Chillisquaque Creek Headwaters Watershed Sediment TMDL

Montour and Columbia Counties, Pennsylvania

Prepared by:

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Final Draft

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Executive Summary

"Total Maximum Daily Loads" (TMDLs) for sediment were developed for the Chillisquaque Creek Headwaters Watershed (Figure 1) to address the siltation impairments noted in the 2018 Final Pennsylvania Integrated Water Quality Monitoring and Assessment Report (Integrated Report), including the Clean Water Act Section 303(d) List. Agriculture was identified as the cause of the 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 Chillisquaque Creek Headwaters Watershed was estimated to be 7,102,951 pounds per year. To meet water quality objectives, annual average sediment loading should be reduced by 48% to 3,692,901 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 allowance for point sources, annual average loading from croplands should be reduced by 61%, while loading from hay/pasture lands and streambanks should be reduced by 46% each.

Table 1. Summary of Annual Average TMDL ($TMDL_{Avg}$) Variables for the Chillisquaque Creek Headwaters Watershed

lbs/yr:						
Pollutant	$TMDL_{Avg}$	MOS_{Avg}	WLA_{Avg}	LA_{Avg}	LNR_{Avg}	ALA_{Avg}
Sediment	3,692,901	369,290	214,915	3,108,696	15,999	3,092,697

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 Chillisquaque Creek Headwaters Watershed was estimated to be 305,618 pounds per day. To meet water quality objectives, 99th percentile daily sediment loading should be reduced by 36% to 195,125 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 Chillisquaque Creek Headwaters Watershed

lbs/d:						
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}	LNR_{Max}	ALA_{Max}
Sediment	195,125	19,512	14,970	160,642	827	159,815

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.

In addition to making reductions to nonpoint sources, a wasteload allocation was established for the Montour LLC powerplant. While this allocation would not require reductions relative to current loading rates, they would limit the powerplant's ability to increase discharged suspended sediment loads and exacerbate the sedimentation problem in the watershed. The wasteload allocation will be set at 177,986 lbs/yr as an annual average and 13,019 lbs/d as a daily maximum (99th percentile conditions).

Introduction

The "Chillisquaque Creek Headwaters Watershed" contains the East and Middle Branches of Chillisquaque Creek and a short, approximately one- and three-quarter mile, reach of the Chillisquaque Creek mainstem below their junction (Figure 1). The downstream terminus of the watershed was just upstream of the junction with the West Branch of Chillisquaque Creek, about 0.7 miles north of the borough of Washingtonville. This Total Maximum Daily Load (TMDL) document has been prepared to address siltation from agriculture impairments listed for most of the watershed (Table 3, Figure 1), per the 2018 Final Integrated Report (see Appendix A for a description of assessment methodology). The watershed area was approximately 17.8 square miles and occurred within Montour and Columbia Counties. It contained approximately 41 stream miles, all of which are designated for Warm-Water Fishes (WWF) and Migratory Fishes (MF).

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

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

While agriculture has been identified as the source of the impairments, this TMDL document is applicable to all significant sources of solids that may settle to form deposits.

According to the "Model My Watershed" application, land use in the study watershed was estimated to be 37% forest/naturally vegetated lands, 55% agriculture, and 5% mixed development. The agricultural lands were approximately 20% croplands and 35% hay/pasture (Appendix B, Table B1). While there were five NPDES permitted point source discharges active in the watershed, only one, Montour LLC's coal fired power plant, had substantial loading rates relevant to sedimentation (Table 4). Of the others, three were permits for residential small flow wastewater treatment plants that were practically negligible sources of sediment and one was an industrial stormwater permit that did not have numeric sediment limits.

Table 3. Aquatic-Life Impaired Stream Segments in the Chillisquaque Creek Headwaters Watershed per the 2018 Final Pennsylvania Integrated Report				
HUC: 02050206 – Lower West Branch Susquehanna				
Source	EPA 305(b) Cause Code	Miles	Designated Use	Use Designation
Agriculture	Siltation	34.3	WWF, MF	Aquatic Life
Industrial Point Source	Other Habitat Alterations	1.80	WWF, MF	Aquatic Life

HUC= Hydrologic Unit Code; WWF=Warm 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.

Note, this TMDL document does not address “other habitat alterations” as it is not a pollutant. However, stream segments with this impairment designation were also impaired for siltation and thus are covered under the TMDLs.

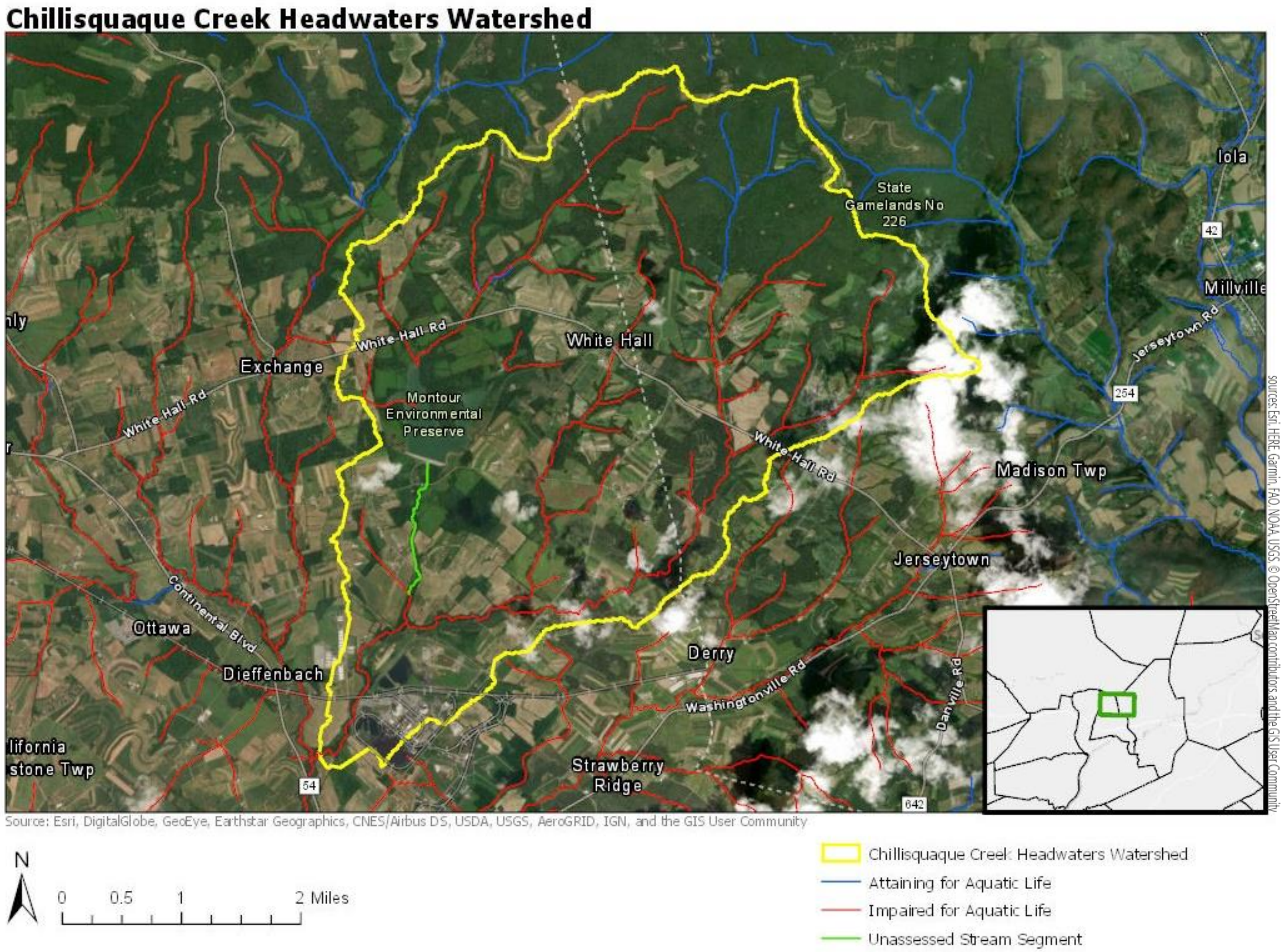

Figure 1. Chillisquaque Creek Headwaters Watershed. All stream segments with aquatic life use impairments were listed as impaired for siltation due to agriculture per the approved 2018 Integrated Report. The downstream most reach below the two main headwater branches was also impaired for "other habitat alterations" due to "industrial point source". Note that the "Unassessed Stream Segment" has been sampled but not formally assessed for aquatic life use.

Table 4. Existing NPDES-Permitted Discharges in the Chillisquaque Creek Headwaters Watershed and their Potential Contribution to Sediment Loading.			
Permit No.	Facility Name	Load, mean lbs/yr	Load, max lbs/d
PA0008443	Montour LLC[1]	177,986	13,980
PA0111805	Dwayne & Lisa Derr WWTP[2]	NA	NA
PAG044842	Robert Gardner WWTP[3]	8	0.067
PAG044908	David & Karen Ellis WWTP[3]	8	0.067
PAG045156	Carol Ann & Raymond K Jr Bowen WWTP[3]	8	0.067
PAR604832	Madison Salvage & Recycling LLC[4]	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.

