Total Maximum Daily Load (TMDL) For Nutrients and Sediments in the South Branch Wyalusing Creek

Susquehanna County

Pennsylvania Department of Environmental Protection
Northeast Regional Office
Water Management Program

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Table of Contents

Tables

Figures

Attachments

Attachment A	Model Results
Attachment B	Maps
Attachment C	Strategy For Conducting Nutrient-Related TMDL Assessments for Streams in PA
Attachment D	Introduction to Watershed Hydrology, Simulation, and Pollutant Transport
Attachment E	GWLF Users Manuel
Attachment F	Equal Marginal Percent Reduction (EMPR)
Attachment G	Comment and Response (Final Document Only)

TMDLs for South Branch Wyalusing Creek Watershed

Executive Summary

Total Maximum Daily Loads or TMDLs were developed for the South Branch of Wyalusing Creek (SBWC) watershed to address the impairments noted on Pennsylvania's 1996 and 1998 Clean Water Act Section 303(d) Lists. The impairments were found during biological surveys of the aquatic life in the stream. The impairments are caused by excess nutrient and sediment loads from agriculture. As listed in 25 PA Code Chapter 93, Section 93.9i, the designated aquatic life use for the South Branch Wyalusing Creek is Warm Water Fishery. The nutrient portion of the TMDL focuses on control of nitrogen and phosphorus.

Pennsylvania does not currently have water quality criteria for sediment or nutrients. For this reason, we developed a reference watershed approach to identify the TMDL endpoints or water quality objectives for nitrogen, phosphorus and sediment in the impaired segments of the SBWC watershed. By comparison to a similar non-impaired watershed, Pennsylvania estimated that the amount of nitrogen loading that will meet the water quality objectives for SBWC is 14,418 pounds per year. Phosphorus loading must be limited to 1,858 pounds per year, while sediment loading must be limited to 2,480,930 pounds per year. When these values are met, SBWC will support its aquatic life uses.

The TMDLs for SBWC are allocated as shown in the table below.

TMDL for South Branch of Wyalusing Creek

Pollutant	TMDL (lb/yr)	LA (lb/yr)	WLA (lb/yr)	MOS (lb/yr)
Nitrogen	14,418	12,976	0	1,442
Phosphorus	1,858	1,672	0	186
Sediment	2,480,930	2,232,837	0	248,093

The TMDLs are allocated to all non-point sources (Load Allocations - LAs) with 10% of the allowable loading reserved as a margin of safety (MOS). There are no wasteload allocations (WLA) for point sources because there are no known point source discharges in the impaired areas of the watershed. The TMDL establishes a reduction in nitrogen loading of 44% from the current yearly loading of 23,104 pounds, a reduction in phosphorus loading of 53% from the current yearly loading of 3,529 pounds, and a reduction in sediment loading of 56% from the current yearly loading of 5,033,030 pounds.

Introduction

Total Maximum Daily Loads or TMDLs were developed for the South Branch of Wyalusing Creek (SBWC) watershed to address the impairments noted on Pennsylvania's 1996 and 1998 Clean Water Act Section 303(d) Lists.

It was first determined that SBWC was not meeting its designated water quality uses for protection of aquatic life based on a 1985 aquatic biological survey, which included kick screen analysis and habitat surveys. As a consequence of the survey, Pennsylvania listed SBWC on the 1996 and 1998 Section 303(d) Lists of Impaired Waters. The stream was listed because of impacts by suspended solids and nutrients from agriculture. The only difference between the 1996 and 1998 303(d) listings is the addition of 2.74 stream miles on the 1998 List. Pennsylvania is using a method to develop TMDLs based on comparing the impacted watershed to a reference watershed to determine the appropriate watershed loading for nutrients and sediments. Based on the predominance of agricultural land use in the watershed, nutrients and sediments are the most likely pollutants causing SBWC to violate the aquatic life use. Although the cause of the impairment on the 1996 and 1998 Section 303(d) Lists, aside from nutrients, is suspended solids, it is believed that the TMDLs for nutrients and sediment will address the suspended solids impairment. Total suspended solids (TSS) includes both an inorganic and an organic component. The sediment TMDL will reduce the inorganic portion of the suspended solids, while the organic fraction of TSS is addressed through the proposed nutrient reductions. Therefore, the TMDLs proposes reducing the nitrogen, phosphorus and sediment loadings in SBWC watershed to levels consistent with the Millard Creek watershed, the reference watershed. Because of the similarities in landuse between the two watersheds, achieving nutrient and sediment loadings in the SBWC TMDL will ensure that the aquatic life use is achieved and maintained as evidenced in Millard Creek.

Table 1. Section 303(d) Listings for South Branch Wyalusing Creek Watershed

Year	Segment ID	Stream Code	Stream Name	Source	Cause	Miles
1996		29838	South Branch Wyalusing Creek	Agriculture	Nutrients, Suspended Solids, Other	3
1998	4398	29838	South Branch Wyalusing Creek	Agriculture	Nutrients, Suspended Solids, Unknown	5.74

The 1996 303(d) List includes a cause listing of “other”, while the 1998 includes an “unknown” cause code. The original survey was conducted in 1985 by the Susquehanna River Basin Commission and has not been resurveyed. However, upon field inspection of the watershed, these additional listings of “other” and “unknown” are considered spurious and erroneous as nutrient over-enrichment and sediment delivered to the stream from agricultural sources are the only existing causes of impairment. Due to the time that has elapsed since the survey and the lack of documentation identifying the reasons for these additional listings, this report will address the nutrient and TSS listings believing that removal of impairments from these pollutants will restore the ability of the South Branch Wyalusing Creek to support its designated uses.

The primary method that the Department has adopted for evaluating the waters of the Commonwealth changed between the publication of the 1996 and 1998 303(d) lists. The Department is now using a modification of EPA’s Rapid Bioassessment Protocol II (RPB-II) as the primary mechanism to assess Pennsylvania’s unassessed waters. The assessment method requires selecting stream sites that would reflect impacts from surrounding land uses that are representative of the stream segment being assessed. The biologist selects as many sites as necessary to establish an accurate assessment for a stream segment. At each site, a biological assessment is conducted using the modified RBP II method. The length of stream that can be assessed per site varies. There are several factors that determine site location and how long a “single site” assessed segment can be. Some of these factors are distinct changes in stream characteristics, surface geology, riparian land use, point-source and nonpoint-source discharge locations, and the pollutant that is causing impairment.

Neither Pennsylvania nor EPA currently has water quality criteria for sediment or nutrients. It is for this reason, we developed a reference watershed approach to identify the TMDL endpoints or water quality objectives for nutrients and sediment in the SBWC watershed. The nutrient portion of the TMDL for this watershed will address nitrogen and phosphorus. Phosphorus is generally held to be the limiting nutrient in a waterbody when the total nitrogen (TN) to total phosphorus (TP) ratio exceeds 10 to 1. The TN:TP ratio in South Branch Wyalusing Creek is only about 6.5:1; therefore, this TMDL will address both nitrogen and phosphorus.

Reference Watershed Approach

Since Pennsylvania has no instream criteria for the pollutants of concern we adopted a reference watershed approach to set allowable loading rates in the affected watersheds. The reference watershed approach is used to estimate the necessary loading reduction of nutrients and sediment that would be needed to restore a healthy aquatic community and allow the streams in the watershed to achieve their designated uses. The reference watershed approach is based on selecting a non-impaired watershed that has similar land use characteristics and determining the current loading rates for the pollutants of interest. This is done by modeling the loads that enter the stream, using precipitation and land use characteristic data. For this analysis we used the AVGWLF model (the Environmental Resources Research Institute of the Pennsylvania State University’s ArcView based version of the Generalized Watershed Loading Function model developed by Cornell University). This modeling process uses loading rates in the non-impaired watershed as a target for loading reductions in the impaired watershed. The impaired watershed is modeled to determine the current loading rates and determine what reductions are necessary to meet the loading rates of the non-impaired watershed.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. All of the equations used by the model can be viewed in Attachment E, GWLF Users Manuel.

