Pond Creek Watershed Restoration Plan

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1.0 Introduction

The Pond Creek Watershed in east Tennessee covers 23,579 acres of which dairy and pasture-based beef operations are the primary land uses. Segments of the primary stream running through the watershed, Pond Creek and two of its major tributaries Greasy Branch and Mud Creek, are listed as only partially supporting their designated uses according to the 2004 Tennessee 303(d) list of impaired waterways prepared by the Tennessee Department of Environment and Conservation (TDEC). The State of Tennessee's final 2004 303(d) list (TDEC 2004a) was approved by the U.S. Environmental Protection Agency (EPA), Region IV in August of 2005.

Under the 1977 U.S. Clean Water Act, states are required to establish water quality standards and create Total Maximum Daily Loads (TMDL) for impaired waters. A TMDL is a calculation of the maximum amount of a pollutant load that a waterbody can receive and still meet water quality standards described by Section 303 of the Clean Water Act. The final version of a TMDL for Watts Bar Watershed, the reservoir into which Pond Creek deposits, cites *Escherichia coli* as a high priority, nitrates as a medium priority and physical substrate habitat alteration as a medium priority (TDEC 2005).

The TMDL identifies pollutant sources such as pasture grazing, livestock in stream and animal feeding operations, all classified as nonpoint pollutant sources. As such, this restoration plan was developed for the watershed, suggesting best management practices, and the subsequent post-plan estimates of pollution. In October, 2005 TDEC Nashville had the draft TMDL for pathogens for the Watts Bar Watershed approved (TDEC 2005). A copy of this TMDL can be found at the TDEC website at:

http://www.state.tn.us/environment/wpc/tmdl/approvedtmdl/WattsBarPathF1.pdf

By definition a pathogen is any biological agent that causes disease or illness to its host, and can be bacteria, a virus, protozoa, fungi, or parasite. The 303(d) list for Tennessee and the TMDL identified the bacteria *E. coli* as the priority pathogen; however the general term pathogen will be used in this plan. The pathogen reduction goals for Pond Creek outlined in the TMDL will form the basis of this watershed restoration plan developed for Pond Creek. Due to the inherent difficulty in estimating nonpoint sources of pollutants, few, if any, watershed restoration plans have been developed that consider these sources. Using the best tools available we identified and proposed practices that minimize nonpoint sources of pollution.

1.1 Location

Pond Creek Watershed (HUC: TN06010201013) is located in the Upper Tennessee River Basin, within the Watts Bar/Fort Loudon Watershed of east Tennessee (Figure 1.1). This watershed includes southern sections of Loudon, western McMinn and northern Monroe Counties, between metropolitan areas of Knoxville and Chattanooga.

Pond Creek is in the Ridge-and-Valley physiographic system that is indicative, or occupies much of the eastern United States from central Mississippi to southern New York, along the Appalachian Mountain chain. Land usage in Pond Creek watershed is very typical of the Appalachian region, consisting primarily of rural, family-based agriculture operations, with no municipal separate storm sewer systems. Based on these characteristics, this watershed can be considered a model watershed system to evaluate the relative and absolute impacts of Best Management Practices (BMPs) on lands of east Tennessee and/or lands which are currently classified as Ridge-and-Valley.

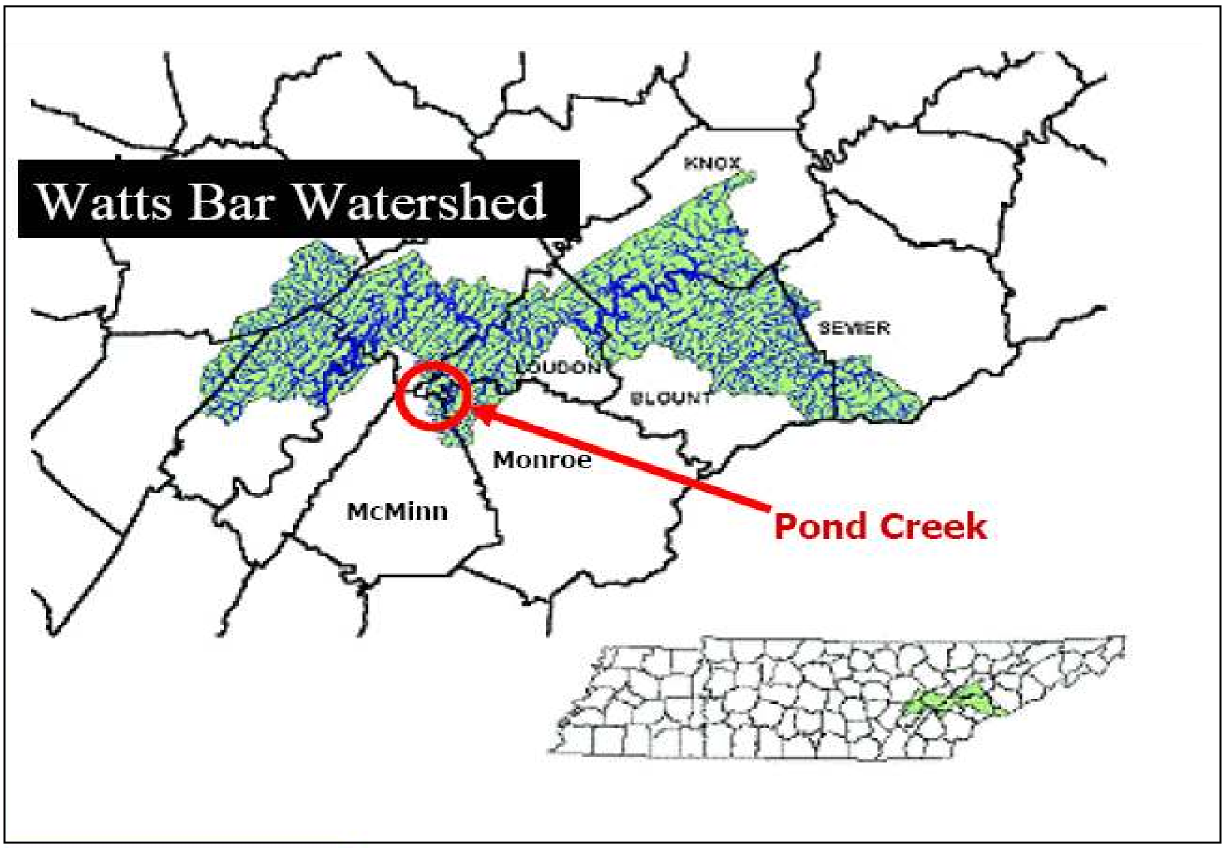

Figure 1.1. Location of Pond Creek Watershed within Watts Bar hydrological unit in Tennessee. Map from TDEC 2005.

