Pond Creek Watershed Nonpoint Source Pollution Inventory and Pollutant Load Estimates

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List of Acronyms

BMP	Best Management Practice
EPA	Environmental Protection Agency
GIS	Geographic Information System
IPSI	Integrated Pollution Source Inventory
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Services
RUSLE	Revised Universal Soil Loss Equation
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment and Conservation
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Sediment
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation

Nonpoint Source Inventory

The nonpoint source (NPS) inventory is based upon a geographic and numeric database originally developed by the Tennessee Valley Authority (TVA) that consists of information on local watershed features such as land use/land cover, streambank erosion sites, and livestock operations that are known or suspected to be nonpoint pollution sources. Values of acreage and land management practices are applied to characterize nonpoint sources of pollution, and the impact which they have. The results of this analysis are meant to identify and estimate sources of pollution so as they can be addressed in supporting documents.

1.0 Methods

These databases are originally derived from remote sensing techniques used to acquire and interpret aerial photography and develop the NPS inventory and atlas. The structure of the GIS database and assumptions and equations used in the pollutant loading model are described below.

1.1 Aerial photography acquisition

The NPS inventory was based on color infrared aerial photography taken in March 2002, with flight plan parameters determined by analysis of project requirements. The photography scale was 1:24,000, and the exposures were overlapping to enable the interpreter to use stereoscopes to view the landscape in three dimensions, i.e. binocular parallax. The film type or emulsion was color infrared. The makeup of color infrared film is unique in that one of the three layers of the film's emulsion is sensitive to the near infrared portion of the light spectrum. Healthy plant chlorophyll is highly reflective in the near infrared and this characteristic allows the interpreter to make inferences about vigor and type of vegetation not always possible with color or black and white film.

These photographic data were digitized into a GIS database that consists of information on watershed features such as land use, streambank and roadbank erosion sites, crop, pasture and forest lands, and livestock operations that are known or suspected to be nonpoint pollution sources. The desktop GIS uses ArcView software for managing and viewing the data generated by the NPS inventory. This combination of tools allows the user to investigate relationships among various geographic and/or land use features. This methodology also serves as a working verification as each image layer is related and must coincide with others.

A significant component of a NPS inventory is accurate knowledge of the natural and cultural characteristics of the study area. This knowledge can be used to confirm, or in some cases override, the aerial photography and GIS model, especially as land uses change with time. Whenever possible, the photographic interpretations offered for the study area were referenced with site visits throughout the restoration process. These visits also provided observations of the relationships of terrain, land use, and stream network.

1.2 Land use classification

The Pond Creek watershed study area was divided into unique polygons based on land use characteristics, as interpreted from aerial photography. Each polygon was assigned a land use code, after Anderson and colleagues (1971), as described in Table 1.1. Land use classes were grouped into eight major headings of Residential, Commercial and Industrial, Agriculture Cropland, Pasture, Forest Lands, Open Water, Mined and Disturbed Lands, and Wetlands.

Table 1.1. Land use classification and code scheme used in NPS Inventory analysis of Pond Creek watershed. Land use polygons were classified after Anderson et al. 1971.

Residential
- 11. Residential
- 1111 and 1121. Residential-under-construction

Commercial / Industrial
- 12. Commercial, Service
- 13. Industrial
- 14. Transportation, Communication, Utility (Right-of-Way)

Row Crops
- 2101. Low Residue (0 to 10%)
- 2102. High Residue (> 30%)
- 2103. Strip Crop
- 2104. Medium Residue (10 to 30%)

Pasture
- 212. Good pasture (well maintained)
- 213. Fair Pasture (uneven growth and condition; minimal maintenance
- 215. Heavily Overgrazed Pasture
- 216. Poor Pasture (sparse cover, shallow soils, steep slopes)
- 217. Feedlot and Loafing Area

Forest
- 22. Orchard (Sod Farm)
- 32. Shrub and Scrub (Old Field with volunteer woody growth)
- 4. Forest Land
- 45. Harvested Forest Land

Water
- 5. Open Water

Mine / Disturbed
- 75. Mines, Quarries and Borrow Areas
- 76. Disturbed Areas (little or no cover, non-agriculture land)

Wetland
- P. Palustrine Wetland

Urban land classes

Pond Creek watershed is primarily an agriculture land area, with minimal urban land use. The major urban land use is in the form of single family residential units. These units are distributed throughout the watershed at a low density of generally less than 2 units per acre. Estimates of residential numbers and densities could be formulated by population numbers and US Census data (Table 1.2) that were later georeferenced with aerial photography and ground verification.

Table 1.2. Population statistics for Pond Creek watershed from 2000 US Census data.

County	2000 Population	County Area (ac)	Portion of land in watershed (%)	Appx. Area in watershed (ac)	Appx Density (persons/ac)	Appx. Population in watershed
Loudon	39086	146560	7.52	11021	0.067	738
Monroe	38961	422400	1.82	7688	0.095	730
McMinn	49015	276600	1.76	4868	0.095	462
total				23577		1931

Conflicting population values have been estimated for the study area. Table 1.2 estimates 1931 people in the watershed, and is based on land proportions and population density data accessed from the 2000 US Census. Considering the significant accuracy of approximated area of the watershed via this method, we believe the approximate population to be close to accurate as well. Tennessee Department of Environment and Conservation (TDEC 2005) estimates Pond Creek watershed population at 3382 utilizing an EPA-developed GIS-based program and 1997 county census data. Using data from Emergency Medical Services, a household estimate of 600 was projected. Using estimates from Table 1.2, this translates to 3.2 persons per household, which appears likely for the area. In summary, an accurate population count for the study area has not been obtained, and the inherent difficulty associated with a count occludes any such success. As useful as an accurate count may be in implementing the goals and objectives of watershed restoration, such an effort is beyond the scope of this document.

On-site septic systems

Stressed on-site septic systems can contribute contaminants to surface water through overland flow, particularly when saturated soil conditions exist. Aerial photography interpretation identified and employed specific signatures associated with on-site septic systems to accurately assess suspect wastewater systems. The four conditions identified are listed in Table 1.3. These conditions likely indicate a stressed or potentially stressed system.

Table 1.3. Septic system classification for use in NPS inventory for Pond Creek watershed.

Condition	Observation(s)	Description / Implication
1	Distinctive moisture pattern	Effluent plume from visible drain field pattern, or prominent ponding downslope from drain field.
2	Suspicious moisture pattern	Visible plume pattern, but no drain field apparent; can be straight-pipe from septic system, roof drainage, or natural seepage / spring
3	Distinctive drain field	Visible drain field pattern, but no plume evident; may indicate slow leaching, but no apparent breakout of a seasonally or hydraulically stressed system.
4	Suspect location	No plume or drain field visible; home sites on very steep slopes, small lots, visible rock outcrops, or in close proximity to streams or reservoirs, especially those on heavily-wooded lots.

Roads, roadbanks and streambanks

Base information for road coverage was obtained from standard 1:24,000 USGS topographic maps. The road network was updated to the date of the photography (March 2003). Road conditions interpreted for the NPS inventory were surface type and significant erosion features associated with the road. Road surfaces were classified as either paved (impervious) or unpaved. Unpaved roads include all classes of unpaved surfaces from well-maintained gravel roads to off-road vehicle trails. Significant erosion features associated with roads include eroding cuts and fills, eroding road banks, and eroding roadside ditches.

Impervious surfaces include roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape. Imperviousness is defined as the percentage of total area of the mapped unit covered by impervious surfaces. A percent imperviousness, excluding paved roads, was assigned to each land use/land cover polygon based on interpretation of the photography. For example, a low-density residential area might have a percent imperviousness of 25%, based on the estimated coverage of structures, driveways, and sidewalks. The percentage of area covered by paved roads was calculated from the roads' coverage layer in the database. Percent imperviousness for each watershed was calculated by multiplying the imperviousness for each polygon by the area for each polygon. The products for each polygon were then summed and divided by the total watershed area.

The stream network was based on the blueline streams from the 7.5 minute USGS maps. The streams were entered into the GIS either by loading USGS Digital Line Graphics (DLG) or by digitizing the stream network from the maps. This base level of streams was then enhanced based on photo interpretation. Near infrared wavelengths are absorbed by water, resulting in clear waterbodies appearing black in photographs.

Riparian condition in the NPS inventory is a characterization of the land cover buffer adjacent to a stream. Benefits of a well-managed riparian buffer include reducing stream bank erosion; filtering nutrients, soil, and pesticides from runoff; providing food and habitat for stream life; and contributing to the microclimate within the waterway by providing shade. The riparian conditions in the present inventory are mapped in two categories of 1) riparian areas dominated by woody vegetation, and 2) riparian area lacking woody vegetation. Category 2 includes stream segments adjacent to grass, bare ground, or urban land cover.

The following riparian buffer features were mapped for both the left and right (looking downstream) banks of perennial streams:

- Vegetative type identified as either woody, grass, or bare.
- Percent of coverage coded as 0 to 33%, 34 to 66%, or 67 to 100% for woody vegetation.
- Grass cover quality rated as poor, moderate, or good.
- Width of vegetation coded as 1 to 25 feet, 26 to 100 feet, or greater than 100 feet.

A riparian buffer classification matrix was used to rate the ability of the riparian buffer to filter runoff before entering the stream (Table 1.4). The assumption is that the quality and extent of the buffer zone has a direct relationship to the potential ecological health and water quality of a stream by reducing nonpoint source pollutants entering the stream. The riparian buffer was rated as adequate, marginal, or inadequate with regard to the ability to remove pollutants.

Table 1.4. Riparian buffer classification for woody and non-woody vegetation within Pond Creek watershed.

Woody Vegetation			
Width / Cover	0 to 33 %	34 to 66 %	67 to 100%
0 to 25 ft	Inadequate	Marginal	Marginal
26 to 100 ft	Marginal	Marginal	Adequate
Over 100 ft	Marginal	Adequate	Adequate

Non-Woody Vegetation			
Width / Cover	Poor Quality	Moderate Quality	Good Quality
0 to 25 ft	Inadequate	Marginal	Marginal
26 to 100 ft	Inadequate	Marginal	Adequate
Over 100 ft	Inadequate	Adequate	Adequate

Crop, pasture, forest, mining and disturbed lands

Two major applications of remote sensing in agriculture are the identification and inventory of specific land use patterns. Color infrared photography allows quantification of land reflectivity that permits discrimination of vegetation types. For plant foliage, visible (400-750 nm wavelengths) and near infrared (750-2500 nm) absorbance (or conversely reflectance) spectra are the product of complex patterns of scattering and absorption by numerous structural and biochemical components. Characteristics of leaf reflectance spectra are determined by the surface properties of the leaf, as well as internal structure and biochemical components. One example of this is the distinctive ‘‘red edge’’ which occurs as a sharp increase in reflectance around 700 nm. The red edge exists because of the strong chlorophyll-a absorption band around 670– 680 nm, coupled with scattering of near-infrared reflectance within the leaf, which causes large reflectance above 700 nm.

Leaf reflectance at visible and near-infrared wavelengths is related primarily to pigmentation, leaf structure and water content, and is an important tool for studying stress physiology and relationships between plants and their growth environment. The amount of radiation absorbed by a leaf is largely a function of the foliar concentrations of photosynthetic pigments, which are generally dependent on available nitrogen. As such, the information content of a sample reflectance spectrum is very high, because it provides a concise and rich snapshot of the overall biochemical composition of vegetation.

Color infrared photography was used to distinguish between and among agriculture lands. Healthy chlorophyll appears deep red using color infrared photography and abnormal chlorophyll appears a lighter shade of red to white. The spongy mesophyll tissue of a healthy leaf, which is turgid, distended by water, and full of air spaces, is a very efficient reflector of any radiant energy and therefore of the near-infrared wavelengths (Knipling 1970).

Livestock operations

Livestock activity and density are important factors for structuring vegetation in silvopastoral systems. Livestock may influence vegetation through forage removal, manure deposition and trampling. These three activities have different impacts on the land, creating fine-scale mosaics within the landscape. The spatial pattern of foraging locations depends on herbage quality and quantity, water availability, relief, slope, natural and artificial barriers, herd social interactions, prior experience and climate. The spatial distribution of feces deposition is also not uniform and concentrations are often higher in areas near water sources, along gates or fences, and in shade areas (Davies-Colley et al. 2004). Trampling distribution depends not only on the number and pressure of foot steps in an area, but also on the sensitivity of the area.

The spatial patterns of grazing, dunging and trampling are not congruent and as such, efforts were made to account for fine-scale patterns within the landscape. Livestock operations were mapped by interpretation of facilities and their associations with features such as soil compaction, soil staining, soil moisture content, size and presence of barns and other structures, presence of hay bales, animal trails, water sources, fencing, and feedlots. These relationships and associated land cover were used to determine the relative size and type of livestock operation. The type of operation was identified by clues such as exercise rings for horse operations, silos and loafing areas for dairies, and large open pastures for beef cattle operations.

Aerial photographs dated from March 2002 were referenced with on-site visits throughout the restoration process. Field verification included number of animals per site size, identified as small, medium, or large based on animal population. These sites were further delineated by their proximity to the intermittent and perennial stream, classified as adjacent or nonadjacent to the stream.

Wildlife populations

Wildlife inputs typically represent natural background sources of pollutants, although they can be important in rural watersheds. Wildlife sources are often uncontrollable, however it is important to consider their potential impact on water quality and their loading relative to other sources. As with livestock, wildlife deposit pathogens and nutrients with their feces onto the land, where it can be transported during a rainfall runoff event to nearby streams. In the watershed model applied, the wildlife pollutant contribution is accounted for solely in the deer population, as population estimates of raccoons, waterfowl, and other wildlife are not readily available. Additionally, fecal contributions from most transitory wildlife and birds can rarely be properly monitored or controlled without significant on-the-ground BMP installation.

The Tennessee Wildlife Resources Agency (TWRA) estimates the deer population to be 23 animals per 640 acres in this area. It is assumed that the wildlife population remains constant throughout the year, and is uniformly distributed on all land uses classified in the NPS inventory as forest, cropland, and wetlands. Pasture lands are excluded as most of these lands house livestock and/or are fenced.

1.3 Soil loss estimates

Soil loss was calculated for selected land use classes and other high-impact erosion features identified in the inventory. The amount of soil loss estimated was the total potential soil movement for the feature via detachment, transport and deposition. For example, the soil loss for a particular agricultural field was an estimate of the amount of soil movement on the field, in tons per acre per year, based on the Revised Universal Soil Los Equation, or RUSLE (Renard et al. 1997), originally developed by Wischmeier and Smith (1978). The soil loss from unpaved roads was calculated by estimating an average erosion rate and assuming an average road width.

In the United States, RUSLE is a reliable and accepted methodology for estimating soil loss erosion rates, and is required for assistance through conservation programs of the Federal Agriculture Improvement and Reform Act of 1996. Original coefficients from the RUSLE specific to the ecoregion were applied to the current model although several revisions to the equation have been developed, e.g. RUSLE 1.04 and RUSLE2. Such values were used as they are 1) easily recognizable in all regions, 2) easily defended due to their application use and history, and 3) they are easily accessible to users irrespective of location or condition. If the present pollutant loading model is to be justified and made available universally, the tools to import into the model must be made available.

The average soil loss computed by RUSLE is both a temporal (annual) and spatial (generally greater than 1 acre) average for a given field, based on the variability of both the landscape and soil types within it. On sites with considerable spatial variability, modelers exercised judgment in selecting values for individual parameters in the RUSLE algorithm. Accommodating field variability was best resolved by identifying land sub-units for separate analyses. This was done for Pond Creek watershed by identifying 19 subwatersheds delineated by source streams, which vary in area from 59 to 2433 acres (Figure 2.1). These individualized sub-units are still considered complex fields with multiple landscape features, so RUSLE users identified separate factors to compute soil loss within the area and then developed a weighted average for the entire subwatershed.

The overall aim of the present document is to quantify relative differences in pollutant loads pre- and post-BMP implementation. By applying basic coefficients to the default model, one may easily compare the two output values. As elevation, soil types and soil textures do not vary considerably within a sub-unit, the applied average factor is suitable for the purpose of the present management plan. Thus, in addition to the validations listed above, the utility of standard RUSLE values as imports into the model for simple identification of differences, justifies the application.

1.4 Pollution loading model

Biogeochemical models have increasingly been used to quantify and track local and regional nutrient budgets in order to determine whether specific areas are sources or sinks for certain nutrients. These local assessments, such as those of individual agricultural fields or a forest stand, significantly contribute to the comprehension of ecosystem function by further qualifying nutrient cycling. The objectives of this section were to develop a model that would simulate nitrogen, phosphorus and sediment budgets on Pond Creek watershed, and also evaluate the model in terms of specific land covers and/or land use practices

In general, the wash-off of pollutants from a land area towards another land area, or a waterway is a loading factor. Techniques to estimate pollutant loading include generalized relationships to hydrology and soil and sediment movement. A pollutant loading model was developed to estimate annual NPS pollutant loads of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) based on the NPS inventory. TP is currently not a listed pollutant priority as defined by TDEC (2004a), however documented sample data are in excess of target values and we include TP loading estimates as a proactive measure. The model can be used to estimate pollutant loads for TSS, TN, and TP from the following sources: residential, commercial, industrial, transportation, cropland, pasture, forests, beef cattle, dairy cattle, swine, horses, and poultry.

Pond Creek watershed is currently classified as not fully supporting all of its listed uses due to high pathogen levels; although these annual pollution loads are inherently difficult to estimate for large areas. A strong correlation exists between pathogens and quantifiable pollutants (nutrients) in this watershed. Additional work suggests that river TN loads are strongly related to river TSS loads (Ittekot and Zhang 1989, Ludwig and Probst 1996), and it is reasonable to infer that river TP loads would also scale with TSS loads. Thus, the present pollutant loading model will be used as a proxy for flux estimates of pathogens within the study area. Since sediment has been recognized as a major nonpoint source problem for many years, several standards have been established for erosion on croplands. These standards are based on the loss of a soil resource rather than any downstream environmental impact. Many of these accepted formulaic standards, including the RUSLE, were used to estimate pollution loading. From these load estimates and published water quality sample data, we can then estimate pathogen levels.

The model uses a Microsoft Excel (Microsoft Corp. Redman, WA) workbook to perform the calculations and display the results in tabular and graphical form. The workbook consists of sheets for the land use inventory, RUSLE factors, other loading parameters (defined in subsequent headings below), and a calculation sheet for each loading parameter, accompanied by graphs to display results. These parameters were developed as discussed below. Treatment scenarios can be explored by changing model parameters in the original model and viewing the changes in the linked graphs and tables. These models can also be used to demonstrate the effect of potential nonpoint source management strategies on pollutant loads.

Several water quality models estimate nonpoint water pollution into watersheds based on the input of either event mean concentrations (especially for urban areas) or export coefficients (notably for rural and agriculture areas). Event mean concentrations represent the concentration of a specific pollutant contained in runoff originating from a particular land use, reported as mass per unit volume of water (usually mg/L). Export coefficients represent the average total amount of pollutant loaded annually into a system from a defined area, reported as mass per unit area per year.

Due to the specific climatological and physiographic characteristics of individual watersheds, regional and local agricultural and urban land uses can exhibit a wide range of variability in nutrient export (Omernik 1977, Reckhow et al. 1980). Site-specific values of both input types are unavailable for the current project, as this is a relatively novice approach to local watershed-scale pollutant modeling. As such, there remain some reservations as to the applicability of employing export coefficients or event mean concentrations for different land uses developed from region to region. The coefficients included in this analysis were all screened using certain acceptance criteria, based on the accuracy, precision, local representativeness, and spatial and temporal extent of data sampling.

Not all data described in the Methods and Summary Section were used in the model. Population statistics, onsite waste system information and riparian buffer information were intended to support management activities, but were not used in the loading model.

Loads from urban land classes

Pollutant loads from urban land uses (residential, subdivisions under construction, commercial, industrial, and transportation) were estimated using a method described by the EPA (EPA 1990) using the following equation:

$$M = RainV \times Rv \times Area \times Conc \times 0.0001135 \qquad \text{Equation (1)}$$

Where:

M	=	mass load (tons)
RainV	=	average annual rainfall (inches)
Rv	=	runoff coefficient (unitless)
Area	=	drainage area (acres), derived from the inventory
Conc	=	average runoff concentration (mg/L)
0.0001135	=	unit conversion factor

The areas used for each land class were generated by the NPS inventory. Annual rainfall estimates were obtained from a National Climatic Data Center weather station at Athens, TN. Estimates of annual rainfall for the area range from 53 to 57 inches over the 19 subwatersheds and were applied at the sub-unit scale. Runoff coefficients for the different land classes were estimated using the following equation taken from the EPA (1990) report, “Urban Targeting and BMP Selection”:

$$Rv = 0.050 + 0.009 (PI) \quad \text{Equation (2)}$$

Where:

PI is percent imperviousness

The values used for PI by land use/land cover class were determined by remote sensing. Pollutant concentrations (mg/L) were taken from the EPA’s National Urban Runoff Study (EPA 1982) in conjunction with local water conditions defined in a companion document. Values were determined based on median and 90th percentile urban concentrations presented by EPA, plus high and low values from on-site sampling to obtain pollutant concentrations presented in Table 1.5.

Table 1.5. Runoff coefficients and pollutant concentrations imported in the pollutant load model for urban land uses within Pond Creek watershed.

	Residential	**Residential construction**	**Commercial**	**Industrial**	**Transportation, communication, utility**
Runoff Coefficient	.2759	0.2075	0.5504	0.6926	0.2696
TSS Concentration (mg/L)	100	1500	100	150	100
TN Concentration (mg/L)	2.4	4.6	4.2	3.45	2
TP Concentration (mg/L)	0.35	0.35	0.9	0.4	0.2
Percent Impervious	25.1	17.5	55.6	71.4	24.4

A selection of local, regional and national event mean concentrations (for urban land classes) previously developed and published has been provided in Table 1.6. This is not meant to be a complete or comprehensive list of all coefficients, nor does it communicate the full extent of knowledge related to pollutant fate in the environment. Coefficients applied to the present nutrient loading model vary from these published values based on the criteria listed above and are derived primarily from high water quality sampling data and land class condition, i.e., rate, frequency and intensity of management practices.

Table 1.6. Published event mean concentrations of total phosphorus and total nitrogen for urban areas as found through a non-exhaustive search of relevant articles, and concentrations applied to the present nutrient loading model. Numbers refer to references defined as 1. Baldys et al. 1998; 2. Guerard and Weiss 1995; 3. Los Angeles County 1999; 4. Harper 1998.

	Total Phosphorus (mg/L)					Total Nitrogen (mg/L)				
	1	2	3	4	Model Input	1	2	3	4	Model Input
Residential	0.38	0.75	0.25	0.30	0.35	2.10	3.80	2.23	2.29	2.40
Commercial	0.18	0.28	0.40	0.29	0.90	1.50	1.80	1.67	2.01	4.20
Industrial	0.28	0.36	0.50	0.31	0.40	1.50	2.90	3.09	1.79	3.45

Loads from roads, roadbanks and streambanks

Pollutant loads from streambanks, roadbanks, and roads are directly related to soil loss. Soil loss for streambanks, roadbanks, and roads was calculated using:

$$A = ER \times EA \qquad \text{Equation (3)}$$

Where:

A = soil loss from streambanks, road banks, or roads (tons/year)
ER = erosion rate for streambanks or road banks (measured in tons/foot/year) and unpaved roads (measured in tons/acre/year)
EA = eroding area from inventory for streambanks or road banks (measured in feet) and unpaved roads (measured in acres)

Values for streambank and road bank erosion rates were estimated from calculations based on the average bank height and average recession rates of eroding banks. Values for each of these parameters were obtained by site visits and consultation with NRCS using critical erosion rates for the ecoregion. Road surface erosion rates were estimated from literature values and from NRCS staff. Watershed specific erosion rates and eroding area estimates are listed as:

Eroding stream bank rate: 0.0270 tons/ft/yr
Eroding road bank: 0.0090 tons/ft/yr
Eroding unpaved road: 25 tons/ac/yr

Pollutant loads from streambanks, road banks, and roads were determined by the following equation:

$$M = A \times PC \times DR \qquad \text{Equation (4)}$$

Where:

M = mass load (tons/year)
A = soil loss (tons/year)
PC = pollutant coefficient (ton pollutant/ton soil)
DR = sediment delivery ratio (unitless)

The area-based sediment delivery ratio was estimated from the USDA National Engineering Handbook, Section 3 - Sedimentation, Chapter 6 - Sediment Sources, Yields and Delivery Ratios (USDA 1978) as:

$$DR = 0.417762 \times A^{-0.134958} - 0.127097 \qquad \text{Equation (5)}$$

Where:

DR = Delivery Ratio (unitless)
A = Area (sq smiles)

This equation was developed mainly from reservoir sedimentation data and therefore has been used mainly for sizing reservoir dams. This equation, however, does not account for watershed characteristics such as land use, relief, and flow direction. Because this equation has been used for many years and has appeared to provide reasonable “average” estimates of sediment yield, and because this value will not change from default it can be used as an additional basis for evaluating new practices (i.e., RUSLE C factors).