The SBWC Watershed TMDL Information Sheet that is attached to this document provides a primer for TMDLs (What are they and why are we doing them?) and water quality standards (What makes up a water quality standard?). Attachments C and D provide information on the method being used by Pennsylvania for establishment of TMDLs for stream segments impaired by nutrients and sediment and, watershed hydrology and pollutant transport.

Watershed Description

The SBWC is located in Susquehanna County in Northeastern Pennsylvania, with the headwaters originating in Bridgewater Township near the Village of South Montrose. One can get there by taking Exit 67 off Interstate Route 81 and taking State Route 11 west, approximately one mile to the junction with State Route 706. Stay on Route 706 west for approximately 10 miles, travelling through the town of Montrose. To the south, the stream is approximately 5.7 miles in length and drains an area of 5.4 square miles in Bridgewater and Jessup Townships. It is a tributary to the East Branch of Wyalusing Creek with the confluence located just southwest of the Village of Fairdale adjacent to State Route 706.

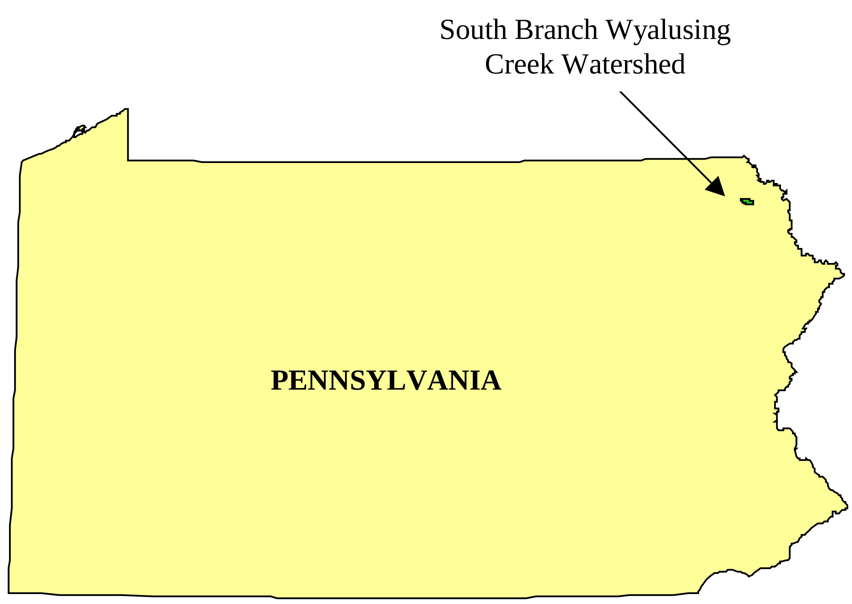

Figure 1 – Watershed Location within Pennsylvania

The topography and geology of an area determine drainage patterns, surface flow characteristics; land use and groundwater characteristics. The SBWC is located in the glaciated low plateaus section of the Appalachian Plateaus Province. The topography is characterized by long, parallel ridges and associated valleys which generally trend northeastward. The shape of the land is that of smooth, rolling hills rounded by glacial action with moderate slope, dissected by streams flowing through shale and sandstone formations which originate from glacially produced lakes and ponds.

Land use patterns have a major impact on water quality, quantity and utilization. Major land use categories in the SBWC watershed are forest, agricultural and urban. Approximately 66% of the watershed is forested and 32% is agricultural. Dairy farming is the major agricultural pursuit in the area, and the hilly wooded and open terrain has a short growing season. Less than 1% of the watershed is urban or built-up and is limited to the Village of South Montrose and its general vicinity. Growth, if any, would be centered around this Village.

At present, there are no permitted point source discharges to the SBWC. The watershed area generally depends upon on-lot sewage disposal.

The 5 square mile size of the SBWC watershed is smaller than the basin size generally used for modeling purposes, and there were no impaired watersheds nearby that could be included in the TMDL. As shown in Figure 2, the SBWC is part of the East Branch Wyalusing Creek (EBWC) Watershed, which has no other impaired segments. Therefore, the reference watershed was chosen such that the size of both the impaired and reference watersheds matched. This match made the inaccuracies in model loading predictions based on scale consistent across both watersheds. Additionally, it is the relative difference in loadings, not the absolute difference, that is used as the basis for assigning reductions.

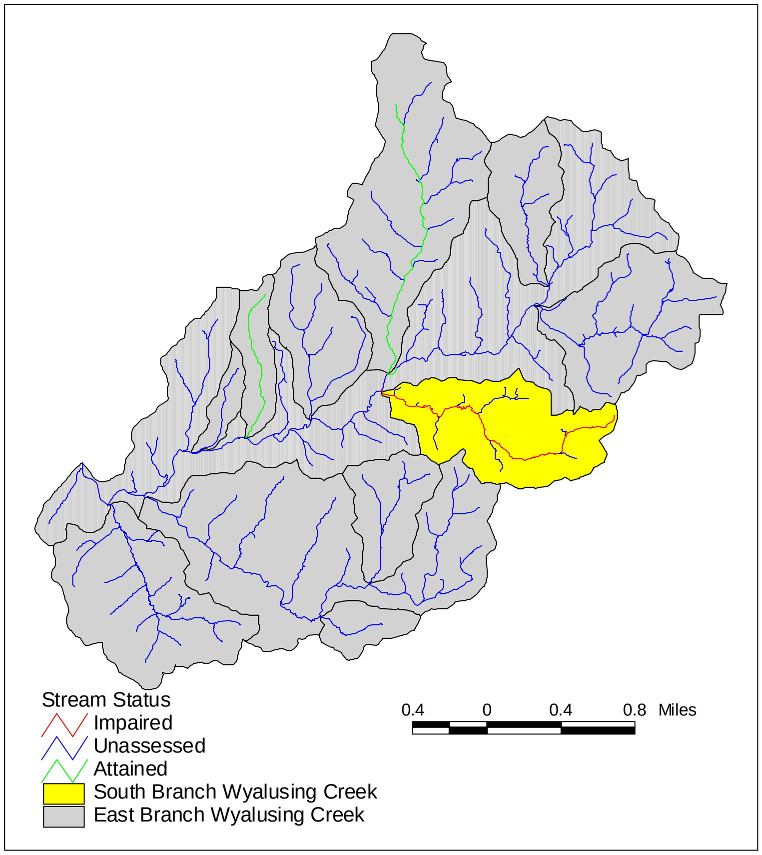

Figure 2 - South Branch Wyalusing Creek within the East Branch Wyalusing Creek Basin

TMDL Endpoints

The TMDLs address nitrogen, phosphorus, and sediment. Because neither Pennsylvania nor EPA has water quality criteria for nutrients or sediment, we had to develop a method to determine water quality objectives for these parameters that would result in the impaired stream segments attaining their designated uses. The method employed for these TMDLs is termed the "Reference Watershed Approach".

The Reference Watershed Approach pairs two watersheds, one attaining its uses and one that is impaired based on biological assessment. Both watersheds must have similar land cover and land use characteristics. Other features such as base geologic formation are matched to the extent possible; however, most variations can be adjusted in the model. The objective of the process is to reduce the loading rate of nutrients and sediment in the impaired stream segment to a level equivalent to or slightly lower than the loading rate in the non-impaired, reference stream segment. This load reduction will allow the biological community to return to the impaired stream segments.

The TMDL endpoints established for this analysis were determined using Millard Creek as the reference watershed. These endpoints are discussed in detail in the TMDL section.