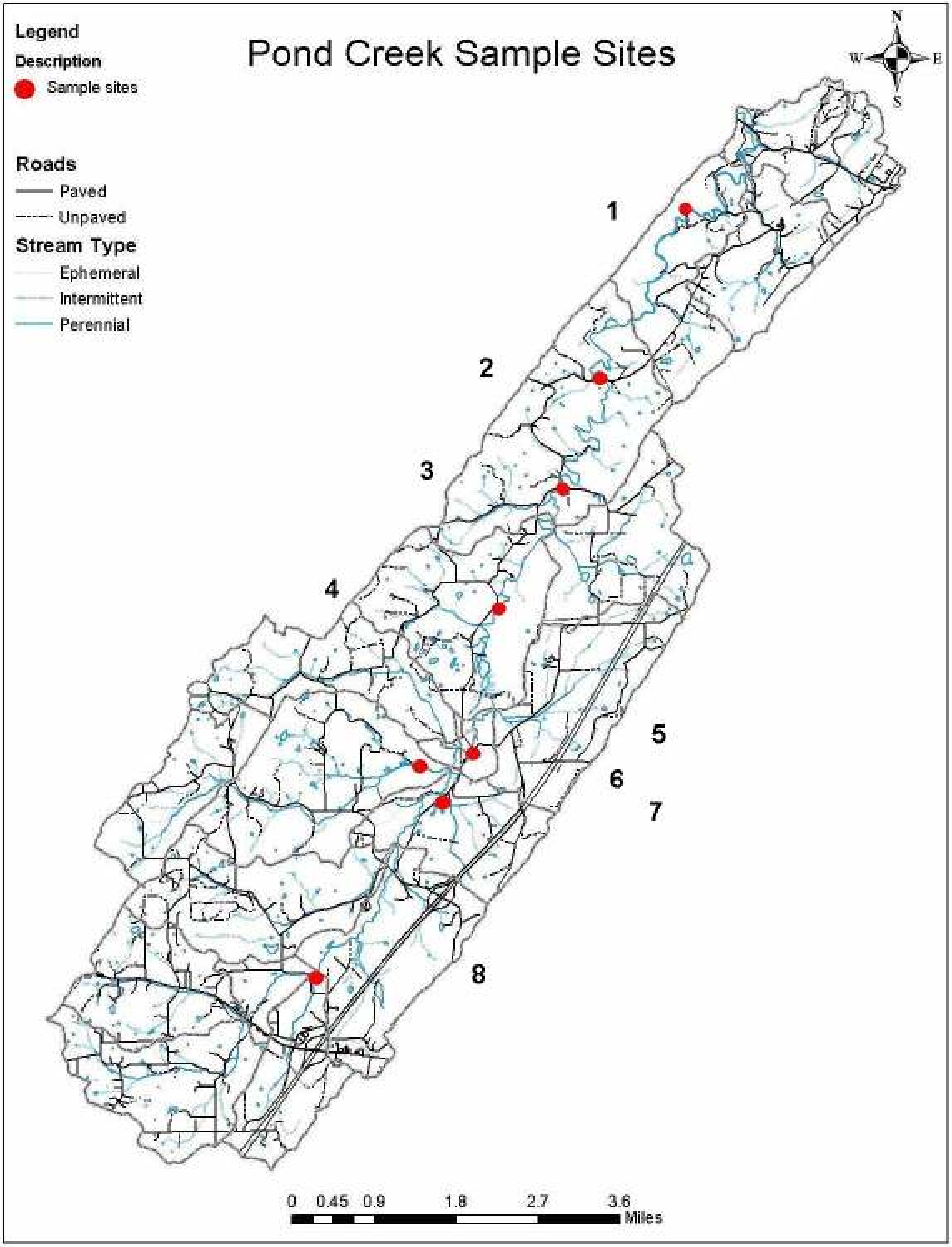

Figure 1.2. Water quality monitoring sites within Pond Creek Watershed. Numbers 1-8 correspond to water quality sample sites described in text.

1.2 Partnerships

The Watts Bar Watershed TMDL, which specifies current water quality of Pond Creek, was developed by TDEC using data collected by the University of Tennessee and University of Tennessee Extension, herein collectively referred to as UT. Eight water quality monitoring stations within the Pond Creek watershed provided data for TDEC (Figure 1.2). Supplemental monitoring was conducted by UT at several of the same locations.

The Tennessee Valley Authority (TVA) has developed an Integrated Pollution Source Identification (IPSI) tool to assist stakeholders to identify sources of pollution and estimate pollutant loads from the various sources. The tool includes a nonpoint source (NPS) inventory, desktop Geographic Information System (GIS), and pollutant load models. IPSI methodology and pollutant load model inputs are further described in Section 3.1, NPS Inventory Methods.

In addition to the above mentioned agencies supporting Pond Creek restoration, intellectual, technical and financial resources have also been provided by EPA Region IV, USDA - Natural Resources Conservation Service (NRCS), Soil and Water Conservation Offices of Loudon, McMinn and Monroe Counties, Tennessee Department of Agriculture (TDA), Tennessee Department of Environment and Conservation (TDEC), Tennessee Wildlife Resources Agency (TWRA), Tennessee Farmers Co-operative, Agriculture Extension agents of Loudon, McMinn and Monroe Counties, and perhaps most importantly, landowners of the watershed.

1.3 Accomplishments

Since April 2003, UT has maintained an on-going long-term project to improve water quality in Pond Creek. Funding to support a watershed coordinator, an extension research associate, water quality monitoring activities and the implementation of BMPs has come from a number of sources including EPA, TVA and TDA.

With support from both the TVA and a Federal 319 grant, the project has offered free soil tests, grass seed, and herbicides to local load owners within the study area. In 2005 for example, six landowners received assistance with 50 soil samples, and four farmers received herbicides for spraying weedy pastures. The resulting recommendations saved the local producers hundreds of dollars in fertilizer costs, compared to the standard recommendations being provided by the local farmers Co-op. The results were also used by the farmers to select fields that would be more appropriate for manure application and avoid those where additional manure phosphorus and potassium were unnecessary and may have posed a risk to water quality from runoff.

Five farmers received free grass seed (fescue and orchardgrass) for seeding or re-seeding pastures. Additionally, several infrastructure BMPs were installed on six farms in the watershed. Design work and advice for each of these projects was given by the District Conservationist of Loudon County. Examples of select actions include delivery of 8 loads of gravel for establishing livestock heavy-use-areas, installation of 1,750 ft of fencing for excluding livestock direct stream access, and laying 1,705 ft of pipe for the installation of alternative watering systems for livestock.

The NRCS requires that all producers who receive financial assistance from the United States Department of Agriculture (USDA) have and follow a comprehensive nutrient management plan (CNMP). Personnel with the Pond Creek project have assisted NRCS with the collection and collation of the information needed to develop CNMPs for operations in the watershed. Currently four of the dairy operations in Pond Creek are enrolled (or are in the process to enroll) in the affiliated Environmental Quality Incentive Program (EQIP), which offers financial and technical assistance to install or implement structural and management practices on eligible agricultural land.

Over the past two years, the project coordinator, watershed coordinator and extension research associate have attended several Field Days hosted by UT and outside agencies. A booth and demonstration was prepared and presented for the McMinn County Farm Day. The demonstration showed effects of rainfall on an open soil slope, soil with grass strips, and full grass. Information booths presenting the status and accomplishments of the current project have also been constructed at many of UT Extension Field Days, most recently including UT Beef and Forage Field Day in June 2006, which was attended by 280 farmers, exhibitors and local officials.

In 2006, the affiliated staff has hosted two educational tours of Pond Creek Watershed (including a tour to Region IV EPA officials), organized two community meetings presenting goals and accomplishments to local stakeholders, produced two newsletters for land owners within the watershed, and participated in a Watershed Analysis and Planning Workshop hosted by TVA. Watershed meetings are open to the public, and most meetings were represented by citizens who live in the watershed, NPDES permitees, business people, farmers, and those with local river conservation interests. Locations for meetings were frequently chosen after consulting with people who live and work in the watershed. Everyone with an interest in clean water was, and is, actively encouraged to be a part of the public meeting process.

The goals of the meetings were to 1) present the objectives of the Watershed Approach to improving water quality, 2) introduce local, state, and federal agency and non-government organization partners, 3) summarize the most recent water quality monitoring data and provide justification for the restoration activities, 4) solicit input from the public, and 5) discuss BMPs and other nonpoint source tools available through TVA, the TDA 319 Program and NRCS conservation assistance programs.

Major concerns and comments originating from these community meetings include:

- Agriculture impact from and in small operations
- Destruction of riparian areas
- Groundwater contamination from failing septic systems
- Contaminated drinking water in wells
- Draft Watershed Water Quality Management Plan
- “Watershed Approach”
- Landowner Assistance Programs (TVA, NRCS and TDA, among others)

Monthly monitoring efforts are continuing at eight locations throughout the watershed. All water samples collected by UT are analyzed in the Biosystems Engineering and Soil Science Department laboratory (Knoxville, TN) for the physical, chemical and biological parameters:

Physical: temperature, electrical conductivity, turbidity, total dissolved solids, total solids, and total suspended solids
Chemical: pH, dissolved oxygen, total carbon, nitrate-N, ammonia-N, total-N, chloride, sulphate, total phosphorus, and soluble phosphorus
Pathogens: *Enterococcus*, total coliform, and *E. coli*

The Pond Creek watershed project continues working to improve water quality and aquatic habitats. Communication and planning efforts are tailored to individual farms and operations to improve soil, crop, and livestock management. An example of a tangible accomplishment of the Pond Creek restoration project is the documented improvement of local fish assemblages. In 2001 and again in 2006, TVA conducted an assessment of the local fish population using the common Index of Biotic Integrity (IBI), and found a remarkable improvement over the past five years. Since 2001, the variety of fish increased 30%, and the total count more than doubled. This success, along with other observations, improved the rating of this site from fair/poor to fair.

1.4 Plan Purpose

Watershed restoration and sustainable management practices have been increasingly accepted as effective tools to improve watershed function and health, and thus maximize the ecological services such as clean and stable water resource supply. This project therefore aims at developing an effective and integrated land management and monitoring approach for community stakeholders, which include local land owners, communities, authorities and resource managers, as they are required to make coherent, informed decisions regarding land resources and their future. In this context, the project will make use of local knowledge, GIS and remote sensing technology to inform effective decision making.

Water quality data from the published TMDL and current sampling collections are being incorporated into the pollutant load model described. UT is interpreting the results of this analysis to develop strategies to improve water quality in Pond Creek in conjunction with input from local and federal officials and stakeholders of the watershed. Appropriate BMPs will be recommended to reduce erosion and/or pollutant problems from areas identified as critical. To estimate the potential benefits of implementing BMPs, default inputs to the model were altered to reflect the application of recommended management practices. The results of the field monitoring, IPSI analysis and suggested practices for improving water quality for Pond Creek are summarized in this report.