Loads from crop, pasture, forest, mining, and disturbed lands

The first step in estimating pollutant loads from crop, pasture, forest, mining and disturbed lands was determining the soil loss for each land class using the RUSLE (Wischmeier and Smith 1978, Renard et al. 1997):

$$A = R \times K \times LS \times C \times P \qquad \text{Equation (6)}$$

Where:

A = soil loss (tons/acre/year)
R = rainfall energy factor
K = soil erodibility factor
LS = slope-length factor
C = cropping management factor
P = erosion control practice factor

The RUSLE factors for the watershed were established through referencing ecoregion 67f values, general RUSLE values for pasture (Wischmeier and Smith 1978), and through consultation with local NRCS personnel. The RUSLE factors employed for this analysis are listed in Table 1.6 below. The site-specific variability in soil types and landscape position account for the differences in soil erodibility and slope-length factors respectively.

The pollutant loads from these lands within the watershed were estimated using the soil loss values calculated from Equation (6) and the following equation:

$$M = A \times Area \times DR \times PC \qquad \text{Equation (7)}$$

Where:

M	= pollutant loading (tons/year)
A	= soil loss (tons/acre/year) determined from RUSLE
Area	= land class area (acre)
DR	= sediment delivery ratio (unitless)
PC	= pollutant coefficient (tons pollutant/ton soil)

The acreage used for the various land classes were determined by the NPS inventory. Most soil pollutant coefficients used in the model varied with land use, although several land use classes utilized the same coefficient values for a pollutant.

Nutrient characteristics (pollutant coefficients) were based on literature values and calibrations to water quality data in previous studies of similar nature. TSS is estimated to be 70 percent of the eroded soil that reaches the stream for all agricultural, forest, and disturbed area land uses. This equates to 0.7 tons pollutant for each ton of soil. Pollutant coefficients for TN varied, with a value of 0.003 tons pollutant/tons soil for most agricultural land uses; 0.015 for animal feedlots and loafing areas; and 0.001 for forests, mining, and disturbed areas. TP soil pollutant coefficient value for all agricultural land uses is 0.0002, and 0.0001 for forests and disturbed area land uses. Nutrient characteristics were based on Stewart et al. (1975) and Mills et al. (1985).

Table 1.7. Values used for RUSLE (Revised Universal Soil Loss Equation) for each Pond Creek subwatershed.

					Row Crops				Pasture					Forest					
					Low Residue	High Residue	Strip cropped	Medium Residue	Good	Fair	Heavily Overgrazed	Poor	Feedlot/ Loafing	Orchard	Scrub/ shrub	Forest	Clearcut	Mine	Disturbed Areas
Sub ID	R	K	LS	P	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
01	200	0.2983	0.5553	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
02	200	0.2939	0.7240	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
0201	200	0.3062	0.5621	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
03	200	0.2976	0.6028	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
04	200	0.3096	0.3819	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
0401	200	0.3102	0.4320	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
05	200	0.3300	0.2048	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
0501	200	0.3298	0.3603	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
06	200	0.3300	0.1695	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
0601	200	0.3081	0.4392	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
07	200	0.3295	0.3107	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
0701	200	0.2988	0.3989	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
0702	200	0.3031	0.3107	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
08	200	0.3018	0.3867	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
0801	200	0.3267	0.3443	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
0802	200	0.3248	0.3141	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
080201	200	0.3298	0.3593	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
0803	200	0.3066	0.3499	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1
080301	200	0.2848	0.4491	1	0.551	0.149	0.125	0.300	0.003	0.013	0.200	0.450	0.750	0.003	0.003	0.002	0.150	1	1

Pollutant loads from livestock operations

The pollutant loads from beef cattle, dairy and horse operations were estimated using the following equation:

$$M_n = Na_n \times WT_n \times PR_n \times 0.0001825 \times DR_n \times NS_n \qquad \text{Equation (8)}$$

Where:

M	= pollutant loading (tons/year)
NA	= number of animals (number/site)
WT	= animal weight (pounds)
PR	= pollutant production rate (lb pollutant/day/1000 lb live wt)
0.0001825	= unit conversion factor
DR	= delivery ratio (unitless)
NS	= number of sites of type n
n	= type of livestock operation

The number and type of livestock sites within the study area were identified by the nonpoint source inventory, including both aerial photographs and field verification. The (as excreted) pollutant production rates (PR above) for TN and TP were obtained from the NRCS Agricultural Waste Management Field Handbook (USDA 1996) and a non-exhaustive literature review. The production rate for TSS was based on values derived from "Livestock Manure Characterization Values from the North Carolina Database" (Barker et al. 1990).

This component of the loading model primarily accounts for the direct deposition of animal waste into streams, but also considers nutrient-rich material on pastures that is available for direct washoff. Differences in animal weights and size of individual operations were considered in pollutant load calculations. Livestock calculations differed in delivery ratios for each pollutant adjacent to stream sites and estimated time spent in streams. While these differences exist, the general process used to estimate delivery of animal waste was similar for each type of livestock. Values entered in the pollutant model for each livestock class are displayed on Table 1.8.

Table 1.8. Values used to estimate pollutant loadings from livestock operations. See text for methodology.

		Beef Cattle	Dairy	Horse
Number of animals per site	Large	400	150	25
	Medium	80	75	15
	Small	20	25	5
Animal weight (lb/animal)		1000	1200	1000
Delivery Ratio - Adjacent	TSS	0.0466	0.0714	0.0100
	TN	0.0486	0.0734	0.0100
	TP	0.0437	0.0687	0.0100
Delivery Ratio - Non-Adjacent	TSS	0.0060	0.0060	0.0010
	TN	0.0085	0.0085	0.0010
	TP	0.0025	0.0025	0.0010
Pollutant Production (lb/day/1000 lb live weight)	TSS	3.39	5.00	6.20
	TN	0.31	0.45	0.31
	TP	0.11	0.07	0.16

Pollutant loads from beef cattle operations

Analyzing cattle behavior and producer management was critical in selecting delivery ratios for beef cattle operations. The patchiness of a pasture depends not only on the resource variability and the overall stocking rate, but also on patterns of livestock activity in space and time. Estimating the amount of time cattle spend loafing or drinking in or immediately adjacent to streams provided a basis for estimation of the direct delivery of waste. Pollutant delivery to the stream primarily depends on: (1) where the cattle are located in the watershed and (2) the fate of the pollutant once it is introduced into the environment (i.e., movement, adsorption, volatilization, etc.).

A certain amount of waste enters streams from inadequate waste management systems (overflowing lagoons, runoff from land application, runoff loafing areas). Because of the limitations of the remote-sensing process, waste treatment facilities were not considered in this model. A closer look at the individual operations would be needed to further refine these values.

Through consultation with local NRCS staff and relevant literature (Byers et al. 2004, Davies-Colley et al. 2004, Kleinman et al. 2005), time estimates for livestock proximity to water were derived based on the following estimates about cattle behavior:

1. The time spent in the stream is primarily in June through September; although year round accessibility is available.
2. Minimal time spent in stream at night, and essentially no waste is deposited.
3. Potential stream access occurs 12-18 hours per day June through September.
4. One-third of 12 hours is spent in stream or near stream (four hours per day).
5. One-sixth of 12 hours is spent in stream (two hours per day June through September).
6. For April, May, October, and November, one-half hour per day spent in stream.
7. For December, January, February, and March, minimal time spent in stream, and essentially no waste deposited.
8. Estimate half of the cattle are not environmentally sensitive and are 50 percent less likely to be in the stream than stated in the above estimates.
9. Percent of time spent in stream is averaged over the year (0.833 hours per day for environmentally-sensitive animals and 0.417 hours per day for insensitive animals). This gives an average for all animals of 0.625 hours per day or 2.6 percent.

For those sites adjacent to the stream, it was estimated that the cattle spent time in one of three general areas as follows:

2.5 percent of the time in the perennial stream
16.7 percent of the time near the perennial stream
80.8 percent of the time in the pasture away from the perennial stream

For those sites nonadjacent to the stream, the following estimates were made for time spent:

0 percent of the time in the perennial stream
0 percent of the time near an intermittent drain
100 percent of the time in the pasture away from an intermittent drain

The following estimates were made about the fate of the pollutant once it was introduced into the environment:

1. When the animal is in the stream, 100 percent of all pollutants enter the stream with no losses.
2. When the animal is near the stream, 10 percent of nitrogen and phosphorus enters the stream.

3. In addition, 25 percent of ammonia is lost due to volatilization prior to it entering the stream, and 10 percent of the organic nitrogen is converted to ammonia prior to entering the stream.
4. When the animal is in the pasture, 0.85 percent of the nitrogen, and 0.25 percent of the phosphorus enters the stream. These numbers are based on values for land applied poultry litter (Kingery et al. 1994).
5. The delivery ratio used for TSS was 0.6 percent.

The delivery ratio was calculated by summing the products of the time spent in the general areas and the respective fates, or:

$$DR = \Sigma_{area} (time \times fate) \qquad \text{Equation (9)}$$

Where:

Area = proximity to waterway (in, near or away)
Time = time spent in an area
Fate = fate of pollutant

Pollutant loads from dairy operations

The delivery of pollutants from dairy operations varies greatly from operation to operation. Factors which influence delivery of pollutants to the stream include type and amount of confinement, management of lagoons or waste storage ponds, proximity of cows to streams, and timing and amount of land application of wastes. As such, the delivery ratio consists of two components: a management component and a stream access component.

The delivery ratio for the stream access component for all pollutants was modified by 0.05. This is based on the assumption that lactating cows require a greater volume of water intake than do dry cows, calves and heifers (OSU 2004). A final estimate was developed so that dairy cows with stream access spend 5 percent of their time in the stream, 16.7% near the stream and 78.3% away from the stream. Pollutant fate was defined as beef cattle above.

Pollutant loads from horse operations

The process used to estimate delivery of horse waste was similar to that used for cattle. According to observers, horses spend only long enough in the stream to drink, and their time in the stream does not change seasonally. Time in the stream for horses is estimated at 15 minutes per day, or 1% of time on an annual basis. Delivery ratio for horse sites adjacent to the stream was 0.01, and for non-adjacent sites this value was 10% of this, or 0.001.

A selection of published nutrient loads from livestock contributions has been provided in Table 1.9, for comparison to present model inputs. This is not meant to be a complete or comprehensive list of all coefficients. Coefficients applied to the present nutrient loading model vary from these published values based on the criteria listed on page **29**, and are derived primarily from high water quality sampling data and land class condition, i.e., rate, frequency and intensity of management practices and livestock behavior.

Table 1.9. Published nutrient loads of total phosphorus and total nitrogen contributed by beef and dairy cows with unrestricted access to the adjacent waterway found through a search of relevant articles, and concentrations applied to the present nutrient loading model. Numbered columns represent coefficient references: 1. Kleinman et al. 2005; 2. Byers et al. 2004; 3. Davies-Colley et al. 2004; values have been amended to represent constant animal behavior i.e., 14-18 hr/day of pasture grazing, over 300 days/year.

	Total Phosphorus (lb/cow/day)			Total Nitrogen (lb/cow/day)		
	1	2	Model Input	1	3	Model Input
Beef	0.93	0.89	1.76			5.5
Dairy	1.62	1.54	2.1	7.56	19	14.46

Pollutant loads from wildlife

Terrestrial and avian wildlife populations vary in habitat preferences, but for the purpose of the pollutant loading model, habitats were limited to forests, croplands, and wetlands. The process used for calculations of pollutant loading is similar to livestock, but does not include limitations based on operational sites (size, proximity to waterway). The pollutant loads from wildlife were estimated using the following equation:

$$M = Na \times WT \times PR \times DR \times 0.0001825 \qquad \text{Equation (10)}$$

Where:

M = pollutant loading (pounds/year)
NA = number of animals (number/subwatershed)
WT = animal weight (pounds)
PR = pollutant production rate (lb pollutant/day/1000 lb live wt)
DR = delivery ratio (unitless)
0.0001825 = unit conversion factor

A constant weight of 140 lbs was used for all wildlife, based primarily on information for deer (fawn = 100, doe = 140, and buck = 160 lbs or greater), although it is recognized that all species and sizes of wildlife are present in the watershed. Delivery ratio is set at a constant 0.001 for all pollutants. Pollutant production rate is set at 6.20, 0.31, and 0.16 for TSS, TN, and TP respectively, assuming minimal watershed degradation caused by wildlife.

2.0 Nonpoint Source Inventory Summary

A NPS inventory is a geographic database of land use and features that contribute or have the potential to contribute NPS pollution. The database was generated from the interpretation of low-altitude, color-infrared aerial photography concurrent with several recent field verification visits. The data generated for this study were managed using ESRI's ARC/INFO and ArcView software along with applications of Excel spreadsheets. This section of this report provides a summary of the NPS inventory.

Land use classification

The dominant land use in the study area is pasture (for livestock), comprising 55.0% of the total land area, which occurs primarily in the valley and flatland regions of the watershed. Also in these regions is cropland (6.6%) and supporting residential units (4.0%). Commercial and Industrial land uses total 3.7% which primarily follows Interstate-75 corridor. Figures 3.2.1 and 3.2.2 summarize general land use patterns in Pond Creek watershed.

The primary land use component of the ridges within the area is forest (29.0%). Wetlands and disturbed areas make up an additional 0.7% and 0.2% respectively, with the remaining 0.8% of land use in the form of open water.

2.1 Urban land use classes

Of the total 23,579 acres within Pond Creek watershed, 1,809 acres are classified as urban (Table 2.1). Subwatershed 080301 holds the largest number of residential units, followed by 0803, both in the southwest region of the watershed in McMinn County. Subwatershed 01, the northern most subwatershed, houses the largest land use area for commercial and industrial, followed by 0801 and 080201 in the south. These are areas that allow easy access to interstate traffic. Right-of-way land class is also highly dependent on proximity to major roadways. Subwatersheds that surround Interstate-75 have a substantially greater area of right-of-way land classification.

Suspect on-site septic systems

Using the remote sensing process, 54 sites were identified with on-site septic systems that may contribute contaminants to the surface water through overland flow, particularly when saturated soil conditions exist. Field investigations should be conducted before concluding any absolute condition of these systems. A breakdown by watershed and reason for suspicion are given in Table 2.2 and Figure 2.3 for mobile homes, houses, and commercial facilities.

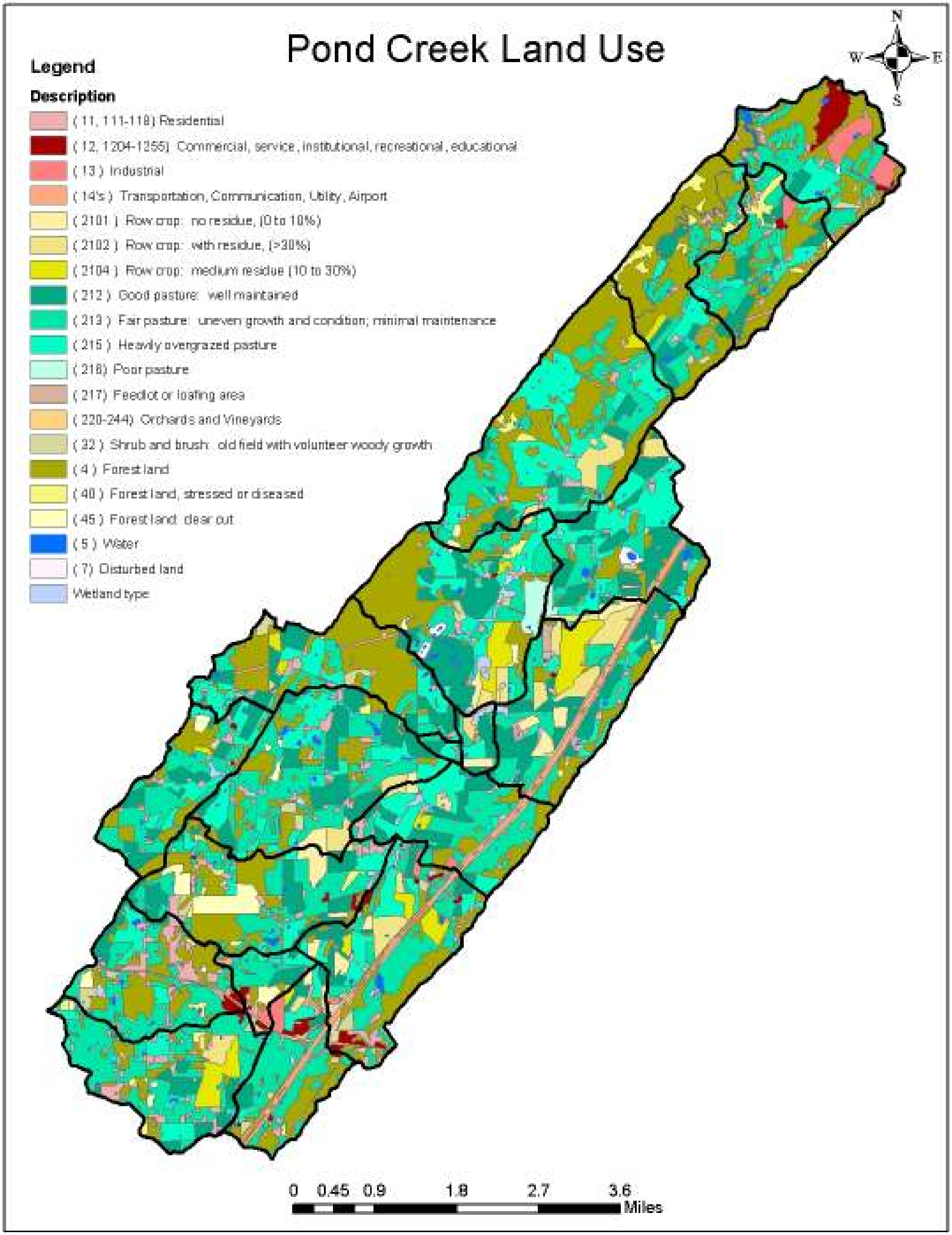

Figure 2.1. Land use classification map of Pond Creek watershed. See text for methodology and delineations.

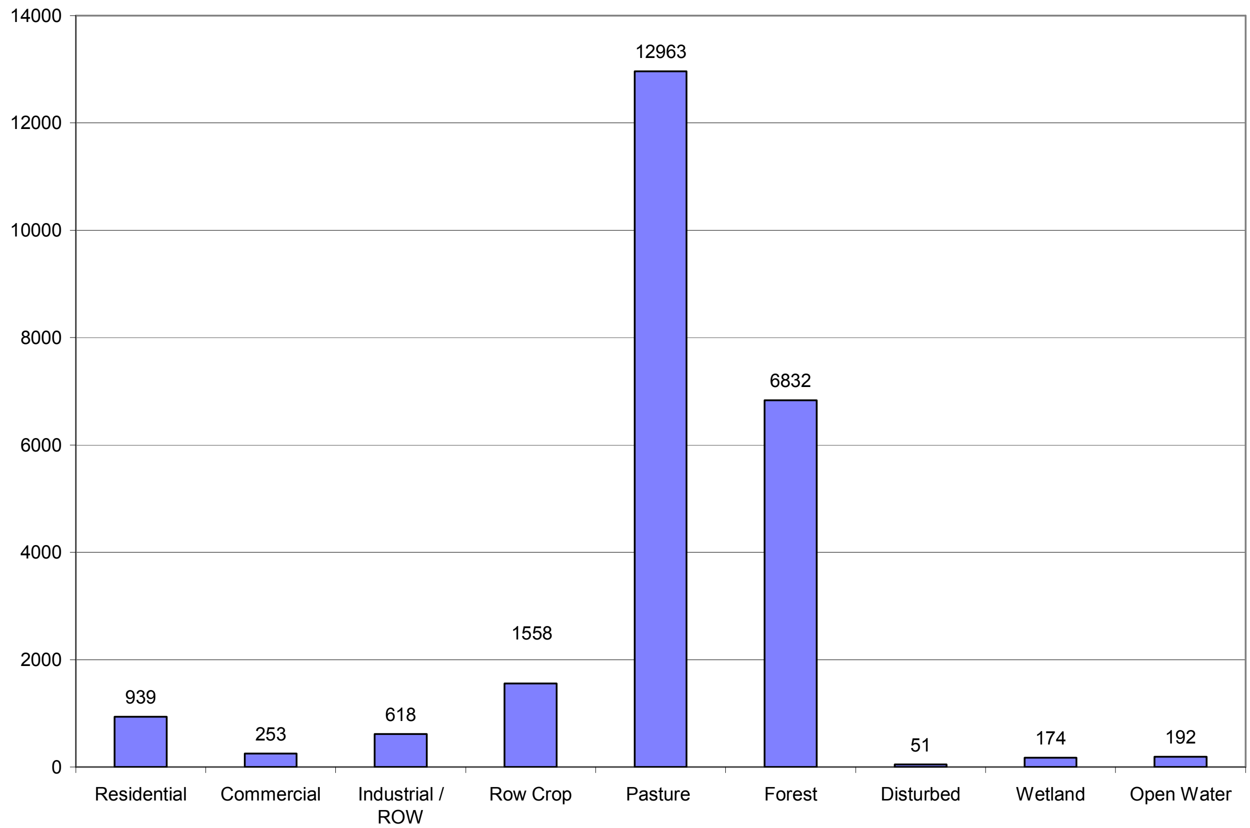

Figure 2.2. Major land use distribution (in acres) within Pond Creek watershed.

Table 2.1. Urban land use areas, in acres, for Pond Creek watershed, as defined in text.

Sub ID	Total urban area	Residential	Residential construction	Commercial	Industrial	Transportation, communication, utility
01	286.45	49.09	1.68	111.15	119.48	5.05
02	33.48	29.42	0.00	0.00	0.00	4.05
0201	79.73	45.58	0.00	7.67	19.35	7.13
03	57.81	54.99	0.00	0.00	0.00	2.82
04	35.61	32.41	0.00	1.89	0.00	1.31
0401	53.11	26.99	0.00	0.00	0.00	26.12
05	2.93	2.93	0.00	0.00	0.00	0.00
0501	148.80	44.72	0.00	2.16	0.00	101.92
06	0.73	0.73	0.00	0.00	0.00	0.00
0601	53.04	36.43	0.00	0.00	0.00	16.61
07	86.89	38.51	0.00	0.00	9.92	38.46
0701	74.13	74.13	0.00	0.00	0.00	0.00
0702	40.55	36.92	0.00	3.62	0.00	0.00
08	97.73	80.72	0.00	17.01	0.00	0.00
0801	227.08	65.79	0.00	52.35	19.40	89.53
0802	57.64	18.08	0.06	16.62	17.49	5.38
080201	166.98	21.22	0.00	32.09	33.10	80.58
0803	104.34	97.68	6.66	0.00	0.00	0.00
080301	202.38	157.22	16.57	8.25	0.00	20.34
Total	1809.40	913.56	24.97	252.81	218.74	399.31

Table 2.2. Suspect septic system location and condition within Pond Creek watershed. See text for condition (number) definitions.

Sub ID	Total	Mobile Home					House					Commercial				
		1	2	3	4	Subtotal	1	2	3	4	Subtotal	1	2	3	4	Subtotal
01	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
02	2	0	1	0	0	1	0	0	0	1	1	0	0	0	0	0
0201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03	2	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0
04	2	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0
0401	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0501	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0601	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
07	2	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0
0701	6	0	1	0	1	2	0	2	0	2	4	0	0	0	0	0
0702	3	0	0	0	0	0	0	1	0	1	2	0	0	0	1	1
08	7	0	0	0	0	0	1	1	3	1	6	0	0	0	1	1
0801	9	0	0	0	6	6	0	0	0	2	2	0	0	0	1	1
0802	2	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1
080201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0803	5	0	0	0	1	1	0	1	3	0	4	0	0	0	0	0
080301	12	0	1	0	0	1	0	1	4	6	11	0	0	0	0	0
Total	54	0	4	0	8	12	1	10	10	17	38	0	0	0	4	4

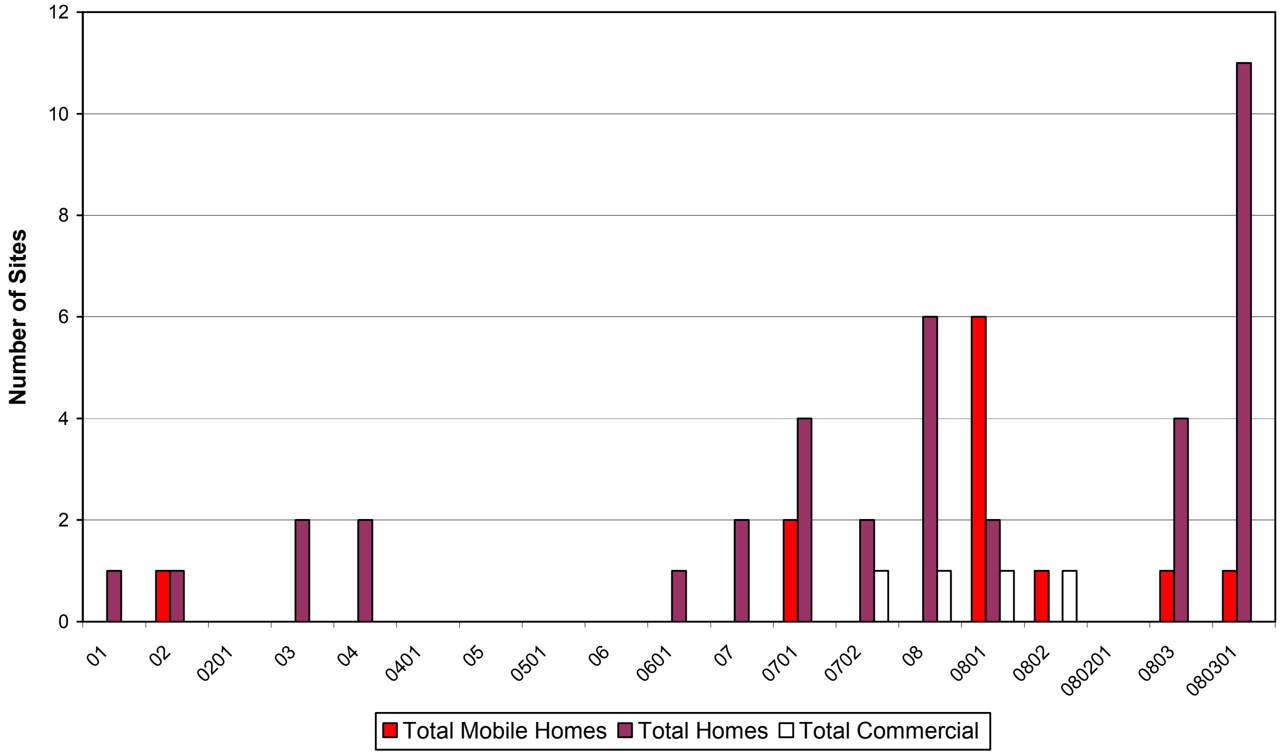

Figure 2.3.Pond Creek watershed suspect on-site septic systems, delineated by major land use

Most (93%) of the suspect sites serve residences. Of the total suspect house sites, 26.3% exhibited a visible plume pattern, with no drain field apparent. This may indicate a straight-pipe from a septic system, roof drainage, gray water disposal or natural seepage/spring. Another 44.7% showed no visible plume or drain field, but were at locations that are questionable for on-site septic systems. Such locations include home sites on very steep slopes, small lots, visible rock outcrops, or close proximity to streams, especially those on heavily wooded lots. Only one house site exhibited an effluent plume from a visible drain field pattern or prominent ponding down slope from the drain field, likely representing a failing system.