Selection of the Reference Watershed

Two factors formed the basis to select a suitable reference watershed. The first factor was to use a watershed that had been assessed by the Department using the Unassessed Waters Protocol and had been determined to attain water quality standards. The second factor was to find a watershed that closely resembled the SBWC watershed in physical properties such as land cover/landuse, physiographic province, size, and geology.

The first step in determining the reference watershed was to locate a watershed that had been recently assessed and was not impaired. Step two involved comparing the landcover data coverage by watershed and selecting unimpaired watersheds that looked similar to the SBWC watershed. The Millard Creek Watershed was found to be a good match in both size and landuse as can be seen in the following chart:

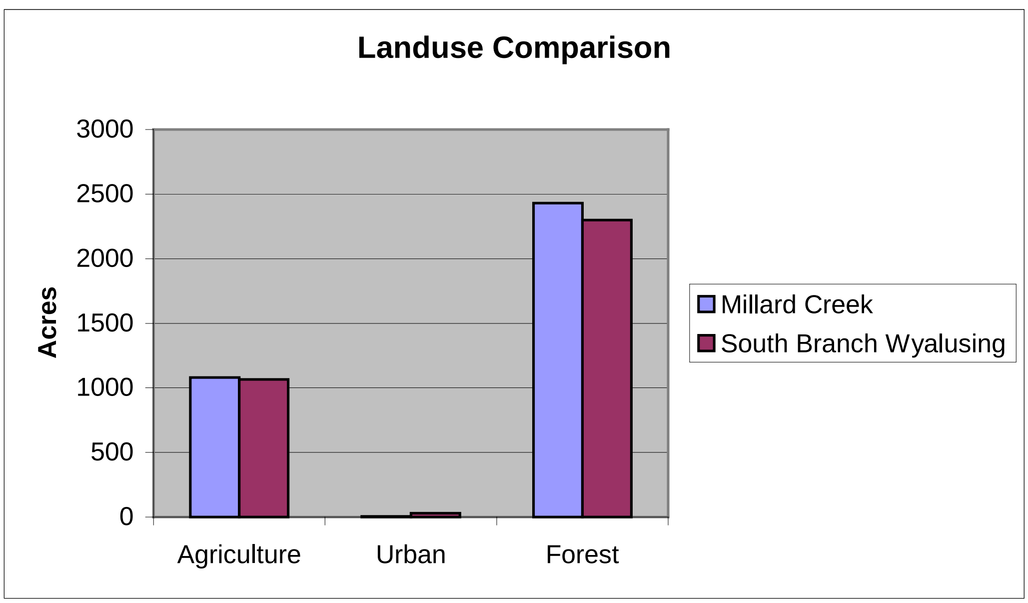

Figure 3 – Generalized Land Use Distribution in the South Branch Wyalusing Creek and Millard Creek Watersheds

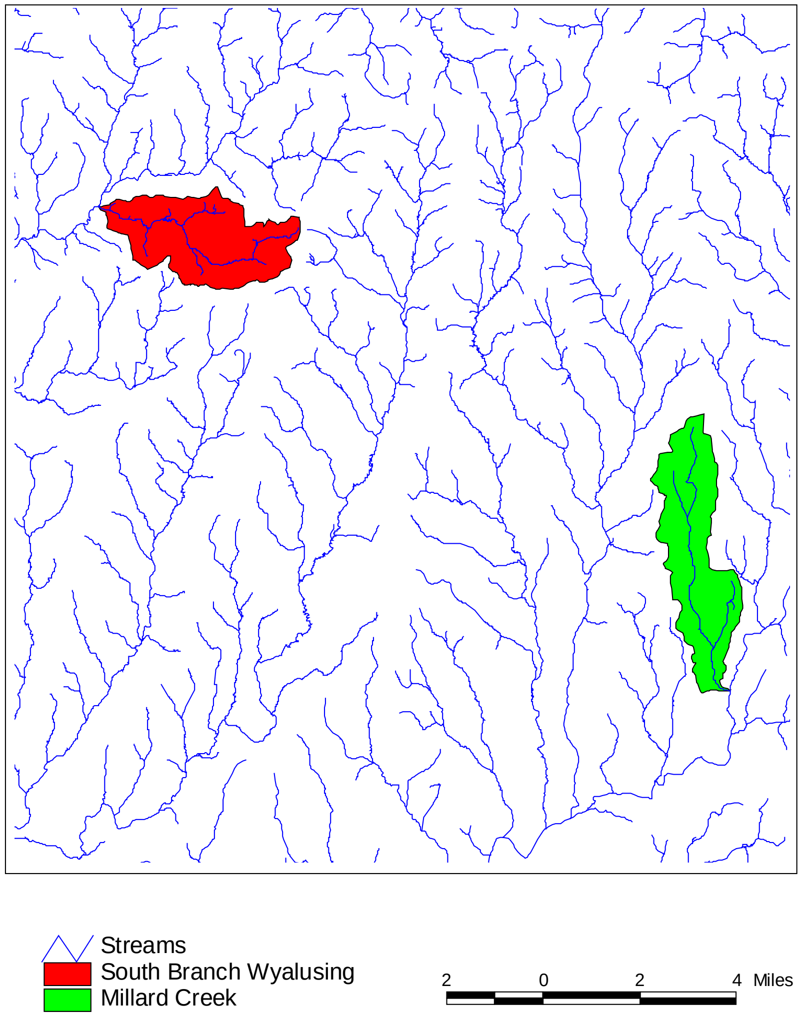

Figure 4 – South Branch Wyalusing Creek and Millard Creek Watersheds

As listed in 25 PA Code Chapter 93, Section 93.9i, the designated aquatic life use for Millard Creek is Cold Water Fishes. The comparison of geology between the two watersheds also yielded favorable results as both watersheds are 100% Interbedded Sedimentary Rock within the Catskill Formation.

Data Compilation and Model Overview

The TMDLs were developed using the Generalized Watershed Loading Function or GWLF model. The GWLF model provides the ability to simulate runoff, sediment, and nutrient (N and P) loadings from 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 which 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 a combined distributed/lumped parameter watershed model. For surface loading, it is distributed in the sense that it allows multiple land use/cover scenarios. Each area is assumed to be homogenous in regard to various attributes considered by the model. Additionally, the model does not spatially distribute the source areas, but aggregates the loads from each area into a watershed total. In other words, there is no spatial routing. For sub-surface 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 sub-surface zone, where infiltration is computed as the difference between precipitation and snowmelt minus surface runoff plus evapotranspiration.

GWLF models surface runoff using the Soil Conservation Service Curve Number (SCS-CN) approach with daily weather (temperature and precipitation) inputs. Erosion and sediment yield are estimated using monthly erosion calculations based on the Universal Soil Loss Equation (USLE) algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (e.g., land cover/soil type combination). The KLSCP factors are variables used in the calculations to depict changes in soil loss erosion (K), the length slope factor (LS), the vegetation cover factor (C), and conservation practices factor (P). A sediment delivery ratio based on watershed size and a transport capacity based on average daily runoff are applied to the calculated erosion to determine sediment yield for each source area. 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. Point source discharges can also contribute to dissolved loads to the stream and are specified in terms of kilograms per month. Manured areas, as well as septic systems, can also be considered. Urban nutrient inputs are all assumed to be solid-phase, and the model uses an exponential accumulation and washoff function for these loadings. Sub-surface losses are calculated using dissolved N and P coefficients for shallow groundwater contributions to stream nutrient loads, and the sub-surface sub-model only considers a single, lumped-parameter contributing 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. All of the equations used by the model can be viewed in Attachment E, GWLF Users Manual.