[1]The permit for this coal power plant, issued August 15, 2018, listed two outfalls with numeric permit limits discharging to the Chillisquaque Creek. Discharge concentration limits for total suspended solids were 30 mg/l monthly average, 100 mg/l daily max, and 125 mg/l instantaneous max. Effluent limitations in the permit were based on discharge rates of 6.8 and 3.0 MGD for the two outfalls. However, given the magnitude of this point source, additional effort was taken to derive loads from an analysis of discharge monitoring reports rather than simply calculating loads from permit limits. To calculate mean annual loads, average monthly flow in MGD and average monthly total suspended solids concentrations in mg/l were used to derive an average daily load for each month for years 2012 through 2019. This was then multiplied by the number of days in the month, and the loads from all the months of the year were summed to derive an annual total load for each year. The mean load in lbs/yr presented above was calculated as an average of these 8 years of loads. The maximum daily load presented above was the maximum calculated daily load during this 8-year period. Note that for calculations, DMR values with "<" symbols were simply changed to the number without the symbol.

[2]Permit for a small flow treatment facility that ceased discharging. The permit was terminated in 2014.

[3]Permit for a small flow treatment facility. Mean annual load was calculated assuming a flow rate of 262.5 gpd for a single-family residence and a total suspended solids concentration of 10 mg/l. Maximum daily load was calculated assuming a flow rate of 400 gpd and total suspended solids concentration of 20 mg/l.

[4]Permit for industrial stormwater facilities. Note that sediment loading associated with development is accounted for in Model My Watershed.

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, the "Reference Watershed Approach" was used. This method estimates pollutant loading rates in both the impaired watershed as well as a similar watershed that is not listed as impaired for the same use. Then, the loading rate in the unimpaired watershed is scaled to the area of the impaired watershed so that necessary load reductions may be calculated. It is assumed that reducing loading rates in the impaired watershed to the levels found in the attaining watershed will result in the impaired stream segments attaining their designated uses.

Selection of the Reference Watershed

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

To find potential references, a GIS analysis was conducted to search for nearby watersheds that were of similar size as the Chillisquaque Creek Headwaters Watershed but lacked stream segments listed as impaired for aquatic life. 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, bedrock geology, hydrology, soil drainage types, land use etc. Furthermore, benthic macroinvertebrate and physical habitat assessment scores were reviewed to confirm that a reference was attaining its aquatic life use and not impaired for sediment. Preliminary modelling was conducted to make sure that use of a particular reference would result in a reasonable pollution reduction.

There were two major difficulties in finding a reference for the Chillisquaque Creek Headwaters Watershed. The first was that it was relatively large which makes it more difficult to find potential references without impaired reaches. Consideration was given to breaking the Chillisquaque Creek Headwaters Watershed into multiple subwatersheds, however doing so would have either excluded the downstream-most reach of mainstem (Figure 1) which was clearly impaired, or would have resulted in a complex treatment of the watershed via multiple TMDLs. The second difficulty was matching the topography of the watershed, as it was apparent that it was a major factor controlling patterns of sediment deposition. The Chillisquaque Creek Headwaters Watershed had three main topographic regions: a mountainous and largely forested headwaters region, a hilly agricultural middle section and a very flat agricultural and developed downstream region (see Figures 1 and 2). While stream segments in the mountainous and hilly areas typically had no to moderate sediment deposition problems, stream segments in the low gradient downstream-most reaches experienced heavy deposition (Figure 3). It is thought that sediment eroded from the hilly agricultural areas were accumulating in the downstream-most reaches where conditions were conducive to deposition. Because this seemed to be a major explanatory factor for the observed pollution problems, a reference with similar topography was sought.

The Pohopoco Creek Subwatershed (see Figure 4) was approximately 60 miles to the east and similar to the Chillisquaque Creek Headwaters Watershed with regard to many natural factors (Table 5). Of particular interest however was the fact that it had similar topography, including passing through a relatively flat valley for its final reach (Figures 4 and 5). Yet, it lacked aquatic life impairment listings. Site observations confirmed that it had far better substrate conditions with most stream reaches exhibiting minimal sediment deposition regardless of watershed region (Figure 6).

Table 5. Comparison of the Impaired Chillisquaque Creek Headwaters Watershed and the attaining Pohopoco Creek Subwatershed.

	Chillisquaque Creek	Pohopoco Creek
Phys. Province[1]	100% Susquehanna Lowland Section of the Ridge and Valley Province	86% Blue Mountain Section of the Ridge and Valley Province 14% Glaciated Pocono Plateau Section of the Appalachian Plateaus Province
Land Area[2], ac	11,178	11,385
Land Cover[2]	56% Agriculture 37% Forest/Natural Vegetation 5% Development	17% Agriculture 53% Forest/Natural Vegetation 30% Development
Soil Infiltration[3]	2% Group A 26% Group B 4% Group B/D 23% Group C 7% Group C/D 39% Group D	23% Group A 21% Group B 3% Group B/D 27% Group C 6% Group C/D 20% Group D

Dominant Bedrock[4]	69% Shale 30% Siltstone 1% Calcareous Shale	80% Sandstone 9% Shale 7% Siltstone 4% Black Shale
Average Precipitation[5], in/yr	41.5	39.9
Average Surface Runoff[5], in/yr	3.4	2.7
Average Elevation[5] (ft)	752	1,144
Average Slope[5]	9%	9%
Stream Channel Slope[5]	1st order: 2.7% 2nd order 0.8% 3rd order 0.13%	1st order: 3.7% 2nd order 1.0%

[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

As for other watershed characteristics, both the Chillisquaque Creek Headwaters Watershed and the Pohopoco Creek Subwatershed were approximately the same size and were at least partially within the Ridge and Valley Physiographic Province (Table 5). Both also had a wide range of soil drainage types and were dominated by non-carbonate sedimentary bedrocks. The surface runoff rates of both watersheds were similar, and their average slopes were approximately the same. However, stream channel slopes were somewhat greater in the Pohopoco Creek Subwatershed. One major difference between the watersheds however was their distribution of land coverage types. At 55% of its land area, the Chillisquaque Creek Headwaters Watershed was dominated by agriculture whereas the Pohopoco Creek Subwatershed was dominated by forest/natural vegetation landcover (53%). Agricultural lands were only 17% of the landcover within the Pohopoco Creek Subwatershed, but it did have far more developed lands than the Chillisquaque Creek Headwaters Watershed (30% of land area versus 5%).

A potentially concerning difference between the Chillisquaque Creek Headwaters Watershed and the Pohopoco Creek Subwatershed was that reaches of the Pohopoco Creek had very high assessment scores. In fact, they were high enough to justify a high-quality cold-water fishes (HQ-CWF) designation. In contrast, no stream reaches within the Chillisquaque Creek Headwaters Watershed were designated for special protection. Use of a watershed that is actually attaining a special protection status (high quality of exceptional value) as a reference for a non-special special protection watershed could cause prescribed pollution reductions to be unnecessarily stringent. However, this concern was dismissed because many other non-special protection potential reference watersheds were identified that had lower estimated sediment loading than the Pohopoco Creek Subwatershed.

There were two NPDES permitted point source discharges within the Pohopoco Creek Subwatershed with limits relevant to sediment loading, but neither were comparable in magnitude to Montour LLC powerplant. Both were wastewater treatment plants; one for a healthcare facility, the other for a residence (Table 6).

Table 6. Existing NPDES-Permitted Discharges in the Pohopoco Creek Subwatershed and their Potential Contribution to Sediment Loading.

Permit No.	Facility Name	Load, mean lbs/yr	Load, max lbs/d
PA0057380	Whitney SRSTP[1]	8	0.08
PA0062260	Brookmont Healthcare CTR LLC WWTP[2]	3,655	20

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, stormwater construction permits were not included above.

[1]Permit for a residential wastewater treatment facility. See permit issued March 14, 2011. Mean annual load was calculated assuming a flow rate of 262.5 gpd for a single-family residence and a total suspended solids concentration of 10 mg/l. Maximum daily load was calculated using a flow rate of 500 gpd and total suspended solids concentration of 20 mg/l. Note that even though this permit has been terminated, it was included in the calculation of the reference watershed's loading since records indicate it was in operation during watershed assessments.

[2]Permit issued September 20, 2017 listed effluent limitations for total suspended solids of 30 mg/l monthly average and 60 mg/l instantaneous max. Loads were estimated using a discharge rate of 0.04 MGD and the 30 mg/l concentration for mean lbs/yr and 60 mg/l for max lbs/yr.

After selecting the potential reference, the watersheds were visited during February and/or March of 2020 to confirm the suitability of the reference as well as to explore whether there were any obvious land use differences that may help explain why one watershed was impaired for sediment while the other was attaining.

According to site observations, the most obvious reasons for impairment in the Chillisquaque Creek Headwaters Watershed were: the high amount of agricultural landcover; potentially degrading agricultural practices; areas with high streambank erosion; and the aforementioned topography of the watershed. At 55% of total land area, agricultural coverage was sufficiently high that some impairment might be expected even if practices were exceptionally good. On top of this however, potentially degrading agricultural conditions were observed, including: an abnormally high rate of conventional tillage, the formation of gully erosion in crop fields, drainageways in and around cropfields without adequate buffers, pastures with bare soils, and direct cattle access to streams (Figures 7 and 8). Severe bank erosion was apparent at some sites. In some cases this was at least partially due cattle (Figure 8), but some degraded sites were not being grazed (Figure 9), suggesting that there may have been legacy sediments from historic upland erosion and/or former milldams. It should also be noted that many protective agricultural practices were observed within the Chillisquaque Creek Headwaters Watershed, especially the allowance for forested/naturally vegetated riparian buffers, which were estimated to comprise 81% of land area within 100 feet of NHD flowlines in the agricultural areas (Figure 10). In some cases cropland drainageways were protected with herbaceous buffers and many agricultural fields were observed with high levels of crop residues and vegetative cover (Figure 10).

