

**Total Maximum Daily Loads (TMDLs)**

**Little Cacoosing Creek Watershed  
Berks County**

**Pennsylvania Department of Environmental Protection  
Southcentral Regional Office  
Water Management Program**



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## Summary of the Little Cacoosing Creek TMDLs

1. These TMDLs were developed for Little Cacoosing Creek, a tributary to Cacoosing Creek in SWP 03C (Tulpehocken Creek), located in Berks Counties, Pennsylvania. Access to the watershed is available by traveling west from Reading on Route 422 for approximately 5 miles. The stream originates near Cushion Peak in South Heidelberg Township and flows for approximately 4.7 miles in a northeasterly direction to its confluence with Cacoosing Creek north of Sinking Spring. Approximately 12.1 miles of streams drain the 7.9 square mile watershed. Protected stream uses in the watershed include aquatic life, water supply, and recreation. The entire basin is currently designated as Warm Water Fishes (WWF) under §93.9f in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001).
2. TMDLs for the Little Cacoosing Creek watershed were developed to address use impairments caused by siltation and nutrients. Little Cacoosing Creek first appeared on Pennsylvania's 303(d) list in 1996, when the lower 4.4 miles of the mainstem were listed as impaired by nutrients emanating from upstream agricultural activities. Assessments conducted by the Department in 2001 documented designated use impairments for the entire watershed, including the mainstem and its numerous unnamed tributaries. Agricultural land use activities were identified as the source of impairment, with nutrients and siltation being the pollutants causing the impairments. The entire Little Cacoosing Creek basin is expected to be included on Pennsylvania's 2002 303(d) list. Sediment and total phosphorus TMDLs were developed to address siltation and nutrient impairments identified in the Department's current 305b database. In order to ensure attainment and maintenance of water quality standards in the Little Cacoosing Creek watershed, mean annual loading of sediment and total phosphorus will need to be limited to 1,015,970 and 1,886 lbs./yr., respectively.

The major components of the Little Cacoosing Creek watershed TMDLs are summarized below:

<b>Component</b>	<b>Sediment (lbs./yr.)</b>	<b>Total Phosphorus (lbs./yr.)</b>
<b>TMDL (Total Maximum Daily Load)</b>	1,015,969.50	1,885.56
<b>WLA (Wasteload Allocation)</b>	0	0
<b>MOS (Margin of Safety)</b>	101,596.95	188.56
<b>LA (Load Allocation)</b>	914,372.55	1,697.00

3. The current mean annual sediment loading to Little Cacoosing Creek is estimated to be 1,406,126 lbs./yr., requiring a 28% reduction to meet the TMDL. Mean annual total phosphorus loading is estimated to be 3,411 lbs./yr. and will require a 45% reduction to meet the TMDL.
4. There are no known point sources of sediment or total phosphorus located in the Little Cacoosing Creek watershed; therefore the TMDLs do not include Waste Load Allocations (WLA). Load Allocations (LA) for sediment and total phosphorus were made to the following nonpoint sources: hay and pasture lands; croplands; coniferous forest; mixed forest; deciduous forest; transition land, low intensity development; high intensity development; stream bank erosion; groundwater; and septic systems.
5. Since there are no industrial or municipal point sources, or other point source discharges subjected to general permits in the Little Cacoosing Creek watershed, the TMDLs do not include WLAs.
6. The sediment TMDL includes a nonpoint source load allocation (LA) of 914,372 lbs./yr. Allocations to sources receiving reductions (hay and pasture, cropland, and stream bank erosion) total 883,772 lbs./yr. Sediment loadings from the remaining nonpoint sources (loads not reduced) were maintained at 30,600 lbs./yr. The total phosphorus TMDL includes a nonpoint source LA of 1,697 lbs./yr. Allocations to sources receiving reductions (hay/pasture, cropland, and stream bank erosion) add up to 781 lbs./yr. Total phosphorus loadings from all other nonpoint sources were maintained at 916 lbs./yr. Allocations of sediment and total phosphorus to all nonpoint sources in the Little Cacoosing Creek watershed are summarized below:

<b>Load Allocations for Sources of Sediment</b>			
<b>Source</b>	<b>Current Loading (lbs./yr.)</b>	<b>Load Allocation (lbs./yr.)</b>	<b>% Reduction</b>
<b>Hay and Pasture</b>	71,400.00	56,997.05	20%
<b>Cropland</b>	1,152,200.00	705,496.16	39%
<b>Stream Bank Erosion</b>	151,926.20	121,279.34	20%
<b>NPS Loads Not Reduced</b>	30,600.00	30,600.00	-
<b>Total</b>	<b>1,406,126.20</b>	<b>914,372.55</b>	<b>35%</b>

<b>Load Allocations for Sources of Total Phosphorus</b>			
<b>Source</b>	<b>Current Loading (lbs./yr.)</b>	<b>Load Allocation (lbs./yr.)</b>	<b>% Reduction</b>
<b>Hay and Pasture</b>	309.60	205.07	34%
<b>Cropland</b>	2,097.20	517.26	75%
<b>Stream Bank Erosion</b>	88.42	58.57	34%
<b>NPS Loads Not Reduced</b>	916.10	916.10	-
<b>Total</b>	<b>3,411.32</b>	<b>1,697.00</b>	<b>50%</b>

7. Ten percent of the Little Cacoosing Creek sediment and total phosphorus TMDLs were set-aside as a margin of safety (MOS). The MOS is that portion of the pollutant loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. The MOS for the sediment TMDL and the MOS for the total phosphorus TMDL were set at 101,597 lbs./yr. and 189 lbs./yr., respectively.
8. The continuous simulation model used for developing the Little Cacoosing Creek TMDLs 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 accounts for seasonal variability.

## **I. Introduction**

### **A. Watershed Description**

Little Cacoosing Creek is part of State Water Plan subbasin 03C (Tulpehocken Creek) and is located just west of Sinking Springs in Berks County, Pennsylvania ([Figure 1](#)). Access to the watershed is available by traveling west from Reading on Route 422 for approximately 5 miles. Little Cacoosing Creek flows under Route 422 approximately 0.5 miles east of Wernersville. The stream originates near Cushion Peak in South Heidelberg Township and flows for approximately 4.7 miles in a northeasterly direction to its confluence with Cacoosing Creek north of Sinking Spring. Approximately 12.1 miles of streams drain the 7.9 square mile watershed. Protected stream uses in the watershed include aquatic life, water supply, and recreation. The entire basin is currently designated as Warm Water Fishes (WWF) under §93.9f in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001).

### **B. Topography & Geology**

Little Cacoosing Creek drains portions of the Ridge & Valley and New England physiographic provinces. Ninety two percent of the basin is located in the Great Valley Section (Ridge & Valley) and 8% is in Reading Prong Section (New England). The Great Valley Section consists of a very broad lowland area lying south of Blue Mountain in southeastern Pennsylvania. The lowland is characterized by gently undulating hills eroded into shales and siltstones on the north side of the valley and a lower elevation, flatter landscape developed on limestones and dolomites on the south side. The Little Cacoosing Creek watershed is located on the south side of the Great Valley. Elevations in this portion of the watershed ranges from 700 to 280 feet. Approximately 4.5 miles of the Little Cacoosing Creek mainstem flows through the Great Valley Section, dropping a mere 210 feet in elevation (< 1% average slope).

The extreme headwater reaches of the Little Cacoosing Creek watershed are located in the Reading Prong Section. The Reading Prong Section consists of low hills and ridges that project upward in significant contrast to the lowlands of the Great Valley Section. The hills and ridges are made up of metamorphic and igneous rocks, including granitic gneiss, granodiorite, and quartzite. These rocks are very resistant to erosion and thus the hills and ridges stand higher than the softer sedimentary rocks that surround them. The slopes of these hills and ridges are steep and have a very well defined change in slope where the bases of the hills and ridges meet the lower and gentler slopes of the adjacent lowlands. Streams eroding into the hills and ridges are usually short and steep.

### **C. Land Use**

Land use in the Little Cacoosing Creek basin is dominated by agriculture (71%) and forest and (26%). Other land uses include development (2%), and wetlands/waterbodies (1%). Agricultural activities, primarily row and cover crops, dominate the landscape to the north and west of Little Cacoosing Creek. Development activities are rapidly increasing throughout the watershed. Residential areas include both older and more densely populated areas along the Route 422 corridor, as well as newer and rapidly expanding single-family housing developments.

### **D. Surface Water Quality**

Pennsylvania's 1996 303(d) list identified 4.4 miles of Little Cacoosing Creek as impaired by nutrients emanating from agricultural activities in the basin ([Table 1](#)). The original listing of Little Cacoosing Creek resulted from a special nonpoint source survey conducted by the Department's Central Office in 1989. One-time chemical and biological sampling was conducted at a single station on the mainstem of Little Cacoosing Creek. Chemical sampling consisted of a mid-stream, mid-depth grab sample and biological sampling included kick screen sampling of benthic macroinvertebrates. Kick screen samples were identified to family in the field. The 305b database entry for the station on Little Cacoosing Creek includes the following comment: "11 macroinvertebrate taxa present; high level of phosphorus." Based on data collected, the investigator

concluded that the entire mainstem of Little Cacoosing Creek was impaired. The 1998 303(d) list identified 4.69 miles of designated use impairment for Little Cacoosing Creek (Table 1)(Figure 2). Segment ID 375 included the entire mainstem of Little Cacoosing Creek from its source downstream to its confluence with Little Cacoosing Creek. The source and cause of the impairment was still identified as agriculture and nutrients. The slight increase in miles (0.29) over the 1996 listing was the result of a GIS-based recalculation. Streams in the rest of the Little Cacoosing Creek watershed, including all unnamed tributaries to Little Cacoosing Creek, had not been assessed prior to development of the 1998 303(d) list.