For execution, the model requires three separate input files containing transport-, nutrient-, and weather-related data. The transport (TRANSPRT.DAT) file defines the necessary parameters for each source area to be considered (e.g., area size, curve number, etc.) as well as global parameters (e.g., initial storage, sediment delivery ratio, etc.) that apply to all source areas. The nutrient (NUTRIENT.DAT) file specifies the various loading parameters for the different source areas identified (e.g., number of septic systems, urban source area accumulation rates, manure concentrations, etc.). The weather (WEATHER .DAT) file contains daily average temperature and total precipitation values for each year simulated.

GIS Based Derivation of Input Data

The primary sources of data for this analysis were geographic information system (GIS) formatted databases. A specially designed interface was prepared by the Environmental Resources Research Institute of the Pennsylvania State University in ArcView (GIS software) to generate the data needed to run the GWLF model, which was developed by Cornell University. The new version of this model has been named AVGWLF (ArcView Version of the Generalized Watershed Loading Function)

In using this interface, the user is prompted to identify required GIS files and to provide other information related to "non-spatial" model parameters (e.g., beginning and end of the growing season, the months during which manure is spread on agricultural land and the names of nearby weather stations). This information is used to automatically derive values for required model input parameters which are then written to the TRANSPRT.DAT, NUTRIENT.DAT and WEATHER.DAT input files needed to execute the GWLF model. For use in Pennsylvania, AVGWLF has been linked with statewide GIS data layers such as land use/cover, soils, topography, and physiography; and includes location-specific default information such as background N and P concentrations and cropping practices. Complete GWLF-formatted weather files are also included for eighty-eight weather stations around the state. Table 2 lists the GIS data sets and provides explanation of how they were used for development of the input files for the GWLF model.

State-Wide GIS Data Sets

The following GIS data sets were used during the modeling process using AVGWLF:

Table 2 GIS Data Sets

Censustr	Coverage of Census data including information on individual homes septic systems. The attribute *susew_sept* includes data on conventional systems, and *su_other* provides data on short circuiting and other systems.
County	The County boundaries coverage lists data on conservation practices which provides C and P values in the Universal Soil Loss Equation (USLE).
Gwnback	A grid of background concentrations of N in groundwater derived from water well sampling.
Landuse5	Grid of the MRLC that has been reclassified into five categories. This is used primarily as a background.
Majored	Coverage of major roads. Used for reconnaissance of a watershed.
MCD	Minor civil divisions (boroughs, townships and cities).
Npdespts	A coverage of permitted point discharges. Provides background information and cross check for the point source coverage.
Padem	100 meter digital elevation model. This used to calculate landslope and slope length.
Palumrlc	A satellite image derived land cover grid which is classified into 15 different landcover categories. This dataset provides landcover loading rate for the different categories in the model.
Pasingle	The 1:24,000 scale single line stream coverage of Pennsylvania. Provides a complete network of streams with coded stream segments.
Physprov	A shapefile of physiographic provinces. Attributes *rain_cool* and *rain_warm* are

	used to set recession coefficient
Pointsrc	Major point source discharges with permitted N and P loads.
Refwater	Shapefile of reference watersheds for which nutrient and sediment loads have been calculated.
Soilphos	A grid of soil phosphorous loads which has been generated from soil sample data. Used to help set phosphorus and sediment values.
Smallsheds	A coverage of watersheds at the 1:24,000 scale. This coverage is used with the stream network to delineate the desired level watershed.
Statsgo	A shapefile of generalized soil boundaries. The attribute *mu_k* sets the k factor in the USLE. The attribute *mu_awc* is the unsaturated available capacity., and the *muhsg_dom* is used with landuse cover to derive curve numbers.
Strm305	A coverage of stream water quality as reported in the Pennsylvania's 305(b) report. Current status of assessed streams.
Surfgeol	A shapefile of the surface geology used to compare watersheds of similar qualities.
T9sheds	Data derived from a DEP study conducted at PSU with N and P loads.
Zipcode	A coverage of animal densities. Attribute *aeu_acre* helps estimate N & P concentrations in runoff in agricultural lands and over manured areas.
Weather Files	Historical weather files for stations around Pennsylvania to simulate flow.

As described in the Data Compilation and Model Overview section, the GWLF model provides the ability to simulate surface water runoff, as well as sediment and nutrient loads from a watershed based on landscape conditions such as topography, land use/cover, and soil type. In essence, the model is used to estimate surface runoff and non-point source loads from different areas within the watershed. If point source discharges are identified, and the corresponding nutrient loads are quantified, these loads are summed to represent the total pollutant loads for the watershed.

In the GWLF model, the non-point source load calculated is affected by terrain conditions such as amount of agricultural land, land slope, and inherent soil erodibility. It is also affected by farming practices utilized in the area, as well as by background concentrations of nutrients (i.e., N and P) in soil and groundwater. Various parameters are included in the model to account for these conditions and practices. The more important parameters are summarized below:

Areal extent of different land use/cover categories: This is calculated directly from a GIS layer of land use/cover.

Curve number: This determines amounts of precipitation that infiltrates into the ground or enters surface water as runoff. It is based on specified combinations of land use/cover and hydrologic soil type, and is calculated directly using digital land use/cover and soils layers.

K factor: This factor relates to inherent soil erodibility, and affects the amount of soil erosion taking place on a given unit of land.

LS factor: This factor signifies the steepness and length of slopes in an area and directly affects the amount of soil erosion.

C factor: This factor is related to the amount of vegetative cover in an area. In agricultural areas, this factor is largely controlled by the crops grown and the cultivation practices utilized. Values range from 0 to 1.0, with larger values indicating greater potential for erosion.

P factor: This factor is directly related to the conservation practices utilized in agricultural areas. Values range from 0 to 1.0, with larger values indicating greater potential for erosion.

Sediment delivery ratio: This parameter specifies the percentage of eroded sediment that is delivered to surface water and is empirically based on watershed size.

Unsaturated available water-holding capacity: This relates to the amount of water that can be stored in the soil and affects runoff and infiltration. It is calculated using a digital soils layer.

Dissolved nitrogen in runoff: This varies according to land use/cover type, and reasonable values have been established in the literature. This rate, reported in mg/l, can be re-adjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Dissolved phosphorus in runoff: Similar to nitrogen, the value for this parameter varies according to land use/cover type, and reasonable values have been established in the literature. This rate, reported in mg/l, can be re-adjusted based on local conditions such as rates of fertilizer application and farm animal populations.

Nutrient concentrations in runoff over manured areas: These are user-specified concentrations for N and P that are assumed to be representative of surface water runoff leaving areas on which manure has been applied. As with the runoff rates described above, these are based on values obtained from the literature. They also can be adjusted based on local conditions such as rates of manure application or farm animal populations.

Nutrient build-up in non-urban areas: In GWLF, rates of build-up for both N and P have to be specified. In Pennsylvania, this is estimated using historical information on atmospheric deposition.

Background N and P concentrations in groundwater: Subsurface concentrations of nutrients (primarily N) contribute to the nutrient loads in streams. In Pennsylvania, these concentrations are estimated using recently published data from USGS.

Background N and P concentrations in soil: Since soil erosion results in the transport of nutrient-laden sediment to nearby surface water bodies, reasonable estimates of background concentrations in soil must be provided. In Pennsylvania, this information is based on literature values as well as soil test data collected annually at Penn State University. These values can be adjusted locally depending upon manure loading rates and farm animal populations.

Other less important factors that can affect sediment and nutrient loads in a watershed are also included in the model. More detailed information about these parameters and those outlined above can be obtained from the GWLF Users Guide provided in Appendix F of this document.

(Specific details that describe equations and typical parameter values used can be found on pages 15 through 41 in this Guide). Additional descriptions of hydrologic functions and pollutant transport processes that operate within a watershed can be found in Appendix D. As described in the next section, the GIS interface was first used to derive values for the various GWLF input parameters.