Another feature of the Chillisquaque Creek Headwaters Watershed with the potential to influence sediment dynamics was the presence of a large reservoir referred to as Lake Chillisquaque (See Figure 11; also note that this lake is within the "Montour Environmental Preserve" shown in Figure 1). The dam creating this reservoir was completed in 1971 for the purpose of establishing a water supply for the aforementioned powerplant, but also for recreation and flood control (Kimball and Chuang 1979). Given the size of this reservoir, it is expected that it effectively traps most of the sediment from the approximately 14 square kilometers draining to it.

The fact that stream substrate conditions were so much better in the Pohopoco Creek Subwatershed (Figure 6) was likely in large part to due to its lesser agricultural landcover and greater natural vegetation cover versus the Chillisquaque Creek Headwaters Watershed (see Table 5). On top of this however, agricultural practices typically appeared to be good in the Pohopoco Creek Subwatershed. Like the Chillisquaque Creek Headwaters Watershed, its rate of riparian buffering was also exceptionally high in its agricultural areas (approximately 73% of the land area within 100 feet of NHD flowlines). However, the quality of buffering with regard to the expansiveness of mature forests appeared to have been better in the Pohopoco Creek Subwatershed (See Figure 12). With a few exceptions (see Figure 13), crop fields with bare soils and pasture lands with cattle access to streams were rare in the Pohopoco Creek Subwatershed. It did however have far more developed lands, and some of these sites were on fairly steep terrain or not well buffered (Figure 13). However, most of this land was developed open space (see Appendix Table B2), and thus is expected to have low pollutant loading. The Pohopoco Creek Subwatershed did not have any lakes or reservoirs comparable to Lake Chillisquaque, but it did have a small impoundment on one of its channels that was almost completely full of fine sediments (Figure 14). Given its small size and the fact that it may have equilibrated with regard to sediment retention/export, it was disregarded as a factor controlling watershed sediment dynamics. It should also be noted that better streambed conditions within the Pohopoco Creek Subwatershed may also be in part due to it having somewhat steeper stream channel slopes versus the Chillisquaque Creek Headwaters Watershed (Table 5).

Figure 2. Agricultural landscapes within the Chillisquaque Creek Headwaters Watershed. The upper photograph looks down upon the hilly middle region of the watershed. The lower photograph shows the flatter lower watershed.

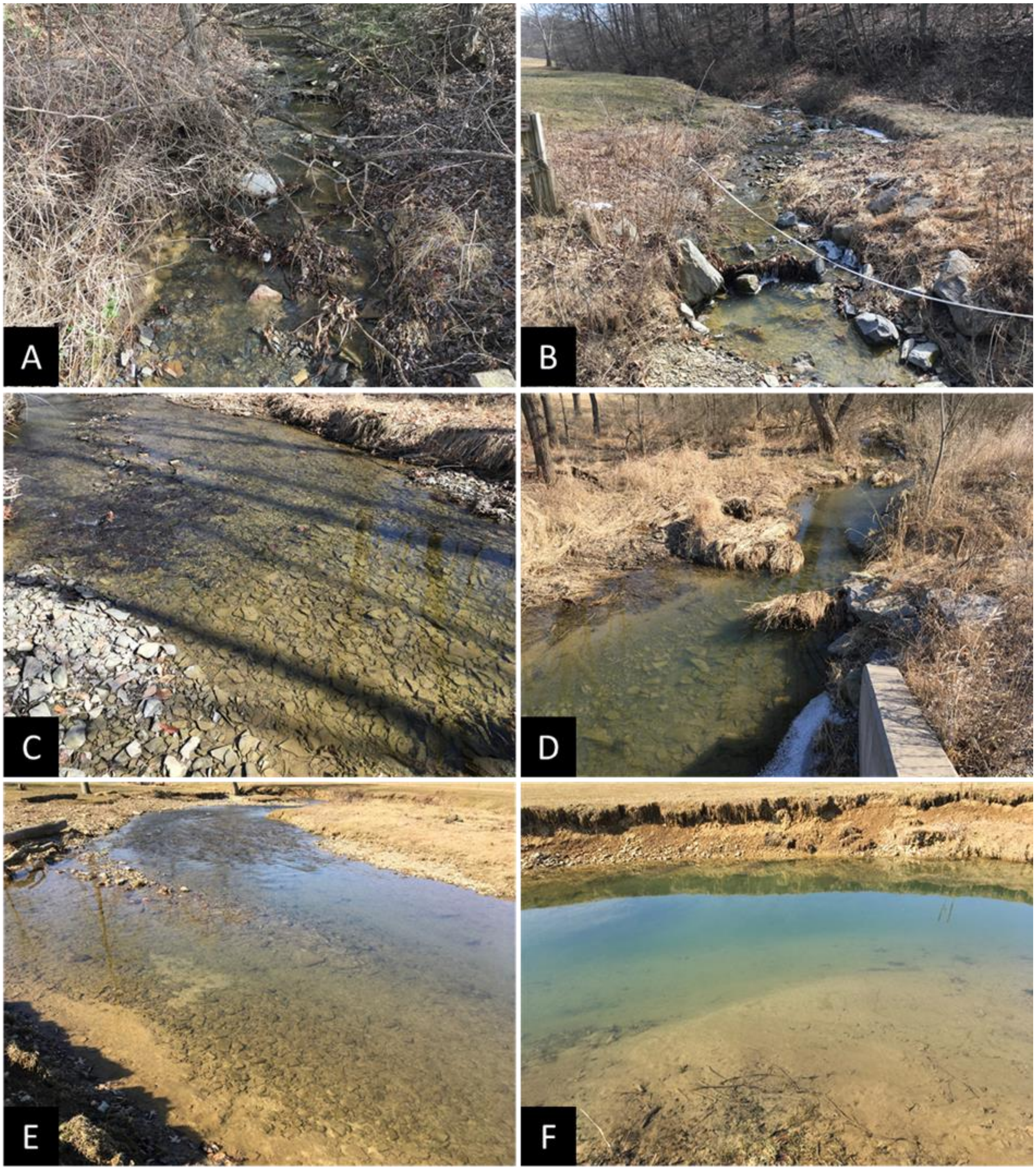
A
B
C
D
E
F

Figure 3. Example stream substrate conditions within the Chillisquaque Creek Headwaters Watershed. Small, low order streams in the mountain/hilly areas tended to be rocky and without obvious fine sediment impairment (Photographs A and B). Likewise, many of the larger stream segments in the hilly middle part of the watershed had predominantly rocky substrates (Photographs C and D). However, heavy sediment deposition became apparent as streams entered the flatter lower portion of the watershed. Photographs E and F show such a site running through a heavily grazed pasture. The most extreme fine sediment deposition was observed in the final, approximately 0.6 mile, reach of mainstem downstream of PPL Road to the junction of the West Branch of Chillisquaque Creek (photographs G and H).