As part of the Department’s ongoing Unassessed Waters (UW) program and in anticipation of TMDL development, assessments were conducted in the Little Cacoosing Creek watershed in June 2001. The UW program protocol was used to determine the status of designated use attainment for the entire 12.1 miles of streams in the watershed, including numerous unnamed tributaries. Information collected during these assessments identified designated use impairments for the entire Little Cacoosing Creek watershed (Figure 3). The Department anticipates placing the identified impairments on the 2002 303(d) list. Approximately 12.1 stream miles are being impaired by nutrients and siltation emanating from agricultural land uses in the watershed. Kick screen sampling at impaired stations documented the presence of compromised benthic macroinvertebrate communities. Taxa richness (family level ID or higher) ranged from 2 to 10. The number of mayfly, stonefly, and caddisfly families present ranged from 0 to 3. There were no stonefly families present at 2 of the 3 stations sampled. A single family of filter feeders (hydropsychidae) was the only caddisfly collected. Abundant taxa in samples collected from the Little Cacoosing Creek watershed included planaria (turbellaria), aquatic sow bugs (asellidae), and pouch snails (physidae). Habitat evaluations documented the presence of marginal to sub-optimal conditions in the impaired portions of the watershed, with total habitat scores ranging from 90 to 139, out of a possible 240. Habitat parameters that evaluate instream impacts of siltation consistently scored low, as did those associated with riparian buffer zones and streamside vegetation.

**Table 1 - 1996 & 1998 303(d) Listings for Little Cacoosing Creek Watershed**

<b>1996 303(d) LIST</b>					
<b>STREAM NAME</b>	<b>STREAM CODE</b>	<b>SOURCE</b>	<b>CAUSE</b>	<b>MILES</b>	
Little Cacoosing Creek	1853	Agriculture	Nutrients	4.4	
<b>1998 303(d) LIST</b>					
<b>SEGMENT ID</b>	<b>WATERSHED</b>	<b>STREAM CODE</b>	<b>SOURCE</b>	<b>CAUSE</b>	<b>MILES</b>
375	Little Cacoosing Creek	01853	Agriculture	Nutrients	4.69

Figure 1 - Little Cacoosing Creek Watershed  
Berks County

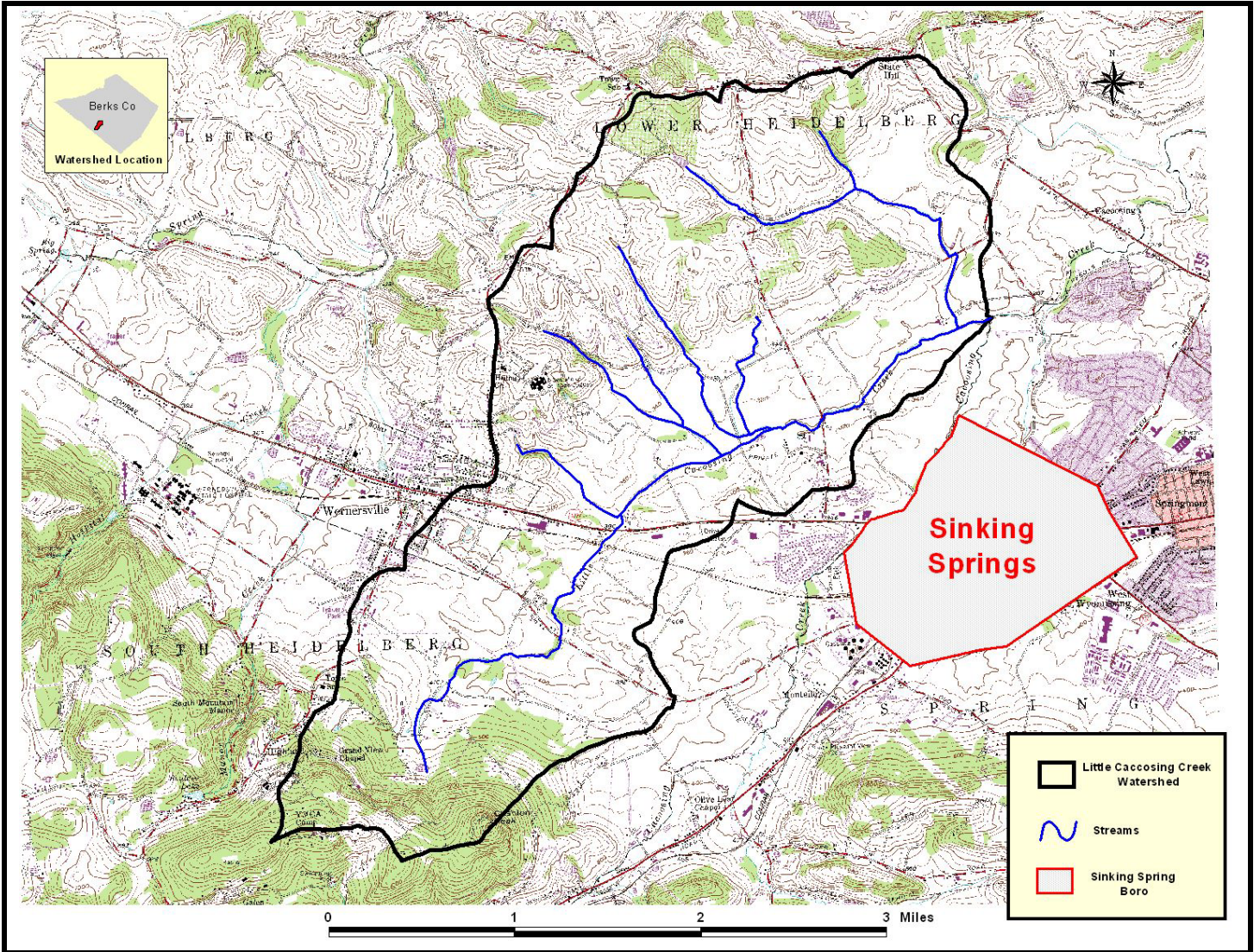


Figure 2 - Stream Segment on the 1996 and 1998 303(d) List  
Little Cacoosing Creek Watershed