Watershed Assessment and Modeling

The AVGWLF model was run in both the South Branch Wyalusing Creek and Millard Creek watersheds to establish existing loading conditions. The 17-year (1976-1993) mean results for each watershed are shown in Tables 4 and 5. The Unit Area Load for each pollutant in each watershed was estimated by dividing the mean annual loading(lbs/year) by the total area (acres) resulting in an approximate loading per unit area for the watershed. Table 3 presents an explanation of the header information contained in Tables 4 and 5.

Table 3. Header information for Tables 4 and 5

Land Use Category	The land cover classification that was obtained by from the MRLC database
Area (acres)	The area of the specific land cover/land use category found in the watershed.
Total P	The estimated total phosphorus loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area P Load	The estimated loading rate for phosphorus for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year
Total N	The estimated total nitrogen loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area N Load	The estimated loading rate for nitrogen for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year
Total Sed	The estimated total sediment loading that reaches the outlet point of the watershed that is being modeled. Expressed in lbs./year.
Unit Area Sed Load	The estimated loading rate for sediment for a specific land cover/land use category. Loading rate is expressed in lbs/acre/year

Table 4. Existing Loading Values for South Branch Wyalusing Creek							
Land Use Category	Area (acres)	Total P (lbs/yr)	Unit Area P Load (lbs/acre/ yr)	Total N (lbs/yr)	Unit Area N Load (lbs/acre/ yr)	Sed Load (lbs/year)	Unit Area Sed Load (lbs/acre/ yr)
Hay/Pasture/ Grass	215	105	0.49	1,002	4.7	126,936	572
Cropland	892	3,112	3.49	18,151	20.4	4,620,323	5,025
Coniferous	193	5	0.03	49	0.3	6,322	32
Mixed Forest	279	9	0.03	78	0.3	11,673	41
Deciduous	1,840	167	0.09	1026	0.6	247,130	130
Transition*	0.25	2	8.92	12	48.2	3,413	13,399
Low Intensity Development	17	2	0.10	14	0.8	9,917	636
High Intensity Development	5	6	1.29	57	11.5	7,315	1,632
Groundwater		117		1,804			
Point Source		0		0			
Septic Systems		4		912			
Total	3,441	3,529	1.03	23,104	6.71	5,033,030	1,462

* The MRLC Land Cover used in AVGWLF classified approximately 72 acres of land as "Transition". Upon field verification and inspection of the USGS DOQQs, it was determined that this was Cropland that had been misclassified. Therefore, all except 0.1 ha were added to the Cropland landuse prior to the model runs. The DOQQs are shown in Attachment A.

Table 5. Existing Loading Values for Millard Creek							
Land Use Category	Area (acres)	Total P (lbs/yr)	Unit Area P Load (lbs/acre/ yr)	Total N (lbs/yr)	Unit Area N Load (lbs/acre/ yr)	Sed Load (lbs/year)	Unit Area Sed Load (lbs/acre/ yr)
Hay/Pasture/ Grass	264	76	0.29	941	3.56	88,255	297
Cropland	808	1,585	1.96	10,509	13.01	2,600,926	2,865
Coniferous	571	12	0.02	128	0.23	17,638	28
Mixed Forest	413	9	0.02	94	0.23	13,164	28
Deciduous	1,421	58	0.04	452	0.32	93,348	58
High Intensity Development	7	9	1.25	83	11.24	9,011	1,082
Groundwater		108		1,203			
Point Source		0		0			
Septic Systems		4		1,194			
Total	3,484	1,861	0.54	14,604	4.19	2,822,343	721

TMDL Computations for Nitrogen, Phosphorus and Sediment

The TMDLs established for SBWC consist of a load allocation (LA) and a margin of safety (MOS) for nitrogen, phosphorus and sediment. There is no wasteload allocation (WLA) for this TMDL because there are no known point source discharges.

Nitrogen was included in the TMDL because it could not be confirmed that the stream was phosphorus limited. If the ratio of nitrogen to phosphorus is greater than 10 to 1 it means that phosphorus will be the limiting nutrient in the stream. However, in this case, the TN:TP ratio was ≈ 6.5:1. In some cases where the TN:TP ratio is less than 10:1, controlling phosphorus may be the most cost-effective means of attaining water quality standards, particularly when sediment reductions are necessary. Therefore, TMDL computations will be made for all three pollutants.

The basis for the load reduction calculations in SBWC are based on the current loading rates for nutrients and sediment in Millard Creek, the reference watershed for this analysis. Based on biological assessment, it was determined that Millard Creek was attaining its Aquatic life uses. Its loading rates for nitrogen, phosphorous and sediment were determined by running the AVGWLF model on it. These loading rates were then used as the basis for establishing the TMDLs for SBWC.

The TMDL equation is as follows: TMDL = WLA + LA + MOS

The WLA (wasteload allocation) portion of this equation is the total loading that is assigned to point sources. The LA (load allocation) is the portion of this equation that is assigned to non-point sources. The MOS (margin of safety) is the portion of loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. Table 6 presents the TMDLs for SBWC.

Table 6. TMDLs for South Branch Wyalusing Creek

Pollutant	TMDL (lb/yr)	LA (lb/yr)	WLA (lb/yr)	MOS (lb/yr)
Nitrogen	14,418	12,976	0	1,442
Phosphorus	1,858	1,672	0	186
Sediment	2,480,930	2,232,837	0	248,093

The individual components of the TMDLs are discussed in detail below.

TMDL Computation

The TMDLs for all pollutants of concern were computed in the same manner. Each pollutants unit loading rate in Millard Creek was multiplied by the total watershed area of SBWC to give the TMDL value. Table 7 presents this information.

Table 7. TMDL Computation			
Pollutant	**Unit Area Loading Rate in Millard Creek (lbs/acre/year)**	**Total Watershed Area in SBWC (acres)**	**TMDL Value (lbs/year)**
Nitrogen	4.19	3,441	14,418
Phosphorus	0.54	3,441	1,858
Sediment	721	3,441	2,480,930

<u>Margin of Safety</u>

The Margin of Safety (MOS) for this analysis is explicit. Ten percent of each of the TMDLs was reserved as the MOS. Using ten percent of the TMDL load is based on professional judgement and will provide an additional level of protection to the uses of the waterbody.

Nitrogen – 14,418 x 0.1 = 1,442 lbs/year
Phosphorus – 1,858 x 0.1 = 186 lbs/year
Sediment – 2,480,930 x 0.1 = 248,093 lbs/year

<u>Load Allocations</u>

The load allocation (LA) for the entire watershed was computed by subtracting the margin of safety value from the TMDL value. Individual load allocations were then assigned to each land uses/ sources that are shown in Tables 8a – 8c. Not all land use/ source categories were included in the allocation because they are difficult to control, or provide an insignificant portion of the total load. Loading values for land uses/ sources that were not part of the allocation were carried through at their existing loading value. The following section shows the allocation process in detail.

Nitrogen

1. The margin of safety value was subtracted from the TMDL value. This quantity represents the load allocation (LA).

   LA = 14,418 – 1,442
   LA = 12,976 lbs/year

2. The loads not considered in the reduction scenario were subtracted from the LA value. These are the loads: Transition, Lo Int Dev (Low Intensity Development), Hi Int Dev (High Intensity Development), Groundwater, Septic systems. The total load for these land uses/sources is 7,106 lbs. This quantity was subtracted from the LA.

   Adjusted LA = 12,976 – 3,951
   Adjusted LA = 9,025 lbs/year

This is the portion of the load that is available to allocate among the contributing sources. This is termed the allocable load.