All of the commercial sites and two-thirds of mobile home sites with on-site suspect septic systems were classified as condition four. This rating refers to systems that showed no visible plume or drain field but were located in areas that are questionable for on-site septic systems. Four mobile home sites exhibited a visible plume pattern, but no drain field was evident. This may indicate straight-piping from a septic system to a stream.

2.2 Roads, roadbanks and streambanks

The remote sensing process identified 120.6 miles of stream contained within the study area. Stream segments that are eroding in this plan have visible, collapsed banks. The interpretation process identified 26.9 miles of eroding streambank, or 22% out of a total 120.6 miles of digitized stream (Table 2.3). A high degree of variability is present regarding streambank condition and subwatershed, and locations of impaired streambank due to erosion can be visualized in Figures 3.2.4 and 3.2.5. More than 18.6 miles of the stream have been channelized, meaning they had been straightened in some form in an attempt to reduce or redirect flooding.

The recommended width for successful stream riparian buffer is 50 feet for flat lying areas in east Tennessee (Price and Karesh 2002). More than half of the stream sections evaluated for vegetation condition within the study watershed were found to have both left and right bank vegetation widths of less than 15 feet. Only 22.4% of the left and right banks are considered to have adequate vegetative buffers based on width. The vegetative cover density, however, was estimated as 67% or greater in the majority of the evaluated stream sections. Approximately 62% of left bank and 61% of right bank buffer is considered adequate based on vegetation cover. Hence, stream buffers were narrow yet dense.

Table 2.3. Summary of streambank and roadbank conditions in Pond Creek watershed. Values are length in feet.

Sub ID	Total streambank	Eroding streambank	Total paved rd	Eroding road bank	Total unpaved rd	Eroding Unpaved Rd
01	35856	6999	41309	27395	35825	22769
02	32864	2444	11660	4644	25097	4373
0201	23378	5237	26583	4279	13555	995
03	71344	20449	34018	2949	28523	613
04	53865	11011	25978	11405	31670	10548
0401	32542	8385	23743	0	19331	0
05	5568	67	5055	540	0	0
0501	54795	12417	64974	714	25337	0
06	1379	0	128	128	0	0
0601	36657	6753	23097	5997	27012	5920
07	32229	8114	33861	1692	15342	1469
0701	47465	13518	29889	8682	29025	8517
0702	30449	7191	21266	2990	8018	1949
08	36863	9291	31195	23504	32031	20475
0801	49054	7630	71648	1390	12294	0
0802	8178	3326	10726	3325	4784	2107
080201	23289	4910	52587	3735	11161	2517
0803	34236	8893	40068	3616	14011	2021
080301	26992	5586	35997	6775	22212	3823
Total feet	637003	142221	583782	113760	355228	88096
Total miles	120.64	26.94	110.56	21.55	67.28	16.68

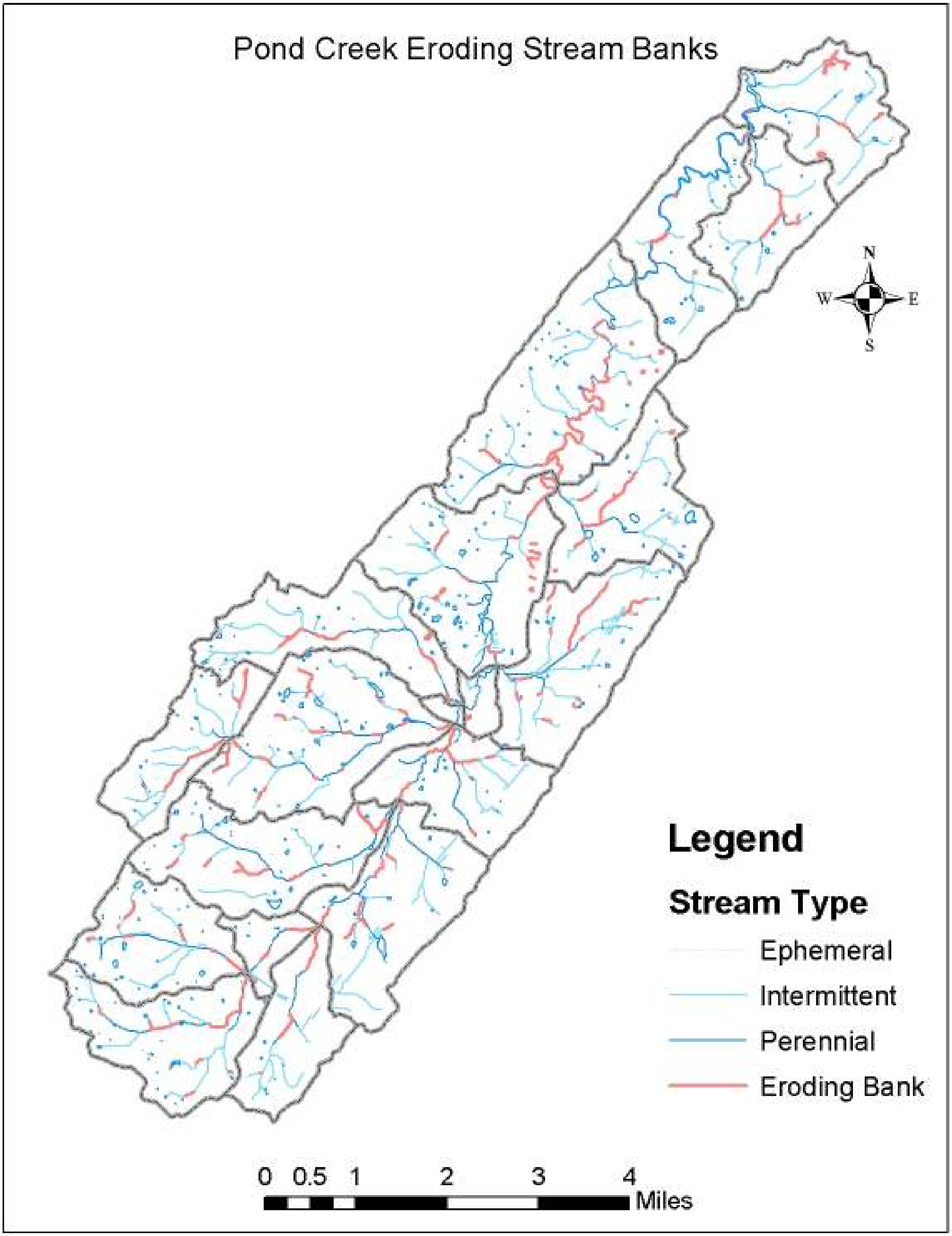

Figure 2.4. Locations of eroding streambanks within Pond Creek watershed study area.

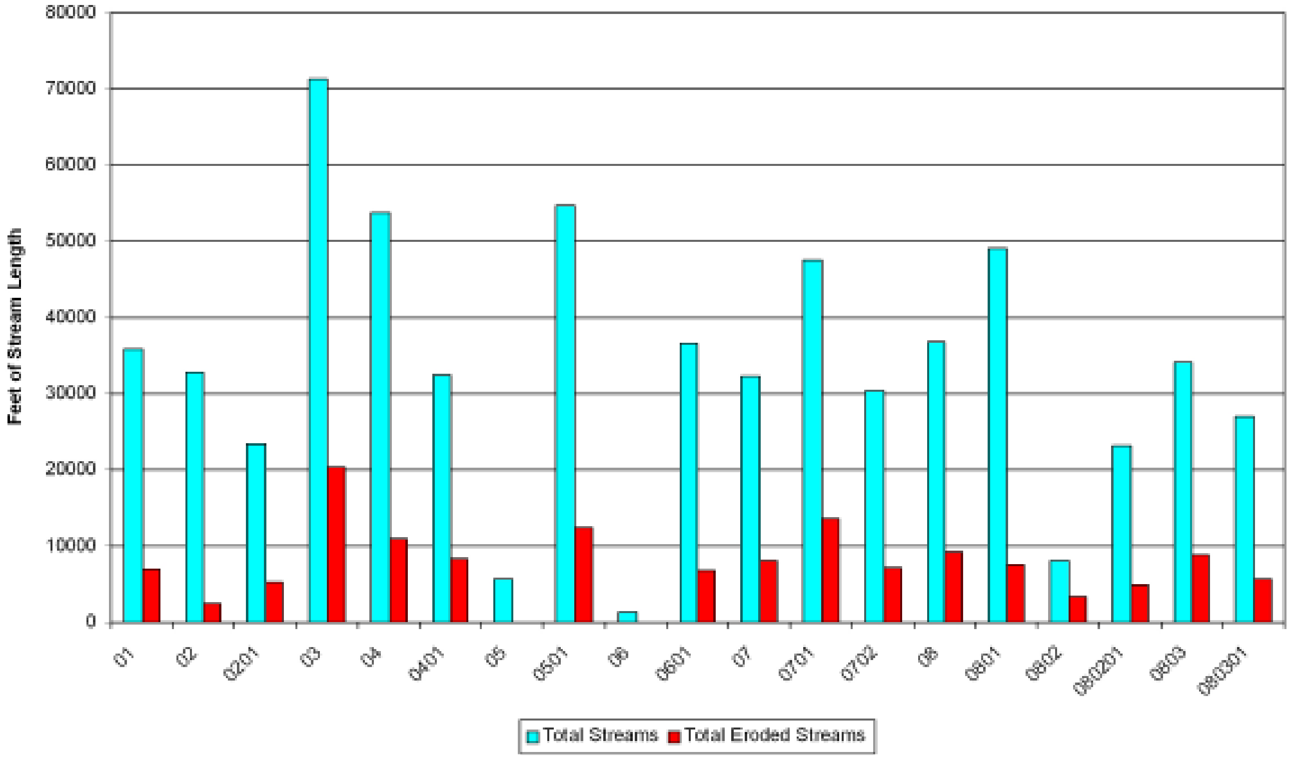

Figure 2.5. Pond Creek watershed eroding streambank totals.

Imperviousness changes the flow characteristics of streams within a watershed. Changes include increased amounts of water the stream must carry during rain events (peak flows), increased flooding frequencies, and lower base flows. These changes occur because more water runoff is created by the impervious surfaces. As runoff increases, so does stream flow, and the stream channel subsequently becomes unstable. The stream channel becomes deeper and wider in order to carry the increased flow. This results in increased sediment loads and loss of aquatic and riparian habitat as soil and vegetation are scoured from the bottom and banks cave into the stream.

As the amount of imperviousness within a watershed increases the amount of pollutants delivered to the stream increases. Impervious surfaces collect and accumulate pollutants deposited from the atmosphere, leaked from cars, during rain events, or derived from other activities which can transport pollutants o the nearest waterway. Percent imperviousness for Pond Creek watershed is estimated at 0.027%, or 628 acres. This value is lower than those classified as stressed after Schueler (1994a, b), and as such is not considered here to be a major source of pollutant loading.

Within the 23579 acres of Pond Creek watershed, a total of 110.6 linear miles is paved road, and 67.3 miles are unpaved roads (Table 2.3). A significant correlation exists between paved roads and industrial land use for Pond Creek watershed ($N = 19$, $r^2 = 0.365$, $P = 0.006$) and between paved roads and commercial land use (r^2 = 0.389, P = 0.004). So where commercial and industrial complexes exist, so do paved roads; likely as a function of accessibility. A correlation also exists with unpaved roads and residential units (r^2 = 0.161, P = 0.089), likely resulting from unpaved driveways.

Estimated length of eroding paved roads is 21.5 miles, or 19.5% of total paved roads. Estimated length of eroding unpaved roads is 16.7 miles, or 24.8% of total unpaved roads. As with streambanks, roadbank erosion is unequally distributed throughout the study area, as seen in Figures 3.2.6 and 3.2.7. It should be noted that areas containing US Interstate-75 had low percentages of eroding roadbank, at ≤ 7%, compared to other areas as high as 75% eroding roadbank.

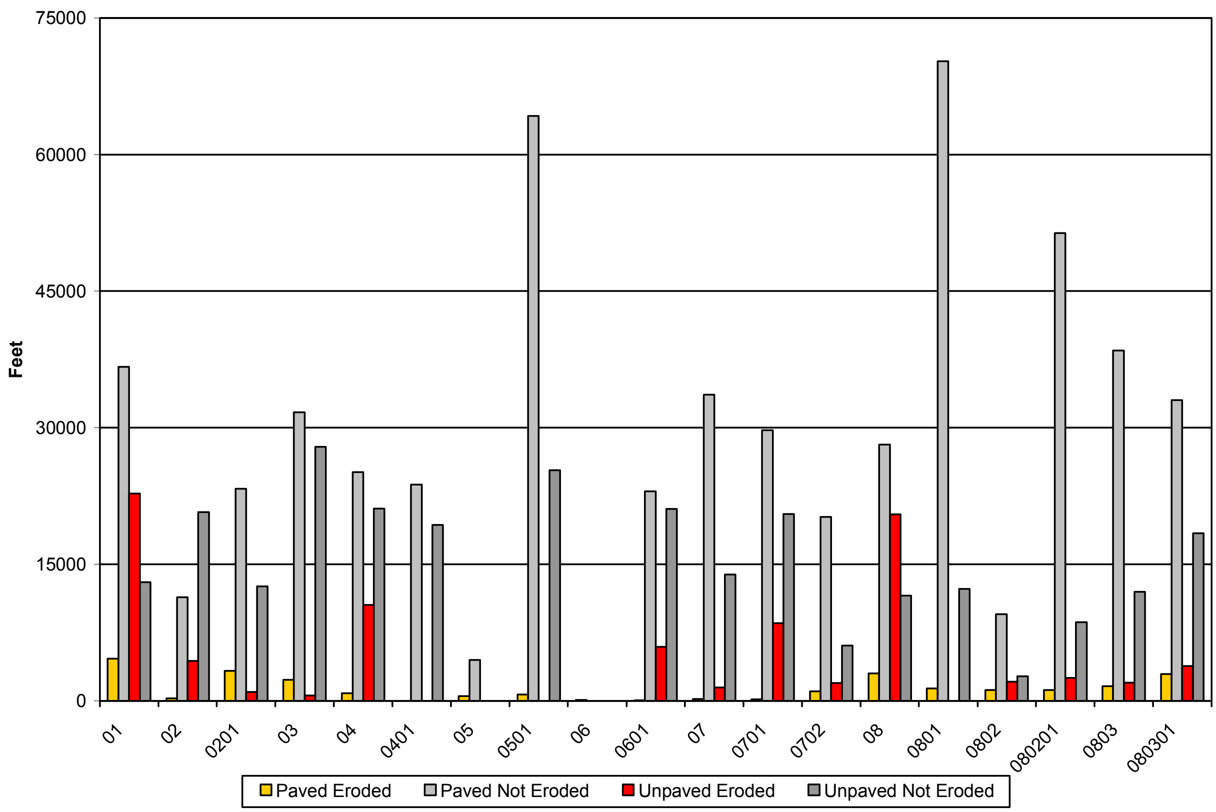

Figure 2.6. Pond Creek watershed eroding roadbank totals (in feet) for paved and unpaved roads.

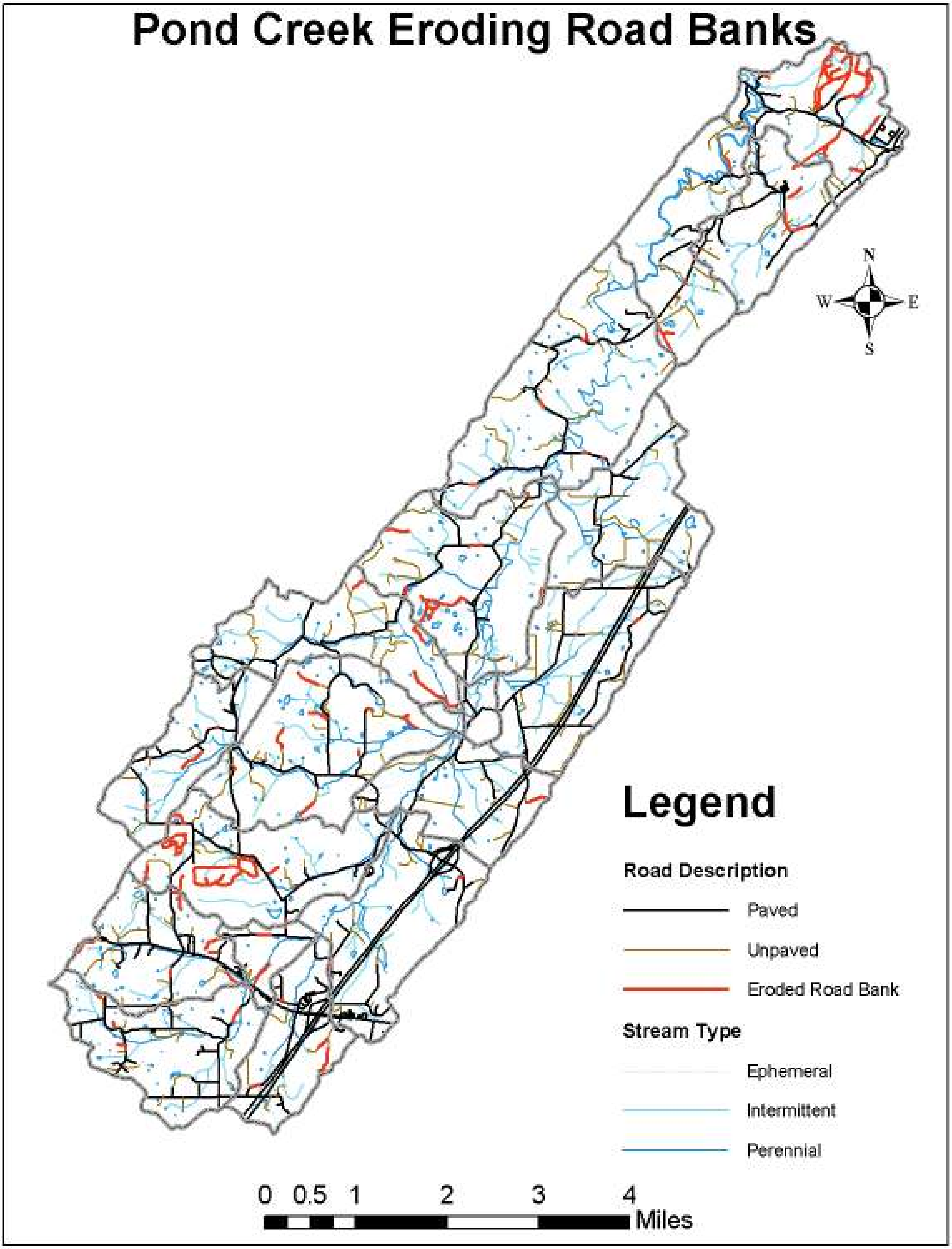

Figure 2.7. Locations of eroding roadbanks within Pond Creek watershed study area.

2.3 Crop, pasture, forest, mining and disturbed lands

Agriculture land use (cropland, pasture and farmsteads) is unevenly distributed throughout Pond Creek watershed, as illustrated in Figure 2.8. Acreage of high residue crops, medium residue crops, low residue crops and the sum of all cropland by subwatershed is shown in Table 2.4. No area had strip cropped land and this land use class was thus eliminated from the model. Total cropland acreage for the study area was 1,557.6 acres. Subwatershed 0501 had the highest amount of cropland acreage (418.4 acres), with 45% of the cropland in high residue and 33% in medium residue crops. This crop delineation trend is constant for the majority of all subwatersheds. Out of the total 1,557 acres of cropland, 42% is high residue, 35% medium, and 23% low residue.

A breakdown of pasture condition as determined by the photo interpretation is shown in Table 2.4. Subwatersheds 0701 and 03 have the greatest amount of pasture with 1,383 acres and 1,298 acres, respectively. Within the total study area, 12,962 acres are pasture with the majority (46%) in fair condition. Approximately 27% of all pasture was identified as heavily overgrazed and 26% was classified as good.

Forested lands are scattered throughout the study area, with major concentrations located in the northern subwatersheds as part of the ridge terrain. These six northern-most areas contain over 50% of all 6,135 acres of forest found within the watershed (Table 2.5). Subwatershed 08 contains two large areas of harvested forest which is approximately 59% of all harvested lands in the entire study area.

Total mined and disturbed land classes within Pond Creek were near 0.2% of the total 23,579 acres of the study area. Mining operations existed as of time of aerial photography (March 2003), mainly in areas 04 and 0401. Excavation was likely for barite, as this area is part of the Sweetwater barite district. Land classes considered disturbed were limited to only 5 subwatershed locations, as seen in Table 2.5.

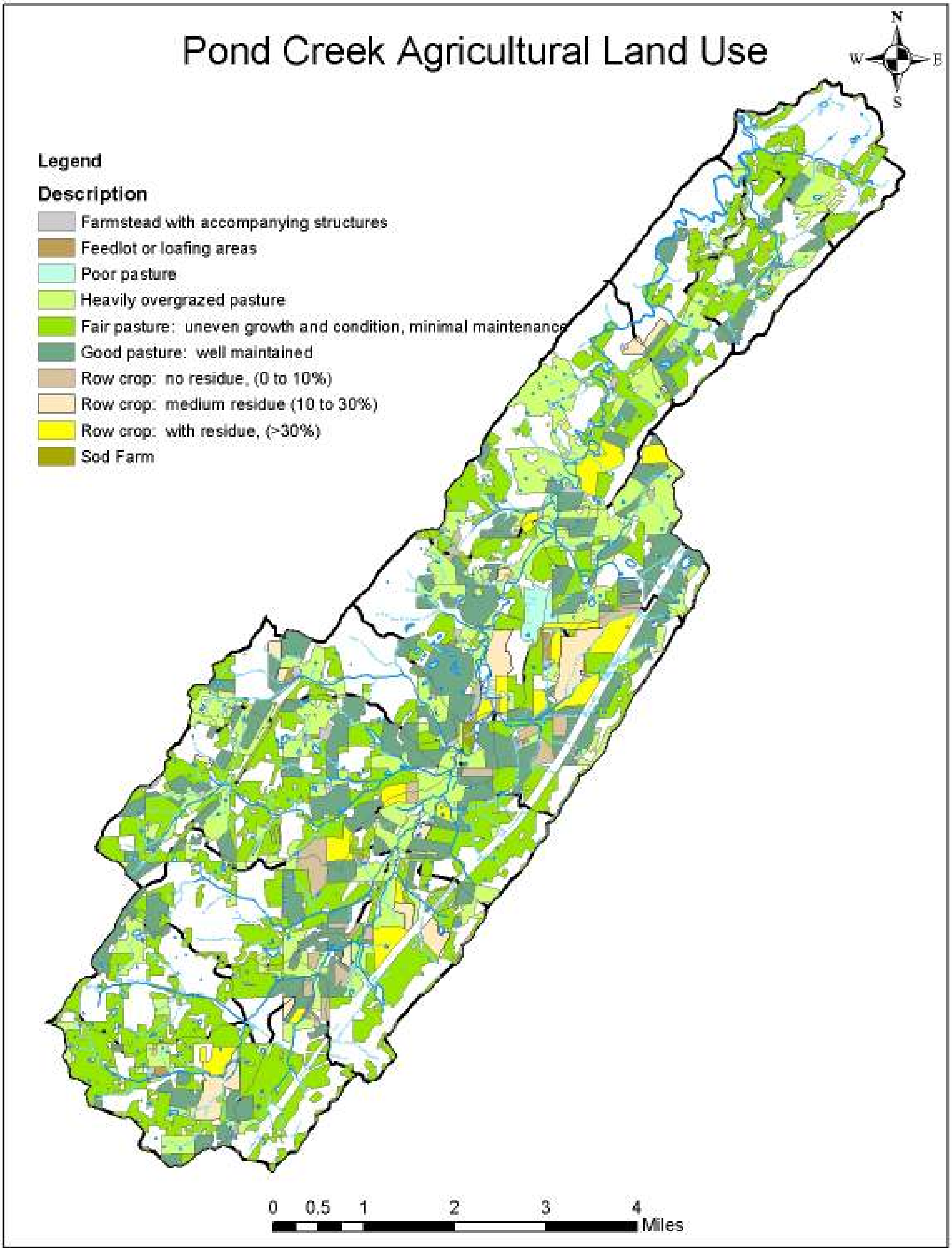

Figure 2.8. Agriculture land classes for Pond Creek watershed March 2003.