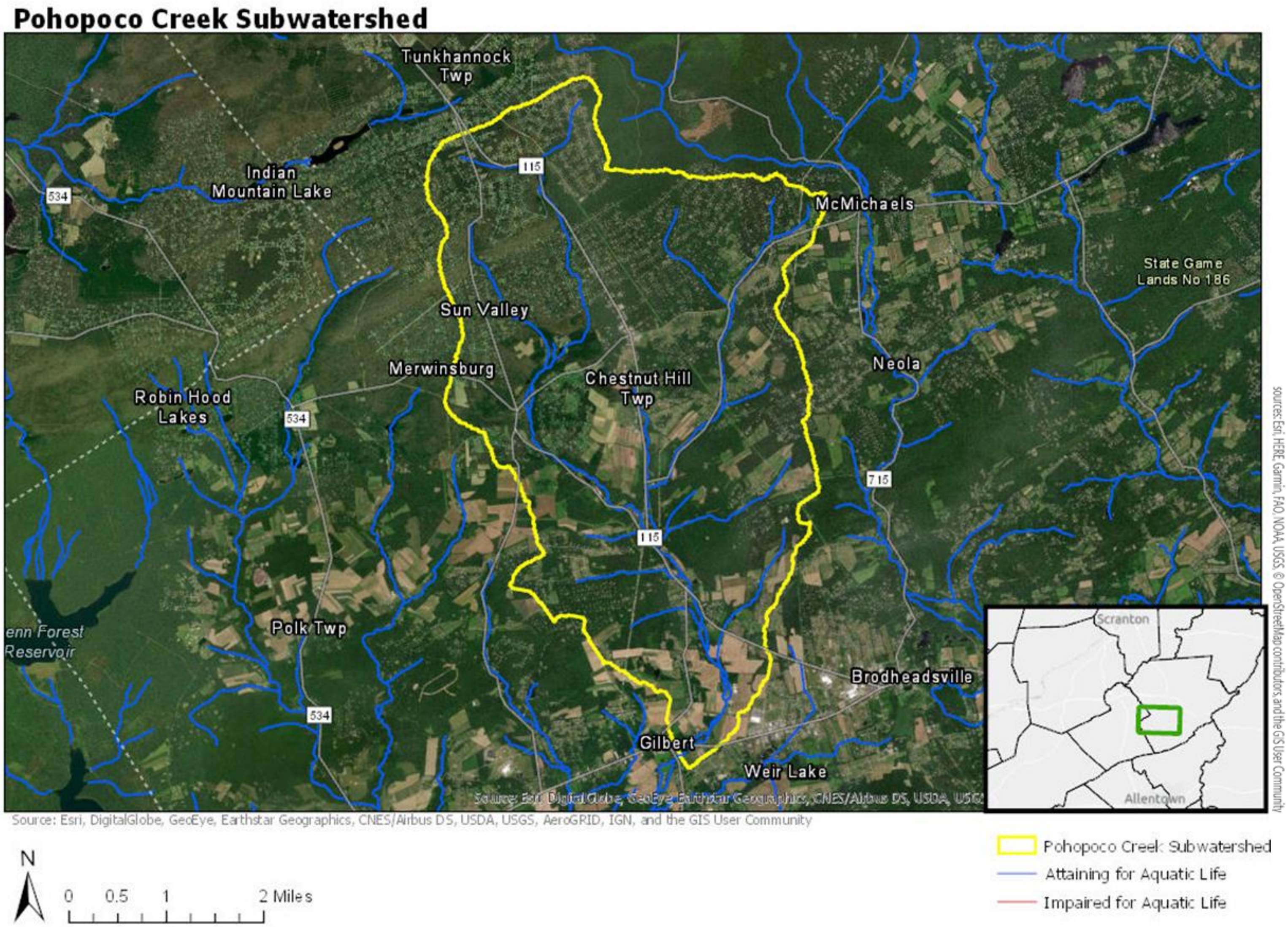

Figure 4. Pohopoco Creek Subwatershed. All stream segments within the subwatershed were listed as attaining for aquatic life per PA DEP's 2018 Integrated Report Viewer available at: https://www.depgis.state.pa.us/integrated_report_viewer/index.html.

Figure 5. Landscapes within the Pohopoco Creek Subwatershed. The upper portions of the watershed were largely forested with some low-density residential development as in the upper photograph. The downstream-most portion of the watershed was a broad agricultural and developed valley.


A
B
C
D
E
F

Figure 6. Stream substrate conditions in the Pohopoco Creek Subwatershed. From top to bottom, each paired row typically represents increasing stream size, so pictures A and B are examples of small tributaries while G and H are examples of the downstream mainstem. Sites were typically very rocky with some minor exceptions, such as the small tributary shown in photograph B that exhibited some fine sediment deposition. Also, there was some fine sediment deposition in slower waters of the downstream most reaches (photograph H), though swifter sections were very rocky in this area (G).

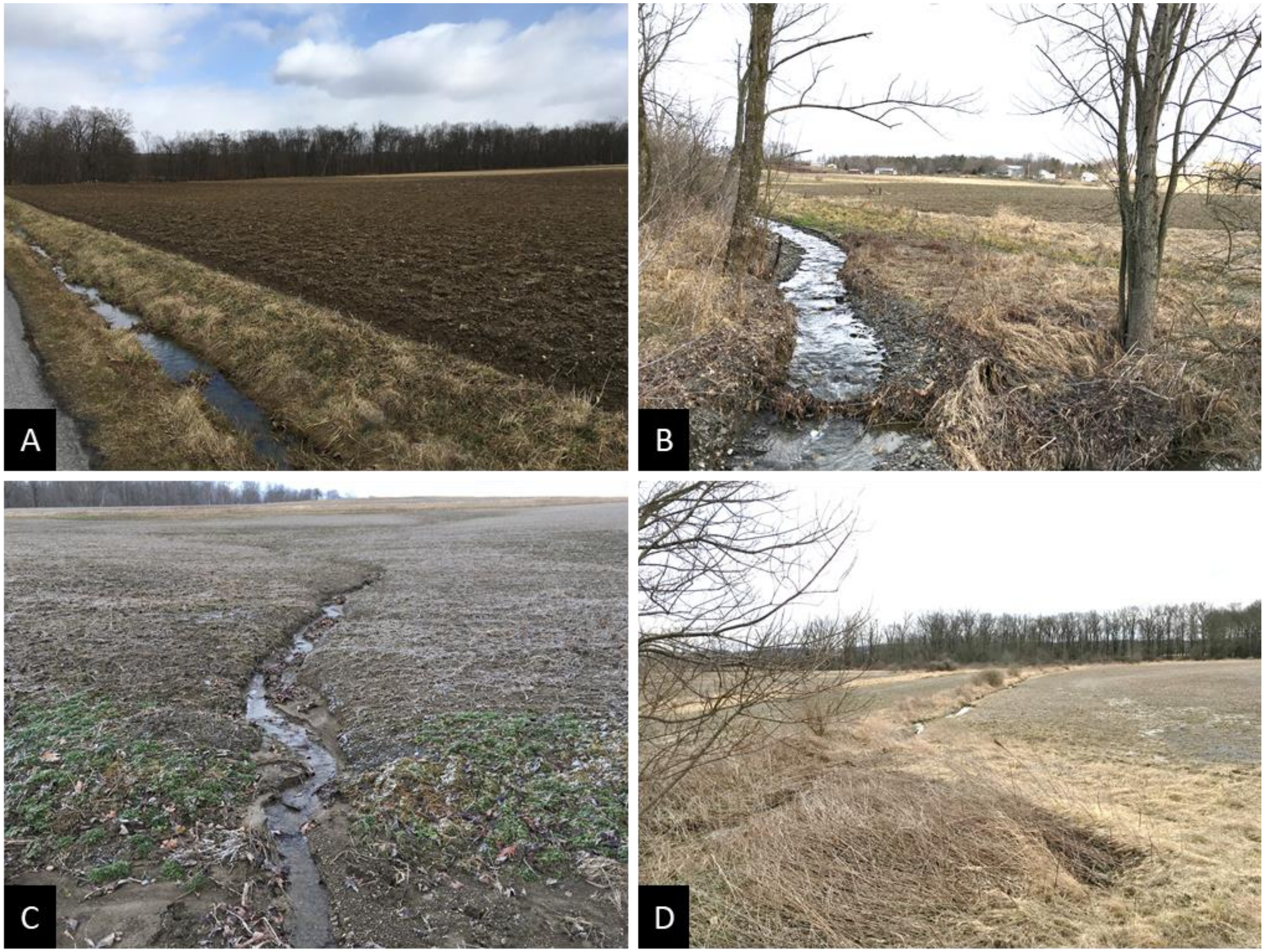

Figure 7. Stream segments and drainageways flowing through croplands with conditions that may exacerbate sediment loading in the Chillisquaque Creek Headwaters Watershed. Note the lack of substantial forested buffers, the use of conventional tillage in photographs A and B, and the formation of gully erosion in photograph C.

Figure 8. Stream segments and drainageways flowing through pasturelands with conditions that may exacerbate sediment loading in the Chillisquaque Creek Headwaters Watershed. Note that cattle had direct access to the stream and there were no forested buffers in these cases. The barnyard area in Photograph A appears to have been trampled so heavily that soils were bare.

Figure 9. Examples of severe bank erosion in the Chillisquaque Creek Headwaters Watershed.

Figure 10. Stream segments and drainageways flowing through areas of the Chillisquaque Creek Headwaters Watershed with land uses and practices that may be protective against sediment loading. Photograph A shows a forested landscape while photographs B through D show expansive riparian buffers amongst agricultural lands. Photographs E and F show drainageways among agricultural fields that were protected with herbaceous/wetland buffers.

Figure 11. Lake Chillisquaque. Note that the location of this lake can be seen in Figure 1 with the label “Montour Environmental Preserve”.

Figure 12. Landscape conditions within the Pohopoco Creek Subwatershed that may be protective against sediment loading. Much of the watershed was forested as in photograph A. Streams flowing through areas that were not predominantly forested often had substantial forested buffers, as in photographs B through D. Photograph E shows a pasture where cattle had been fenced out of the stream and photograph F shows a soy field with high crop residue coverage.

Figure 13. Examples of land uses that may exacerbate sediment loading in the Pohopoco Creek Subwatershed. Photograph A shows a soy field with some minor bare soils due to erosion occurring along a drainageway. Photograph B shows a pasture where cattle had direct access to the stream. Photograph C shows a developed area along a stream without a forested riparian buffer, and photograph D shows an example of a residential development on sloping land with degraded gravel roads.

Figure 14. Example of a dammed stream segment in the lower Pohopoco Creek Subwatershed. The ponded area was so full of fine sediment that it nearly reached the top of the dam, so it was assumed that this pond no longer functioned to accumulate sediment. Stream substrates above and below the ponded area appeared to be rocky and free of major fine sediment deposition.

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), 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 average curve number and average 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 (2020).

Model My Watershed allows the user to adjust model parameters, such as the area of land coverage types, the use of conservation practices and the efficiencies of those conservation practices, the watershed's sediment delivery ratio, etc. Default values were used for the modelling run, except that flows from the point source discharges found in Tables 4 and 6 were added as inputs. Note that rather than using the flows listed in the permit, the flow used for the Montour LLC powerplant was based on the same average monthly discharge monitoring report values that were analyzed for calculating sediment loads.

In order to explore whether corrections should be made for a discrepancy in existing riparian buffers between the impaired watershed and the reference watershed, 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. 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. The selection polygons are shown in Figures 15 and 16. 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 slightly greater in the agricultural area of the impaired watershed (81%) versus that of the reference watershed (73%). However, site observations suggested that the quality of riparian buffers with regard to width of mature forests may have been better in the reference watershed. For these reasons no additional corrections were made to account for existing riparian buffers.