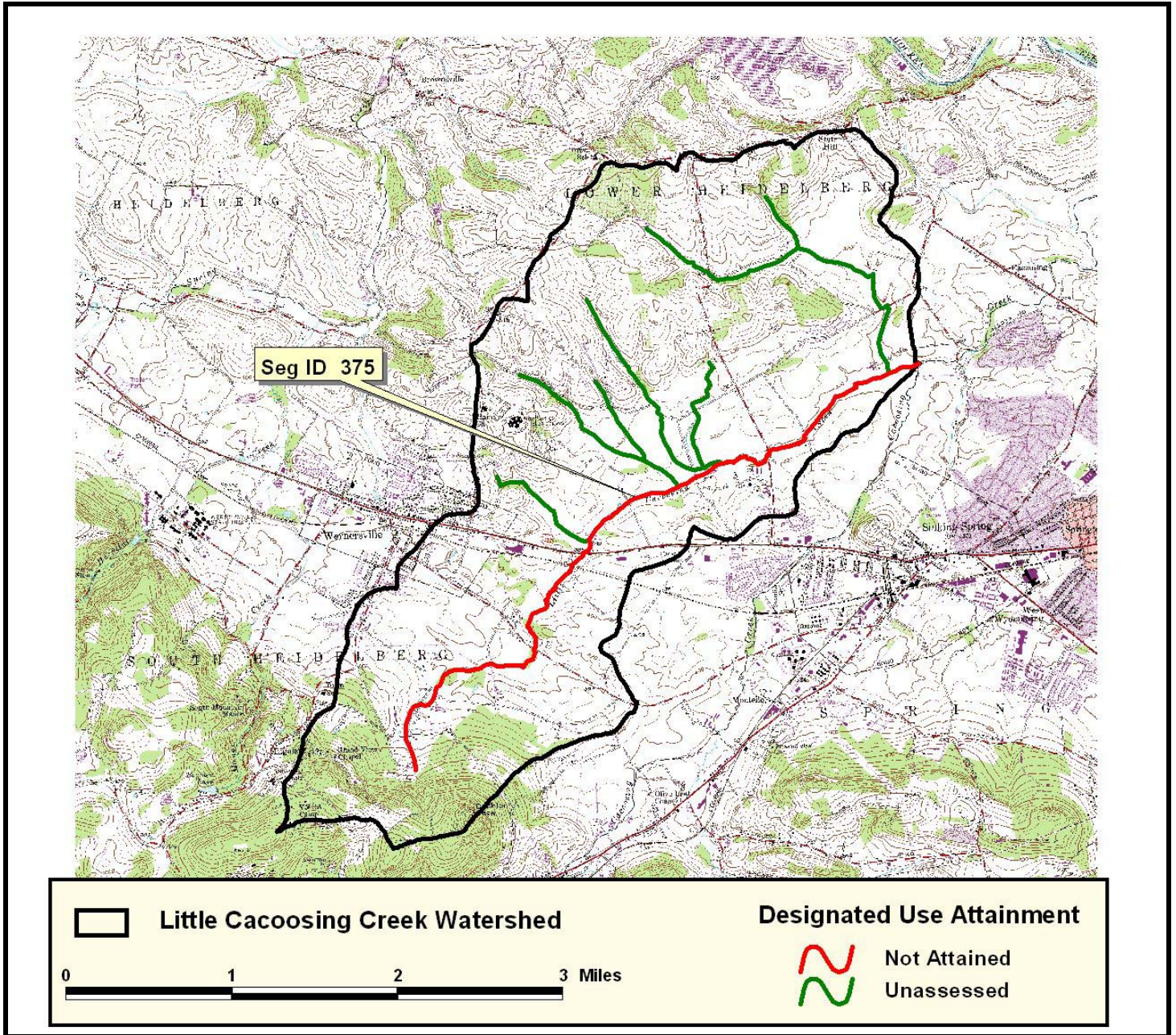
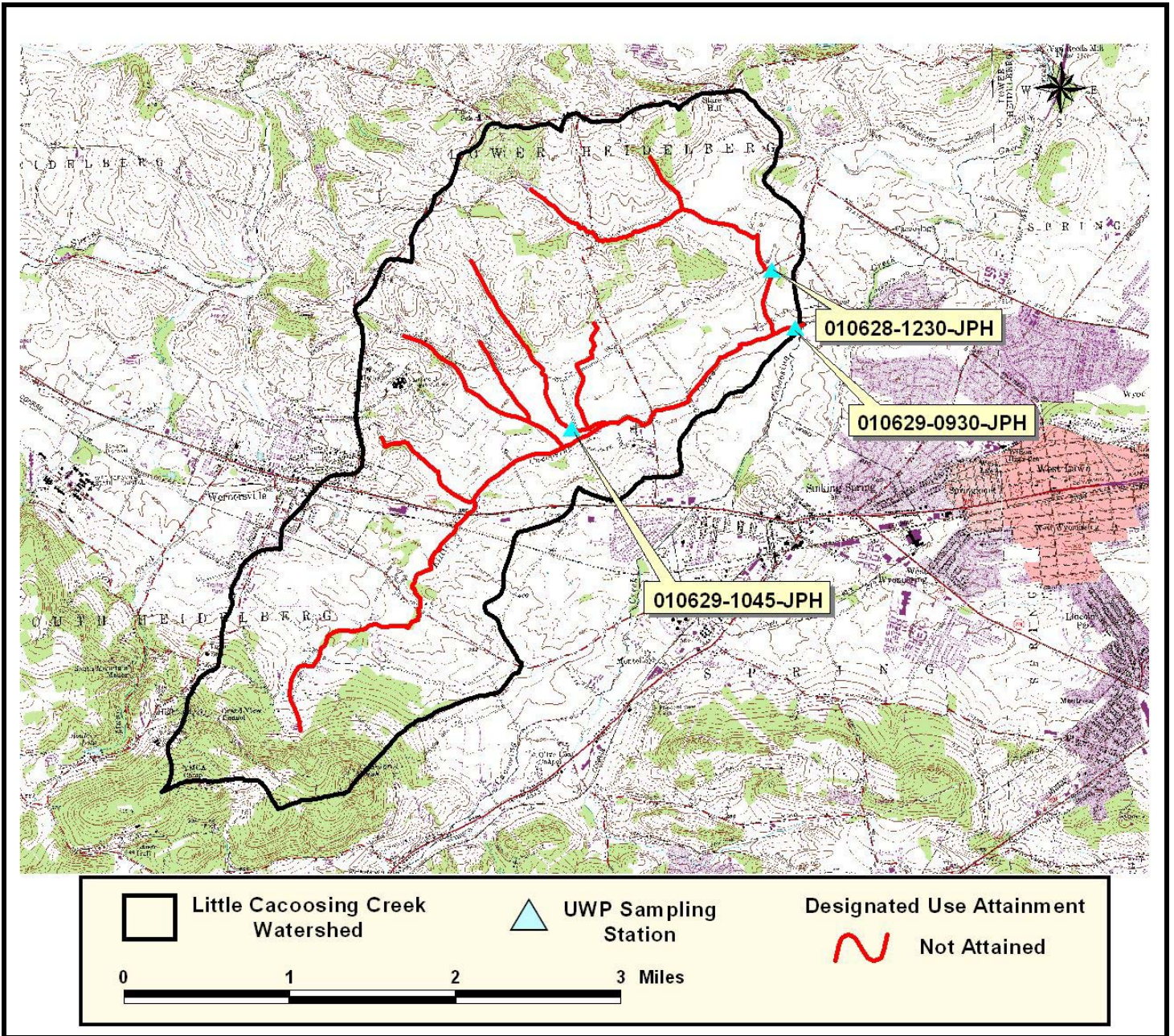


Figure 3 - Current Status of Designated Use Attainment  
Little Cacoosing Creek



## **II. Approach to TMDL Development**

### **A. Pollutants & Sources**

Nutrients and siltation have been identified as the pollutants causing designated use impairments in the Little Cacoosing Creek watershed. Based on information contained in the Department's 305(b) report database and visual observations made in May and June 2001, agricultural activities appear to be the primary source of both pollutants. There are no known point source discharges of nutrients present in the watershed.

### **B. TMDL Endpoints**

In an effort to address nutrient and siltation impairments found in the Little Cacoosing Creek watershed, Total Maximum Daily Loads (TMDLs) were developed for sediment and total phosphorus. The sediment TMDL was developed to address siltation impairments from agricultural activities that were documented in June 2001. The total phosphorus TMDL is intended to address current nutrient impairments in the Little Cacoosing Creek watershed, including impairments that were first identified in Pennsylvania's 1996 303(d) list. The decision to use phosphorus load reductions to address nutrient impairments was based on an understanding of the relationship between nitrogen, phosphorus, and organic enrichment in stream systems. Elevated nutrient loads (nitrogen and phosphorus in particular) can lead to increased productivity of plants and other organisms (Novotny and Olem, 1994). In aquatic ecosystems the quantities of trace elements are typically plentiful; however, nitrogen and phosphorus may be in short supply. The nutrient that is in the shortest supply is called the limiting nutrient because its relative quantity affects the rate of production (growth) of aquatic biomass. If the limiting nutrient load to a water body can be reduced, the available pool of nutrients that can be utilized by plants and other organisms will be reduced and, in general, the total biomass can subsequently be decreased as well (Novotny and Olem, 1994). In most efforts to control the eutrophication processes in water bodies, emphasis is placed on the limiting nutrient. This is not always the case, however. For example, if nitrogen is the limiting nutrient, it still may be more efficient to control phosphorus loads if the nitrogen originates from difficult to control sources such as nitrates in ground water.

In most freshwater systems, phosphorus is the limiting nutrient for aquatic growth. In some cases, however, the determination of which nutrient is the most limiting is difficult. For this reason, the ratio of the amount of N to the amount of P is often used to make this determination (Thomann and Mueller, 1987). If the N/P ratio is less than 10, nitrogen is limiting. If the N/P ratio is greater than 10, phosphorus is the limiting nutrient. For Little Cacoosing Creek, the N/P ratio is estimated to be near 19, which points to phosphorus as the limiting nutrient. Controlling the phosphorus loading to Little Cacoosing Creek will limit plant growth, thereby helping to eliminate use impairments currently being caused by excess nutrients.

### **C. Reference Watershed Approach**

The TMDLs developed for the Little Cacoosing Creek watershed address sediment and phosphorus. Because neither Pennsylvania nor EPA has instream numerical water quality criteria for these pollutants, a method was developed to implement the applicable narrative criteria. The method employed for these TMDLs is termed the "Reference Watershed Approach." Meeting the water quality objectives specified by these TMDLs will result in the impaired stream segments attaining their designated uses.

The Reference Watershed Approach compares two watersheds, one attaining its uses and one that is impaired based on biological assessments. Both watersheds must have similar land use/cover distributions. Other features such as base geologic formation should be 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 pollutants in the impaired stream segment to a level equivalent to, or slightly lower than, the loading rate in the non-impaired, reference segment. This load reduction will result in conditions favorable to the return of a healthy biological community to the impaired stream segments.

#### **D. Selection of the Reference Watershed**

In general, three factors are considered when selecting a suitable reference watershed. The first factor is to use a watershed that the Department has assessed and determined to be attaining water quality standards. The second factor is to find a watershed that closely resembles the impaired watershed in physical properties such as land cover/land use, physiographic province, and geology. Finally, the size of the reference watershed should be within 20-30% of the impaired watershed area. The search for a reference watershed for Little Cacoosing Creek that would satisfy the above characteristics was done by means of a desktop screening using several GIS coverages, including the Multi-Resolution Land Characteristics (MRLC), Landsat-derived land cover/use grid, the Pennsylvania's 305(b) assessed streams database, and geologic rock types