Table 2.4. Agriculture land use in acres for Pond Creek watershed, delineated by land use condition. See text Section 3.1.2 for definitions.

Sub ID	Total Agriculture (ac)	Row Crops			Pasture				
		Low Residue	High Residue	Medium Residue	Good	Fair	Heavily Overgrazed	Poor	Feedlot/ Loafing
01	443.59	0.00	0.00	0.00	34.80	300.24	108.55	0.00	0.00
02	478.18	0.00	0.00	22.39	128.62	217.33	109.84	0.00	0.00
0201	544.30	0.00	0.00	1.26	130.85	280.05	131.23	0.00	0.91
03	1445.93	13.82	114.59	19.48	162.32	495.28	636.25	0.00	4.20
04	1218.84	25.81	51.05	103.90	379.67	276.81	291.53	85.84	4.22
0401	1067.82	14.75	49.70	0.21	401.47	170.22	410.22	21.25	0.00
05	136.71	19.85	4.50	0.00	62.37	14.72	35.26	0.00	0.00
0501	1229.48	93.14	186.54	138.69	346.26	339.43	95.40	0.16	29.86
06	56.01	0.00	0.00	0.00	19.66	11.55	24.81	0.00	0.00
0601	660.08	0.00	0.00	23.57	222.20	156.14	250.07	0.00	8.10
07	821.83	9.29	28.20	15.51	171.87	361.15	235.80	0.00	0.00
0701	1496.22	44.20	68.14	0.00	396.99	621.29	360.52	0.00	5.08
0702	695.82	0.00	0.00	7.67	198.99	344.43	144.01	0.00	0.72
08	894.56	65.69	3.76	0.00	237.94	457.71	122.43	0.00	7.03
0801	975.39	59.11	74.65	84.52	132.77	411.54	212.80	0.00	0.00
0802	198.36	1.54	0.00	3.76	41.41	112.43	39.23	0.00	0.00
080201	538.58	19.46	12.78	9.83	82.99	334.36	67.15	0.00	12.02
0803	1060.89	0.00	55.51	110.73	145.51	592.87	145.63	0.00	10.65
080301	557.72	0.00	0.00	0.00	65.45	400.50	91.77	0.00	0.00
Total	14520.31	366.65	649.42	541.53	3362.13	5898.06	3512.49	107.25	82.79

Table 2.5. Forest and disturbed land classes in acres for Pond Creek watershed.

Sub ID	Total Area (ac)	Forest					
		Orchard	Scrub/ shrub	Forest	Clearcut	Mined areas	Disturbed Areas
01	461.51	0.00	18.74	438.71	0.00	0.00	4.06
02	784.92	0.00	10.69	774.23	0.00	0.00	0.00
0201	403.32	0.00	2.68	400.65	0.00	0.00	0.00
03	920.89	0.00	2.41	915.55	1.19	1.75	0.00
04	585.58	0.82	26.14	520.00	16.49	22.12	0.00
0401	189.52	0.00	17.05	152.27	0.00	20.20	0.00
05	21.79	19.44	0.00	2.35	0.00	0.00	0.00
0501	253.10	0.00	51.08	202.02	0.00	0.00	0.00
06	0.03	0.00	0.00	0.03	0.00	0.00	0.00
0601	656.79	0.00	47.76	608.60	0.44	0.00	0.00
07	175.49	0.00	22.96	152.53	0.00	0.00	0.00
0701	371.09	0.00	27.18	326.31	17.60	0.00	0.00
0702	226.28	0.00	4.89	203.98	17.41	0.00	0.00
08	587.37	0.00	16.78	416.07	154.52	0.00	0.00
0801	375.09	0.00	74.06	301.04	0.00	0.00	0.00
0802	62.67	0.00	7.77	29.28	25.61	0.00	0.00
080201	233.21	0.00	34.68	198.53	0.00	0.00	0.00
0803	192.61	0.00	13.48	165.98	13.15	0.00	0.00
080301	382.24	0.00	36.74	327.28	15.31	2.91	0.00
Total	6883.52	20.26	415.08	6135.40	261.72	46.99	4.06

2.4 Livestock operations

Tables 2.6, 2.7 and 2.8 show the number and type (small, medium, or large and adjacent or nonadjacent to the stream) of beef cattle, dairy, and horse sites for Pond Creek watershed. The classification of small, medium, or large as reported here is a relative relationship among sites within the study area (Table 1.7). The classification is assigned by aerial photo interpretation and recent field verification and is for the purpose of comparing potential water quality impacts among sites and watersheds. It is independent of any regulatory definitions regarding livestock operations. Total estimated livestock numbers are: 1,960 beef cattle, 960 calves and dry dairy cows, 1,575 mature, lactating dairy cows, and 45 horses.

Beef cattle operations

Beef cattle sites (Table 2.5) are the most prevalent in Pond Creek watershed, outnumbering dairy and horse operations. A total of 59 beef cattle sites were identified in the study area. Most beef cattle operations were classified as small (<25 animals), with only two of the sites classified as large operations (400 animals) within the study area. Cattle sites located adjacent to the stream (59%)

and nonadjacent to the stream (41%) were fairly evenly distributed spatially. The two large (>400 animals) beef sites are located in areas 02 and 0401.

Dairy operations

Few dairy operations (Table 2.6) were identified in the study area. A total of 12 sites were reported, all adjacent to the stream. The majority of dairy sites in the study area are deemed large, that is having greater than 150 animals per site. This land use classification gained the most accuracy from field referencing activities. Interpretation of aerial photos taken in 2003 identified 20 dairy sites within the study area: 13 large, 6 medium and 1 small. Current site visits however have yielded up-to-date livestock data as: 9 large, 3 medium and no small sites. Several of the 2003 sites assigned as dairy have since gone out-of-business or changed to beef cattle sites.

Horse operations

The total number of horse site operations (Table 2.8) for the study area was 7, with 100% located on land not adjacent to the streams. As seen with beef cattle operations, most of the horse sites in the study area are small operations scattered throughout the watershed. These small sites representing 5 animals or less are likely recreational horse sites.

Table 2.6. Summary statistics for beef cattle sites located within Pond Creek watershed. See text for definitions.

Beef Cattle		Adjacent to Stream				Nonadjacent to Stream			
Sub ID	Total	Large	Medium	Small	Subtotal	Large	Medium	Small	Subtotal
01	4	0	0	2	2	0	0	2	2
02	5	1	0	1	2	0	0	3	3
0201	3	0	0	1	1	0	0	2	2
03	4	0	2	0	2	0	0	2	2
04	3	0	0	1	1	0	0	2	2
0401	5	1	0	2	3	0	0	2	2
05	0	0	0	0	0	0	0	0	0
0501	5	0	1	1	2	0	0	3	3
06	0	0	0	0	0	0	0	0	0
0601	2	0	0	1	1	0	0	1	1
07	4	0	0	2	2	0	0	2	2
0701	4	0	0	3	3	0	0	1	1
0702	3	0	0	3	3	0	0	0	0
08	2	0	0	1	1	0	0	1	1
0801	4	0	1	2	3	0	0	1	1
0802	1	0	0	1	1	0	0	0	0
080201	4	0	2	1	3	0	0	1	1
0803	4	0	1	2	3	0	0	1	1
080301	2	0	0	2	2	0	0	0	0
Total	59	2	7	26	35	0	0	24	24

Table 2.7. Summary statistics for dairy sites located within Pond Creek watershed.

Dairy Sites		Adjacent to Stream		
Sub ID	**Total**	**Large**	**Medium**	**Small**
01	0	0	0	0
02	0	0	0	0
0201	1	0	1	0
03	1	1	0	0
04	1	1	0	0
0401	0	0	0	0
05	0	0	0	0
0501	2	1	1	0
06	0	0	0	0
0601	3	2	1	0
07	0	0	0	0
0701	1	1	0	0
0702	0	0	0	0
08	1	1	0	0
0801	0	0	0	0
0802	0	0	0	0
080201	1	1	0	0
0803	1	1	0	0
080301	0	0	0	0
Total	12	9	3	0

Table 2.8. Summary statistics for horse sites located within Pond Creek watershed.

Horse Sites		Nonadjacent to Stream		
Sub ID	**Total**	**Large**	**Medium**	**Small**
01	1	0	0	1
02	1	0	0	1
0201	0	0	0	0
03	1	0	0	1
04	0	0	0	0
0401	0	0	0	0
05	0	0	0	0
0501	0	0	0	0
06	0	0	0	0
0601	0	0	0	0
07	0	0	0	0
0701	0	0	0	0
0702	1	0	0	1
08	0	0	0	0
0801	0	0	0	0
0802	0	0	0	0
080201	1	0	1	0
0803	0	0	0	0
080301	2	0	0	2
Total	7	0	1	6

An additional note of concern from livestock operations is the identification of failing, or improperly managed, manure systems. On-site tours of the study area have identified six manure storing systems that are failing and are presently, or have the potential to be, contributing additional nutrients and/or pathogens to the watershed.

As with suspect septic systems, as defined in Section 2.1 above, additional field verification would be prudent to further make any claims on absolute condition of these failing or improperly managed manure systems. Additionally, field testing should be conducted to identify the magnitude of any additional pollutant loading from these structures.

Wildlife population

Estimates of local wildlife populations are presented in Table 2.9, with a total estmation of 308 animals. These figures, unlike livestock figures, are not static as most wildlife is transient with no regard to watershed boundaries. Subwatershed 03 is estimated to contain the largest population of wildlife at 38 animals, followed by 02 and 04 at 29 animals each. These areas hold the greatest area of forested land, which is, in the current model, the primary habitat for terrestrial wildlife. Area 04 is also estimated to contain the largest land class of wetland throughout the entire study area at 59 acres.

Table 2.9. Summary statistics for wildlife estimates within Pond Creek watershed based on land use (in acres) and estimated animal density.

Sub ID	Forest	Cropland	Wetland	total applicable land	number of wildlife
01	457.45	0	0	457.45	16
02	784.92	22.39	0	807.31	29
0201	403.32	1.26	0	404.59	15
03	919.14	147.89	0.39	1067.43	38
04	563.45	180.76	59.42	803.64	29
0401	169.32	64.66	6.46	240.43	9
05	21.79	24.36	15.11	61.26	2
0501	253.1	418.37	19.21	690.68	25
06	0.03	0	2.66	2.69	0
0601	656.79	23.57	0.72	681.08	24
07	175.49	53	15.72	244.22	9
0701	371.09	112.34	13.84	497.27	18
0702	226.28	7.67	10.14	244.1	9
08	587.37	69.45	10.85	667.66	24
0801	375.09	218.28	9.58	602.95	22
0802	62.67	5.3	0	67.97	2
080201	233.21	42.07	3.41	278.69	10
0803	192.61	166.23	0.34	359.19	13
080301	379.33	0	6.23	385.56	14
totals	6832.45	1557.6	174.08	8564.17	308

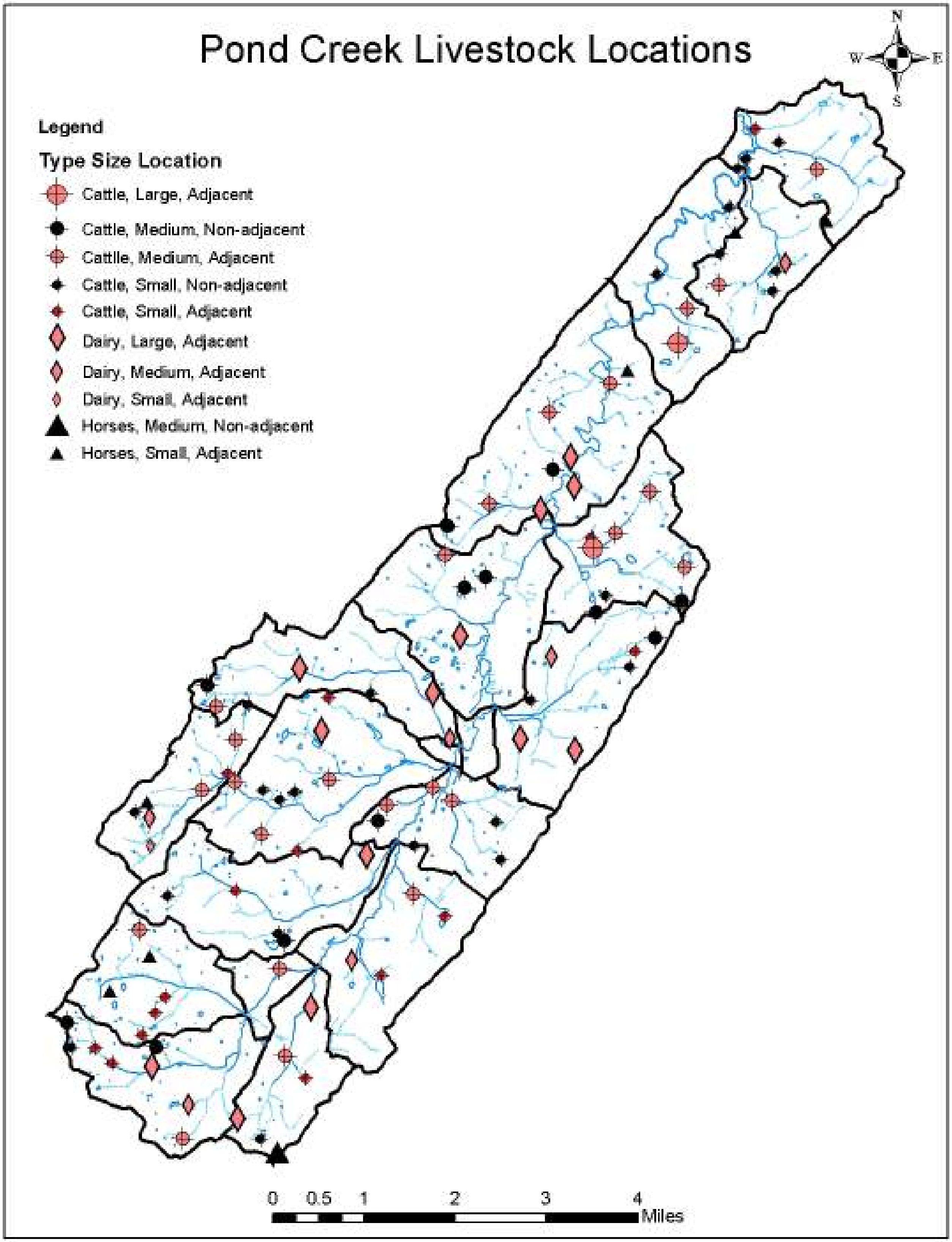

Figure 2.9. Locations and classifications of livestock operations within Pond Creek watershed.

3.0 Soil Loss Estimates

Using RUSLE parameters and coefficients referenced in the methodology of Section 1.3, the estimated soil loss for all of Pond Creek watershed is 43,253 tons/yr, which corresponds to 1.83 tons/acre/year. The estimated soil loss from select land use categories are given in Tables 3.1 and 3.2. As estimated soil loss is derived from RUSLE coefficients defined in Table 1.6, an analysis was conducted to identify effects of C factors on soil loss expressed as tons/ac/yr. Overall, there exists a strong relationship between the two values (r^2 = 0.976, $P \leq 0.001$) yielding a regression equation of:

Soil Loss (tons/ac/yr) = (C factor x 28.109) - 0.510

Another way to visualize the relationship between site condition and soil loss is through the representation of percent ground cover on each site. As ground cover is a primary component of RUSLE C factors, a strong relationship exists between % ground cover and soil loss expressed as tons/ac/yr (r^2 = 0.914, P =0.044, Figure 3.1). The regression equation for this relationship is as follows:

Soil Loss (tons/ac/yr) = 9.384 - (% ground cover x 0.107)

Care should be taken when expressing differences in soil loss values across land use classes. That is, annual soil loss per acre is largely a function of C values, and total annual soil loss is largely a function of acreage. To better understand soil loss in these separate contexts, values will be further described in relative (tons/ac/yr) and absolute (tons/yr) terms below. Figures 3.2 and 3.3 display soil loss as both tons/ac/yr and tons/yr for Pond Creek subwatersheds and land classes

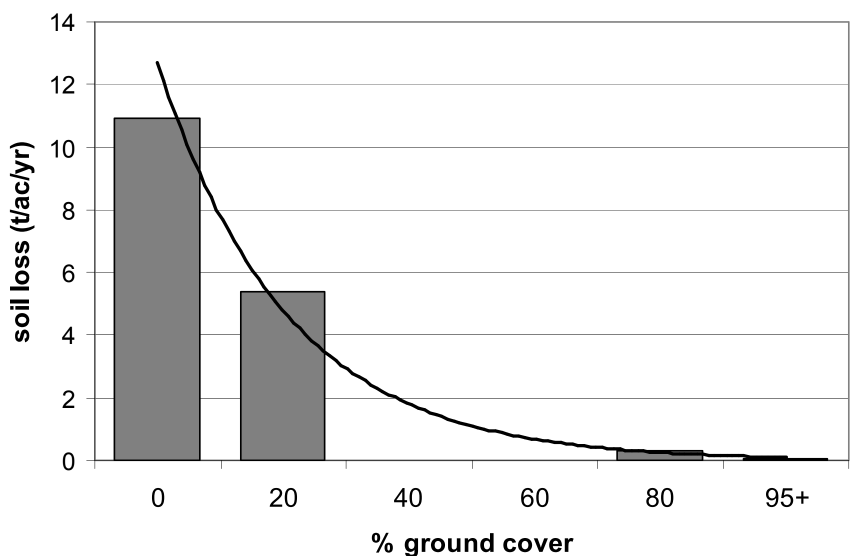

Figure 3.1. Relationship between soil loss estimates (tons/ac/yr) from Pond Creek watershed with percent ground cover values used in RUSLE.

Table 3.1. Estimated soil loss (tons/yr) from select land classes within Pond Creek watershed.

Sub ID	Total load/area	Total Load (tons/yr)	Row Crops			Pasture					Forest				Mine	Disturbed Areas
			Low Residue	High Residue	Medium Residue	Good Pasture	Fair Pasture	Heavily Overgrazed	Poor Pasture	Feedlot	Orchard	Scrub/ shrub	Forest	Clearcut		
01	0.8323	1017.56	0.00	0.00	0.00	3.46	129.31	719.21	0.00	0.00	0.00	1.86	29.07	0.00	0.00	134.65
02	1.0777	1424.58	0.00	0.00	285.80	16.42	120.23	934.87	0.00	0.00	0.00	1.37	65.89	0.00	0.00	0.00
0201	1.0725	1106.54	0.00	0.00	13.04	13.51	125.32	903.45	0.00	23.37	0.00	0.28	27.58	0.00	0.00	0.00
03	2.5301	6156.76	273.22	612.49	209.68	17.47	230.98	4564.88	0.00	112.90	0.00	0.26	65.69	6.40	62.80	0.00
04	2.2656	4340.51	336.33	179.88	737.05	26.93	85.09	1378.72	913.46	74.89	0.06	1.85	24.59	58.48	523.17	0.00
0401	2.6292	3516.49	217.84	198.51	1.70	32.29	59.32	2199.41	256.30	0.00	0.00	1.37	8.16	0.00	541.60	0.00
05	1.4589	258.21	147.85	9.07	0.00	2.53	2.59	95.32	0.00	0.00	0.79	0.00	0.06	0.00	0.00	0.00
0501	2.4162	4000.11	1219.88	660.70	989.08	24.69	104.89	453.55	1.68	532.38	0.00	3.64	9.60	0.00	0.00	0.00
06	0.9672	57.85	0.00	0.00	0.00	0.66	1.68	55.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0601	1.3221	1820.93	0.00	0.00	191.36	18.04	54.93	1353.52	0.00	164.46	0.00	3.88	32.94	1.80	0.00	0.00
07	1.2380	1365.82	104.77	86.03	95.25	10.56	96.11	965.45	0.00	0.00	0.00	1.41	6.25	0.00	0.00	0.00
0701	1.4830	2933.35	580.52	241.99	0.00	28.39	192.51	1718.63	0.00	90.90	0.00	1.94	15.56	62.91	0.00	0.00
0702	0.7670	748.76	0.00	0.00	43.35	11.24	84.33	542.48	0.00	10.19	0.00	0.28	7.68	49.20	0.00	0.00
08	1.4178	2269.20	844.67	13.08	0.00	16.66	138.86	571.44	0.00	122.99	0.00	1.17	19.42	540.90	0.00	0.00
0801	1.6610	2658.12	732.55	250.16	570.32	8.96	120.33	957.25	0.00	0.00	0.00	5.00	13.54	0.00	0.00	0.00
0802	0.9801	312.90	17.27	0.00	23.05	2.54	29.83	160.13	0.00	0.00	0.00	0.48	1.20	78.42	0.00	0.00
080201	1.0833	1021.58	254.04	45.12	69.87	5.90	102.99	318.20	0.00	213.58	0.00	2.46	9.41	0.00	0.00	0.00
0803	1.3994	1911.85	0.00	177.48	712.86	9.37	165.40	625.06	0.00	171.38	0.00	0.87	7.12	42.32	0.00	0.00
080301	0.6557	760.56	0.00	0.00	0.00	5.02	133.21	469.59	0.00	0.00	0.00	2.82	16.75	58.77	74.39	0.00
Total		37681.66	4729	2475	3942	255	1978	18987	1171	1517	0.85	30.94	360.52	899.19	1201.96	134.65
loss/acre	27.257	1.598	12.898	3.810	7.280	0.076	0.335	5.405	10.923	18.324	0.042	0.075	0.059	3.436	25.581	33.129

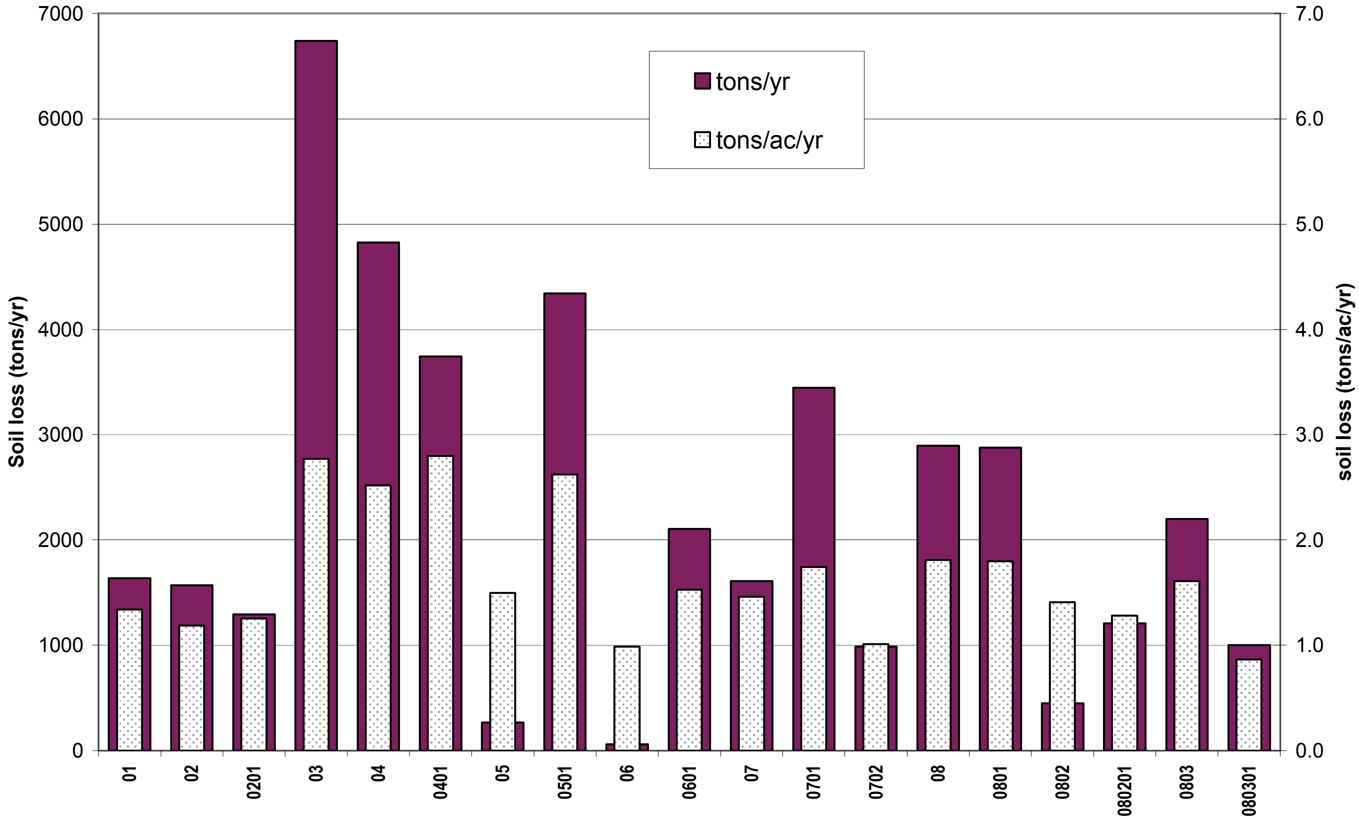

Figure 3.2. Soil loss estimates per subwatershed for all applicable land classes in Pond Creek watershed.