While it is recognized that "Lake Chillisquaque" retains large amounts of sediment, no corrections were made to the overall watershed load or TMDL values to account for this. Not correcting for the lake effect allows for the calculation of a single prescribed load reduction, that if achieved on paper, would be expected to result in the amelioration of sediment impairments throughout the watershed. Another logical option would be to generate separate TMDL values for the two main branches of the watershed and the overall outlet. However, this would greatly increase the complexity of the document with little foreseeable benefit. Also, not "crediting" the lake for sediment removal seems fair given that it reduces sediment load at the watershed's outlet by retaining it within former stream and riparian habitat. And, lakes are known to have negative effects on stream life. It should be clearly noted however that if sufficient best management practices were implemented such that the target TMDL load were reached on paper, measurements taken at the outlet of the watershed may indicate a lower load than would be expected due to sediment retention within the lake. By calculating this expected discrepancy however, this document may help allow calculated loads and measured loads to be reconciled.

The estimated magnitude of this discrepancy under average annual conditions is reported below in Table 10. These calculations were made within a modified version of the "BMP Spreadsheet Tool" provided by Model My Watershed using calculation features that were originally intended for estimating the amount of a watershed's total load that comes from MS4 sewersheds. First, Model My Watershed's watershed delineation tool was used to delineate the "Lake Chillisquaque Subwatershed" from the dam's outlet. Then, the reported land areas were pasted into the BMP spreadsheet tool previously prepared for the entire Chillisquaque Creek Headwaters Watershed. The spreadsheet automatically calculated the amount to which lands within the lake subwatershed contributed to sediment loading of the entire watershed (uncorrected for sediment accumulation within the lake). These results were broken down by land use type and streambanks. For details on how these calculations are made, including a step by step description of how streambank loading associated with a subwatershed is estimated, see the "BMP Spreadsheet Tool" provided by Model My Watershed.

It was assumed that the lake retained 95% of the sediment load reporting to it based on relationships of reservoir sediment "trap efficiency" provided by Randle and Bountry (2016). Two methods were used that gave approximately the same result. One was a graph of an empirical relationship originally provided by Brune (1953) between % sediment trapped versus the ratio of reservoir capacity to average annual inflow. Using the normal pool volume of Lake Chillisquaque reported by Kimball and Chuang (1979) and the estimated mean stream flow at the lake's outlet from the USGS's StreamStats application, it was estimated that sediment trapping efficiency was about 95%. A second method was an equation relating sediment trap efficiency to reservoir storage capacity and drainage area originally provided by Brown (1944). In this case, the normal pool volume was used along with the estimated drainage area reported by Model My Watershed. Sediment trap efficiency was estimated to be 98% in this case. For simplicity, a 95% reduction was chosen.

Finally, it should be stated that the powerplant and reservoir create some very complex hydrologic dynamics that are further compounded by the fact that water is imported from the West Branch of the Susquehanna to maintain a particular pool level in the lake. It would be expected that some sediment would be imported from the river, and extra water would increase streambank erosion. However, given the complexity of the situation and the uncertain, though likely minor, effects that these factors have on watershed wide sediment loading relative to sediment retention within the lake, no further corrections were attempted to account for altered hydrology of the watershed, aside from the aforementioned addition of the point sources as inputs.

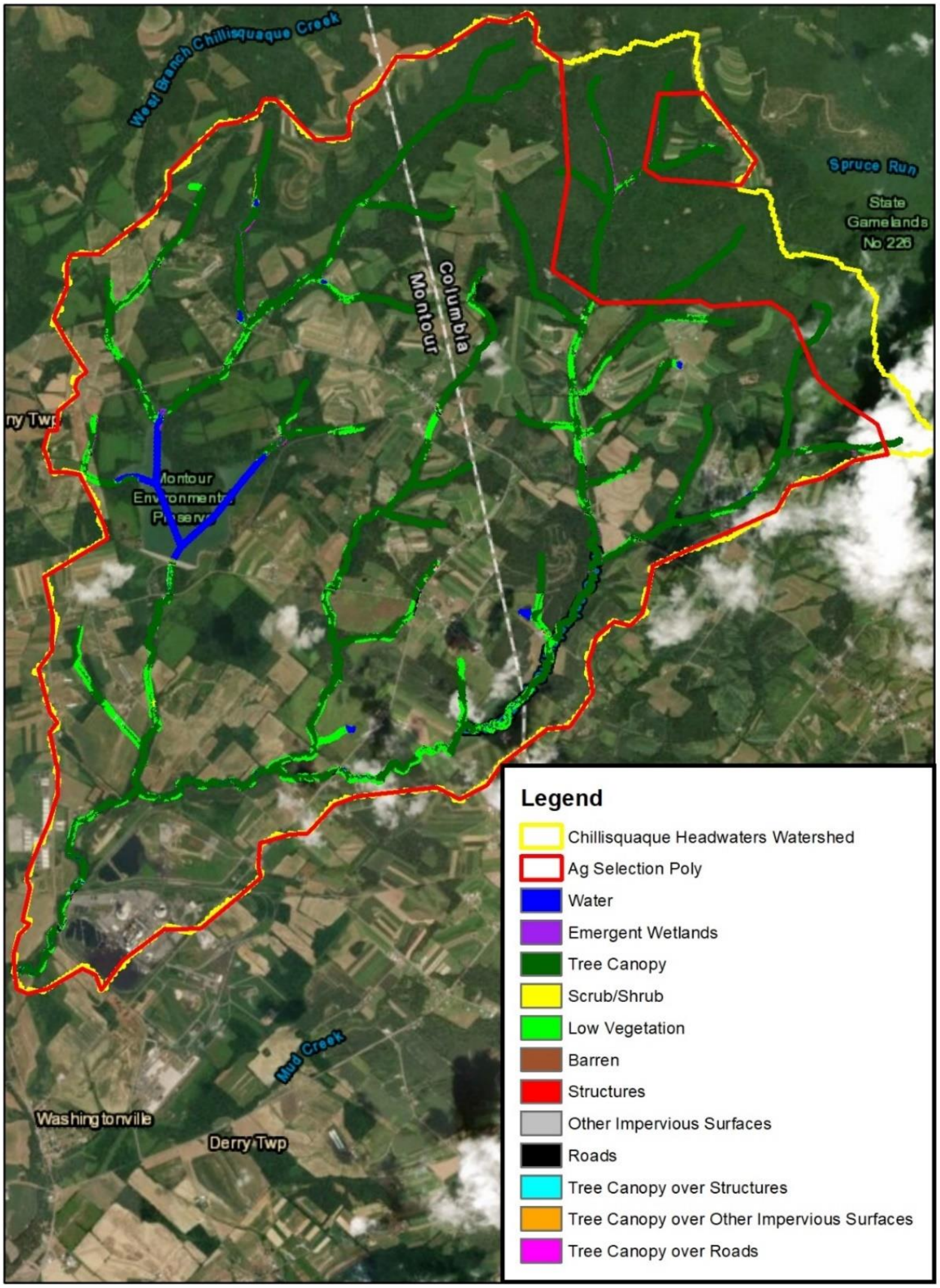

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Figure 15. Riparian buffer analysis in the Chillisquaque Creek Headwaters Watershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of NHD flowlines. The rate of riparian buffering within the agricultural selection polygons was estimated to be about 81%.