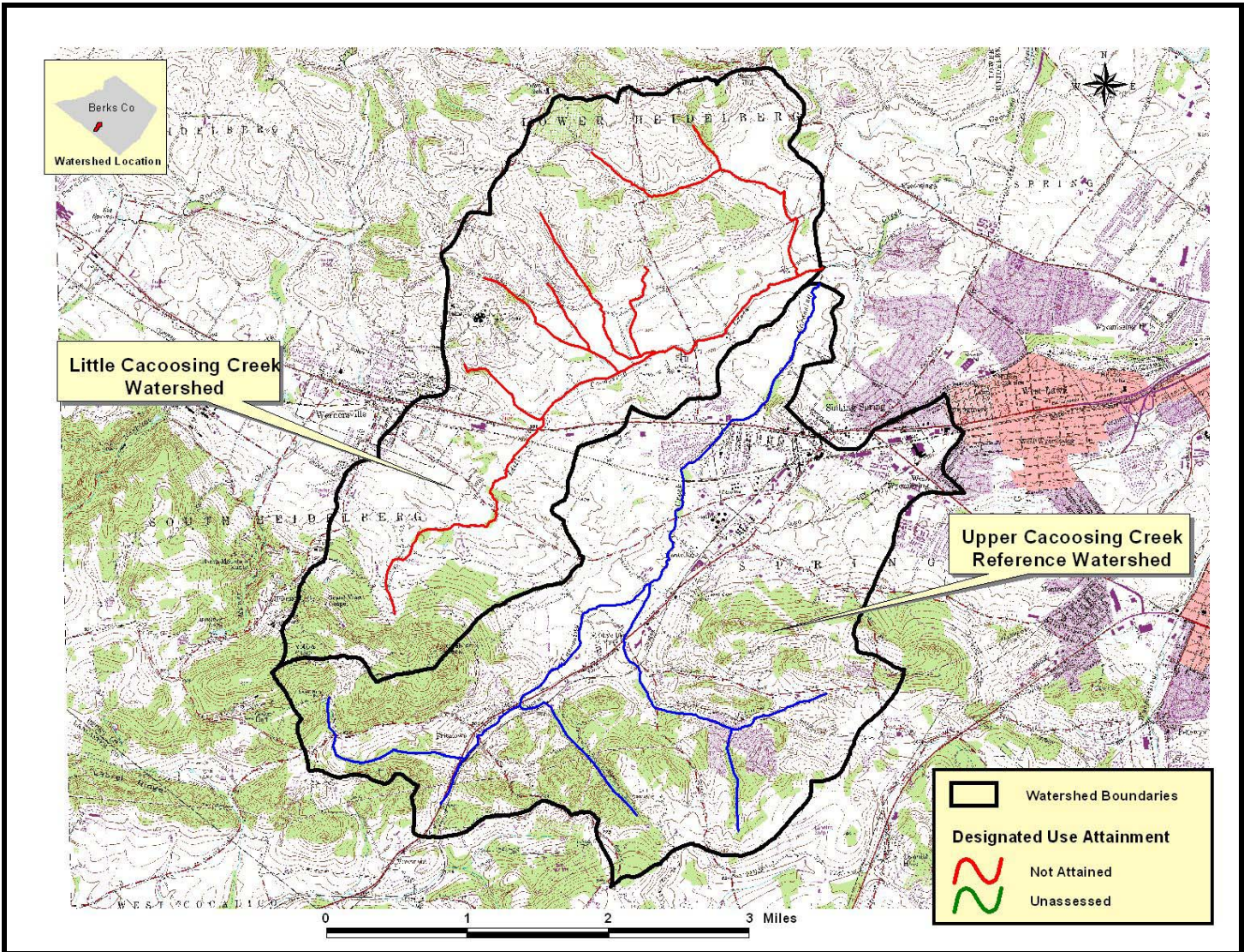
The portion of the Cacoosing Creek watershed located upstream of Little Cacoosing Creek was selected as the reference watershed for developing the Little Cacoosing Creek TMDLs (Figure 4). The watershed is located in State Water Plan subbasin 03C and protected uses include aquatic life, water supply, and recreation. The reference portion of the Cacoosing Creek is currently designated as Warm Water Fishes (WWF) under §93.9f in Title 25 of the Pa. Code (Commonwealth of Pennsylvania, 2001). Based on the Department's 305(b) report database, the upper portion of Cacoosing Creek is currently attaining its designated uses. The attainment of designated uses is based on sampling done by the Department in 2001, using the Unassessed Waters program protocol.

Drainage area, location, and other physical characteristics of the Little Cacoosing Creek watershed were compared to the upper Cacoosing Creek watershed (Table 3). An analysis of value counts for each pixel of the MRLC grid revealed that while land cover/use distributions are not an exact match, both watersheds are similar. Agriculture, including cropland and pasture, and forest are the dominant land use categories in both watersheds. Surficial geology in the upper and Little Cacoosing Creek watersheds were also compared. Rock types in the Little Cacoosing Creek watershed include carbonate (53%), shale (20%), interbedded sedimentary (16%), and metamorphic/igneous (11%). The upper Cacoosing Creek watershed also contains carbonate (43%), interbedded sedimentary (10%), and metamorphic/igneous (32%) rocks, along with conglomerate rocks (14%). Bedrock geology primarily affects surface runoff and background nutrient loads through its influences on soils, landscape, fracture density, and directional permeability. Little Cacoosing Creek and the upper Cacoosing Creek watershed are very similar in terms of soil types, soil K factor, precipitation, and average runoff, (Table 2).

**Table 2 - Comparison Between Little Cacoosing Creek and Upper Cacoosing Creek Reference Watershed**

ATTRIBUTE	WATERSHED	
	Lt. Cacoosing Creek	Upper Cacoosing Creek
<b>Physiographic Province</b>	Ridge & Valley (92.1%) New England (7.9%)	Ridge & Valley (57%) Piedmont (39%) New England (5%)
<b>Area (mi<sup>2</sup>)</b>	7.9	9.3
<b>Land Use</b>	Agriculture (71%) Forested (26%) Development (2%) Wetlands/Waterbodies (1%)	Agriculture (41%) Forested (46%) Development (12%) Wetlands/Waterbodies (1%)
<b>Geology</b>	Carbonate (53%) Shale (20%) Interbedded Sedimentary (16%) Metamorphic/Igneous (11%)	Carbonate (43%) Metamorphic/Igneous (32%) Conglomerate (14%) Interbedded Sedimentary (10%)
<b>Soils</b>	Hagerstown-Duffield-Clarksburg (60%) Chester-Glenelg-Manor (17%) Neshaminy-Lehigh-Glenelg (12%) Berks-Weikert-Bedington (11%)	Ungers-Penn-Klinesville (27%) Chester-Glenelg-Manor (23%) Hagerstown-Duffield-Clarksburg (23%) Neshaminy-Lehigh-Glenelg (21%) Neshaminy-Lehigh-Glenelg (5%)
<b>Dominant HSG</b>	C (47%) B (43%) D (9%) A (1%)	B (52%) C (35%) D (12%) A (1%)
<b>K Factor</b>	0.31	0.31
<b>20-Year Average Rainfall (in)</b>	42.4	43.5
<b>20-Year Average Runoff (in)</b>	3.4	2.7

Figure 4 - Upper Cacoosing Creek Reference Watershed



### III. Watershed Assessment and Modeling

TMDLs for the Little Cacoosing Creek watershed were developed using the ArcView Generalized Watershed Loading Function (AVGWLF) model as described in [Appendix B](#). The AVGWLF model was used to establish existing loading conditions for the Little Cacoosing Creek watershed and the upper Cacoosing Creek reference watershed. All modeling outputs have been attached to this TMDL as [Appendices C](#) and [D](#). DEP staff visited both watersheds in October 2001. These field visits were conducted to get a better understanding of existing conditions that might influence the AVGWLF model. General observations of the individual watershed characteristics include:

#### Little Cacoosing Creek Watershed

- Croplands (primarily corn) consisted of very large, monotypic row crops in some areas ([Figure 5](#)).
- Plowing practices on some farms were causing obvious erosion problems, while other farms included the use of soil conservation practices such as leaving crop residue after harvesting row crops and planting of winter wheat ([Figure 6](#)).

-In some areas, instream habitat, including substrate and water depth, was severely impacted by sediment deposition ([Figure 7](#)).

**Upper Cacoosing Creek Reference Watershed**

-Less intensive agricultural activity.

-Greater use of conservation practices on croplands, including strip cropping ([Figure 8](#)).

No adjustments were made to specific parameters used in the AVGWLF model based on observations made while touring the watersheds.

**Figure 5 - Example of Large, Monotypic Row Crops in the Little Cacoosing Creek Watershed**



**Figure 6 - Example of Soil Conservation Practices on Croplands in the Little Cacoosing Creek Watershed**



**Figure 7 - Example of Siltation Impacts in the Little Cacoosing Creek Watershed**



**Figure 8 - Example of Strip Cropping in the Upper Cacoosing Creek Reference Watershed**



The AVGWLF model produced information on watershed size, land use, sediment loading, and total phosphorus loading (Tables 3 and 4). The sediment and total P loads represent an annual average over the 20 years simulated by the model (1978 to 1998). This information was then used to calculate existing unit area loading rates for the Little Cacoosing Creek and upper Cacoosing Creek reference watersheds.

Unit area loading rates for sediment and total phosphorus were estimated for each watershed by dividing the mean annual loadings (lbs./yr.) by the total area (acres). Unit area load estimates for sediment and total phosphorus in the Little Cacoosing Creek watershed are 283.38 lbs./acre/yr. and 0.69 lbs./acre/yr., respectively (Table 3). Unit area load estimates for sediment and total phosphorus in the upper Cacoosing Creek reference watershed are 204.75 lbs./acre/yr. and 0.38 lbs./acre/yr., respectively (Table 4).

<b>Table 3 - Existing Sediment and Total Phosphorus Loads for the Little Cacoosing Creek Watershed</b>					
<b>Pollutant Source</b>	<b>Area (ac)</b>	<b>Sediment</b>		<b>Total Phosphorus</b>	
		<b>Mean Annual Loading (lbs./yr.)</b>	<b>Unit Area Loading (lbs./ac./yr.)</b>	<b>Mean Annual Loading (lbs./yr.)</b>	<b>Unit Area Loading (lbs./ac./yr.)</b>
<b>HAY/PAST</b>	1,210.80	71,400.00	58.97	309.60	0.26
<b>CROPLAND</b>	2,359.90	1,152,200.00	488.24	2,097.20	0.89
<b>CONIF FOR</b>	108.70	400.00	3.68	0.70	0.01
<b>MIXED FOR</b>	173.00	1,000.00	5.78	1.30	0.01
<b>DECID FOR</b>	988.40	23,600.00	23.88	28.40	0.03
<b>TRANSITION</b>	2.50	3,400.00	1,360.00	4.60	1.84
<b>LO INT DEV</b>	89.00	1,800.00	20.22	-	-
<b>HI INT DEV</b>	29.70	400.00	13.47	-	-
<b>Stream Bank</b>	-	151,926.20	-	88.42	-
<b>Groundwater</b>	-	-	-	868.00	-
<b>Septic Systems</b>	-	-	-	13.10	-
<b>Total</b>	<b>4,962.00</b>	<b>1,406,126.20</b>	<b>283.38</b>	<b>3,411.32</b>	<b>0.69</b>