The results from this watershed restoration plan will enhance economic, ecologic and social development through the dissemination of findings and the transfer of ideas to: (i) local communities; (ii) the wider scientific community; and (iii) other community planning initiatives within the region.

2.0 Overview of Pond Creek Watershed

Pond Creek Watershed lies within the Ridge-and-Valley Ecoregion (67) defined by the EPA. This is a relatively low-lying region between the Blue Ridge Mountains to the east and the Cumberland Plateau on the west. Pond Creek watershed has been divided into 19 subwatersheds that correspond to source streams (Figure 2.1). The coding scheme used in this study was adapted from a hierarchical system developed by the United States Geological Survey (USGS). These delineations are used in this restoration plan.

2.1. Physiography

Pond Creek Watershed is typical of the ridge-and-valley region of the eastern U.S., with rolling hills and many meandering tributaries and agriculture operations located in the floodplain. Elevations range from 73 to 102 ft. Annual precipitation for the watershed ranges from 40-54 inches. Average summer temperatures range from 66 to 87 ºF, and January temperatures range from 26 to 45 ºF.

The Southern Limestone/Dolomite Valleys and Low Rolling Hills (sub-Ecoregion 67f) form a heterogeneous region composed predominantly of limestone and cherty dolomite. Landforms are mostly low rolling ridges and valleys, with few steep ridges. Bedrock geology consists of Quaternary cherty clay solution residuum and Ordovician dolomite and limestone. Soils vary in their productivity under the great group of Ultisols, and soil series Fullerton, Dewey, Decatur, Bodine, and Waynesboro (NRCS 2004). Table 2.1 below further describes characteristics of soils found within the study area.

White oak forests, bottomland oak forests, and sycamore-ash-elm riparian forests are the common forest types, with grassland barrens intermixed with cedar-pine glades also occurring here. Land cover includes very little urban and industrial areas, with small discontinuous segments of thick forest and intensive agriculture. There are no incorporated towns or centers of population within the watershed.

The number of dairy farms has been declining, and conversion of the dairies to beef cattle production is a typical outcome. When this restoration initiative began there were 17 dairy farms operating in the watershed. Five of those have since gone out of business, with two of these stopping in the last twelve months. Of the recent dairies that ceased, most of the cattle remained in the watershed, because they were purchased or leased by other farmers.

Among the 35.7 miles of stream classified as impaired by TDEC (2005), less than 5% has a history of channelization. Physical stream alteration was conducted and completed during the 1930s.

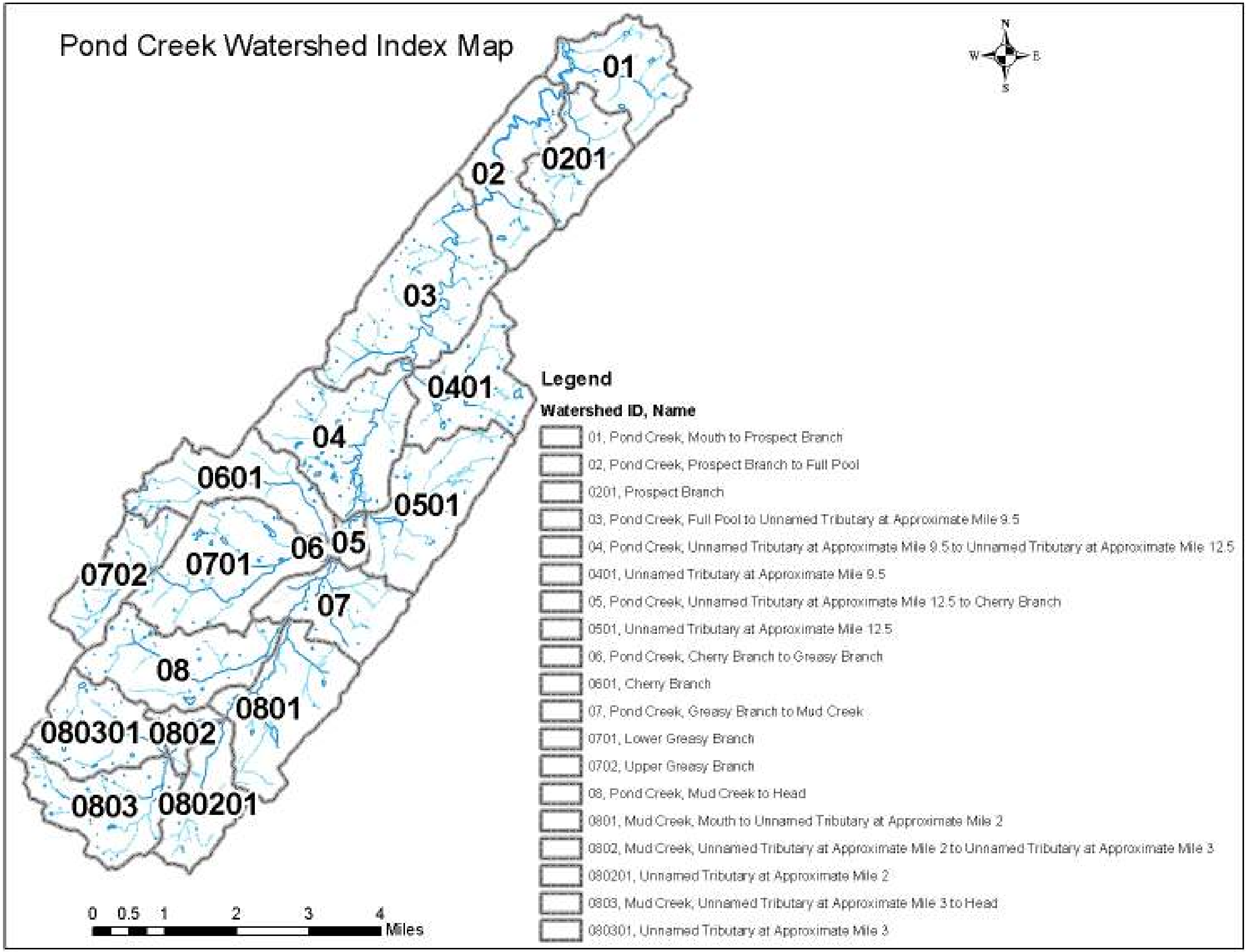

Figure 2.1. Pond Creek Watershed index map defining subwatershed locations and HUC codes.

Table 2.1. Soil series within Pond Creek watershed classification and description; adapted from NRCS 2004. Very deep represents a non-limiting substrate.

Series	Depth	Drainage Class	Permeability	Landscape Position	Parent Material	Taxonomic Class
Bodine	'Very deep'; C horizon >60in	Excessively drained	Moderately rapid	Ridge crests, shoulder slopes, side slopes	Derived from cherty limestone and dolomite	Loamy-skeletal, siliceous, semiactive, thermic Typic Paleudults
Decatur	'Very deep'; to bedrock: 4-14ft; C horizon >67in	Well drained	Moderate	Ridge crests and side slopes	Old alluvium or colluvium underlain by residuum derived from limestone or dolomite	Fine, kaolinitic, thermic Rhodic Paleudults
Dewey	'Very deep'; to bedrock: 5-20ft; C horizon >70in	Well drained	Moderate	Ridge crests and side slopes	Old alluvium underlain by residuum derived from limestone or dolomite	Fine, kaolinitic, thermic Typic Paleudults
Fullerton	'Very deep'; to bedrock: 10-40ft; C horizon >60in	Well drained	Well-drained	Ridge crests, shoulder slopes, side slopes	Derived from cherty limestone or dolomite	Fine, kaolinitic, thermic Typic Paleudults
Waynesboro	'Very deep'; to bedrock: 2-20ft; C horizon >60in	Well drained	Moderate	Ridge crests, stream terraces, side slopes	Old alluvium derived from sandstone, shale, and limestone	Fine, kaolinitic, thermic Typic Paleudults

2.2 Water Quality Assessment

The Tennessee 303(d) list identifies 35.7 stream miles of Pond Creek as impaired for one or more uses. Included in the watershed are 7.2 miles of Mud Creek and 7.3 miles of Greasy Branch, two tributaries of Pond Creek, and 21.2 miles of Pond Creek (TDEC 2004a). These waterways are unable to support fish and aquatic life, and recreation at the same level as the ecoregion reference stream. Portions of Pond Creek are also designated for irrigations and livestock and wildlife watering. Identified causes of impairment are pathogens, nitrates and habitat alteration, likely stemming from pasture grazing, livestock in streams, and animal feeding operations (TDEC 2005).