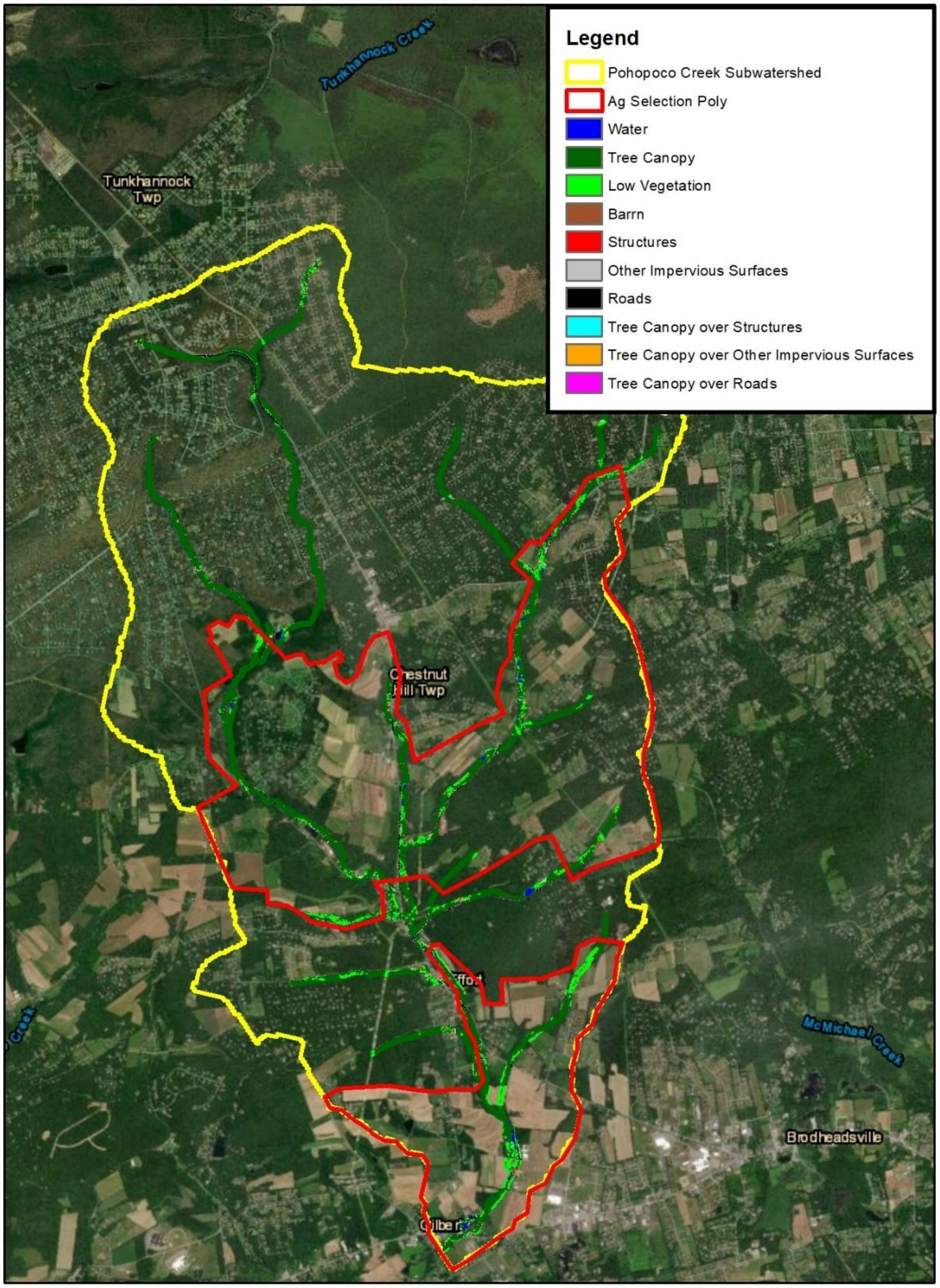

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Figure 16. Riparian buffer analysis in the Pohopoco Creek Subwatershed. A raster dataset of high-resolution land cover (University of Vermont Spatial Analysis Laboratory 2016) is shown within 100 feet (geodesic) of either side of NHD flowlines. The rate of riparian buffering within the agricultural selection polygons was estimated to be about 73%.

Calculation of the $TMDL_{Avg}$

The mean annual sediment loading rate for the unimpaired reference watershed (Pohopoco Creek Subwatershed) was estimated to be 330 pounds per acre per year (Table 7). This was substantially lower than the estimated mean annual loading rate in the impaired Chillisquaque Creek Headwaters Watershed (635 pounds per acre per year, Table 8). Thus, to achieve the loading rate of the unimpaired watershed, sediment loading in the Chillisquaque Creek Headwaters Watershed should be reduced to 3,692,901 pounds per year or less (Table 9).

Table 7. Existing Annual Average Loading Values for the Pohopoco Creek Subwatershed, Reference

Source	Area ac	Sediment lbs/yr	Unit Area Load, lbs/ac/yr
Hay/Pasture	1,469	968,911	660
Cropland	462	338,344	733
Forest and Shrub/Scrub	5,980	9,725	2
Wetland	7	20	3
Herbaceous/Grassland	12	340	28
Bare Rock	2	1	0
Low Intensity Mixed Development	3,407	37,442	11
Medium Intensity Mixed Development	37	2,372	64
High Density Mixed Development	7	422	57
Streambank[1]		2,400,182	
Point Sources		3,663	
Additional Buffer Discount[2]		0	
total	11,385	3,761,424	330

[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 Sediment Loading Values for the Chillisquaque Creek Headwaters Watershed, Impaired			
Source	Area, ac	Sediment lbs/yr	Unit Area Load lbs/ac/yr
Hay/Pasture	4,005	1,257,019	314
Cropland	2,240	4,258,610	1,902
Forest and Shrub/Scrub	4,015	5,938	1
Wetland	49	111	2
Herbaceous/ Grassland	106	2,213	21
Bare Rock	173	82	0
Low Intensity Mixed Development	565	6,006	11
Medium Intensity Mixed Development	17	1,137	66
High Intensity Mixed Development	7	512	69
Streambank		1,393,313	
Point Sources		178,010	
total	11,178	7,102,951	635

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

Table 9. Calculation of an Annual Average TMDL Value for the Chillisquaque Creek Headwaters Watershed			
Pollutant	Mean Loading Rate in Reference, lbs/ac/yr	Total Area in Impaired Watershed, ac	Target $TMDL_{Avg}$ Value, lbs/yr
Sediment	330	11,178	3,692,901

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 allocation, the margin of safety and wasteload allocation 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} was explicitly designated as ten-percent of the $TMDL_{Avg}$ based on professional judgment. Thus:

3,692,901 lbs/yr $TMDL_{Avg}$ * 0.1 = 369,290 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 four National Pollutant Discharge Elimination System (NPDES) point source discharges with numeric limits for sediment, but only one was a substantial contributor to loading (Table 4). Based on discharge monitoring reports, the Montour LLC powerplant was estimated to contribute on average 177,986 pounds of sediment per year (Table 4), or about 2.5% of the watershed's total load. While far less than contributions from croplands (60% of the load), hay/pasture lands (18% of the load) or streambanks (20% of the load), the powerplant's current permit had no sediment load limitations and thus could increase. If the powerplant continuously discharged at their concentration limit of 30 mg/l total suspended solids and the design flow rates for the two outfalls that discharge to Chillisquaque Creek, the average annual sediment load would be 895,546 lbs, or 13% of watershed's total load. Even this however does not imply an absolute loading limit since flows could increase beyond design flows.

In setting a loading limit for the Montour LLC powerplant, one factor that should be considered is the net effect of the powerplant on sediment loads within the watershed. Lake Chillisquaque (see Figures 1 and 11), was built as a water source for the powerplant and is owned by the power company (currently Talen Energy). Given its large size, it is estimated to retain >95% of the sediment reporting to it, or about 1.8 million pounds per year (see the Hydrologic/Water Quality Modelling section and Table 10). Thus, it can be argued that the amount of sediment in the downstream area where the powerplant discharges is actually far less than it would be if not for the powerplant/dam. A counter argument to this, however, is that sediment is only reduced in the downstream area because it is being retained in a lake which encompasses former stream channels. And, artificial lakes can have negative effects on streams. Even so, the lake is a valued recreational area ("The Montour Preserve") and the Department generally does not list stream segments as impaired simply due to the presence of a historic dam.

Table 10. Calculation of the Reservoir-Shed Load and its Effect on Sediment Retention

Source	Raw Unit Area Load lbs/ac/yr	Reservoir-Shed Area, ac	Reservoir-Shed Load, lbs/yr
Hay/Pasture	314	1,314	412,290
Cropland	1,902	556	1,056,436
Forest and Shrub/Scrub	1	1,264	1,870
Wetland	2	30	67
Herbaceous/ Grassland	21	7	154
Bare Rock	0.5	0	0
Low Intensity Mixed Development	11	165	1,757
Medium Intensity Mixed Development	66	2	162
High Intensity Mixed Development	69	0	0
Streambank			402,775
Point Sources			

Total Reservoir Shed Load		3,338	1,875,511
Retained Load Assuming 95% Retention			1,781,735

Thus, with all of this in consideration, a balance was sought whereby a new load limit was established that allows the powerplant to continue to discharge at its historic rate, but limits its ability to increase sediment loading and worsen existing impairment. The powerplant's loading limit to Chillisquaque Creek is thus established as its current average load of 177,986 lbs/yr. Note that this only applies to outfalls with numeric permit limits to Chillisquaque Creek, as the plant also has stormwater outfalls and discharges to other watersheds. For compliance evaluation purposes, it is suggested that the Department's reviewer calculate the average annual sediment discharge per Table 4, footnote 1, over the five previous years during the quinquennial permit renewal to determine whether the facility remained under this value.

It is expected that the powerplant's discharges to Chillisquauque Creek will greatly decrease within the next few years, as plans are currently underway to re-route much of the wastewater discharge from Chillisquaque Creek to the West Branch of the Susquehanna River to address thermal pollution concerns. Consequently, the facility's non-stormwater point source discharge of sediment to Chillisquaque Creek could decrease by 85%. Given these pending changes it is suggested that compliance with the annual average wasteload allocation be considered over the next permit cycle, rather than the current permit cycle which ends in August 2023.

The other three point sources with numeric limits were all small flow wastewater treatment facilities serving residences, and at approximately 8 pounds of sediment per year each, they were virtually negligible sediment sources. Therefore, these facilities they will not be given individual wasteload allocations but rather be covered under the bulk reserve, which we defined as one percent of the targeted TMDL. The bulk reserve will also allow for insignificant dischargers and minor new sources.

Thus, the WLA was calculated as:

3,692,901 lbs/yr $TMDL_{Avg}$ * 0.01 = 36,929 lbs/yr bulk $reserve_{Avg}$ + 177,986 lbs/yr from Montour LLC = 214,915 lbs/yr WLA_{Avg}

Load Allocation

Now that the margin of safety and wasteload allocation have been defined, the load allocation (LA) is calculated as:

3,692,901 lbs/yr $TMDL_{Avg}$ – (369,290 lbs/yr MOS_{Avg} + 214,915 lbs/yr WLA_{Avg}) = 3,108,696 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, non-agricultural herbaceous/grasslands, bare rock and developed lands within the Chillisquaque Creek Headwaters Watershed were considered loads not reduced (LNR). LNR_{Avg} was calculated to be 15,999 lbs/yr (Table 11).