**Table 4 - Existing Sediment and Total Phosphorus Loads for the Upper Cacoosing Creek Reference Watershed**

Pollutant Source	Area (ac)	Sediment		Total Phosphorus	
		Mean Annual Loading (lbs./yr.)	Unit Area Loading (lbs./ac./yr.)	Mean Annual Loading (lbs./yr.)	Unit Area Loading (lbs./ac./yr.)
HAY/PAST	877.20	69,600.00	79.34	133.40	0.15
CROPLAND	1,532.10	801,800.00	523.33	1,007.90	0.66
CONIF FOR	197.70	1,200.00	6.07	1.40	0.01
MIXED FOR	249.60	1,600.00	6.41	1.70	0.01
DECID FOR	2,337.60	91,200.00	39.01	81.40	0.03
LO INT DEV	326.20	12,200.00	37.40	1.10	0.00
HI INT DEV	355.80	12,600.00	35.41	13.50	0.04
Stream Bank	-	212,956.40	-	91.25	-
Groundwater	-	-	-	874.20	-
Septic Systems	-	-	-	20.70	-
<b>Total</b>	<b>5,876.20</b>	<b>1,203,156.40</b>	<b>204.75</b>	<b>2,226.55</b>	<b>0.38</b>

#### IV. TMDLs

Targeted TMDL values for the Little Cacoosing Creek watershed were established based on current loading rates for sediment and total phosphorus in the upper Cacoosing Creek reference watershed. The entire length of Cacoosing Creek is currently designated as Warm Water Fishes (WWF) and recent Unassessed Waters program assessments have determined that the portion of the basin used as a reference is attaining its designated uses. Reducing the loading rates of sediment and total phosphorus in the Little Cacoosing Creek basin to levels equal to, or less than, the upper Cacoosing Creek reference watershed will provide conditions favorable for the reversal of current use impairments.

##### A. Background Pollutant Conditions

There are two separate considerations of background pollutants within the context of these TMDLs. First, there is the inherent assumption of the reference watershed approach that because of the similarities between the reference and impaired watershed, the background pollutant contributions will be similar. Therefore, the background pollutant contributions will be considered when determining the loads for the impaired watershed that are consistent with the loads from the reference watershed. Second, the AVGWLF model implicitly considers background pollutant contributions through the soil and the groundwater component of the model process.

##### B. Targeted TMDL

Targeted TMDL values for sediment and total phosphorus were determined by multiplying the total area of the Little Cacoosing Creek watershed (4962.00 acres) by the appropriate unit area loading rates for the upper Cacoosing Creek reference watershed ([Table 5](#)).

<b>Table 5 - Targeted TMDLs for the Little Cacoosing Creek Watershed</b>			
<b>Pollutant</b>	<b>Area (ac.)</b>	<b>Unit Area Loading Rate Upper Cacoosing Cr. Ref. Watershed (lbs./ac./yr.)</b>	<b>Targeted TMDL (lbs./yr.)</b>
<b>Sediment</b>	4962.00	204.75	1,015,969.50
<b>Total P</b>	4962.00	0.38	1,885.56

Targeted TMDL values were than used as the basis for load allocations and reductions in the Little Cacoosing Creek watershed, using the following two equations:

1.  $TMDL = WLA + LA + MOS$
2.  $LA = ALA - LNR$

where:

TMDL = Total Maximum Daily Load  
WLA = Waste Load Allocation (point sources)  
LA = Load Allocation (nonpoint sources)  
ALA = Adjusted Load Allocation  
LNR = Loads not Reduced

### C. Wasteload Allocation

The waste load allocation (WLA) portion of the TMDL equation is the total loading of a pollutant that is assigned to point sources. Reviewing the Department’s permitting files identified no point sources of sediment or nutrients in the Little Cacoosing Creek watershed; therefore WLAs were set at zero.

### D. Margin of Safety

The margin of safety (MOS) is that portion of the pollutant loading that is reserved to account for any uncertainty in the data and computational methodology used for the analysis. For this analysis, the MOS is explicit. Ten percent of the targeted TMDLs for sediment and total phosphorus were reserved as the MOS. Using 10% of the TMDL load is based on professional judgment and will provide an additional level of protection to the designated uses of Little Cacoosing Creek. The MOS for the sediment TMDL and the MOS for the total phosphorus TMDL were set at 101,596.95 lbs./yr. and 188.56 lbs./yr., respectively.

$$\begin{aligned} \text{MOS (Sediment)} &= 1,015,969.50 \text{ lbs./yr. (TMDL)} \times 0.1 = 101,596.95 \text{ lbs./yr.} \\ \text{MOS (Phosphorus)} &= 1,885.56 \text{ lbs./yr. (TMDL)} \times 0.1 = 188.56 \text{ lbs./yr.} \end{aligned}$$

### E. Load Allocation

The load allocation (LA) is that portion of the TMDL that is assigned to nonpoint sources. Since there are no point sources present in the Little Cacoosing Creek watershed, load allocations for sediment and phosphorus were computed by subtracting the MOS value from the targeted TMDL value. Load Allocations for sediment and phosphorus were 559,344.38 lbs./yr. and 1,474.74 lbs./yr., respectively.

$$\begin{aligned} \text{LA (Sediment)} &= 1,015,969.50 \text{ lbs./yr. (TMDL)} - 101,596.95 \text{ lbs./yr. (MOS)} = 914,372.55 \text{ lbs./yr.} \\ \text{LA (Phosphorus)} &= 1,885.56 \text{ lbs./yr. (TMDL)} - 188.56 \text{ lbs./yr. (MOS)} = 1,697.00 \text{ lbs./yr.} \end{aligned}$$

## F. Adjusted Load Allocation

The adjusted load allocation (ALA) is the actual portion of the LA distributed among those nonpoint sources receiving reductions. It is computed by subtracting those non-point source loads that are not being considered for reductions (loads not reduced or LNR) from the LA. Since the Little Cacoosing Creek watershed TMDLs were developed to address impairments resulting from agricultural activities, only agriculture related sources were considered for reductions. Reductions were applied to HAY/PASTURE, CROPLAND, and Stream Bank erosion sources for both sediment and total phosphorus. Those land uses/sources for which existing loads were not reduced (CONIF\_FOR, MIXED\_FOR, DECID\_FOR, TRANSITION, LO\_INT\_DEV, HI\_INT\_DEV, Groundwater, and Septic Systems) were carried through at their existing loading values (Table 6). The ALA for sediment and phosphorus were 883,772.55 lbs./yr. and 780.90 lbs./yr., respectively.

<b>Table 6 - Load Allocations, Loads Not Reduced, and Adjusted Load Allocations for Little Cacoosing Creek TMDLs</b>		
	<b>Sediment (lbs./yr.)</b>	<b>Total P (lbs./yr.)</b>
<b>Load Allocation</b>	914,372.55	1,697.00
<b>Loads Not Reduced</b>	30,600.00	916.10
CONIF FOR	400.00	0.70
MIXED FOR	1,000.00	1.30
DECID FOR	23,600.00	28.40
TRANSITION	3,400.00	4.60
LO INT DEV	1,800.00	
HI INT DEV	400.00	
Groundwater	-	868.00
Septic Systems	-	13.10
<b>Adjusted Load Allocation</b>	883,772.55	780.90

## G. TMDLs

Both the sediment and total phosphorus TMDLs established for the Little Cacoosing Creek watershed consists of a Load Allocation (LA) and a Margin of Safety (MOS). No TMDL was established for nitrogen because the stream is phosphorus limited. The individual components of the TMDLs are summarized in Table 7.

<b>Table 7 - TMDL, WLA, MOS, LA, LNR, and ALA for Little Cacoosing Creek Watershed</b>		
<b>Component</b>	<b>Sediment (lbs./yr.)</b>	<b>Total Phosphorus (lbs./yr.)</b>
<b>TMDL (Total Maximum Daily Load)</b>	1,015,969.50	1,885.56
<b>WLA (Wasteload Allocation)</b>	0	0
<b>MOS (Margin of Safety)</b>	101,596.95	188.56
<b>LA (Load Allocation)</b>	914,372.55	1,697.00
<b>LNR (Loads Not Reduced)</b>	30,600.00	916.10
<b>ALA (Adjusted Load Allocation)</b>	883,772.55	780.90

## V. Calculation of Sediment and Nutrient Load Reductions

Adjusted load allocations established in the previous section represent the sediment and total phosphorus loads that are available for allocation between contributing sources in the Little Cacoosing Creek watershed. Data needed for load reduction analyses, including land use distribution, were obtained by GIS analysis. The Equal Marginal Percent Reduction (EMPR) allocation method ([Appendix E](#)) was used to distribute the ALA between the appropriate contributing land uses.

The load allocation and EMPR procedures were performed using MS Excel and results are presented in [Appendix F. Table 8](#) contains the results of the EMPR for sediment and total phosphorus for the appropriate contributing land uses in Little Cacoosing Creek watershed. The load allocation for each land use is shown, along with the percent reduction of current loads necessary to reach the targeted LA.