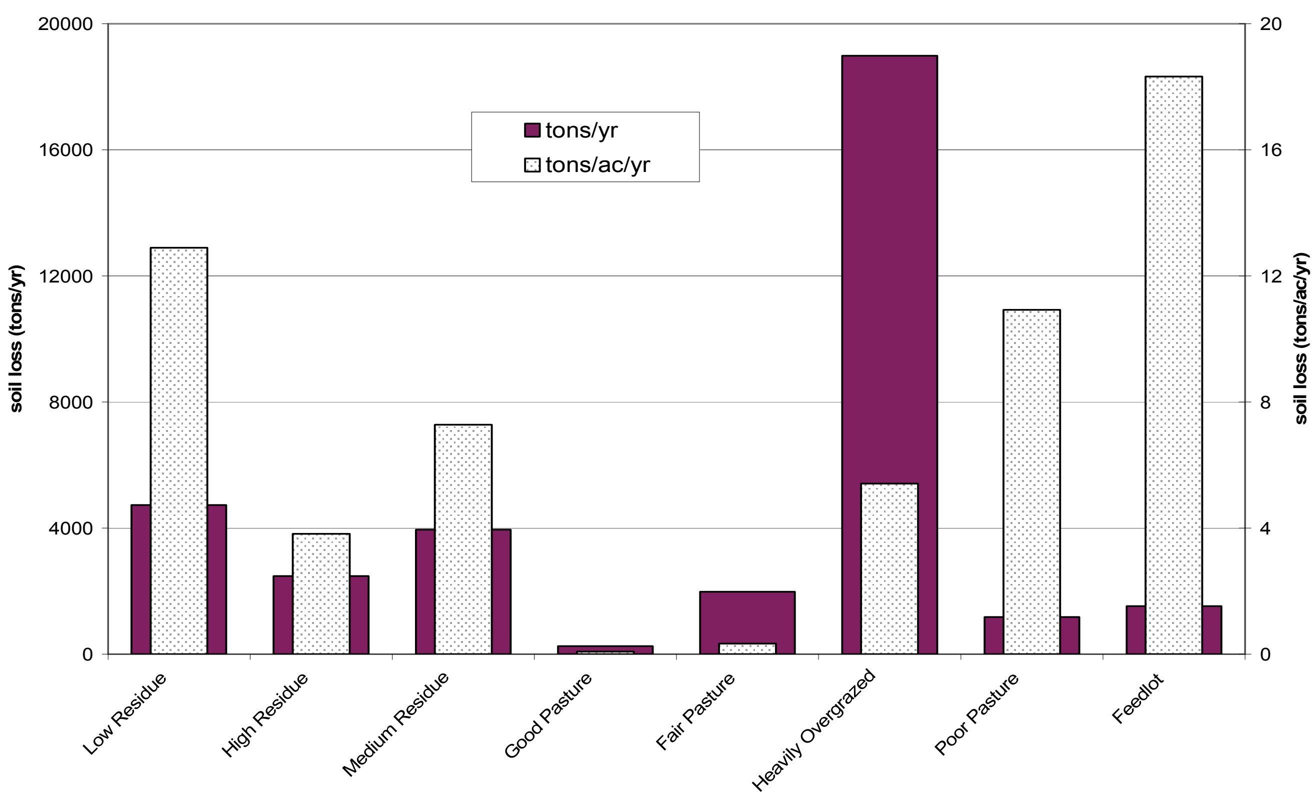

Figure 3.3. Soil loss estimates from agriculture land classes in Pond Creek watershed.

Within the study area, disturbed and mined areas contributed the greatest soil loss per acre at 25.58 and 33.13 tons/ac/yr, respectively (Table 3.1). These elevated values are likely due to high C-factors used in the USLE and the relatively small amount of acreage within the study area. Of the land classes categorized as agriculture, livestock feedlot/loafing areas (18.32 tons/ac/yr), low-residue cropland (12.89), and poor pasture (10.92) contributed the greatest per acre rate of soil loss. Rate of soil loss per acre for cropland nearly doubles from high- to medium-residue and from medium- to low-residue. Good pasture, orchards, forest, and scrub and shrub areas contributed the least amounts of soil loss for the study area, all less than 0.01 ton/ac/yr.

When expressed as absolute tons of soil loss per year over the entire watershed, heavily overgrazed pasture lands were the dominant land class of soil loss (43.9% of all soil loss). The rate of soil loss (tons/ac/yr) for this land class was small, representing only 4.3% of all soil loss per acre. However, the area that this land class occupies within the study area creates a high total loss per watershed (18,987 tons/yr). Other significant sources of annual soil loss are low and medium residue cropland at 10.9% and 9.1%, respectively. Small estimates of soil loss per watershed come from disturbed (0.3%) and mined areas (2.8%); rising from the small percentage of area designated as these land classifications.

Some land uses, such as forest clear-cuts and disturbed areas, are temporary changes to the landscape. Therefore, care should be exercised when comparing annual soil loss from these temporary land changes with long-term land uses such as pasture and crop land. Because aerial photography is used to generate the database, the database is a snapshot in time. A forest clear-cut or construction site present at the time of photography could have revegetated or been completed, while new ones in a different area within the watershed could exist by the time the inventory is completed.

Soil loss estimates for streambanks, road banks, and unpaved roads are presented in Table 3.2. Of these land classes, streambanks have the greatest amount of soil loss (3,840 tons per year), contributing 8.9% of all annual soil loss in the watershed. Estimated soil losses for the study area were greater for paved road banks (1,024 tons per year) than unpaved road banks (708 tons per year). This is likely due to total area of eroding paved road banks also being greater than area of eroding unpaved road, as seen in Table 2.2. As percentage of roadbank erosion is low along Interstate-75, so is tons/year amounts of soil loss for these areas. The IPSI loading model identifies these areas as relatively low contributors of soil loss.

Table 3.2. Soil loss (tons/yr) estimates from streambanks, roadbanks and unpaved roads in Pond Creek watershed.

Sub ID	Total Load (tons/yr)	stream bank	road bank	unpaved road
01	618.47	188.97	246.56	182.95
02	142.92	65.99	41.80	35.14
0201	187.90	141.40	38.51	7.99
03	583.59	552.12	26.54	4.93
04	484.69	297.30	102.65	84.75
0401	226.40	226.40	0.00	0.00
05	6.67	1.81	4.86	0.00
0501	341.69	335.26	6.43	0.00
06	1.15	0.00	1.15	0.00
0601	283.87	182.33	53.97	47.57
07	246.11	219.08	15.23	11.80
0701	511.56	364.99	78.14	68.43
0702	236.73	194.16	26.91	15.66
08	626.91	250.86	211.54	164.51
0801	218.52	206.01	12.51	0.00
0802	136.66	89.80	29.93	16.93
080201	186.41	132.57	33.62	20.22
0803	288.89	240.11	32.54	16.24
080301	242.51	150.82	60.98	30.72
Total	5571.65	3839.97	1023.84	707.84

Estimates of soil loss per acre averaged 1.66 tons/ac/yr throughout the 19 subwatersheds of the study area. Areas with the highest soil loss values were subwatersheds 0401 (2.80 tons/ac/yr), 03 (2.77), 0501 (2.62) and 04 (2.52), as displayed in Figure 3.3.2. These subwatersheds contained high land proportions of pasture and streambank. Subwatershed 03 contains the highest land area of heavily overgrazed pasture and eroding streambank, which partially explains the elevated rate of soil loss per acre here. Areas 04 and 0401 contain the greatest land area of mined lands, and area 0501 has the largest cropland acreage.

Total soil loss by subwatershed averaged 2,276 tons/yr, with large deviations from the mean across the study area (standard deviation of 1,785). Subwatershed 03 was the greatest source of soil loss contributing 6,740 tons soil/yr, due to both high loss per acre and high total acreage. Area 0701 contains the second largest land area, and the greatest area of pasture, however estimates of annual soil loss here was less than that in areas 04 and 0501. A possible explanation for the differences is that area 03 contains the greatest acreage of overgrazed and poor pasture, which is a major source of soil loss, and area 0701 has the greatest areas of good and fair pasture, which is a minimal source (Figures 2.8 and 3.2). The smallest subwatersheds, 05 and 06, contribute the least amount of soil loss to the whole study area, despite having comparable loss per acre values.

4.0 Nonpoint Pollution Sources

The pollutant loads presented in this report were generated using the IPSI system and pollutant loading model described under Methods heading 1.0. The absolute accuracy of these estimates was not determined; however, the estimates provided should be useful for planning purposes (see Model Calibration, Section 6.0). To determine the accuracy of these estimates, timely and consistent comparisons with water quality monitoring data would be required. The pollutant loading model utilized for this report allows for the adjustment of the default equation values as better information on water quality and watershed conditions becomes available or changes with time. The model should prove useful to predict the response to and evaluated potential of NPS management strategies as discussed in subsequent documents.

Pollutant loads were estimated for the following land uses and livestock operations: residential, commercial, industrial, transportation and right-of-way, cropland, pasture, forest, clearcuts, mining, disturbed areas, and beef cattle, dairy and horse operations. Pollutant loads were estimated for the following pollutants: total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS), as these are currently, or have the potential to be, sources of impairment. Pollution loads were estimated for the year 2003 when photography was acquired, with every effort made to include current conditions based on field visits. Data analysis for this purpose is inherently coarse, identifying simple summary statistics of annual loading.

As with soil loss, comparisons of pollutant loads from forest clearcuts, disturbed areas and construction sites with the other sources should be done with caution. There is no doubt that these changes in the landscape contribute substantially to the NPS pollution load. The annual load from these sources, however, is more variable because the sources are not long-term land covers as compared with the other land class sources. To estimate the loads from these sources, information is needed on the rate of establishment and recovery of clear-cutting, mining and construction. Such information was beyond the scope of this study.

Annual pollution loads per acre and total loads for major land use categories within Pond Creek watershed are summarized in Tables 4.1 and 4.2. Annual per-acre estimates of TP, TN, and TSS loads were lowest for forested areas and good and fair pastures. Urban areas contributed greater per-acre loads of TP and TN than agricultural areas in the watershed. Urban areas including residential, commercial and industrial lands contributed nearly 57% of all TP/ac/yr, and 24% of TP/yr. Low residue croplands and livestock loafing areas contributed a less but still substantial TP per acre load. The primary TN loads per acre sources were animal feedlots followed by commercial and industrial lands.

Estimates of TSS load per acre identified disturbed and mined lands as primary sources. Animal loafing areas and low residue croplands also contributed significant amounts of TSS load per acre. A general trend emerged for all pollutants in that as pasture conditions worsen, load per acre increases. Load per acre of each pollutant nearly doubled with a stepwise drop in pasture condition.

Livestock and overgrazed pastures (affiliated with livestock) had the highest annual estimated TN and TSS loads for Pond Creek watershed, cumulatively contributing 35 and 52% of TN and TSS respectively. Agriculture (cropland, pasture and livestock) contributed over 70% of annual TP and TN loads, and nearly 80% of TSS loads. This is in part because a large portion of the study area is in agriculture. Urban areas contributed the second highest annual TP, TN, and TSS loads in the watershed, at 24, 17 and 6% of total annual load respectively. These results are also described in Figures 4.1, 4.3 and 4.5 below. Pollutant load estimates by subwatershed for all land classes are seen in Figures 4.2, 4.4 and 4.7.

Pollutant loads by land class are further defined in Section 4.1 for Urban, 4.2 for Roads and Streambanks, 4.3 for non-agriculture idle lands, 4.4 for Agriculture lands. 4.5 for Livestock, and 4.6 for Wildlife.

Table 4.1. Estimated pollutant loads (tons/ac/yr), percent of total load, and top five rankings for select land use classes within Pond Creek watershed using IPSI tools described in text.

	TP		TN		TSS	
	(ton/ac/yr)	(% of total)	(ton/ac/yr)	(% of total)	(ton/ac/yr)	(% of total)
Urban						
Residential	0.0011	(4) 10.5	0.0103	6.7	2.1798	(5) 9.4
Commercial	0.0031	(1) 30.0	0.0145	(3) 9.3	0.3443	1.5
Industrial	0.0017	(3) 16.6	0.0148	(2) 9.5	0.6429	2.8
ROW	0.0003	3.3	0.0034	2.2	0.1717	0.7
Cropland						
Low Residue	0.0006	(5) 6.2	0.0095	(4) 6.1	2.2135	(4) 9.5
High Residue	0.0002	1.8	0.0027	1.8	0.6344	2.7
Medium Residue	0.0004	3.4	0.0053	3.4	1.2395	5.3
Pasture						
Good Pasture	< 0.0001	< 0.05	0.0001	< 0.05	0.0131	< 0.5
Fair Pasture	< 0.0001	< 0.5	0.0002	< 0.5	0.0583	< 0.5
Overgrazed	0.0003	2.6	0.0040	2.5	0.9234	3.9
Poor Pasture	0.0005	5.1	0.0078	5.0	0.8058	3.5
Feedlot	0.0018	(2) 17.4	0.0673	(1) 43.3	3.1424	(3) 13.5
Forest						
Orchard	< 0.0001	< 0.05	< 0.0001	< 0.05	0.0105	< 0.5
Scrub/shrub	< 0.0001	< 0.05	< 0.0001	< 0.05	0.0130	< 0.5
Forest	< 0.0001	< 0.05	< 0.0001	< 0.05	0.0101	< 0.5
Clearcut	0.0001	0.8	0.0009	0.6	0.6043	2.6
Other						
Mine	0.0002	1.5	0.0062	4.0	4.3377	(2) 18.6
Disturbed	0.0001	0.7	0.0085	(5) 5.5	5.9301	(1) 25.5
Total (tons/ac/yr)	0.0103		0.1555		23.2751	

Table 4.2. Estimated pollutant loads (tons/yr), percent of total load, and top five rankings for separate land use classes within Pond Creek watershed using IPSI tools described in text.

	TP		TN		TSS	
	(ton/yr)	(% of total)	(ton/yr)	(% of total)	(ton/yr)	(% of total)
Urban						
Residential	0.5734	(5) 8.0	4.0052	(5) 6.6	210.5549	2.8
Commercial	0.7834	(4)10.9	3.6559	6.0	87.0464	1.2
Industrial	0.3750	5.2	3.2346	5.3	140.6335	1.9
ROW	0.1371	1.9	1.3712	2.2	68.5604	0.9
Cropland						
Low Residue	0.2357	3.3	3.4782	5.7	811.5796	(2) 10.7
High Residue	0.1177	1.6	1.7657	2.9	411.9929	5.4
Medium Residue	0.1918	2.7	2.8768	4.7	671.2496	(3) 8.9
Pasture						
Good Pasture	0.0126	0.2	0.1894	0.3	44.1955	0.6
Fair Pasture	0.0983	1.4	1.4745	2.4	344.0485	(5) 4.5
Overgrazed	0.9266	(3) 12.9	13.8997	(1) 22.7	3243.2717	(1) 42.9
Poor Pasture	0.0556	0.8	0.8334	1.4	86.4224	1.1
Feedlot	0.1487	2.1	5.5746	(3) 9.1	260.1502	3.4
Forest						
Orchard	<0.0001	< 0.01	0.0009	< 0.01	0.2136	< 0.01
Scrub/shrub	0.0008	< 0.01	0.0077	0.01	5.4072	0.1
Forest	0.0089	0.1	0.0885	0.1	61.9732	0.8
Clearcut	0.0226	0.3	0.2260	0.4	158.1681	2.1
Other						
Mine	0.0291	0.4	0.2912	0.5	203.8108	2.7
Disturbed	0.0034	0.0	0.0344	0.1	24.1026	0.3
Streambank	0.0947	1.3	0.9465	1.6	378.6123	(4) 5.0
Road Bank	0.0257	0.4	0.2573	0.4	102.9197	1.4
Unpaved Road	0.0176	0.2	0.1765	0.3	70.5926	0.9
Livestock						
Beef Cattle	1.6739	(1) 23.3	5.3965	(4) 8.8	55.9207	0.7
Dairy	1.6577	(2) 23.0	11.3853	(2) 18.6	123.1358	1.6
Horse	0.0011	< 0.1	0.0026	< 0.01	0.0526	< 0.01
Wildlife	0.0013	< 0.1	0.0024	< 0.01	0.1472	< 0.01
Total	7.1927		61.1728		7564.6148	

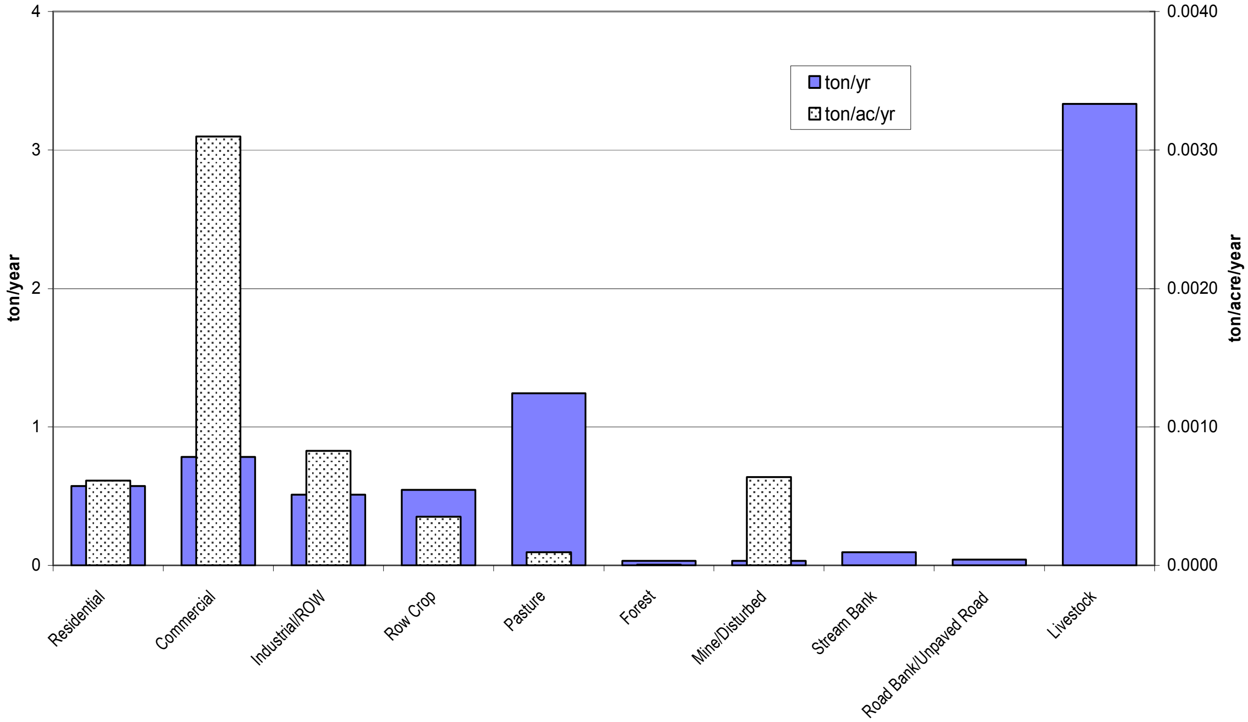

Figure 4.1. Total phosphorus loading by source for Pond Creek watershed expressed as tons/year and tons/acre/year.

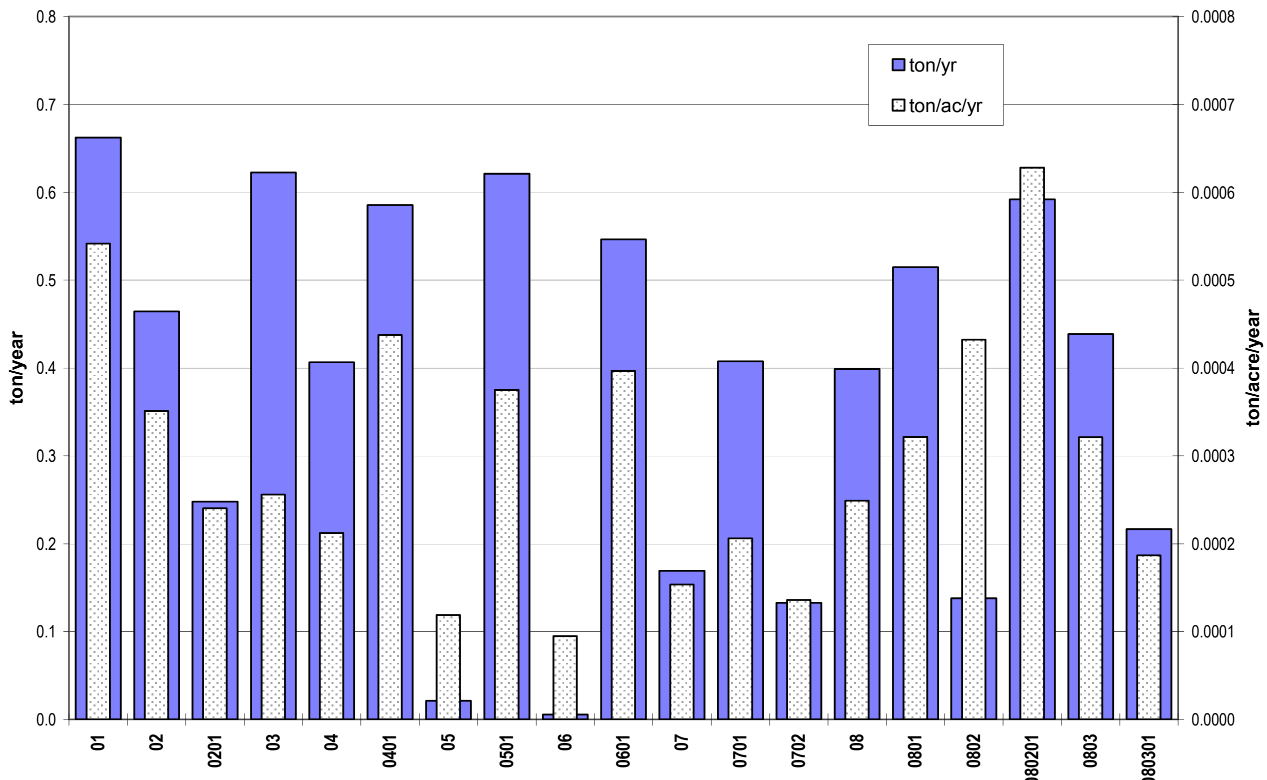

Figure 4.2. Total phosphorus loading by subwatershed within Pond Creek watershed.

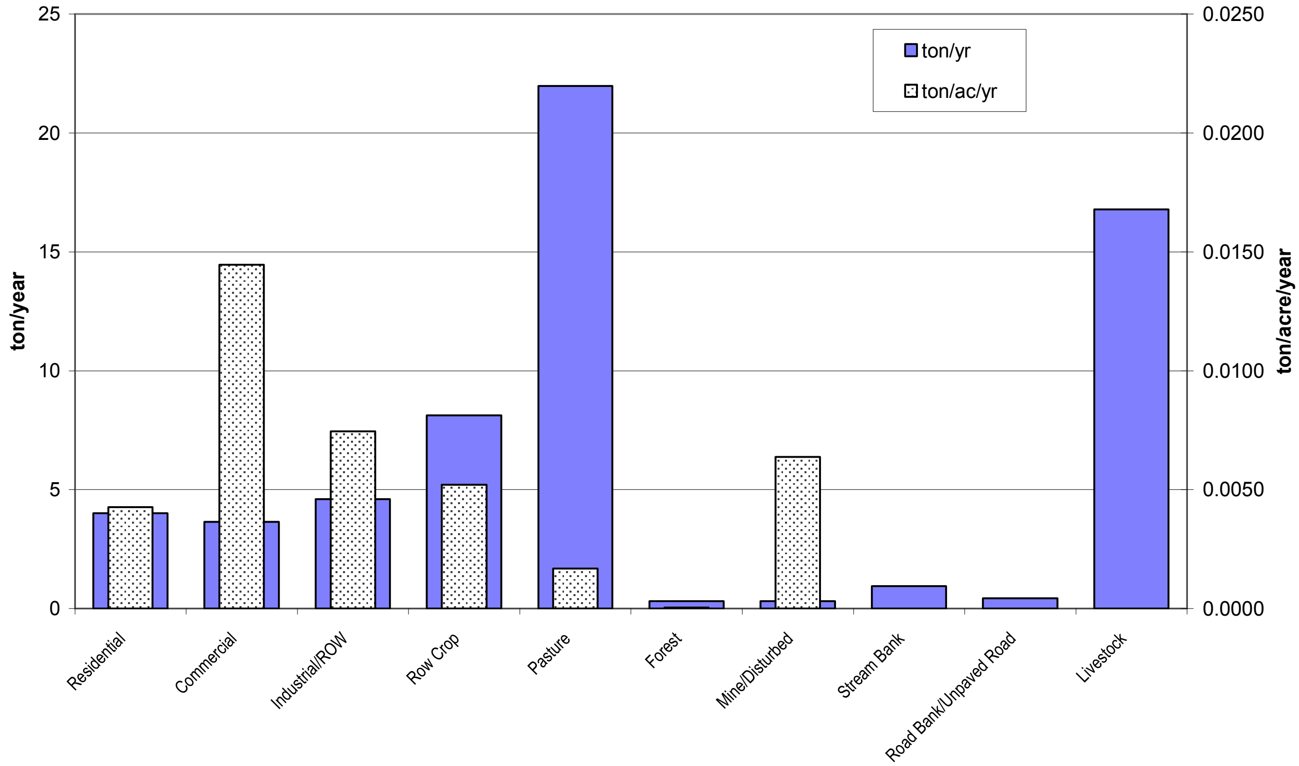

Figure 4.3. Total nitrogen loading by source for Pond Creek watershed expressed as tons/year and tons/acre/year.