The primary concern in Pond Creek watershed is elevated pathogen levels posing human health risks and prohibiting recreational opportunities. As such, data and assessments on fish populations and macroinvertebrate assessments will be minimal or not be included in this plan. Instead, data compilation and analysis efforts will focus on data that will likely help characterize the likely sources of pathogen loads to the stream.

Surface waters in this watershed have been monitored, and continue to be monitored, as part of the 5-year watershed management cycle. Past and recent chemical and biological monitoring results are summarized below.

2.2.1 Pathogens

Utilizing data from eight water quality monitoring stations throughout Pond Creek, a pathogen TMDL was established under a broader watershed TMDL for Watts Bar (TDEC 2005). The TMDL notes 9 out of 9 stations with *E. coli* observations over 1,000 cfus (colony forming units, or a measure of viable bacteria numbers), with some observations greater than 100,000 cfus. Based on water quality findings in the document the TMDL proposes a required 99.1% reduction in pathogens for Pond Creek.

An ongoing monitoring survey conducted by UT has resulted in a site-specific assessment of pathogen levels for Pond Creek. A 12-month survey (Sasser 2003) monitored water quality for Pond Creek watershed utilizing the same sampling sites as TDEC, as defined in Figure 1.2 and Table 2.2. Biological, physical, and chemical characteristics of water from Pond Creek monitored from July 2001 to May 2002 are presented in Table 2.3. To present any differences over time (years), recent water quality sampling characteristics from 2006 are displayed in Table 2.4.

Table 2.2. Pond Creek water quality monitoring stations. Data from Sasser 2003 and TDEC 2004a.

Site	TDEC Code	Subwatershed Location	Lat (N), Long (W)	Soil Type	Subbasin Drainage Area (ac)	Land Use per Subbasin	Site Description
1	POND002.3LO	02	35°43"53.42' -84º26"30.73'	Silt loam Ultisol	1584	Agriculture (806ac); mixed forest	Moderately dense forest and shrubs with shaded banks
2	POND005.7LO	03	35º42"19.11' -84º27"32.18'	Silt loam Ultisol	1154	Agriculture (764ac); Dairy, mixed forest	Gently rolling hills with moderate riparian damage
3	POND008.2LO	03	35º41"18.28' -84º27"59.80'	Silt loam Ultisol	2343	Agriculture (2031ac); Dairy and Emu	Dairy and Emu farm in close proximity to stream, moderate to severe riparian damage
4	POND011.0LO	04	35°39"57.57' -84º28"59.47'	Silt loam Ultisol, Loamy Entisol	3007	Agriculture (2340ac); Dairy, mixed forest	Heavy dairy use, poor ground cover, severe riparian damage
5	POND013.1MO	05	35°38'46.15' -84º29"7.77'	Silt loam Ultisol, Loamy Entisol	1913	Agriculture (1549ac); Dairy, mixed forest	Good ground cover, good riparian zone, low cattle use
6	GREAS000.5MO	06	35°38"37.13' -84º29"40.55'	Silt loam Ultisol	3603	Agriculture (2516ac); Dairy, evergreen forest	Low cattle use, sever undercuts in riparian zone
7	POND013.9MO	07	35°38"20.38' -84º29"30.91'	Silt loam Ultisol, Loamy Entisol	2708	Agriculture (2140ac); Dairy, mixed forest	Presence of dead and decaying cattle next to stream bank, severe riparian damage
8	MUD001.9MO	080201	35°36"41.58' -84º30"56.63'	Silt loam Ulitosl, Silt loam Entisol	3726	Agriculture (2970ac); Dairy, mixed forest	Moderate cattle use, sever undercuts in riparian zone

Table 2.3. Chemical characteristics of water from Pond Creek sites averaged over all months, July 2001 to May 2002. Data taken from Sasser 2003 and TDEC 2004a. N = nitrogen; P = phosphorus; SS = suspended solids; EC = *E. coli*; FC = fecal coliform; N = sample size.

Site	Total N	Total P	Total SS	pH	Flow	Avg. EC	Avg. FC	N
		mg/L			m^3/sec	cfu/100ml		
1	3.14	0.16	36	7.8	0.52	11628	3182	12
2	3.84	0.18	46	7.8	0.39	7280	4406	12
3	3.45	0.17	47	7.8	0.21	13196	6550	12
4	3.70	0.32	102	7.6	0.10	29676	10783	12
5	3.62	0.20	70	7.8	0.19	14471	6996	12
6	2.23	0.18	40	8.0	0.11	6868	7685	11
7	3.41	0.24	66	8.1	0.13	36021	3136	11
8	4.19	0.43	289	7.5	0.08	12860	5702	12
Geometric Mean	3.40	0.22	67	7.8	.18	14059	5589	

Table 2.4. Chemical characteristics of water from Pond Creek sites averaged over all months, January 2006 to April 2006. Data from UT; heading definitions are taken from Table 2.3.

Site	Total N	Total P	Total SS	pH	Flow	Avg. EC	Avg. FC	N
		Mg/L			m^3/sec	cfu/100ml		
1	7.70	0.34	73	8.1	2.21	> 2419	> 2419	4
2	7.59	0.33	190	7.8	2.17	> 2419	> 2419	4
3	7.30	0.24	50	7.7	2.39	> 2419	> 2419	4
4	7.93	0.19	38	7.7	1.48	> 2419	> 2419	4
5	7.13	0.18	54	7.8	0.91	> 2419	> 2419	4
6	5.98	0.12	43	7.8	0.50	> 2419	> 2419	4
7	7.10	0.21	34	7.8	0.57	> 2419	> 2419	4
8	7.19	0.20	17	8.1	0.21	> 2419	> 2419	4
Geometric Mean	7.22	0.22	49	7.8	0.99	> 2419	> 2419	

Data were averaged over the monitoring sites to evaluate trends over time (months), resulting in no set trend, with uneven bacteria distribution over time (Figure 2.2). Months with high stream flow yielded significantly higher *E. coli* concentrations (ANOVA on months $P \leq 0.001$) than months with low rainfall amounts, as seen in Figure 2.2. Additionally, no single monitoring site yielded consistently higher or lower *E. coli* observations ($P = 0.202$), when averaged over months.

The state of Tennessee uses ecoregion reference streams as background data to assess the physical, chemical, and biological quality of streams also in that ecoregion. Reference streams are considered “control” streams of water quality in the ecoregion, as these waterways have the least amount of disturbance and impaction. The reference stream for Pond Creek Watershed (Ecoregion 67f) is Wolf Creek (TDEC site number ECO67F07; TN06010201070_1000), which is a Roane County tributary of Watts Bar Reservoir. Mean *E. coli* levels for Wolf

Creek are 222.0 cfus per 100mL, compared to Pond Creek mean *E. coli* levels of 15,552 cfus per 100mL over 8 sampling sites and 11 dates (over 70x greater). To meet ecoregion targets for *E. coli*, Pond Creek levels must decline 98.5%. Mean fecal coliform levels for Wolf Creek and Pond Creek are 452 and 6,055 cfusper 100mL respectively (13x greater), representing a required decline by 92.5%.

State of Tennessee water quality standards (TDEC 2004b) for the *E. coli* group require that the concentration shall not exceed 126 cfus per 100 mL, as a geometric mean based on a minimum of 5 samples collected from a given site. Individual samples can range from 1 to 941 cfus per 100 mL. The single sample standard, as designated by TDEC was exceeded at every site within the watershed, at every sample date within 2001 - 2002. These data were used by TDEC for construction of load duration curves for fecal coliforms and *E. coli* analyses (Figures 2.3, 2.4).