<b>Table 8 - Sediment and Phosphorus Load Allocations &amp; Reductions for the Little Cacoosing Creek Watershed</b>						
<b>Sediment</b>						
<b>Pollutant Source</b>	<b>Acres</b>	<b>Unit Area Loading Rate (lbs./ac./yr.)</b>		<b>Pollutant Loading (lbs./yr.)</b>		<b>% Reduction</b>
		<b>Current</b>	<b>Allowable</b>	<b>Current</b>	<b>Allowable (LA)</b>	
<b>HAY/PASTURE</b>	1,210.80	58.97	47.07	71,400.00	56,997.05	20%
<b>CROPLAND</b>	2,359.90	488.24	298.95	1,152,200.00	705,496.16	39%
<b>Stream Bank</b>	-	-	-	151,926.20	121,279.34	20%
<b>Total</b>				1,375,526.20	883,772.55	36%
<b>Total Phosphorus</b>						
<b>Pollutant Source</b>	<b>Acres</b>	<b>Unit Area Loading Rate (lbs./ac./yr.)</b>		<b>Pollutant Loading (lbs./yr.)</b>		<b>% Reduction</b>
		<b>Current</b>	<b>Allowable</b>	<b>Current</b>	<b>Allowable (LA)</b>	
<b>HAY/PASTURE</b>	1,210.80	0.26	0.17	309.60	205.07	34%
<b>CROPLAND</b>	2,359.90	0.89	0.22	2,097.20	517.26	75%
<b>Stream Bank</b>	-	-	-	88.42	58.57	34%
<b>Total</b>				2,495.22	780.90	69%

## VI. 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.

## VII. 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.

## **VIII. Recommendations for Implementation**

TMDLs represent an attempt to quantify the pollutant load that may be present in a waterbody and still ensure attainment and maintenance of water quality standards. The Little Cacoosing Creek TMDLs identify the necessary overall load reductions for those pollutants currently causing use impairments and distribute those reduction goals to the appropriate nonpoint sources. Reaching the reduction goals established by these TMDLs will only occur through changes in current land use practices, including the incorporation of more agricultural “best management practices” (BMPs). BMPs that would be helpful in lowering the amount of sediment and nutrients reaching Little Cacoosing Creek include stream bank fencing, riparian buffer strips, strip cropping, contour plowing, conservation crop rotation, and heavy use area protection, among many others.

The Natural Resources Conservation Service maintains a National Handbook of Conservation Practices (NHCP), which provides information on a variety of BMPs. The NHCP is available online at [http://www.ncg.nrcs.usda.gov/nhcp\\_2.html](http://www.ncg.nrcs.usda.gov/nhcp_2.html). Many of the practices described in the handbook could be used on agricultural lands in the Little Cacoosing Creek watershed to help limit siltation and nutrient impairments. Determining the most appropriate BMPs, where they should be installed, and actually putting them into practice, will require the development and implementation of a comprehensive watershed restoration plan. Development of any restoration plan will involve the gathering of site-specific information regarding current land uses and existing conservation practices. The required level of detail is outside the scope of this TMDL document and is an activity best accomplished at the local level. Successful implementation of the activities necessary to address current use impairments to Little Cacoosing Creek will require local citizens taking an active interest in the watershed and the enthusiastic cooperation of local landowners.

By developing TMDLs for the Little Cacoosing Creek watershed, the Department has set the stage for local citizens to design and implement restoration plans to correct current use impairments. The Department will support local efforts to develop and implement watershed restoration plans based on the reduction goals specified in the TMDLs. Interested parties should contact the appropriate Watershed Manager in the Department’s Southcentral Regional Office (717-705-4700) for information regarding technical and financial assistance currently available. Individuals and/or local watershed groups interested in “fixing” the identified problems in the Little Cacoosing Creek watershed are strongly encouraged to avail themselves of funding sources available through DEP and other state and federal agencies (e.g., Growing Greener or 319 Program). The Little Cacoosing Creek watershed is located within the boundaries of PA’s Coastal Zone Management Plan. Additional remediation funding may be available through NOAA’s Coastal Service Center (<http://www.csc.noaa.gov/>) and/or the Department’s Coastal Zone Management Program (<http://www.dep.state.pa.us/river/czmp.htm>).

## **IX. Public Participation**

A notice of availability for comments on the draft Little Cacoosing Creek watershed TMDLs was published in the PA Bulletin on August 10, 2002 and on the Department’s web page shortly thereafter. In addition, a public meeting was held on August 26, 2002 at the Berks County Agricultural Center in Leesport, PA to address any outstanding concerns regarding the draft TMDLs. A notice on the public meeting was published in the Lebanon Daily News newspaper on August 22, 2002. A 60-day period (ending on October 10, 2002) was provided for the submittal of comments. No comments were received during the 60-day comment period.

Notice of final TMDL approvals will be posted on the Department’s website.

## **Literature Cited**

Commonwealth of Pennsylvania. 2001. Pennsylvania Code. Title 25 Environmental Protection. Department of Environmental Protection. Chapter 93. Water Quality Standards. Harrisburg, PA.

Novotny, V. and H. Olem, 1994. Water Quality: Prevention, Identification, and Management of Diffuse Pollution. Van Nostrand Reinhold, New York.

Thomann, R.V. and J.A. Mueller, 1987. Principles of Surface Water Quality Modeling and Control. Harper & Row, New York.

## Appendix A - Information Sheet for Little Cacoosing Creek Watershed TMDLs

### ***What is being proposed?***

Total Maximum Daily Load (TMDL) plans have been developed to improve water quality in the Little Cacoosing Creek watershed.

### ***Who is proposing the plans? Why?***

The Pennsylvania Department of Environmental Protection (PADEP) is proposing to submit the plans to the U.S. Environmental Protection Agency (U.S. EPA) for review and approval as required by federal regulation. In 1995, U.S. EPA was sued for not developing TMDLs when Pennsylvania failed to do so. PADEP has entered into an agreement with U.S. EPA to develop TMDLs for certain specified waters over the next several years. These TMDLs have been developed in compliance with the state/U.S. EPA agreement.

### ***What is a TMDL?***

A TMDL sets a ceiling on the pollutant loads that can enter a waterbody so that it will meet water quality standards. The Clean Water Act requires states to list all waters that do not meet their water quality standards even after pollution controls required by law are in place. For these waters, the state must calculate how much of a substance can be put in the water without violating the standard, and then distribute that quantity to all sources of the pollutant on that water body. A TMDL plan includes waste load allocations for point sources, load allocations for nonpoint sources, and a margin of safety. The Clean Water Act requires states to submit their TMDLs to U.S. EPA for approval. Also, if a state does not develop the TMDL, the Clean Water Act states that U.S. EPA must do so.

### ***What is a water quality standard?***

The Clean Water Act sets a national minimum goal that all waters are to be “fishable” and “swimmable.” To support this goal, states must adopt water quality standards. Water quality standards are state regulations that have two components. The first component is a designated use, such as “warm water fishes” or “recreation.” States must assign a use, or several uses to each of their waters. The second component relates to the instream conditions necessary to protect the designated use(s). These conditions or “criteria” are physical, chemical, or biological characteristics such as temperature and minimum levels of dissolved oxygen, and maximum concentrations of toxic pollutants. It is the combination of the “designated use” and the “criteria” to support that use that make up a water quality standard. If any criteria are being exceeded, then the use is not being met and the water is said to be in violation of water quality standards.

### ***What is the purpose of the plans?***

Little Cacoosing Creek is impaired by excess siltation and nutrients. These TMDL plans include a calculation of sediment and nutrient loadings that will meet water quality objectives.

### ***Why was the Little Cacoosing Creek watershed selected for TMDL development?***

In 1996, Pa. DEP listed a portion of the Little Cacoosing Creek watershed under Section 303(d) of the federal Clean Water Act as impaired due to excess nutrient loading from agricultural activities. The watershed was re-surveyed in 2001 as part of the Department’s ongoing unassessed waters program. The entire Little Cacoosing Creek watershed was determined to be impaired due to siltation and nutrients emanating from agricultural activities.

### ***What pollutants do these TMDLs address?***

The proposed plans provide calculations of the stream’s total capacity to accept sediment and phosphorus. Based on an evaluation of the concentrations of nutrients in Little Cacoosing Creek, phosphorus is the cause of nutrient impairment to the stream. Sediment loading is being used to address siltation.

### ***Where do the pollutants come from?***

The sediment and nutrient related impairments in the Little Cacoosing Creek watershed come from nonpoint sources (NPS) of pollution, primarily overland runoff from agricultural land uses and stream bank erosion.

### ***How was the TMDL developed?***

PADEP used a reference watershed approach to estimate the necessary loading reduction of sediment and phosphorus that would be needed to restore a healthy aquatic community. 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, PADEP 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 load 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. The reference stream approach was used to set allowable loading rates in the affected watershed because neither Pennsylvania nor U.S. EPA has water quality criteria for sediment or phosphorus.

***How much pollution is too much?***

The allowable amount of pollution in a water body varies depending on several conditions. TMDLs are set to meet water quality standards at the critical flow condition. For a free flowing stream impacted by nonpoint source pollution loading of sediment and nutrients, the TMDL is expressed as an annual loading. This accounts for pollution contributions over all stream flow conditions. PADEP established the water quality objectives for sediment and phosphorus by using the reference watershed approach. This approach assumes that the impairment is eliminated when the impaired watershed achieves loadings similar to the reference watershed. Reducing the current loading rates for sediment and phosphorus in the impaired watershed to the current loading rates in the reference watershed will result in meeting the water quality objectives.

***How will the loading limits be met?***

Best Management Practices (BMPs) will be encouraged throughout the watershed to achieve the necessary load reductions.

***How can I get more information on the TMDL?***

To request a copy of the full report, contact Joseph P. Hepp at 717-705-4788 during the business hours of 8:00 a.m. to 3:00 p.m., Monday through Friday. One may also contact Mr. Hepp by mail at the Water Management Program, SCRO PADEP, 909 Elmerton Avenue Harrisburg, PA 17110 or by e-mail at [jhepp@state.pa.us](mailto:jhepp@state.pa.us).

***How can I comment on the proposal?***

You may provide e-mail or written comments postmarked no later than October 10, 2002 to the above addresses.

## Appendix B - AVGWLf Model Overview & GIS-Based Derivation of Input Data

TMDLs for the Little Cacoosing Creek watershed 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 transport capacities 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 losses 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 GWLF Users Manual, available from the Department's Bureau of Watershed Conservation, Division of Assessment and Standards.

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.