3. This quantity was allocated among the five remaining land use/sources. The allocation method used was Equal Marginal Percent Reduction (EMPR).

   EMPR is carried out in the following manner. Each land use/source load will be compared with the allocable load to determine if any contributor would exceed the allocable load by itself. The evaluation is carried out as if each source is the only contributor to the pollutant load to the receiving waterbody. If the contributor exceeds the allocable load, that contributor would be reduced to the allocable load. This is the baseline portion of EMPR. After any necessary reductions have been made in the baseline the multiple analysis is run.

   The multiple analysis will sum all of the baseline loads and compare them to the allocable load. If the allocable load is exceeded, an equal percent reduction will be made to all contributors' baseline values. After any necessary reductions in the multiple analysis, the final reduction percentage for each contributor can be computed. (See Attachment F for a more detailed description of this calculation).

4. The results of the Load Allocation are presented in Table 8a. The LA for each land use is shown along with the reduction necessary for each source.

Phosphorus

1. The margin of safety value was subtracted from the TMDL value. This quantity represents the load allocation (LA).

   LA = 1,858 - 186
   LA = 1,672 lbs/year

2. The loads not considered in the reduction scenario were subtracted from the LA value. These are the loads: Transition, Lo Int Dev (Low Intensity Development), Hi Int Dev (High Intensity Development), Groundwater, Septic systems. The total load for these land uses/sources is 311 lbs. This quantity was subtracted from the LA.

   Adjusted LA = 1,672 – 311
   Adjusted LA = 1,361 lbs/year

   This is the portion of the load that is available to allocate among the contributing sources. This is termed the allocable load.

3. This quantity was allocated among the five remaining land use/sources. The allocation

method used was Equal Marginal Percent Reduction (EMPR). (See Attachment F for a detailed description of this calculation).

4. The results of the Load Allocation are presented in Table 8b. The LA for each land use is shown along with the reduction necessary for each source.

Sediment

1. The margin of safety value was subtracted from the TMDL value. This quantity represents the load allocation (LA).

   LA = 2,480,930 – 248,093 lbs/year
   LA = 2,232,837 lbs/year

2. The loads not considered in the reduction scenario were subtracted from the LA value. These are the loads: Coniferous Forest, Mixed Forest, Deciduous Forest, Transition, Low Intensity Development and High Intensity Development. The total load for these land uses/sources is 285,771 lbs. This quantity was subtracted from the LA.

   Adjusted LA = 2,232,837 – 285,771
   Adjusted LA = 1,947,066 lbs/year

   This is the portion of the load that is available to allocate among the sources contributing sources. This is termed the allocable load.

3. This quantity was allocated among the two remaining land use/sources. The allocation method used was Equal Marginal Percent Reduction (EMPR). (See Attachment F for a detailed description of this calculation).

4. The results of the Load Allocation are presented in Table 8c. The LA for each land use is shown along with the reduction necessary for each source.

Table 8a. Nitrogen Load Allocation by Land Use

Land Use	Area (acres)	Unit Area Loading Rate (lbs/acre/ year)	Annual average load (lbs/year)	LA [annual average] (lbs/year)	Load Allocation % Reduction
Hay/Pasture/ Grass	215	4.7	1,002	902	8%
Cropland	892	20.4	18,151	8,124	44%
Coniferous	193	0.3	49	49	0%
Mixed Forest	279	0.3	78	78	0%
Deciduous	1,840	0.6	1,026	1,026	0%
Transition	0.25	48.2	12	12	0%
Low Intensity Development	17	0.8	14	14	0%
High Intensity Development	5	11.5	57	57	0%
Groundwater			1,804	1,804	0%
Point Source			0	0	0%
Septic Systems			911	911	0%
Total	**3,441**	**7.00**	**23,104**	**12,976**	**44%**

Table 8b. Phosphorus Load Allocation by Land Use

Land Use	Area (acres)	Unit Area Loading Rate (lbs/acre/ year)	Annual average load (lbs/year)	LA [annual average] (lbs/year)	Load Allocation % Reduction
Hay/Pasture/Grass	215	0.49	105	98	7%
Cropland	892	3.49	3,112	1,264	59%
Coniferous	193	0.03	5	5	0%
Mixed Forest	279	0.03	9	9	0%
Deciduous	1,840	0.09	167	167	0%
Transition	0.25	8.92	2	2	0%
Low Intensity Development	17	0.10	2	2	0%
High Intensity Development	5	1.29	6	6	0%
Groundwater			117	117	0%
Point Source			0	0	0%
Septic Systems			4	4	0%
Total	**3,441**	**1.03**	**3,529**	**1,673**	**53%**

Table 8c. Sediment Load Allocation by Land Use					
Land Use	Area (acres)	Unit Area Loading Rate (lbs/acre/ year)	Annual average load (lbs/year)	LA [annual average] (lbs/year)	Load Allocation % Reduction
Hay/Pasture/ Grass	215	591	126,936	119,167	6%
Cropland	892	5,182	4,620,323	1,827,899	60%
Coniferous	193	33	6,323	6,323	0%
Mixed Forest	279	442	11,673	11,673	0%
Deciduous	1,840	134	247,130	247,130	0%
Transition	0.25	13,817	3,413	3,413	0%
Low Intensity Development	17	574	9,917	9,917	0%
High Intensity Development	5	1,481	7,315	7,315	0%
Groundwater		0	0	0	0%
Point Source		0	0	0	0%
Septic Systems		0	0	0	0%
Total	**3,441**	**1,593**	**5,033,030**	**2,232,837**	**56%**

Consideration of Critical Conditions

The AVGWLF model is a continuous simulation model which 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. Therefore, all flow conditions are taken into account for loading calculations. Because there is generally a significant lag time between the introduction of sediment and nutrients to a waterbody and the resulting impact on beneficial uses, establishing these TMDLs using average annual conditions is protective of the waterbody.

Consideration of Seasonal Variations

The continuous simulation model used for this analysis considers seasonal variation through a number of mechanisms. Daily time steps are used for weather data and water balance calculations. The model requires specification of the growing season, and hours of daylight for each month. The model also considers the months of the year when manure is applied to the land. The combination of these actions by the model accounts for seasonal variability.

Recommendations

The pollutant reductions in the TMDLs are allocated entirely to agricultural activities in the watershed. Implementation of best management practices (BMPs) in the affected areas should achieve the loading reduction goals established in the TMDLs. Substantial reductions in the amount of sediment reaching the streams can be made through the planting of riparian buffer zones, contour strips, and cover crops. These BMPs range in efficiency from 20% to 70% for sediment reduction. Implementation of BMPs aimed at sediment reduction will also assist in the reduction of nitrogen and phosphorus. Cover crops will provide nitrogen uptake in between growing seasons when the subsurface transport of nitrogen is greatest. Comprehensive nutrient management plans on farms in the watershed will be implemented to ensure that on-farm practices support the nutrient and sediment reduction goals for the watershed. Additionally, nitrogen and phosphorus reductions can be achieved through the installation of more effective animal waste management systems and stone ford cattle crossings. Other possibilities for attaining the desired reductions in nutrients and sediment include streambank stabilization and fencing. Further ground truthing will be performed in order to assess both the extent of existing BMPs, and to determine the most cost-effective and environmentally protective combination of BMPs required to meet the nutrient and sediment reductions outlined in this report.

Public Participation

Public notice of the draft TMDL for South Branch Wyalusing Creek was published in the *Susquehanna County Independent* on November 8, 2000 and in the *Pennsylvania Bulletin* on November 11, 2000. Public comments were accepted through January 11, 2001. Notice of final plan approval will be published on the Pennsylvania Department of Environmental Protection website.