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

3,108,696 lbs/yr LA_{Avg} – 15,999 lbs/yr LNR_{Avg} = 3,092,697 lbs/yr ALA_{Avg}

Table 11. Average Annual Load Allocation, Loads Not Reduced and Adjusted Load Allocation

	Sediment, lbs/yr
Load Allocation (LA_{Avg})	**3,108,696**
Loads Not Reduced (LNR_{Avg}):	**15,999**
Forest	5,938
Wetlands	111
Herbaceous/Grassland	2,213
Bare Rock	82
Low Intensity Mixed Development	6,006
Medium Intensity Mixed Development	1,137
High Density Mixed Development	512
Adjusted Load Allocation (ALA_{Avg})	**3,092,697**

Note, the ALA is comprised of the anthropogenic sediment sources targeted for reduction: croplands, hay/pasturelands and streambanks (assuming an elevated erosion rate). The LNR is comprised of both natural and anthropogenic sediment sources. While anthropogenic, developed lands were considered a negligible sediment source in this watershed and thus not targeted for reduction. Forests, wetlands, herbaceous/grassland and bare rock 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 D. Although this Chillisquaque Creek Headwaters TMDL was developed to address impairments caused by agricultural activities, streambanks were also significant contributors to the sediment load 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 evaluation croplands exceeded the entire allocable load by itself. Thus, it received a greater percent reduction (61%) than hay/pasture lands and streambanks, which received reductions of 46% each (Table 12).

Table 12. Annual Average Sediment Load Allocations for Source Sectors in the Chillisquaque Creek Headwaters Watershed

		Load Allocation	Current Load	Reduction Goal
Land Use	Acres	lbs/yr	lbs/yr	
CROPLAND	2,240	1,665,458	4,258,610	61%
HAY/PASTURE	4,005	676,921	1,257,019	46%
STREAMBANK		750,317	1,393,313	46%
AGGREGATE		3,092,697	6,908,942	55%

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.

Model My Watershed currently does not report daily loading rates, but its predecessor program, "MapShed" does. Thus, for the calculation of a $TMDL_{Max}$ value, modelling was initially conducted in Model My Watershed, and the "Export GMS" feature was used to provide an input data file that was 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 loads in both the Chillisquaque Creek Headwaters and Pohopoco Creek 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 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). The maximum daily sediment loads from the point sources shown in Tables 4 and 6 were added to the loads from the two watershed totals. As with the average loading values reported previously (see the Hydrologic / Water Quality Modelling section), no correction was made for sediment accumulation in Lake Chillisquaque. This could be estimated however by assuming that loading from land uses and streambanks within the lake subwatershed are the same percentage of the watershed-wide land use + streambank value under 99 percentile conditions as they were under average annual conditions (26%). If it is also assumed that the lake is 95% retentive under 99 percentile conditions, then the maximum daily lake retention is estimated to be 75,036 lbs/d.

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 195,125 pounds per day (Table 13), which would be a 36% reduction from Chillisquaque Creek's current 99th percentile daily loading rate of 305,618 pounds per day.

Table 13. Calculation of $TMDL_{Max}$ for the Chillisquaque Creek Headwaters 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	17.5	11,178	195,125

Also, in accordance with the previous "Calculation of Load Allocations" section, the WLA_{Max} would consist of a bulk reserve defined as 1% of the $TMDL_{Max}$, and the maximum daily loading allowance for the Montour LLC powerplant. The three small flow wastewater treatment facilities shown in Table 4 would be covered under the bulk reserve. As was the case for annual average calculations, the maximum daily wasteload allocation for the Montour LLC powerplant was based on an analysis of discharge monitoring reports for two outfalls with permit limits that discharged to Chillisquaque Creek. There were 100 estimates of daily flow and sediment concentrations for each outfall, and these were combined to calculate 100 daily loads. One day was excluded because a daily maximum total suspended solids concentration limit was exceeded and thus should not be used to calculate a daily maximum allowable load. Total suspended sediment concentration values with "<" symbols were simply changed to the number without the symbol.

As explained when calculating the wasteload allocation under $TMDL_{AVG}$ conditions, a balance was sought whereby a new load limit was established that allows the powerplant to continue to discharge at its historic rate, but limits its ability to increase sediment loading and worsen existing impairment. Therefore, the powerplant's daily loading limit to Chillisquaque Creek is thus established as its current 99th percentile loading rate (with the noncompliant day excluded) of 13,019 lbs/d. Note that this only applies to outfalls with numeric permit limits to Chillisquaque Creek, as the plant also has stormwater outfalls and discharges to other watersheds.

As was explained previously, it is expected that the powerplant's discharges to Chillisquaque Creek will greatly decrease within the next few years, as plans are currently underway to re-route much of the wastewater discharge from Chillisquaque Creek to the West Branch of the Susquehanna River to address thermal pollution concerns. Given these pending changes it is suggested that compliance with the wasteload allocation be considered over the next permit cycle, rather than the current permit cycle which ends in August 2023. Given that this is a wasteload allocation is an allocation of the 99th percentile TMDL value, it is expected that this daily limit will be met 99% of the time.

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 14 for a summary of these $TMDL_{Max}$ variables.

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

lbs/d:				
Pollutant	$TMDL_{Max}$	MOS_{Max}	WLA_{Max}	LA_{Max}
Sediment	195,125	19,512	14,970	160,642

Mapshed 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 24% of LA_{Avg} it was assumed that it was also 24% 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 Table 15 for a summary of the LA_{Max} variables.

Table 15. Allocation of the 99th Percentile Daily Load Allocation (LA_{Max}) for the Chillisquaque Creek Headwaters Watershed

	Annual Average (lbs/yr)	Proportion of Load Allocation	Max Daily (lbs/d)
Load Allocation	3,108,696		160,642
Loads Not Reduced	15,999	0.005	827
Adjusted Loads Allocation	3,092,697	0.995	159,815
Croplands	1,665,458	0.54	86,063
Hay/Pasturelands	676,921	0.22	34,980
Streambanks	750,317	0.24	38,773

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 24% of LA_{Avg} it was assumed that it was also 24% 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 (see-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 Chillisquaque Creek Headwaters Watershed because 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 Chillisquaque Creek Headwaters Watershed would skyrocket to 71,220,449 lbs/yr, which is more than ten-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 Chillisquaque Creek Headwaters 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 calculations. The source of the weather data (precipitation and temperature) was a dataset compiled by USEPA ranging from 1961-1990 (Stroud Water Research Center 2020). 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 of 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.

Recommendations

This document proposes a 48% reduction in annual average sediment loading for the Chillisquaque Creek Headwaters 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 61% whereas loading from hay/pasture lands and streambanks should be reduced by 46% each. 99^{th} percentile daily sediment loading should be reduced by 36%. 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, Chapter 102.4, see also Appendix E) and through the use of BMPs such as conservation tillage, cover crops, vegetated filter strips, rotational grazing, livestock exclusion fencing, riparian buffers, etc. Based on site observations, it appeared that grazing land management, streambank fencing, streambank stabilization, implementation of agricultural erosion and sedimentation control plans, and use of conservation tillage rather than conventional tillage were especially needed.

In addition to making reductions to nonpoint sources, loading limits were established for the Montour LLC powerplant. While these limits do not require reductions relative to current loading rates, they greatly limit the powerplant's ability to increase discharged suspended sediment loads and exacerbate the sedimentation problem in the watershed. Those limits will be set at 177,986 lbs/yr as an annual average and 13,019 lbs/d as a daily maximum.

Development of a more detailed watershed implementation plan is recommended. Further ground truthing should be performed to assess both the extent of existing BMPs and to determine the most cost effective and environmentally protective combination of BMPs required for meeting the prescribed sediment reductions. Key personnel from the regional DEP office, the County Conservation District, Susquehanna River Basin Commission (SRBC) 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 published in the January 30, 2021 issue of the Pennsylvania Bulletin to foster public comment. A 30-day period was provided for the submittal of comments. No public comments were received.

Citations

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Appendix A: Background on Stream Assessment Methodology

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

Assessment Methods:

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

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

The assessment method called for selecting representative stream segments based on factors such as surrounding land uses, stream characteristics, surface geology, and point source discharge locations. The biologist was to select as many sites as necessary to establish an accurate assessment for a stream segment; the length of the stream segment could vary between sites. The biological surveys were to include kick-screen sampling of benthic macroinvertebrates, habitat surveys, and measurements of pH, temperature, conductivity, dissolved oxygen, and alkalinity. Benthic macroinvertebrates were 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 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) are completed, the biologist are to determine the status of the stream segment. Decisions are to be based on the performance of the segment using a series of biological metrics. If the stream segment is classified as impaired, it was to be 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 any errors in the NHD. A GIS contractor transferred the old DEP stream assessment information to the improved NHD and the old DEP streams layer was archived. Overall, this marked an improvement in the quality of the streams layer and made the stream assessment data compatible with national standards but it necessitated a change in the Integrated Listing format. The NHD is not attributed with the old DEP five-digit stream codes so segments can no longer be listed by stream code but rather only by stream name or a fixed combination of NHD fields known as reachcode and ComID. The NHD is aggregated by Hydrologic Unit Code (HUC) watersheds so HUCs rather than the old State Water Plan (SWP) watersheds are now used to group streams together. A more basic change was the shift in data management philosophy from one of “dynamic segmentation” to “fixed segments”. The dynamic segmentation records were proving too difficult to manage from an historical tracking perspective. The fixed segment methods will remedy that problem. The stream assessment data management has gone through many changes over the years as system requirements and software changed. It is hoped that with the shift to the NHD and OIT's (Office of Information Technology) fulltime staff to manage and maintain SLIMS the systems and formats will now remain stable over many Integrated Listing cycles.