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 subsequently 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 weather stations around the state. The following table lists the statewide GIS data sets and provides an explanation of how they were used for development of the input files for the GWLF model.

<b>GIS Data Sets</b>	
<b>DATASET</b>	<b>DESCRIPTION</b>
<b>Censustr</b>	Coverage of Census data including information on individual homes septic systems. The attribute <i>usew_sept</i> includes data on conventional systems, and <i>sew_other</i> provides data on short-circuiting and other systems.
<b>County</b>	The County boundaries coverage lists data on conservation practices, which provides C and P values in the Universal Soil Loss Equation (USLE).
<b>Gwnback</b>	A grid of background concentrations of N in groundwater derived from water well sampling.
<b>Landuse5</b>	Grid of the MRLC that has been reclassified into five categories. This is used primarily as a background.
<b>Majored</b>	Coverage of major roads. Used for reconnaissance of a watershed.
<b>MCD</b>	Minor civil divisions (boroughs, townships and cities).
<b>Npdespts</b>	A coverage of permitted point discharges. Provides background information and cross check for the point source coverage.
<b>Padem</b>	100-meter digital elevation model. This used to calculate landslope and slope length.
<b>Palumrlc</b>	A satellite image derived land cover grid that is classified into 15 different landcover categories. This dataset provides landcover loading rate for the different categories in the model.
<b>Pasingle</b>	The 1:24,000 scale single line stream coverage of Pennsylvania. Provides a complete network of streams with coded stream segments.
<b>Physprov</b>	A shapefile of physiographic provinces. Attributes <i>rain_cool</i> and <i>rain_warm</i> are used to set recession coefficient
<b>Pointsrc</b>	Major point source discharges with permitted N and P loads.
<b>Refwater</b>	Shapefile of reference watersheds for which nutrient and sediment loads have been calculated.
<b>Soilphos</b>	A grid of soil phosphorous loads, which has been generated from soil sample data. Used to help set phosphorus and sediment values.
<b>Smallsheds</b>	A coverage of watersheds derived at 1:24,000 scale. This coverage is used with the stream network to delineate the desired level watershed.
<b>Statsgo</b>	A shapefile of generalized soil boundaries. The attribute <i>mu_k</i> sets the k factor in the USLE. The attribute <i>mu_awc</i> is the unsaturated available capacity., and the <i>muhsg_dom</i> is used with landuse cover to derive curve numbers.
<b>Strm305</b>	A coverage of stream water quality as reported in the Pennsylvania's 305(b) report. Current status of assessed streams.
<b>Surfgeol</b>	A shapefile of the surface geology used to compare watersheds of similar qualities.
<b>T9sheds</b>	Data derived from a DEP study conducted at PSU with N and P loads.
<b>Zipcode</b>	A coverage of animal densities. Attribute <i>aeu_acre</i> helps estimate N & P concentrations in runoff in agricultural lands and over manured areas.
<b>Weather Files</b>	Historical weather files for stations around Pennsylvania to simulate flow.

## Appendix C - AVGWLF Model Outputs for the Little Cacoosing Creek Watershed

Edit Nutrient File
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Runoff	Dis N mg/L	Dis P mg/L
HAY/PAST	2.9	0.2
CROPLAND	2.9	0.2
CONIF_FOR	0.19	0.006
MIXED_FOR	0.19	0.006
DECID_FOR	0.19	0.006
TRANSITION	2.9	0.2

<b>Manure</b>	2.44	0.38
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Washoff	N kg/ha/d	P kg/ha/d
LO_INT_DEV	0.012	0.0016
HI_INT_DEV	0.101	0.0112

Point source and septic system nitrogen and phosphorus

Month	Pt Src N Kg	Pt Src P Kg	Norm Sys	Pond Sys	Short Circ Sys	Discharge Sys
APR	0	0	370	0	7	0
MAY	0	0	370	0	7	0
JUN	0	0	370	0	7	0
JUL	0	0	370	0	7	0
AUG	0	0	370	0	7	0
SEP	0	0	370	0	7	0
OCT	0	0	370	0	7	0
NOV	0	0	370	0	7	0
DEC	0	0	370	0	7	0
JAN	0	0	370	0	7	0
FEB	0	0	370	0	7	0
MAR	0	0	370	0	7	0

Per capita tank effluent (g/d)

N	12
P	2.5

Growing season (g/d)

N Uptake	1.6
P Uptake	0.4

Sediment (mg/kg)

N	3000
P	1164

Groundwater (mg/l)

N	3.36282
P	0.0582312

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- ERRI
- AVGWLF\_40
- Userdata
- LiCacoosingCr

inutredit1.dat

Load Nutrient File
Save Changes
Close

Edit Transport File
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Rural LU	Area (ha)	CN	K	LS	C	P
HAY/PAST	490	75	0.30595	0.3383	0.03	0.45
CROPLAND	955	82	0.31204	0.33915	0.21	0.52
CONIF_FOR	44	73	0.31454	0.25873	0.002	0.45
MIXED_FOR	70	60	0.31542	0.46781	0.002	0.45
DECID_FOR	400	60	0.3128	1.72997	0.002	0.52
TRANSITION	1	82	0.32	0.16324	0.8	0.8

Urban LU	Area (ha)	CN	K	LS	C	P
LO_INT_DEV	36	83	0.32	0.08843	0.08	0.2
HI_INT_DEV	12	93	0.32	0.05131	0.08	0.2

Month	Ket	Day Hrs	Season	Eros Coef
APR	0.5411	13	0	0.301
MAY	0.8275	14	1	0.301
JUN	0.9935	15	1	0.301
JUL	1.0899	15	1	0.301
AUG	1.1457	14	1	0.301
SEP	1.1781	12	1	0.120
OCT	0.9179	11	0	0.120
NOV	0.7670	10	0	0.120
DEC	0.6795	9	0	0.120
JAN	0.4692	9	0	0.120
FEB	0.5067	10	0	0.120
MAR	0.5285	12	0	0.120

Antecedent Moisture Condition

Day -1	Day -2	Day -3	Day -4	Day -5
0	0	0	0	0

c: [Hard Drive]

- AVGWLF\_40
- Userdata
- LiCacoosingCr

transeedit1.dat

Load Transport File
Save Changes
Close

Init Unsat Stor (cm)	10	Initial Snow (cm)	0
Init Sat Stor (cm)	0	Sed Del Ratio	0.172
Recess Coef (l/day)	0.10052	Sed LE Rate	6.909E-05
Seepage Coef (l/day)	0	Unsat Avail Wat (cm)	23.4862

## GWLF Nutrient Summary for LtCacoosing\_Mar25\_02

Period of analysis: 20 years, from Apr 1978 to Mar 1998

Month	Tons		Nutrient Loads (Pounds)			
	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos.
APR	475.06	16.59	11544.67	11680.11	238.28	290.81
MAY	662.41	23.38	8503.29	8674.47	225.34	291.73
JUN	433.51	17.98	4022.69	4150.82	98.87	148.58
JUL	666.83	35.40	1772.22	1994.56	96.04	182.29
AUG	419.30	15.39	435.59	533.07	23.34	61.15
SEP	236.50	46.72	649.97	934.82	45.05	155.55
OCT	194.71	41.07	1087.02	1338.97	54.09	151.84
NOV	201.26	71.81	2262.55	2703.21	90.74	261.70
DEC	129.72	76.48	6019.37	6499.78	204.11	390.50
JAN	65.61	90.06	6217.64	6780.71	254.79	473.26
FEB	48.65	102.22	8145.54	8786.10	289.01	537.54
MAR	111.79	89.89	11816.58	12390.92	246.13	468.98
<b>Total</b>	<b>3645.34</b>	<b>627.00</b>	<b>62477.14</b>	<b>66467.54</b>	<b>1865.78</b>	<b>3413.92</b>

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Loads by Source

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## GWLF Transport Summary for LtCacoosing\_Mar2!

Period of analysis: 20 years, from Apr 1978 to Mar 1998

Month	Units in Inches				
	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
APR	3.76	1.02	2.61	0.34	2.94
MAY	4.70	2.65	1.93	0.26	2.20
JUN	3.63	4.69	0.94	0.10	1.03
JUL	4.55	6.15	0.32	0.20	0.52
AUG	3.33	5.15	0.04	0.10	0.14
SEP	3.45	2.77	0.00	0.22	0.23
OCT	3.20	1.39	0.10	0.23	0.33
NOV	3.69	0.63	0.32	0.35	0.66
DEC	2.99	0.24	1.32	0.31	1.63
JAN	3.14	0.10	1.27	0.45	1.73
FEB	2.65	0.16	1.74	0.46	2.21
MAR	3.30	0.54	2.66	0.35	3.01
<b>Total</b>	<b>42.41</b>	<b>25.49</b>	<b>13.26</b>	<b>3.38</b>	<b>16.63</b>

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## GWLF Nutrient Summary for UpperCacoosing\_Ref\_Mar25

Period of analysis: 20 years, from Apr 1978 to Mar 1998

Month	Tons		Nutrient Loads (Pounds)			
	Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos
APR	329.63	7.16	8336.61	8441.15	176.87	204.10
MAY	493.50	16.72	6570.30	6732.46	150.51	193.27
JUN	378.27	12.85	3231.93	3351.36	75.30	107.01
JUL	558.49	38.81	1256.44	1528.71	49.39	122.81
AUG	406.28	29.67	342.33	544.97	19.39	74.17
SEP	209.31	37.16	306.46	545.85	21.51	88.10
OCT	151.98	43.48	917.22	1194.24	34.78	112.69
NOV	154.77	60.40	2704.25	3090.83	76.06	185.20
DEC	112.38	55.24	5455.11	5826.28	156.88	261.89
JAN	44.91	69.94	5229.04	5682.23	168.11	297.19
FEB	37.52	50.74	6741.18	7084.94	180.30	278.27
MAR	87.97	72.97	8777.61	9265.93	184.02	322.95
<b>Total</b>	<b>2965.01</b>	<b>495.16</b>	<b>49868.49</b>	<b>53288.93</b>	<b>1293.10</b>	<b>2247.66</b>