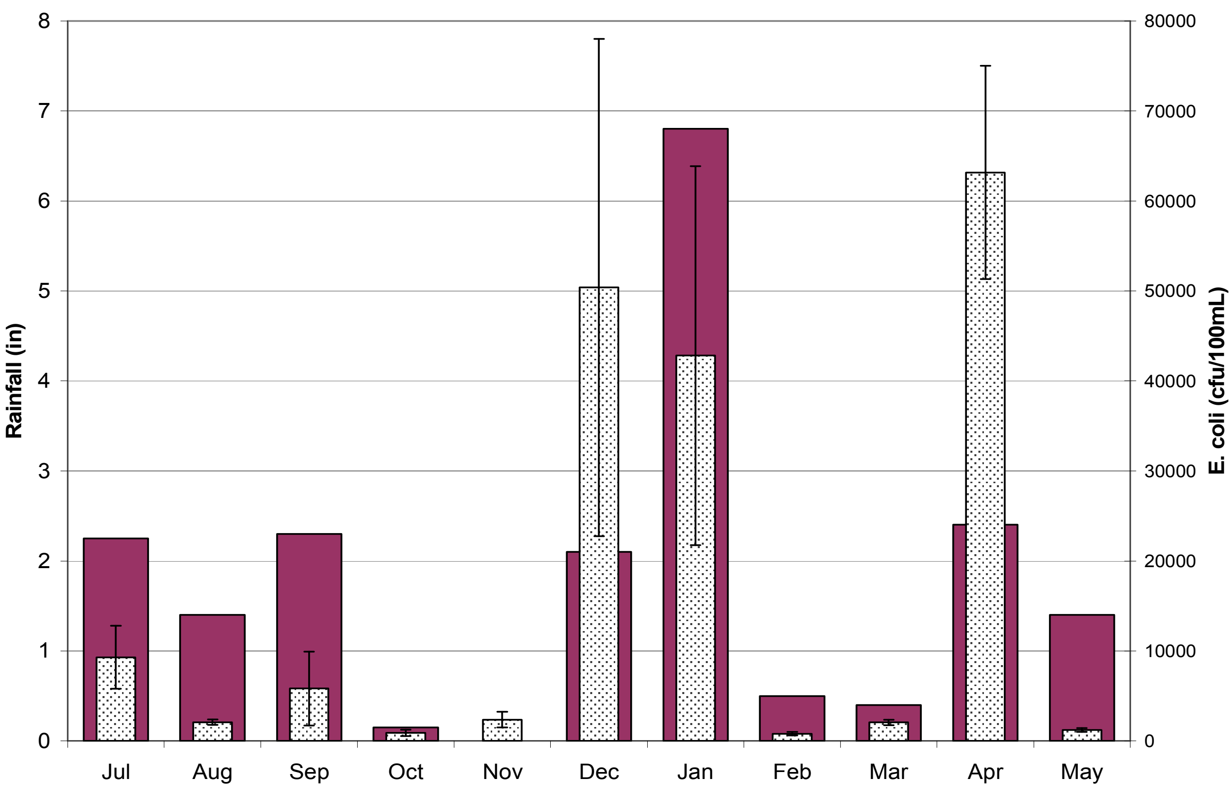

Figure 2.2. *E. coli* counts (open bars) and monthly rainfall (solid bars) from within Pond Creek watershed among 11 sample dates from July 2001 to May 2002. Bars represent mean (± 1 SE) of 8 monitoring sites. Data from Sasser (2003).

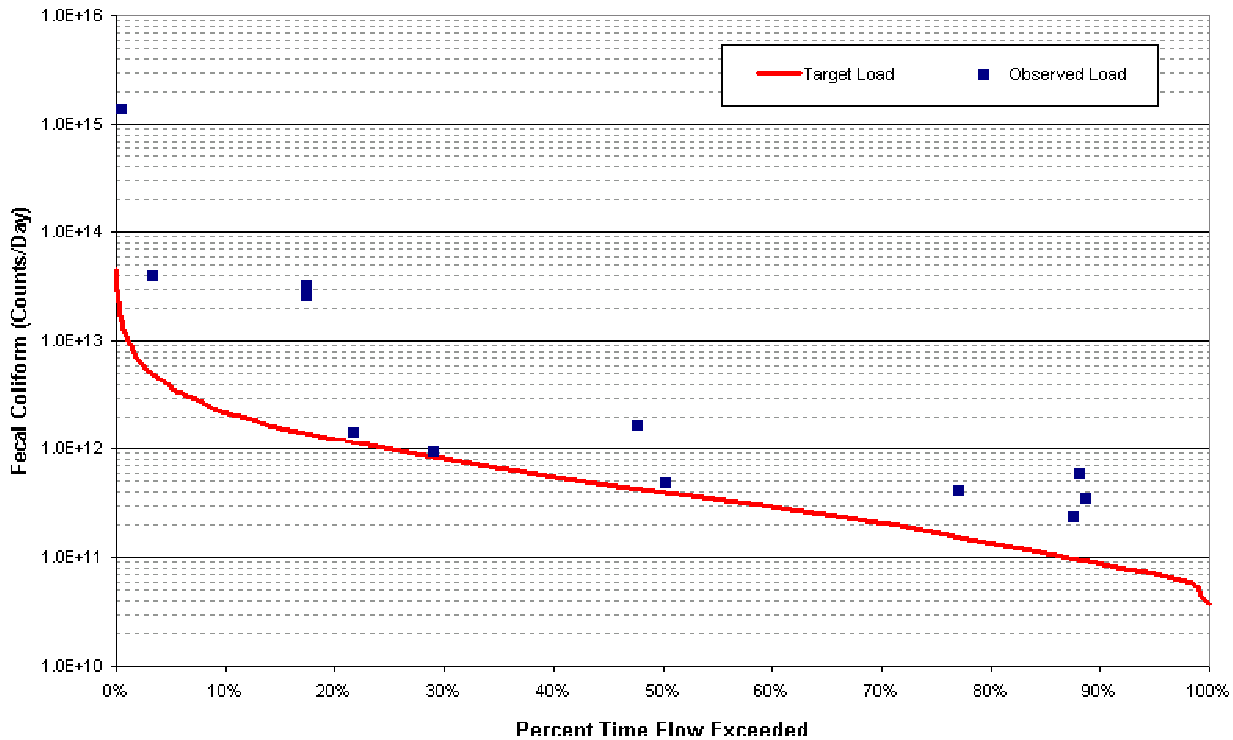

Figure 2.3. Fecal coliform load duration curve for Pond Creek taken from TDEC (2005).

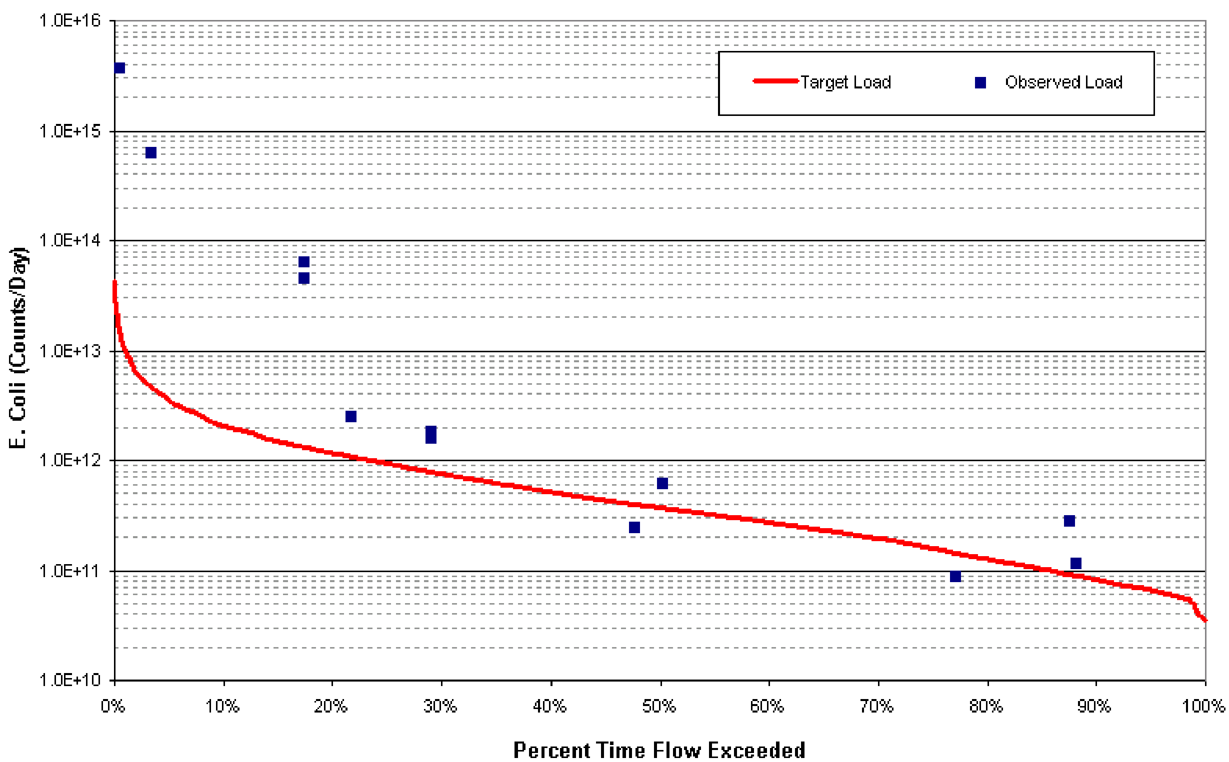

Figure 2.4. *E. coli* load duration curve for Pond Creek taken from TDEC (2005).

2.2.2 Nutrients

Data on water pH and nutrient status from Sasser (2003) for each site within Pond Creek are presented in Table 2.2. Pond Creek satisfies the proposed pH standard of waterbodies for domestic water supplies and freshwater aquatic life.