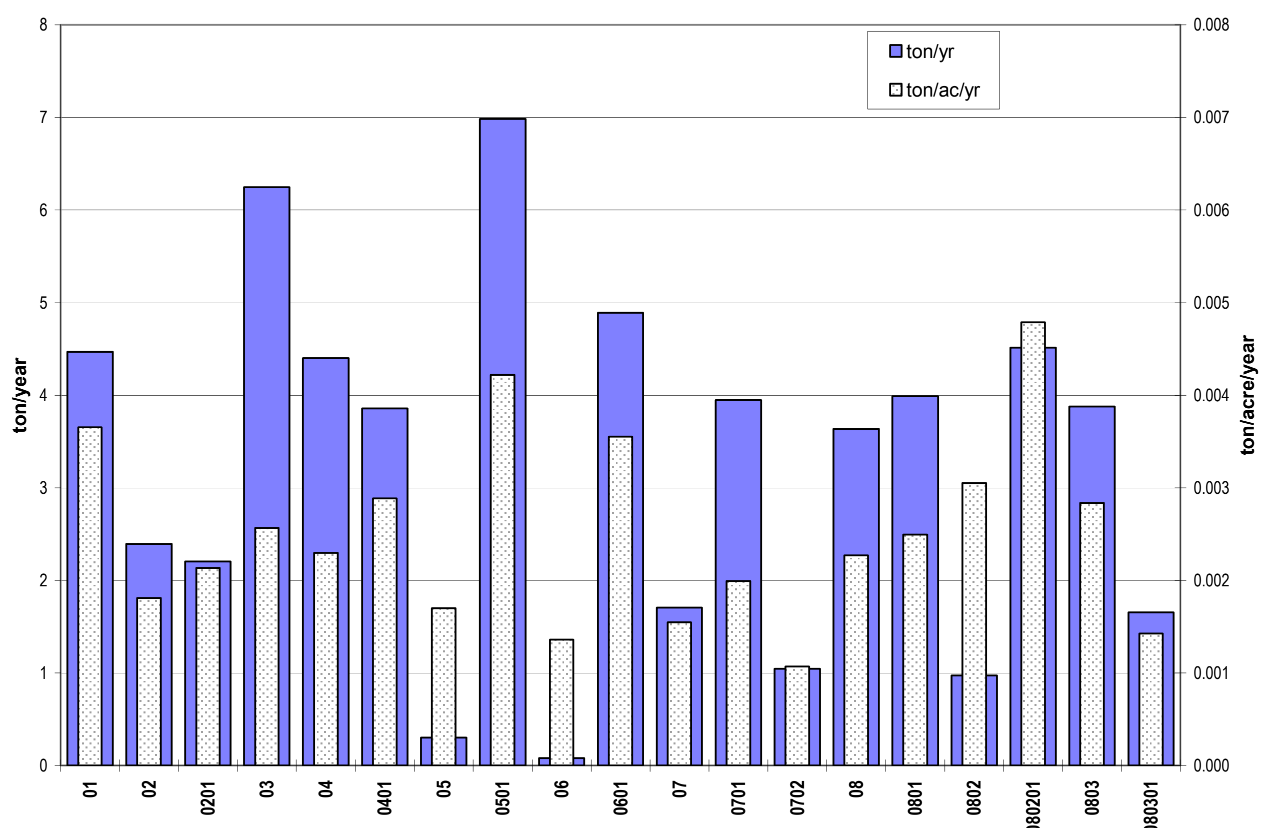

Figure 4.4. Total nitrogen loading by subwatershed within Pond Creek watershed.

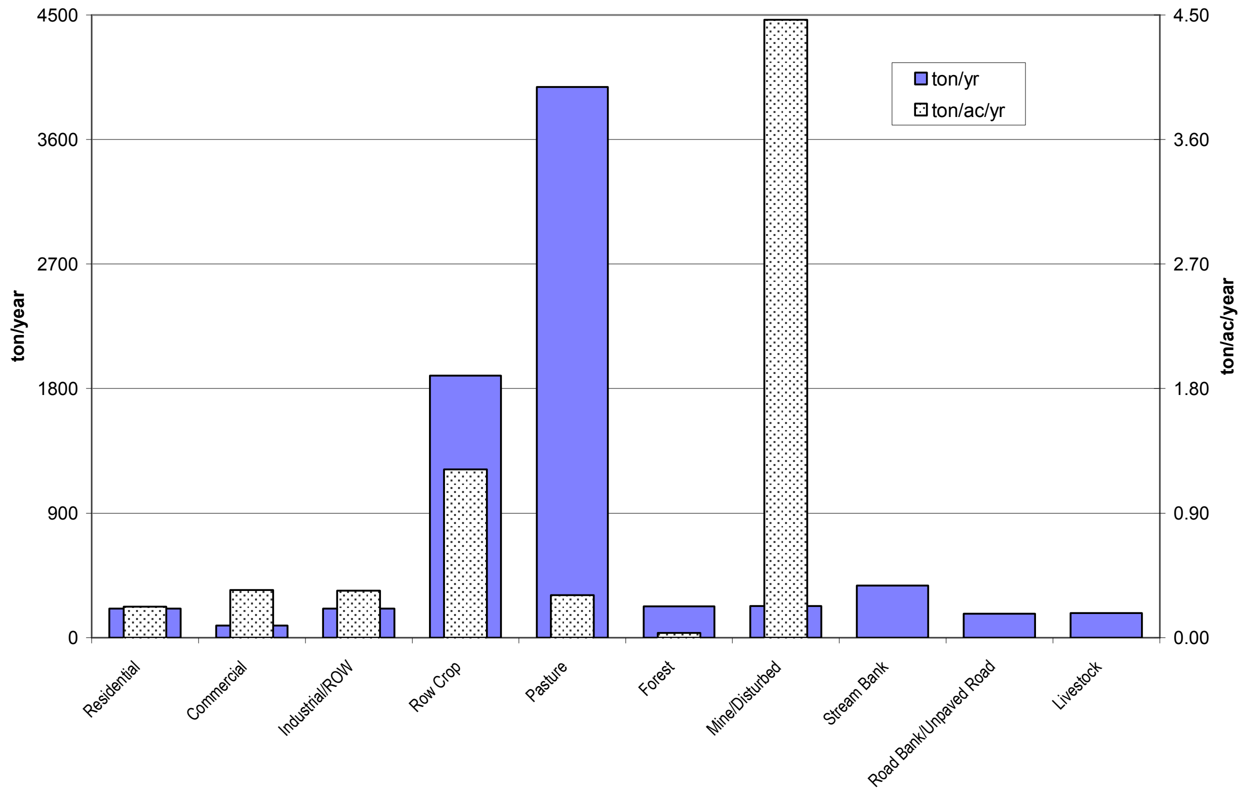

Figure 4.5. Total suspended solids loading by source for Pond Creek watershed expressed as tons/year and tons/acre/year.

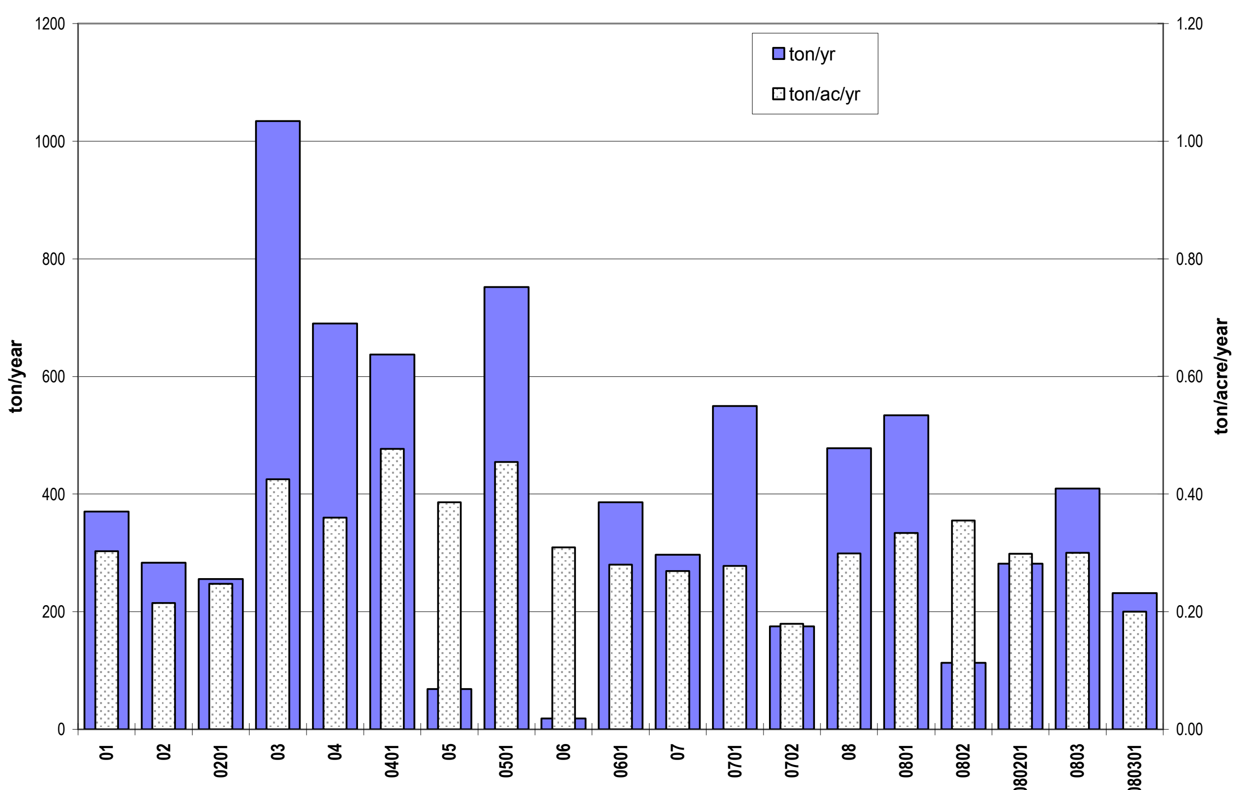

Figure 4.6. Total suspended solids loading by subwatershed within Pond Creek watershed.

4.1 Pollutant loads from urban land classes

Estimates of total annual TP, TN, and TSS loads from urban land classes were highly dependent on total area designated as urban. Residential lands in areas 03, 0701, 08 and 080301 were the leading sources of all pollutants measured. These four areas also contained the greatest acreage of residential lands. This correlation holds true for commercial and industrial lands with estimates of TP, TN, and TSS. Subwatersheds that contained large areas of commercial and industrial designated lands, specifically areas 01, 0801, 0802 and 0803, held greater load per year estimates. Commercial lands contribute the greatest TP load/ac/yr. Pollutant load estimates for urban land classes are displayed in Tables 4.3, 4.4 and 4.5.

Table 4.3. Total phosphorus load (ton/yr) for urban land classifications in Pond Creek watershed.

Watershed ID	Residential		Commercial/Industrial		
	Residential	Residential Construction	Commercial	Industrial	ROW
01	0.0285	0.0007	0.3312	0.1991	0.0016
02	0.0176	0.0000	0.0000	0.0000	0.0014
0201	0.0269	0.0000	0.0233	0.0328	0.0024
03	0.0331	0.0000	0.0000	0.0000	0.0009
04	0.0195	0.0000	0.0059	0.0000	0.0004
0401	0.0163	0.0000	0.0000	0.0000	0.0088
05	0.0018	0.0000	0.0000	0.0000	0.0000
0501	0.0270	0.0000	0.0067	0.0000	0.0343
06	0.0004	0.0000	0.0000	0.0000	0.0000
0601	0.0222	0.0000	0.0000	0.0000	0.0057
07	0.0239	0.0000	0.0000	0.0176	0.0133
0701	0.0461	0.0000	0.0000	0.0000	0.0000
0702	0.0231	0.0000	0.0116	0.0000	0.0000
08	0.0504	0.0000	0.0545	0.0000	0.0000
0801	0.0411	0.0000	0.1678	0.0348	0.0312
0802	0.0113	0.0000	0.0533	0.0314	0.0019
080201	0.0133	0.0000	0.1028	0.0593	0.0281
0803	0.0610	0.0031	0.0000	0.0000	0.0000
080301	0.0982	0.0078	0.0264	0.0000	0.0071
Total load	0.5618	0.0116	0.7834	0.3750	0.1371
Load/acre	0.00061	0.00047	0.00310	0.00171	0.00034

Table 4.4. Total nitrogen load (ton/yr) for urban land classifications of Pond Creek watershed.

Watershed ID	Residential		Commercial/Industrial		
	Residential	Residential Construction	Commercial	Industrial	ROW
01	0.1955	0.0096	1.5456	1.7174	0.0164
02	0.1205	0.0000	0.0000	0.0000	0.0135
0201	0.1848	0.0000	0.1085	0.2830	0.0235
03	0.2273	0.0000	0.0000	0.0000	0.0095
04	0.1340	0.0000	0.0273	0.0000	0.0044
0401	0.1116	0.0000	0.0000	0.0000	0.0879
05	0.0121	0.0000	0.0000	0.0000	0.0000
0501	0.1849	0.0000	0.0312	0.0000	0.3431
06	0.0030	0.0000	0.0000	0.0000	0.0000
0601	0.1525	0.0000	0.0000	0.0000	0.0566
07	0.1637	0.0000	0.0000	0.1521	0.1331
0701	0.3162	0.0000	0.0000	0.0000	0.0000
0702	0.1582	0.0000	0.0542	0.0000	0.0000
08	0.3458	0.0000	0.2544	0.0000	0.0000
0801	0.2819	0.0000	0.7829	0.3000	0.3123
0802	0.0774	0.0000	0.2485	0.2704	0.0188
080201	0.0909	0.0000	0.4799	0.5117	0.2811
0803	0.4184	0.0411	0.0000	0.0000	0.0000
080301	0.6735	0.1023	0.1234	0.0000	0.0710
Total load	3.8521	0.1531	3.6559	3.2346	1.3712
Load/acre	0.00422	0.00613	0.01446	0.01479	0.00343

Table 4.5. Total suspended solids load (ton/yr) for urban land classifications of Pond Creek watershed.

Watershed ID	Residential		Commercial/Industrial		
	Residential	Residential Construction	Commercial	Industrial	ROW
01	8.147	3.141	36.801	74.670	0.820
02	5.021	0.000	0.000	0.000	0.676
0201	7.699	0.000	2.583	12.305	1.177
03	9.471	0.000	0.000	0.000	0.474
04	5.582	0.000	0.650	0.000	0.220
0401	4.648	0.000	0.000	0.000	4.397
05	0.505	0.000	0.000	0.000	0.000
0501	7.703	0.000	0.742	0.000	17.153
06	0.126	0.000	0.000	0.000	0.000
0601	6.353	0.000	0.000	0.000	2.831
07	6.822	0.000	0.000	6.614	6.657
0701	13.175	0.000	0.000	0.000	0.000
0702	6.590	0.000	1.290	0.000	0.000
08	14.407	0.000	6.058	0.000	0.000
0801	11.744	0.000	18.642	13.042	15.616
0802	3.227	0.130	5.917	11.756	0.939
080201	3.787	0.000	11.425	22.246	14.054
0803	17.435	13.414	0.000	0.000	0.000
080301	28.063	33.365	2.938	0.000	3.548
Total load	160.504	50.050	87.046	140.634	68.560
Load/ac	0.176	2.004	0.344	0.643	0.172

4.2 Pollutant loads from roads, roadbanks and streambanks

Total annual pollutant load estimates for streambank, roadbank and unpaved roads are defined in Tables 4.6, 4.7, and 4.8. Estimates of annual TP, TN, and TSS loads from streambanks were largely a function of amount of eroding streambank, which is not constant throughout Pond Creek watershed as seen in Figure 2.4. Areas 03, 04, 0501, and 0701 had the greatest area of eroding streambank, which correlated with areas with greater volumes of pollutants entering the stream.

As with streambanks, annual pollutant loads from roadbanks had more to do with condition of roads rather than area or length of roads. Subwatersheds 01 and 08 consistently contributed the greatest amounts of TP, TN, and TSS, irrespective of not having the greatest areas or lengths of roads. Areas 0501 and 0801 hold the greatest expanse of paved and unpaved roads at roughly 90,000 ft and 83,000 ft respectively, including US Interstate-75, yet do not contribute a comparatively large load of pollutant.

Table 4.6. Total phosphorus load (ton/yr) for non-agriculture or urban land classifications in Pond Creek watershed.

	Forest								
Watershed ID	Orchard	Scrub/ shrub	Forest	Clearcut	Mine	Disturbed Areas	stream bank	road bank	unpaved road
01	0.0000	0.0000	0.0007	0.0000	0.0000	0.0034	0.0048	0.0063	0.0047
02	0.0000	0.0000	0.0017	0.0000	0.0000	0.0000	0.0017	0.0011	0.0009
0201	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0037	0.0010	0.0002
03	0.0000	0.0000	0.0015	0.0001	0.0014	0.0000	0.0122	0.0006	0.0001
04	0.0000	0.0000	0.0006	0.0014	0.0122	0.0000	0.0069	0.0024	0.0020
0401	0.0000	0.0000	0.0002	0.0000	0.0136	0.0000	0.0057	0.0000	0.0000
05	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0000
0501	0.0000	0.0001	0.0002	0.0000	0.0000	0.0000	0.0081	0.0002	0.0000
06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
0601	0.0000	0.0001	0.0008	0.0000	0.0000	0.0000	0.0046	0.0013	0.0012
07	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0057	0.0004	0.0003
0701	0.0000	0.0000	0.0004	0.0015	0.0000	0.0000	0.0085	0.0018	0.0016
0702	0.0000	0.0000	0.0002	0.0013	0.0000	0.0000	0.0052	0.0007	0.0004
08	0.0000	0.0000	0.0005	0.0131	0.0000	0.0000	0.0061	0.0051	0.0040
0801	0.0000	0.0001	0.0003	0.0000	0.0000	0.0000	0.0050	0.0003	0.0000
0802	0.0000	0.0000	0.0000	0.0026	0.0000	0.0000	0.0030	0.0010	0.0006
080201	0.0000	0.0001	0.0003	0.0000	0.0000	0.0000	0.0036	0.0009	0.0005
0803	0.0000	0.0000	0.0002	0.0011	0.0000	0.0000	0.0060	0.0008	0.0004
080301	0.0000	0.0001	0.0004	0.0015	0.0019	0.0000	0.0039	0.0016	0.0008
Total load	0.0000	0.0008	0.0089	0.0226	0.0291	0.0034	0.0947	0.0257	0.0176
Load/acre	0.00000	0.00000	0.00000	0.00009	0.00015	0.00007			

Table 4.7. Total nitrogen load (ton/yr) for non-agriculture or urban land classifications of Pond Creek watershed.

Watershed ID	Forest								
	Orchard	Scrub/ shrub	Forest	Clearcut	Mine	Disturbed Areas	stream bank	road bank	unpaved road
01	0.0000	0.0005	0.0074	0.0000	0.0000	0.0344	0.0483	0.0630	0.0468
02	0.0000	0.0003	0.0166	0.0000	0.0000	0.0000	0.0166	0.0105	0.0088
0201	0.0000	0.0001	0.0073	0.0000	0.0000	0.0000	0.0374	0.0102	0.0021
03	0.0000	0.0001	0.0146	0.0014	0.0139	0.0000	0.1224	0.0059	0.0011
04	0.0000	0.0004	0.0057	0.0136	0.1220	0.0000	0.0693	0.0239	0.0198
0401	0.0000	0.0003	0.0021	0.0000	0.1360	0.0000	0.0568	0.0000	0.0000
05	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0018	0.0000
0501	0.0000	0.0009	0.0023	0.0000	0.0000	0.0000	0.0806	0.0015	0.0000
06	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000
0601	0.0000	0.0010	0.0082	0.0004	0.0000	0.0000	0.0455	0.0135	0.0119
07	0.0000	0.0004	0.0016	0.0000	0.0000	0.0000	0.0572	0.0040	0.0031
0701	0.0000	0.0005	0.0036	0.0146	0.0000	0.0000	0.0846	0.0181	0.0159
0702	0.0000	0.0001	0.0021	0.0132	0.0000	0.0000	0.0519	0.0072	0.0042
08	0.0000	0.0003	0.0047	0.1309	0.0000	0.0000	0.0607	0.0512	0.0398
0801	0.0000	0.0012	0.0033	0.0000	0.0000	0.0000	0.0499	0.0030	0.0000
0802	0.0000	0.0002	0.0004	0.0260	0.0000	0.0000	0.0298	0.0099	0.0056
080201	0.0000	0.0007	0.0025	0.0000	0.0000	0.0000	0.0357	0.0091	0.0054
0803	0.0000	0.0002	0.0018	0.0106	0.0000	0.0000	0.0600	0.0081	0.0041
080301	0.0000	0.0007	0.0043	0.0152	0.0192	0.0000	0.0390	0.0158	0.0079
Total load	0.0009	0.0077	0.0885	0.2260	0.2912	0.0344	0.9465	0.2573	0.1765
Load/ac	0.00005	0.00002	0.00001	0.00086	0.00620	0.00847			

Table 4.8. Total suspended solids load (ton/yr) for non-agriculture or urban land classifications of Pond Creek watershed.

Watershed ID	Orchard	Scrub/ shrub	Forest	Clearcut	Mine	Disturbed Areas	stream bank	road bank	unpaved road
01	0	0.3334	5.2032	0	0	24.1026	19.3296	25.2195	18.7132
02	0	0.2405	11.6102	0	0	0	6.6439	4.2081	3.5376
0201	0	0.0512	5.1085	0	0	0	14.9651	4.0758	0.8461
03	0	0.0402	10.1970	0.9928	9.7480	0	48.9761	2.3543	0.4369
04	0.0095	0.3027	4.0146	9.5472	85.4043	0	27.7324	9.5749	7.9058
0401	0	0.2410	1.4351	0	95.1996	0	22.7399	0.0000	0.0000
05	0.2041	0.0000	0.0164	0	0	0	0.2676	0.7189	0.0000
0501	0	0.6129	1.6161	0	0	0	32.2351	0.6179	0.0000
06	0	0.0000	0.0002	0	0	0	0.0000	0.2065	0.0000
0601	0	0.6775	5.7558	0.3138	0	0	18.2051	5.3890	4.7493
07	0	0.2577	1.1413	0	0	0	22.8776	1.5902	1.2326
0701	0	0.3152	2.5225	10.2012	0	0	33.8204	7.2404	6.3412
0702	0	0.0518	1.4389	9.2132	0	0	20.7766	2.8796	1.6758
08	0	0.1991	3.2905	91.6493	0	0	24.2886	20.4814	15.9287
0801	0	0.8467	2.2946	0	0	0	19.9469	1.2113	0.0000
0802	0	0.1105	0.2776	18.2115	0	0	11.9177	3.9714	2.2467
080201	0	0.4648	1.7740	0	0	0	14.2844	3.6220	2.1791
0803	0	0.1519	1.2468	7.4063	0	0	24.0135	3.2547	1.6240
080301	0	0.5102	3.0298	10.6327	13.4589	0	15.5919	6.3036	3.1756
Total load	0.2136	5.4072	61.9732	158.168	203.810	24.102	378.612	102.919	70.5926
Load/ac	0.0105	0.0130	0.0101	0.6043	4.3377	5.9301	0	0	0

4.3 Pollutant loads from forest, mining and disturbed lands

As with urban land classes, total pollutant loads from forests, mined and disturbed lands were greatest in subwatersheds that contained the greatest acreage of said land classes. Subwatershed 08 had the greatest area of clearcut lands, and contributed the greatest load per year of all pollutants from this land class. Areas 0401 and 04 have the greatest acreage of mined and disturbed lands and contributed the greatest load per year from this land class. Estimates of annual pollutant loads are summarized in Tables 4.6, 4.7, and 4.8 above.