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## GWLF Transport Summary for UpperCacoosing\_R

Period of analysis: 20 years, from Apr 1978 to Mar 1998

Month	Units in Inches				
	Precip	Evapotrans	Gr. Wat. Flow	Runoff	Streamflow
APR	3.46	0.83	2.75	0.23	2.98
MAY	4.69	2.49	2.19	0.17	2.35
JUN	3.81	4.56	1.08	0.09	1.18
JUL	4.64	6.10	0.37	0.16	0.54
AUG	3.54	5.10	0.04	0.16	0.19
SEP	3.74	2.78	0.00	0.20	0.20
OCT	3.41	1.33	0.21	0.21	0.42
NOV	3.70	0.59	0.78	0.29	1.07
DEC	3.12	0.22	1.78	0.27	2.06
JAN	3.23	0.09	1.64	0.36	2.00
FEB	2.71	0.13	2.20	0.28	2.48
MAR	3.46	0.44	2.90	0.23	3.13
<b>Total</b>	<b>43.51</b>	<b>24.66</b>	<b>15.95</b>	<b>2.66</b>	<b>18.61</b>

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Loads by Month

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## GWLF Total Loads for UpperCacoosing\_Ref\_Mar25\_0

Period of analysis: 20 years, from Apr 1978 to Mar 1998

Source	(Acres) Area	(in) Runoff	(Tons)		Total Loads (Pounds)			
			Erosion	Sediment	Dis. Nitr.	Tot. Nitr.	Dis. Phos.	Tot. Phos.
HAY/PAST	877.2	1.28	208.64	34.84	681.31	890.37	73.65	133.37
CROPLAND	1532.1	3.17	2400.33	400.85	2933.17	5338.29	320.82	1007.89
CONIF_FOR	197.7	1.01	3.78	0.63	8.56	12.34	0.27	1.35
MIXED_FOR	249.6	1.01	4.90	0.82	10.80	15.71	0.34	1.74
DECID_FOR	2337.6	1.01	273.30	45.64	101.17	375.02	3.19	81.42
LO_INT_DEV	326.2	5.75	36.45	6.09	0.00	8.03	0.00	1.07
HI_INT_DEV	355.8	13.91	37.61	6.28	0.00	122.05	0.00	13.53
<b>Stream Bank</b>				106.48		319.43		91.25
<b>Groundwater</b>					41617.52	41617.52	874.17	874.17
<b>Point Sources</b>					0.00	0.00	0.00	0.00
<b>Septic Syst.</b>					4515.96	4515.96	20.66	20.66
<b>Totals</b>	<b>5876.2</b>	<b>2.70</b>	<b>2965.0</b>	<b>601.7</b>	<b>49868.49</b>	<b>53214.71</b>	<b>1293.10</b>	<b>2226.46</b>

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Microsoft Excel - LtCacoosing\_Mar25\_02-sum.xls

File Edit View Insert Format Tools Data Window Help

K49 =

	A	B	C	D	E	F	G	H	I	J	K	L
17												
18		<b>Source</b>	<b>Area (ac)</b>	<b>Runoff</b>	<b>Erosion</b>	<b>Sed (tons)</b>	<b>Sed (lbs)</b>	<b>Dis N</b>	<b>Tot N (lbs)</b>	<b>Dis P</b>	<b>Tot P (lbs)</b>	
19		HAY/PAST	877.20	1.28	208.64	34.80	69,600.00	681.30	890.40	73.60	133.40	
20		CROPLAND	1,532.10	3.17	2,400.33	400.90	801,800.00	2,933.20	5,338.30	320.80	1,007.90	
21		CONIF_FOR	197.70	1.01	3.78	0.60	1,200.00	8.60	12.30	0.30	1.40	
22		MIXED_FOR	249.60	1.01	4.90	0.80	1,600.00	10.80	15.70	0.30	1.70	
23		DECID_FOR	2,337.60	1.01	273.30	45.60	91,200.00	101.20	375.00	3.20	81.40	
24		LO_INT_DEV	326.20	5.75	36.45	6.10	12,200.00	-	8.00	-	1.10	
25		HI_INT_DEV	355.80	13.91	37.61	6.30	12,600.00	-	122.00	-	13.50	
26		Stream Bank	-	-	-	106.48	212,956.40	-	319.43	-	91.25	
27		Groundwater	-	-	-	-	-	41,617.50	41,617.50	874.20	874.20	
28		Point Source	-	-	-	-	-	-	-	-	-	
29		Septic Systems	-	-	-	-	-	4,516.00	4,516.00	20.70	20.70	
30		<b>Totals</b>	<b>5,876.20</b>	<b>27.14</b>	<b>2,965.01</b>	<b>601.58</b>	<b>1,203,156.40</b>	<b>49,868.60</b>	<b>53,214.63</b>	<b>1,293.10</b>	<b>2,226.55</b>	
31												
32			<b>Unit area Loading (lbs/ac/yr)</b>									
33		<b>Land Use</b>	<b>Sed</b>	<b>Tot N</b>	<b>Tot P</b>							
34		HAY/PAST	79.34	1.02	0.15							
35		CROPLAND	523.33	3.48	0.66							
36		CONIF_FOR	6.07	0.06	0.01							
37		MIXED_FOR	6.41	0.06	0.01							
38		DECID_FOR	39.01	0.16	0.03							
39		LO_INT_DEV	37.40	0.02	0.00							
40		HI_INT_DEV	35.41	0.34	0.04							
41		<b>Totals</b>	<b>204.75</b>	<b>9.06</b>	<b>0.38</b>							
42												

## Appendix E - Equal Marginal Percent Reduction Method

The Equal Marginal Percent Reduction (EMPR) allocation method was used to distribute Adjusted Load Allocations (ALAs) between the appropriate contributing nonpoint sources. The load allocation and EMPR procedures were performed using MS Excel and results are presented in [Appendix F](#). 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, Margin of Safety, 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 of 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 % reduction for each pollutant source.

## Appendix F - Equal Marginal Percent Reduction Calculations for Little Cacoosing Creek

Microsoft Excel - LtCacoosing_Mar25_02-sum.xls													
File Edit View Insert Format Tools Data Window Help													
H3 = =L5-L6													
A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	<b>Sediment</b>												
2	<b>Step 1:</b>	<b>TMDL Total Load</b>			<b>Step 2:</b>	<b>Adjusted LA = (TMDL total load - MOS) - uncontrollable</b>							
3		Load = Sediment loading rate in ref. * Acres				883,772.55	883,772.55						
4		1,015,969.50									MOS =	101,596.95	
5											LA =	914,372.55	
6											LNR =	30,600.00	
7													
8	<b>Step 3:</b>	Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction	
9		Hay/Past.	71,400.00	1,375,526.20	good	71,400.00	ADJUST	0.06	14,402.95	56,997.05	1,210.80	47.07	20%
10		Cropland	1,152,200.00		bad	883,772.55	223,326.20	0.80	178,276.39	705,496.16	2,359.90	298.95	39%
11		Stream Bank	151,926.20		good	151,926.20		0.14	30,646.86	121,279.34	-	-	20%
12						1,107,098.75		1.00		883,772.55			
13													
14	<b>Step 4:</b>	All Ag. Loading Rate											
15			213.54										
16													
17	<b>Step 5:</b>	Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.						
18		Final Hay/Past. LA	1,210.80	47.07	56,997.05	58.97	71,400.00	20%					
19		Final Cropland LA	2,359.90	298.95	705,496.16	488.24	1,152,200.00	39%					
20		Stream Bank	-	-	121,279.34	-	151,926.20	20%					
21													
22		<b>Total</b>	<b>3,570.70</b>		<b>883,772.55</b>		<b>1,375,526.20</b>	<b>36%</b>					
23													
24													
25													

Microsoft Excel - LtCacoosing_Mar25_02-sum.xls													
File Edit View Insert Format Tools Data Window Help													
H4 = =K6-K7													
A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	<b>Total Phosphorus</b>												
2													
3	<b>Step 1: TMDL Total Load</b>				<b>Step 2:</b>				<b>Adjusted LA = (TMDL total load - MOS) - uncontrollable</b>				
4	Load = TP loading rate in ref. * Acres in Impaired				780.90				780.90				
5	1,885.56								MOS = 188.56				
6									LA = 1,697.00				
7									LNR= 916.10				
8													
9	<b>Step 3:</b>	Annual Average Load	Load Sum	Check	Initial Adjust	Recheck	% reduction allocation	Load Reduction	Initial LA	Acres	Allowable Loading Rate	% Reduction	
10		Hay/Past.	309.60	2,406.80	good	309.60	ADJUST	0.26	104.53	205.07	1,210.80	0.17	34%
11		Cropland	2,097.20		bad	780.90	398.02	0.66	263.64	517.26	2,359.90	0.22	75%
12		Stream Bank	88.42		good	88.42		0.08	29.85	58.57	-	-	34%
13					1,178.93			1.00	398.02	780.90			
14													
15													
16	<b>Step 4:</b>	All Ag. Loading Rate	0.20										
17													
18													
19	<b>Step 5:</b>	Acres	Allowable (Target) Loading Rate	Final LA	Current Loading Rates	Current Load	% Red.						
20		Final Hay/Past. LA	1,210.80	0.17	205.07	0.26	309.60	34%					
21		Final Cropland LA	2,359.90	0.22	517.26	0.89	2,097.20	75%					
22		Stream Bank	-	-	58.57	-	88.42	34%					
23					780.90		2,495.22	69%					
24													
25													
26													