Over the period of July 2001 and May 2002, Mud Creek (monitoring site 8) had the highest mean value of total nitrogen (TN) and total phosphorus (TP) from within Pond Creek Watershed (Table 2.3). Water flow and pH values were lowest at this site. The target concentration of N in the water is 0.610 mg/L, based on ecoregion reference stream data. Pond Creek is in excess of this target at every monitoring station and should be reduced by 82% to meet the Ecoregion target. The target concentration of TP in the water is 0.047 mg/L, again based on ecoregion reference stream data. Pond Creek levels of P are in excess of this target level at every monitoring station, with the mean value being over 5 times greater, suggesting a reduction goal of 80%. The TMDL does not define phosphorus levels as a currently documented priority (TDEC 2004a), however the past and present water quality sample levels of TP are consistently in excess of target values (TDEC 2001, 2004b, Tables 2.3 and 2.4) and as such will be included in the present document.

The 2003 monthly survey conducted by UT allowed a correlation analysis to be performed to determine which factors might be related to one another, if any. The performed correlation showed that rainfall was highly correlated (significant at $P \leq 0.001$) with Log_{10} total coliforms, Log_{10} fecal coliforms, Log_{10} *E. coli*, TP, and TN (Sasser 2003). As rainfall in an area increases more runoff occurs, bringing with it sediment and nutrients attached to soil colloids. This in turn results in increased stream volume. The 2001 to 2002 study by UT illustrates that the highest levels of pathogens and nutrients were observed during the months with high rainfall, as in Figures 2.2 for *E. coli* and 2.5 for nutrients.

Sediment from surface erosion is a major transport vehicle for nutrients, bacteria and toxins often resulting in spatially and temporally dynamic trends (Heathwaite et al. 2000). The larger, heavier sediment particles are first deposited, leaving the finer particles in suspension, which have a high chemical adsorbing potential. Thus, sediment reaching waterways is enriched in clays, organic matter, nutrients, pathogens and pesticides relative to the original soil surface.

The above mentioned 12 month study also illustrates a high correlation between pathogens (total coliforms and *E. coli*) and nutrients (N, and P). A strong relationship exists between P levels and coliforms and *E. coli* ($P \leq 0.001$), and N and coliforms and *E. coli* ($P \leq 0.01$; Sasser 2003). Due to these correlations, nutrient loading will be used as a proxy for pathogen loading for Pond Creek watershed where and when actual pathogen data may not be available. An extensive catalogue of literature currently exists for estimating nutrient loading from various land use classes, intensities and practices, including the Revised Universal Soil Loss Equation (RUSLE, Wischmeier and Smith 1978, Renard et al. 1997), from which we believe will be adequate to characterize and quantify pollutant fate and loads. A multi-year continuation of stream flow, pathogen and nutrient data will be required to better define this relationship.

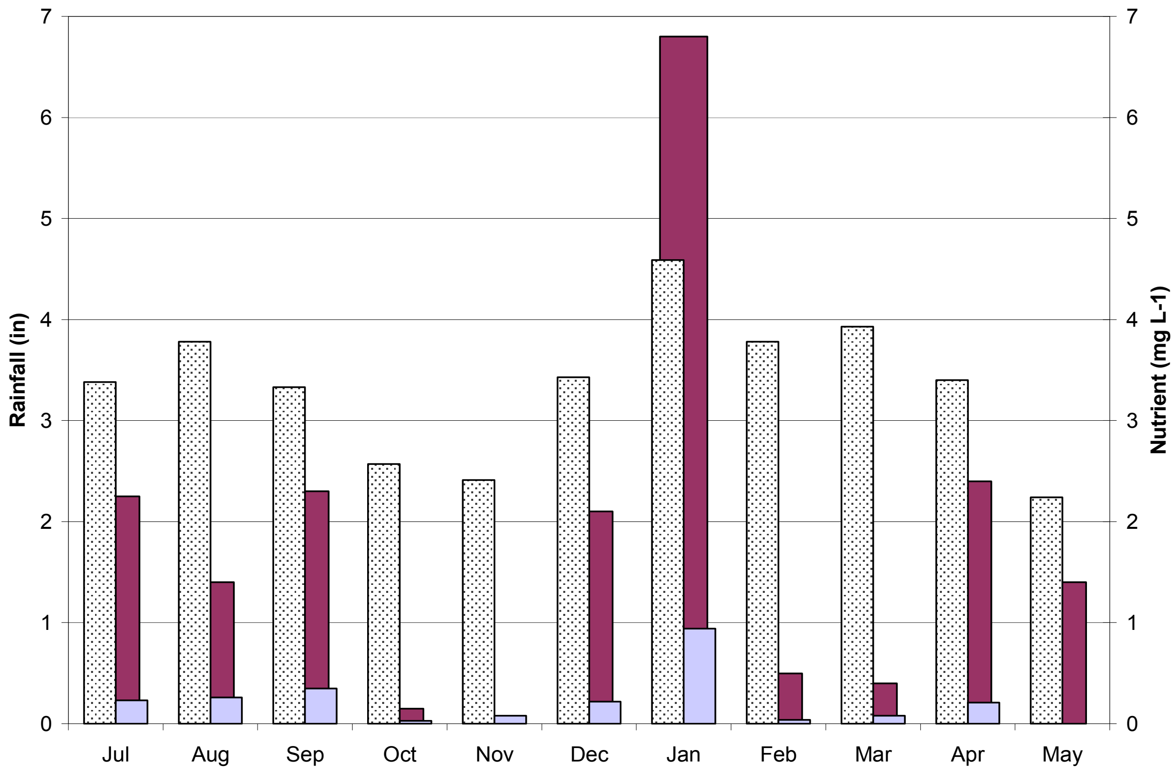

Figure 2.5. Monthly rainfall in inches (dark bar, left y-axis), nitrogen (pattern bar) and phosphorus (light bar) amounts monitored from July 2001 to May 2002. Raw data taken from Sasser 2003.

2.2.3 Fish community assessment

Pond Creek's fish assemblage has been, and continues to be, monitored using the common Index of Biotic Integrity (IBI). Past and current IBI results from sampling site 1 at Bradshaw Hollow are summarized in Table 2.5 below. From 2001 to 2006, IBI scores have gone from poor/fair to fair ratings.

Table 2.5. Fish community index of biotic integrity (IBI) and habitat assessment (HA) data for a single site within Pond Creek watershed; data collected and analyzed by TVA.

Location	Mile	Agency	Sample Date	IBI Score	Fish Count	Rating	HA Score
Bradshaw Hollow Rd	2.1	TVA	3/13/2001	36	214	Poor/Fair	28
			2/27/2006	40	718	Fair	31

2.2.4 Macroinvertebrate assessment

Included in IBI assessment, TVA collected data on macroinvertebrate populations for Pond Creek. Aquatic biologists identified counts of EPT, or Ephemeroptera, Plecoptera, and Trichoptera, which are generally considered to be intolerant to pollution and habitat degradation and are used as a metric for water biological integrity. Taxa counts declined from 2001 to 2006, although the resulting score was still fair/good.

Table 2.6. Macroinvertebrate population data taken from Bradshaw Hollow Rd within the Pond Creek watershed March 2001 and February 2006. EPT: Ephemeroptera + Plecoptera + Trichoptera.

	Mar-01	Feb-06
EPT families	17	12
Oligochaeta	1	1
Crustacea	2	2
Insecta		
Plecoptera	2	2
Odonta	3	5
Ephemeroptera	13	10
Hemiptera	1	1
Trichoptera	11	8
Megaloptera	2	2
Diptera	3	7
Coleoptera	3	0
Gastropoda	2	1
Basommatophora	0	1
Bivalvia	2	1
Score	good	fair/good

2.2.5 Habitat assessment

Along with IBI monitoring, TVA assessed physical habitat within Pond Creek in 2001 and 2006 using common protocols. Characteristics that were evaluated in this assessment include channel flow, channel alteration, sediment deposition, bank stability and riparian condition. Scores are very low and rate as failing at both sample dates (Table 2.5).

2.2.6 Source assessment

An important part of water quality analysis is the identification of individual sources, or source categories of pollutants in the watershed that affect loading. Under the Clean Water Act, pollutants are classified as either coming from point or nonpoint sources, depending on the level of confinement and discrete conveyance from discharge. That is, how a pollutant arrives at a body of water defines its source. For example a pipe emitting a pollutant directly into a river is a point source, compared to pollutants traveling across land being a non-point source.

The National Pollutant Discharge Elimination System (NPDES) regulates point source discharges from three broad categories. Only one of these categories is evident in Pond Creek watershed: NPDES regulated Concentrated Animal Feeding Operations (CAFOs). CAFOs congregate animals, feed, manure and urine, and production operations on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures. Most CAFOs in Tennessee obtain regulatory status under TNA000000, Class II CAFO General Permit, which provides coverage for operations limited to 200 – 700 dairy, or 300 – 1000 beef cattle, which is relevant for several operations in the study area.