Pollutant load per acre estimates from forested lands were consistently the lowest of all land classes, contributing less than 0.01 ton/ac/yr for all pollutants. Mined and disturbed areas contributed the greatest ton/ac/yr for TSS, likely due to the complete lack of vegetative cover. This suggests that this land class, and practices associated, is the most deleterious of non-agriculture lands regarding pollutant loading expressed per acre. However as this land classification is spatially limited, the magnitude of the pollutant loading from this class is minimal.

4.4 Pollutant loads from agriculture lands

Estimates of total annual pollutant loading from pasture were greater than all other land classes for all pollutants modeled. Loading from crop land consistently ranked high in pollutant loading as well. These results are due to high acreages of lands classified as agriculture, but also due to high loading rate per acre (Table 4.2).

Total annual phosphorus loads were greatest in heavily overgrazed pastures, contributing nearly 0.93 tons/year (Table 4.9). Low and medium residue croplands also had high estimates of load/yr at 0.24 and 0.19 respectively. Pasture feedlots had the highest agriculture load/ac/yr value at 0.0018, and good and fair pasture had the lowest values at ≤ 0.0001 (Figure 4.7).

Total annual nitrogen loads were also greatest for heavily overgrazed lands, contributing nearly 13.9 tons/yr (Table 4.10); far more than any other land class. Pasture feedlots had the highest agriculture load/ac/yr value, and good pastures had the lowest value (Figure 4.8). As with TP, good and fair pastures along with high residue croplands contributed the lowest ton/yr estimates of TN. A stepwise increase in TP and TN load/ac/yr is evident as pasture conditions decrease as seen in Figure 4.8.

TSS loads were greatest for heavily overgrazed lands, contributing 3243 tons/yr; over 40% for the study area (Table 4.11). As above, agriculture feedlots were the greatest TSS tons/ac/yr source at 3.1, and good pasture was the lowest source at 0.0131 ton/ac/yr (Figure 4.9). Low residue cropland is also a significant source of TSS ton/ac/yr and tons/yr.

Table 4.9. Total phosphorus load (ton/yr) for agriculture land classifications of Pond Creek watershed.

Watershed ID	Row Crops			Pasture					Livestock		
	Low Residue	High Residue	Medium Residue	Good	Fair	Heavily Overgrazed	Poor Pasture	Feedlot/ Loafing	Beef	Dairy	Horses
01	0.0000	0.0000	0.0000	0.0002	0.0066	0.0368	0.0000	0.0000	0.037	0.000	0.000
02	0.0000	0.0000	0.0144	0.0008	0.0061	0.0471	0.0000	0.0000	0.372	0.000	0.000
0201	0.0000	0.0000	0.0007	0.0007	0.0066	0.0478	0.0000	0.0025	0.020	0.079	0.000
03	0.0121	0.0272	0.0093	0.0008	0.0102	0.2025	0.0000	0.0100	0.142	0.158	0.000
04	0.0157	0.0084	0.0344	0.0013	0.0040	0.0643	0.0426	0.0070	0.020	0.158	0.000
0401	0.0147	0.0100	0.0001	0.0016	0.0030	0.1105	0.0129	0.0000	0.388	0.000	0.000
05	0.0109	0.0007	0.0000	0.0002	0.0002	0.0070	0.0000	0.0000	0.000	0.000	0.000
0501	0.0586	0.0318	0.0475	0.0012	0.0050	0.0218	0.0001	0.0512	0.091	0.237	0.000
06	0.0000	0.0000	0.0000	0.0001	0.0002	0.0050	0.0000	0.0000	0.000	0.000	0.000
0601	0.0000	0.0000	0.0096	0.0009	0.0027	0.0676	0.0000	0.0164	0.019	0.395	0.000
07	0.0055	0.0045	0.0050	0.0006	0.0050	0.0504	0.0000	0.0000	0.037	0.000	0.000
0701	0.0269	0.0112	0.0000	0.0013	0.0089	0.0796	0.0000	0.0084	0.054	0.158	0.000
0702	0.0000	0.0000	0.0023	0.0006	0.0045	0.0290	0.0000	0.0011	0.053	0.000	0.000
08	0.0409	0.0006	0.0000	0.0008	0.0067	0.0277	0.0000	0.0119	0.019	0.158	0.000
0801	0.0355	0.0121	0.0276	0.0004	0.0058	0.0463	0.0000	0.0000	0.106	0.000	0.000
0802	0.0011	0.0000	0.0015	0.0002	0.0020	0.0106	0.0000	0.0000	0.018	0.000	0.000
080201	0.0137	0.0024	0.0038	0.0003	0.0055	0.0171	0.0000	0.0230	0.159	0.158	0.000
0803	0.0000	0.0089	0.0356	0.0005	0.0083	0.0313	0.0000	0.0171	0.106	0.158	0.000
080301	0.0000	0.0000	0.0000	0.0003	0.0069	0.0243	0.0000	0.0000	0.035	0.000	0.000
Total load	0.2357	0.1177	0.1918	0.0126	0.0983	0.9266	0.0556	0.1487	1.674	1.658	0.001
Load/acre	0.00064	0.00018	0.00035	0.00000	0.00002	0.00026	0.00052	0.0000			

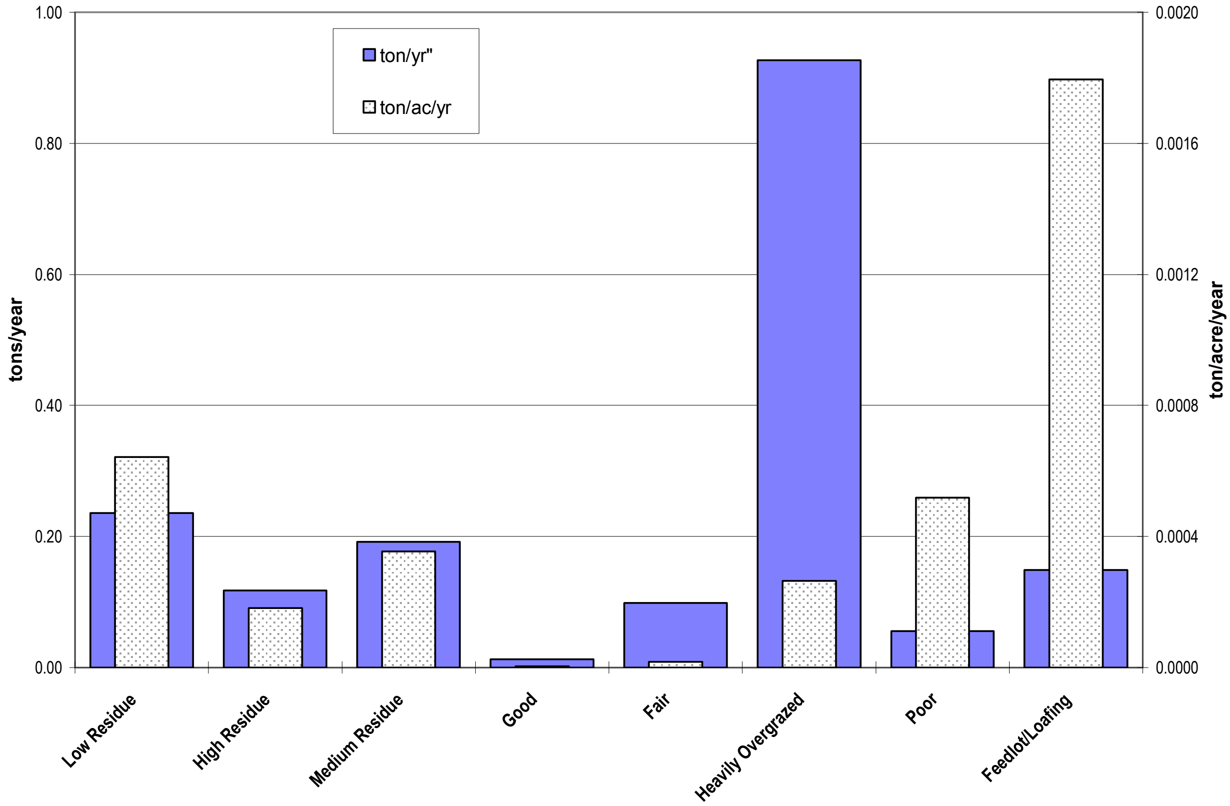

Figure 4.7. Total phosphorus loading by agriculture land classification in Pond Creek watershed.

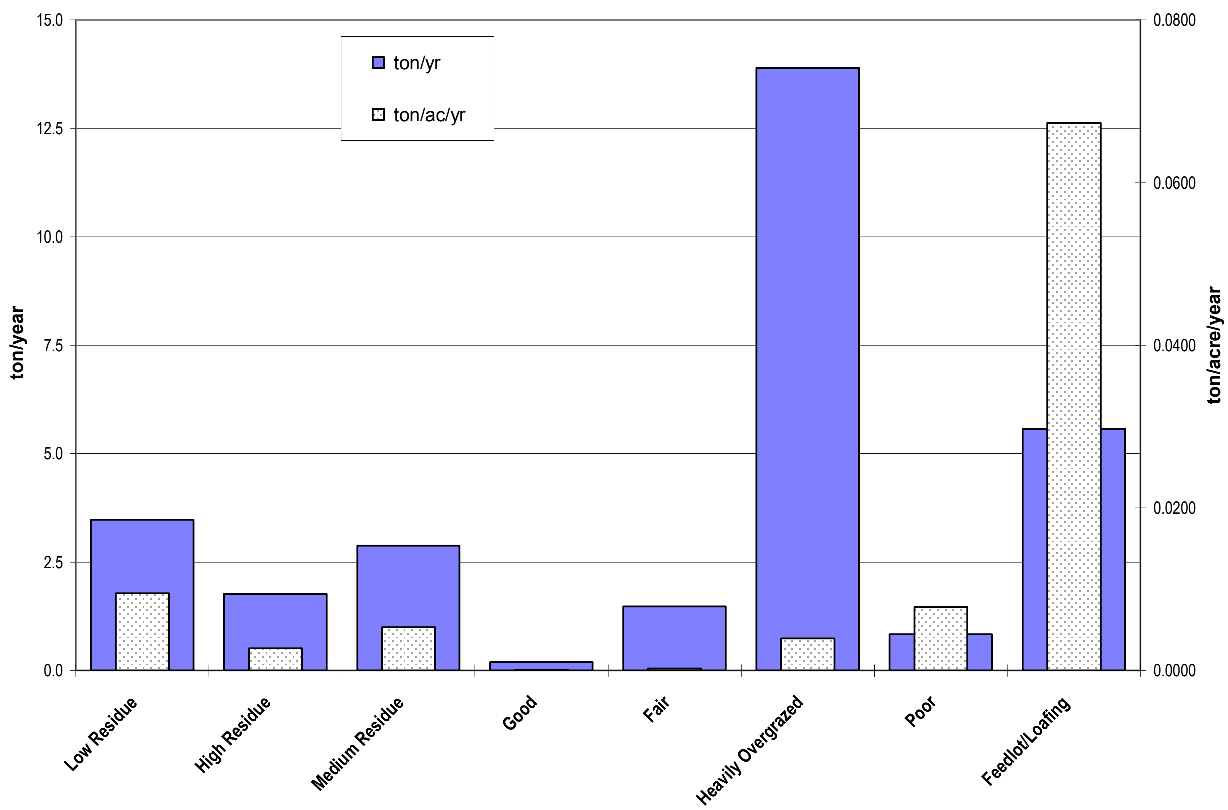

Figure 4.8. Total nitrogen loading by agriculture land classification in Pond Creek watershed.

Table 4.10. Total nitrogen load (ton/yr) for agriculture land classifications of Pond Creek watershed.

Watershed ID	Row Crops			Pasture					Livestock		
	Low Residue	High Residue	Medium Residue	Good	Fair	Heavily Overgrazed	Poor	Feedlot/ Loafing	Beef	Dairy	Horses
01	0.0000	0.0000	0.0000	0.0027	0.0992	0.5517	0.0000	0.0000	0.1291	0.0000	0.0003
02	0.0000	0.0000	0.2158	0.0124	0.0908	0.7059	0.0000	0.0000	1.1830	0.0000	0.0003
0201	0.0000	0.0000	0.0103	0.0107	0.0995	0.7171	0.0000	0.0927	0.0742	0.5422	0.0000
03	0.1818	0.4075	0.1395	0.0116	0.1537	3.0370	0.0000	0.3756	0.4587	1.0844	0.0003
04	0.2353	0.1258	0.5157	0.0188	0.0595	0.9646	0.6391	0.2620	0.0740	1.0844	0.0000
0401	0.1641	0.1495	0.0013	0.0243	0.0447	1.6569	0.1931	0.0000	1.2280	0.0000	0.0000
05	0.1640	0.0101	0.0000	0.0028	0.0029	0.1057	0.0000	0.0000	0.0000	0.0000	0.0000
0501	0.8797	0.4764	0.7132	0.0178	0.0756	0.3271	0.0012	1.9196	0.3035	1.6264	0.0000
06	0.0000	0.0000	0.0000	0.0009	0.0023	0.0746	0.0000	0.0000	0.0000	0.0000	0.0000
0601	0.0000	0.0000	0.1433	0.0135	0.0411	1.0136	0.0000	0.6158	0.0645	2.7109	0.0000
07	0.0821	0.0674	0.0746	0.0083	0.0753	0.7561	0.0000	0.0000	0.1290	0.0000	0.0000
0701	0.4034	0.1682	0.0000	0.0197	0.1338	1.1944	0.0000	0.3158	0.1745	1.0844	0.0000
0702	0.0000	0.0000	0.0348	0.0090	0.0677	0.4354	0.0000	0.0409	0.1650	0.0000	0.0003
08	0.6134	0.0095	0.0000	0.0121	0.1008	0.4150	0.0000	0.4466	0.0645	1.0844	0.0000
0801	0.5320	0.1817	0.4142	0.0065	0.0874	0.6951	0.0000	0.0000	0.3395	0.0000	0.0000
0802	0.0172	0.0000	0.0229	0.0025	0.0297	0.1594	0.0000	0.0000	0.0550	0.0000	0.0000
080201	0.2053	0.0365	0.0565	0.0048	0.0832	0.2571	0.0000	0.8630	0.5045	1.0840	0.0008
0803	0.0000	0.1331	0.5347	0.0070	0.1241	0.4688	0.0000	0.6428	0.3395	1.0840	0.0000
080301	0.0000	0.0000	0.0000	0.0039	0.1033	0.3641	0.0000	0.0000	0.1100	0.0000	0.0006
Total load	3.4782	1.7657	2.8768	0.1894	1.4745	13.8997	0.8334	5.5746	5.3965	11.3853	0.0026
Load/ac	0.0095	0.0027	0.0053	0.0001	0.00025	0.0040	0.0078	0.06734			

Table 4.11. Total suspended solids load/yr and load/ac/yr for agriculture land classifications of Pond Creek watershed.

Watershed ID	Row Crops			Pasture					Livestock		
	Low Residue	High Residue	Medium Residue	Good	Fair	Heavily Overgrazed	Poor Pasture	Feedlot/ Loafing	Beef	Dairy	Horses
01	0.000	0.000	0.000	0.619	23.146	128.741	0.000	0.000	1.3005	0.000	0.006
02	0.000	0.000	50.356	2.893	21.184	164.720	0.000	0.000	12.3184	0.000	0.006
0201	0.000	0.000	2.415	2.503	23.210	167.331	0.000	4.328	0.7240	5.864	0.000
03	42.413	95.079	32.550	2.712	35.856	708.624	0.000	17.526	4.7559	11.727	0.006
04	54.903	29.363	120.319	4.397	13.891	225.067	66.274	12.225	0.7240	11.727	0.000
0401	38.290	34.893	0.298	5.675	10.428	386.603	20.023	0.000	12.8200	0.000	0.000
05	38.273	2.348	0.000	0.655	0.669	24.675	0.000	0.000	0.0000	0.000	0.000
0501	205.260	111.172	166.424	4.155	17.650	76.316	0.125	89.580	3.1019	17.591	0.000
06	0.000	0.000	0.000	0.207	0.527	17.414	0.000	0.000	0.0000	0.000	0.000
0601	0.000	0.000	33.436	3.152	9.599	236.502	0.000	28.736	0.6500	29.318	0.000
07	19.146	15.722	17.406	1.929	17.564	176.433	0.000	0.000	1.3000	0.000	0.000
0701	94.136	39.241	0.000	4.603	31.218	278.692	0.000	14.740	1.8020	11.727	0.000
0702	0.000	0.000	8.118	2.106	15.793	101.588	0.000	1.909	1.7280	0.000	0.006
08	143.121	2.216	0.000	2.823	23.529	96.824	0.000	20.840	0.6500	11.727	0.000
0801	124.126	42.388	96.637	1.518	20.390	162.201	0.000	0.000	3.5300	0.000	0.000
0802	4.010	0.000	5.353	0.589	6.928	37.190	0.000	0.000	0.5760	0.000	0.000
080201	47.902	8.509	13.175	1.112	19.420	60.000	0.000	40.273	5.2580	11.727	0.017
0803	0.000	31.063	124.762	1.640	28.947	109.395	0.000	29.995	3.5300	11.727	0.000
080301	0.000	0.000	0.000	0.909	24.100	84.956	0.000	0.000	1.1520	0.000	0.012
Total load	811.580	411.993	671.250	44.196	344.049	3243.272	86.422	260.150	55.9207	123.136	0.053
Load/ac	2.213	0.634	1.240	0.013	0.058	0.923	0.806	3.142			

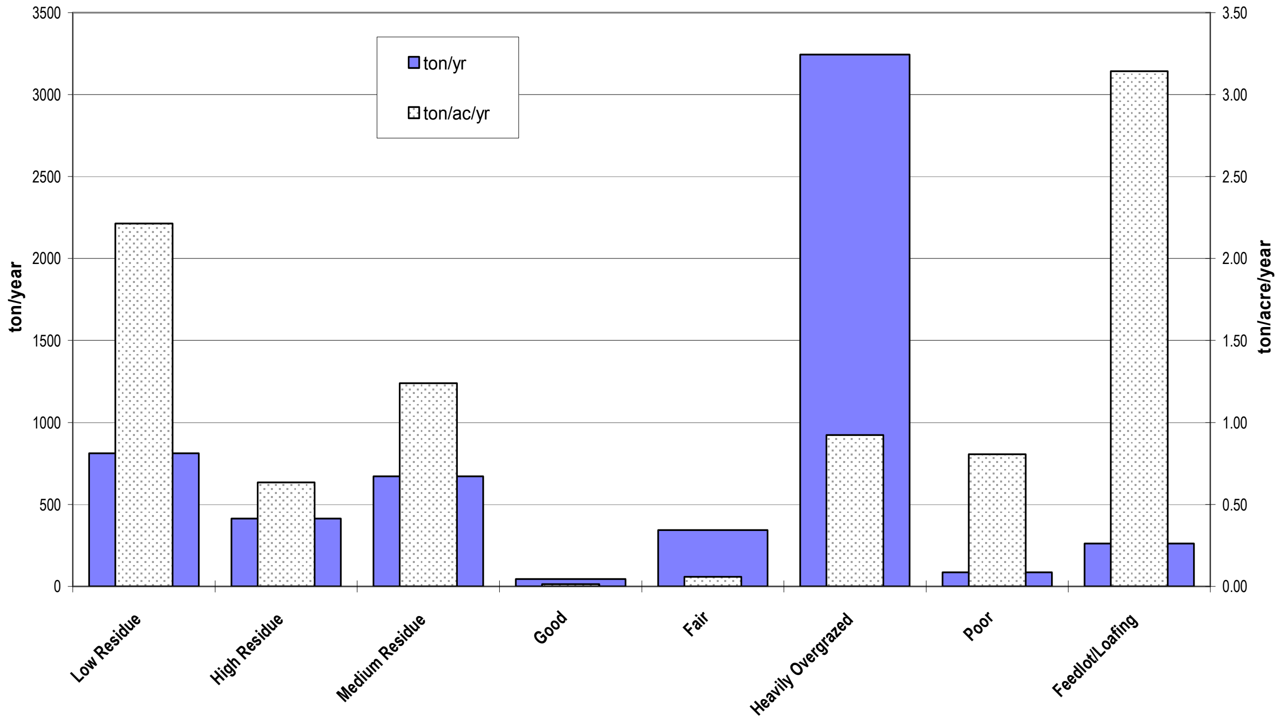

Figure 4.9. Total suspended solids loading by agriculture land classification in Pond Creek watershed.

4.5 Pollutant loads from livestock

Beef and dairy operations were a considerable source of TP and TN throughout Pond Creek watershed. Beef cattle sites were estimated to contribute the greatest ton/yr amount of TP at 1.67 ton/yr, or 23% of all sources. Dairy operations in the study area contributed a comparable amount of TP ton/yr at 1.66, as seen in Table 4.9. Beef and dairy operations were significant sources of annual TN as well, contributing 5.40 and 11.39 tons, respectively (Table 4.10). Estimates of TSS load/yr were minimal relative to many other land use classifications (Table 4.11). Horse operations contributed minimal loads (<0.1 ton/yr) for all pollutants modeled.

As pollutant loading is mostly a function of number of sites, size of sites and proximity of sites to waterways, subwatersheds with greater values of these parameters had higher estimates of loading. Area 0601 contains the greatest number of dairy sites, including two sites classified as large, and as such contributed the greatest load/yr of all pollutants from such operations. Areas 0401 and 02 contain the only large beef sites adjacent to a stream, and were the greatest load/yr sources of TN and TSS for this land class. Areas 080201 and 03 both contain 2 beef cattle sites defined as medium, adjacent to the stream, and contribute the greatest TP load/yr for all beef sites. Conversely, subwatershed 0501 has a total of five beef cattle sites, but most of these sites are non-adjacent to the water, and thus do not contribute excessively high estimates of TP, TN or TSS. Areas 05 and 06 do not contain any livestock operations, adjacent to the stream or otherwise and thus do not contribute any pollutants from these sources. Estimates of TP, TN and TSS load/yr and load/yr/total subwatershed acreage from livestock operations are further summarized in Figures 4.10, 4.11 and 4.12.

Pollutant loads from wildlife

Estimates of annual pollutant load per year from wildlife sources were minimal for all subwatersheds, as seen in Figure 4.13. Annual loading for TP and TN from wildlife was 0.0013 and 0.0024 tons per year, respectively. These values convert to less than 5 lbs per year. Loading of TSS was 0.1472 tons/yr; also one of lowest sources of this pollutant. Subwatersheds 03 and 04 were relatively high annual sources of pollutants from wildlife, as these areas contain high acreages of applicable wildlife habitat defined by forest, cropland and wetland.

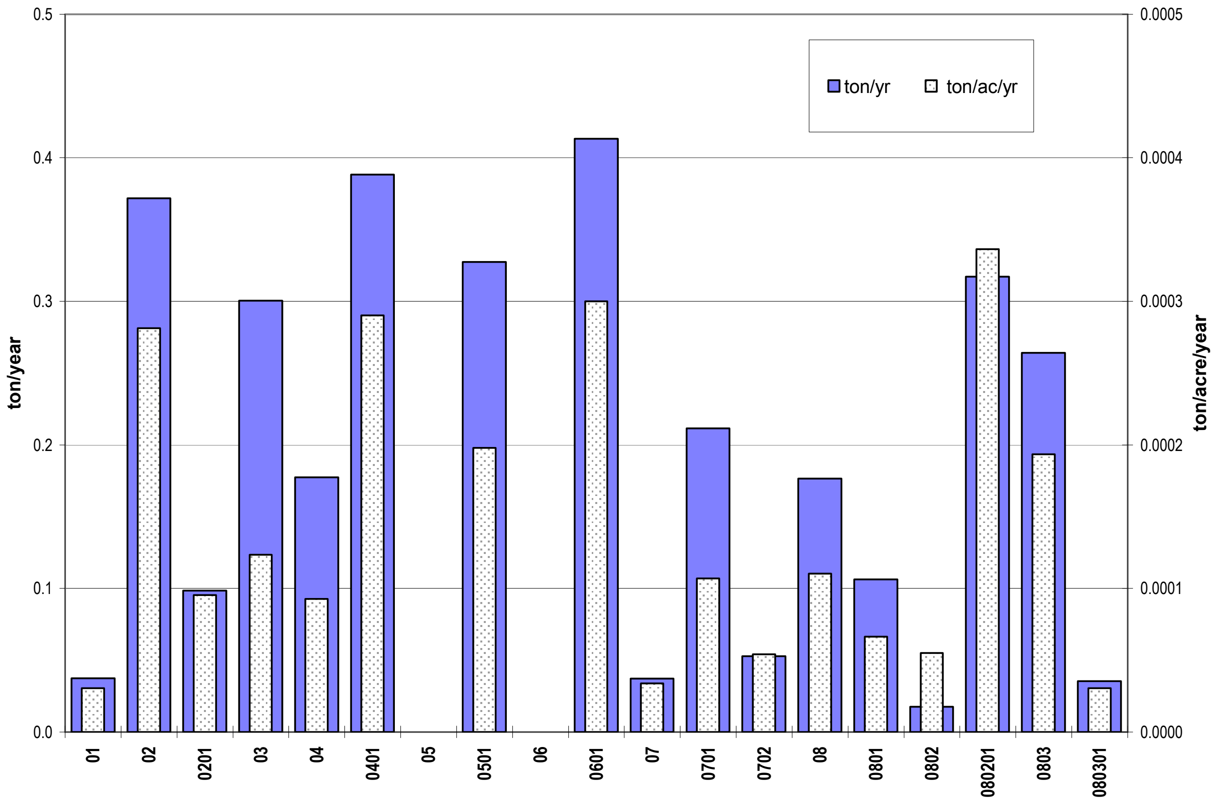

Figure 4.10. Total phosphorus loading from livestock by subwatershed within Pond Creek watershed.