Appendix B: Model My Watershed Generated Data Tables

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.96	2.07
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	1.94	4.21
Developed, Low Intensity	22	0.35	0.76
Developed, Medium Intensity	23	0.07	0.15
Developed, High Intensity	24	0.03	0.07
Barren Land (Rock/Sand/Clay)	31	0.7	1.5
Deciduous Forest	41	12.63	27.33
Evergreen Forest	42	0.65	1.4
Mixed Forest	43	2.63	5.68
Shrub/Scrub	52	0.35	0.76
Grassland/Herbaceous	71	0.43	0.92
Pasture/Hay	81	16.22	35.09
Cultivated Crops	82	9.07	19.62
Woody Wetlands	90	0.11	0.23
Emergent Herbaceous Wetlands	95	0.09	0.19
Total		46.22	100

Table B1. “Model My Watershed” Land Cover Outputs for the Chillisquaque Creek Headwaters Watershed

Type	NLCD Code	Area (km²)	Coverage (%)
Open Water	11	0.09	0.2
Perennial Ice/Snow	12	0	0
Developed, Open Space	21	12.56	27.21
Developed, Low Intensity	22	1.24	2.68
Developed, Medium Intensity	23	0.15	0.31
Developed, High Intensity	24	0.03	0.06
Barren Land (Rock/Sand/Clay)	31	0.01	0.02
Deciduous Forest	41	20.09	43.51
Evergreen Forest	42	3.04	6.58
Mixed Forest	43	1.01	2.18
Shrub/Scrub	52	0.08	0.17
Grassland/Herbaceous	71	0.05	0.1
Pasture/Hay	81	5.95	12.88
Cultivated Crops	82	1.87	4.04
Woody Wetlands	90	0.03	0.07
Emergent Herbaceous Wetlands	95	0	0
Total		46.18	100

Table B2. “Model My Watershed” Land Cover Outputs for the Pohopoco Creek Subwatershed

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	7.92	1.19	5.14	1.59	0.33	7.15
Feb	8.1	1.47	5.19	1.44	0.51	7.31
Mar	8.99	0.79	6.61	1.59	1.85	8.36
Apr	7.49	0.23	5.71	1.54	4.61	8.41
May	5.54	0.22	3.73	1.59	8.52	10.51
Jun	4.65	1.03	2.08	1.54	10.02	10.58
Jul	2.67	0.25	0.83	1.59	9.55	9.86
Aug	2.2	0.2	0.41	1.59	8.17	8.64
Sep	3.2	0.96	0.7	1.54	5.71	9.04
Oct	4.1	0.76	1.75	1.59	3.61	8.06
Nov	5.63	0.64	3.45	1.54	1.77	9.38
Dec	8.27	0.88	5.8	1.59	0.69	8.11
Total	68.76	8.62	41.4	18.73	55.34	105.41

Table B3. "Model My Watershed" Hydrology Outputs for the Chillisquaque Creek Headwaters Watershed.

Month	Stream Flow (cm)	Surface Runoff (cm)	Subsurface Flow (cm)	Point Src Flow (cm)	ET (cm)	Precip (cm)
Jan	4.64	1.01	3.63	0.01	0.32	6.69
Feb	5.56	1.32	4.22	0.01	0.49	6.47
Mar	6.17	0.6	5.56	0.01	1.87	7.4
Apr	5.85	0.54	5.3	0.01	4.04	8.25
May	4.53	0.23	4.29	0.01	8.19	9.96
Jun	3.25	0.35	2.89	0.01	11.58	9.81
Jul	1.86	0.32	1.53	0.01	11.98	10.08
Aug	0.92	0.24	0.67	0.01	9.65	9.66
Sep	1.01	0.6	0.39	0.01	6.03	9.19
Oct	1.01	0.33	0.66	0.01	3.69	7.27
Nov	2.09	0.53	1.56	0.01	1.79	8.82
Dec	3.91	0.74	3.16	0.01	0.67	7.62
Total	40.8	6.81	33.86	0.12	60.3	101.22

Table B4. "Model My Watershed" Hydrology Outputs for the Pohopoco Creek Subwatershed

Sources	Sediment (kg)
Hay/Pasture	570,076.60
Cropland	1,931,342.30
Wooded Areas	2,693.10
Wetlands	50.4
Open Land	1,003.70
Barren Areas	37.1
Low-Density Mixed	419.5
Medium-Density Mixed	515.5
High-Density Mixed	232.3
Low-Density Open Space	2,304.30
Farm Animals	0
Stream Bank Erosion	631,888.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B5. Model My Watershed outputs for sediment in the Chillisquaque Creek Headwaters Watershed.

Sources	Sediment (kg)
Hay/Pasture	439,415.50
Cropland	153,443.90
Wooded Areas	4,410.60
Wetlands	9.1
Open Land	154.4
Barren Areas	0.5
Low-Density Mixed	1,524.20
Medium-Density Mixed	1,075.90
High-Density Mixed	191.6
Low-Density Open Space	15,456.20
Farm Animals	0
Stream Bank Erosion	1,088,518.00
Subsurface Flow	0
Point Sources	0
Septic Systems	0

Table B6. Model My Watershed Outputs for Sediment in the Pohopoco Creek Subwatershed.

Appendix C: Stream Segments in the Chillisquaque Creek Headwaters Watershed with Aquatic Life Use Impairments

Stream Name:	Impairment Source:	Impairment Cause:	COMID:	Miles:
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916363	0.53
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916365	0.48
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916633	0.93
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916639	0.60
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916671	0.01
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66916715	0.50
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66916717	0.82
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66916739	0.96
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916763	0.56
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66916801	0.02
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916807	0.70
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916809	0.15
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916835	1.01
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916865	0.25
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916867	0.12
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916871	0.02
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916885	0.05
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916889	0.01
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916891	0.02
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916903	0.04
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916905	0.12
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916907	0.01
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66916913	0.67
East Branch Chillisquaque Creek	Agriculture	Siltation	66916915	0.48
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916923	1.01
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66916925	0.18
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66916929	0.73
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66916931	1.05
East Branch Chillisquaque Creek	Agriculture	Siltation	66916963	0.20
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66916967	0.75
East Branch Chillisquaque Creek	Agriculture	Siltation	66916969	0.03
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66916971	0.38
White Hall Creek	Agriculture	Siltation	66917035	1.26
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917057	0.40
East Branch Chillisquaque Creek	Agriculture	Siltation	66917059	0.35
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917073	0.80
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917083	0.47
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917085	0.39
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917099	0.84
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917101	0.76
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917103	0.73
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917121	0.12
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917123	0.07
White Hall Creek	Agriculture	Siltation	66917125	0.27
Unnamed Tributary to White Hall Creek	Agriculture	Siltation	66917131	0.40
White Hall Creek	Agriculture	Siltation	66917193	0.25
East Branch Chillisquaque Creek	Agriculture	Siltation	66917217	0.54
Unnamed Tributary to White Hall Creek	Agriculture	Siltation	66917227	0.37
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917235	0.53
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917269	0.27
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917275	0.53
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917327	0.04
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917329	0.02
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917347	0.06
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917351	0.39
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917353	0.01
East Branch Chillisquaque Creek	Agriculture	Siltation	66917399	0.62
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917401	0.16
Unnamed Tributary to White Hall Creek	Agriculture	Siltation	66917505	0.86
White Hall Creek	Agriculture	Siltation	66917507	1.10
Unnamed Tributary to East Branch Chillisquaque Creek	Agriculture	Siltation	66917611	0.42
East Branch Chillisquaque Creek	Agriculture	Siltation	66917613	0.98
Unnamed Tributary to White Hall Creek	Agriculture	Siltation	66917643	0.04
Unnamed Tributary to White Hall Creek	Agriculture	Siltation	66917673	0.20
White Hall Creek	Agriculture	Siltation	66917675	0.75
White Hall Creek	Agriculture	Siltation	66917715	0.38
Unnamed Tributary to Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917719	0.86
East Branch Chillisquaque Creek	Agriculture	Siltation	66917721	1.61
Middle Branch Chillisquaque Creek	Agriculture	Siltation	66917765	0.31
East Branch Chillisquaque Creek	Agriculture	Siltation	66917771	0.96
Chillisquaque Creek	Agriculture	Siltation	66918191	1.80
Chillisquaque Creek	Industrial Point Source	Other Habitat Alterations	66918191	1.80

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

	Non-MS4 Sewershed Current Load, lbs/yr	Any > ALA?	If > ALA, reduce to ALA	How much does sum exceed ALA?	Proportions of total after initial adjust	Assign reductions still needed per proportions after intial adjust	ALA: subtract reductions still needed from initial adjust	proportion Reduction
Cropland	4,258,610	yes	3,092,697		0.54	1,427,239	1,665,458	0.61
Hay/Pasture	1,257,019	no	1,257,019	2,650,332	0.22	580,098	676,921	0.46
Streambank	1,393,313	no	1,393,313		0.24	642,996	750,317	0.46
sum	**6,908,942**		**5,743,029**		**1.00**	**2,650,332**	**3,092,697**	**0.55**

Table D1. Equal Marginal Percent Reduction calculations for the Chillisquaque Creek Headwaters 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.