Nonpoint sources are diffuse sources that cannot be identified as entering a waterbody through a discrete and/or single location. These sources generally involve pollutant accumulation on land surfaces and wash-off as a result of storm events. Nonpoint sources are primarily associated with agriculture and urban land uses. Major contributors of this classification include livestock operations, cropland, wildlife, failing septic systems and urban development. The following nonpoint source inventory and assessment will attempt to quantify nonpoint sources and pollutant loading estimates. With load estimates, we then can offer potential BMPs to slow or minimize pollutant loading within Pond Creek Watershed.

An important aspect of pathogen load reduction activities is the accurate identification of the actual sources of pollution. In cases where the sources of pathogen impairment are not readily apparent, Microbial Source Tracking (MST) is one approach to determining the sources of fecal pollution and pathogens affecting a waterbody. Those methods that use bacteria as target organisms are also known as Bacterial Source Tracking (BST) methods. This technology is recommended for source identification of *E. coli* in impaired waterbodies.

BST is a collective term used for various emerging biochemical, chemical, and molecular methods that have been developed to distinguish sources of human and non-human fecal pollution in environmental samples (EPA 2002). In general, these methods rely on genotypic (also known as “genetic fingerprinting”), or phenotypic (relating to the physical characteristics of an organism) distinctions between the bacteria of different sources. Three primary genotypic techniques are available for BST: ribotyping, pulsed field gel electrophoresis (PFGE), and polymerase chain reaction (PCR).

Samples collected in November 2005 were analyzed for *Bacteroides* using the new methods developed by Dr. Alice Layton, University of Tennessee - Center for Environmental Biotechnology to track bacterial sources. Total fecal, human fecal and bovine fecal concentrations (mg/L) were determined using real-time PCR assays directed towards measuring *Bacteroides* 16S rRNA gene sequences. Concentrations were determined using human fecal dilutions for the total and human fecal *Bacteroides* real-time PCR assays and using bovine fecal dilutions for the bovine *Bacteroides* real-time PCR assays. All samples were run in triplicate for each assay so that standard deviations could be determined. None of the samples showed evidence of PCR inhibition as determined using spike controls. The percentage of feces attributable to humans and bovines was determined by dividing the mg/L of the host-specific assay by the mg/L obtained in the total assay (note that this value may be >100% due tovariability associated with both assays).

The results of this BST analysis are summarized in Table 2.7. Sample site 1 (near where Pond Creek discharges into Watts Bar Reservoir) showed very low concentrations of total feces. Sample sites 7 and 8 showed high concentrations of total feces, and sample sites 2 and 6 showed a relatively high percentage of human feces. One of the samples is directly downstream from a known failing septic system and drainage field. Project personnel are working with the landowner to correct this problem.

None of the samples showed high percentages of bovine feces. This reflects the very dry conditions and low water flows present in the weeks before this sampling date. Additional analyses using these methods are planned for future sampling events.

Table 2.7. Total, human and bovine fecal concentrations and the percentage of human and bovine feces relative to the total in Pond Creek samples from 11/14/05. BDL= below detectable limit; Sample sites correspond to site numbers in Table 2.2.

	Fecal Concentration (mg/L) and Percent of Total		
Sample Site	**Total**	**Human**	**Bovine**
		% of Total	**% of Total**
1	11 (± 7)	BDL	BDL
2	339 (± 52)	598 (±124)	2.9 (±1.5)
		>100%	**3%**
3	237 (± 72)	29 (±38)	5.2 (±7.3)
		12%	**2%**
4	86 (± 22)	5.5 (± 4.6)	4.3 (±5.6)
		6%	**5%**
5	381 (±160)	31 (±13)	11 (±4.4)
		8%	**3%**
6	100 (±64)	67 (±34)	BDL
		72%	
7	1110 (±160)	97 (±44)	34 (±7.4)
		9%	**3%**
8	2470(±428)	58 (±54)	120 (± 5.0)
		2%	**5%**

3.0 Nonpoint Source Inventory

The NPS inventory is based upon a geographic and numeric database originally developed by 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 present document highlights key outputs from the model described.

3.1 Methods

These databases are originally derived from remote sensing techniques used to acquire and interpret aerial photography and develop the NPS inventory and atlas. Frequent site visits were employed to reference, verify or overrule aerial photo interpretation. The structure of the GIS database and assumptions and equations used in the pollutant loading model are further defined in a companion document.

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, based on the RUSLE (Renard et al. 1997) originally developed by Wischmeier and Smith (1978).

A pollutant loading model was used to estimate pollutant loads for total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) from the following sources: residential, commercial, industrial, transportation, cropland, pasture, forests, mined and disturbed lands, beef cattle, dairy cattle, swine, horses, and poultry. Nutrient characteristics (inputs) were based on literature values and calibrations to water quality data in previous studies of similar nature.

3.2 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 follow Interstate-75 corridor. The primary land use component of the ridges within the watershed 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. Figures 3.1 and 3.2 summarize general land use patterns in Pond Creek watershed.

The remote sensing process identified 26.9 miles of eroding streambank, or 22% out of a total 120.6 miles of digitized stream. A total of 110.6 linear miles is paved road, and 67.3 miles are unpaved roads. 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. 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.

Total estimated livestock numbers are: 1,960 beef cattle, 960 calves and dry dairy cows, 1,575 mature, lactating dairy cows, and 45 horses. A total of 59 beef cattle sites were identified in the area. A total of 12 dairy sites were identified, 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. Seven horse operations were identified, all located on land not adjacent to the streams.

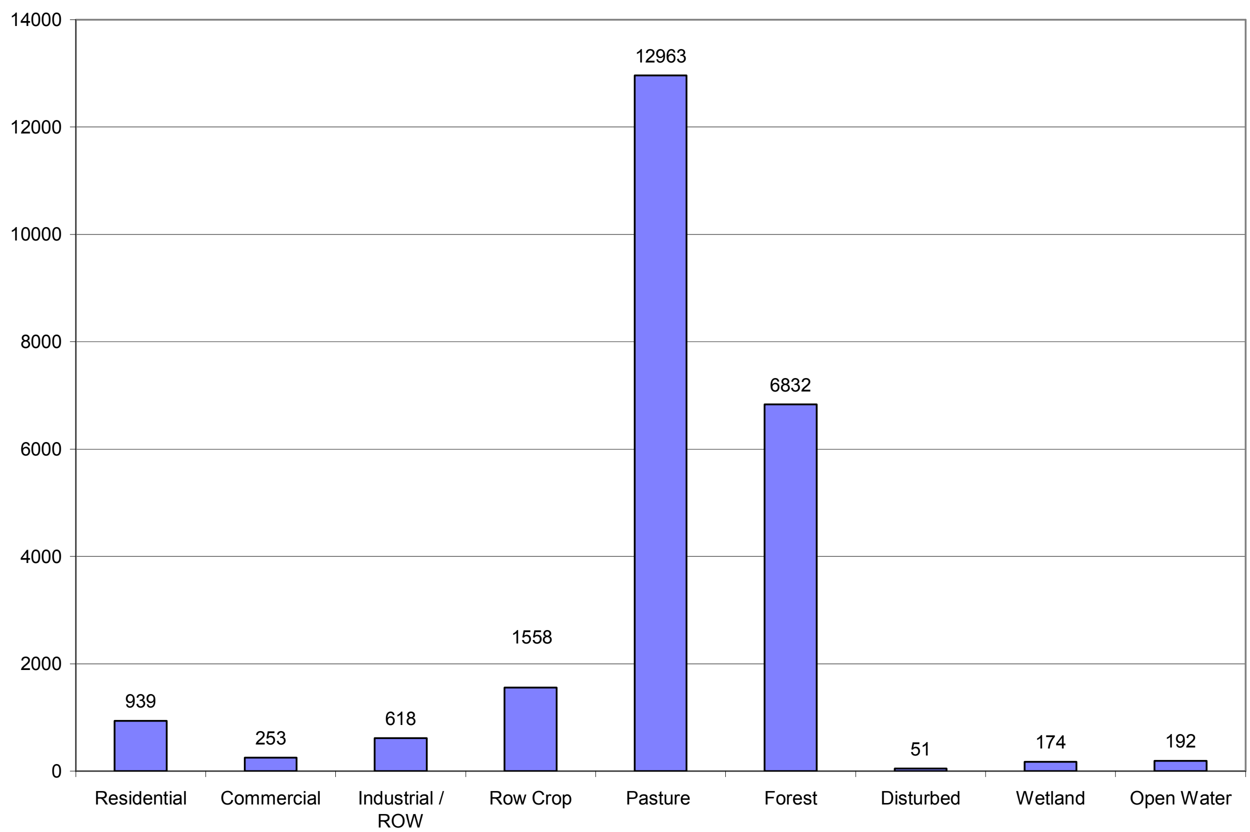

Figure 3.1. Major land use distribution (in acres) within Pond Creek watershed.