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<u>ATTACHMENT A – Model Results</u>

GWLF Output Summary for Millard Creek

Transport Information

	Units in Centimeters				
MONTH	**PRECIP**	**EVAPOTRANS**	**GR.WAT. FLOW**	**RUNOFF**	**STREAMFLOW**
"APR"	10.26	2.02	8.9	1.1	10.1
"MAY"	10.56	6.22	5.8	.4	6.2
"JUN"	9.69	9.52	2.6	.1	2.7
"JUL"	10.78	10.5	.7	.3	.9
"AUG"	8.7	8.17	.6	.2	.8
"SEP"	8.36	5.47	.8	.3	1.1
"OCT"	9.81	3.34	3.4	1	4.5
"NOV"	9.35	1.29	5.1	.7	5.8
"DEC"	7.96	.31	5.4	.9	6.3
"JAN"	7.21	.07	3.6	1	4.6
"FEB"	6.95	.16	4.3	1.5	5.8
"MAR"	8.14	.78	8.2	2.8	11
ANNUAL:	107.78	47.84	49.6	10.3	59.9

Nutrient Information

	Mg (1000 Kg)		**Kg**			
MONTH	**EROSION**	**SEDIMENT**	**DIS. NITR.**	**TOT. NITR.**	**DIS. PHOS.**	**TOT. PHOS**
"APR"	1101.6	179.6	345.1	469.8	16.5	42
"MAY"	1238.5	201.9	181.4	290.6	8.6	31.1
"JUN"	944.2	153.9	72.7	79.1	3.5	4.6
"JUL"	1253	204.2	56.2	93.8	2.9	10.4
"AUG"	922.7	150.4	44.9	134.8	2.3	20.8
"SEP"	411.2	67	188.9	235.9	5.2	14.7
"OCT"	490.5	80	582	1008.9	16.2	104.8
"NOV"	302.4	49.3	459.2	636.8	13.8	50.5
"DEC"	166.1	27.1	242	616.1	11.6	89.2
"JAN"	19.2	3.1	199.3	529.8	9.7	78.3
"FEB"	39.2	6.4	289.3	924.1	14.1	146
"MAR"	96.2	15.7	525.3	1620.2	25.5	253.1
ANNUAL:	6984.9	1138.5	3186.3	6639.8	129.9	845.7

Total Loads by Landuse Category

	(ha)	(cm)	(Kg/ha)		Total Loads (Kg)			
SOURCE	**AREA**	**RUNOFF**	**EROSION**	**SEDIMENT**	**DIS. NITR**	**TOT. NITR**	**DIS. PHOS**	**TOT. PHOS**
"HAY/PAST"	107	9.69	2048	333.8	321	428.1	12.4	34.7
"CROPLAND"	327	15.79	19747.6	3218.9	1620.8	4778.6	62	719.8
"CONIF_FOR"	231	8.43	189.4	30.9	37	58.4	1.2	5.6
"MIXED_FOR"	167	8.43	195.6	31.9	26.8	42.7	.8	4.2
"DECID_FOR"	575	8.43	403.3	65.7	92.1	205.5	2.9	26.5
"HI_INT_DEV"	3	39.23	7457.5	1215.6	0	37.9	0	4.2
GROUNDWATER					546.5	546.5	48.9	48.9
POINT SOURCE					0	0	0	0
SEPTIC SYSTEMS					542.1	542.1	1.7	1.7
TOTAL	1410	10.3	4969.708	810.062	3186.3	6639.8	129.9	845.7

GWLF Output Summary for SBWC

Transport Information

	Units in Centimeters				
MONTH	**PRECIP**	**EVAPOTRANS**	**GR.WAT. FLOW**	**RUNOFF**	**STREAMFLOW**
"APR"	10.43	1.34	9.7	1.2	10.9
"MAY"	9.93	5.49	6.3	.3	6.6
"JUN"	9.99	9.49	2.7	.2	2.9
"JUL"	10.65	10.42	.7	.3	1
"AUG"	9.7	8.52	.7	.3	1.1
"SEP"	8.94	5.41	1.1	.5	1.6
"OCT"	9.6	3.18	3.8	1	4.8
"NOV"	9.9	1.1	5.7	.7	6.4
"DEC"	8.44	.26	5.9	.9	6.8
"JAN"	8.35	.05	3.9	1.2	5.1
"FEB"	7	.11	4.6	1.9	6.5
"MAR"	8.48	.53	9	3	12
ANNUAL:	111.42	45.91	54.2	11.4	65.6

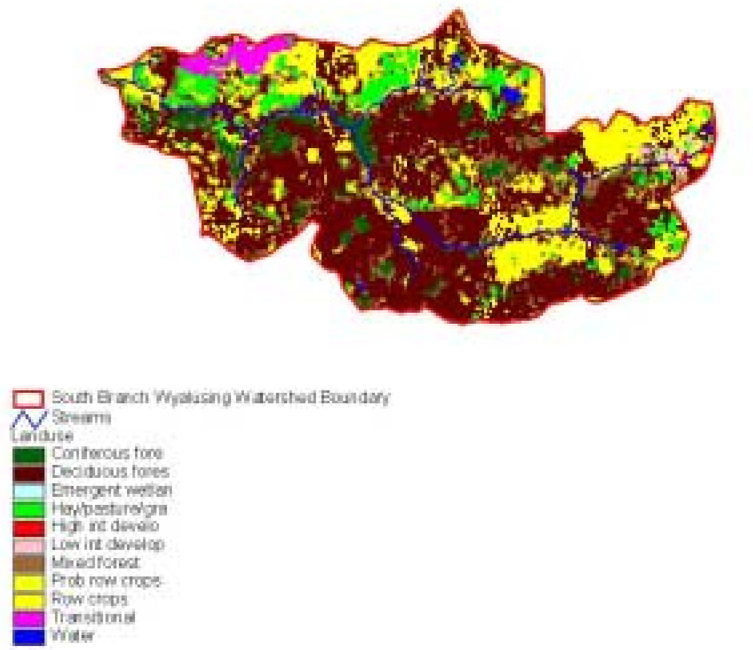
Nutrient Information

	Mg (1000 Kg)		Kg			
MONTH	**EROSION**	**SEDIMENT**	**DIS. NITR.**	**TOT. NITR.**	**DIS. PHOS.**	**TOT. PHOS**
"APR"	2184.3	358.2	380	626.5	17.7	69.8
"MAY"	2116.4	347.1	188	343.5	8.6	41.5
"JUN"	1977.2	324.3	89.3	125.4	4.1	11.6
"JUL"	2320.8	380.6	63.4	149.1	3.2	21.2
"AUG"	2142.7	351.4	64.2	343.5	3.2	62.4
"SEP"	890.9	146.1	280.8	481.5	7.6	50.1
"OCT"	935.7	153.5	596.3	1300.5	16.6	166.1
"NOV"	675.3	110.7	531.1	903.5	15.7	94.5
"DEC"	324	53.1	252.2	927.5	11.9	155.2
"JAN"	84.2	13.8	237.1	882.2	11.4	148.3
"FEB"	57.8	9.5	353	1733.2	17.1	310.3
"MAR"	175.8	28.8	590.1	2672.7	28.3	470.7
ANNUAL:	13885.1	2277.2	3625.4	10488.9	145.3	1601.8

