659.0	1202.5	551.9	60.0%
	HAY/PASTURE	965521.2		good	965521.2	1160650.5	0.4	461019.7	504501.5	1765.4	285.8	47.7%
	STREAMBANK	195129.3		good	195129.3		0.1	93170.9	101958.4			47.7%
					2430769.3		1.0		1270118.8			
4	All Ag. Loading Rate	393.60										
			Allowable		Current	Current	**Reduction**					
	Land Use	Acres	loading rate	Final LA	Loading Rate	Load	**Goal**			CURRENT LOAD	FINAL LOAD ALLOCATION	
5	CROPLAND	1,202	552	663,659	1,379	1,658,377	**60%**		HAY/PASTURE	965,521	504,501	
	HAY/PASTURE	1,765	286	504,501	547	965,521	**48%**		STREAMBANK	195,129	101,958	
	STREAMBANK			101,958		195,129	**48%**		CROPLAND	1,658,377	663,659	
	AGGREGATE		ALA	1,270,119		2,819,028	**55%**		AGGREGATE	2,819,028	1,270,119	



	CURRENT LOAD	FINAL LOAD ALLOCATION
CROPLAND	**1,658,377**	**663,659**
STREAMBANK	**195,129**	**101,958**
HAY/PASTURE	**965,521**	**504,501**
AGGREGATE	**2,819,028**	**1,270,119**

Table D1. Sediment Equal Marginal Percent Reduction calculations for the Cisna Run Watershed.

1	TMDL				2	ALA = TMDL total load - (MOS + WLA + loads not reduced)						
	TMDL = Sediment loading rate in ref. * Impaired Acres					2161.0	2161.0					
	3108.9											
		Annual				Recheck	% reduction	Load			Allowable	%
3		Avg. Load	Load Sum	Check	Initial Adjust	Adjust	allocation	Reduction	Initial LA	Acres	Loading Rate	Reduction
	CROPLAND	1991.6	4437.1	good	1991.6		0.4	1021.6	969.9	1202.5	0.81	51.30%
	HAY/PASTURE	1188.1		good	1188.1	2276.1	0.3	609.4	578.6	1765.4	0.33	51.3%
	STREAMBANK	50.7		good	50.7		0.0	26.0	24.7			51.3%
	Farm Animals	1206.8		good	1206.8		0.3	619.1	587.7			51.3%
					4437.1		1.0		2161.0			
4	All Ag. Loading Rate	0.52										
			Allowable		Current	Current	**Reduction**					
	Land Use	Acres	loading rate	Final LA	Loading Rate	Load	**Goal**			CURRENT LOAD	AL LOAD ALLOCATION	
5	CROPLAND	1,202.47	0.81	969.9	1.656	1,992	**51.30%**		HAY/PASTURE	1,188	579	
	HAY/PASTURE	1,765.4	0.33	578.61	0.67	1,188	**51.3%**		Farm Animals	1,207	588	
	STREAMBANK	-		24.70		51	**51.3%**		CROPLAND	1,992	970	
	Farm Animals			587.74		1,207	**51.3%**		STREAMBANK	51	25	
	AGGREGATE		ALA	2,160.98		4,437	**51.30%**		AGGREGATE	4,437	2,161	



	CURRENT LOAD	FINAL LOAD ALLOCATION
STREAMBANK	51	25
CROPLAND	1,992	970
Farm Animals	1,207	588
HAY/PASTURE	1,188	579
AGGREGATE	4,437	2,161

Table D2. Phosphorus Equal Marginal Percent Reduction calculations for the Cisna Run 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.

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 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: Comment and Response

No public comments were received.