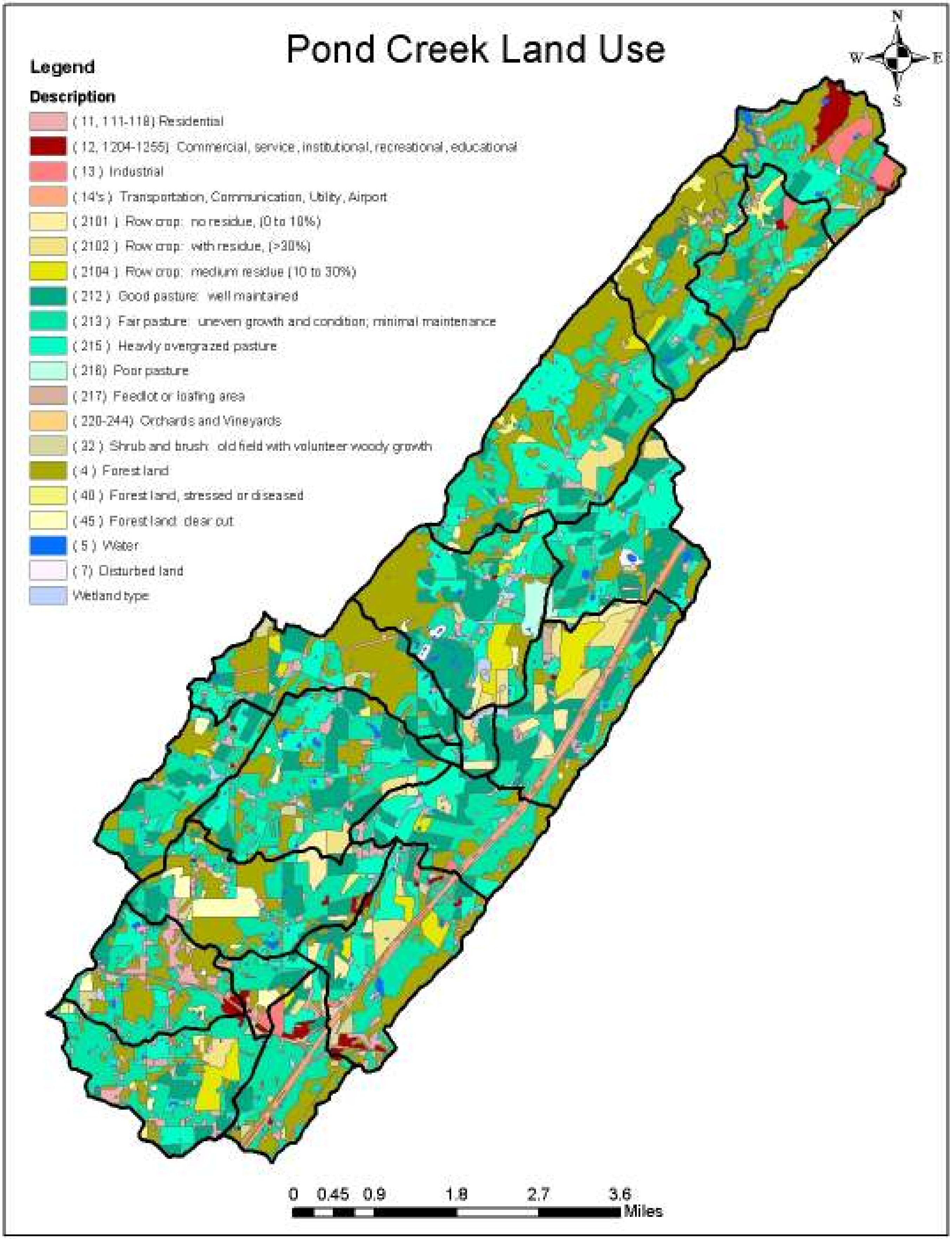

Figure 3.2. Land use classification map of Pond Creek watershed.

3.3 Soil Loss Estimates

Using RUSLE parameters and coefficients referenced in the methodology, the estimated soil loss for all of Pond Creek watershed is 43,253 tons/yr, or 1.83 tons/acre/year. Within the study area, disturbed and (abandoned) mined areas contributed the greatest soil loss per acre at 25.58 and 33.13 tons/ac/yr, respectively. 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 from agriculture. The estimated soil loss from select agricultural land use categories is provided in Figure 3.3.

When expressed as tons per year, 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.

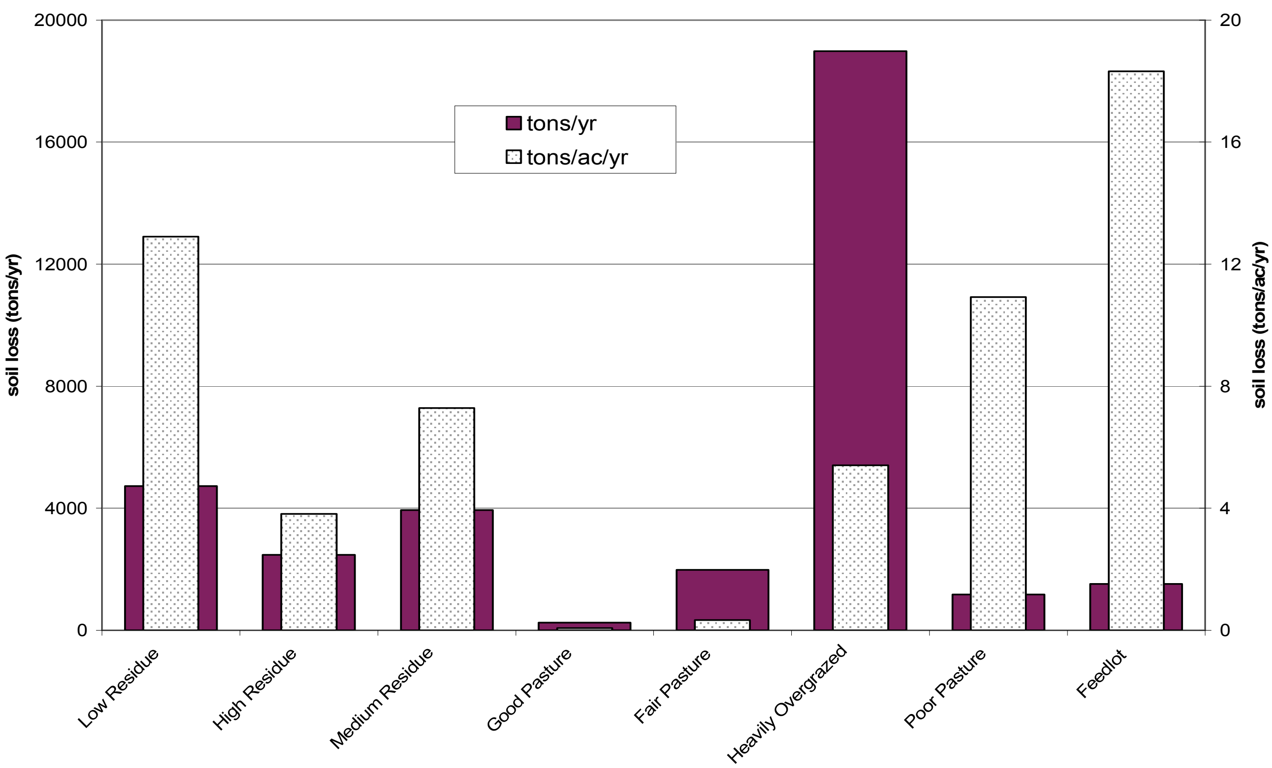

Figure 3.3. Soil loss estimates from agriculture land classes in Pond Creek watershed.

3.4 Nonpoint Pollution Sources

Urban areas including residential, commercial and industrial lands contributed nearly 57% of all TP/ac/yr, and 24% of TP/yr (Table 3.1). The primary TN loads per acre sources were animal feedlots followed by commercial and industrial lands. Load estimates of TSS identified disturbed and abandoned mine lands as primary per acre sources. Animal loafing areas and low residue croplands also contributed significant amounts of TSS load per acre.

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% respectively (Table 3.2). Agriculture (cropland, pasture and livestock) contributed over 70% of annual TP and TN loads, and nearly 80% of TSS loads. 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.

Table 3.1. 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
Loafing Areas	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 3.2. 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
Loafing Areas	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	