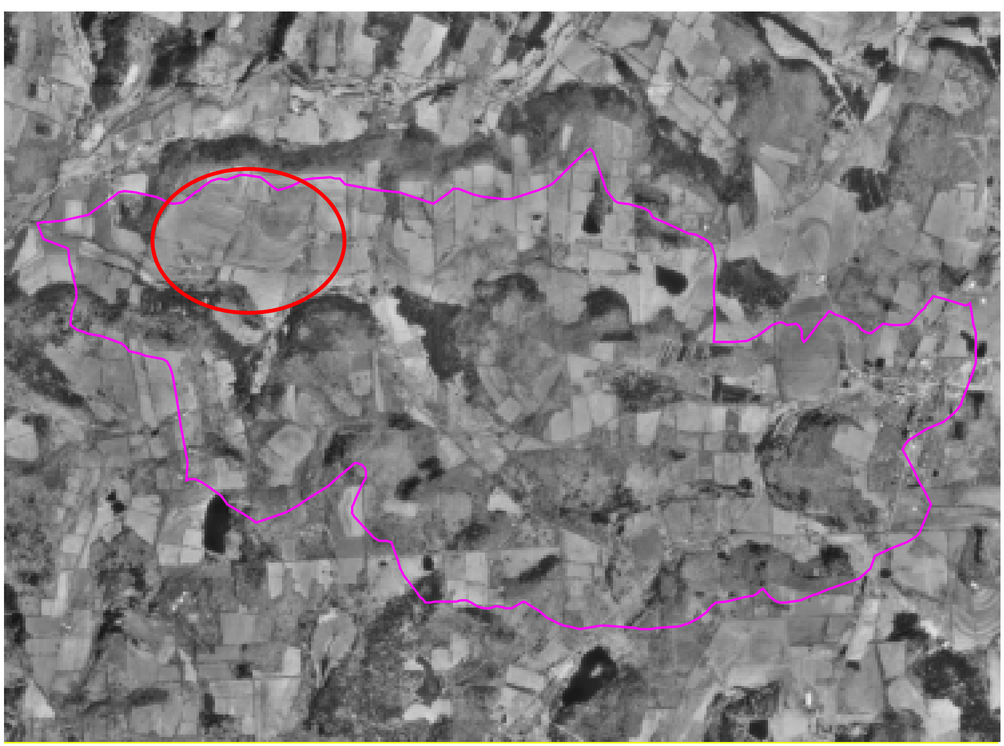
Total Loads by Landuse Category

	(ha)	(cm)	(Kg/ha)		Total Loads (Kg)			
SOURCE	**AREA**	**RUNOFF**	**EROSION**	**SEDIMENT**	**DIS. NITR**	**TOT. NITR**	**DIS. PHOS**	**TOT. PHOS**
"HAY/PAST"	87	10.54	4039.2	662.4	281.8	454.7	10.9	47.7
"CROPLAND"	361	17.26	35430.6	5810.6	1947.7	8240.6	74.6	1412.9
"CONIF_FOR"	78	9.15	224.3	36.8	13.6	22.2	.4	2.3
"MIXED_FOR"	113	9.15	286.1	46.9	19.6	35.5	.6	4
"DECID_FOR"	745	9.15	918.1	150.6	129.5	466	4.1	75.7
"TRANSITION"	.1	25.06	94478.9	15494.5	.7	5.4	.1	1
"LO_INT_DEV"	7	18.55	3921.7	643.2	0	6.2	0	.8
"HI_INT_DEV"	2	42.02	10125.6	1660.6	0	25.9	0	2.9
GROUNDWATER					818.8	818.8	52.9	52.9
POINT SOURCE					0	0	0	0
SEPTIC SYSTEMS					413.8	413.8	1.7	1.7
TOTAL	1393.1	11.43	10001.304	1640.214	3625.4	10488.9	145.3	1601.8

Clipped Landuse Image from AVGWLF showing land classified as Transitional



USGS Digital Orthophotos of South Branch Wyalusing Creek Watershed and Zoomed View of Misclassified Land



COMMENT AND RESPONSE DOCUMENT
South Branch Wyalusing Creek TMDL

Comment: If Millard Creek and South Branch Wyalusing Creek (SBWC) watersheds are very similar in physical characteristics and land use, why does Millard Creek meet water quality standards and SBWC does not?
Response: Although the overall landuses encompassing the entire watersheds are similar, there are also many differences between the watersheds. For example, factors affecting soil erosion from the land or streambank conditions along each creek may vary, thus affecting the actual instream biodiversity.

Comment: The reference watershed, Millard Creek, is designated as a Cold Water Fishery, as opposed to the SBWC that is designated as a Warm Water Fishery.
Response: At the time of the listing of the SBWC as an impaired water, it was classified as a Cold Water Fishery.

Comment: The proposed TMDL fails to establish a daily load. DEP has not explained why setting a yearly limit, which presumably allows for daily, weekly, or monthly fluctuations in loads as long as the yearly totals are not exceeded, adequately protect water quality on a daily basis.

Response: The Clean Water Act requirement for total maximum daily loads allows for the expression of a TMDL in units of mass per unit time, toxicity, or other appropriate measures. DEP, in consultation with EPA, has determined that annual loadings are more appropriate for expression of non-point source TMDLs for nutrients and sediment.

Comment: The SBWC TMDL fails to reflect seasonal variations.
Response: TMDLs for non-point sources of pollution are developed to protect the stream from impacts that occur at "critical" conditions. Critical conditions for non-point sources are times of run-off usually associated with precipitation. Similar to the way TMDLs protect waters from point source pollution at the critical low flow condition ensures protection at other less critical periods, the TMDL developed to protect the stream from impact of non-point sources during runoff ensures protection under all other conditions.

Comment: DEP inadequately accounts for the differences (topography, stream density, animal densities, crops and cropping practices) other than watershed size, between SBWC and the reference watershed.
Response: DEP disagrees with the statement that the modeling analysis does not adequately account for differences in many of the factors listed. Topography and stream density are used in the GIS data derived generation of the Universal Soil Loss Equation (USLE) parameters assigned to model soil erosion. Differences in these factors are realized in the LS factor in the USLE for each watershed. Differences in animal density are accounted for in the model using a GIS coverage of animal populations by zip code as obtained from the U.S. Census of Agriculture. This data layer is used in determining the amount, and nutrient content, of manure applied to cropland in each watershed. Differences in crops and cropping practices are also accounted for both through GIS generation and manual manipulation of the C and P factors in the USLE. Using GIS coverages with typical county-based cropping and BMP implementation practices, C and P factors are generated for each watershed. Finally, geologic similarity is used as one of the criteria for choosing a reference watershed. Also, model parameters such as the groundwater recession coefficient are adjusted based on the underlying geology in the watershed. Therefore, differences in groundwater contributions due to dissimilar geology are accounted for in the analysis.

Comment: From the limited information presented on the effectiveness of possible implementation plans, the TMDL does not provide reasonable assurance that the required reductions will be met. In addition, is BMP implementation planned for the whole watershed or just for impaired areas.
Response: TMDLs developed under section 303(d) of the CWA are not intended to be a step-by-step description of how to restore an impaired watershed. Federal law requires establishment of a pollutant load that will ensure attainment of water quality standards and an allocation of that load among point and nonpoint sources. These TMDLs have established pollutant loads, along with allocations of those loads, which will ensure attainment of water quality standards. Implementation plans, including assurances of specified load reductions, are not currently required as part of the TMDL under section 303(d). Information on potential remediation activities, including BMPs, was provided as an indication that the identified load reductions were achievable. The information should prove helpful to those developing plans to meet the specified reductions. While the Department insures compliance with all applicable laws and regulations, the most effective and achievable means of meeting the goals set forth in these TMDLs will come from the local level. The Department will also provide organizational, technical and financial assistance to watershed groups who undertake implementation. Please contact the Department if you want further information.

Comment: DEP fails to provide a rationale for selecting 10% as the margin of safety. The margin of safety should be based on the inherent uncertainty of the models used rather than the undefined “best professional judgment”.
Response: The use of resources to assess the degree of certainty for all the model factors would be huge and would significantly delay the development of TMDLs. The Department feels that 10% is a fair margin of safety to use to make up for unknowns in the TMDL development process.

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