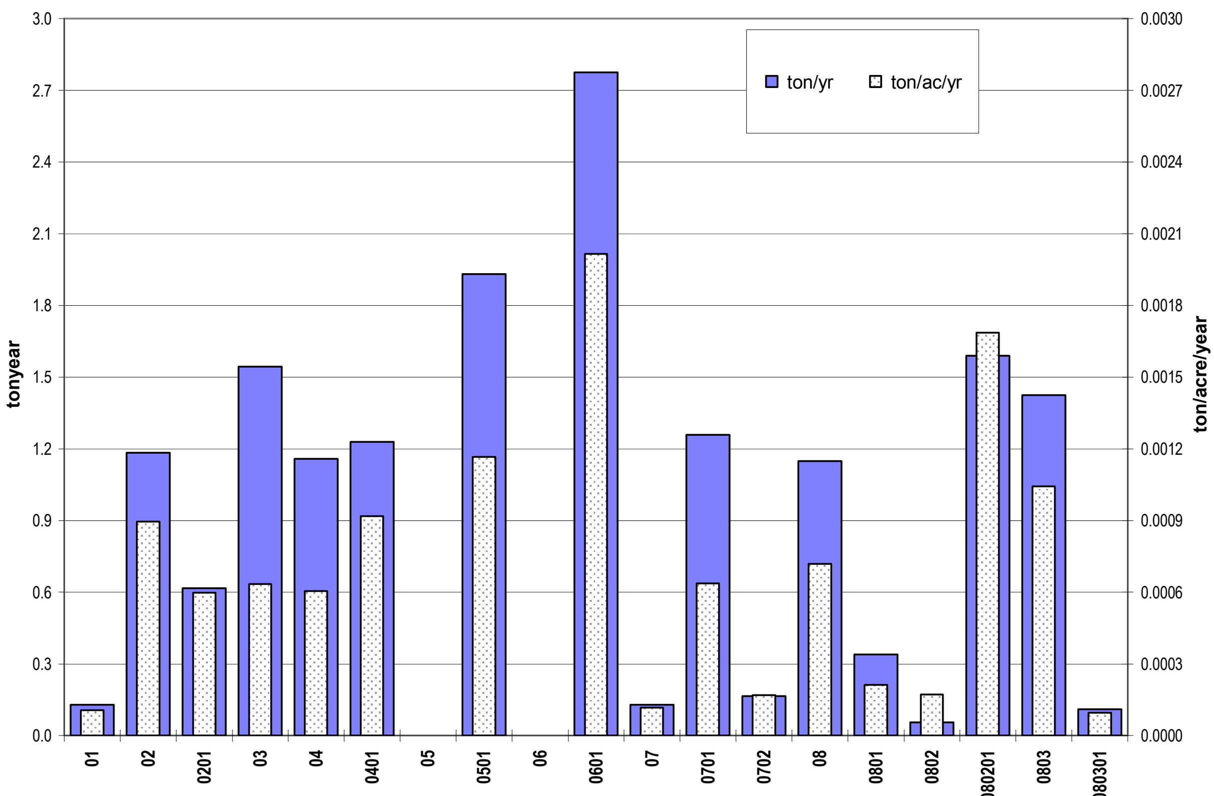

Figure 4.11. Total nitrogen loading by livestock by subwatershed within Pond Creek watershed.

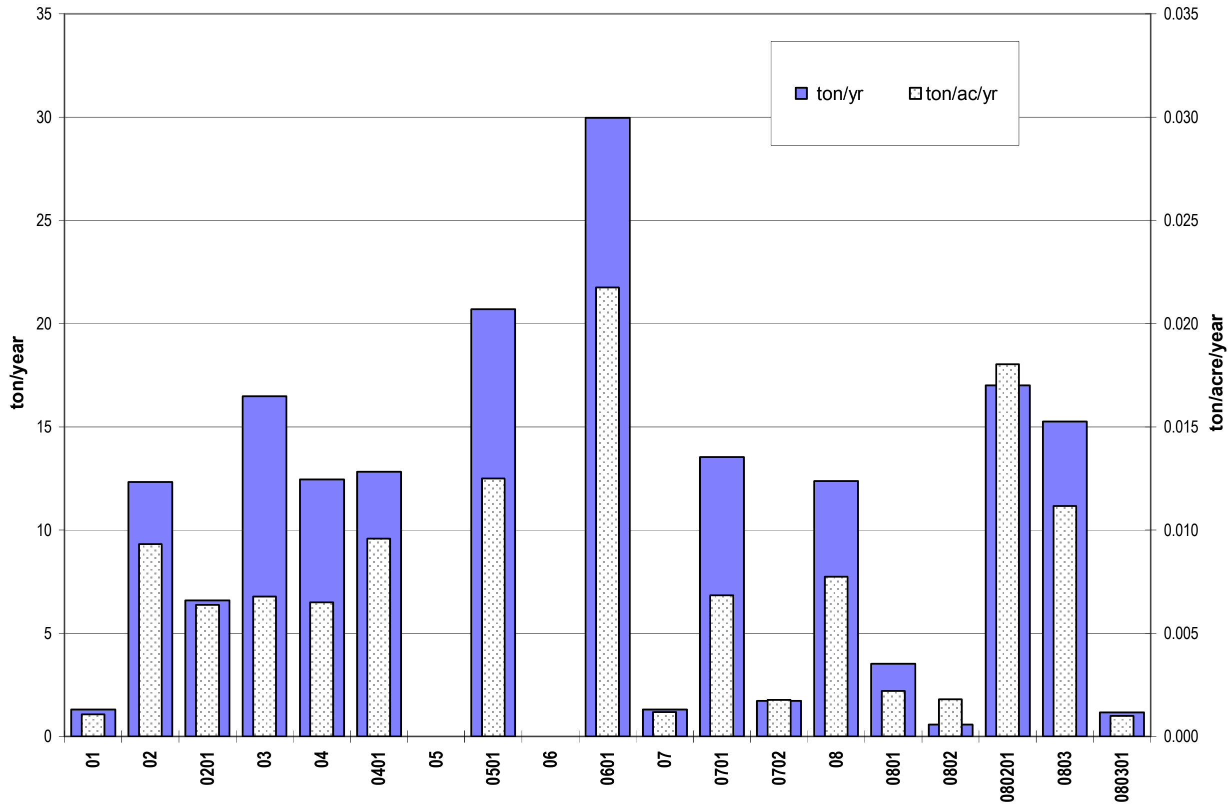

Figure 4.12. Total suspended solids loading by livestock by subwatershed within Pond Creek watershed.

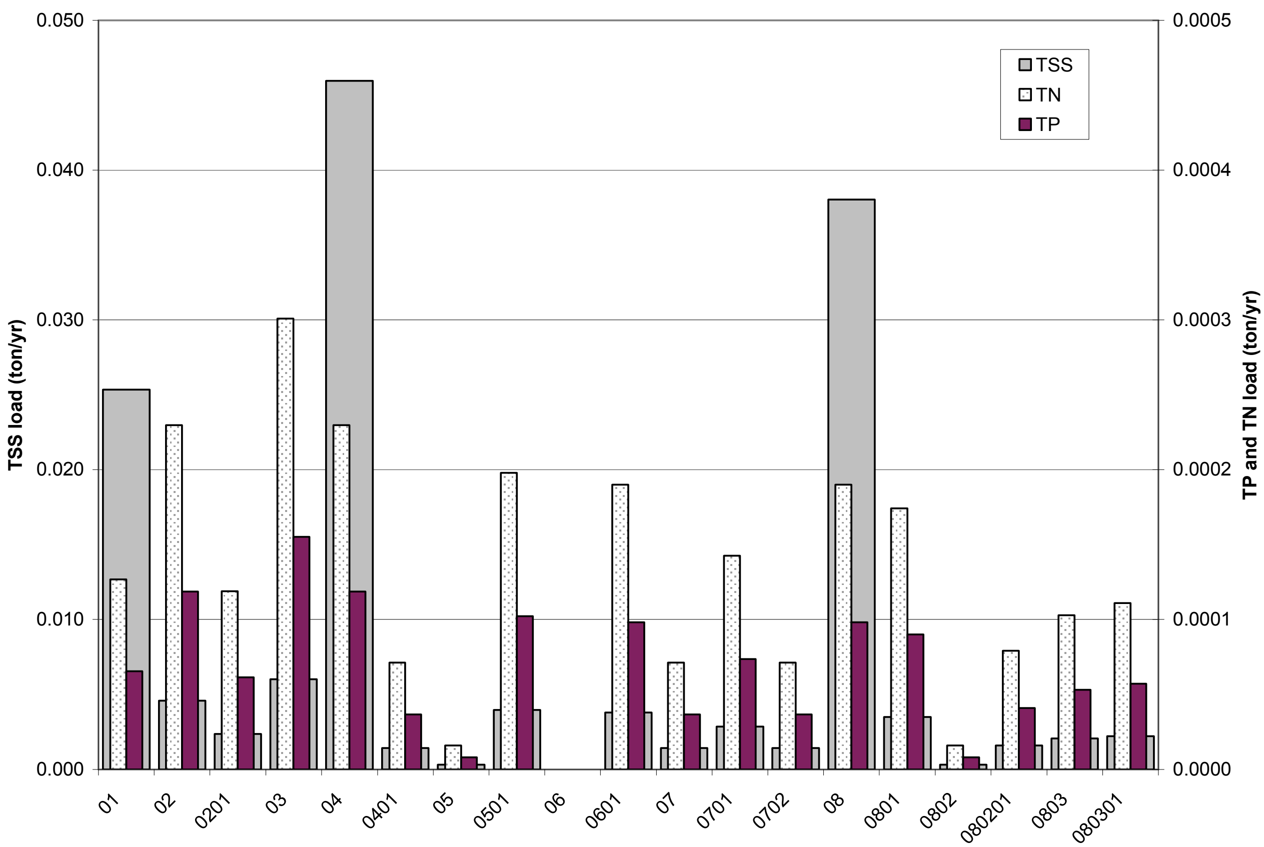

Figure 4.13. Estimated pollutant loading from wildlife for TP and TN (right y-axis) and TSS (left y-axis), delineated by subwatershed.

5.0 Pollution Loading Model Summary

The ultimate goal of this restoration plan is to remove Pond Creek from the Tennessee 303(d) list of impaired waters. While the loading numbers presented above in Tables 4.1 and 4.2 are only estimates of annual pollutant loading, the process identifies specific subwatersheds, sites and land use classes that should be further evaluated and targeted to reduce such loading. The entire modeling process above should be used as a tool to identify regions and practices on which additional monitoring and BMP implementation should concentrate. This targeted effort will prove to be an efficient approach to reduce pollutants on a watershed scale. To better target our efforts of restoration, Table 5.1 displays summary data ouput from the pollutant loading model further described in headings above.

Table 5.1. Primary sources of annual pollutant loading by land class and subwatershed, estimated from IPSI and pollutant loading model described in text.

By land class							
tons/yr							
TP	Overgrazed	TN	Overgrazed	TSS	Overgrazed	Soil Loss	Overgrazed
	Commercial		Feedlot		Low Residue		Low Residue
	Residential		Residential		Med Residue		Med Residue
	Industrial		Commercial		High Residue		High residue
	Low Residue		Low Residue		Stream bank		Stream Bank
tons/ac/yr							
TP	Commercial	TN	Feedlot	TSS	Disturbed	Soil Loss	Disturbed
	Feedlot		Industrial		Mine		Mine
	Industrial		Commercial		Feedlot		Feedlot
	Residential		Residential		Low Residue		Poor Pasture
	Low Residue		Low Residue		Residential		Low Residue
By subwatershed							
tons/yr							
TP	01	TN	0501	TSS	03	Soil Loss	03
	03		03		0501		04
	0501		0601		04		0501
	080201		080201		0401		0401
	0401		01		0701		0701
tons/ac/yr							
TP	080201	TN	080201	TSS	0401	Soil Loss	0401
	01		0501		0501		03
	0401		01		03		0501
	0802		0601		05		04
	0601		0802		04		08

6.0 Model Calibration

Watershed-scale research has a long history and the use of the watershed as a management unit is gaining support in both academic and regulatory environments. Primary reasons for why the watershed is a desirable unit for land use planning and resource management include: an integration of the physical environment revealing the ecological interrelationships between soil, water, and biota; and watersheds serve as natural movement pathways. Temporal and spatial scale issues are critical components of any watershed analysis, and as we upscale in either category, processes become increasingly complex.

Notwithstanding our effort to account for possible bias in the model, some weaknesses still remain to be investigated. For example, precipitation and drought regime – intensity, frequency, duration – is known to be an important ecosystem regulator in the southeast U.S., but is not available as a coherent or consistent dataset and could thus not be incorporated in our modeling framework. A better understanding of the likely impacts of drought and crop moisture cycles specific to the region will allow better predictions and prioritization of conservation strategies to prevent soil loss and pollutant loading.

The surface runoff or streamflow flux of any of the pollutants investigated reflects the integrated pattern of soil dynamics of the land class or streambank affiliated with landform, land use, climate and elevation in the watershed. It has been shown that temporal variation in streamflow was driven by variations in climatic variables (notably precipitation). However, factors controlling the temporal variation in soil dynamics and streamflow are not expected to be the same as those controlling the spatial pattern. While temporal variation in moisture patterns from year to year, or month to month, is much greater than their spatial variation in this small area, the subwatershed to subwatershed variation in biotic factors is perhaps greater than their interannual variations.

Spatial variation in biotic factors (potential N mineralization and plant N demand) likely play a larger role in the spatial pattern of soil N dynamics and streamflow N flux than do climatic (precipitation) and topographic (elevation) factors, in part because of the greater variation of biotic factors compared to abiotic (Johnson et al. 2000). Although in-stream processes have been shown to play an important role in some watersheds (Wickham et al. 2003), stream biological processes and transient storages are likely not sufficiently different when smoothed over long time periods (annually) or large land areas. Stronger estimations of biotic factors may improve predictions of the patterns of soil N dynamics and streamflow N fluxes for the watershed.

Due to the specific meteorological and physiographic characteristics of individual watersheds, regional and local agricultural and urban land uses can exhibit a wide range of variability in nutrient loading (Omernik 1977, Reckhow et al. 1980).

Several examples of loading values expressed as lb/ac/yr are presented in Table 3.6, illustrating the spatial variability of nutrient loads from site to site. Every effort was made to include Pond Creek site-specific meteorological, physiographic, and land use characteristic in the IPSI model, and loading estimates are shown in Table 6.1 for comparison. Estimates of TP and TN from forests are substantially lower for Pond Creek than other lands, perhaps as a result of limited management or disturbances in these land classes.

Table 6.1. Published export coefficient concentrations of total phosphorus and total nitrogen for forest and agriculture lands as found through a non-exhaustive search of relevant articles, and estimated concentrations derived from the present nutrient loading model. Numbered columns represent references: 1. Reckhow et al. 1980; 2. Rast and Lee 1978; 3. Clesceri et al. 1986; 4. Dodd et al. 1992; 5. Loehr et al. 1989; - represents values not reported.

	Total Phosphorus (lb/ac/yr)						Total Nitrogen (lb/ac/yr)					
	1	2	3	4	5	Model est.	1	2	3	4	5	Model est.
Forest	0.21	0.05	0.10	0.12	0.40	0.01	2.60	2.73	3.38	2.12	2.41	0.20
Cropland	0.98	0.45	0.24	0.90	1.35	0.71	4.72	4.55	6.08	8.91	-	10.42
Pasture	1.36	-	0.16	-	0.30	0.19	7.86	-	3.70	-	4.91	3.39

The spatial information of the IPSI model was presented in subwatershed areas ranging from 60 to 2400 acres, although some soil properties may vary at spatial scales < 1 m, for example soil depth (Johnson et al. 2000). Accounting for spatial variability of soil properties and processes within the watershed may lead to more accurate predictions of pollutant loading in the study area. Estimating the spatial variability of soil dynamics is difficult, however, because soil properties vary substantially at a small scale, and methods to account for such variability are often prohibitively expensive. Similarly, site-specific BMPs likely do not follow linear and additive trends, so research in scaling is needed to improve the prediction of cumulative effects of land uses.

Previous efforts of model calibration based on comparisons of modeled outputs with monitored values have yielded strong, supporting results. Water quality data collected by TDEC in 1997 and 1998 from nine stations in the Little River watershed (HUC: 06010204) were used to evaluate the ability of the IPSI model to account for the processes that generate pollution and to calibrate the pollution load model (TVA 2003). Because the model was driven by soil loss estimates for rural land uses, the TSS model agreement with measured values was very good (r^2 = 0.92). The best-fit line (estimated using regression techniques) agreed well with the line of perfect agreement (one to one line through origin) between measured and modeled data, indicating very little bias in the model. The TN fit was not as good as the TSS fit, with r^2= 0.54. A comparison between the best-fit line and the line of perfect agreement showed that model predictions were, on the average, a little lower than measured values. This is to be expected, because the model did not take into account the groundwater contribution of nitrogen. The TP fit was also good with r^2 of 0.76. Model predictions showed a small high bias, especially for watersheds with low pollution loadings.

A second calibration effort for the Flint Creek watershed of north Alabama (HUC: 6030002350) produced stronger results for the support of the pollutant loading model presented here. Pollutant loads were estimated for the Flint Creek watershed using a model similar to the one used to estimate pollutant loads for the Pond Creek watershed. These estimates were then compared to water quality grab samples collected and analyzed monthly from February 1993 through March 1995 by the Alabama Geological Survey. Converse to the comparisons for the Little River watershed estimates, TSS estimates showed the smallest agreement to monitored values with an r^2 of 0.74. The TN and TP fits were very strong with r^2 of 0.93 and 0.94, respectively. Although model estimates have substantial inherent uncertainty, the strong comparisons imply that these outputs can still serve to test the overall ability of the model to predict local conditions and the relative contributions of pollution from different land uses.

Modeling vegetation systems has become one of the most powerful methods for predicting the response of modern vegetation assemblages to changes in land use. There is a wealth of knowledge on how vegetation types have changed in response to changes in land class. Estimated extreme values over time or space are likely smoothed over years and 10,000 acres and given the small relative magnitude of both landform and climate in this case, we believe the output approximations from this model to be adequate (loads per year, loads per 23,570 ac watershed). We believe that this approach provides a valuable tool for describing the fate and volume of nonpoint source nutrients and pollutants in small watersheds. Furthermore, we envision the application of our approach to a number of watersheds in southeastern Tennessee, both agriculture and urban, depending on the scale of the study.

7.0 References

Anderson, J.R., Ernest, E.H., and Roach, J.T. 1971. A Land-Use Classification System for Use with Remote-Sensor Data. USGS Circular 671.

Baldys, S., Raines, T.H., Mansfield, B.L., and Sandlin, J.T. 1998. Urban stormwater quality, event-mean concentrations, and estimates of stormwater pollutant loads, Dallas-Fort Worth area, Texas, 1992-93. USGS Water-Resources Investigation Report 98-4158.

Barker, J.C., Zublena, J.P., and Campbell, C.R. 1990. Livestock Manure Characterization Values from the North Carolina Database. North Carolina Cooperative Extension Service.

Byers H.L., et al. 2005. Phosphorus, sediment, and *Escherichia coli* loads in unfenced streams of the Georgia piedmont, USA. J. Environmental Quality 34: 2293-2300.

Clesceri, N.L., Curran, S.J., and Sedlak, R.I. 1986. Nutrient loads to Wisconsin lakes: Part I. Nitrogen and phosphorus export coefficients. Water Resources Bulletin 22: 983-989.

Davies-Colley, R.J., Nagels, J.W., Smith, R.A., Young, R.G., and Phillips, C.J. 2004. Water quality impact of a dairy cow crossing a stream. NZ Journal Marine and Freshwater Research 38: 569-576.

Dodd, R.C., McMahon, G., and Stichter, S. 1992. Watershed planning in the Albemarle-Pamlico estuarine system: Report 1- annual average nutrient budgets. U.S. EPA, Center for Environmental Analysis, Report 92-10, Raleigh, NC.

EPA. 1982. *NURP Priority Pollution Monitoring Program* -Volume 1: Findings. Monitoring and Data Support Div., Office of Water, U.S. EPA, Washington, DC.

EPA. 1990. *Urban Targeting and BMP Selection: An information and guidance manual for state nonpoint source program staff engineers and managers.* EPA 841-B-90-111, Washington, D.C.

Guerard, P. and Weiss, W.B. 1995. Water quality of storm runoff and comparison of procedures for estimating storm-runoff loads, volume, event-mean concentrations, and the mean load for a storm for selected properties and constituents for Colorado Springs, Southeastern Colorado, 1992. USGS Water-Resources Investigations Report 94-4194, Denver, CO.

Harper, H.H. 1998. Stormwater chemistry and water quality. http://www.stormwaterauthority.org/assets/47chemistry.pdf; last accessed 24 July, 2006.

Ittekkot, V. and Zhang S. 1989. Pattern of particulate nitrogen transport in world rivers. Global Biogeochemical Cycles 3: 383-391.

Johnson, C.E., Driscoll, C.T., Siccama, T.G. and Likens, G.E. 2000. Element fluxes and landscape position in a northern hardwood forest watershed ecosystem. Ecosystems 3: 159-184.

Kingery, W.L., Wood, C.W., Delaney, D.P., Williams, J.C., and Mullins, G.L.. 1994. Impact of long-term land application of broiler litter on environmentally related soil properties. Journal of Environmental Quality. 23:139-147.

Kleinman, P.J.A., Gburek, W.J., Sharpley, A.N., Stout, W.L., and Bryant, R.B. 2005. Impact of pastured dairy cattle on stream and near-stream areas on a Catskill farm; Source evaluation and management of phosphorus in the Town Brook Watershed. Final Report for Cooperative Agreement No. 0055 Between Watershed Agricultural Council of the New York City Watersheds, Inc. and USDA, ARS.

Knipling, E. 1970. Physical and physiological basis for the reflectance of visible and near-infrared radiation from vegetation. Remote Sensing of Environment 1: 155-159.

Loehr, R.C., Ryding, S.O., and Sonzogni, W.C. 1989. Estimating the nutrient load to a waterbody. *The Control of Eutrophication of Lakes and Reservoirs, Volume I, Man and the Biosphere Series.* S.O. Ryding and W. Rast, ed., Parthenon Publishing Group, pp.115-146.

Los Angeles County. 1999. Stormwater Monitoring Report: 1998-1999.

Ludwig, W. and Probst, J-L. 1996. Predicting the oceanic input of organic carbon by continental erosion. Global Biogeochemistry Cycles 10: 23-41.

Mills, W.B., et al. 1985. *Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water*. EPA/600/6-85/002a. USEPA, Athens, GA.

Omernik, J.M. 1977. Nonpoint source-stream nutrient level relationships: a nationwide study. EPA-600/3-77-105, U.S. EPA, Corvallis, Oregon.

OSU. 2004. Water for dairy cattle. Oklahoma Cooperative Extension Service FactSheet F-4275.

Price, J.C. and Karesh, R. 2002. Erosion and Sediment Control Handbook, 2nd ed. State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

Rast, W. and Lee, G.F. 1978. Summary analysis of the North American (U.S. portion) OECD eutrophication project: nutrient loading - lake response relationship and trophic status indices. EPA/3-78-008, Ecological Research Series, U.S. EPA, Corvallis, OR.

Reckhow, K.H., Beaulac, M.N., and Simpson, J.T. 1980. Modeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients. EPA-440/5-80-011, Office of Water Regulations, Criteria and Standards Division, U.S. EPA, Washington, DC.

Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K. and Yoder, D.C. 1997.Predicting soil loss erosion by water: A guide to conservation planning with the revised soil loss equation (RUSLE). USDA Agriculture Handbook No. 703.

Schueler, T.R. February 1994. Sources of Urban Stormwater Pollutants Defined in Wisconsin. Watershed Protection Techniques 1(1): 31.

Stewart, B.A., Woolhiser, D.A., Wischmeier, W.H., Carol, J.H. and Frere, M.H., 1975. *Control of water pollution from cropland.* US Environmental Protection Agency, Washington DC.

TDEC. 2005. Total Maximum Daily Load (TMDL) for Pathogens in the Watts Bar Watershed (HUC 06010201). State of Tennessee, Department of Environment and Conservation, Division of Water Pollution Control.

TVA. 2003. Blount County and Little River Basin nonpoint source pollution inventories and pollutant load estimates.

USDA. 1978. Soil Conservation Service. National Engineering Handbook.

USDA. 1996. Natural Resources Conservation Service. Agricultural Waste Management Field Handbook. USDA, Washington, D.C.

Wickham, J.D., Wade, T.G., Ritters, K.H,. O'Neill R.V., Smith J.H., Smith E.R., Jones K.B., and Neale A.C. 2003. Up-stream-to-downstream changes in nutrient export risk. Landscape Ecology 18: 195-208.

Wischmeier, W.H. and Smith, D.D. 1978. *Predicting rainfall erosion losses*. USDA, Agriculture Handbook Number 537.